8.0 ELECTRIC POWER

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 8.0 - ELECTRIC POWER

8.1 INTRODUCTION

8.1.1 DESCRIPTION OF UTILITY GRID

The Alabama Power Company (APC) is a part of the Southern electric system and, as such, its lines interconnect with the contiguous national utility grid.

[HISTORICAL]

[The interconnections for 1983 are shown on figure 8.1-1.]

The network interconnections between Joseph M. Farley Nuclear Plant (FNP) and the Southern electric transmission system consist of six high-voltage transmission lines and two 500/230-kV autotransformer connections for Units 1 and 2. These lines approach the site on separate rights of way designed and located to minimize the likelihood of their simultaneous failure. The lines also interconnect the FNP with other major sources of generation in the system. Figure 8.2-1 shows the connections of Unit 1, Unit 2, and the transmission lines to the 500-kV and the 230-kV switchyards at the plant. A detailed description of the transmission system is given in subsection 8.2.1.

8.1.2 DESCRIPTION OF ONSITE ELECTRIC SYSTEM

Each unit is provided with at least one unit auxiliary transformer (1A and 1B for Unit 1, 2B for Unit 2) as shown on drawings D-177000 and D-207000. The unit auxiliary transformers are capable of supplying power to 4.16-kV buses A, B, C, D, and E for Unit 1; A, B, and C for Unit 2, as shown on drawings D-177000 and D-207000. Under normal operating conditions, 4.16-kV buses A, B, and C of Units 1 and 2 are powered from unit auxiliary transformer (1B and 2B, respectively). Two startup auxiliary transformers are provided for each unit (1A and 1B for Unit 1, 2A and 2B for Unit 2) as shown on drawings D-177001 and D-207001. The startup auxiliary transformers are capable of supplying power to the nonsafety-related 4.16-kV buses A, B, C, D, and E as well as the safety-related 4.16-kV emergency buses F, G, H, J, K, and L. During normal operations, 4.16-kV buses D and E, along with the 4.16-kV emergency buses F, G, H, J, K, and L of each unit, are powered from the startup auxiliary transformers. Each unit is provided with an adequate number of 600-V load centers and 600-V and 208-V motor-control centers.

The onsite emergency power supply for Units 1 and 2 is obtained from five diesel generators (1-2A, 1B, 2B, 1C, and 2C) feeding the 4.16-kV emergency buses. Of these diesel generators, 1-2A, 1C, 1B, and 2B are dedicated for use during design basis events. Diesel generator 2C is dedicated as the alternate ac (AAC) power source for station blackout (SBO) events. Four diesels (1-2A, 1B, 1C, and 2C) were installed when Unit 1 was constructed and one diesel (2B) was installed when Unit 2 was constructed. Three diesel generators (1-2A, 1C, and 2C) are shared between Units 1 and 2. Diesel generators 1B and 2B are lined up to supply emergency hpower to Units 1 and 2, respectively. Upon loss of offsite power, the diesel generators supply the engineered safeguard loads.

The ac auxiliary power system is described in detail in subsection 8.3.1.

A 125 V-dc system provides a source of reliable, uninterruptible dc power for all emergency control, instrumentation, and power loads. A few normal loads are also supplied from this system. In addition, four separate dc systems provide power for loads in the turbine building, the switchyard, the service water and the cooling tower areas. Each system consists of one or more batteries, battery chargers, and dc distribution panels. For a detailed description of the dc power systems, refer to subsection 8.3.2.

Each unit is equipped with a 7.5-kVA uninterruptible power system (UPS), uniquely assigned to provide a reliable source of control power, ac and dc, for turbine-driven auxiliary feedwater pump and its associated steam admission valves. For a detailed description of this system, refer to subsection 8.3.3.

8.1.3 IDENTIFICATION OF SAFETY LOADS AND FUNCTIONS

The loads required for the engineered safeguard systems are identified in table 8.1-1, which includes a description of the safety function to be performed by each load and the type of electric power being provided (ac or dc).

8.1.4 DESIGN BASIS

The electrical system is designed to provide reliable power sources for electrical equipment for startup, normal operation, safe shutdown, and emergency situations. The following bases are used in the system and equipment design:

A. Electrical systems and components vital to plant safety, including the emergency diesel generators, are designed as Category I and protected as necessary so that their functional integrity is not impaired by the safe shutdown earthquake (SSE), windstorms, floods, tornado winds, or disturbances on the maximum probable natural phenomena expected at the site, with appropriate margin to account for uncertainties in the data.

B. Seismic design requirements established for all Class IE electrical systems and equipment are contained in section 3.10.

C. Components of the system are sized for operation under normal and emergency conditions.

The design bases, criteria, safety guides, standards, and other documents that are implemented in the design of this system are as follows:

All electrical equipment, such as the generators, motors, transformers, switchgear, control panel equipment, control equipment, and cabling system, is in accord with the standards listed below:

A.	ANSI C37[a]	Switchgear.
B.	ANSI C50.2	Alternating current induction motors, induction machines in general and universal motors.
C.	ANSI C57[a]	Transformers, regulators, and reactors.
D.	IPCEA P-46-426-1962	Power cable ampacities, Volume 1 - Copper Conductors.
E.	NEMA SG3-1965	Low voltage power circuit breakers.
F.	NEMA SG4-1968	AC high voltage circuit breakers.
G.	NEMA SG5-1967	Power switchgear assemblies.
H.	NEMA SG6-1966	Power switching equipment.
I.	NEMA TR1-1968	Transformers, regulators, and reactors.
J.	NEMA MG1-1967	Motors and generators.
K.	NFPA No. 70-1971	National Electrical Code - 1971 edition.
L.	NFPA No. 78-1971	Lightning protection code.
M.	UL Standard 96A-1963	Installation requirements - master-labeled lightning protection system.
N.	IES - 1972	Illuminating Engineering Society Standards.

a. Individual equipment specifications should be consulted for actual standard numbers, descriptions, and applicable revision dates.

The power supply for the reactor protection system and the engineered safety features is in accord with Criteria 17 and 18 of NRC General Design Criteria for Nuclear Power Plant Construction Permits, 10 CFR 50, published in Federal Register, February 1971, and the following Regulatory Guides:

A. NRC Regulatory Guide 1.6 - Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems.

B. NRC Regulatory Guide 1.9 - Selection of Diesel Generator Set Capacity for Standby Power Supplies.

C. NRC Regulatory Guide 1.32 - Criteria for Safety-Related Electric Power Systems for Nuclear Power Plants.

The following standards provide the bases for the design of the electrical auxiliary system, including the selection, protection, and specification of electrical equipment associated with the auxiliary system:

Standard No.	Title	How Implemented
A. IEEE 279-1971	Criteria for Nuclear Power Plant Protection Systems	The engineered safety feature systems are designed so that a failure in one safety-related circuit will not jeopardize the corresponding redundant circuit. This aspect is discussed in paragraphs 8.3.1.1, 8.3.1.4, and subsection 8.3.2 and is supported by elementary diagrams in the FSAR. Discussion in regard to instrumentation is covered in paragraph 7.3.2.1 for IEEE-279 and paragraph 7.3.2.5 for IEEE-338.
IEEE Guide (SC-1)	Application of the Single Failure Criterion to Nuclear Power Generating Station Protection Systems	
IEEE 338-1971	Trial-Use Criteria for the Periodic Testing of Nuclear Power Generating Station Protection Systems	

Standard No.		Title	How Implemented
B.	IEEE 317-1971	Electrical Penetration Assembly in Containment Structures for Nuclear Fueled Power Generating Stations	Reference was made (in the specifications for Electrical penetration) that the penetration assemblies shall be subjected to production and prototype test requirements for this period.
C.	IEEE 323-1971	General Guide for Qualifying Class I Electrical Equipment for Nuclear Power Generating Stations	Qualification tests and documentation requirements of these standards were stipulated in the specifications for Class IE Motors installed within the containment.
	IEEE 334-1971	Trial-Use Guide for Type Tests of Continuous – Duty Class I Motors Installed Inside the Containment of Nuclear Power Generating Stations	
D.	IEEE 336-1971	Standards Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment during the Construction of Nuclear Power Generating Stations	Refer to discussion in paragraph 8.3.1.3.
E.	IEEE 344-1971	Guide for Seismic Qualification of Class I Electric Equipment for Nuclear Power Stations	Reference was made in the specifications for Class I electrical equipment that the testing procedure shall be in accordance with this standard.
F.	IEEE 387-1972	Trial Use Standard Criteria for Diesel Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations	The specifications for diesel generators included the requirements outlined under Principal Design Criteria of this standard. The criteria are also discussed in paragraph 8.3.1.1.7 and Technical Specifications. Automatic control aspects are shown on logic diagrams for auto start and loading, drawings D-177032, D-207032, D-177033, D-207033, D-177036, D-207036, D-177037, and D-207037.

Standard No.		Title	How Implemented
G.	IEEE 288-1969	Guide for Induction Motor Protection	Provides the bases for designing the protection system for motors as reflected in paragraph 8.3.1.1.9-(A) and in the single-line diagrams, drawings D-177005, D-207005, D-177006, D-207006, D-177018, D-207018, C-177027, D-207027, C-177043, C-177044, D-177007, D-207007, D-177009, D-207009, D-177010, D-207010, D-177011, D-207011, C-177012, D-177014, D-207014, D-177015, D-207015, D-177045, D-207045, D-177046, D-207046, D-177677, and D-177678.
H.	IEEE 308-1971	Criteria for Class 1E Electrical Systems for Nuclear Power Generating Stations	Refer to discussion in paragraph 8.3.1.2-(E).
I.	IEEE Guide (proposed 384)	Criteria for Separation of Class IE Equipment and Circuits	Refer to discussion in paragraph 8.3.1.4.
J.	IEEE 450-1980	Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations	Refer to discussion in paragraph 8.3.2.1.5.
K.	IEEE 485-1983	Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substation.	Refer to discussion in paragraph 8.3.2.1.1.

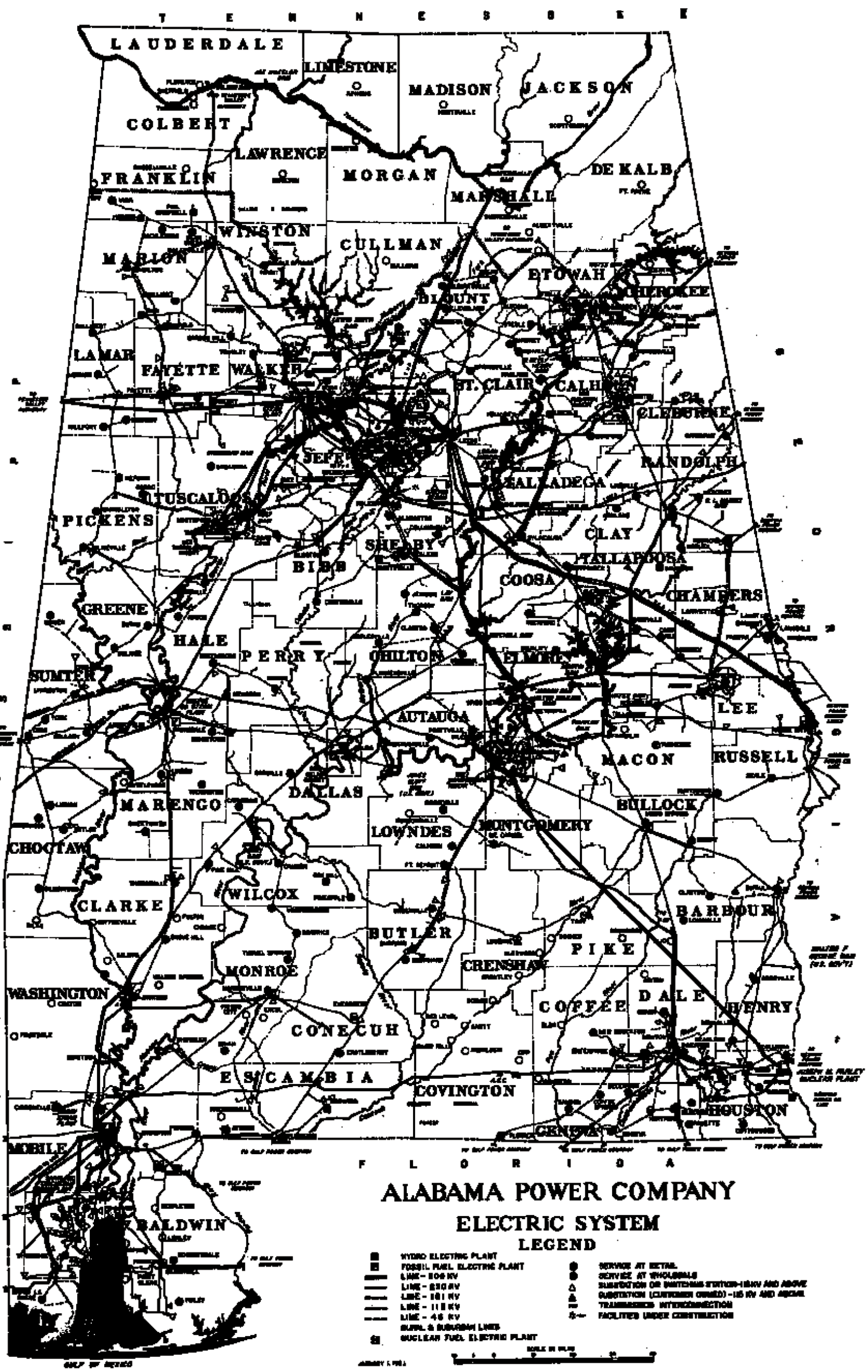
TABLE 8.1-1 (SHEET 1 OF 2)

SAFETY LOADS AND FUNCTIONS

Safety Loads	Safety Function	Power
Residual heat removal/ L.H. safety injection pumps	Emergency core cooling for post-LOCA operation.	ac, dc
Charging/H.H. safety injection pumps	Provide makeup reactor coolant system emergency core cooling for post-LOCA operation.	ac, dc
Auxiliary feedwater pumps (motor driven)	Supply feedwater to steam generators during emergency conditions.	ac, dc, UPS (TDAFW pump only)
Containment spray pumps	Provide cooling spray in containment during LOCA.	ac, dc
Component cooling water pumps	Provide cooling water for safety-related components.	ac, dc
Containment cooler fan	For cooling containment after LOCA.	ac, dc
Spent fuel pool coolant pumps	Cool spent-fuel assemblies in the spent-fuel pool.	ac, dc
Hydrogen recombiners, post-LOCA mixing fans and reactor cavity hydrogen dilution fans	Maintain a safe level of hydrogen in containment vessel after LOCA.	ac, dc
Control room air conditioners and fans	Maintain proper air temperature and habitability of control room.	ac
Battery chargers	Provide dc power for control and power loads.	ac

TABLE 8.1-1 (SHEET 2 OF 2)

Safety Loads	Safety Function	Power
Service water pumps	Satisfy cooling water requirements for: (1) Component cooling water heat exchanger. (2) Containment air coolers. (3) Diesel generator heat exchangers. (4) Various room coolers for rooms containing safety-related equipment (see table 9.2-3 for more information).	ac
Loads off motor control centers A, B, F, G, K, L, N, P, S, T, U, V, CC, and DD	Provide power for M.O.V., small motors, fans, heaters, vital instrument buses, and small pumps associated with safety-related equipment.	ac
Inverters/Constant Voltage Transformers	Supply power to the 120 V-ac vital instrumentation distribution panels.	dc, ac
Safety feature actuation system solenoid valves	Control flow of the NSSS (pneumatic valves with solenoid actuators).	ac, dc
Distribution panel	Supplies power to emergency lighting and protective relay panel.	ac, dc
ESS sequencers	Provide starting signals to safety loads following a safety injection signal.	dc
Reactor trip switchgear	Remove power from the rod cabinets to shut down the reactor.	ac, dc
Emergency diesel generators	Provide power to ESF loads due to a loss of offsite power along with a LOCA.	dc, ac



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SOUTHERN COMPANY *Energy to Serve Your World®*	**JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2**	ALABAMA POWER COMPANY ELECTRIC SYSTEM – 1983 FIGURE 8.1-1

8.2 OFFSITE POWER SYSTEM

8.2.1 SYSTEM DESCRIPTION

The Southern electric transmission system supplies offsite ac energy for operating the emergency busses as well as startup and shutdown of Units 1 and 2.

[HISTORICAL]

[Either unit will be 9 percent of the total installed capacity of the Alabama Power Company (APC) system in 1983 and about 3 percent of the total installed capacity of the Southern electric system in 1983.]

Unit 1 and Unit 2 are connected by separate generator step-up transformers to the 230-kV and 500-kV switchyards, respectively. Six transmission lines interconnect the 230-kV and 500-kV switchyards to the Southern electric transmission system, as shown by figure 8.2-1. The 230-kV switchyard is connected to the 230-kV system by four 230-kV lines and the 500-kV switchyard is connected to the 500-kV system by two 500-kV lines. The 230-kV and 500-kV switchyards are interconnected at the plant site by two 500/230-kV autotransformers. A spare 500/230-kV autotransformer has been provided that will be physically connected if there is a failure with one of the main Bank #1 or Bank #2 autotransformers. A switchable 230-kV shunt reactor is provided to help control switchyard voltages and improve stability during transmission system light load conditions. A switchable 230-kV 90-MVAR capacitor bank is provided for voltage support during periods of high system load.

Six sources of offsite power are available to the 230-kV switchyard. These sources are the four 230-kV lines (Webb, Sinai Cemetery, South Bainbridge, and Pinckard) and the two 500/230-kV autotransformers which connect to the 500-kV system via the two 500-kV lines (Raccoon Creek and Snowdoun). The 230-kV switchyard is interconnected to the onsite electrical distribution system by four physically-separated, underground, oil-static cables. Each cable supplies power to one of the four startup auxiliary transformers which supply power to the emergency busses for Units 1 and 2. Any of the startup auxiliary transformers may be temporarily connected to the 230-kV switchyard by means of an overhead bus available for that purpose. The requirements of GDC No. 17 and Regulatory Guide 1.32 are met by the offsite power system as details provided in the following paragraphs show.

8.2.1.1 Offsite Power Sources

[HISTORICAL]

[Figure 8.1-1 shows the Alabama Power Company transmission system in 1983.]

Figure 8.2-2 shows the general physical plan of lines from the switchyard structures to the plant property boundaries. Figure 8.2-2 also illustrates the separation of lines within the site boundaries and the direction taken by the various right-of-ways emanating from the plant site. Figures 8.2-3 and 8.2-4 show the details for the 230-kV and 500-kV transmission line separation in the vicinity of the 230-kV and 500-kV switchyards, respectively. Table 8.2-1 provides a summary of the lines terminating at the plant and their construction features.

These lines are not considered to have unusual features. Crossing of lines of different voltage levels, as listed in table 8.2-1, is a normal design feature.

8.2.1.2 Switchyard

The 230-kV and 500-kV switchyards are located as shown on figure 8.2-2. Figure 8.2-5 shows the physical arrangement of these switchyards. The 230-kV and 500-kV switchyards both employ a breaker-and-a-half arrangement to provide the necessary operating flexibility, and consequently, reliability. This breaker arrangement is redundant in that it incorporates two energized main busses so that either of the main busses can be removed from service without interruption of power flow. In most cases, three breakers service a pair of connections. In some cases, additional reliability is provided for more critical connections by using two breakers to service a single connection. Details on the electrical connections for the switchyards are shown on figure 8.2-1.

The switchyard is equipped with a switchhouse containing two independent batteries, independent primary and secondary relaying, and breaker failure relaying.

Two trip coils are provided in each circuit breaker for independent tripping from the primary and secondary relay systems. Redundant closing coils are not provided in the circuit breakers. The closing coils for the circuit breakers are supplied from one of the two substation batteries so that the loss of either battery will not prevent closing breakers as required to energize at least one startup transformer for each unit.

Each of the 230-kV and 500-kV circuit breakers has independent gas and independent air supplies for the pneumatic mechanism.

Four terminals are provided in the switchyard to supply power to the four transformers referred to in paragraph 8.2.1.3. These four transformers (1A, 1B, 2A, and 2B) are supplied through separate oil-static cables from separate 230-kV terminals. An overhead bus arrangement provides a temporary backup connection to any of the four transformers.

Each of the four underground cable circuits consists of three single-conductor 500-MCM compact round aluminum conductors. Each conductor has 0.760 in. of paper insulation, zinc alloy shielding tape, and a 0.0063-in. x 0.188-in. zinc alloy skid wire. Metalized paper tape is provided adjacent to the conductor and also over the insulating paper tapes. The three single-conductor cables of each circuit are contained in a 6 5/8-in. O.D. x 0.250-in. wall somastic-coated pipe. The oil-static cable system requires no forced cooling and has an ampacity of 341 A. The current rating of the cable system is established by the maximum allowable conductor temperature of 85°C. This conductor temperature ensures that the cable's insulation system operates within its thermal capacity. At each end of the cable circuit, a termination (trifucator) assembly is used as a transition between the 6 5/8-in. underground pipe and the three above-ground cable terminations. A 90-degree type termination assembly is used at the transformer end of each circuit and an angular, or sloping-type, termination assembly is used at the transmission substation end of each circuit. Each of these assemblies consists of the necessary pipe bend, spreader head assembly, and riser pipes. Each end of each of the three single-conductor cables in each circuit is terminated with 230-kV pothead assembly. The cables are buried with a minimum cover of 3 ft. except where they exit the ground. Separation is provided as indicated on figure 8.2-5 and drawing D-173000, sheet 1. Typical interfaces between underground and overhead transmission are shown on figures 8.2-6 and 8.2-7.

The entire cable containment system, including the 6 5/8-in. diameter pipe, the spreader head assembly, stainless steel riser pipes, and potheads is filled with polybutene oil that is maintained at a static pressure head of approximately 200 psi by an automatic pressure system. The automatic pressure system consists of two indoor, dual unit-type pumping plants, each with a 1000-gal oil storage tank normally maintained at approximately 750 gal. Each of the two pumping plants is connected to pressurize two of the four cable systems. One supplies the cable system for transformer 1A and 2B and the other supplies the cable system for transformer 1B and 2A.

Power supply for the pumping plants is provided by redundant transformers connected to busses 1D and 2E. The pumping plants and transformers are separated by firewalls. Redundant pumps are provided in each pumping plant.

8.2.1.3 Offsite Power Supply to Plant

Each unit is provided with at least one unit auxiliary transformer (1A for Unit 1 and 2B for Unit 2) as shown on drawing D-173000, sheet 1. The unit auxiliary transformer (2B) normally supplies power to 4.16-kV busses A, B, and C of Unit 2.

The four startup auxiliary transformers, two for each unit, are connected to the APC transmission system through four separate 230-kV oil-static cables as shown on figure 8.2-5 and drawing D-173000, sheet 1. These transformers provide a source of power for startup, shutdown, and after-shutdown requirements for both units. Under normal operating conditions, these startup transformers supply power to 4.16-kV busses A, B, C, D, and E for Unit 1 and D and E only for Unit 2 along with 4.16-kV emergency busses F, G, H, J, K, and L. A spare startup auxiliary transformer, which can be fed by the overhead bus system, is available and can be moved in place in case one of the four startup transformers fails.

The breaker arrangement (figure 8.2-1) employed by Alabama Power Company provides breaker-and-a-half protection for all four startup transformers (1A, 1B, 2A, and 2B). A single failure of any electrical component employed by this arrangement will preclude a simultaneous trip of both units due to the loss of one offsite power source and loss of all onsite power. This breaker arrangement provides for greater overall system protection and is designed to minimize the simultaneous failure of the circuits under postulated accident and environmental conditions.

Each circuit supplies power to the associated emergency busses under normal operating conditions, with a provision for supplying the other redundant bus if the second circuit is not available. A simultaneous loss of all onsite ac power supplies and loss of one of the offsite power circuits will fail a maximum of one group of emergency busses. The redundant emergency busses continue to supply the safety-related loads and are designed to shut down the unit safely. Power to the failed emergency busses can be restored in a few seconds by closing the normally open breaker on the affected emergency bus. An interlock is provided to prevent simultaneous closing of both the normal and standby supply breakers.

8.2.1.4 Summary

The system of lines, switchyards, and transformer connections are planned around the requirements of GDC No. 17 and Regulatory Guide 1.32 and are considered to meet the requirements of these criteria for the offsite power system.

The redundancy and backup features in the system described are such that most active components (i.e., circuit breakers, relays, meters, batteries, battery chargers, etc.) can be removed from service, maintained, and tested without loss of offsite power. However, those components that can be tested without removal from service will normally be tested in service. In the event that it should become necessary, an oil-static cable and its associated transformer can be removed from service for tests with only temporary loss of offsite power to one of the two trains of safety-related busses. The design of the switchyard and connections to the plant are considered to meet the requirements of GDC No. 18 as applicable to the offsite power system.

8.2.2 ANALYSIS

8.2.2.1 Loss of Either Farley Unit No. 1 or No. 2 or Largest Unit (Gaston No. 5) (Effect on Offsite Power)

Farley Unit 1 and Unit 2 are connected to the 230-kV and 500-kV transmission systems as described in subsection 8.2.1.

Periodic studies simulating peak conditions are made to determine the effect of the loss of either Farley Unit 1 or 2 on the APC transmission system and the system's ability to maintain continuity of service to the loads. These studies have revealed that the transmission system will be adequate to maintain continuity of service to the load areas and the offsite power to the safety-related emergency busses at the Farley plant.

The loss of the largest unit (Gaston No. 5) on the APC system will not result in the loss of the offsite power to the safety-related emergency busses at the Farley plant.

8.2.2.2 Farley Plant Transient Stability

Transient stability studies simulating “worst case” anticipated loading conditions are periodically performed to verify operational capability of off-site preferred power supply to the Class 1E loads at Farley Nuclear Plant. The offsite power system is designed to prevent a complete loss of preferred power (LOSP) due to a single event such as electrical fault, loss of a generator, loss of load, or loss of a transmission line. Stability analyses also verify that grid failure modes do not result in frequency variations exceeding the 5 hertz per second maximum decay rate assumed in the accident analysis for loss of reactor coolant flow.

Under normal expected transmission system operating conditions, the grid will remain stable and safety-related busses will continue to be supplied by the offsite preferred power source for single contingency events and faults. The additional contingency of breaker failure is also considered in conjunction with faults in order to optimize the stable operation and design of the FNP units and the system grid. Grid stability is maintained if, after a disturbance such as a fault, the power system returns to equilibrium without experiencing cascading trips of lines or units that could result in the system or voltage collapse. For the double contingency of fault plus breaker failure, FNP may experience unit trips.

3-Phase faults (230 kV and 500 kV) at FNP which involve the additional contingency of breaker failure include maximum breaker failure clearing times of 8.50 cycles for the 230-kV breakers and 9 cycles for the 500-kV breakers. The 230-kV and 500-kV switchyards are arranged so that only one transmission line will be lost after a 3-phase fault at the Farley plant where breaker failure is involved.

8.2.2.3 Grid Availability

[HISTORICAL]

[Table 8.2-2 is derived from the Alabama Power Company 1983 Transmission Monthly Summaries. It should be noted that the higher voltage lines have better operating records than lower voltage lines.]

The use of 230-kV and 500-kV lines and two 230/500-kV Autobank Transformers for connecting FNP to the grid provides reliable service to the plant. A spare 500/230-kV autotransformer has been provided that will be physically connected if there is a failure with one of the main Bank #1 or Bank #2 autotransformers.

8.2.2.4 Offsite Power System Operating Voltage Range

The normal offsite power system operating voltage range for Plant Farley Units 1 and 2 is within 101.6% to 104.5% of 230 kV. System studies have shown that this range can be maintained when at least one Farley unit is on line for system voltage support and will assure reliable unit operation. Offsite power system voltage is not intentionally lowered below the 101.6% voltage level because some nonsafety-related loads are not analyzed for operation below 101.6%. System voltages for worst-case single contingencies are expected to remain at or above 100% of 230 kV. This includes the contingency that assumes one Farley unit is in a LOCA and the other unit is tripped. The value of 100% assures acceptable terminal voltages, with margin, for safe shutdown equipment to perform its safety function. Therefore, continued unit operation is acceptable in the unlikely event that system voltage is found to be < 101.6% but above 100%. Voltages > 104.5% are allowed as long as 4160-V bus voltage levels do not cause equipment maximum voltage ratings to be exceeded.

Periodic transmission system planning studies are performed to help ensure that voltages can be maintained within acceptable limits.

TABLE 8.2-1 (SHEET 1 OF 2)

SUMMARY OF 230-kV AND 500-kV LINE CONSTRUCTION

	Farley Webb	Farley Pinckard	Farley S. Bainbridge	Farley Raccoon Creek	Farley Snowdoun	Farley Sinai Cemetary
Operating voltage	230 kV	230 kV	230 kV	500 kV	500 kV	230 kV
Tower design	Guyed aluminum delta	Guyed aluminum delta	Guyed steel pole H-frame	Self-supported latticed	Self-supported latticed	H-frame
Conductor	2-1351 ACSR	2-1033 ACSR	1-1351 ACSR	3-1113 ACSR	3-1033 ACSR	3-1351 ACSS/A
R/W width	125 ft	125 ft	125 ft	150 ft	200 ft	100 ft
Location of line on R/W	C/L	C/L	C/L	C/L	C/L	C/L
Line length	10 miles	35 miles	46 miles	62 miles	97 miles	47 miles
Terrain	Flat to rolling	Flat to rolling	Flat to rolling	Flat to rolling	Flat to rolling	Flat to rolling
Isokeraunic level	70	70	60-70	60-70	60-70	70-75
Phase/phase clearance	24 ft	24 ft	20 ft	28.5 ft	31 ft	20 ft
Phase/ground clearance at maximum operating condition	30 ft	30 ft	27 ft	33 ft	33 ft	30 ft
Remote line termination	Webb transmission substation	Pinckard T. W.	South Bainbridge Service Station	Raccoon Creek	Snowdoun substation	Sinai Cemetery substation
Unusual operating condition	None	None	None	None	None	None

TABLE 8.2-1 (SHEET 2 OF 2)

	Farley Webb	Farley Pinckard	Farley S. Bainbridge	Farley Raccoon Creek	Farley Snowdoun	Farley Sinai Cemetary
Major transmission line crossing (a)	None	115-kV Webb-Scholtz 115-kV Pinckard-Dothan #2 115-kV Pinckard-Columbia	500-kV Raccoon Creek on plant site 500-kV Snowdoun 115-kV Blakeley Cedar Springs 115-kV East Bainbridge-Donalsonville 115-kV Colquitt-Donalsonville	115-kV Mitchell-Moultrie 230-kV Mitchell-Thomasville 115-kV Blakely-East Bainbridge 230-kV South Bainbridge on plant site 115-kV Blakeley-Cedar Springs	230-kV Montgomery-Pinckard (3 crossings) 115-kV Union Springs-Pinckard 115-kV Troy-Union Springs 230-kV South Bainbridge on plant site 115-kV Pinckard Columbia 115-kV Webb-Eufaula	115-kV Scholtz-Marianna

a. Includes 115 kV and above.

[HISTORICAL]

[TABLE 8.2-2

SUMMARY OF 115-kV THROUGH 500-kV TRANSMISSION LINE FAILURES

Type of Failure	*Number*	*Cause of Failure*	*Number*
Pole/tower	*12*	*Lightning*	*5*
Crossarm	*18*	*High wind*	*12*
Insulator	*4*	*Tree*	*6*
Arrester	*0*	*Cold weather*	*5*
Shield wire	*10*	*Others*[(b)]	*51*
Span	*13*		
Sleeve	*2*		
Jumper	*1*		
Other[(a)]	*19*		
Total Failures	*79*		*79*

Voltage Class	*Structure Miles*[(c)]	*Number of Failures*	*Failures Per 100 Miles of Line*
500 kV	*192.14*	*5*	*2.60*
230 kV	*1,307.70*	*18*	*1.38*
161 kV	*295.08*	*5*	*1.69*
115 kV	*3,712.20*	*51*	*1.37*
Total	*5,507.12*	*79*	*1.43*

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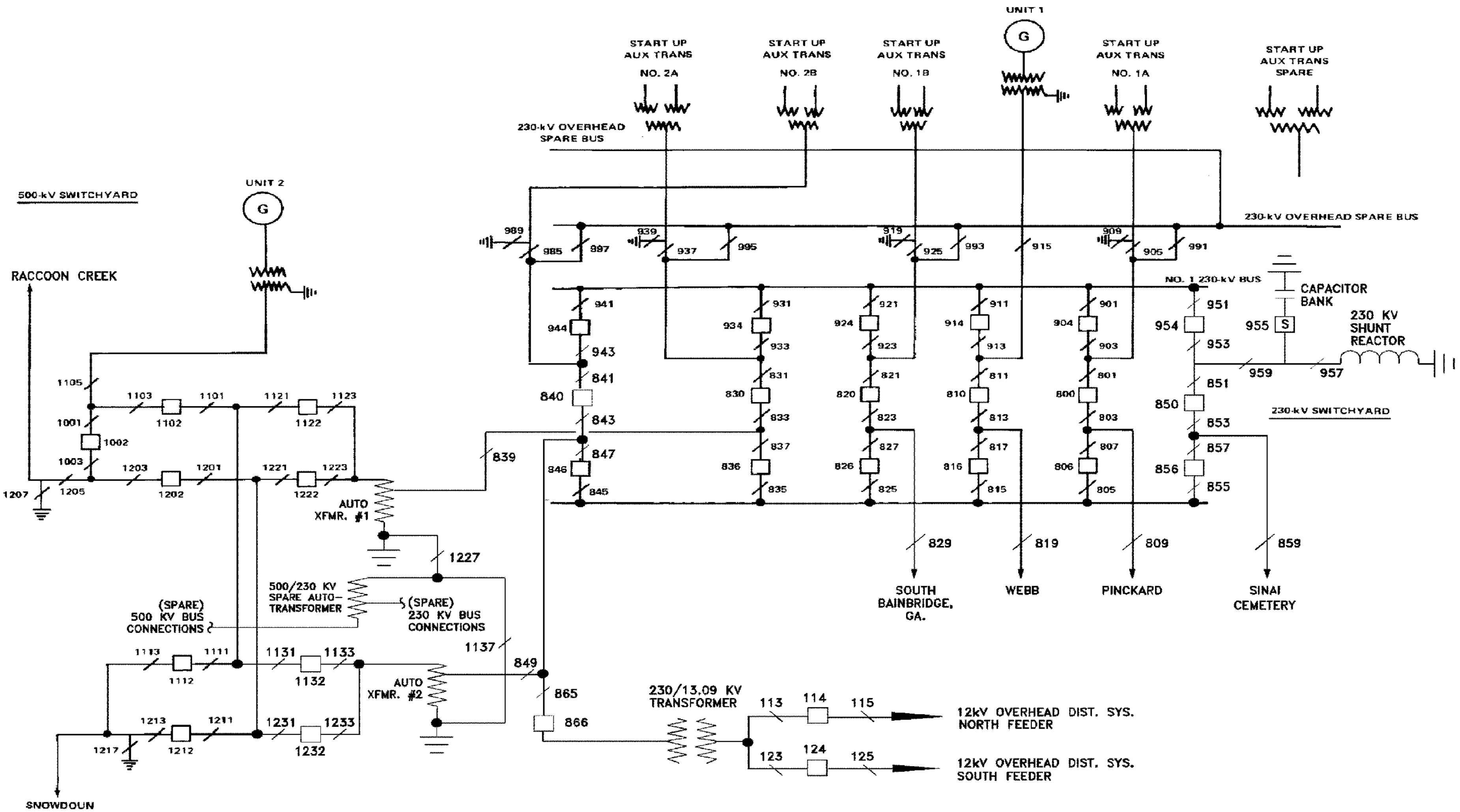
a. Includes conductor shorted together, foreign matter on lines, line switch failures, etc., and unknown causes.

b. Includes vandals, autos, trucks, airplanes, etc., and unknown causes.

c. Structure miles as of December 31, 1982.]



REV 25 4/14

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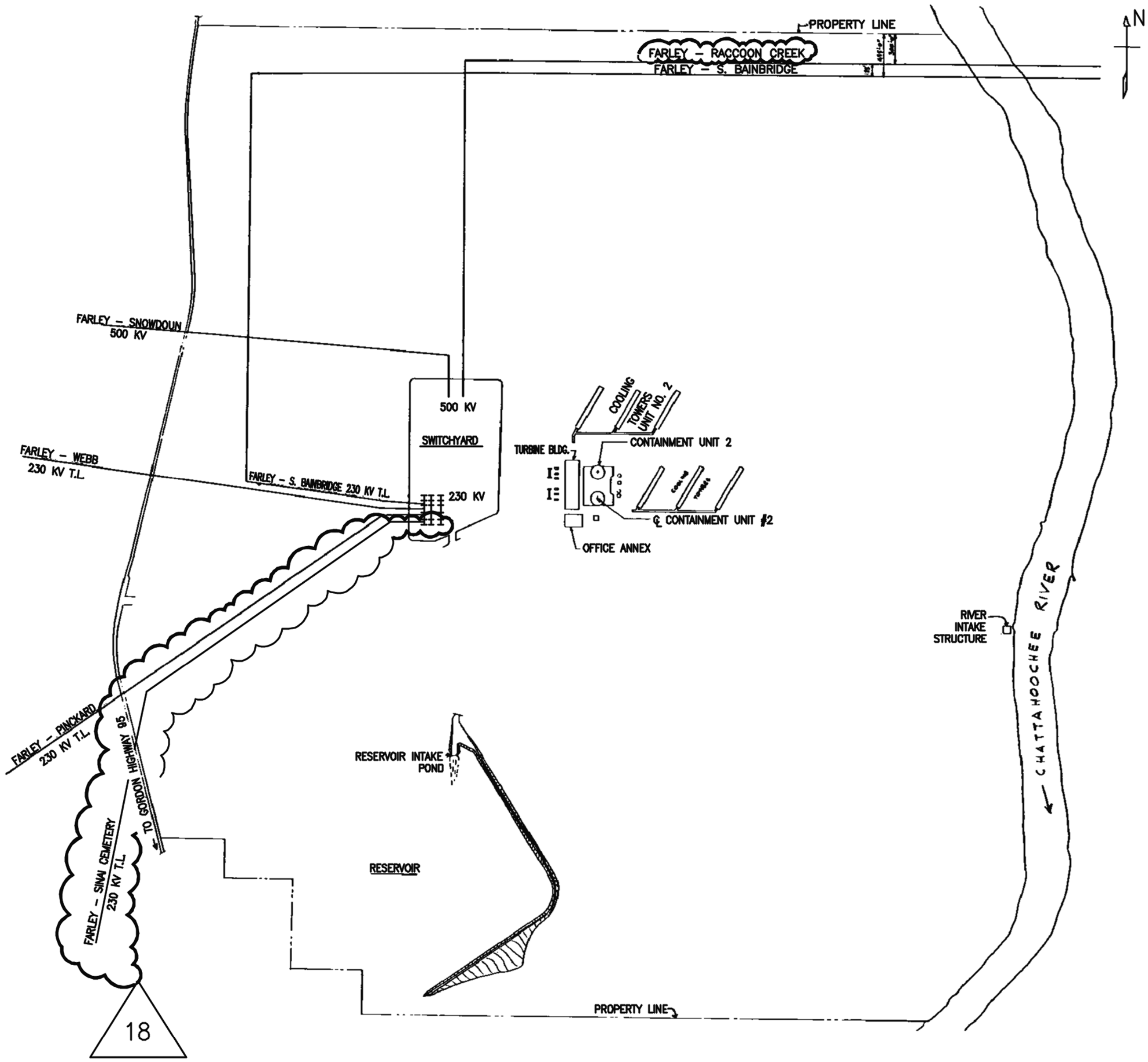
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SWITCHYARD ARRANGEMENT ONE-LINE DIAGRAM

FIGURE 8.2-1

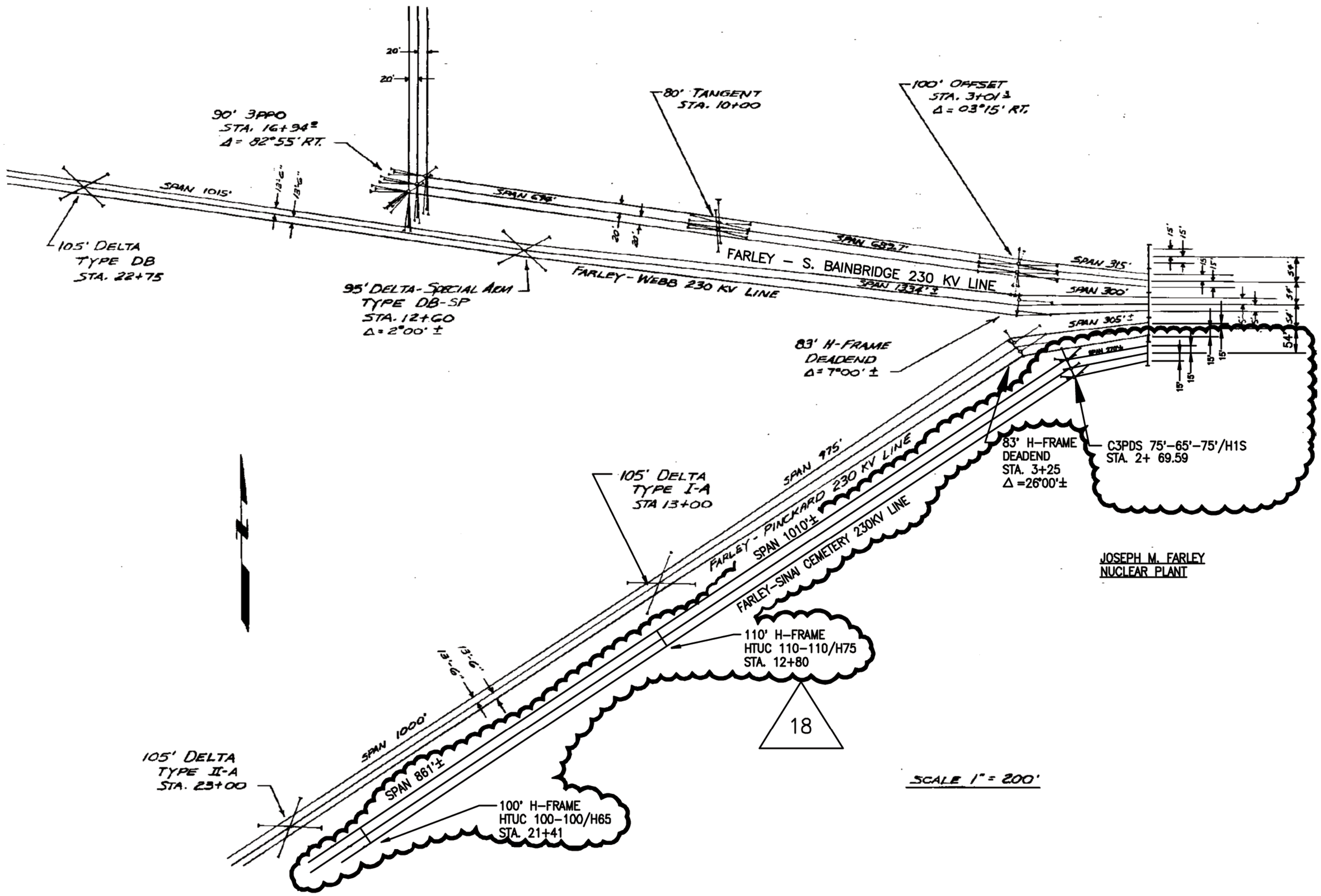


REV 21 5/08

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

TRANSMISSION LINE SEPARATION

FIGURE 8.2-2



REV 21 5/08

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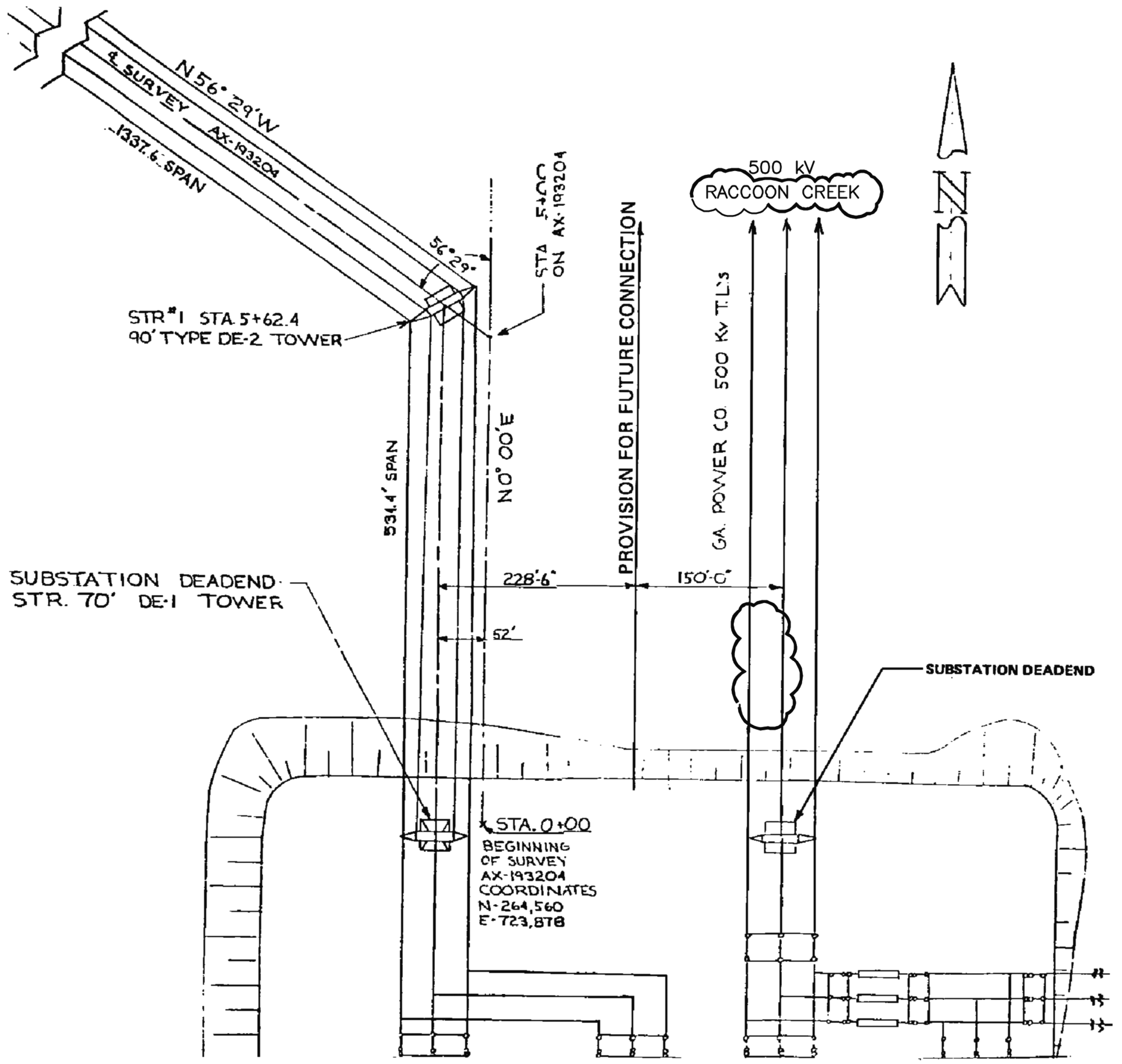
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

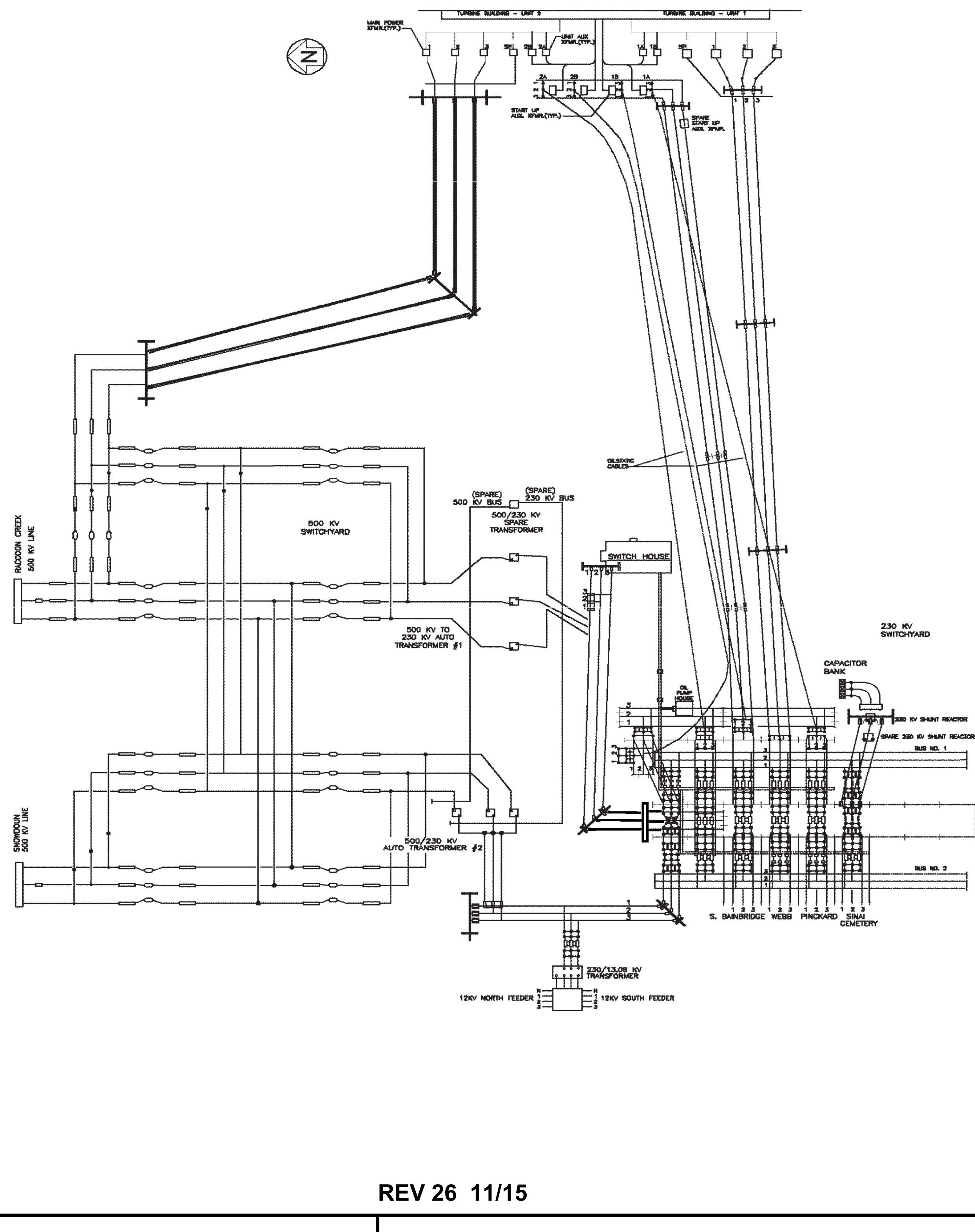
230 kV TRANSMISSION LINE SEPARATION

FIGURE 8.2-3



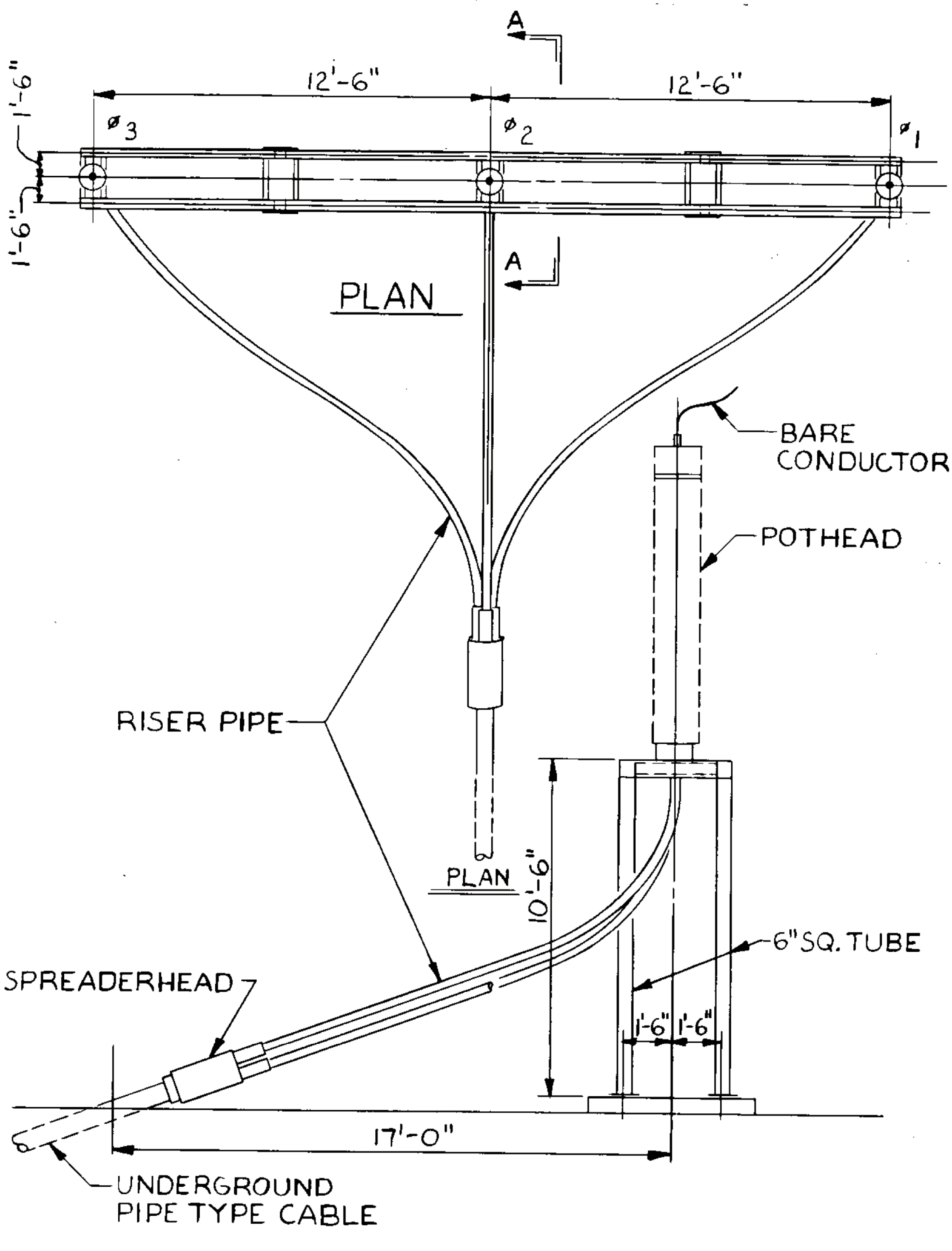
N 56° 29'W
℄ SURVEY AX-193204
1337.6' SPAN
56° 29'
STA 5+00 ON AX-193204
STR#1 STA.5+62.4
90' TYPE DE-2 TOWER
PROVISION FOR FUTURE CONNECTION
500 kV
RACCOON CREEK
GA. POWER CO. 500 Kv T.L.'s
N
531.4' SPAN
N 0° 00'E
SUBSTATION DEADEND
STR. 70' DE-1 TOWER
228'-6"
150'-0"
52'
SUBSTATION DEADEND
STA. 0+00
BEGINNING
OF SURVEY
AX-193204
COORDINATES
N-264,560
E-723,878

REV 21 5/08



REV 26 11/15

SOUTHERN COMPANY *Energy to Serve Your World®* **JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2**	SWITCHYARD ARRANGEMENT FIGURE 8.2-5



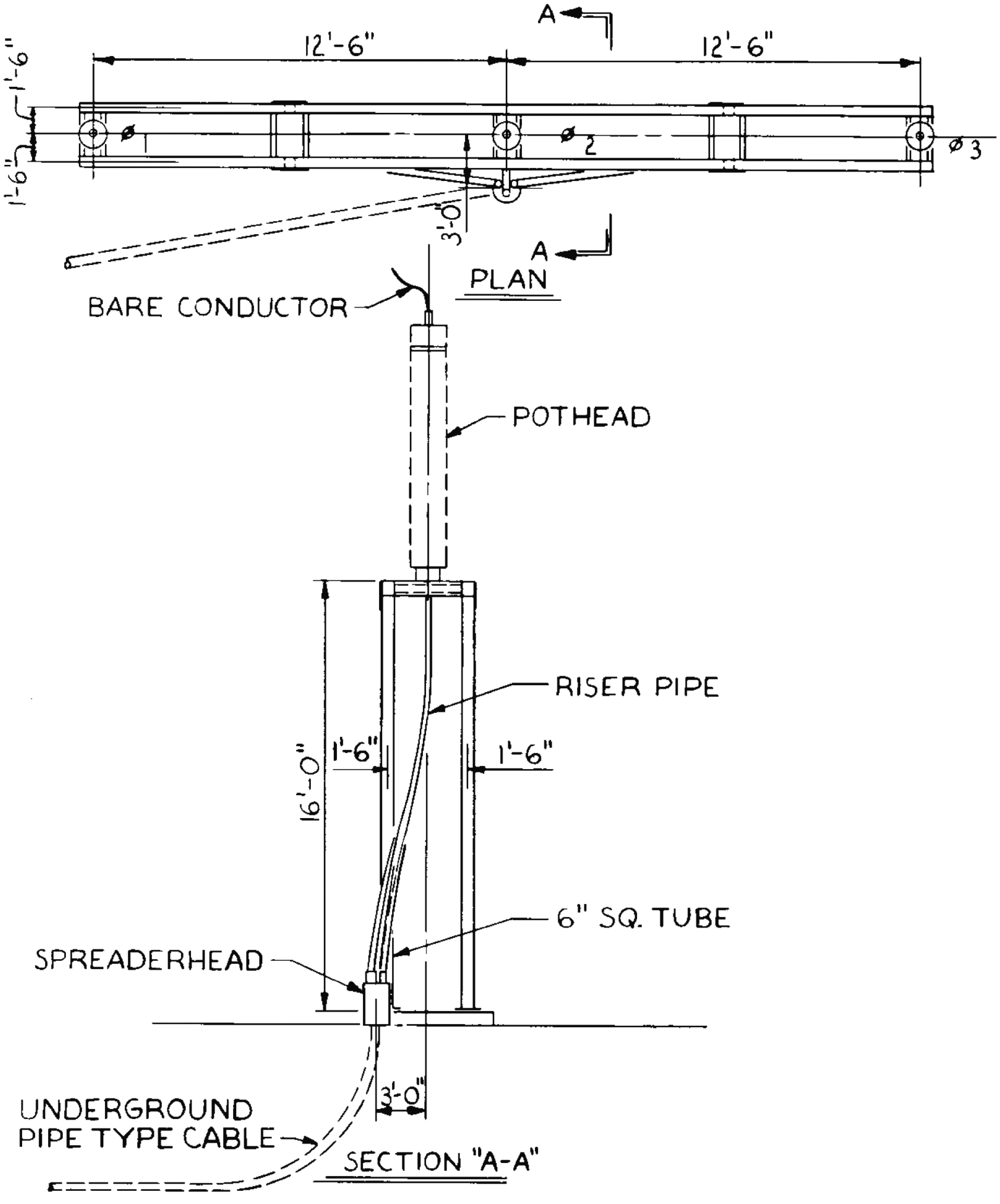
REV 21 5/08

SOUTHERN COMPANY
Energy to Serve Your World®

JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2

TYPICAL INTERFACE BETWEEN UNDERGROUND AND OVERHEAD TRANSMISSION AT SUBSTATION

FIGURE 8.2-6



REV 21 5/08

SOUTHERN COMPANY
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

TYPICAL INTERFACE BETWEEN UNDERGROUND AND OVERHEAD TRANSMISSION AT TRANSFORMER

FIGURE 8.2-7

8.3 ONSITE POWER SYSTEMS

8.3.1 AC POWER SYSTEMS

The ac auxiliary system for each unit consists of the 4.16-kV, 600-V, 480-V, 208-V, and 120-V subsystems, each designed to provide reliable electrical power during all modes of plant operation and shutdown conditions. The system for each unit is designed with a sufficient number of power sources and redundant buses to accomplish this. Engineered safeguard circuits are arranged so that the loss of a single bus section results in only single losses of engineered safeguards. A redundant engineered safeguard circuit is available to perform the same function.

The auxiliary system for each unit is capable of starting the largest required drive with the remainder of the connected motor load in service. Each unit is provided with a fast, dead-bus transfer feature which transfers the 4.16-kV buses A, B, and C from the unit auxiliary transformers to the startup auxiliary transformers following a turbine generator trip or reactor trip.

Protective relaying is arranged for selective tripping of circuit breakers after occurrence of an electrical fault. The electrical one-line diagrams for Unit 1 are shown on drawings D-177000 and D-177001, and for Unit 2 on drawings D-207000 and D-207001.

8.3.1.1 Description

8.3.1.1.1 Auxiliary System (4.16-kV)

A. Safety-Related Systems

The 4.16-kV emergency buses, which supply equipment essential for the safe shutdown of the plant, are comprised of six buses F, G, H, J, K, and L for each unit and are supplied from two startup transformers connected to the offsite source during normal and emergency operating conditions. Buses H and J also supply power to the river water system nonsafety-related loads. The preferred and the normal power supplies being the same, no transfer to a preferred source is required to be made in the event of an emergency. All components are designed to conform with Class 1E Electrical System Design Criteria as defined in IEEE Standard 308. In the unlikely event of a failure of one startup auxiliary transformer, three emergency buses are deenergized and their loss annunciated in the main control room.

The remaining emergency buses of the affected unit are capable of supplying the minimum required engineered safeguards independently as indicated in table 8.3-1. Manual action is required to reenergize the bus from the other startup auxiliary transformer.

No single failure of an active component will remove two startup auxiliary transformers in redundant circuits at one time. The capacity of the transformers and circuit breakers is sufficient to permit full-plant operation with one transformer out of service.

Each 4.16-kV emergency bus, except K and L (which are considered extensions of buses F and G) is equipped with a set of undervoltage relays which provide protection against a loss of voltage condition. Upon recognition of a loss of voltage on a 4.16-kV emergency bus, these relays, configured in a two-out-of-three coincidence logic, initiate a signal to effect the following:

A. Load shedding.

B. Diesel generator starting (except diesel 2C).

C. Tripping of 4.16-kV preferred offsite power supply breakers.

The undervoltage relays employed for loss of voltage protection are induction disc-type relays with an inverse time trip characteristic set at 3255 V, approximately 78.24 percent of the nominal (4160-V) bus voltage and with the time dial selected in such a way as to avoid nuisance tripping during normal operating conditions.

In addition, each of the 4.16-kV emergency buses F and G is equipped with a degraded grid alarm and a second set of undervoltage relays to provide protection against a sustained degraded grid voltage condition. Upon recognition of a sustained degraded grid voltage condition at or below the alarm setpoint, the alarm will alert operators so that actions can be taken to restore voltages to normal levels. For continued voltage degradation that leads to sustained degraded voltage levels at or below the relay setpoint, the degraded grid undervoltage relays, configured in a two-out-of three coincidence logic, initiate a signal to trip the 4.16-kV preferred power supply breakers.

The degraded grid alarms are set at 3850 V, approximately 92.55 percent of the nominal (4160-V) bus voltage to avoid any nuisance alarms during normal operating conditions. The undervoltage relays employed for sustained degraded voltage protection are induction disc-type relays with an inverse time trip characteristic set at 3675 V, approximately 88.34 % of the nominal (4160-V) bus voltage and with a time dial setting of 1.5, calculated to avoid any nuisance tripping during normal operating conditions without exceeding the maximum time delay assumed in the accident analyses. The degraded grid alarm setpoint and the degraded grid relay voltage and time settings were also selected to ensure that voltage requirements of the safety-related loads at all onsite system distribution levels are met.

The voltage levels at safety-related buses are optimized for the expected load conditions throughout the anticipated range of voltage of the offsite system by adjustment of transformer taps. The analysis has been verified to be accurate by testing.

The onsite emergency ac power supply for Units 1 and 2 consists of five diesel generator units which supply standby power for 4.16-kV emergency service buses F, G, H, J, K, and L of each unit. For a detailed description of the operation of the diesel generators, refer to paragraph 8.3.1.1.7. A schematic arrangement of the diesel generators and the safeguard buses is shown in figure 8.3-1.

The engineered safety feature loads are divided between the emergency buses of each unit in a balanced, redundant load grouping so that the failure of one emergency diesel generator or one emergency bus in each unit will not prevent the safe shutdown of both reactors.

Drawings C-177119, C-177120, and C-177121 show the interlocking scheme for 4-kV pump motors which can be aligned either to bus F or bus G. Elementary diagrams for the operation of the startup transformer incoming feeders are covered in drawings D-177155, D-207155, D-177161, D-207161, D-177168, and D-177169. Drawings D-177185, D-207185, D-177187, and D-207187 show the controls for the swing component cooling pump B. This design is typical for the high head safety injection pump B and service water pump C.

B. Nonsafety-Related System

The 4.16-kV auxiliary system for the nonsafety-related loads is comprised of five buses: A, B, C, D, and E. Nonsafety-related river water system loads are supplied from safety-related buses H and J. During normal operations, the unit auxiliary transformers supply power for buses A, B, and C of each unit while buses D and E for each unit are powered from the unit startup transformers.

Condensate Pump A, the reactor coolant pumps, and the circulating water pumps are supplied from buses A, B, and C. Provision has been made on these buses for a fast, dead-bus transfer to the startup transformer source in the event of failure of the normal supply from the unit auxiliary transformers. For a fault that is nonelectrical and restricted to the turbine system, the tripping of the generator and, consequently, the initiation of a fast transfer is delayed by 30 s to permit continued operation of the reactor coolant pumps. For reasons of safety and optimum utilization of the flywheel energy in the reactor coolant pump, the latter is electrically disconnected from the 4.16-kV system upon the occurrence of an undervoltage or an underfrequency condition.

8.3.1.1.2 600-V, 480-V, and 208-V Auxiliary Systems

Twenty 600-V load centers are provided for Unit 1 and another 20 for Unit 2. In addition, seven load centers are being shared between the two units. Two more 600-V load centers, powered from Unit 1, are provided for the Visitors Center. Each load center, except 1, 2, and 3, derives its power supply from the 4.16-kV auxiliary system through individual 4160/600-V station service transformers rated at either 1000 kVA or 300 kVA. Load centers 1, 2, and 3 derive their power from the 12-kV overhead distribution system through individual station service transformers rated 1250 kVA.

Load center F, with a separate 1000-kVA transformer, is a spare and provides a standby source of power supply to load centers A, B, C, D, E, G, M, N, P, and Q. Each load center receiving power from load center F has a key interlock to ensure that it is supplied from only one source at a time (dead bus transfer), with the exception of maintenance performed under plant maintenance procedures that allow for the simultaneous connection of any of these load centers to both the primary and standby source during the transfer between power sources (hot bus transfer). A typical interlock schematic is shown in drawing D-177122. The capacity of the spare transformer located in load center F and the arrangement of the 600-V load center tie breakers permit plant operation with one transformer out of service. For operation of load center F, key interlocks are provided between the 4.16-kV supply breakers, the associated disconnects, and the 600-V feeder breaker to ensure correct alignment to one of the two 4160-V engineered safeguard buses F or G. Details of the interlocking scheme are shown on drawing C-177118.

600/208-V, 600-V, and 208-V motor control centers (MCCs) are provided to supply power to equipment within their related areas. Most of these MCCs are dedicated to either Unit 1 or Unit 2, but several supply shared equipment and/or are located in shared structures. Each MCC is fed from a 600-V load center or the 120/208-V switchgear.

In addition, two 480-V MCCs 1Q and 1R supply power to loads in the service building. These MCCs are in turn supplied from 4160-V bus 1E through 4160-V, 750-kVA transformers.

A. Safety-Related System

All components are designed to conform with Class 1E electrical system design criteria as defined in IEEE Standard 308.

600-V load centers D, E, K, L, R, and S supply power for engineered safety features equipment. Load centers K, L, R, and S are shared between the two units. Load centers A and C have one bus section allocated for supplying safety-related loads (see drawings D-177007, D-207007, D-177009, and D-207009). In addition, spare load center F is provided to supply standby power to load centers D and E under the conditions previously outlined in this section.

Under normal operating conditions, load centers A and C are operated as continuous sections. In the event of loss-of-offsite-power (LOSP), the emergency part of load centers 1C and 2C can be manually disconnected from the normal side and supplied from load centers 1E and 2E, respectively, through electrically interlocked breakers. In the event of a LOSP, the emergency part of the load center A is automatically disconnected from the normal side and supplied from load center D through electrically interlocked breakers. With A and C transferred to D and E, the total load on load centers D and E is within the rated capacity of the individual station service transformer of each bus.

The loss of one 600-V emergency bus or the failure of any redundant component of the emergency system deprives the unit of only part of the equipment associated with that particular function. The remaining operational equipment is adequate for the shutdown of the unit under normal or accident conditions.

Safety-related 600/208-V MCCs are provided to supply power for safety-related equipment within their related areas. Each safety-related MCC is fed from a safety-related 600-V load center.

Some nonsafety-related loads are fed from safety-related load centers or MCCs. Primary protection of the safety-related load centers and MCCs has been selected such that a fault at the terminals of nonsafety-related equipment powered from a safety-related load center or MCC will not result in a loss of the associated load center or MCC bus.

B. Nonsafety-Related System

600-V load centers A, B, C, G, H, I, J, M, N, P, Q, U, V, W, X, Y, Z, 1, 2, and 3 supply power for nonsafety-related equipment. Load centers H, J, and N are shared between the two units. 600-V load centers 1O and 1T provide power to the Visitors Center. In addition, spare load center F is provided to supply standby power to load centers A, B, C, G, M, N, P, and Q under the conditions previously outlined in this section.

600/208-V, 600-V, 480-V, and 208-V MCCs are provided to supply power to nonsafety-related equipment within their related areas.

8.3.1.1.3 Equipment Rating

A. Transformer

Drawings D-177000, D-177001, D-207000, and D-207001 show the unit auxiliary transformers and startup transformers electrical arrangement. The unit auxiliary transformers are capable of supplying power to 4.16-kV buses A, B, C, D, and E for Unit 1 and A, B, and C for Unit 2. The startup transformers are also capable of supplying power to 4.16-kV buses A, B, C, D, and E, along with 4.16-kV emergency buses F, G, H, J, K, and L of each unit. The ratings of the transformer are as follows:

1. Unit auxiliary transformer 1A

Winding	55°C Rise	65°C Rise
22-kV	20/26.67/33.33 MVA	22.4/29.87/37.33 MVA
4.16-kV	10/13.33/16.67 MVA	11.2/14.93/18.67 MVA
4.16-kV	10/13.33/16.67 MVA	11.2/14.93/18.67 MVA

Three-phase, 60 hertz, class OA/FA/FOA, 10.4% (1A) impedance at 10-MVA base.

2. Unit auxiliary transformer 1B

Winding	65°C Rise
22-kV	28/37.33/46.66 MVA
4.16-kV	14/18.66/23.33 MVA
4.16-kV	14/18.65/23.33 MVA

Three-phase, 60 hertz, class ONAN/ONAF/ONAF, design impedance 12.4% ±10% at 14-MVA base.

3. Unit auxiliary transformer 2B

Winding	55°C Rise	65°C Rise
22-kV	25/33.3/41.67 MVA	28/37.33/46.7 MVA
4.16-kV	12.5/16.67/20.83 MVA	14/18.67/23.33 MVA
4.16-kV	12.5/16.67/20.83 MVA	14/18.67/23.33 MVA

Three-phase, 60 hertz, class OA/FA/FOA, 11.1% (2B) impedance at 12.5-MVA base.

4. Startup auxiliary transformers A and B

Winding	55°C Rise	65°C Rise
230-kV	26/34.6/43.2 MVA	29.1/38.75/48.38 MVA
4.16-kV	13/17.3/21.6 MVA	14.56/19.38/24.19 MVA
4.16-kV	13/17.3/21.6 MVA	14.56/19.38/24.19 MVA

Three phase, 60 hertz, class OA/FOA/FOA, 13.89% (1A & 1B), 13.8% (2A), or 13.9% (2B) impedance at 13-MVA base.

B. 4160-Volt Switchgear

The general arrangement of buses F, G, H, J, K, and L, including the description of loads supplied, is indicated in the single-line diagrams of drawings D-177005, D-207005, D-177006, D-207006, D-177018, D-207018, C-177027, D-207027, C-177043, and C-177044. The switchgear is of metal-clad construction and is equipped with three-pole, drawout-type, electrically and remotely controlled circuit breakers. The ratings of the switchgear are as follows:

1. Rated short-circuit current = 41-kA rms (sym) at 4.76-kV.

2. Rated current of breakers:

   - 1200 amperes
   - 2000 amperes
   - 3000 amperes

3. Rated current of main bus bars:

   - 1200 amperes
   - 2000 amperes
   - 3000 amperes

C. 600-Volt Load Center

Drawings D-177007, D-207007, D-177009, D-207009, D-177010, D-207010, D-177011, D-207011, C-177012, D-177014, D-207014, D-177015, D-207015, D-177045, D-207045, D-177046, D-207046, D-177677, and D-177678 show the bus and feeder arrangement of load centers A, C, D, E, F, H, J, K, L, R, and S. The main bus bars, rated at 1600 amperes and 600 volts, are braced for a fault duty of 22,000 amperes ac. The load centers are of metal-enclosed construction and are equipped with three-pole, drawout-type, electrically and remotely controlled air circuit breakers, except load center F, which is equipped with a manually operated breaker. All breakers are rated to interrupt a fault current of 22,000 amperes at 600 volts. The continuous current ratings and trip sensor rating for the breakers are given in the relevant single-line diagrams. The breaker trip settings for each breaker can be found on its associated relay setting sheet (see drawings A-177048 or A-207048).

D. 600-Volt and 208-Volt MCCs

The MCCs are equipped with combination across-the-line starter and molded-case circuit breakers and have the following ratings:

	600-V MCC	208-V MCC
Breaker interrupting current rms (sym)	18,000 A	18,000 A
Starter size, minimum	No. 1	No. 1
Bus rating	600 A	150 A

The 208-V MCCs obtain their power supply from the associated 600-V MCC through 30-kVA, 45-kVA, or 75-kVA 600- to 208/120-V dry-type transformers. The 600-V and the 208-V MCC form a single lineup. The 600-208/120-V transformer in each MCC is protected on the 600-V side by a molded-case circuit breaker or a disconnect switch and fuses.

8.3.1.1.4 120-Volt Vital Instrument Power System

Four redundant channelized 120 V-ac vital instrumentation distribution panels are provided for each unit to supply power for essential instrumentation and control loads under all operating conditions (see drawings D-177024, D-207024, D-177025, and D-207025). Each distribution panel is supplied separately from a static inverter.

The normal power source for each static inverter is the associated Class 1E battery charger via the 125 V-dc switchgear. Loss of the battery charger will not render the normal power source inoperable, as the inverter will automatically begin to draw power from the associated Class 1E battery via the same 125 V-dc switchgear without interruption. In case of inverter failure, overload, or branch fault resulting in inverter output voltage outside the specified limits, the static transfer switch (STS), which is part of the inverter unit, transfers the 120-V vital ac distribution panel to an alternate source: Class 1E CVT. Retransfer of the inverter back to its normal power source can only be achieved manually. Each inverter is also equipped with a manual bypass switch (MBS) to be used when the inverter is to be taken out of service for maintenance purposes.

Each of the four redundant channels of nuclear instrumentation, as described in chapter 7, is supplied from a separate channelized distribution panel. Also, each of the four independent and redundant channels of the reactor protection system and engineered safeguards system is supplied from a separate channelized distribution panel. The system is arranged so that any type of single failure within the system will involve only one channel and will not prevent the reactor protection system or the engineered safeguards system from performing its safety function.

Two redundant train oriented 120 V-ac vital instrumentation distribution panels are provided for each unit to supply power to nonchannelized essential instrumentation and control loads under all operating conditions (see drawings D-177024, D-207024, D-177025, and D-207025). Each train oriented distribution panel is supplied in a manner similar to the channelized instrumentation distribution panels.

8.3.1.1.5 120 Volt-ac Regulated Instrument Power System

The system provides power for nonessential instrumentation, control, and loads requiring regulated 120 V-ac power. It consists of distribution panels and regulating transformers fed from MCCs as shown in drawings D-177024, D-207024, D-177025, and D-207025.

8.3.1.1.6 208/120 Volt-ac Power System

The distribution cabinets that make up the 208/120 V-ac, 3-phase, 4-wire, unregulated power system derive their supply from a 208-V MCC or the 120/208-V switchgear located in the turbine building. The system provides power for nonessential instrumentation, small motors (3-hp and less), and other miscellaneous 208- or 120-V loads.

The 208/120 V-ac distribution panels have a main bus which shall be compatible with the maximum design load assigned to the panel and can withstand the short circuit current calculated for the actual location of the panel. The branch circuit breakers are of molded case design and provide overload and short circuit protection for the panels and are capable of interrupting fault current.

Safety-related loads are supplied from distribution panels fed from safety-related MCCs. The distribution system is arranged to provide adequate independence and redundancy so that a single failure will not prevent the ESF system from performing its required function. Some nonsafety-related loads are fed from safety-related distribution cabinets. These nonsafety-related loads will not affect the integrity of the safety-related loads.

All other nonsafety-related loads are supplied from distribution panels fed from nonsafety-related MCCs and various other distribution cabinets fed from the 120/208-V switchgear.

8.3.1.1.7 Onsite Emergency Power Systems

8.3.1.1.7.1 <u>General</u>. The onsite emergency ac power supply for Units 1 and 2 consists of five diesel generators which supply standby power for 4160-V emergency buses F, G, H, J, K, and L of each unit when offsite power is unavailable. These buses provide power to the emergency loads. As documented in Section 8.3.3 of NUREG 0117, Supplement 5 to NUREG-75/034 dated March 1981, the NRC acceptance criteria associated with the design of the diesel generators and their auxiliary systems is contained in GDC 17, 18, 21, and NUREG/CR-0660.

The LOSP loads are the emergency loads required to function during the shutdown process of a nonaccident unit when that unit experiences the loss of its offsite power sources.

The engineered safeguard system loads are the emergency loads required to function during the shutdown process of an accident unit.

The emergency loads are divided between the emergency buses of each unit in two balanced, redundant load groups so that the failure of a redundant group does not prevent the safe shutdown of either reactor.

The 4160-V emergency buses F, H, and K of each unit and their associated emergency loads are designated as the redundant load group train A.

The 4160-V emergency buses G, J, and L of each unit and their associated emergency loads are designated as the redundant load group train B.

Diesel generators 1-2A and 1C are assigned to the redundant load group train A, while diesel generators 1B, 2B, and 2C are assigned to the redundant load group train B (as discussed below, diesel generator 2C is dedicated to SBO events).

The five diesel generators are of two different sizes, as follows: three 4075-kW diesel generators 1-2A, 1B, and 2B and two 2850-kW diesel generators, 1C and 2C.

The capacity of each of these diesel generators ensures that sufficient power will be available at its respective emergency bus to provide for the operation of its required emergency loads during design basis events or an SBO event as applicable.

The design of the onsite emergency power system is such that the plant meets its licensing basis for all design basis events using only four of the diesel generators, namely 1-2A, 1C, 1B, and 2B.

Therefore, these four diesel generators are dedicated for use during the design basis events as discussed in paragraph 8.3.1.1.7.2.

Diesel generator 2C is dedicated as the alternate ac (AAC) power source for use during station blackout (SBO) events as discussed later in paragraph 8.3.1.1.7.3.

Diesel generator 2C, being the AAC for SBO events, is not considered a candidate for the design basis single failure. However, diesel generator 2C meets all applicable safety-related criteria and thus, it is available for use on B-train during design basis events.

Each generator is supplied with a high-speed voltage regulator designed to return generator voltage to its rated value within an acceptable delay after starting of the largest motor.

Voltage and frequency relays connected to potential transformers on the diesel generator output circuit at the local control panel detect generator voltage and frequency conditions. When voltage and frequency conditions are acceptable, they provide a permissive interlock for closing of the respective generator output circuit breaker.

Interlocks are provided to prevent closing of a diesel generator breaker to a faulty bus.

Synchronizing by the plant operator is performed per plant procedures when paralleling the diesel generator with the startup auxiliary transformers.

Each diesel generator is equipped with means for periodic starting to test for readiness and loading, and means for synchronizing the unit onto the bus without interrupting the service.

The diesel generators 1C, 2B, and 2C starting circuit includes a start to idle feature which allows the operator to perform a modified start for maintenance or surveillance testing in order to reduce stress and wear on the diesel engine. With the idle start mode selected, a manual diesel generator start brings the diesel generator up to idle speed with the field flash circuit blocked. Following engine warmup at idle speed, the operator can raise the engine speed to rated and manually flash the field by placing the RATED/IDLE selector switch in the RATED position. For diesel generator 2C, if either Unit 1 or 2 experiences a station blackout while the diesel generator is in the idle mode, depressing the SBO start pushbutton automatically places the circuit in the rated mode and the diesel generator responds normally. For diesel generators 1C and 2B, either a safety injection signal or undervoltage signal received while the diesel generator is in the idle mode automatically places the circuit in the rated mode and the diesel generator responds normally.

Diesel fuel oil storage tanks and day tanks provide sufficient fuel oil to support required diesel generator operation. The diesel generator fuel oil system is described in subsection 9.5.4.

The quality of fuel oil in long term storage is monitored by periodic sampling of the fuel oil in the storage tanks and sampling of new fuel in accordance with plant procedures. If the fuel oil in the storage tanks does not meet the required specifications identified in the plant procedures, corrective actions are initiated to return the fuel oil within the acceptable limits. These corrective actions may range from chemical additions to complete replacement of the fuel oil.

The diesel generators are housed in reinforced concrete, Category I seismic structures. Each unit is completely enclosed in its own concrete cell and isolated from the other units. Each diesel generator has an electrically powered standby warming system which will automatically maintain the engine, cooling water, and lubricating oil temperature at a satisfactory level to allow fast starting of the diesel generator sets. Local annunciation and local indication of malfunctions are provided so that, in the event of a failure, an operator may immediately determine the cause. Two complete and independent starting-air-supply systems with receivers, valves, and fittings are supplied with each diesel. The starting air receivers for each of the starting systems have enough capacity for a minimum of five consecutive starts.

Each diesel generator is cooled through a closed loop series of three heat exchangers. For diesels 1-2A, 1B, and 2B, service water enters the intercooler heat exchanger through an engine-driven cooling water pump, passes through the jacket water heat exchanger, and finally through the lubricating oil heat exchanger before returning to the service water system. For diesels 1C and 2C, service water enters the intercooler heat exchanger through an engine driven cooling water pump, passes through the lubricating oil heat exchanger, and finally through the jacket water heat exchanger before returning to the service water system.

The cooling medium flowing through the tube side is part of the service water system. Each diesel engine heat exchanger can be supplied from two service water headers. The cooling water system for the diesels is discussed in subsection 9.5.5.

Typically, emergency diesel generator engines for this service operate for approximately 3 min at full load without cooling water supply. This provides time, in the event of a dead bus, for the initiation of flow in the service water system.

The dc power required for emergency buses and diesel generators for Units 1 and 2 is provided as shown on drawings D-177082, D-177083, D-207082, and D-207083. Diesel generators 1-2A, 1C, and 2C can receive dc power from either Unit 1 or Unit 2 batteries. Automatic transfer switches, mechanically held, are provided. The transfer is initiated when the selected source is deenergized.

Loss of dc control power for each diesel generator is annunciated locally and in the control room. The alarm local to the diesel generators indicates “control circuit failure” upon loss of dc control power. The control room alarm is located on the EPB and alerts the operators to “diesel generator trouble.” At the same time the EPB annunciator sounds, the diesel generator “ready for automatic start” lamp goes out. The lamp is also located on the EPB.

During emergency power operation only a limited number of protective devices will lead to a trip of the unit. These will include the following:

- Engine overspeed.
- Lubrication oil pressure low.[a]
- Generator differential.

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a. Two lube-oil pressure switches will be installed and wired in series so that two-out-of-two signals will be necessary to trip.

During periodic testing operation, the conditions causing a trip are as follows:

- Engine overspeed.
- Generator differential.
- Lubrication oil pressure low.
- High jacket water temperature.
- High lubrication temperature.
- Generator under frequency.
- Reverse power flow.
- Loss of excitation.
- Jacket water pressure low.
- Crankcase pressure high.
- Generator overcurrent.

Should a diesel fail to achieve sufficient speed to clear its starting interlocks within 7 s, its starter air supply and the fuel are cut off and an alarm is sounded.

8.3.1.1.7.2 **Response to Design Basis Events.** During normal plant operation the four design basis diesels 1-2A, 1C, 1B, and 2B are set for emergency operation, each with its mode selector switch (MSS) in Mode 1 position. With this setting, the starting, alignment, and loading of these four diesel generators are entirely automatic in all design basis events, with no need for any manual operator action.

These four diesel generators are each uniquely assigned to a redundant train of safe shutdown equipment for one unit in each design basis event.

A safety injection (SI) signal from either unit will start shared diesel generators 1-2A and 1C. Diesel generators 1B and 2B will also start on an SI signal if their corresponding unit is experiencing an accident.

An undervoltage (LOSP) signal on the 4-kV ac train A buses of either unit will start the associated shared diesel generator (diesel generator 1-2A associated with buses 1F and 2F, diesel generator 1C associated with buses 1H and 2H). Diesel generators 1B and 2B will also start upon receipt of an undervoltage (LOSP) signal from their assigned 4-kV ac train B buses (diesel generator 1B assigned to bus 1G and diesel generator 2B assigned to bus 2G).

Diesel generators 1B and 2B are uniquely dedicated to train B of Unit 1 and Unit 2, respectively. Diesel generators 1-2A and 1C are shared between both units and are directly connectable to the units through dedicated breakers, not through bus interties. Diesel generators 1-2A and 1C are dedicated to train A, but there are no design basis events in which diesel generator 1-2A or 1C supplies power to safety loads of both units simultaneously. In all events, diesel generators 1-2A and 1C are assigned to only one of the two units, depending on the event. The Unit 1 and Unit 2 breakers for each of these two diesels are interlocked so as to prevent the diesels from being connected to both units at the same time; therefore, diesel generators 1-2A and 1C are characterized as "shared" only from the point of view of their capability to align to either Unit 1 or Unit 2.

The capacity of the diesel generators and their unit alignment must ensure adequate power for the safe shutdown loads during the worst case loading scenario (LOSP on both units concurrent with a loss-of-coolant accident (LOCA) on one unit). Diesel generators 1-2A, 1B, and 2B each have a continuous rating of 4075 kW (4353 kW for the 2000-h rating), which is sufficient to ensure adequate power for one complete train of normal (LOSP) or accident shutdown loads in one unit. Diesel generator 1C has a continuous rating of 2850 kW (3100 kW for the 2000-h rating), which is sufficient to ensure adequate power for one complete train of normal (LOSP) shutdown loads in one unit.

Consequently, the alignment of train B diesel generators 1B and 2B, which remains the same during all design basis events, ensures adequate power for a complete train B of LOSP or accident shutdown loads in each unit.

Of the two train A diesel generators, 1-2A and 1C, diesel generator 1C has sufficient capacity to only provide power to a complete train of shutdown loads of a nonaccident unit (LOSP only). Since a LOCA is assumed to occur on only one unit, the alignment logic of these two train A diesel generators is designed to ensure that in events involving a LOCA, diesel generator 1-2A aligns to the accident unit and diesel generator 1C aligns to the nonaccident unit. The alignment chosen for these train A diesels in scenarios involving LOSP only is arbitrary (1-2A is aligned to Unit 1 and 1C is aligned to Unit 2 for a dual unit LOSP event), since both diesel generators 1-2A and 1C have sufficient capacity to energize the required loads in these events. Therefore, the alignment logic of the two train A diesel generators, 1-2A and 1C, ensures adequate power for a complete train of required shutdown loads in each unit.

When offsite power is not available from the startup auxiliary transformer, the emergency buses are isolated from those sources and all main-load feeder breakers off these buses are tripped.

The emergency loads required for design basis events are automatically energized by the diesel generators in a predetermined sequence with time intervals sufficient to allow the inrush current of large motors to decay and the diesel generator to recover from one load step prior to the application of the next load step. Drawings D-177645, D-177646, D-177647, D-177648, D-177649, D-177650, D-177653, and D-177654 show the loading sequence for diesel generators 1-2A, 1B, and 1C for Unit 1. Similar circuits determine the loading for diesel generators 1-2A, 2B, and 1C for Unit 2.

The loading requirements of the emergency buses, as a function of time for the design basis accident and for the shutdown conditions, are shown in table 8.3-1. The main loads in the loading tables are conservatively based on a detailed analysis of the manufacturer’s data (nameplate ratings, horsepower curves) and the field preoperational test results. The miscellaneous loads are determined by the nameplate ratings along with application of an appropriate diversity factor.

The alignment and maximum estimated loading of each design basis diesel generator during all design basis and SBO events are shown in tables 8.3-2 and 8.3-2A, respectively.

The diesel generator ratings in table 8.3-3 are compared to the maximum calculated automatic sequenced loading for design basis and SBO events. This table, in conjunction with tables 8.3-1, 8.3-2, and 8.3-2A demonstrates that each of the diesel generators and its respective alignment to the emergency buses are adequate to supply their required loads during design basis events.

Due to the full redundancy provided by the four diesel generators and the existing full redundancy of the safe shutdown loads, the failure of a complete train in one unit will not prevent the safe shutdown of that unit.

It should be noted that if an emergency situation occurs while a diesel generator is being prepared for test with its MSS in Mode 2 position (remote manual), the automatic signals generated by the emergency situation (SI and/or LOSP) will override the test mode and, therefore, the diesel generator will automatically start and align for the event.

8.3.1.1.7.3 Response to Station Blackout (SBO). FNP is capable of withstanding and recovering from a total loss of both offsite and onsite emergency ac power sources (called "station blackout") as required by 10 CFR 50.63 for a specified duration. For Farley, this duration was determined to be 4 h. This ability to cope with an SBO is consistent with the guidance contained in Regulatory Guide 1.155 and NUMARC 87-00, including supplement, and therefore meets the NRC acceptance criteria contained in 10 CFR 50.63.

The initiating event is assumed to be a LOSP at a plant site. At a multiunit site such as Farley, the LOSP is assumed to affect all units, while the SBO is assumed to occur in only one unit.

SBO is not a design basis accident (DBA). Therefore, single failures of equipment and other assumptions normally considered for DBAs and analysis need not be considered. The unaffected unit must be able to achieve safe shutdown with a single failure; a DBA need not be considered.

FNP selected the AAC approach for coping with an SBO event and dedicated Class 1E diesel generator 2C as the AAC power source to cope with an SBO event in either unit for the required duration (4 h).

Given this selected approach and the assumptions that must be made (LOSP on both units concurrent with the simultaneous failures of any three of the four diesel generators: 1-2A, 1C, 1B, and 2B), an SBO event at FNP falls into one of the following four configurations:

1. SBO in Unit 1 (LOSP and failure of diesel generators 1-2A and 1B) concurrent with the Unit 2 LOSP and failure of diesel generator 1C.

2. SBO in Unit 1 (LOSP and failure of diesel generators 1-2A and 1B) concurrent with the Unit 2 LOSP and failure of diesel generator 2B.

3. SBO in Unit 2 (LOSP and failure of diesel generators 1C and 2B) concurrent with the Unit 1 LOSP and failure of diesel generator 1-2A.

4. SBO in Unit 2 (LOSP and failure of diesel generators 1C and 2B) concurrent with the Unit 1 LOSP and failure of diesel generator 1B.

In all four of the above configurations, diesel generator 2C will be manually aligned and started from the control room and automatically loaded. The remaining design basis event diesel in the non-SBO unit will be aligned, started, and loaded automatically utilizing its respective logic. The SBO configurations are shown in table 8.3-2A.

An SBO in Unit 1 assumes LOSP on both units concurrent with the failure of both redundant diesel generators 1-2A and 1B in Unit 1. At least one of the two redundant Unit 2 diesel generators, 1C and 2B, will be available to power a complete train of safe shutdown loads of Unit 2. Bus 1J is required to support operation of diesel generator 2C in the event of a Unit 1 SBO.

A complete train B of safe shutdown loads of Unit 1 will be powered by diesel generator 2C as the dedicated AAC source for this event. The starting and unit selection are performed manually by operator actions from the EPB in the control room. The closing of diesel generator 2C Unit 1 breaker DJ06, as well as the loading of diesel generator 2C with Unit 1 train B safe shutdown loads are automatic. The Unit 1 train B large LOSP shutdown loads are sequenced onto diesel generator 2C by the Unit 1 train B LOSP sequencer. This is identical to the loading of diesel generator 1B with Unit 1 train B large LOSP shutdown loads during a LOSP event in Unit 1.

An SBO in Unit 2 assumes LOSP on both units concurrent with the failure of both redundant diesel generators 1C and 2B in Unit 2. At least one of the two redundant Unit 1 diesel generators 1-2A and 1B will be available to power a complete train of safe shutdown loads of Unit 1. Bus 2J is required to support operation of diesel generator 2C in the event of a Unit 2 SBO.

A complete train B of safe shutdown loads of Unit 2 will be powered by diesel generator 2C as the dedicated AAC source for this event. The starting and unit selection are performed manually by operator actions from the EPB in the control room. The closing of diesel generator 2C Unit 2 breaker DJ06, as well as the loading of diesel generator 2C with Unit 2 train B safe shutdown loads are automatic. The Unit 2 train B large LOSP shutdown loads are sequenced onto diesel generator 2C by the Unit 2 train B LOSP sequencer. This is identical to the loading of diesel generator 2B with Unit 2 train B large LOSP shutdown loads during a LOSP event in Unit 2.

A comparison of the maximum loading of diesel generator 2C to its rating during an SBO event is shown in table 8.3-3.

The above evaluation demonstrates that diesel generator 2C can be characterized as a fully capable AAC power source since it has the capacity to power a complete safety train (train B) of LOSP shutdown loads for one unit, and therefore is able to safely shut down either unit in the event of an SBO in that unit.

Although diesel generator 2C is dedicated the AAC power source, it still may be used during design basis events if diesel generator 1B or 2B fails. Diesel generator 2C does not have the capacity to carry a complete train of ESS loads in one unit in the event of a LOSP and LOCA but it can be used to power partial train B loads.

8.3.1.1.8 Tests and Inspections

Class 1E electric power systems are designed to permit periodic testing of the following aspects of the electric power system:

A. The operability and functional performance of the components of Class 1E electric power systems (diesel generators, emergency buses, dc system, and 120-V vital instrument power system).

B. The operability of these electric power systems as a whole, and under conditions as close to design as practical, including the full operational sequence that brings these systems into operation.

The 230-kV and 500-kV circuit breakers will be inspected, maintained, and tested on a routine basis. This can be accomplished without removing the generators, transformers, and transmission lines from service.

Transmission line protective relaying will be tested on a routine basis. This can be accomplished without removing the transmission lines from service. Generator, unit auxiliary transformer, and startup auxiliary transformer relaying will be tested when the generator is offline. Protective relaying associated with the 4160-V and the 600-V systems has provisions for inservice testing and calibration.

The 4160-V and 600-V circuit breakers and associated equipment can be tested when the individual equipment controlled by the breaker is shut down. The circuit breakers may be placed in the "test" position and tested functionally. Circuit breakers and contactors for redundant or duplicated circuits can be tested one at a time without interfering with the operation of the plant.

Preventive maintenance, inspection, and testing intervals for Unit 2 circuit breakers required to be operable as containment penetration conductor overcurrent protective devices are specified in the Technical Requirements Manual.

Channel calibration intervals for safety-related motor-operated valves thermal overload protection devices which are not permanently bypassed are specified in the Technical Requirements Manual.

[HISTORICAL]

[Following final assembly and preliminary startup testing, each diesel generator unit has been tested at the site, prior to reactor fuel loading, to demonstrate the capability of the unit to perform up to the limits of design. The following tests have been performed on the diesel generator units to certify the adequacy of the unit for the intended service:

A. Starting tests have demonstrated the capability to attain frequency and voltage within the rated limits and time.

B. Load acceptance tests have demonstrated the capability to accept the desired loads in the desired sequence and time duration.

C. Operation tests have demonstrated the capability of carrying the required loads without exceeding the manufacturer's design limits, in accordance with drawings D-177033, D-177032, D-177036, and D-177037.

D. *Load rejection tests have demonstrated the capability of rejecting the largest single load without exceeding speeds or voltages which will cause tripping, mechanical damage, or harmful overstresses.]*

The diesel generator units are tested/inspected periodically, in accordance with the Technical Specifications or the Technical Requirements Manual, as applicable, to demonstrate the continued capability of the unit to perform to the limits of the qualified design. The diesel generator surveillance test frequency is generally based on Regulatory Guide 1.108, "Periodic Testing of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants," Revision 1, August 1977, with adjustments made in accordance with Generic Letters and adjustments made to preclude overtesting which has been verified by the manufacturer to be detrimental to diesel generator reliability. Refer to the Technical Specification Bases for a further discussion of diesel generator surveillance test frequency conformance to Regulatory Guide 1.108.

4.16-kV emergency bus loss of voltage relays, degraded grid voltage relays, and degraded grid voltage alarms are periodically tested in accordance with the Technical Specifications.

8.3.1.1.9 Design Criteria

The criteria used for initial design and procurement of electrical equipment associated with safety-related systems are provided below. Evaluations performed to ensure the components and associated systems meet the design intent are based on information specific to the application.

A. Motors

Motor Size:

The horsepower rating of the motors is based on continuous operation of the driven equipment load without exceeding the NEMA standard temperature rise above the stated ambient temperature.

Motor Starting Torque:

Motors are capable of accelerating the load in accordance with the load-speed torque curves with 75-percent rated motor-nameplate voltage at the motor terminals.

Motors rated 250 hp and above have minimum torque values in percent-of-full-load torque as follows:

Locked rotor torque .... 100 percent
Pull-up torque .... 75 percent
Breakdown torque............... 200 percent

The starting current does not exceed 6.5-times full-load current at rated voltage and frequency.

Motors rated 200 hp and below have torque characteristics as established in NEMA Standards for Designs B and C, without the starting current exceeding 6.5-times full-load current at rated voltage and frequency.

Insulation:

The motor insulation system is designed for the special environmental conditions described in table 3.11-1. The insulation system is a combination of materials and processes which provide high resistance to moisture, radiation, and other contaminants experienced by the motors in specified service conditions.

B. Interrupting Capacity of Breakers

The interrupting capacities of breakers associated with 4160-V switchgear, 600-V load centers, 600-V and 208-V MCCs, and distribution panels are adequate to interrupt the maximum calculated fault current experienced on the associated circuit. Paragraph 8.3.1.1.3 gives the interrupting capacities for 4160-V switchgear, 600-V load centers, and 600-V and 208-V MCCs. Paragraph 8.3.1.1.6 gives the interrupting capacities for 208/120 V-ac distribution panels. Paragraph 8.3.2.1.4 gives the interrupting capacities for the dc distribution panels.

Relay settings are established to provide coordinated tripping of related feeders and are shown on relay setting sheets. These sheets are controlled design documents similar to engineering drawings and are handled and stored in the same manner.

C. Grounding Requirements

All electrical equipment and building steel, such as motor frames, load centers, lighting cabinets, contactors, conduits, cable trays, transformer tanks, stairs, handrails, etc., are effectively and permanently grounded by direct connection to the building ground bus.

Each floor has its own ground bus which is connected by a number of vertical conductors to the main ground bus on the grade level.

8.3.1.2 <u>Analysis</u>

The following analysis demonstrates compliance with NRC General Design Criteria 17 and 18; NRC Regulatory Guides 1.6, 1.9, and 1.155; and IEEE Standard 308.

A. Compliance with Criterion 17

The ESF system is designed with sufficient capacity, independence, and redundancy to ensure that core cooling, containment integrity, and other vital functions are maintained in the event of postulated accidents, assuming a single failure.

The engineered safety features ac power system of each unit is divided into two separate and redundant subsystems. Each subsystem is comprised of 4160-V switchgear buses, 600-V load centers, 600-V/208-V MCCs, and 120-V vital instrument power system buses (refer to subsection 8.3.1 for the ac power system details). The ac power system has adequate capacity and capability to start and supply the engineered safety feature load necessary to safely shut down the reactor, without exceeding fuel design limits or reactor coolant pressure boundary limits, defined in the Technical Specifications, during normal operation or any design basis event. Each diesel generator unit is capable of supplying, without exceeding its design rating, the loads of its associated ac power subsystem that are required for operation during design basis events and hot shutdown conditions. See paragraph 8.3.1.1.7 and tables 8.3-1 and 8.3-2 for details.

In the event of a loss of all onsite power and the failure of an offsite circuit, power for the redundant ESF load group is available through the other offsite circuit. No switching of circuits is necessary to achieve this.

Supply to the ESF buses from the onsite power source during any design basis event is established automatically only if the supply from the network is disconnected. This ensures that any failure or fault in the network will not affect the ESF distribution system.

Complete separation and independence has been maintained between the two train systems so that any single failure in one train will not prevent the other train from performing its required safety function.

As shown in drawing D-177001, the ESF buses for each unit are connected to the 230-kV switchyard by two physically independent circuits through startup auxiliary transformers. The switchyard is connected to the network by four 230-kV and two 500-kV high voltage transmission lines. See section 8.2 for a detailed description of the offsite power system. A fault on any component of the two offsite circuits will result only in the loss of power to the associated ESF buses aligned to the faulted circuit. Power can be restored to the affected buses from the other startup auxiliary transformer by manual switching.

B. Compliance with Criterion 18

The auxiliary electrical system is designed to permit inspection and testing of all important areas and features, especially those that have a standby function and whose operation is not normally demonstrated. Details of the testing program for the ESF equipment including diesel generators are discussed in paragraph 8.3.1.1.8.

Testing of the integrity of safeguard action initiating relays with the unit in service is discussed in paragraph 7.2.2.2.1.F.

C. Compliance with Regulatory Guide 1.6

The standby ac power system for both units consists of five diesel generator sets, feeding two independent and redundant safety load groups.

Each load group has the capability to provide the minimum safety functions necessary to shut down the unit and maintain it in the safe shutdown condition. Each diesel can be aligned only to load groups within its own redundant system. Diesel 1-2A automatically aligns itself with the accident unit.

Except for the following, no provision has been made in the design to permit a load or a bus to swing between redundant power sources:

- Component Cooling Water Pump B
- Safety Injection Pump B
- Service Water Pump C
- Auxiliary Building Battery Charger C
- 600-V Load Center F.

In each of the above cases, a breaker and a disconnect switch separate the two trains so that a failure of either one will not affect the redundant train.

Key interlocking (see drawings C-177118, C-177119, C-177120, C-177121, and C-177133 for Unit 1 and D-207118, D-207119, D-207120, D-207121, and D-207133 for Unit 2) ensures alignment to one train only.

The design of the ESF system meets the requirements of the guide and particularly the following:

1. No provisions exist for automatically paralleling two diesel generators from redundant load groups. There are also no provisions for automatically paralleling two diesel generators within the same load group to the same ac buses within one unit. Although it it possible to parallel two diesels of the same load group manually to the same unit during testing, operating procedures specifically call for testing one diesel at a time. As stated above, the parallel operation of diesel generators from redundant load groups is not feasible.

2. No provisions exist for automatically transferring loads between redundant power sources.

D. Compliance with Regulatory Guide 1.9

The selection of diesel generators 1-2A, 1B, 1C, 2B, and 2C conforms with the purpose of this guide to provide an adequate power source for meeting the starting and continuous power requirements of the safety-related loads. The ratings are discussed in paragraph 8.3.1.1.7.

The sequencing of large loads at 5-s intervals allows large motors to accelerate before the succeeding loads are applied. Dynamic simulations (based on verification testing) are used to model the response of critical components (generators, buses, and loads). The results are evaluated to verify satisfactory performance of the required loads. Engineering evaluations verify that the MCC contactors and other relay type components can function as required during the first load step. After the first load step, the decreases in frequency and the MCC voltages are limited to 95 and 60 percent of nominal, respectively. This ensures that the succeeding voltage dips will not affect the continued operation of the MCC contactors and other relay type components.

Prototype qualification tests on 4075-kW diesels and actual tests conducted on 2850-kW units indicate that the diesel generators are capable of starting and accelerating the required ESF loads to rated speed in accordance with the sequence shown in tables 8.3-1 and 8.3-2.

E. Compliance with IEEE 308

All components of the Class 1E electric system (discussed in paragraph 8.3.1.1) are designed to meet their functional requirements under conditions produced by the design basis events.

The Class 1E electric system has been designed to voltage and frequency limits for proper functional requirements of the ESF equipment.

All incoming circuits to ESF buses are monitored in the control room through breaker position indication lights and/or by analog indicators. Abnormal conditions of these circuits are annunciated in the control room. Separate status indication lights are provided for monitoring each diesel generator and its associated equipment.

Complete separation and independence has been maintained between all redundant systems so that any component failure in one ESF load group will not disable any component in the other ESF load group. See paragraph 8.3.1.4 for a detailed analysis of Independence of redundant systems.

[HISTORICAL]

[The Class 1E electric equipment was purchased and installed under a strict quality assurance program described in subsection 17.1.2. Certified records of quality assurance inspections and tests performed during production were obtained from the manufacturer.

The ESF 4160-V switchgear, 600-V load centers, and 600-V motor control centers have been qualified by both tests and successful application under similar operating conditions. Current-carrying capability and fault interrupting tests have been successfully performed on prototypes in accordance with applicable ANSI standards listed in subsection 8.1.4. Standard production tests were performed on the above equipment assemblies in accordance with the same ANSI standards.

Class 1E equipment has been qualified to meet seismic requirements by either tests or analyses, or by a combination of both. This is discussed at length in section 3.10.]

Each component of the Class 1E electric system in one train has a redundant component in the other train. A single failure within a train, therefore, will not prevent satisfactory performance of the minimum ESF loads required for safe shutdown and for maintaining the plant in a hot shutdown condition.

The Class 1E electric systems are designed to preclude a common mode failure for two or more diesel generator units under conditions of a design basis event.

Provision has been made to disconnect the non-Class 1 equipment from the Class 1E systems by Class 1 breakers.

Following a loss of offsite power, the onsite power sources can accept full loads within a time compatible with the ESF loading requirements.

Automatic and manual controls are provided to permit the following:

1. Selecting of the most suitable power source for the Class 1E electric system.

2. Disconnecting the appropriate loads when offsite power is not available.

3. Starting and loading the onsite power supply.

Protection systems are provided and designed to isolate failed equipment and to identify the equipment that has failed. For the protection system related to the ESFs and essential functions, complete redundancy, independence, and inservice testability have been provided. Essential instrumentation, control, and power requirements are supplied by reliable, independent, and redundant sources designed to ensure that no single failure will result in loss of power to redundant safety-related equipment.

Table 3.2-1 identifies the safety-related equipment required to operate in a hostile environment. A discussion of the qualification tests and design bases for this equipment is given in section 3.11.

F. Compliance With Regulatory Guide 1.155, "Station Blackout"

FNP selected the AAC approach for coping with an SBO event and dedicated Class 1E emergency diesel generator 2C as the AAC power source to cope with an SBO event in either unit for the required duration (4 h). The remaining four diesel generators -- 1-2A, 1B, 1C, and 2B -- ensure that the plant meets its licensing commitments for all design basis events.

The Farley approach to SBO meets the basic requirements for an "AAC" as stated in RG 1.155, section 3.3.5 and as summarized below:

1. It is connectable to but not normally connected to the offsite or onsite emergency ac power systems.

2. It has minimum potential for common mode failure with offsite or onsite emergency ac power sources.

3. It is available in a timely manner after the onset of an SBO. The time required for making this equipment available should not be more than 1 h; therefore, plants using the AAC approach must assess their ability to cope for 1 h. However, if an AAC power source can be shown by test to be available within 10 min of the onset of SBO, then no coping assessment is required.

   The 10-min requirement is meant to cover the period between the time when the operator realizes that an SBO has occurred and the time when the AAC source is ready for loading the shutdown loads. When actions from the control room are unsuccessful in restoring offsite or onsite emergency ac power, the onset of SBO has been verified. If the AAC source can be started and ready for loading within the next 10 min, taking all actions from within the control room, the 10-min criterion is met.

4. It has sufficient capacity and reliability to operate the systems necessary for coping with an SBO for the time required to bring the plant to and maintain it in safe shutdown. Therefore, the AAC source must power all the shutdown loads, which would normally be powered by the onsite emergency ac source(s) in the event of an LOSP.

   An AAC power source serving a multiunit site where onsite emergency ac sources are not shared between units should have, as a minimum, the capacity and capability for coping with SBO in any of the units. If the onsite emergency ac sources are shared between units, the AAC power source(s) should have the capacity and capability to ensure that all units can be brought to and maintained in safe shutdown.

At multiunit sites, where the combination of onsite emergency ac sources exceeds the minimum redundancy requirements for normal safe shutdown (non DBA) of all units, one of the existing onsite emergency ac sources may be used as an AAC power source provided it meets the applicable criteria for an AAC source. Also, an existing onsite emergency ac source could qualify as an AAC source on the basis of excess capacity provided specific modifications to enhance connectability are made.

If an existing Class 1E emergency diesel generator is used as an AAC power source, this existing Class 1E diesel generator must continue to meet all applicable safety-related criteria.

Paragraph 8.3.1.1.7.3 demonstrates Farley compliance with the above regulatory requirements.

8.3.1.3 *[HISTORICAL] [Conformance With Appropriate Quality Assurance Standards*

To ensure conformance with requirements of appropriate quality assurance standards and criteria such as IEEE Standards and NRC Criteria B-10 CFR 50, a field quality control program is being enforced by use of written field quality control procedures, checklists, and planned periodic audits.

A. Receipt

The installation prerequisites of the above standards, and criteria for electrical materials and equipment in both the ac and dc power systems, are being complied with by field receiving, inspection, and documentation procedures to verify conformance with specifications and drawings on receipt of equipment at the jobsite.

B. Storage

To preserve their integrity and prevent physical, mechanical, and/or electrical damage while in storage, an inspection and maintenance program is enforced by written procedures and manufacturer's recommendations.

C. Installation

An inspection program is also being enforced to ensure that the equipment is being located, installed, assembled and/or connected in strict accordance with latest approved-for-construction drawings, installation specifications and field quality control procedures.

The field quality control inspection program for equipment and material installation consists of checking for the required separation of redundant engineered safeguards, reactor protection, and the balance of Class 1E electrical system cables and components, and for proper termination and marking of these cables.

D. *Testing*

A test program to verify the quality and performance of Class 1 and 1E instrumentation and electrical equipment is being planned and implemented. Procedures and instructions are being prepared to ensure that tests are performed in accordance with the latest specifications and requirements. A system will be established whereby construction testing procedures and instructions are prepared and approved by qualified test personnel. Test results will be documented and evaluated by the construction testing department to ensure that all components comply with specified design criteria. Nonconforming equipment will be identified and procedures to eliminate the nonconforming situation will be initiated.

Tests during construction will include, as appropriate, electrical continuity and resistance, phase rotation, proper circuit functioning, pressure tests, and other tests as necessary to assure equipment quality.

A procedure to ensure that test equipment meets required standards of accuracy will be enforced. Test instruments will undergo a periodic calibration and will be marked to indicate the date of the next required calibration. Test control will be established so that any construction or other work affecting the tests will be completed prior to the conduct of the test. Final construction verification will be conducted to ensure that all temporary connections have been removed, all deficiencies have been resolved, installation is in accordance with specifications, deterioration has not reduced quality, and equipment and system functions are in accordance with design.]

8.3.1.4 Independence of Redundant Systems

8.3.1.4.1 Design Basis

The design criteria for cable, electrical penetrations, and circuit routing have been established to prevent a failure in electrical cable and penetration systems from initiating a fire and to minimize and localize the effect of a fire should one occur. These criteria are met by the following provisions:

A. Cable derating and cable tray fill.

B. Cable routing.

C. Cable routing in cable spreading room.

D. Sharing of cable trays with nonsafety-related cables.

E. Fire detection and protection.

F. Cable and cable tray marking.

G. Spacing of wiring and components on control board and relay racks.

H. Fire barriers and separation between redundant trays.

I. Electrical penetrations.

8.3.1.4.2 Cable Derating and Cable Tray Fill

Ampacity rating of cables is established in accordance with IPCEA P-46-426 and manufacturer's standards. To this basic rating, a grouping derating factor, also in accordance with IPCEA P-46-426, is applied. Wherever applicable, a load diversity factor is taken into consideration. As a minimum, all power cables are selected utilizing a 100-percent load factor and continuously rated at 125 percent of the full-load current.

As a minimum requirement,[a] cable trays carrying low voltage power cables are limited to 40-percent fill by cross-section and 60-percent fill for trays carrying control cables. In addition, all 4-kV and larger 600-V cables will have, as a minimum, one cable diameter spacing between all cables in the same tray.

8.3.1.4.3 Cable Routing

Normal and emergency power and control cables are routed in a manner which meets the physical separation criteria presented in the following paragraphs. Cable and raceway installation throughout the plant is designed to satisfy the single-failure criteria and ensures an optimum level of circuit integrity and operating reliability.

Cables associated with redundant equipment are classified by safety train and are routed in redundant conduits, cable trays, ducts, penetrations, etc. (i.e., raceways), which are also classified by safety train. Cables are also classified and segregated by voltage level.

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a. Cable trays may exceed the above fill limits if an engineering evaluation indicates that the included cables will satisfactorily perform their intended functions and there are no adverse seismic effects from the additional weight of the cables.

The first character after the facility (examples of facility identifiers are 1V for the auxiliary building, 1T for the containment building) in all cable and raceway numbers classifies the cable or raceway by safety train. A list of the characters used to identify the safety train classification of circuits and raceways is shown in table 8.3-5. The next character in all raceway numbers after the safety train classification identifies the voltage level of the circuits routed through the raceway. See table 8.3-4 for a list of the characters used to identify the raceway voltage level. Each cable is routed in the appropriate raceways based on the cable's safety train, voltage level, and usage.

Cable trays are arranged with the highest voltage at the top, the next higher voltage at the next level, etc., with instrumentation at the lowest level whenever feasible.

Power and control cables are installed in ladder-type trays and conduits. Low-level instrumentation cables are installed either in solid, nonventilated-type trays with solid covers or in rigid conduits.

Arrangement of electrical equipment and cabling will be such that fire in one redundant system will not propagate to the other system. In the absence of confirming analysis to support less stringent requirements, the following general rules are followed:

A. Routing of cables for instrumentation, control, or power through rooms or spaces where there is potential for accumulation of large quantities of oil or other combustible fluids through leakage or rupture of lube-oil or cooling systems is avoided. Where such routing is practically unavoidable, only one redundant system of cables is allowed in any such space, and the cables are protected from dripping oil by conduits or covered trays.

B. In any room or compartment in which the only source of fire is of an electrical nature, cable trays of redundant systems have a minimum horizontal separation of 3 ft if no physical barrier exists between trays.

   In the limited number of areas where separation of 3 ft is unattainable, a fire barrier(a) is installed extending at least 1 ft above (or to the ceiling), and 1 ft below (or to the floor). The separation provided when conduits are used for cable routing is described in appendix 3A. Refer to paragraph 8.3.1.4.4 for additional requirements in the cable spreading room.

C. For cable trays of redundant systems in any area in which the only source of fire is of an electrical nature, there is a minimum vertical separation of 5 ft between open-top trays stacked vertically one above the other, if no physical barrier is installed between trays. Vertical stacking of redundant trays is avoided wherever possible. In the limited number of areas where a vertical separation of 5 ft is unattainable, a fire barrier is placed between the two redundant systems. The barrier extends 1 ft on each side of the tray system. Refer to paragraph 8.3.1.4.4 for additional requirements in the cable spreading room.

D. In the case of crossover of one tray over another carrying redundant systems in any area in which the only source of fire is of an electrical nature, there is a minimum vertical separation of 15 in. (clear space between trays) with a fire barrier extending 1 ft from each side of each tray and 5 ft along each tray from the crossover.

E. Any openings in fire-rated-area floors for vertical runs of cables are sealed with fire resistant material.

F. Any openings in fire walls for horizontal runs of cables are sealed with fire resistant material.

Arrangement and/or protective barriers are such that no locally generated force or missile can destroy redundant systems. In the absence of confirming analysis to support less stringent requirements, the following rules are given:

A. In rooms or compartments having rotating heavy machinery, such as the reactor coolant pumps, or in rooms containing high pressure feedwater piping or high pressure steam lines, such as those existing between the containment and the turbine building, a minimum separation of 20 ft or a 6-in.-thick reinforced concrete wall is maintained between trays containing cables of redundant systems, unless it can be shown by analysis that lesser separation distances in the vicinity of specific hazards cannot prevent the raceways and their included cables from performing their protective functions.

B. Any switchgear associated with redundant systems is separated by a protective wall, ceiling, or floor equivalent to a 6-in.-thick reinforced concrete wall.

Supports for cable trays carrying Class 1E and non-1E circuits in safety-related structures are designed to meet Category I seismic requirements. Cable trays at FNP are designated as nonsafety-related equipment. However, their design provides assurance that the function of the Class 1E circuits contained in these trays will not be affected and the trays will not pose a II/I concern during a seismic event at Farley Nuclear Power Plant.

All cables entering the cable spreading room and control room areas, and interconnecting cables between these two rooms, follow the foregoing wiring separation criteria. The penetrations associated with these cables are sealed where they penetrate the room boundary to ensure the integrity of each area.

Figures 8.3-2 through 8.3-5 show the routing of cables that is typical for the Farley plant. These figures, while representing actual Farley plant drawings, are examples and will not be updated for subsequent design changes.

8.3.1.4.4 Design Criteria for Cables in Cable Spreading Room

Cables in the cable spreading room associated with the reactor protection system and the engineered safeguards system are arranged so that redundant circuits for each of the individual systems are isolated by physical separation or by fire barriers where physical separation cannot be maintained to completely prevent the spread of fire in any one tray or conduit system to other redundant circuits of the same system.

The minimum horizontal and vertical separation requirements in the cable spreading room are in accordance with paragraph 8.3.1.4.3. However, additional specific requirements are as follows:

A. Where it is necessary that cables or cable trays of redundant systems approach the same or adjacent control panels with less than 1-ft horizontal spacing, a fire barrier is installed and extends from 1 ft below to 1 ft above the trays; or the cables of each system are installed in rigid conduits from the floor penetrations back to a point where the 1-ft spacing exists. Where it is not possible to install fire barriers, solid aluminum covers are provided on the tops and bottoms of redundant trays.

B. Vertical stacking of trays is avoided wherever possible for trays containing cables of different separation divisions. However, where unavoidable, cables of redundant systems may be stacked one above the other with less than 3-ft vertical spacing if a fire barrier is installed between the trays and extends 1 ft to each side of the tray system. In addition, a solid aluminum standard tray cover is installed on the lower tray where less than 3-ft vertical separation exists. Where it is not possible to install fire barriers, solid aluminum covers are provided on the lower tray and also on the bottom of the top redundant tray. An acceptable alternate is for the cables of each redundant system to be installed in rigid conduits where less than 3-ft vertical separation exists. The separation provided when conduits are used for cable routing is described in appendix 3A.

The cable spreading room cable tray layout is shown on drawing D-177754.

No ducts or pipes, except those required to recirculate or exhaust air from the cable spreading room and piping for the fire protection system, are located in the cable spreading room. There are no 4160-V and 600-V power cables in the cable spreading room.

In addition to the utilization of physical separation and fire barriers, an automatic sprinkler system and a manually-initiated CO_2 fire protection system are installed, complete with fire detectors and alarms.

8.3.1.4.5 Sharing of Cable Trays with Nonsafety-Related Cables

Nonsafeguard cables may be intermixed with ESF cables of the same voltage level, but the specific nonsafeguard cable is not intermixed with both channels of redundant systems. All cables have adequate overload and short circuit protective features to ensure that nonsafeguard cables do not jeopardize the integrity of the vital cables.

The nonsafeguard cables, when routed in 'A' train raceways, are assigned an 'X' train scheme cable number in accordance with table 8.3-5. Routing procedures ensure that these 'X' cables are not run in 'B' train raceways.

8.3.1.4.6 Fire Detection and Protection

Adequate fire detection and protection measures have been taken where cables and safety-related equipment are installed. Appendix 9B has the necessary details.

8.3.1.4.7 Cable and Cable Tray Marking

All cables and raceways have their scheme cable or raceway code number permanently affixed at both ends. This is more completely described in paragraph 8.3.1.5.

8.3.1.4.8 Spacing of Wiring and Components

8.3.1.4.8.1 <u>Control Board and Relay Racks</u>. In the control board panel wiring separation, control board switches and associated lights are furnished in modules. Modules provide a degree of physical separation between associated lights and wiring of redundant trains.

The control board layout is based on making it easy for the operator to relate the control board devices to the physical plant and to determine the status of related equipment at a glance. This is referred to as providing a functional layout. Within the boundaries of a functional layout, modules are arranged in vertical columns. Control functions associated with the trains for reactor protection and engineered safeguards systems which require physical separation are grouped in columns by train. Teflon wire is used within the module and between the module and the first termination point.

Mutually redundant safety train wiring is routed to maintain a minimum of 6 in. of air separation between wires associated with different trains. Where such air separation is not available, barriers are provided in lieu of air space.

When a device such as braided sheath material (known as shielding and bonding cable) is used to provide a barrier in lieu of the 6-in. dimension, the braided sheath is not in physical contact with the redundant circuit. An example of this sheath material is Belden Braid. When this sheath material is used to provide a barrier, it is sized and secured to the wire bundle and provides a minimum of 90-percent surface coverage.

Mutually redundant safety train wiring is not terminated on single devices.

The interface between the control board wiring and field wiring is made in terminal board cabinets at el 139 ft. Teflon-covered cables with connectors provide the interconnection between control board and terminal board cabinets. This precludes any self-generated fire in the control board as a potential loss of separation. These cables are supported on metal supports to ensure separation of the cables consistent with the separation criteria discussed above.

Rack and panel separation for the protection of engineered safeguards actuation systems and physical separation of redundant wiring is maintained by use of separate metal enclosed cabinets and separate wireways. For other systems where separation is required between redundant wiring, either separate panels or metal barriers are used to maintain the required physical separation.

Separation of redundant channels running between the electrical penetration rooms and the cable spreading room is achieved by the use of four duct banks. Each duct bank consists of 3-in. and 4-in. rigid steel conduits embedded in concrete with a minimum of 2 in. of spacing between conduits, each carrying the control and instrumentation cables associated with one of the redundant channels of the reactor protection system and the engineered safeguards system.

Vertical runs of cable trays have solid covers up to a minimum height of 7 ft above the floor.

Wherever an open wireway passes through a floor or a wall, a fire stop is provided to prevent the spread of fire through the wall or floor.

Solid tray covers are used where cables may be subject to falling debris or hot weld material. Particular care is exercised during construction to ensure that the cables are not damaged. Also, solid tray covers are used on trays directly under gratings or other areas subject to dirt and oil drippings. Temperature monitoring of cables is not provided.

The cable installation associated with the reactor protection and ESF systems is subject to quality assurance procedures to ensure that the design criteria are met through all stages of design, procurement, and installation.

Circuit and raceway schedules are prepared and cables are routed in the engineering design office to provide a permanent record of the designation, routing, and terminations of cables and the designations of raceways. Circuit coding provides identification of the associated system either directly, by means of total plant numbering system equipment numbers used as circuit location numbers, or indirectly by means of coded switchgear cell numbers or abbreviated total plant equipment numbers.

8.3.1.4.8.2 <u>Emergency Power Board (EPB)</u>. Because of the plastic wireways inside the emergency power board (EPB), the two 4-in. conduits are shielded from potential fire sources in an opposite train board section. Each conduit is enclosed in a 14-gauge metal shroud along its entire length of exposure to an opposite train compartment. The shroud is insulated with 2 in. of Cera-Form thermal insulation (rated to withstand continuous exposure to a full 2100°F) on the top and rear surfaces. Conservative calculations indicate that, from the start of a fire, in excess of 3 h is required for the cables included in the subject conduits to reach their rated ambient temperature of 90°C, and in excess of 14 h for the assemblies to reach a maximum steady-state temperature of 118°C. However, from the assessment of the amount of flammable material in the EPB, it has been determined that there is not enough material to support a fire for 3 h of such magnitude that safe temperatures (90°C) would be exceeded within the conduit.

8.3.1.4.9 Fire Barriers and Separation Between Redundant Trays

Paragraphs 8.3.1.4.3 and 8.3.1.4.4 discuss separation between redundant cable trays.

8.3.1.4.10 Electrical Penetrations

The power, control, and instrument cables pass through the containment wall in electrical penetrations which are described in chapter 6.0.

Three penetration rooms, separated from each other by concrete walls, provide the necessary physical separation for redundant systems.

The criteria for the separation of electrical penetrations are as follows:

A. Separate penetrations are provided for 4160-V and 600-V power, control, and instrumentation cables.

B. Redundant circuits of a two-out-of-three logic matrix associated with the reactor protection system and the engineered safeguards system are run through different penetration rooms as shown in figure 8.3-2. (Figure 8.3-2 is not updated for design changes. See paragraph 8.3.1.4.3.) Redundant circuits of a two-out-of-four logic matrix associated with the reactor protection system and the engineered safeguards system are run through the three penetration rooms as follows:

    1. Channels 2 and 3 - through one room. A minimum separation of 6 ft is provided between channels 2 and 3.

    2. Channel 1 - through the second room.

    3. Channel 4 - through the third room.

   Conductors inside the penetration are applied with consideration to the aforementioned application criteria, the number of circuits, the load factor, and the ambient temperature within the penetration. Test data have been obtained to determine the offgassing properties of the conductor insulation. The method of applying cables and the test performed on insulation ensure that offgassing within the penetration does not occur. Tests performed ensure that all connections for wiring have been made properly.

8.3.1.5 Physical Identification of Equipment and Associated Cables

All equipment and associated cables are allocated a color scheme to identify each type of equipment or cable as follows:

Equipment Train Designation	Cable Train Designation	Color Identification
A	A - Safety-related	Red
B	B - Safety-related	Blue
C	C - Safeguard cable that may be Train A at one time or Train B at other times	Red/Blue
N	N - Nontrain-oriented Nonsafety-related	Black (or unpainted or natural color)
	X - N cables in A raceways	Pink
	Y - N cables in B raceways	Violet
	Z - N cables run separately from all other trains	Pink/ Violet

ESF equipment is divided into safety channels with a color scheme as follows:

Safeguard Channel I............. Yellow
Safeguard Channel II............ Green
Safeguard Channel III........... Orange
Safeguard Channel IV .... Silver

No other train cables may be run in engineered safety channel raceways.

Cable trays are marked with a marker which presents a color mark of the color scheme shown above, as well as the last six digits of the raceway number.

These markers are applied at both ends and at approximately 20-ft intervals on the trays.

The conduits and 4-in. channels are marked at both ends with a marker which presents a color mark of the color scheme shown above, as well as the last six digits of the raceway number. In addition, the conduits and 4-in. channels have a color mark of the color scheme shown above applied at 20-ft intervals along their length (where visible) and at each side of the wall and floor penetrations. These markers are applied at a position most accessible to view.

Cables are marked at both ends with marker tags which have a color dot of approximately 1/8-in. diameter, of the proper scheme color. A color marking of the proper scheme color is also provided at intervals of from 10 to 15 ft along the cable.

Switchgear, control panels, control boxes, rectifiers, battery chargers, and other similar pieces of equipment are marked with a descriptive nameplate which has white or black letters and a background of the proper scheme color.

Concrete pullboxes have markers on the ends of conduits run into them.

8.3.2 DC POWER SYSTEMS

8.3.2.1 Description

The direct current systems which provide a reliable source of continuous power for control, instrumentation, and emergency lighting consist of independent and redundant subsystems, used primarily for safety-related loads, and separate subsystems for the other direct current loads required for power generation, as described in the following:

A. Safety-Related Systems

1. A 125 V-dc system in the auxiliary building provides a source of reliable dc power for control, instrumentation, and power loads required for operation under normal conditions and during design basis accidents. This system and the bus arrangement are shown in drawings D-177082 and D-177083 for Unit 1 and in drawings D-207082 and D-207083 for Unit 2.

   The system for each unit consists of two 125 V-dc switchgear assemblies, three 125 V-dc battery chargers, two 125 V-dc batteries, and six dc distribution cabinets. Each 125 V-dc bus is supplied from one of the battery chargers with one battery floating on the bus. The 125 V-dc system is ungrounded and is equipped with ground detectors installed in each switchgear for continuous monitoring.

2. The separate 125 V-dc system for the service water area consists of two independent and redundant subsystems. Each subsystem consists of two battery/charger sets and two dc distribution panels. Either battery/charger set is capable of providing 100-percent power to both dc distribution panels while recharging its batteries. One battery/charger set provides power to the dc distribution panels while the other is on standby. The active battery/charger set is selected by means of a manual selector switch. The two dc distribution panels feed Unit 1, Unit 2, and shared loads. The majority of these loads are switchgear control supply.

Several loads that are not safety related are also supplied from these systems. These nonsafety-related loads will not affect the integrity of the safety-related systems. All components are designed to conform with Class 1E power system design criteria as defined in IEEE Standard 308.

B. Nonsafety-Related System (Power Generation)

The dc system for the nonsafety-related loads is comprised of three separate subsystems. Each of these subsystems is independent of and separated from the safety-related dc system.

1. The dc system serving the cooling tower area consists of one 125-V battery, two battery chargers, and one dc distribution panel.

2. The turbine building dc system is comprised of two 125-V batteries, three battery chargers (including one standby), and four dc distribution panels. Two of these distribution panels are located in the auxiliary building and supply dc control power to the nonsafety-related 4160-V switchgear buses 1A, 1B, and 1C and 600-V load centers 1B, 1I, 1M, and 1N. The two 125-V batteries are connected in series to provide a 250-V source for the emergency dc seal-oil pump and other normal loads.

3. Two 125-V battery chargers and two independent 60-cell batteries located in the high voltage switchyard supply separate dc distribution cabinets to provide power for tripping through primary and secondary relay systems for protection and control of 230-kV and 500-kV circuits associated with the 230-kV and 500-kV systems.

8.3.2.1.1 Safety-Related Batteries

The safety-related battery systems consist of two batteries for the auxiliary building and four batteries for the service water building (two batteries per train). Each battery contains 60 lead-calcium cells electrically connected in series to establish a nominal 125-V power supply. Each cell is of a sealed type, assembled in a shock-absorbing, clear plastic container with covers bonded in place to form a leakproof seal. The batteries are mounted on corrosion-resistant racks. The batteries are floated at 2.20 V per cell. The auxiliary building and service water building battery systems are discussed separately in the paragraphs which follow.

8.3.2.1.1.1 Auxiliary Building Battery System. The auxiliary building station batteries are sized in accordance with the methodology contained in section 6 of IEEE 485-1983. The 1A, 1B, 2A, and 2B batteries have a rated capacity of 1300 A-h based on a 2-h discharge rate at 77ºF to 1.75 V per cell average. Under both normal and accident conditions the batteries are designed such that they will provide the voltage required for operation of safety-related components, considering an aging factor of 25 percent and electrolyte temperature within the range of 60°F to 110°F.

8.3.2.1.1.1.1 Normal Operating Conditions. The capacity requirement for the batteries during normal operation is to carry the loads necessary to support plant operation for 2 h. The 2-h duration is based on the time required for the operators to connect the spare battery charger to the system if the connected battery charger fails on either train. During this 2-h period, the redundant train of the dc system with operable battery charger is available for accident mitigation, if required.

The normal load on the batteries during the 2-h period will not exceed 250 A for batteries 1A, 2A, and 2B and 300 A for battery 1B.

8.3.2.1.1.1.2 Design Basis Accident Conditions. The capacity requirement for the batteries during the design basis accident (LOSP or LOSP+LOCA) is to carry the dc loads necessary to support accident mitigation for the time period from the initiation of the LOSP until the battery chargers are reenergized from the emergency diesel generators. After battery charger reenergization, the battery chargers provide the necessary support for the dc loads. The battery chargers are sequenced back onto the emergency diesel generators during the last load sequencing step. Therefore, the batteries are required to provide adequate voltage to all safety-related components without battery charger support for less than 40 s (37 s from LOSP initiation to the last load sequencer step plus or minus the timer tolerance). The design calculations for verifying the adequacy of dc system voltage have been conservatively performed based upon a 1-min voltage. Any failure of the battery charger to be sequenced onto the emergency diesel generators is considered a single failure and the redundant train will be available for safe shutdown. There is no design basis accident scenario where the auxiliary building batteries will be required to supply LOSP or LOSP+LOCA loads for a period greater than 1 min without charger support.

The design basis accident load profile for the auxiliary building batteries is shown below. The load consists primarily of emergency lighting, vital bus inverters, and dc-operated controls and instruments as detailed in table 8.3-6.

Accident Conditions

Time Period (min)	Current (A)
0 to 1	500

Although not a requirement for mitigation of the design basis accidents, the batteries are capable of supplying adequate voltage to all safety-related components for an extended period without battery charger support under the following scenario:

After initiation of a LOSP or LOSP+LOCA, the batteries will have sufficient capacity to support automatic diesel generator starting and load sequencing. The batteries are sized to support control room operation of all required safety-related dc loads for 2 h, assuming a battery charger failure occurs after initiation of the LOSP or LOSP+LOCA event. Diesel generator automatic start or load sequencing failures with multiple attempts for diesel generator restart and automatic sequencing are not assumed during the event. The load profile for this scenario is shown below.

Time	Load
0 to 1 min	500 A
1 to 120 min	350 A

The service test for the batteries will be performed using the load profile above and test voltages below which envelope both the normal and design basis accident load profiles.

To assure the minimum voltage requirement for each of the connected emergency loads is satisfied, the battery terminal voltage at the end of each load profile test interval shall be greater than or equal to the following:

Battery	1st Minute	120th Minute
1A	113.4 V	111 V
1B	113.4 V	111 V
2A	113.4 V	110 V
2B	113.4 V	110 V

Test voltage limits listed above are greater than the minimum required design voltage to provide acceptable margin to support future design load additions or variations. In the event post-test terminal voltages are lower, comparison of actual values to minimum acceptable design voltages is required to determine whether the battery is capable of satisfactorily supplying design loads. In addition, all individual cell voltages (ICVs) at the end of the test should be ≥ 1.75 V. While overall battery terminal voltage may be acceptable, single (or multiple) ICVs of < 1.75 V are indicative of degraded cell(s) that must be evaluated for corrective action or potential replacement.

8.3.2.1.1.2 Service Water Building. The service water building safety-related station batteries are sized in accordance with Section 6 of IEEE-485-1983 for operation at a minimum electrolyte temperature of 35°F and including an aging factor of 25 percent. The batteries have a capacity of 75 A-h based on an 8-h discharge rate to 1.75 V per cell. The battery load primarily includes switchgear controls and indication. Each battery has adequate storage capacity to carry its load without charger support for a period of at least 2 h.

Battery terminal voltage shall remain greater than or equal to 105 V and ICVs should remain greater than or equal to 1.75 V when the batteries are subjected to a service test with the load profile below which envelops the load requirements under all conditions.

Time	Load
0 to 1 min	47 Amps
1 to 120 min	3 Amps

Test voltage limits listed above are greater than the minimum required design voltage and provide acceptable margin to support future design load additions or variations. In the event post-test terminal voltages are lower, comparison of actual values to minimum acceptable design voltages is required to determine whether the battery is capable of satisfactorily supplying design loads. In addition, all Individual Cell Voltages (ICVs) at the end of the test should be greater than or equal to 1.75 V. While overall battery terminal voltage may be acceptable, single (or multiple) ICVs of less than 1.75 V are indicative of degraded cell(s) that must be evaluated for corrective action or potential replacement.

8.3.2.1.2 Safety-Related Battery Chargers

Each 125 V-dc bus is supplied from one of the battery chargers with one battery floating on the bus. The chargers are adjusted to give an output voltage of 132 V for floating the batteries. The supply to each of the normally-operating battery chargers is from a separate ac emergency bus. Each battery charger can recharge a discharged battery and simultaneously supply the steady-state normal or emergency loads. Each charger is housed in a separate metal enclosed cabinet. Battery charger ratings are given as follows:

A. Rated output current:

Auxiliary building - 600 A (660 A maximum)	Service water building - 12 A (13.8 A maximum)

B. Voltage and frequency variation: maintain ± 0.5 percent of rated dc volts from 0- to 100-percent capacity with a ± 10 percent ac line voltage variation and ± 5 percent frequency variation.

C. Maximum ambient temperature for continuous operation at rated current and voltage: 104°F.

For the auxiliary building, one spare battery charger is provided between the two batteries as backup for the normally operating chargers. The spare battery charger can be supplied from either of the redundant ac emergency buses. Mechanically interlocked breakers and inline disconnects prevent inadvertent paralleling of the two redundant ac emergency buses or the two redundant dc buses. Drawing C-177133 gives details of the interlocking scheme.

For the service water building, each of the four batteries has its own dedicated charger. Two of the charger/battery sets (one operating and one in standby) are fed from one ac bus while the other two are fed from the redundant ac bus.

8.3.2.1.3 DC Switchgear

The bus and feeder arrangement of each switchgear, including the description of loads being supplied, is indicated in the single-line diagrams (drawings D-177082 and D-207082 for 125 V-dc bus A and drawings D-177083 and D-207083 for 125 V-dc bus B). The main bus bars, rated at 1000 A, 250 V, are braced for a fault duty of 25,000 A-dc.

The switchgear is of metal-clad construction and is equipped with two-pole, drawout-type, electrically- and remotely-controlled air circuit breakers having an interrupting duty of 25,000 A-dc at 125 V-dc. The continuous current ratings and trip settings for the breakers are given in the single-line diagrams.

8.3.2.1.4 DC Distribution Panel

Three dc distribution panels connected to each dc switchgear bus supply safety-related loads as indicated in the single-line diagrams. Each dc panel has a 125-V, 400-A main bus braced for 10,000 A. The branch breakers are of molded case design capable of interrupting a fault current of 10,000 A.

8.3.2.1.5 Testing

The dc switchgear, batteries, and battery chargers will be inspected and tested on a periodic basis in accordance with manufacturer's recommendations. The inspection and testing include, but are not limited to, the following:

A. Checking the specific gravity of the electrolyte, voltage, and temperature of the battery cells.

B. Opening and closing functions of breakers.

C. Checking battery charger float voltage and current.

The procedure for battery acceptance, performance, and service tests is in accordance with IEEE Standard 450-1980. The modified performance discharge test is in accordance with the guidance of IEEE 450-1995. A service (load profile) test will be performed at intervals as required by the Technical Specifications. The service test will be based on the load profiles listed in paragraph 8.3.2.1.1.1.2. A performance discharge test or a modified performance discharge test is also required by the Technical Specifications. A performance test is also required to be performed by the battery vendor prior to shipment. Testing of batteries and chargers is in accordance with the Technical Specifications.

8.3.2.1.6 Separation and Redundancy Requirements

The equipment design and layout arrangement for the auxiliary building and service water building provides two completely independent and redundant dc systems. The batteries are installed in rooms separated by walls and doors with a Class A fire rating to prevent simultaneous damage to both batteries. Each battery room is ventilated with exhaust fans as described in section 9.4. Fire dampers are provided in the HVAC penetrations of each battery room to limit the effects of a fire to one fire area. For the auxiliary building the dc switchgear, together with the associated battery charger, are located in separate rooms outside the individual battery rooms. The spare charger is located in a room that adjoins, but is separated from, the two other rooms. At the service water building, the battery chargers are located in separate rooms outside the individual battery rooms.

The design basis for routing cables, trays, and conduit described in paragraph 8.3.1.4 are applicable to the dc system.

8.3.2.2 Analysis

The 125 V-dc Class 1E electric systems are designed to meet the requirements of IEEE-308-1971, 10 CFR General Design Criteria 17 and 18, and NRC Regulatory Guide 1.6. The safety design bases for each of the 125-V batteries is to provide adequate capacity to supply vital loads required to safely shut down the reactor without charger support until ac power is restored.

The battery chargers are automatically sequenced to the diesel generators. The auxiliary building battery chargers are in operation within 40 s after LOSP initiation. The service water intake structure battery chargers are in operation within 12 s after LOSP initiation (i.e., as soon as the MCCs providing power to the chargers are energized from the diesels). In case a battery charger fails to energize, the operator will be notified by a failure alarm in the main control room. In the unlikely event that a battery charger fails, the spare battery charger will be manually placed in service. During the period of changeover to the spare charger, the battery will carry the normal loads.

The basis for design for each battery charger is to provide adequate capacity to restore its battery to full charge after the battery has been discharged while carrying steady-state normal or emergency loads. The time required to recharge the battery to full charge is compatible with the recommendation of the battery manufacturer.

Each dc system is equipped with the following indications in the control room to provide a continuous monitoring of dc power source condition:

- dc undervoltage alarm.
- Battery current indication.
- Charger current indication.

- Charger input ac failure alarm.
- dc voltage indication.
- dc ground alarm.
- Tripping of battery breaker (applies only to the auxiliary building batteries).
- Each Unit 1 auxiliary building battery charger has a common trouble window in the control room which is activated by any of the following charger alarm conditions: input ac failure, dc output failure, dc output undervoltage, dc output overvoltage, dc output breaker open, fan failure, overtemperature, ac input breaker open.
- The alarms for service water intake structure (SWIS) battery chargers 2 and 4 have trouble windows on the emergency power board (EPB) in the control room. Any of the following charger alarm conditions for chargers 2 and 4 will activate its respective trouble window: ac input failure, dc failure (loss of dc output/loss of charging current), dc undervoltage, dc overvoltage, ac input breaker open, and dc output breaker open.

The undervoltage relay features an extra-high dropout characteristic and is designed specifically to monitor the charging supply for a station battery and sound an alarm if this supply fails. The anticipated setting of the relay is above 125 V.

In order to maintain the required capacity of the dc systems, one battery charger per train is kept energized and maintains a constant voltage to supply the batteries with sufficient current to keep them fully charged and to maintain the steady-state load of dc instruments, control circuits, and inverters. In case of loss of auxiliary system power, the batteries will continue to supply the required dc and vital ac equipment. When ac power is regained from the diesel generators, the battery chargers will be reenergized and resume normal operation. The batteries are sized to supply the anticipated dc and vital ac load, without support from battery chargers, for a period of 2 h under normal operating conditions. The service water building batteries are sized to supply the anticipated load requirement for 2 h, without battery charger support, for both normal and design basis accident conditions.

The battery chargers are designed to prevent the ac source from becoming a load on the battery because of a power feedback as a result of loss of ac power to the chargers.

In the event of failure of a battery charger, the battery will continue to supply the normal operating dc load without interruption for a minimum of 2 h. This gives the operator sufficient time to manually line up the backup battery charger.

The entire auxiliary building dc system for each unit consists of two independent and redundant subsystems. The service water dc system consists of two independent and redundant subsystems. Each subsystem supplies the Unit 1, Unit 2, and shared loads of one of the two redundant safety-related dc systems at the building. Necessary and sufficient separation has been maintained between components of each subsystem so that a single fault within a subsystem does not prevent the reactor protection system from performing all safety functions. Also, within each subsystem, the component design is based on the premise that the probability of failure is kept to the practical minimum. The separation and redundancy requirements are covered in paragraph 8.3.2.1.6.

No provision has been made for automatically connecting either 125 V-dc system to its redundant dc load group. Also, as explained in paragraph 8.3.2.1.2, adequate interlocks are provided to prevent paralleling of the redundant dc systems. An outline of the inspection and tests that will be performed on the dc systems is provided in paragraph 8.3.2.1.5.

8.3.3 AC AND DC UNINTERRUPTIBLE POWER SUPPLY FOR THE TURBINE-DRIVEN AUXILIARY FEEDWATER PUMP

8.3.3.1 Design Basis

Each plant unit is equipped with a 7.5-kVA uninterruptible power system (UPS), uniquely assigned to provide a reliable source of control power, ac and dc, for the turbine-driven auxiliary feedwater pump and its associated steam admission and discharge valves.

The NRC acceptance criteria for the design of the UPS are as follows.

The UPS and its associated circuits are physically separated from the two train (A and B)-oriented ac and dc systems and their associated circuits, so that in the event of a feedwater pipe break with the loss of all offsite power sources and a single failure which would result in the loss of electrical train A (which provides the ac source of control power to the turbine-driven auxiliary feedwater pump), the turbine-driven auxiliary feedwater pump (in conjunction with the train B motor-driven auxiliary feedwater pump) will be able to start and deliver feedwater to the steam generators. A single failure of electrical train B will not affect the operation of the turbine-driven auxiliary feedwater pump; therefore, the pump (in conjunction with the train A motor-driven auxiliary feedwater pump) will be able to start and deliver feedwater to steam generators. Additionally, the power supply meets the requirements of General Design Criterion 44.

The UPS supplies control power to the following loads:

A. 125 V-dc to the turbine-driven auxiliary feedwater pump control panel.

B. 125 V-dc to the turbine-driven auxiliary feedwater steam admission valves HV-3235A, HV-3235B, and HV-3226.

C. 120 V-ac for the turbine-driven auxiliary feedwater pump speed control.

8.3.3.2 System Description

The UPS is rated 7.5-kVA "continuous service," powered from an emergency ac source 575-V, 3-phase, 60 Hz, and consists of the following components (see drawings D-177944, sh. 1 and D-207944):

A. One battery charger, rated to continuously supply the inverter operating load while completely recharging the battery within 12 h after a 2-h outage. The charger is equipped with an automatic battery recharge/equalize function.

   The input voltage is 575-V, 3-phase, 60 Hz, taken from an emergency train A MCC. The output voltage is 125 V-dc. A dc ammeter and a dc voltmeter measure the output amperage and voltage, respectively. The charger is complete with input and output circuit breaker protection. The following fault conditions are locally identified by individual indicating lights:

   1. High dc voltage.

   2. Charger failure.

   3. AC input failure.

   4. Positive ground.

   5. Negative ground.

   These conditions are remotely alarmed (visual and audible) in the common annunciator window provided in the control room for UPS faults.

B. One inverter, rated to continuously supply 7.5-kVA, 120 V-ac, 1-phase, 60 Hz with an input supply voltage of 125 V-dc. The inverter is complete with input and output circuit breaker protection and is provided with an automatic transfer contactor which will transfer the load to the bypass ac supply in the event of an inverter failure. The inverter output amperage and voltage are measured by an ac ammeter and an ac voltmeter, respectively. The following fault conditions are locally identified by individual indicating lights:

   1. Inverter failure.

   2. Low dc voltage.

   3. Low ac output voltage.

   4. High ac output voltage.

   5. Fan failure.

6. Overtemperature.

7. Static switch transfer.

These conditions are remotely alarmed in the common annunciator window provided in the control room for UPS faults.

C. One rectifier to operate from the inverter output or from the bypass ac supply in the event of an inverter failure. The rectifier provides 125-V, 12-A, fully regulated dc. A dc ammeter and a dc voltmeter measure the output amperage and voltage, respectively. The rectifier is complete with input and output circuit breaker protection. The following fault conditions are remotely alarmed in the common annunciator window provided in the control room for UPS faults:

1. DC failure.

2. High dc voltage.

3. Low dc voltage.

Fuses are provided externally for the dc load circuits.

D. One stepdown transformer, 575/124-V, 1-phase, 60-Hz in the bypass ac supply provides the ac power for the external load (HSP panel F) and the rectifier, so that the dc loads also will be supplied in the event of an inverter failure. The load transfer from the failed inverter to the stepdown transformer is automatic. The input power supply to the stepdown transformer is provided internally by connecting the transformer primary to the same train A MCC supply which feeds the battery charger. The stepdown transformer input is equipped with a disconnect switch.

E. A 125-V nominal battery containing 60 calcium-lead-acid cells, electrically connected in series, and rated to supply the inverter at full load for 2 h. The battery is complete with explosion protecting vents, deadtop construction, and with an earthquake protected, 2-step and/or single-tier, single-row battery rack and necessary interunit connector and accessories.

Each UPS system is provided with additional component redundancy to enhance the reliability of the UPS system. This redundancy includes an alternate (backup) UPS system (battery charger, inverter, rectifier).

The analysis of paragraph 8.3.3.3 remains valid since it applies to a single UPS system.

The battery charger and inverter are in a compact arrangement inside a freestanding cabinet located in the auxiliary building, room 190 (2190 for Unit 2) at el 100 ft. This unit is furnished to

TABLE 8.3-1 (SHEET 1 OF 4)

4160-V EMERGENCY BUSES ESTIMATE OFMINIMUM LOADING REQUIREMENTS

				0 to 1 hour			1 hour to 8 hours			Beyond 8 hours			
Seq. Step	Loads	Motor Rating (hp)	Max. Motor Demand (hp)	No. of Pumps Run'g	Demand hp	Demand kW	No. of Pumps Run'g	Demand hp	Demand kW	No. of Pumps Run'g	Demand hp	Demand kW	Remarks
A.	LOSP LOADS 4-kV Buses 1F & 1K, 2F & 2K, 1G & 1L, or 2G & 2L												
1	Charging pump	900	840	1	600	473	1	600	473	1	600	473	
2	Service water pump	600	600 (583)	1	600 (583)	487 (462)	1	600 (583)	487 (462)	1	600 (583)	487 (462)	Values in parentheses apply to Unit 2 buses.
2	CRDM cooler fan	100	84.5	1	100	78	1	100	78	1	100	78	
3	Service water pump	600	600 (583)	1	600 (583)	487 (462)	1	600 (583)	487 (462)	1	600 (583)	487 (462)	Values in parentheses apply to Unit 2 buses.
4	CCW pump	400	350	1	350	282	1	350	282	1	350	282	
4	Ctmt. coolers-low speed	125	79	1	54	43	1	54	43	1	54	43	
5	Aux. feedwater pump	450	450	1	450	361	1	450	361	1	450	361	
6	Battery charger	120 kVA	-	1	-	60	-	-	60	-	-	60	
6	Station air compressor 1C/2C	200	200	1	200	160	1	200	160	1	200	160	Values apply to 4-kV buses 1F and 1K and 2F and 2K only.
6	Ltg. xfmr.1B	225 kVA	-	-	-	70	-	-	70	-	-	70	Applies to 4-kV buses 1F and 1K only. Load connected when 600V L/C 1A energized.
6	Ltg. xfmr.2B	225 kVA	-	-	-	65	-	-	65	-	-	65	Applies to 4-kV buses 2F and 2K only. Load connected when 600V L/C 2A energized.
(a)	Spent-fuel pool pump	100	100	1	100	81	1	100	81	1	100	81	Manually loaded.

TABLE 8.3-1 (SHEET 2 OF 4)

				0 to 1 hour			1 hour to 8 hours			Beyond 8 hours			
Seq. Step	Loads	Motor Rating (hp)	Max. Motor Demand (hp)	No. of Pumps Run'g	Demand hp	Demand kW	No. of Pumps Run'g	Demand hp	Demand kW	No. of Pumps Run'g	Demand hp	Demand kW	Remarks
(a)	Emergency ac lighting	-	-	-	-	40	-	-	40	-	-	40	Manually loaded.
(a)	Pressurizer heaters	270 kW	-	-	-	-	-	-	270	-	-	270	Manually loaded.
(b)	Auto sequenced load total excluding miscellaneous loads-kW					2507			2507			2507	Values apply to 4-kV buses 1F and 1K only.
						2277			2277			2277	Values apply to 4-kV buses 1G and 1L only.
						2452			2452			2452	Values apply to 4-kV buses 2F and 2K only.
						2227			2227			2227	Values apply to 4-kV buses 2G and 2L only.
B.	ESS LOADS 4-kV Buses 1F & 1K, 2F & 2K, 1G & 1L, or 2G & 2L												
1	Charging pump	900	840	1	900	709	1	900	709	1	900	709	
2	RHR pump	400	400	1	400	324	1	400	324	1	400	324	400 hp envelopes Units 1 and 2 RHR pump loads.
2	Ctmt. spray pump	400	450	1	450	359	1	450	359	1	450	359	
3	Service water pump	600	600 (583)	2	1200 (1166)	974 (924)	2	1200 (1166)	974 (924)	2	1200 (1166)	974 (924)	Values in parentheses apply to Unit 2 buses.
4	CCW pump	400	350	1	350	282	1	350	282	1	350	282	
4	Ctmt. coolers-low speed	125	79	2 [1]	250 [125]	202 [101]	2 [1]	250 [125]	202 [101]	2 [1]	250 [125]	202 [101]	Values in brackets apply to LOSP/SI events only.
5	Aux. feedwater pump	450	450	1	450	361	-	-	-	-	-	-	

TABLE 8.3-1 (SHEET 3 OF 4)

				0 to 1 hour			1 hour to 8 hours			Beyond 8 hours			
Seq. Step	Loads	Motor Rating (hp)	Max. Motor Demand (hp)	No. of Pumps Run'g	Demand hp	Demand kW	No. of Pumps Run'g	Demand hp	Demand kW	No. of Pumps Run'g	Demand hp	Demand kW	Remarks
5	Reac. cav. H2 dil. fan	25	25	1	25	22	1	25	22	1	25	22	Load included as a misc load in Unit 2.
6	Battery charger	120 kVA	-	1	-	60	1	-	60	1	-	60	
6	Station air compressor 1C/2C	200	200	1	200	160	1	200	160	1	200	160	Values apply to 4-kV buses 1F and 1K and 2F and 2K LOSP/SI events only.
6	Ltg. xfmr. 1B	225 kVA	-	-	-	70	-	-	70	-	-	70	Applies to 4-kV buses 1F and 1K LOSP/SI events only. Load connected when 600V L/C 1A energized.
6	Ltg. xfmr. 2B	225 kVA	-	-	-	65	-	-	65	-	-	65	Applies to 4-kV buses 2F and 2K LOSP/SI events only. Load connected when 600V L/C 2A energized.
(a)	Spent-fuel pool pump	100	100	1	100	81	1	100	81	1	100	81	Manually loaded.
(a)	Emergency ac lighting	-	-	-	-	40	-	-	40	-	-	40	Manually loaded.
(a)	H2 recombiner	75 kW	-	-	-	75	-	-	75	-	-	75	Manually loaded.
(b)	Auto sequenced load total excluding miscellaneous loads-kW					3293			2932			2932	Values apply to Unit 1 buses only.
						(3221)			(2860)			(2860)	Values in parentheses apply to Unit 2 buses.
						3403			3042			3042	Values apply to LOSP/SI events for 4-kV buses 1F and 1K only.
						3173			2812			2812	Valves apply to LOSP/SI events for 4-kV buses 1G and 1L only.

TABLE 8.3-1 (SHEET 4 OF 4)

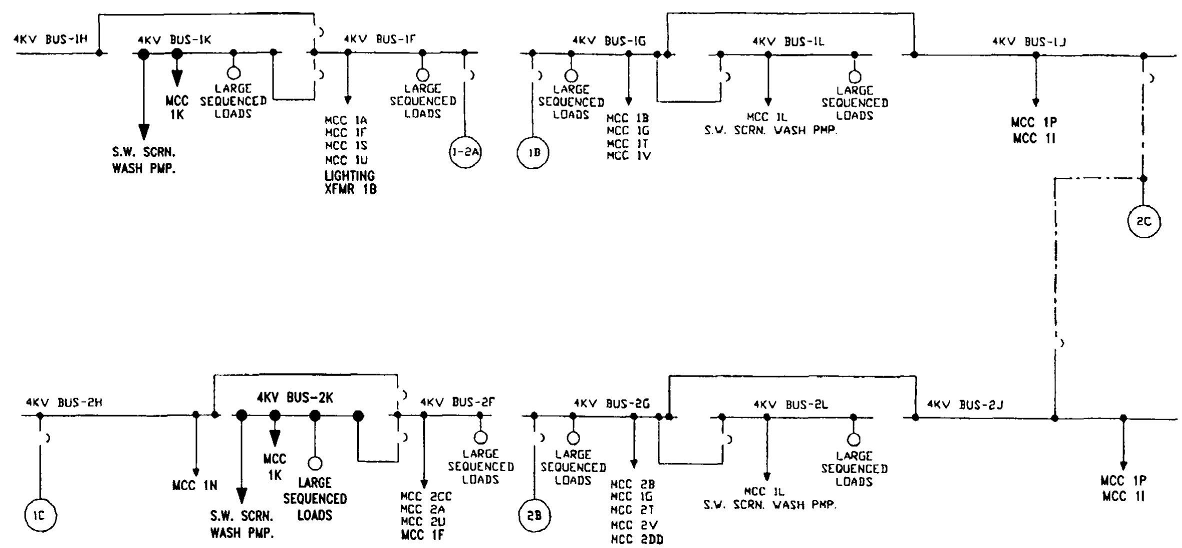
Seq. Step	Loads	Motor Rating (hp)	Max. Motor Demand (hp)	0 to 1 hour: No. of Pumps Run'g	0 to 1 hour: Demand hp	0 to 1 hour: Demand kW	1 hour to 8 hours: No. of Pumps Run'g	1 hour to 8 hours: Demand hp	1 hour to 8 hours: Demand kW	Beyond 8 hours: No. of Pumps Run'g	Beyond 8 hours: Demand hp	Beyond 8 hours: Demand kW	Remarks
						3345			2984			2984	Values apply to LOSP/SI events for 4-kV buses 2F and 2K.
						3120			2759			2759	Values apply to LOSP/SI events for 4-kV buses 2G and 2L only.
C.	Emergency LOADS 4-kV Buses 1H, 2H, IJ, or 2J.												
(a)	Station air comp.	125	125	1	125	104	1	125	104	1	125	104	Manually loaded for 4-kV buses 1J and 2J only.
(a)	Water treatment plant	-	-	-	-	-	-	-	-	-	150	125	Manually loaded (90% eff. assumed).
(a)	600-V load (turb. aux.)	-	-	-	200	166	-	200	166	-	200	166	Manually loaded (90% eff. assumed).
(b)	Miscellaneous loads												

a. Prior to any manual loading, the operator must check the available capacity of the diesel generators.

b. Miscellaneous loads that are not shed are shown on table 8.3-2.

TABLE 8.3-2 (SHEET 1 OF 7)

DIESEL GENERATOR ALIGNMENTS FOR DESIGN BASIS EVENTS

UNIT(S) IN OPERATION	POSTULATED EVENT	SCHEMATIC ARRANGEMENT DIESEL GENERATORS & 4KV EMERGENCY BUSES (TRAIN 'A' / TRAIN 'B')
1. UNIT #1 AND UNIT #2	1. LOSP ON BOTH UNITS	

NOTES (APPLICABLE TO ALL SHEETS OF THIS TABLE):
1. '— — — —' INDICATES THE DIESELS 1B, 2B AND 1-2A ALIGNMENT IN THE EVENT THAT DIESELS 1C AND/OR 2C FAILS, AS APPLICABLE.
2. '—·—·—' DIESEL 2C IS DEDICATED TO SBO EVENT. HOWEVER, IN THE EVENT DIESEL 1B OR 2B FAILS DURING A DESIGN BASIS EVENT, DIESEL 2C MAY BE MANUALLY ALIGNED TO UNIT 1 OR 2 AS SHOWN.

TABLE 8.3-2 (SHEET 2 OF 7)

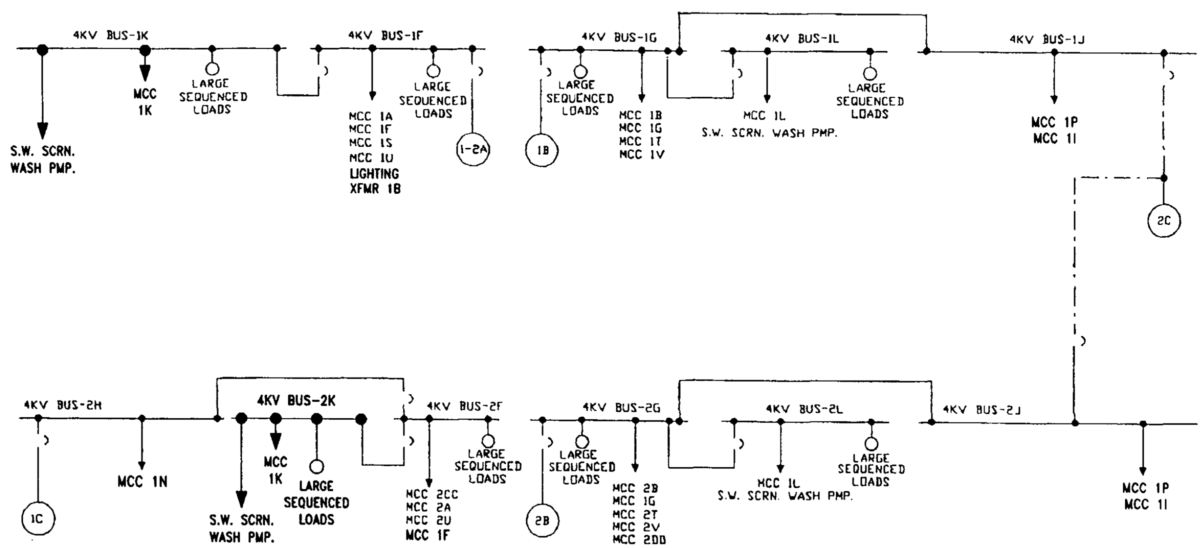
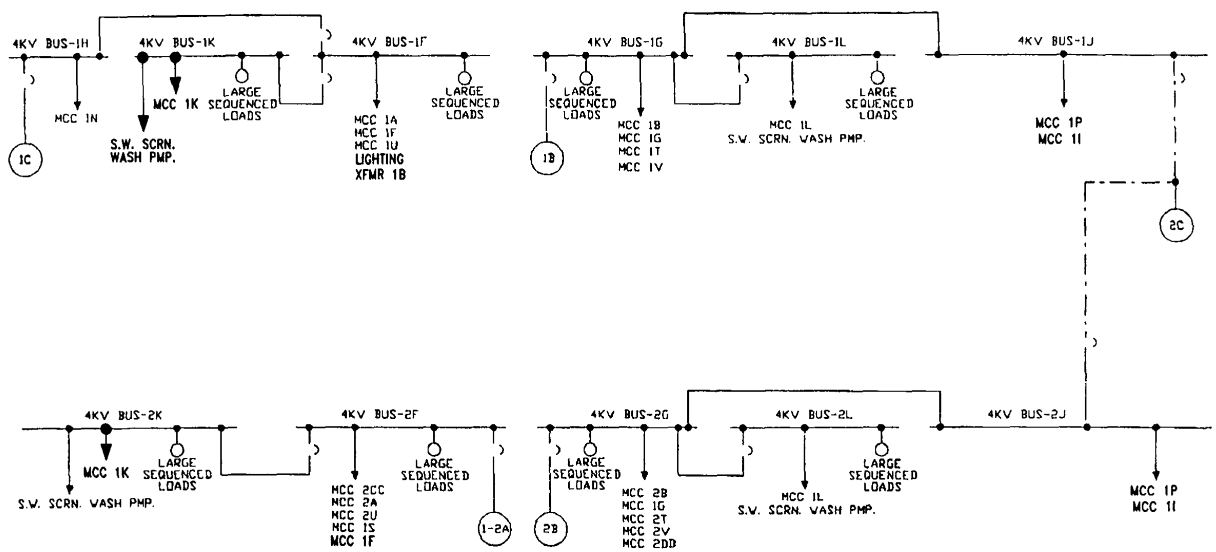
UNIT(S) IN OPERATION	POSTULATED EVENT	SCHEMATIC ARRANGEMENT DIESEL GENERATORS & 4KV EMERGENCY BUSES TRAIN 'A' TRAIN 'B'
1. UNIT #1 AND UNIT #2	2. LOSP ON BOTH UNITS & LOCA ON UNIT #1	 SEE SHEET 1 OF THIS TABLE FOR NOTES.

TABLE 8.3-2 (SHEET 3 OF 7)

UNIT(S) IN OPERATION	POSTULATED EVENT	SCHEMATIC ARRANGEMENT DIESEL GENERATORS & 4KV EMERGENCY BUSES (TRAIN "A" / TRAIN "B")
1. UNIT #1 AND UNIT #2	3. LOSP ON BOTH UNITS & LOCA ON UNIT #2	

SEE SHEET 1 OF THIS TABLE FOR NOTES.

TABLE 8.3-2 (SHEET 4 OF 7)

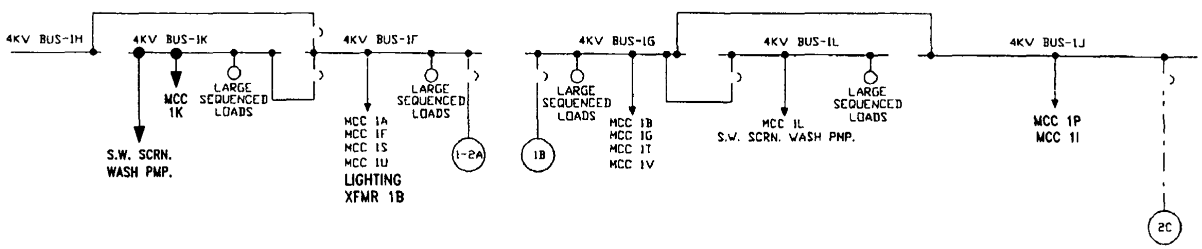
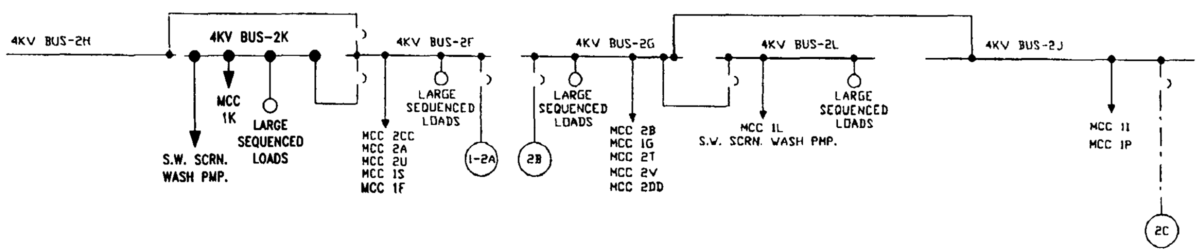
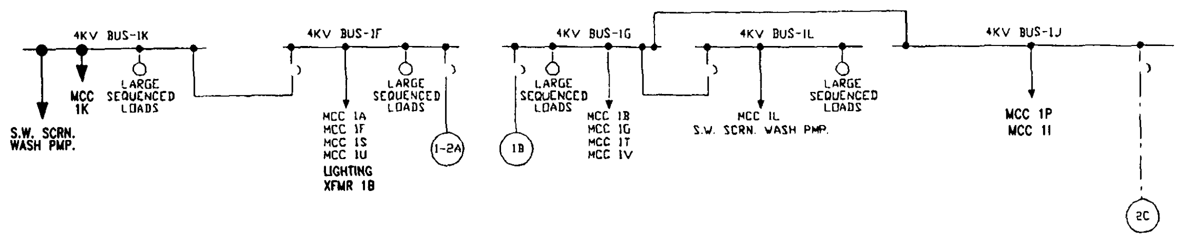
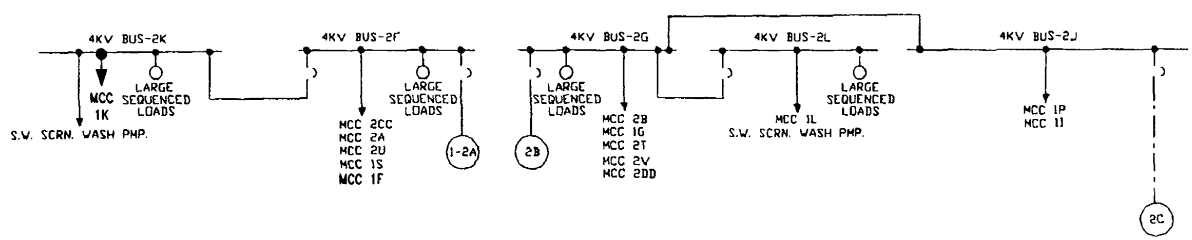
UNIT(S) IN OPERATION	POSTULATED EVENT	SCHEMATIC ARRANGEMENT DIESEL GENERATORS & 4KV EMERGENCY BUSES (TRAIN 'A' / TRAIN 'B')
1. UNIT #1 AND UNIT #2	4. LOSP ON UNIT #1	
	5. LOSP ON UNIT #2	 SEE SHEET 1 OF THIS TABLE FOR NOTES.

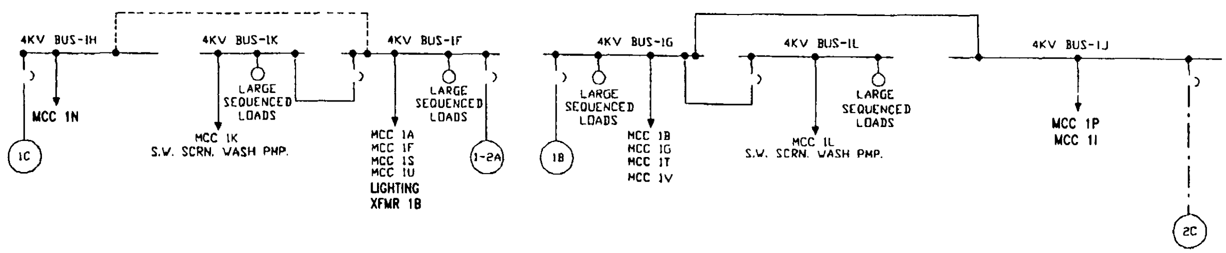
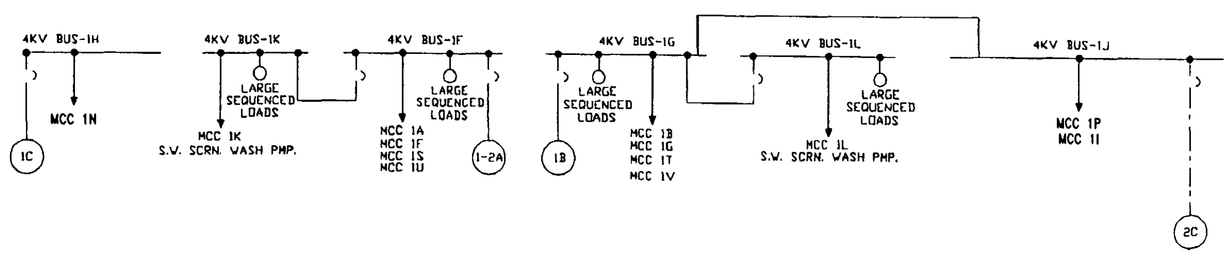
TABLE 8.3-2 (SHEET 5 OF 7)

<table>
<tr><th>UNIT(S) IN OPERATION</th><th>POSTULATED EVENT</th><th>SCHEMATIC ARRANGEMENT
DIESEL GENERATORS & 4KV EMERGENCY BUSES
TRAIN 'A' TRAIN 'B'</th></tr>
<tr><td>1. UNIT #1 AND UNIT #2</td><td>6. LOSP & LOCA ON UNIT #1</td><td>


</td></tr>
<tr><td></td><td>7. LOSP & LOCA ON UNIT #2</td><td>


SEE SHEET 1 OF THIS TABLE FOR NOTES.
</td></tr>
</table>

TABLE 8.3-2 (SHEET 6 OF 7)

<table>
<tr><th>UNIT(S) IN OPERATION</th><th>POSTULATED EVENT</th><th>SCHEMATIC ARRANGEMENT
DIESEL GENERATORS & 4KV EMERGENCY BUSES
TRAIN 'A' TRAIN 'B'</th></tr>
<tr><td>II. UNIT #1</td><td>1. LOSP</td><td>
</td></tr>
<tr><td></td><td>2. LOSP AND LOCA</td><td>

SEE SHEET 1 OF THIS TABLE FOR NOTES.</td></tr>
</table>

TABLE 8.3-2 (SHEET 7 OF 7)

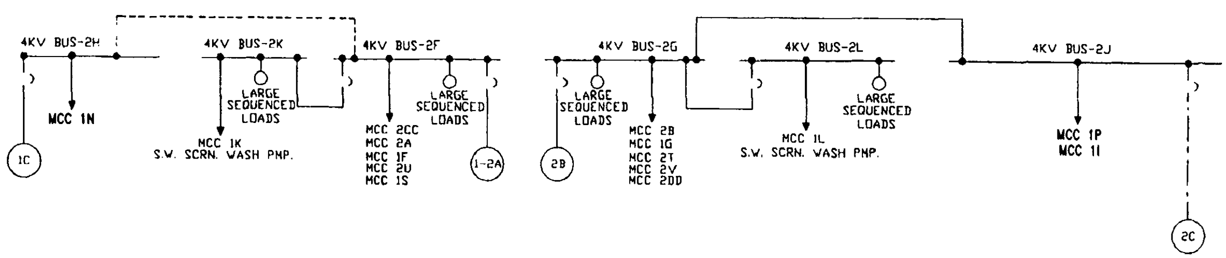
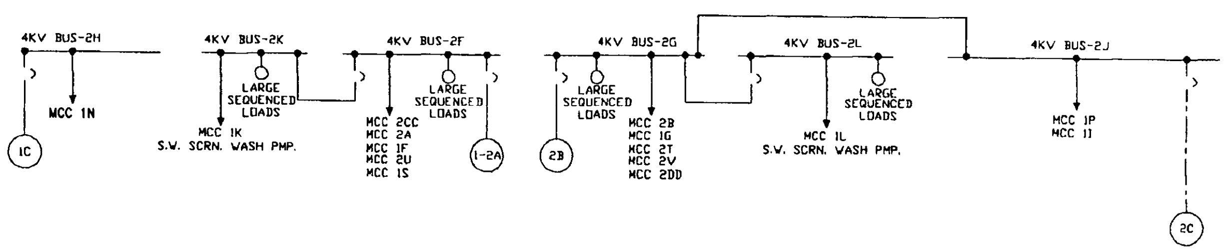
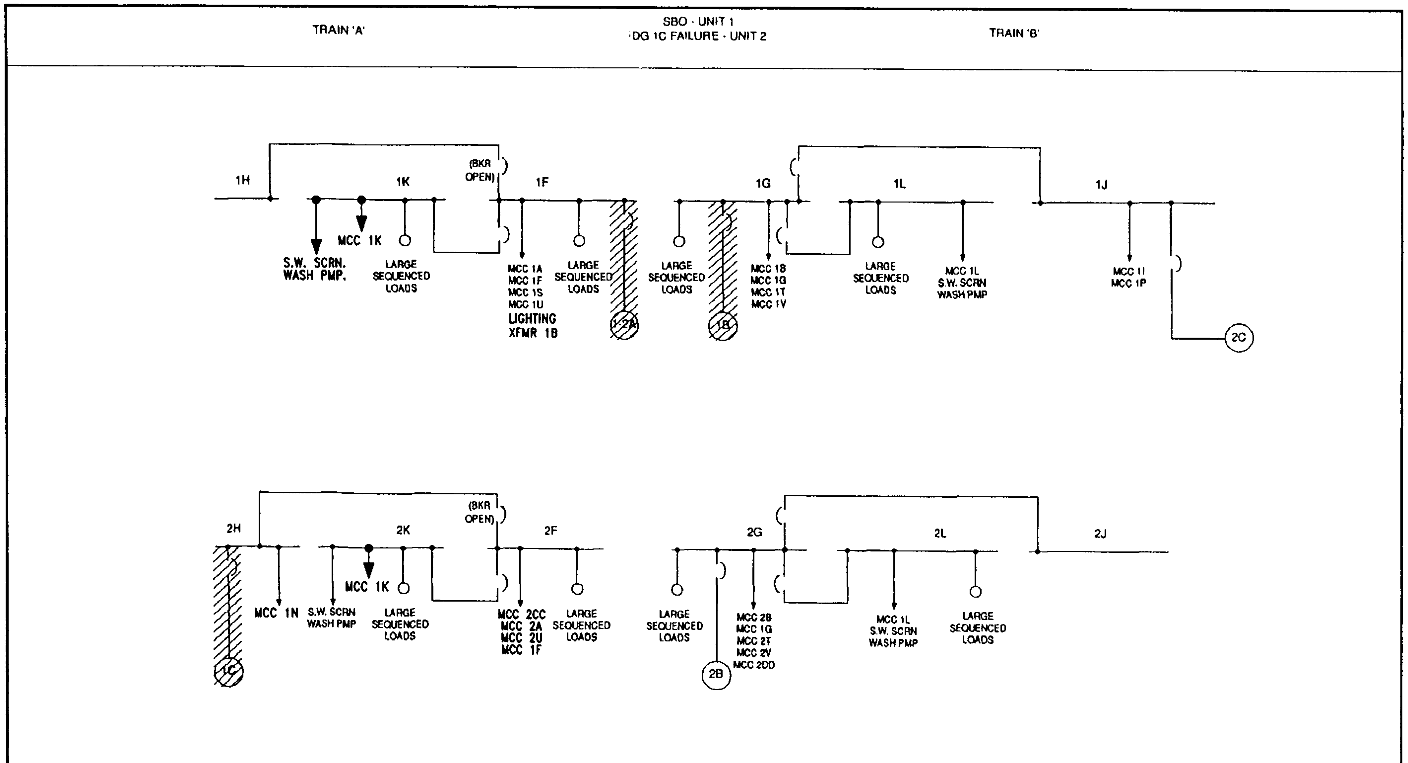
UNIT(S) IN OPERATION	POSTULATED EVENT	SCHEMATIC ARRANGEMENT DIESEL GENERATORS & 4KV EMERGENCY BUSES TRAIN 'A' / TRAIN 'B'
III. UNIT #2	1. LOSP	
	2. LOSP AND LOCA	 SEE SHEET 1 OF THIS TABLE FOR NOTES.

TABLE 8.3-2A (SHEET 1 OF 4)

DIESEL GENERATOR BUILDING ALIGNMENTS FOR STATION BLACKOUT



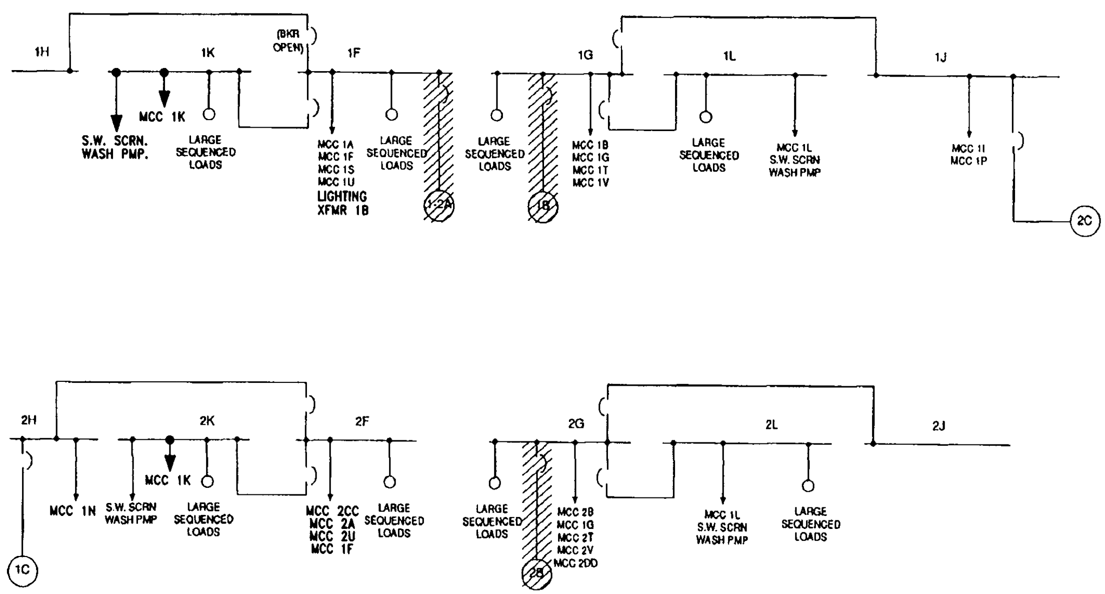
NOTES:
1. EDG 2C DEDICATED TO SBO.
2. SBO IS DEFINED AS A LOSP IN BOTH UNITS CONCURRENT WITH THE FAILURE OF 3 EDGs

TABLE 8.3-2A (SHEET 2 OF 4)

TRAIN 'A'

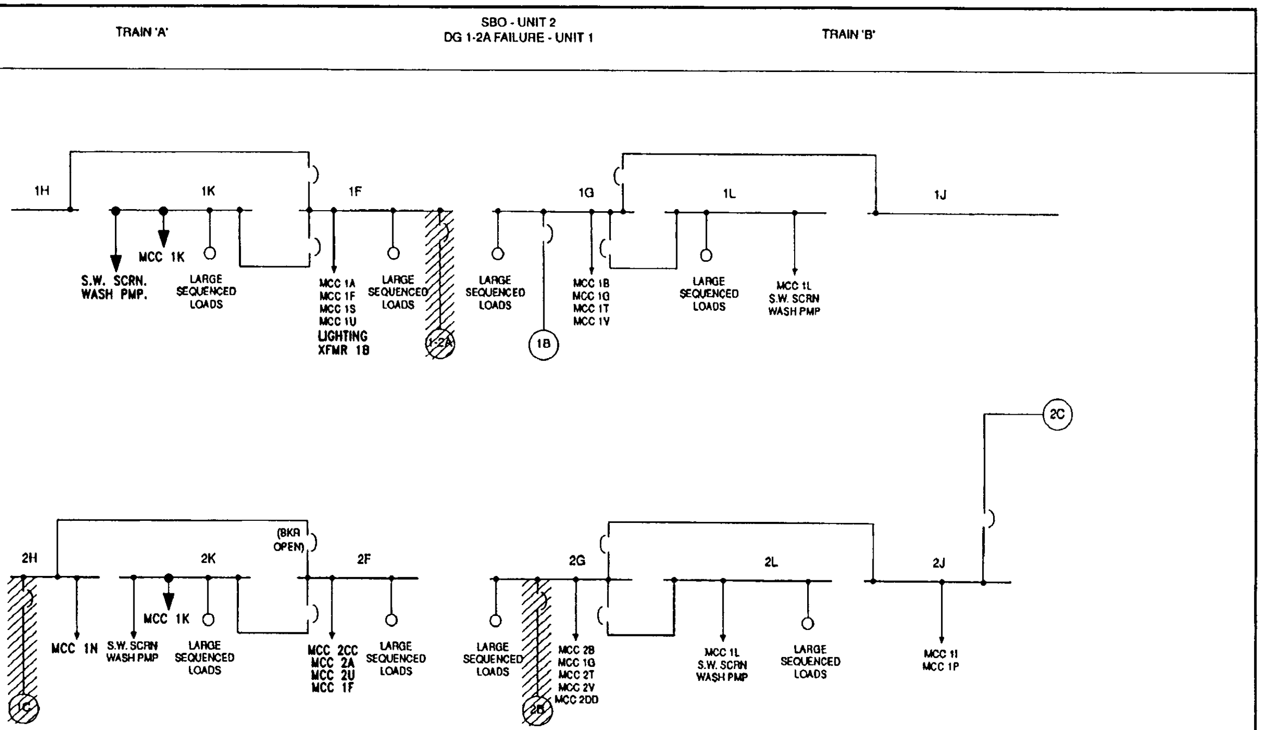
SBO - UNIT 1
DG 2B FAILURE - UNIT 2

TRAIN 'B'



NOTES:
1. EDG 2C DEDICATED TO SBO.
2. SBO IS DEFINED AS A LOSP IN BOTH UNITS CONCURRENT WITH THE FAILURE OF 3 EDGs

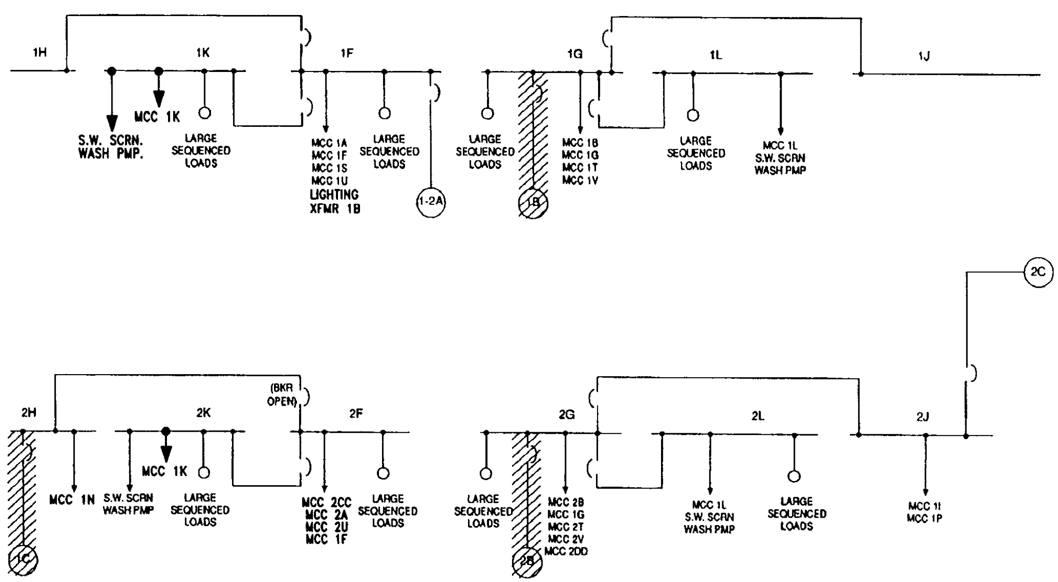
TABLE 8.3-2A (SHEET 3 OF 4)



NOTES:
1. EDG 2C DEDICATED TO SBO.
2. SBO IS DEFINED AS A LOSP IN BOTH UNITS CONCURRENT WITH THE FAILURE OF 3 EDGs

TABLE 8.3-2A (SHEET 4 OF 4)

TRAIN 'A' | SBO - UNIT 2 DG 1B FAILURE - UNIT 1 | TRAIN 'B'



NOTES:
1. EDG 2C DEDICATED TO SBO.
2. SBO IS DEFINED AS A LOSP IN BOTH UNITS CONCURRENT WITH THE FAILURE OF 3 EDGs

TABLE 8.3-3

DIESEL GENERATOR RATINGS AND MAXIMUM CALCULATED LOAD

	Ratings-kW					
Diesel Generators	Continuous Rating	2000 h per Year[e]	300 h per Year	30 min in 24-h Period	Maximum Calculated Automatic-Sequence Loads-kW[a]	
1-2A,1B, and 2B	4075	4353	4474	4881	1-2A	<4075[b]
					1B	<4075[b]
					2B	<4075[b]
1C and 2C	2850	3100	3250	3500	1C	>2850[c]
					2C	>2850[d]

a. Maximum diesel generator steady state loading for design basis and SBO is maintained by Calculation E-42.

b. Diesel generators 1-2A, 1B and 2B steady state loading for design basis and SBO events is calculated to be below the continuous ratings.

c. Diesel generator 1C steady state loading in some design basis scenarios and in SBO events is calculated to be above the continuous rating by less than 5% but below the 2000-hour rating.

d. Diesel generator 2C is the dedicated SBO diesel and its steady state loading in SBO events is calculated to be above the continuous rating by less than 5% but below the 2000-hour rating.

e. The diesel generators are subject to more than normal mechanical wear and tear when the intercooler water temperature exceeds 120°F without altering the electrical output at a specific electrical load rating. Operating the diesels above the intercooler temperature limit of 120°F may cause a major inspection/overhaul to be prematurely required. In order to keep the intercooler temperatures within limitations, the allowable kW output of the diesel should be manually reduced for a specific load rating (i.e., the diesel should be manually derated). Manual derating of the diesels for post-accident required automatic sequenced loads is not necessary. However, operations may desire to manually add load to cope with certain post accident scenarios. At service water temperature conditions above 97.3°F, the allowable kW for diesel generators 1-2A, 1B and 2B should be 4279 kW and the allowable kW for diesel generators 1C and 2C, the small OP diesels, should be 3044 kW for their respective 2000-hour ratings.

TABLE 8.3-4

CLASSIFICATION OF RACEWAYS BY VOLTAGE

D	4160-V power cables.
E	600-V heavy power cables requiring maintained spacing (1/0 AWG and larger).
	480-V heavy power cables requiring maintained spacing (1/0 AWG and larger).
	277-V heavy power cables requiring maintained spacing (1/0 AWG and larger).
	125 V-dc heavy power cables requiring maintained spacing (1/0 AWG and larger).
F[a]	600-V low power cables not requiring maintained spacing (No. 2 AWG and smaller).
	480-V low power cables not requiring maintained spacing (No. 2 AWG and smaller).
	277-V low power cables not requiring maintained spacing (No. 2 AWG and smaller).
	125 V-dc low power cables not requiring maintained spacing (No. 2 AWG and smaller).
G & H	208-V power.
	120 V-ac control.
	250 V-dc power.
	125 V-dc control.
	High-level instrumentation.
I	Low-level instrumentation.
P	Plate, penetration, conduit, etc., in main control room floor (access device only, not voltage related).

---

a. Letter F is used for cable trays only. Level F cable trays carry low power cables that do not require maintained spacing. Conduits containing low power cables use voltage letter E. All voltage level letters except F can apply to any type of raceway (i.e., conduits, cable trays, channels).

TABLE 8.3-5

CLASSIFICATION OF CABLES AND RACEWAYS BY SAFETY TRAINS

N	Nonsafeguard or normal.	
A	Train A	1 train of the ESS or RPS 2-train redundant systems.
B	Train B	Mutually redundant train to Train A.
C	Train AB	Train assigned to those cables capable of being operated in either Train A or Train B at different times.
1 -	Channel 1	Channels 1, 2, 3 and 4, respectively, of the ESS, RPS, and NIS 3- and 4-channel systems.
2 -	Channel 2	
3 -	Channel 3	
4 -	Channel 4	
X -	Nonsafeguard cable associated with (routed through) A train system.	
Y -	Nonsafeguard cable associated with (routed through) B train system.	
Z -	Nonsafeguard cable routed separate from all other trains.	

TABLE 8.3-6 (SHEET 1 OF 2)

UNIT 1 SAFETY-RELATED dc LOAD

A. Loads supplied from 125 V-dc switchgear bus 1A:

1. Inverters 1A, 1B, and 1F.
2. Diesel control panels 1-2A and 1C.
3. Emergency lighting in the control room.
4. Auxiliary relay rack A associated with reactor protection system and engineered safety features system.
5. Annunciator system.
6. Supply to safety feature actuation system solenoid valves.
7. 4160-V switchgear buses 1F and 1H.
8. 600-V load center buses 1A, 1D, and 1R.
9. Reactor trip switchgear.
10. Emergency lighting.

B. Loads supplied from 125 V-dc switchgear bus 1B:

1. Inverters 1C, 1D, and 1G.
2. Diesel control panel 1B and 2C.
3. Emergency lighting in control room.
4. Auxiliary relay rack B associated with reactor protection system and engineered safety features system.
5. Annunciator system.
6. Supply to safety feature actuation system solenoid valves.
7. 4160-V switchgear buses 1G and 1J.
8. 600-V lead center buses 1C, 1E, and 1S.
9. Reactor trip switchgear.
10. Emergency lighting.

TABLE 8.3-6 (SHEET 2 OF 2)

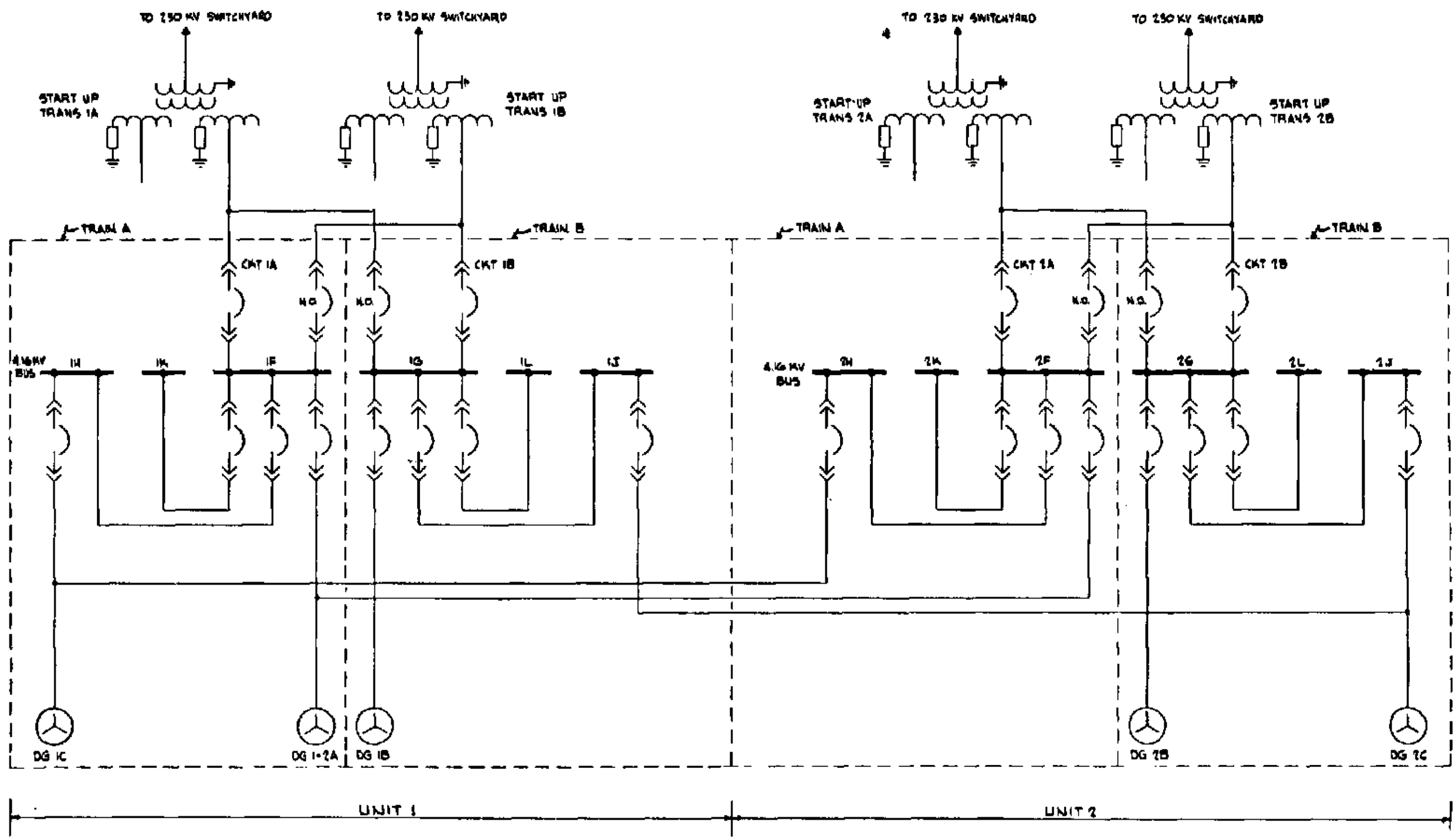
UNIT 2 SAFETY-RELATED dc LOAD

A. Loads supplied from 125 V-dc switchgear bus 2A:

1. Inverters 2A, 2B, and 2F.
2. Diesel control panels 1-2A and 1C.
3. Emergency lighting in the control room.
4. Auxiliary relay rack A associated with reactor protection system and engineered safety features system.
5. Annunciator system.
6. Supply to safety feature actuation system solenoid valves.
7. 4160-V switchgear buses 2F and 2H.
8. 600-V load center buses 2A, 2D, and 2R.
9. Reactor trip switchgear.
10. Emergency lighting.

B. Loads supplied from 125 V-dc switchgear bus 2B:

1. Inverters 2C, 2D, and 2G.
2. Diesel control panel 2B and 2C.
3. Emergency lighting in control room.
4. Auxiliary relay rack B associated with reactor protection system and engineered safety features system.
5. Annunciator system.
6. Supply to safety feature actuation system solenoid valves.
7. 4160-V switchgear buses 2G and 2J.
8. 600-V lead center buses 2C, 2E, and 1S.
9. Reactor trip switchgear.
10. Emergency lighting.



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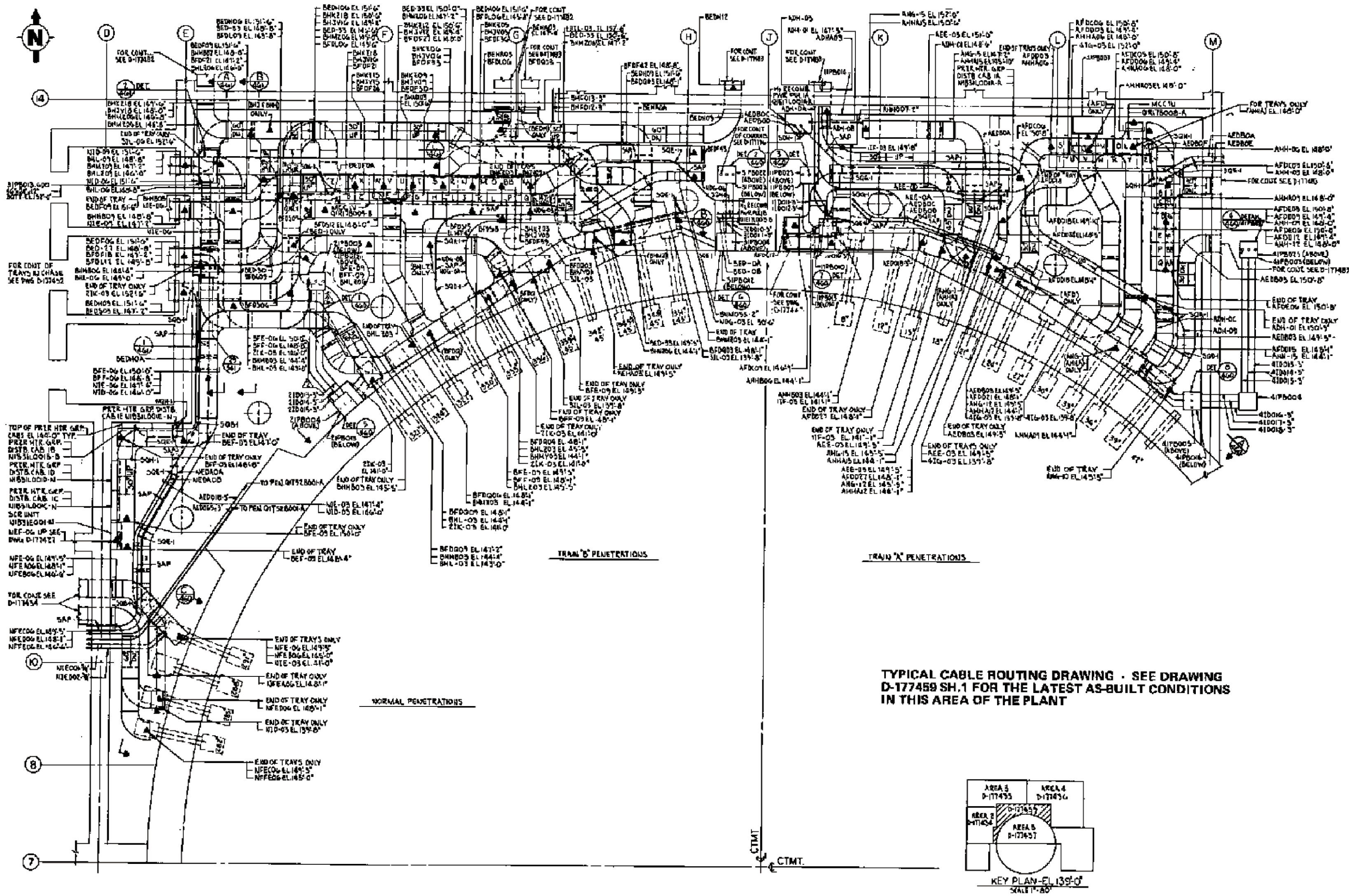
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SCHEMATIC ARRANGEMENT DIESEL GENERATORS AND 4160-V EMERGENCY

FIGURE 8.3-1



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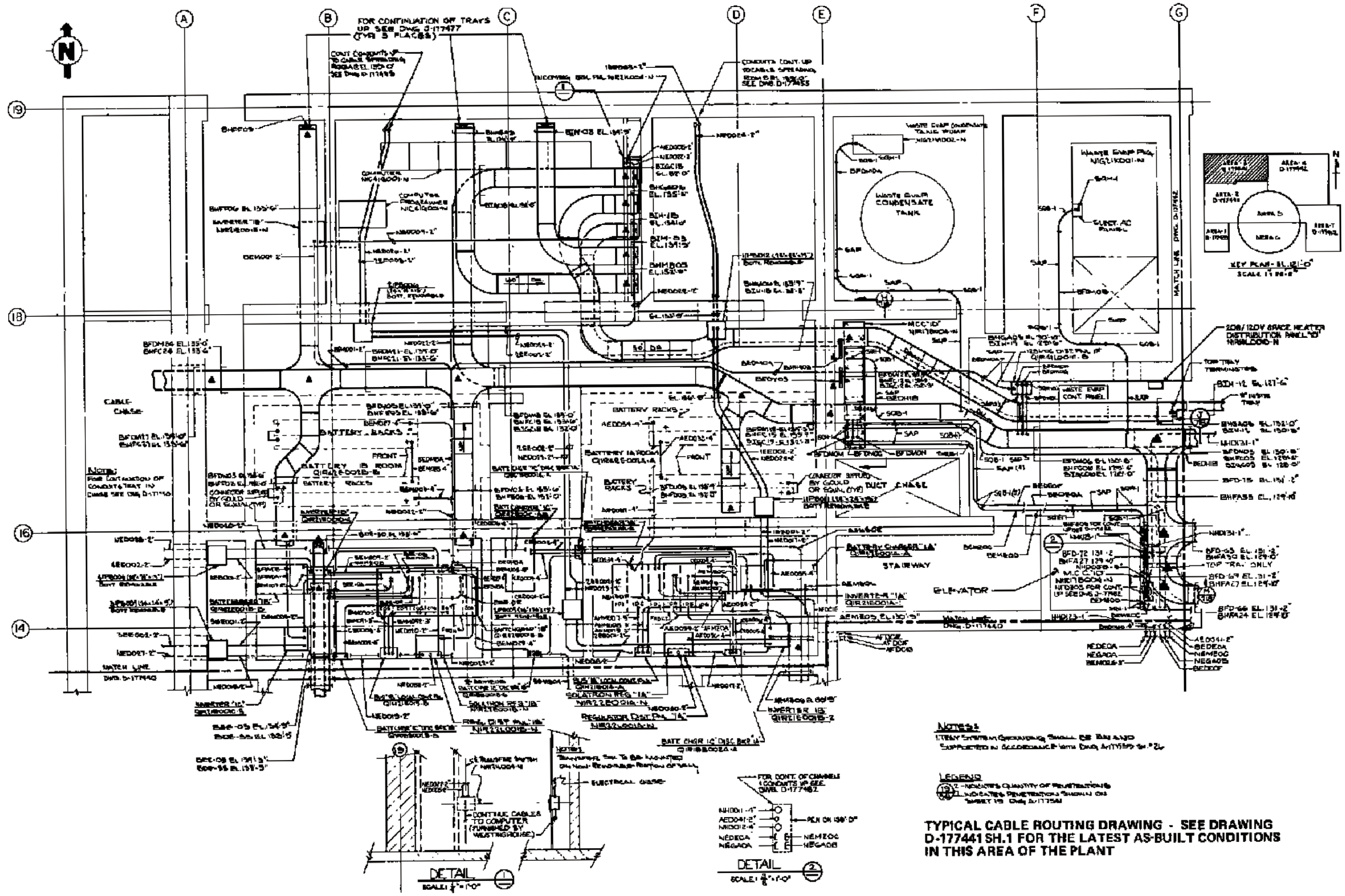
NUCLEAR PLANT
UNIT 1 AND UNIT 2

TRAY AND CONDUIT LAYOUT ELECTRICAL PENETRATION ROOM ABOVE el 139

FIGURE 8.3-2



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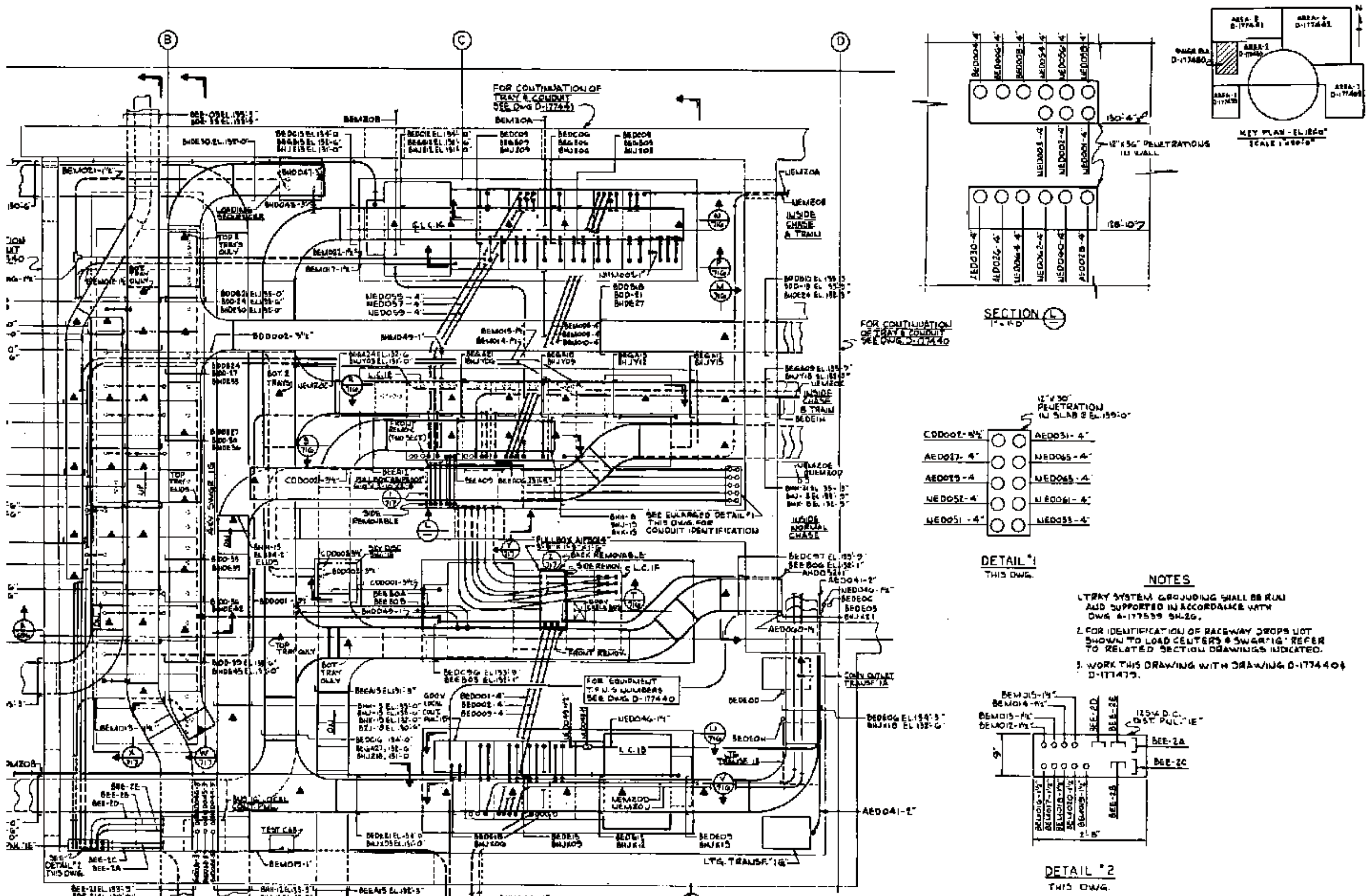
NUCLEAR PLANT
UNIT 1 AND UNIT 2

TRAY AND CONDUIT LAYOUT AUXILIARY BUILDING el 121

FIGURE 8.3-3



TYPICAL CABLE ROUTING DRAWING - SEE DRAWING D-177480 FOR THE LATEST AS-BUILT CONDITIONS IN THIS AREA OF THE PLANT

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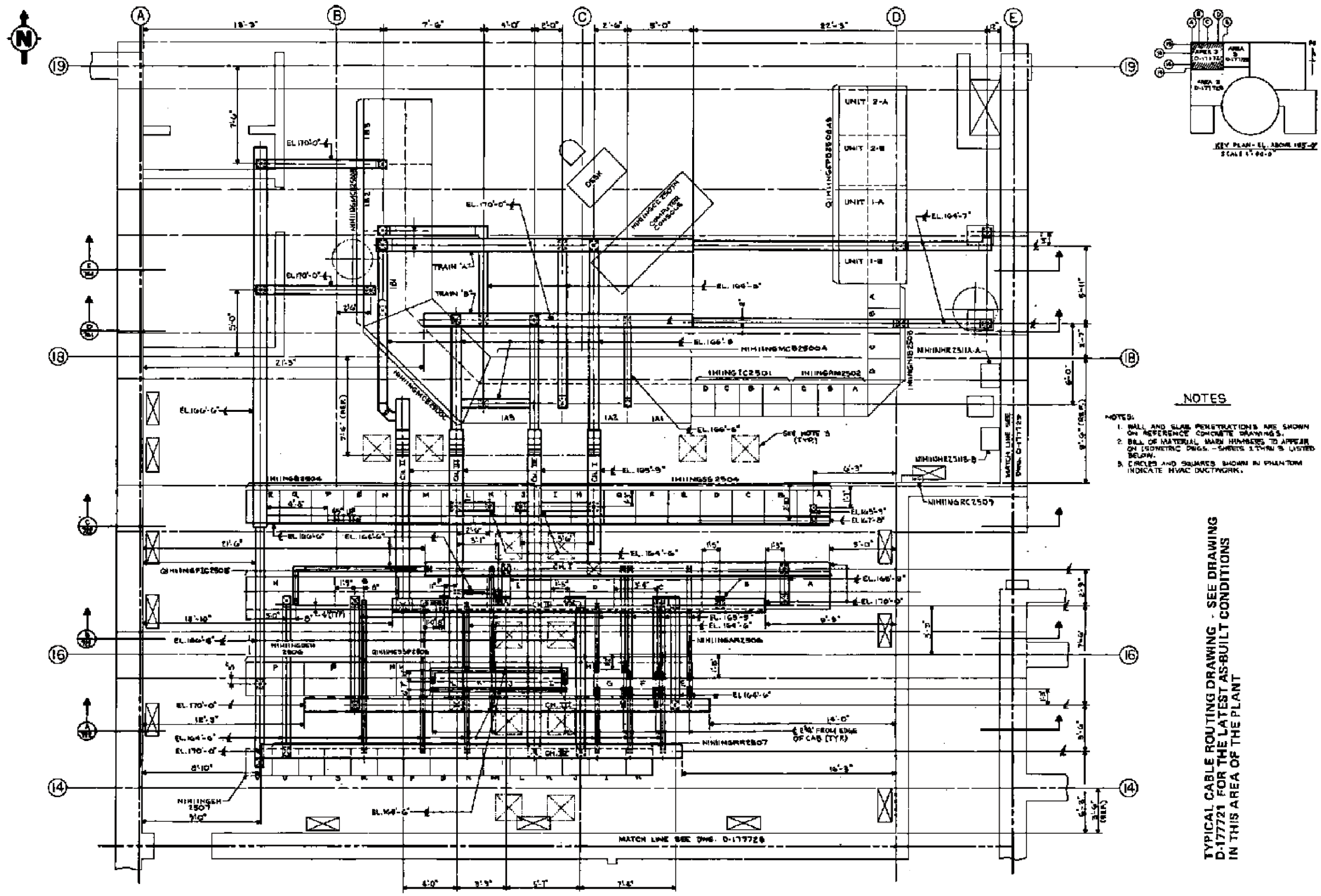
UNIT 1 AND UNIT 2

TRAY AND CONDUIT LAYOUT AUXILIARY BUILDING ABOVE el 121 SWGR ROOM

FIGURE 8.3-4



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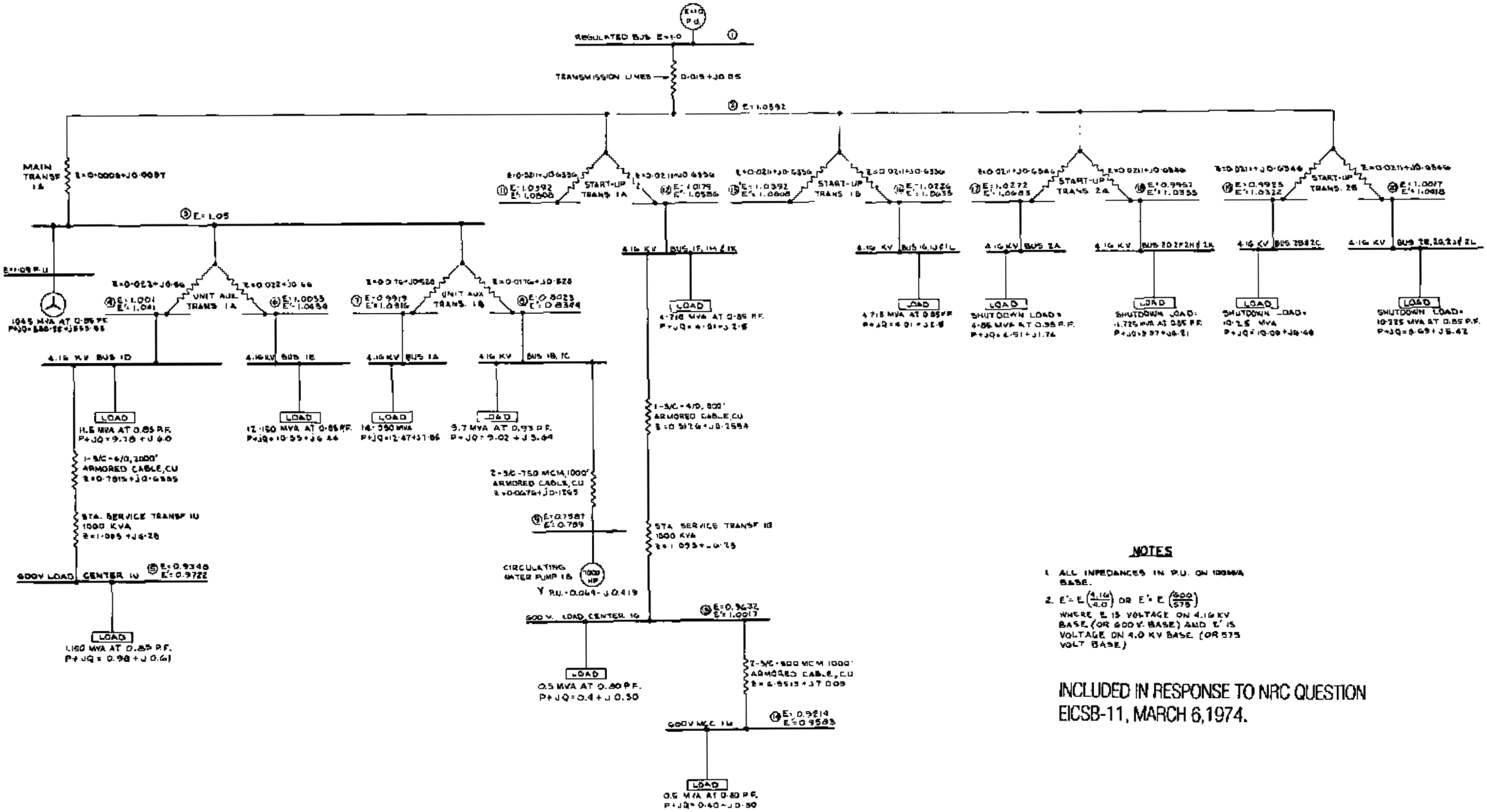
UNIT 1 AND UNIT 2

WIREWAY INSTALLATION LAYOUT AUXILIARY BUILDING ABOVE el 155 CONTROL ROOM

FIGURE 8.3-5



NOTES

1. ALL IMPEDANCES IN P.U. ON 100MVA BASE.
2. $E' = E\left(\frac{4.16}{4.0}\right)$ OR $E' = E\left(\frac{600}{575}\right)$
   WHERE E IS VOLTAGE ON 4.16 KV BASE (OR 600 V. BASE) AND E' IS VOLTAGE ON 4.0 KV BASE (OR 575 VOLT BASE)

INCLUDED IN RESPONSE TO NRC QUESTION EICSB-11, MARCH 6,1974.

CASE 7: STARTING 7000 H.P. CIRCULATING WATER PUMP MOTOR ON 4.16 KV BUS 1B.
UNIT 1 IS OPERATING WITH ALL LOADS REQUIRED FOR 100 PERCENT POWER GENERATION ON UNIT AUXILIARYS AND START-UP TRANSFORMERS, AND UNIT 2 WITH SHUTDOWN LOADS ON START-UP TRANSFORMERS.

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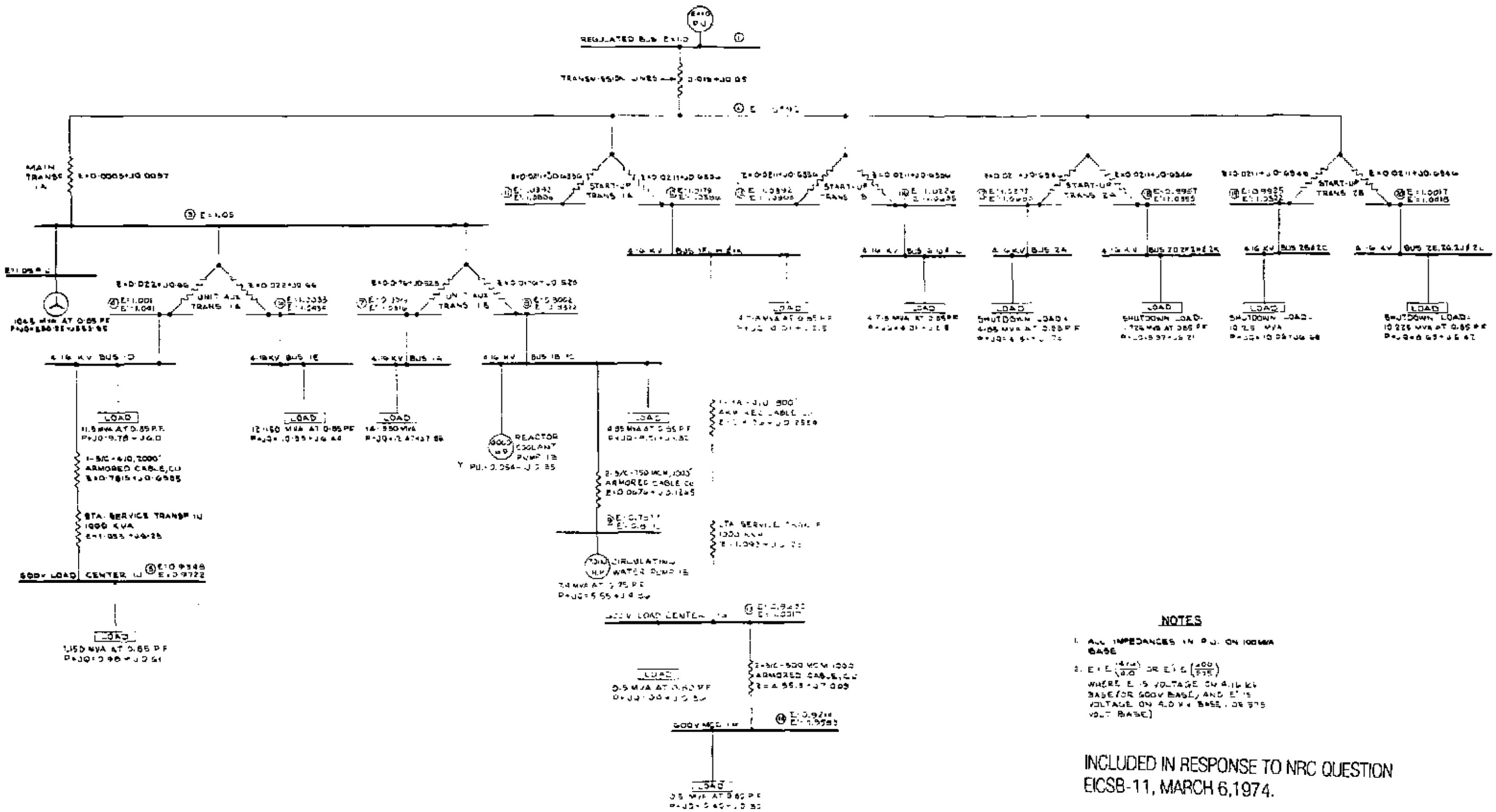
VOLTAGE DROP CALCULATIONS USING COMPUTER

FIGURE 8.3-6



NOTES

1. ALL IMPEDANCES IN P.U. ON 100MVA BASE
2. $E' = E\left(\frac{4.16}{4.0}\right)$ OR $E' = E\left(\frac{600}{575}\right)$
   WHERE E IS VOLTAGE ON 4.16 KV BASE (OR 600V BASE), AND E' IS VOLTAGE ON 4.0 KV BASE, OR 575 VOLT BASE)

INCLUDED IN RESPONSE TO NRC QUESTION EICSB-11, MARCH 6,1974.

CASE 6 - STARTING 6000 H.P. REACTOR COOLANT PUMP MOTOR ON 4.16 KV BUS 1B

UNIT 1 IS OPERATING WITH ALL LOADS REQUIRED FOR 100 PERCENT POWER GENERATION ON UNIT AUXILIARYS AND START-UP TRANSFORMERS, AND UNIT 2 WITH SHUTDOWN LOADS ON START UP TRANSFORMERS.

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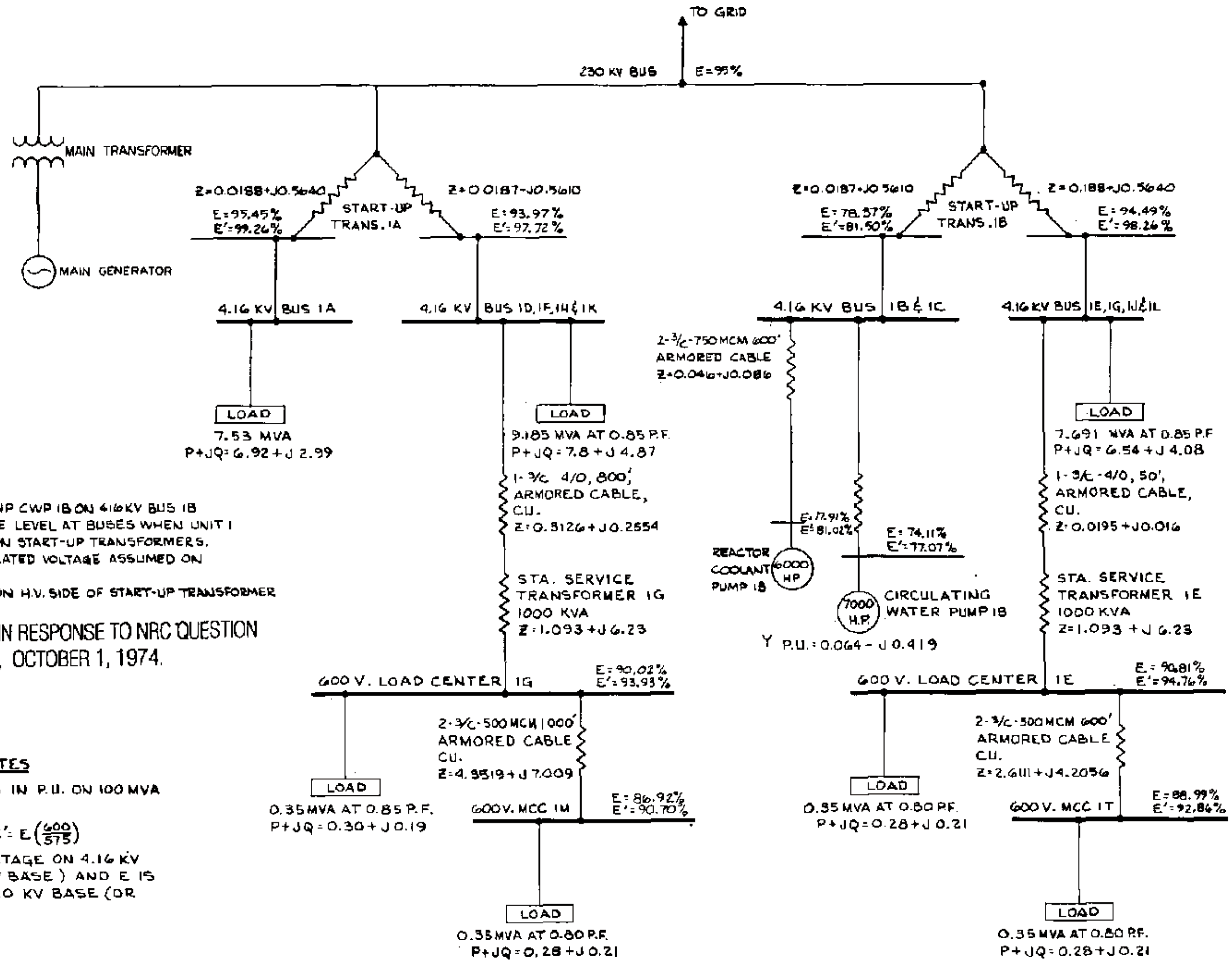
VOLTAGE DROP CALCULATIONS USING COMPUTER

FIGURE 8.3-7



CASE 2: STARTING 7000 HP CWP 1B ON 4.16 KV BUS 1B TO FIND VOLTAGE LEVEL AT BUSES WHEN UNIT 1 IS STARTING UP ON START-UP TRANSFORMERS.

DATA: 1) 0.95 REGULATED VOLTAGE ASSUMED ON 230 KV BUS

2) - 2 1/2 % TAP ON H.V. SIDE OF START-UP TRANSFORMER

INCLUDED IN RESPONSE TO NRC QUESTION EICSB-11A, OCTOBER 1, 1974.

NOTES

1. ALL IMPEDANCES IN P.U. ON 100 MVA BASE.
2. $E' = E\left(\frac{4.16}{4.0}\right)$ OR $E' = E\left(\frac{600}{575}\right)$

   WHERE E IS VOLTAGE ON 4.16 KV BASE (OR 600 V BASE) AND E IS VOLTAGE ON 4.0 KV BASE (OR 575 V BASE)

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VOLTAGE DROP CALCULATIONS USING COMPUTER

FIGURE 8.3-8

9.0 AUXILIARY SYSTEMS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

9.0 AUXILIARY SYSTEMS

9.1 FUEL STORAGE AND HANDLING

Special nuclear material (SNM) in the form of fuel is stored in three locations at FNP. These are the new fuel storage area, the spent-fuel pool, and the independent spent-fuel storage installation (ISFSI). Storage of new fuel is described in FSAR subsection 9.1.1. Wet spent-fuel storage in the spent-fuel pool is described in FSAR subsection 9.1.2. Dry spent-fuel storage in the ISFSI is described in FSAR subsection 9.1.6.

9.1.1 NEW FUEL STORAGE

9.1.1.1 Design Bases

New fuel is stored in racks (figure 9.1-1). Each rack is composed of individual vertical cells which can be fastened together in any number to form a module that can be firmly bolted to anchors in the floor of the new fuel storage area. The new fuel storage racks are designed to include storage for approximately 1/2 core (62 fuel assemblies in the west new fuel pit and 14 fuel assemblies in the east new fuel pit) at a center-to-center spacing of 21 in. This spacing provides a minimum separation between adjacent fuel assemblies of 12 in., which is sufficient to maintain a subcritical array even in the event that the building is flooded with unborated water. All surfaces that come into contact with the fuel assemblies are made of austenitic steel, whereas the supporting structure may be painted carbon steel.

The west new fuel pit racks are designed to withstand nominal operating loads as well as safe shutdown earthquake (SSE) and one-half SSE seismic loads meeting American Nuclear Society (ANS) Safety Class 3 and American Institute of Steel Construction (AISC) requirements.

The east new fuel pit racks are designed to withstand nominal operating loads as well as SSE and one-half SSE seismic loads meeting ANS Safety Class 3 and American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Subsection NF, requirements.

In addition, an exemption from 10 CFR 70.24, relative to the authorization to possess special nuclear material at Farley Nuclear Plant, has been granted by the Nuclear Regulatory Commission[2] that provides relief from the requirement to install criticality monitors. These monitors are not needed because inadvertent or accidental criticality will be precluded through compliance with the plant Technical Specifications, geometric spacing of fuel assemblies in the new fuel storage area and spent-fuel storage pool, administrative controls imposed on fuel handling procedures, and the use of nuclear instrumentation that monitors the behavior of nuclear fuel in the reactor vessel.

9.1.1.2 Facilities Description

The new fuel storage area is shown on figure 1.2-1. The racks are shown on figure 9.1-1.

9.1.1.3 Safety Evaluation

The design basis for preventing criticality outside the reactor is that, including uncertainties, there is a 95-percent probability at a 95-percent confidence level (95/95 probability/confidence) that the effective multiplication factor (k_{eff}) of the fuel assembly array will be no greater than 0.95. The k_{eff} limit of 0.95 applies to the new (fresh) fuel racks under all conditions, except under low water density (optimum moderation) conditions where the k_{eff} limit is 0.98. The new fuel racks are maintained in a dry environment under normal conditions. Therefore, the introduction of full density and low density (optimum moderation) water are the bounding reactivity events. For both cases, k_{eff} remains below the NRC acceptance criteria of 0.95 and 0.98, respectively.

The new fuel assemblies are stored dry, the 21-in. x 21-in. spacing ensuring an ever-safe geometric array. Under these conditions, a criticality accident during refueling and storage is not considered credible.

Design of the facility in accordance with Regulatory Guide 1.13 ensures adequate safety under normal and postulated accident conditions. Consideration of criticality safety analyses is discussed in paragraph 4.3.2.7.

The new fuel storage racks are designed to withstand a pullup force equal to the load rating of the new fuel monorail hoist (2500 lb).

9.1.2 WET SPENT-FUEL STORAGE

9.1.2.1 Design Bases

Spent fuel is stored in the spent-fuel pool in 10.75 in. center-to-center spent-fuel racks. The spent-fuel storage capacity is about 9 cores (1407 fuel assemblies). Spent fuel is stored in racks (figure 9.1-2) which are composed of individual austenitic stainless steel cans that are assembled together in any reasonable number to form a module. The spent-fuel rack modules are freestanding and free to move on the pool liner floor during a seismic event. The racks maintain a center-to-center spacing of 10.75 in. between spent-fuel assemblies, which is sufficient to maintain a subcritical array. Mechanical design criteria for these racks are given below.

Additionally, loose fuel pellets and fuel rod debris from fuel rod failures may be stored in a pellet canister trap inside a transport container in the spent-fuel storage racks. The criticality safety analyses for the spent-fuel pool racks are discussed in paragraph 4.3.2.7.2.

Individual fuel rods removed during the fuel reconstitution process can be stored in the fuel rod storage canister (FRSC), which is located in a spent-fuel rack. Criticality and thermal/hydraulic analyses for the FRSC have confirmed that all design criteria for spent-fuel storage continue to be met.

Spent-fuel racks are designed to withstand shipping, handling, and normal operating loads (impact and dead loads of fuel assemblies) as well as SSE and one-half SSE seismic loads meeting ANS Safety Class 3 and AISC requirements. The spent-fuel racks are also designed to meet Category 1 seismic requirements of Regulatory Guide 1.13.

9.1.2.2 Facilities Description

The wet spent-fuel storage area is shown in figure 1.2-3. The racks are shown in figure 9.1-2.

9.1.2.3 Safety Evaluation

Design of this storage facility, in accordance with Regulatory Guide 1.13, ensures a safe condition under normal and postulated accident conditions. Consideration of criticality safety analyses is discussed in paragraph 4.3.2.7.

The design basis for preventing criticality outside the reactor is that, including uncertainties, there is a 95-percent probability at a 95-percent confidence level (95/95 probability/confidence) that the effective multiplication factor (k_{eff}) of the fuel assembly array will be no greater than 0.95. The resulting k_{eff} for the Farley spent-fuel storage racks was less than 0.95 and included all appropriate biases and uncertainties at a 95/95 probability/confidence level. This meets the NRC acceptance criteria of 0.95.

Spent-fuel pool cooling is discussed in subsection 9.1.3.

The storage racks are designed to withstand a pullup force equal to the load rating of the spent-fuel pool bridge hoist (4000 lb).

The spent-fuel storage racks are designed to withstand a fuel bundle drop from 42 in. above the rack impacting on the middle of the top grid, the corner of the top grid, or free falling through an empty cavity and impacting the bottom grid. They are also designed to withstand the drop of an inclined fuel bundle on top of the rack or a gate drop from 9 inches above the rack impacting on the top of the rack.

An analysis was performed for a fuel assembly drop assuming a load of 3000 lb at a height of 42 in. This analysis conservatively bounds the drop of a standard 17-x-17 fuel assembly, which weighs approximately 2000 lb with a control rod and handling fixture at the maximum lift height of 39.5 in. The analyzed fuel assembly drop load of 3000 lb at 42 in. represents the worst fuel rack impact load condition, i.e., highest kinetic energy, of all loads that could be moved over the spent fuel. The results of the analysis showed that the fuel can deform in compression and shorten in length, but the fuel assemblies would not be damaged and the accident would not result in an unsafe geometric spacing of the fuel assemblies (K_{eff} remains $\leq$ 0.95, as described in paragraph 4.3.2.7).

The only heavy load handled by the spent-fuel pool bridge crane is the spent-fuel pool transfer slot gate, which weighs approximately 3600 lb. Administrative controls prevent the transfer slot gate from being carried over the fuel assemblies in the spent-fuel pool. At the beginning of fuel transfer operations, the transfer slot gate is moved from its normal position directly to its stored position, which is located immediately adjacent to its normal position. This procedure is reversed at the end of fuel transfer operations. However, the racks are designed to withstand a gate drop from 10 1/4 in. The drop height is limited by a physical limitation in lifting capability. Additionally, administrative controls prevent handling equipment capable of carrying loads with a higher impact energy from transporting these loads over the fuel storage area.

9.1.3 SPENT-FUEL POOL COOLING AND CLEANUP SYSTEM

The spent-fuel pool cooling and cleanup system is designed to remove decay heat generated by stored spent-fuel assemblies from the spent-fuel pool water.

A second function of the system is to maintain clarity (visual) and purity of the spent-fuel pool water, the transfer canal water, and the refueling water.

9.1.3.1 Design Bases

The spent-fuel pool cooling and cleanup system design parameters are given in table 9.1-1.

9.1.3.1.1 Spent-Fuel Pool Cooling

The spent-fuel pool cooling and cleanup system is designed to remove an amount of decay heat in excess of that produced by the number of spent-fuel assemblies that are stored in the pool following a normal refueling plus any fuel assemblies that may remain in the pool from previous refuelings. The system design incorporates two trains of equipment, either train being capable of removing 100 percent of the design heat load. When the spent-fuel assemblies resulting from a partial core offload refueling are in the spent-fuel pool, either cooling train can maintain the spent-fuel pool water temperature at or below 150°F when the heat exchanger is supplied with component cooling water at the design flow and temperature. The flow through the pools provides sufficient mixing to maintain uniform water conditions. For a full core offload refueling with the spent-fuel assemblies from previous refuelings in the pool, either cooling train can maintain the spent-fuel pool water at or below 180°F. It should be noted that the heat load calculations are based on an 18-month fuel cycle discharge schedule with high-density racks installed with uncertainty factors applied.

In addition to the cases discussed above, the heat load from a third "best-estimate" case is also presented in table 9.1-1. This case represents start/completion of a normal full-core offload 150 h after shutdown. No uncertainty factors were applied to the decay heat results for this case.

The design basis analyses for the refueling cases assume that the complete batch of spent fuel is instantaneously offloaded from the reactor vessel to the pool at the assumed time with the pool at equilibrium conditions.

An operational sensitivity evaluation for transient fuel movement operations has been performed for a refueling outage full core offload. This evaluation is conservative for less than a full core offload. This evaluation assumed an initial spent-fuel pool temperature of 111 °F, CCW inlet temperature to the spent-fuel pool HX maintained ≤ 105 °F, and a core offload rate of 8 assemblies per hour starting at 100 h after reactor shutdown. The pool operational temperature limit of 130°F provides for personnel safety and limits room air temperature for habitability. The evaluation demonstrated suspending movement into the spent-fuel pool at 130°F ensures pool design temperature limits will not be reached. The operational evaluation is provided for outage planning purposes and is bounded by the design basis analyses discussed above.

9.1.3.1.2 Spent-Fuel Pool Dewatering Protection

System piping is arranged so that failure of any pipeline cannot drain the spent-fuel pool below the water level required for radiation shielding. A depth of approximately 12 ft of water over the top of the stored spent-fuel assemblies will reduce direct radiation to 2.5 mrem/h, which is a factor of two below the threshold level for a radiation area as defined in 10 CFR 20.1003.

In order to perform inspection and/or maintenance of equipment located in the transfer canal, the water in the transfer canal may be transferred to the spent-fuel pool or cask wash area by means of a submersible pump. When pumping to the spent-fuel pool, as the water level is increased, the water is transferred to the refueling water storage tank or to the recycle holdup tanks. The level in the spent-fuel pool is also monitored to ensure that the level in the spent-fuel pool does not decrease below that required for radiation shielding. When pumping to the cask wash area, which drains to the floor drain tank, the water level in the floor drain tank is monitored to ensure that the tank does not overflow.

9.1.3.1.3 Water Purification

The system's demineralizers and filters are designed to provide adequate purification to permit unrestricted access for plant personnel to the spent-fuel storage area and maintain optical clarity of the spent-fuel pool water. The optical clarity of the spent-fuel pool water surface is maintained by use of the system's skimmers, strainer, and skimmer filter. To assist in maintaining optical clarity, a temporary in-pool filter can be used.

9.1.3.2 System Description

The spent-fuel pool cooling and cleanup system piping and instrumentation diagram shown in drawing D-205043 consists of two cooling trains, a purification loop, and a surface skimmer loop. The spent-fuel pool cooling and cleanup system removes decay heat from fuel stored in the spent-fuel pool. Spent fuel is placed in the pool during the refueling sequence and stored there until it is relocated to an onsite or offsite storage facility, or relocated for reprocessing. The system normally handles the heat loading from typical core discharges from the reactor as described in table 9.1-1, plus the heat loading from any stored assemblies from previous refuelings. Heat is transferred from the spent-fuel pool cooling and cleanup system through the heat exchanger to the component cooling system.

When either cooling train is in operation, water flows from the spent-fuel pool to the spent-fuel pool pump suction, is pumped through the tube side of the heat exchanger, and is returned to the pool. The suction line, which is protected by a strainer, is located at an elevation 4 ft below the normal spent-fuel pool water level, while the return line terminates in the pool at an elevation 6 ft above the top of the fuel assemblies and contains an antisiphon hole near the surface of the water to prevent gravity drainage of the pool.

Figures 9.1-3 and 9.1-4 show the layout of the spent-fuel heat exchangers, the arrangement of the return piping from the heat exchangers to the spent-fuel pool, and the dimensions of the cask wash and storage areas.

While the heat removal operation is in process, a portion of the spent-fuel pool water may be diverted through a demineralizer and a filter to maintain spent-fuel pool water clarity and purity. Transfer canal water may also be circulated through the same demineralizer and filter by removing the gate between the canal and the spent-fuel pool. This purification loop is sufficient for removing fission products and other contaminants which may be introduced if a fuel assembly with defective cladding is transferred to the spent-fuel pool.

The spent-fuel pool demineralizer and filter may be isolated from the heat removal portion of the spent-fuel pool cooling and cleanup system. By so doing, the isolated equipment may be used in conjunction with the refueling water purification pump to clean and purify the refueling water while spent-fuel pool heat removal operations proceed. Connections are provided so that the refueling water may be pumped from either the refueling water storage tank or the refueling cavity through the filter and demineralizer and discharged to either the refueling cavity or refueling water storage tank. Connections in the suction and discharge piping of the refueling water purification pump allow a reverse osmosis filter skid to be connected for silica removal from the refueling water storage tank contents.

To assist further in maintaining spent fuel water clarity, the water surface is cleaned by a skimmer loop. Water is removed from the surface by the skimmers, pumped through a strainer and filter, and returned to the pool surface at three locations remote from the skimmers.

The spent-fuel pool is initially filled with water that is at the same boron concentration as that in the refueling water storage tank. Borated water may be supplied from the refueling water storage tank via the refueling water purification pump connection or by running a temporary line from the boric acid blender located in the chemical and volume control system directly into the pool. Demineralized water can also be added for makeup purposes (i.e., to replace evaporative losses) through a connection in the recirculation return line. An assured Seismic Category I water makeup source is provided by a reactor makeup water system hose station, which is located at the el 155 ft operating area adjacent to the spent-fuel pool. In the unlikely event of the failure of both trains of the spent-fuel pool cooling system and the demineralized water system, reactor makeup water can be added to the spent-fuel pool by the use of a temporary hose connection.

The spent-fuel pool water may be separated from the water in the transfer canal by a gate. The gate is installed so that the transfer canal may be drained to allow maintenance of the fuel transfer equipment. The water in the transfer canal is first pumped, via a portable pump, into the spent-fuel pool or the cask wash area. If the water is pumped to the spent-fuel pool, it may be transferred to the recycle holdup tanks or the refueling water storage tank to maintain the spent-fuel pool level. When maintenance on the fuel transfer equipment is completed, water is returned to the transfer canal from either the spent-fuel pool or the cask wash area using a portable pump. Proceduralized administrative requirements are utilized to maintain control when transferring water from the spent-fuel pool. Water may also be transferred to the transfer canal directly from the recycle holdup tanks using the evaporator feed pumps.

9.1.3.2.1 Component Description

Spent-fuel pool cooling and cleanup system codes and classifications are given in section 3.2. Equipment design parameters are given in table 9.1-2.

A. Spent-Fuel Pool Pumps

   The pumps are horizontal, centrifugal units, with all wetted surfaces being stainless steel. The pumps are controlled manually from a local station.

B. Spent-Fuel Pool Skimmer Pump

   This horizontal, centrifugal pump circulates surface water through a strainer and a filter and returns it to the pool. The pump is controlled manually from a local station.

C. Refueling Water Purification Pump

   The refueling water purification pump is used to circulate water from the refueling water storage tank through the spent-fuel pool demineralizer and filter. The pump is operated manually from a local station. The pump can be started only when both upstream automatic isolation valves are open and will trip if either valve closes.

D. Spent-Fuel Pool Heat Exchangers

The heat exchangers are the shell and U-tube type. Spent-fuel pool water circulates through the tubes while component cooling water circulates through the shell.

E. Spent-Fuel Pool Demineralizer

This flushable, mixed-bed demineralizer is designed to provide adequate fuel pool water purity for unrestricted access of plant personnel to the pool working area. A specialty resin, such as a coated weak acid cation resin, may be added in a layer on top of the mixed-bed resin to facilitate removal of particulate material to improve clarity of spent-fuel pool water or reactor cavity water.

F. Spent-Fuel Pool Filter

The spent-fuel pool filter is designed to improve the pool water clarity by removing particles which obscure visibility.

G. Spent-Fuel Pool Skimmer Filter

The spent-fuel pool skimmer filter is used to remove particles which are not removed by the strainer.

H. Spent-Fuel Pool Strainers

A strainer is located in each spent-fuel pool pump suction line to prevent introduction of relatively large particles which might otherwise clog the spent-fuel pool demineralizer or damage the spent-fuel pool pumps.

I. Spent-Fuel Pool Skimmer Strainer

The spent-fuel pool skimmer strainer is designed to remove debris from the skimmer process flow.

J. Spent-Fuel Pool Skimmers

Two spent-fuel pool skimmers are provided to remove water from the spent-fuel pool water surface in order to remove floating debris.

K. Valves

Manual and automatic stop valves are used to isolate equipment, and manual throttle valves provide flow control. Valves in contact with spent-fuel pool water are austenitic stainless steel or equivalent corrosion resistant material.

L. Piping

All piping in contact with spent-fuel pool water is austenitic stainless steel. The piping is welded except where flanged connections are used to facilitate maintenance.

9.1.3.2.2 Instrumentation Description

The instrumentation provided for the spent-fuel pool cooling and cleanup system is discussed below. Alarms and indications are provided as noted. The spent-fuel pool area radiation monitor is discussed in subsection 12.1.4, and the spent-fuel pool exhaust flow gas monitors are discussed in paragraph 11.4.2.2.

A. Temperature

Instrumentation is provided to measure the temperature of water in the spent-fuel pool and give local indication as well as annunciation in the control room when normal temperatures are exceeded.

Instrumentation is also provided to give local indication of the temperature of the spent-fuel pool water as it leaves either heat exchanger.

B. Pressure

Instrumentation is provided to measure and give local indication of the pressures in the spent-fuel pool pump suction and discharge lines and in the refueling water purification pump discharge line.

Instrumentation is also provided at locations upstream and downstream of the spent-fuel pool filter and the spent-fuel pool skimmer filter so that the pressure differential across these filters can be determined.

C. Flow

Instrumentation is provided to measure and give local indication of the flow in the outlet line of the spent-fuel pool filter.

D. Level

A float type level instrument is provided to give an alarm in the control room when the water level in the spent-fuel pool reaches either the high or low level setpoints (within 6 in. above or below the normal water level in the pool). Local visual indication of the spent-fuel pool level is provided.

9.1.3.3 Safety Evaluation

9.1.3.3.1 Availability and Reliability

The spent-fuel pool cooling and cleanup system has no emergency function during an accident. This manually controlled system may be shut down for limited periods of time for maintenance or replacement of malfunctioning components. In the event of a failure of a spent-fuel pool pump or loss of cooling to a spent-fuel pool heat exchanger, the second cooling train provides 100-percent backup capability, thus ensuring continued cooling of the spent-fuel pool.

9.1.3.3.2 Spent-Fuel Pool Dewatering

The most serious failure of this system would be complete loss of water in the storage pool. To protect against the possibility, the spent-fuel pool cooling suction connections enter near the normal water level so that the pool cannot be siphoned. The cooling water return line contains an antisiphon hole to prevent the possibility of draining the pool. These design features ensure that, for breaks of < 150 gal/min, the spent-fuel pool will not drain below el 149 ft 8 in. For larger breaks, the spent-fuel pool will not drain down below 140 ft 6 in.

The spent-fuel pool is designed in accordance with Regulatory Guide 1.13 and ensures adequate safety under normal and accident conditions. Pool water losses resulting from normal evaporation and the rupture of suction and discharge piping have been considered. The possibility of cracking the spent-fuel pool liner plate and the surrounding concrete structure is highly unlikely, since it is not possible to bring a sufficiently heavy load, such as a spent-fuel cask, into the spent-fuel pool area.

The spent-fuel cask crane, discussed in subsection 9.1.4, is prevented by design from moving above or into the vicinity of the spent-fuel pool.

The spent-fuel pool is a Seismic Category I structure located entirely within the auxiliary building and is not affected by cyclonic winds or tornado-generated missiles.

Makeup water to compensate for spent-fuel pool losses is provided by the demineralized water system, discussed in subsection 9.2.3. The reactor makeup water system discussed in subsection 9.2.7 is also available as a Seismic Category I water source in the event that the demineralized water system is unavailable.

9.1.3.3.3 Water Quality

Only a very small amount of water is interchanged between the refueling canal and the spent-fuel pool as fuel assemblies are transferred in the refueling process. Whenever a fuel assembly with defective cladding is transferred to the spent-fuel pool, a small quantity of fission products may enter the spent-fuel cooling water. The purification loop provided removes fission products and other contaminants from the water, by maintaining radioactivity concentrations in the spent-fuel pool water at 5×10^{-3} $\mu Ci/cm^3$ (β and γ) or less and thus allowing unrestricted access for plant personnel.

9.1.3.4 Tests and Inspections

Active components of the spent-fuel pool cooling and cleanup system are either in continuous or intermittent use during normal system operation. Periodic visual inspection and preventive maintenance are conducted using normal industry practice.

9.1.4 FUEL HANDLING SYSTEM

9.1.4.1 Design Bases

The fuel handling system consists of equipment and structures utilized for the refueling operation in a safe manner.

The following design bases apply to the fuel handling system:

A. Fuel handling devices have provisions to avoid dropping or jamming of fuel assemblies during transfer operation.

B. Fuel lifting and handling devices are capable of supporting maximum loads under SSE conditions.

C. The fuel transfer system, where it penetrates the containment, has provisions to preserve the integrity of the containment pressure boundary.

D. Cranes and hoists used to lift spent fuel have a limited maximum lift height so that the minimum required depth of water shielding is maintained.

In addition, an exemption from 10 CFR 70.24, relative to the authorization to possess special nuclear material at Farley Nuclear Plant, has been granted by the Nuclear Regulatory Commission(2) that provides relief from the requirement to install criticality monitors. These monitors are not needed because inadvertent or accidental criticality will be precluded through compliance with the plant Technical Specifications, geometric spacing of fuel assemblies in the new fuel storage area and spent-fuel storage pool, administrative controls imposed on fuel handling procedures, and the use of nuclear instrumentation that monitors the behavior of nuclear fuel in the reactor vessel.

9.1.4.2 System Description

The fuel handling system consists of the equipment needed for the refueling operation on the reactor core. Basically this equipment is comprised of cranes, handling equipment, and a fuel transfer system. The structures associated with the fuel handling equipment are the refueling cavity, the refueling canal, the spent-fuel storage pool, and the new fuel storage area.

New fuel assemblies received are removed one at a time from the shipping cask and stored in the new fuel storage racks located in the new fuel storage area. New fuel assemblies are transferred from the new fuel storage area and are lowered into the new fuel elevator by the new fuel monorail hoist. New fuel is delivered to the reactor by placing a fuel assembly into the new fuel elevator, lowering it into the spent-fuel pool, and taking it through the fuel transfer system.

The fuel handling equipment is designed to handle the fuel under water from the time it leaves the reactor vessel until it is placed in a cask for temporary onsite storage in the independent spent-fuel storage installation (ISFSI) or shipment from the site. Underwater transfer of spent fuel provides an effective, economical, and transparent radiation shield as well as a reliable cooling medium for removal of decay heat. The boric acid concentration in the water is sufficient to preclude criticality.

The associated fuel handling structures may be generally divided into three areas: the refueling cavity and refueling canal, which are flooded only during plant shutdown for refueling; the spent-fuel pool, which is kept full of water and is always accessible to operating personnel; and the new fuel storage area, which is separate and protected for dry storage. The refueling canal and the spent-fuel pool are connected by a fuel transfer tube. This tube is fitted with a blind flange on the canal end and a gate valve on the spent-fuel pool end. The blind flange is in place except during refueling to ensure containment integrity. Fuel is carried through the tube on an underwater transfer car.

Fuel is moved between the reactor vessel and the refueling canal by the manipulator crane. A rod cluster control changing fixture is located on the refueling canal wall for transferring control elements from one fuel assembly to another.

The upender at either end of the fuel transfer tube is used to pivot a fuel assembly. Before entering the transfer tube, the upender pivots a fuel assembly to the horizontal position for passage through the transfer tube. After the transfer car transports the fuel assembly through the transfer tube, the upender at that end of the tube pivots the assembly to a vertical position so that it can be lifted out of the fuel container.

In the spent-fuel pool, fuel assemblies are moved about by the spent-fuel bridge hoist. When lifting spent-fuel assemblies, the hoist uses a long-handled tool to ensure that sufficient radiation shielding is maintained. A shorter tool is used to handle new fuel, but the new fuel elevator must be used to lower the assembly to a depth at which the hoist, using the long-handled tool, can place the new assembly into the fuel transfer container in the upending device.

The spent-fuel pool bridge is the only structure capable of transporting heavy objects over the spent-fuel pool area. The spent-fuel pool bridge and spent-fuel hoist will not be used to handle loads of more than 3000 lb. over the spent-fuel pool. See paragraph 9.1.2.3 regarding lifting of the transfer slot gate. The spent-fuel handling tool is designed to preclude its accidental decoupling from the hoist. Fuel assemblies are gripped by four cam-actuated latching fingers, and a pin is inserted in the tool handle to preclude fingers from being accidentally unlatched during fuel handling operations.

Decay heat from the spent-fuel assemblies in the spent-fuel pool is removed by the spent-fuel pool cooling system. After a sufficient decay period, the fuel is removed from the racks and loaded into casks for temporary onsite storage in the ISFSI or removal from the site.

9.1.4.2.1 Refueling Procedure

The refueling operation follows a detailed procedure that provides a safe, efficient refueling operation. The following significant points are ensured by the refueling procedure:

A. The boron concentration of the refueling water and the reactor coolant, together with the negative reactivity of control rods, is sufficient to keep the core approximately 5 percent $\delta k/k$ subcritical during the refueling operations. It is also sufficient to maintain the core subcritical in the unlikely event that all of the rod cluster control assemblies were removed from the core.

B. The water level in the refueling cavity is high enough to keep the radiation levels within acceptable limits when the fuel assemblies are being removed from the core.

The refueling operation is divided into four major phases: preparation, reactor disassembly, fuel handling, and reactor assembly. A general description of a typical refueling operation through the four phases is given below:

A. Phase I - Preparation

The reactor is shut down and cooled to cold shutdown conditions with a final k_{eff} < 0.95 (all rods in). Following a radiation survey, the containment vessel is entered. At this time, the coolant level in the reactor vessel is lowered to a point slightly below the vessel flange. Then the fuel transfer equipment and manipulator crane are checked for proper operation.

B. Phase II - Reactor Disassembly

All cables are disconnected and the insulation is removed from the vessel head. The refueling cavity is then prepared for flooding by sealing off the reactor cavity; checking of the underwater lights, tools, and fuel transfer system; closing the refueling canal drain holes; and removing the blind flange from the fuel transfer tube. With the refueling cavity prepared for flooding, the vessel head is unseated and raised approximately 1 ft above the vessel flange. The vessel is then inspected to ensure that no binding has occurred on vessel internals or bolts. It is then raised and placed on the storage stand.

Once the head is placed on the storage stand, the water from the refueling water storage tank is pumped into the reactor coolant system by the residual heat removal pumps, causing the water to overflow into the refueling cavity. The water level in the refueling cavity is raised to a level sufficient to unlatch control rod drive shafts. The control rod drive shafts are disconnected and, with the upper internals, are removed from the vessel. The fuel assemblies and rod cluster control assemblies are now free from obstructions, and the core is ready for refueling.

C. Phase III - Fuel Handling

The refueling sequence is specified in the refueling procedure which is developed for each reload. Typically, the entire core is unloaded with all assemblies being transferred to the spent-fuel pool. Change out of fuel inserts (RCCAs, discrete burnable absorbers, etc.) is normally performed in the spent-fuel pool. During reload, fresh fuel assemblies along with partially spent-fuel assemblies are transferred from the spent-fuel pool room into the reactor core.

The typical general fuel handling sequence is:

1. The manipulator crane is positioned over a fuel assembly in the core.

2. The fuel assembly is lifted by the manipulator crane to a predetermined height sufficient to clear the reactor vessel and still leave sufficient water covering the fuel assembly, to eliminate any radiation hazard to the operating personnel. For Unit 1 and Unit 2, an in-mast sipping test may be performed at this time to determine whether the fuel assembly contains leaking fuel rods.

3. The fuel container is moved through the fuel transfer tube to containment by the transfer car.

4. The fuel assembly container is pivoted to the vertical position by the upender.

5. The manipulator crane is moved to line up the fuel assembly with the fuel transfer system.

6. The manipulator crane loads a fuel assembly into the fuel assembly container of the transfer car.

7. The container is pivoted to the horizontal position by the upender.

8. The fuel container is moved through the fuel transfer tube to the spent-fuel pool by the transfer car.

9. The fuel assembly container is pivoted to the vertical position. The fuel assembly is unloaded by the spent-fuel handling tool attached to the spent-fuel pool bridge hoist.

10. The fuel assembly is placed in the spent-fuel storage rack location designated by the refueling procedure.

11. Steps 1 through 10 are repeated until the entire core is unloaded.

12. The fuel inserts are shuffled in the spent-fuel pool using tools in the spent-fuel pool. Any fuel assembly that is to be placed in a control position will have a RCCA inserted into it. This RCCA transfer is normally accomplished by use of a portable change tool or tools in the spent-fuel pool. Alternatively, this transfer can be accomplished by use of the RCCA change fixture in containment.

13. For the reload, fresh fuel assemblies are brought to the upender fuel assembly container by the spent-fuel pool crane either from spent-fuel pool storage locations or from the new fuel elevator. Partially spent-fuel assemblies are brought to the upender fuel assembly container by the spent-fuel pool crane from spent-fuel pool storage locations.

14. The fuel assembly is loaded into the fuel assembly container of the transfer car.

15. The container is pivoted to the horizontal position by the upender.

16. The fuel container is moved through the fuel transfer tube to containment by the transfer car.

17. The fuel assembly container is pivoted to the vertical position. The fuel assembly is unloaded by the manipulator crane.

18. The fuel assembly is placed in the reactor core location designated by the refueling procedure.

19. Steps 13 through 18 are repeated until refueling is completed.

D. Phase IV - Reactor Assembly

Reactor assembly, following refueling, is essentially achieved by reversing the operations given in Phase II.

9.1.4.2.2 Component Description

9.1.4.2.2.1 **<u>Manipulator Crane</u>**. The manipulator crane (figure 9.1-5) is a rectilinear bridge and trolley crane with a vertical mast extending down into the refueling water. The bridge spans the refueling cavity and runs on rails set into the edge of the refueling cavity. The bridge and trolley motions are used to position the vertical mast over a fuel assembly in the core. A long tube with a pneumatic gripper on the end is lowered down out of the mast to grip the fuel assembly. The gripper tube is long enough so that the upper end is still contained in the mast when the gripper end contacts the fuel. A winch mounted on the trolley raises the gripper tube and fuel assembly up into the mast tube. The fuel is transported while inside the mast tube to its new position.

For Unit 1 and Unit 2, fuel may be checked for leaking rods using the in-mast sipping system. After the fuel assembly is raised into the mast, a small amount of air is introduced through a manifold at the bottom of the mast. The air will rise to the top where it is captured and analyzed for radiological content.

All controls for the manipulator crane are mounted on a console on the trolley. The bridge is positioned on a coordinate system laid out on one rail. Unit 2 uses a video camera to view the bridge rail demarcations via a video monitor on the console to indicate the position of the bridge, whereas in Unit 1 the bridge position is indicated on the original electrical readout system on the console. The trolley is positioned with the aid of a scale on the bridge structure. The scale is read directly by the operator at the console. The drives for the bridge, trolley, and winch are variable speed and controlled by console-mounted switches for each drive for continuous operation at a variable speed. Unit 2 has an additional switch for each drive motor to facilitate jogging its associated motor. A recorder is provided to archive the loads applied to any particular fuel assembly. Electrical interlocks and limit switches on the bridge and trolley drives prevent damage to the fuel assemblies. The winch is also provided with limit switches and a mechanical stop to prevent a fuel assembly from being raised above a safe shielding depth, should the limit switch fail. In an emergency, the bridge, trolley, and winch can be operated manually using a handwheel on the motor shaft.

The manipulator crane is designed in accordance with Electric Overhead Industrial Crane specification No. 61 and meets the requirements of the Occupational Safety and Health Administration (OSHA) and of 29 CFR 1910.179, Subpart N, Materials Handling and Storage.

9.1.4.2.2.2 **Spent-Fuel Pool Bridge**. The spent-fuel pool bridge (figure 9.1-6) is a wheel-mounted walkway, spanning the spent-fuel pool, which carries an electric monorail hoist on an overhead structure. The fuel assemblies are moved within the spent-fuel pool by means of a long-handled tool suspended from the hoist. The hoist travel and tool length are designed to limit the maximum lift of a fuel assembly to a safe shielding depth.

9.1.4.2.2.3 **New Fuel Elevator**. The new fuel elevator consists of a box-shaped elevator assembly with its top end open and sized to house one fuel assembly.

The new fuel elevator is used to lower a new fuel assembly to the bottom of the spent-fuel pool where it is transported to the fuel transfer system by the spent-fuel pool bridge hoist.

The new fuel elevator (NFE) recon basket replaces or interchanges with the site spent-fuel pool new fuel elevator basket. The NFE recon basket is designed to rigidly support the repair fuel assembly and accept removable top nozzle (RTN) tooling required for fuel reconstitution.

9.1.4.2.2.4 **Spent-Fuel Cask Crane**. The spent-fuel cask crane (figures 9.1-7 through 9.1-11) is a Crane Manufacturers Association of America (CMAA) specification No. 70, Class A1 outdoor electric overhead traveling, unequal leg gantry crane, complete with a single trolley and all the necessary motors, controls, brakes, and accessories. The main hoist is rated at 125 tons and the auxiliary hoist is rated at 15 tons. The crane has been designed for outdoor service and will be used to handle spent-fuel casks. The crane will transfer the spent-fuel cask between the east alleyway to the cask wash and cask storage areas as shown in figure 1.2-1.

The spent-fuel cask crane complies with the requirements of OSHA and of 29 CFR 1910.179, Subpart N, Materials Handling and Storage, insofar as applicable to outdoor powerhouse cranes. The spent-fuel cask crane was designed, fabricated, installed, and tested in accordance with applicable sections of the following codes and standards:

A. American Gear Manufacturers Association (AGMA), for defining and calculating gear durability and strength horsepower requirements.

B. AISC, for specification for rails and structural methods.

C. American Iron and Steel Institute (AISI), for specifying materials.

D. American National Standards Institute (ANSI), safety code B30.2 for electric overhead cranes.

E. American Society of Civil Engineers (ASCE), for determining wind loading factors.

F. American Society for Testing Materials (ASTM), for material testing procedures and for specifying material types.

G. American Welding Society (AWS), AWS D2.0, for welding procedures.

H. Association of Iron and Steel Engineers (AISE), for design of structural members.

I. CMAA, specification No. 70, for structural, mechanical, and electrical design parameters.

J. Institute of Electrical and Electronics Engineers (IEEE), for industrial controls and recommended practices.

K. National Electrical Code (NEC), for specifying wiring, insulation, and fastenings.

L. National Electric Manufacturers Association (NEMA), for specifying electrical equipment such as controls and panels.

M. Occupational Safety and Health Administration (OSHA), for safety requirements and for maintenance and operation checkout and testing procedures.

N. Steel Structures Painting Council (SSPC), for cleaning, surface preparation, and painting specifications.

O. Local and state codes, such as the Alabama State Code and the Southern Standard Building Code.

The new fuel bridge crane and the new fuel monorail hoist were designed, fabricated, installed, and tested in accordance with applicable sections of the AISC, ANSI, ASTM, ANS, CMAA, IEEE, NEC, NEMA, OSHA, SSPC, and state and local codes as outlined above.

9.1.4.2.2.5 **Spent-Fuel Cask Lifting Hardware**. The special lift devices which are used to attach the spent-fuel cask to the spent-fuel cask crane will comply with the design, fabrication, testing, maintenance, and quality assurance requirements of ANSI N14.6, as clarified by NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants,” without exception. This requirement will be reflected in procurement documents for spent-fuel cask crane special lift devices.

9.1.4.2.2.6 **New Fuel Bridge Crane**. The new fuel bridge crane is a top running single I beam crane spanning the new fuel storage area. Underhung from the I beam is an electric monorail hoist. The new fuel assemblies are moved within the new fuel storage area by the use of a new fuel assembly handling fixture suspended from the hoist.

9.1.4.2.2.7 **New Fuel Monorail Hoist**. The new fuel monorail hoist is an electric hoist which removes a new fuel assembly from the new fuel storage rack, moves laterally to a position over the new fuel elevator, and then lowers the new fuel assembly into the new fuel elevator. The new fuel assemblies are handled by a new fuel assembly handling fixture suspended from the hoist.

9.1.4.2.2.8 **Fuel Transfer System**. The fuel transfer system includes a cable-driven transfer car that runs on tracks extending from the refueling canal through the transfer tube and into the spent-fuel pool and an operator lifting frame at each end of the transfer tube. The upender in the refueling canal receives a fuel assembly in the vertical position from the manipulator crane. The fuel assembly is then lowered to a horizontal position for passage through the transfer tube and is raised to a vertical position by the upender in the spent-fuel pool. The spent-fuel pool bridge hoist takes the fuel assembly up to a position in the spent-fuel storage racks.

Positive means for control of the fuel assemblies within the fuel transfer canal are provided in the following manner.

The conveyor car is a horizontal wheel-supported structure which is driven by an above-water cable-driven system. The function of the conveyor car is to support and position the fuel assembly container.

The fuel assembly container is a box structure mounted at one end on a pivot support on the conveyor car. The fuel assembly container goes through the transfer tube in a horizontal position and is raised to the vertical position by the lifting frames for loading or unloading fuel assemblies.

The lifting frames are structures, pivot-mounted at the lower end, that straddle the support structure at the loading and unloading points. A winch on the operating deck raises and lowers the frame. When resting on stops in the horizontal position, the frame is positioned so that the conveyor car passes under the frame until it reaches the travel limit stop. As the conveyor car moves under the lifting frame, the fuel container engages the frame so that both components can be lifted to the vertical together.

The transfer tube connects the refueling canal to the spent-fuel pool through the plant containment. The tube is sealed to the plant containment and the steel liners in both the refueling canal and spent-fuel pool. A gate valve is mounted permanently on one end and guides for the conveyor car are mounted in the tube. The blind flange is considered part of the plant containment; it is, therefore, equipped with a double gasket seal serving as a continuously monitored test channel.

Electric winches are used to drive the refueling canal lifting frame and the spent-fuel pool lifting frame. The winches are mounted on the operating deck and are connected to the components through stainless steel wire rope guided by underwater sheaves. Conveyor car position is provided by a rotary resolver on the pit side winch and a programmable limit switch assembly.

Electric winches mounted above water in the fuel storage building are used to drive the carriage. The winches are interlocked together such that when one winch is energized, the countertorque of the other energized winch maintains cable tension at all times. The winches operate at two speeds and are faster when transiting the center of the tube once past designated slow zones at each end of the tube. The winches are connected to the carriage components through a stainless steel cable guided by underwater sheaves to move the carriage between the reactor and pit side upenders.

Two control panels are required, one inside the plant containment and one in the spent-fuel pool area. Each panel contains controls for the adjacent lifting frame. In addition, the panel adjacent to the conveyor car drive provides for its control. The two panels are interlocked to prevent hazardous operation.

A stuck fuel assembly does not cause a problem since the fuel container sides have a minimum of 30-percent open area for water circulation and since the stuck fuel assembly is retrievable.

The Unit 1 conveyor car can be moved back to the spent-fuel pool by means of hand cranking the winches on the cable drive system. Hand cranking serves as the emergency removal method that allows the car to be retrieved in the event the motorized cable drive system will not move the car. Depending on which cable or winch assembly is postulated to fail, the cart can be moved by use of the other winch. One winch would allow the cart to be moved to the pool end while the other would allow it to be moved to the containment side. Once in either of these locations the fuel assembly can be retrieved. Therefore, the emergency removal cable is no longer required.

During reactor operation, the transfer car is stored in the spent-fuel pool. A blind flange is bolted on the refueling canal end of the transfer tube to seal the reactor containment. The terminus of the tube outside the containment is closed by a gate valve.

9.1.4.2.2.9 **Rod Cluster Control Changing Fixture**. Rod cluster control elements are transferred from one fuel assembly to another by means of the rod cluster control changing fixture (figure 9.1-12). Five major subassemblies comprise the changing fixture, including frame and track structure, carriage, guide tube, gripper, and drive mechanism. The carriage is a movable container supported by the frame and track structure. The tracks provide a guide for the four flanged carriage wheels and allow horizontal movement of the carriage during changing operations. Positioning stops on both the carriage and frame locate each of the three carriage compartments directly below the guide tube. Two of these compartments are designed to hold individual fuel assemblies, while the third is made to support a single rod cluster control element. Situated above the carriage and mounted on the refueling canal wall is the guide tube. This assembly provides for the guidance and proper orientation of the gripper and rod cluster control element as they are being raised or lowered. The gripper is a pneumatically actuated mechanism responsible for engaging the rod cluster control element. It has two flexure fingers which can be inserted into the top of the rod cluster control element when air pressure is applied to the gripper piston. Normally, the fingers are locked in a radially extended position. Mounted on the operating deck is the drive mechanism assembly. Its components include a manual carriage drive mechanism, a revolving stop operating handle, a pneumatic selector valve for actuating the gripper piston, and an electric hoist for elevation control of the gripper.

9.1.4.2.2.10 **Spent-Fuel Handling Tool**. This tool is used to handle new and spent fuel in the spent-fuel pool. It is a manually actuated tool on the end of a long pole suspended from the spent-fuel pool bridge hoist. An operator on the spent-fuel pool bridge guides and operates the tool.

9.1.4.2.2.11 **New Fuel Assembly Handling Fixture**. This short-handled tool is used to handle new fuel on the operating deck of the new fuel storage area, to remove the new fuel from the shipping container, and to facilitate inspection and storage of the new fuel and loading of fuel into the fuel elevator.

9.1.4.2.2.12 **Reactor Vessel Head Lifting Device**. The reactor vessel head lifting device (figure 9.1-13) consists of a welded and bolted structural steel frame, with suitable rigging to enable the crane operator to lift the head and store it during refueling operations. The head lifting device has been integrated into the head assembly upgrade package that integrates the CRDM missile shield, a permanent radiation shield, and the CRDM cooling system into the existing head assembly structure. The modification eliminates the concrete and steel missile shield, CRDM cooling system mounted on the missile shield, and the associated ductwork that was part of the original configuration. Two CRDM cooling fans are included in the modified head assembly and, with the addition of an upper plenum structure and internal ducting, supply the cooling air flow to the CRDM coils. The lifting device, the CRDM cooling system, the radiation shield, and the missile shield are permanently attached to the reactor vessel head. Attached to the head lifting device are the monorail and hoists for the reactor vessel stud tensioners.

9.1.4.2.2.13 **Reactor Internals Lifting Device**. The reactor internals lifting device (figure 9.1-14) is a structural frame suspended from the overhead crane. The frame is lowered onto the guide tube support plate of the upper and lower internals and is affixed to the support plate at three equally spaced locations using roto-lock inserts that engage into mating devices in the guide tube support plate. Bushings on the frame engage guide studs in the vessel flange to provide guidance during removal and replacement of the internals package.

9.1.4.2.2.14 **Reactor Vessel Stud Tensioner**. Stud tensioners (figure 9.1-15) are employed to secure the head closure joint at every refueling. The stud tensioner is a hydraulically operated device that uses oil as the working fluid. The device permits preloading and unloading of the reactor vessel closure studs at cold shutdown conditions. Stud tensioners minimize the time required for the tensioning or unloading operations. Three tensioners are provided and are applied simultaneously to three studs located 120° apart. A single hydraulic pumping unit operates the tensioners, which are connected in series. The studs are tensioned to their operational load in predetermined optimal steps to prevent high stresses in the flange region and unequal loadings in the studs. Relief valves on each tensioner prevent overtensioning of the studs due to excessive pressure.

9.1.4.2.2.15 **Temporary Reactor Vessel Cover**. The temporary reactor vessel cover is a stainless steel structure frame consisting of an elliptical dome and flange. The cover is lifted and placed on the reactor vessel mating surface following core off load using the 3-legged reactor vessel internals lifting rig. The cover seals at the top of the reactor vessel and allows for the reactor vessel to be drained without the need to drain the entire refueling cavity. The cover is used when scheduling flexibility is desired for work performed in a full or partially flooded cavity.

9.1.4.2.3 Spent-Fuel Cask Handling Procedure

The following discussion is typical of the spent-fuel cask handling to be used at FNP.

As described in subsection 9.1.6, the spent-fuel cask system consists of a multipurpose canister (MPC), transfer overpack, and storage overpack. The MPC is a stainless steel container which contains a basket designed specifically for PWR fuel assemblies. The transfer and storage overpacks provide missile protection and shielding for the loaded MPC during various phases of the loading and storage operations.

The transfer overpack is used during spent-fuel loading operations inside the auxiliary building and removal of the MPC from the auxiliary building. The MPC and transfer overpack may be delivered to the site by rail car or truck. Upon arrival, the MPC and transfer overpack are cleaned and inspected in accordance with the requirements of the applicable cask final safety analysis report (FSAR). Following completion of cleaning and inspection activities, the transfer overpack is moved using the cask transporter to the transfer pad located in the east alley way behind the auxiliary building. The spent-fuel cask crane is fitted with a special lift device (i.e., lift yoke) specifically designed to interface with the spent-fuel cask crane and the transfer overpack trunnions. The spent-fuel cask crane lifts the transfer overpack from the transfer pad; lifts it over the auxiliary building roof; and lowers it through the roof hatch into the spent-fuel cask wash area (figure 9.1-16).

The MPC is typically transported inside the storage overpack by the transporter to the transfer pad where the storage overpack is set on a specially designed seismic isolation device. The spent-fuel cask crane lifts the MPC from the storage overpack; lifts it over the auxiliary building roof; and lowers it through the roof hatch into the transfer overpack located in the spent-fuel cask wash area. Loading preparations for the MPC and transfer overpack are performed in the spent-fuel cask wash area. Upon completion of loading preparations, the transfer overpack containing the MPC is lifted by the spent-fuel cask crane and moved from the spent-fuel cask wash area to the spent-fuel cask storage area. A lift yoke extension is used whenever a spent-fuel cask is moved in or out of the spent-fuel cask storage area in order to prevent submerging the crane hook to facilitate decontamination. Provisions are made for storage of the lift yoke extension in the spent-fuel cask wash area when not in use.

When the water level in the cask storage area has been equalized with the spent-fuel pool water level, the spent-fuel bridge crane removes the transfer slot gate (figure 1.2-7) which isolates the spent-fuel pool from the cask storage area. The spent-fuel assemblies are removed from the storage racks and are placed in the MPC by the spent-fuel bridge crane. When MPC loading is completed, the isolation gate is installed over the transfer slot by the spent-fuel bridge crane. The MPC lid is placed on the MPC, and the transfer overpack containing the loaded MPC is removed from the cask storage area and placed in the cask wash area. A special lift yoke extension is used to avoid submergence of the crane hook.

MPC closure operations are performed in the spent-fuel cask wash area. These typically include:

- MPC and transfer overpack decontamination.
- MPC lid welding operations.
- MPC blowdown to remove the water from the MPC.
- MPC drying operations.
- Helium backfill operations.
- Final radiological surveys.

Prior to removal of the transfer overpack and MPC from the auxiliary building, the storage overpack located in the east alley way will be fitted with a mating device which is bolted to the storage overpack. The mating device facilitates the removal of the transfer overpack bottom lid to allow MPC transfer from the transfer overpack to the storage overpack.

Following completion of MPC closure activities, the transfer overpack containing the loaded MPC is lifted from the cask wash area through the roof hatch, moved over the auxiliary building roof, and lowered onto the storage overpack in the east alley way using the spent-fuel cask crane and lift yoke. The mating device will be secured to both the transfer overpack and the storage overpack to provide stability for the stacked configuration during MPC transfer operations. The lift yoke arms will be disconnected from the transfer overpack trunnions and the MPC lifted slightly by slings attached to the special lift device to allow the transfer door to be opened. The MPC will be lowered into the storage overpack. Upon completion of the MPC transfer, the slings will be disconnected and the lift yoke arms reconnected to the transfer overpack. The transfer overpack will be returned to the spent-fuel cask wash area using the spent-fuel cask crane and the lift yoke.

Following completion of MPC transfer operations, the HI-STORM 100 overpack lid and lift brackets are installed. The lift brackets provide the interface between the loaded HI-STORM 100 and the spent-fuel cask transporter. The HI-STORM 100 cask is lifted by the cask transporter and moved from the transfer pad to its assigned storage location in the ISFSI following the heavy load path defined on drawing D-506467.

Spent-fuel cask handling for unloading operations involves similar cask movements and equipment with the exception that a helium cooldown system and MPC lid removal system may be required for unloading operations. The helium cooldown system and lid removal systems utilize skid mounted equipment that may be remotely located in the new fuel storage area.

The spent-fuel cask crane is prevented from moving above or into the vicinity of the spent-fuel pool by rail stops and mechanical bumpers which are permanently attached to the rails in positions as shown in figure 1.2-9. These stops limit the main hook approach to the wall, which separates the cask wash and storage areas from the transfer canal, to 6 ft 4 in. as shown on figure 1.2-1.

The spent-fuel cask crane is shared between Units 1 and 2. When the spent-fuel cask crane conveys the spent-fuel cask from the east alley way to the Unit 1 cask wash area and then returns over the route shown in figure 9.1-16, the spent-fuel cask will traverse over safety-related equipment separated by intervening floors. A similar, but opposite hand, path exists for Unit 2.

9.1.4.3 <u>Design Evaluation</u>

9.1.4.3.1 Safe Handling

The manipulator crane design includes the following provisions to ensure safe handling of fuel assemblies:

A. Bridge, trolley, and winch drives are mutually interlocked, using redundant interlocks, to prevent simultaneous operation of any two drives.

B. Bridge and trolley drive operation is prevented except when both gripper tube up-position switches are actuated.

C. An interlock is supplied which prevents the opening of a solenoid valve in the airline to the gripper except when zero suspended weight is indicated by a force gauge. As backup protection for this interlock, the mechanical weight actuated lock in the gripper prevents operation of the gripper under load even if air pressure is applied to the operating cylinder.

D. Two redundant excessive suspended weight switches open the hoist drive circuit in the up direction when the loading is in excess of 110 percent of a fuel assembly weight.

E. An interlock of the hoist drive circuit in the up direction permits the hoist to be operated only when either the open or closed indicating switch on the gripper is actuated.

The hoist gripper position interlock consists of two separate circuits that work in parallel so that one circuit must be closed for the hoist to operate. If one or both interlocking circuits fail in the closed position, an audible and visual alarm on the console is actuated.

F. An interlock of the bridge and trolley drives prevents the bridge drive from traveling beyond the edge of the core, unless the trolley is aligned with the refueling canal centerline. The trolley drive is locked out when the bridge is beyond the edge of the core.

G. Suitable restraints are provided between the bridge and trolley structures and their respective rails to prevent derailing due to the SSE. The manipulator crane is designed to prevent disengagement of a fuel assembly from the gripper under the SSE.

H. The main and auxiliary hoists are equipped with two independent braking systems. A solenoid release spring set electric brake is mounted on the motor shaft. This brake operates in the normal manner to release upon application of current to the motor and to set when current is interrupted. The second brake is a mechanically actuated load brake internal to the hoist gear box, which sets if the load starts to overload the hoist. It is necessary to apply torque from the motor to raise or lower the load. In raising, the motor cams the brake open; in lowering, the motor slips the brake allowing the load to lower. This brake actuates upon loss of torque from the motor for any reason and is not dependent on any electrical circuits. On the main hoist the motor brake is rated at 350-percent operating load and the mechanical brake at 300 percent.

The main hoist system is supplied with redundant paths of load support so that failure of any one component will not result in free fall of the fuel assembly. Two wire ropes are anchored to the winch drum and carried over independent sheaves to a load equalizing mechanism on the top of the gripper tube. In addition, supports for the sheaves and equalizing mechanism are backed up by passive restraints to pick up the load in the event of failure of this primary support. Each cable system is designed to support 13,750 lb or 27,500 lb acting together.

The design load is specified at 5400 lb; the working load of fuel assembly plus gripper is approximately 2500 lb.

The gripper itself has four fingers gripping the fuel, any two of which will support the fuel assembly weight.

The gripper and hoist system are routinely load tested to 3250 lb.

The following safety features are provided for in the fuel transfer system control circuit:

A. Transfer car operation is possible only when both upenders are in the down position as indicated by the limit switches.

B. The remote control panels have a permissive switch in the transfer car control circuit that prevents operation of the transfer car in either direction when either switch is open; i.e., with two remote control panels, one in the refueling canal and one in the spent-fuel pool, the transfer car cannot be moved until both "go" switches on the panels are closed.

C. Two redundant interlocks allow upender operation only when the transfer car is at either end of its travel.

D. Transfer car operation is possible only when the transfer tube valve position switch indicates the valve is fully open.

E. The refueling canal upender is interlocked with the manipulator crane. The upender cannot be operated unless the manipulator crane gripper tube is in the fully retracted position or the crane is over the core.

    1. The fuel transfer system upender operation is interlocked with the spent-fuel pool bridge to prohibit the lowering if the bridge is positioned over the upender area. The raising operation is not interlocked with the bridge operation.

       The fuel storage crane interlock bypass switch is provided to permit upender operation in either direction when the bridge is over the upender. The switch must be placed in the bypass position for this emergency operation.

       The bridge and hoist controls are interlocked to prevent simultaneous operation of bridge drive and hoist.

       The design load on the hoist is the weight of one fuel assembly (1500 lb) plus the weight of the tool, which gives it a total weight of approximately 2000 lb. The crane is erected in the shop and given a complete functional test that includes a load test at 125 percent of rated load. The electrical wiring meets the applicable requirements of the National Fire Code, Electrical Volume 5, Article 610.

Restraining bars are provided on each truck to prevent the bridge from overturning.

2. The new fuel elevator has an upper limit switch which enables the elevator to accept a new fuel assembly from the new fuel handling tool and a lower limit stop switch.

3. Spent-fuel handling tool. When the fingers are latched, a pin is inserted into the operating handle and prevents inadvertent actuation. The tool weighs approximately 385 lb and is shop-tested at 2500 lb.

4. New fuel assembly handling tool. When the fingers are latched, a safety screw is screwed in, preventing inadvertent actuations. The tool weighs approximately 100 lb and is shop-tested at 2500 lb.

F. All fuel handling tools and equipment handled over an open reactor vessel are designed to prevent inadvertent decoupling from crane hooks (i.e., lifting rigs are pinned to the crane hook and safety latches are provided on hooks supporting tools).

Tools required for handling internal reactor components are designed with fail-safe features that prevent disengagement of the component in the event of operating mechanism malfunction. These safety features apply to the following tools.

1. Control rod drive shaft unlatching tool. The air cylinders actuating the gripper mechanism are equipped with backup springs that close the gripper in the event of loss of air to the cylinder. Air valves are equipped with safety locking rings to prevent inadvertent actuation.

2. Guide tube cover handling tool. The mechanical gripper latching mechanism is equipped with an operating handle requiring a vertical lift, horizontal rotation, and vertical lift, in this sequence, for operation.

The following safety features are provided for the new fuel bridge crane and new fuel monorail hoist:

A. Limit switches are provided for all crane and hoist motions.

B. For hook travel, two independent limit switches are provided, one geared upper-lower limit switch and one upper block actuated limit switch.

C. All hoist motors are provided with two independent braking systems, an automatic electric brake which stops hoist motion whenever power to the hoist motor is interrupted, and a multiple disc mechanical load brake which holds the load when the motor is at rest and prevents excessive speed when lowering.

9.1.4.3.2 Spent-Fuel Cask Crane Design Evaluation

As discussed in paragraph 9.1.4.2.2, the spent-fuel cask crane is rated at 125 tons. Table 9.1-3 contains spent-fuel cask crane design data.

All mechanical and structural components of the spent-fuel cask crane are designed to have a minimum safety factor of 5, based on the ultimate strength of the materials when handling the full rated load.

The spent-fuel cask crane is Seismic Category I and is designed to withstand, without loss of load carrying function, the forces resulting from an SSE when the crane is handling the full-rated load. The crane bridge and trolley are provided with seismic upkick legs to ensure that the bridge and trolley will not derail under seismic motion. The computer program used to perform the seismic analysis assumes that the full-rated load, at both high- and low-hook elevations, is suspended from the main hook for different trolley positions across the bridge span. The results of this analysis show that the highest seismically induced vertical displacements of the load occur when the trolley is fully loaded and is located at the center of the bridge. For the trolley at the center of the bridge with full-rated load at the high-hook position (el 209.5 ft), the calculated seismically induced vertical displacement is less than 0.1 in. The calculated seismically induced vertical displacement for the load at the low hook position (el 114.5 ft) is less than 0.35 in. It must be noted that all loads supported by the spent-fuel cask crane with the trolley at the center of the span must be above the el 175 ft roof (reference figure 9.1-16). Although the figures for trolley at center and load at low hook position are a physical impossibility, they have been included here for comparison. The maximum rope force created by the above loadings gives a calculated rope safety factor of 7.36 based on 16 parts rope holding the load or 5.55 based on lead line pull.

The main hoist is provided with a dual load path through the hoist gear trains, the reeving system, and the load block. Two separate ropes (figure 9.1-11) are used to provide redundancy for the main hoist. Each 1 1/8-in. diameter, 6 x 37 carbon steel IWRC rope is anchored to the drum and the equalizer assembly and is received through the block and upper sheave assemblies, so that each rope has active parts in each quadrant of the load block about the vertical axis of the hook. If one rope loses its effectiveness, the load will be supported by the remaining rope. With all 16 parts of the main hoist rope sharing the full-rated load and based on the ultimate rope strength and the static rated load as defined by CMAA specification No. 70, the minimum static safety factor is 9.43. In the unlikely event that one cable fails and the full rated load is supported by the remaining cable, then the static safety factor as defined above is 4.72. Based on lead line pull with both cables effective, the calculated safety factor in the lead line is 7.08. Rigid inspection and checking of the cable will ensure dependable service and reliability.

A failure of one of the main hoist ropes allows the load, which was previously shared between the two ropes, to be entirely supported by the remaining redundant main hoist rope. For this sudden load transfer, both the impact force on the remaining rope and the maximum load displacement have been calculated. The highest impact force on the single remaining unbroken main hoist rope is generated when the trolley is fully loaded and is located at either end of the bridge, the main hoist is at its highest position (el 209.5 ft), and one rope fails. For the impact loading generated by a load transfer under these conditions, the safety factor in the remaining rope is 3.15 based on eight parts of rope equally sharing the load or 2.79 based on lead line pull. Under these conditions, the vertical load displacement due to dynamic cable stretch is 0.52 in. For the same trolley position but with the full rated load considered to be suspended from the main hook at the low hook position (el 114.5 ft), the vertical load displacement due to dynamic cable stretch is 2.61 in.

The equalizer assembly consists of an equalizer bar, hydraulic dampers, mechanical stops, and special retainers which ensure continued retention of the load in the event of a pivot pin failure. The main functions of the equalizer assembly are to continually adjust the hook load, so that any load under normal operation will be shared equally by the redundant reeving system and to transfer the shock of a cable break in an acceptable, safe, dynamic fashion to the remaining cable. If there is an exaggerated displacement of the equalizer assembly, such as that caused by a cable break, a limit switch system is activated and automatically terminates hoisting motion. From the time the limit switches are activated, the hoisting motion will be stopped within a maximum of 3 in. of vertical travel. The 3 in. of vertical travel includes the movement of the equalizer bar necessary to activate the limit switch system. Prior to making a lift, a visual inspection of the equalizer assembly will be made so that unnecessary power shutoffs do not occur. Rope readjustment should not be required until a new rope is installed on the crane. However, if the equalizer assembly needs adjustment during a lift, the load will be lowered and the adjustment would be made on the adjusting nut provided in the rope socket assembly on either end of the equalizing bar. If the equalizing bar reaches the limits of its travel, which should occur only in the event of a cable failure, the load can be safely lowered with the remaining cable after any debris has been cleared away.

In conformance with CMAA specification No. 70, the upper and lower block sheaves are a minimum of 24 rope diameters in size and, as shown in figure 9.1-11, are so arranged that active parts of each rope are located in each quadrant of the load block. The reeving system design is such that, with either or both parts of the rope retaining the load, the total holding force of all effective parts of rope will remain nearly coaxial and concentric with the vertical axis of the hooks. Each sheave in both the upper and lower load blocks is provided with retainers in both the vertical and horizontal planes. These retainers will capture and retain the sheave in the event of a sheave pin, bearing, or sheave failure. Failure of any of these items will not result in loss of load, and the load can be safely lowered and repairs effected.

The main load block is provided with redundant load carrying devices, a lifting eye and a sister hook. Each of these load carrying devices is designed to handle the full-rated load and to transmit it into the load block and sheaves while providing the normal load rotational capabilities found in standard crane designs. The lifting eye and sister hook may be rotated to all degrees with respect to each other, thus allowing redundant connections to the cask lifting apparatus. The vertical position of the lifting eye can be adjusted approximately 1/4 in. relative to the sister hook. This vertical adjustment can be used to tighten the fit between a special lifting device as described in paragraph 9.1.4.2.2.5 and the lifting eye and sister hook, thus minimizing any vertical displacement of the load in the event of a load transfer from one lifting element to the other. The lifting eye and each side of the sister hook are designed for the full-rated load. Each lifting device can safely support a static load of 4W, where W is the design rated load. Both lifting elements have been tested to 200 percent of design rated capacity and were given a magnetic particle inspection in accordance with ASTM-A275. The block is a safety housing type and is provided with retainers to capture the sheaves in the event of a sheave, swivel, or bearing failure. As an added conservatism in the design, the swivel has a safety factor in excess of 7.5 on ultimate strength. The loss of any of the above components will not result in the loss of load, and the load may be safely lowered to effect repairs.

If a redundant cask lifting device is used, a failure of one half of the redundant cask lifting device, or yoke, could allow the cask to free fall downward for a small distance prior to engagement of the full load carrying capacity of the intact half of the redundant lifting device. The impact force generated in the main hoist reeving system and the total cask vertical displacement have been calculated assuming a 1/2 in. cask free fall. The highest rope impact force occurs when the trolley is at either end of the bridge and is supporting the main hoist's full-rated load at the high-hook position (el 209.5 ft). For an initial cask free fall height of 1/2 in. and the crane loading conditions outlined above, the rope safety factors for the impact load are 3.18 based on 16 parts rope equally sharing the load or 2.40 based on lead line pull. The total calculated downward cask movement, including free fall due to yoke failure, is 1.1 in. For the same trolley position but with the full-rated load suspended at the low hook position (el 114.5 ft), total calculated downward cask movement is 1.64 in.

As shown on figure 9.1-16, the highest object which lies in the path of the spent-fuel cask, as it is transported from the rail car to the spent-fuel area, is the parapet at el 188 ft. Actual as-built field measurements of the parapet show that the top of the parapet ranges between a high point of el 187 ft 11 3/4 in. and a low point of el 187 ft 11 1/2 in. The design elevations of the crane runways were el 177 ft 1 1/2 in and el 154 ft 6 in. As-built field measurements have shown that the runways are essentially straight and true and are installed at el 177 ft 1 13/16 in. and el 154 ft 6 1/4 in. The actual as-built parapet and runway dimensions are such that, for a specified high-hook elevation, the actual clearance between the bottom of the load and the top of the parapet is 1/2 in. greater than design.

A review of the various failure analyses shows that the largest vertical displacement of the cask, due to a failure when the load is in the high-hook position over the parapet, is the 1.1-in. displacement due to a yoke failure. The guaranteed maximum static bridge deflection caused by the full-rated load at the center of the bridge is 1.365 in. As the trolley moves toward the end of the bridge (toward the parapet), this static deflection will decrease. Conservatively assuming the 1.365-in. maximum static deflection can occur over the parapet and adding the 1.1-in. clearance required for a yoke failure, a minimum clearance of 2.465 in. is required between the parapet and the bottom of the lifted load.

Preoperational testing at FNP will establish the actual as-built high-hook position for the spent-fuel cask crane. Using that data, all spent-fuel cask designs used at FNP will be reviewed to establish that a conservative minimum clearance of 3 in. is provided between the bottom of the cask and the top of the parapet.

The reeving system outlined above will remain essentially plumb throughout its length of travel for both normal operation and after a cable break. Based on the ultimate strength of the rope material, either rope of the redundant reeving system can safely support a load of 3W, where W is the crane's design rated load. The redundant reeving system provides the capability for careful, continued operation after the failure of any single element. This allows the cask to be set down in the cask wash area, the cask storage area, on a specified roof location, on the ground, or on the transport vehicle.

Figure 9.1-17 shows one-half of the dual-path reeving system and is marked to show the associated fleet angles. The 3.57° fleet angle occurring at the drum when the block is in the upper position will diminish rapidly as the block is lowered. It will go to 0° within the first few drum revolutions and will increase to 2.92° when the block is in the low position. The remaining fleet angles are at their maximum when the hook is in its highest position and will diminish rapidly as the main load block is lowered. For a total 2-rope reeving system, there are 26 possible sheave fleet angles.

Of these, 16 (61.5 percent) are less than 1 1/2°, 2 are allowed at 3 1/2°, and 8 (30.8 percent) exceed 1 1/2°. Of the eight fleet angles that exceed 1 1/2°, two are at 1.8°, two at 2.18°, two at 3.0°, and two at 3.72°. For many years, Whiting Corporation had an unwritten standard used in crane design which limited fleet angles to a maximum of 1 in. in 12 in. or 4° 45'. In 1955, this standard was formally published as part of the Whiting Crane Handbook and has been used as formal design criteria since that date. Whiting's history encompasses more than 10,000 cranes, and no particular problems have been reported due to the use of the 1 in. in 12 in. fleet angle standard. The cask crane fleet angles, as shown in figure 9.1-17, are well within the maximum limits allowed by the 1 in. in 12 in. criteria.

The influence of the fleet angles on rope life is measured by the amount of rope abrasion or rope wear. Abrasion occurs from rope to rope on the drum or at the point of rope entry into a sheave. Abrasive wear could occur fairly rapidly on a high speed, cyclic duty crane operating under severe loading and environmental conditions; however, on a slow speed, low cyclic duty crane, such as the spent-fuel cask crane, abrasive wear develops over a long period of time. This relatively long time period provides ample time for the planned crane inspection program to detect rope wear and to replace the rope.

Excessively large fleet angles could theoretically have an influence on the rope's ability to spool properly onto the drum or to remain seated in the sheave throat. Whiting's experience with the 1 in. in 12 in. maximum fleet angle criteria demonstrates that improper spooling due to large fleet angles has not been a problem. This experience is further enhanced by the fact that the dual-path reeving is less severe than that which can be found in conventionally reeved cranes. In the unlikely event that improper spooling did occur, the rotating equalizing bar would move, tripping the equalizing bar movement limit switch system, and deactivate the crane.

When the redundant reeving system is examined to determine whether reverse bends occur which can cause rope stress reversals, it is found that reverse bends occur only in the section of rope between the drum and the first sheave and that all other rope bends do not constitute stress reversals. This comment also applies to conventional reeving systems and points out that, in essence, there is no difference between conventional reeving and the redundant reeving when one is considering reverse bends.

There has been some concern that the location of the upper sheaves in a plane that is rotated 90° from the plane that contains the lower load block sheaves does, in fact, create reverse bends in the rope. Although cranes have been built and operated in this country with this type of sheave arrangement, the CMAA specification No. 70 and other American crane codes do not directly address the question of sheave orientation. The European crane code, Federation Europeenne de la Manutention, Rules for the Design of Hoisting Appliances, does directly address the 90° sheave orientation and clearly states that such an orientation does not constitute a reverse bend. An example of an operating crane built by Whiting and which has 90° sheave orientation is the 350-ton capacity crane owned and operated by General Electric Company in Pittsfield, Massachusetts. This crane was put in service in 1968 and since that time has been making approximately 280 lifts of 250 tons or more per year. As of February 1975, the original sheaves, drums, blocks, and wire rope were still in service and were in excellent condition with no unusual signs of wear or degradation. Because of the European crane code and the operating experience accumulated to date on both conventionally and redundantly reeved cranes built by Whiting with 90° sheave orientations, it is apparent that the 90° sheave orientation does not create reverse bends which could degrade rope strength.

Wire rope is unique in the consideration of stress reversals in that reversals will not occur if the distance between the points of tangency exceeds one or two lays of rope. Since the spent-fuel cask crane's point of tangency exceeds nine lays of rope, it can be concluded that reverse bends do not occur.

The main hoist drum, shaft, and bearings are designed to accept the forces and bending moments produced by the full-rated load. Safety hub assemblies have been provided which will prevent loss of pinion mesh and loss of load supporting capability due to failure of the main hoist drum shafts or supporting bearings. Failure of a drum shaft will result in 1/8-in. movement (drop) of the affected end of the drum; however, this 1/8-in. movement will not cause binding in the gear train which drives the other end of the drum. The main hoist drum is a single element in the lifting machinery, but a review of the drum geometry shows that its depth-to-length configuration falls far short of the requirements, as shown in "Formulas for Stress and Strain" by Roark, to consider it as a beam in bending. The stresses in the drum are generally of a localized nature and primarily are compressive. These stress conditions reduce the probability of crack propagation and resultant drum failure.

Redundancy of main hoist lifting machinery is provided by two complete gear trains located between the main hoist motor and the hoist drum. Each gear train drives a separate end of the drum and is designed to handle the most conservative of either full-rated load with a safety factor of 5, or 90 percent of yield strength, with 300-percent motor torque. Bearings have been selected in accordance with CMAA specification No. 70. A fatigue analysis was not performed on the cask crane mechanical gear trains. However, the redundant gear train design inherently has a longer fatigue life than a single-gear train design. The gear trains used in the hoisting machinery are a time proven design used on many crane applications. Each gear train contains a load brake rated in excess of 200 percent of motor torque. The load brakes of the automatic safety type set (if power should fail) and are released only during hoist operation when the system is energized. An eddy current brake is provided to prevent overspeed of the main hoist motor and to regulate lowering speed. The eddy current brakes are wired so that, if brake excitation is interrupted during hoisting motion, the hoisting motion will be automatically terminated. There are no friction devices used to transmit power through the gear train.

The design calculations show that a 92.8-hp motor was required for the main hoist service, and a 100-hp motor was provided. A means of continuously monitoring main hoist motor temperature has not been provided, but the motor is protected for thermal and current overload.

All crane controls are located in the operator's cab which is mounted on the trolley. Provisions have been made in the crane design for the possible future installation of radio control. Crane controls are Whiting full magnetic, reversing, variable speed type with spring return to center, and floating points have been provided on the first step of the bridge and trolley. Crane controls are of a fail-safe design, and all failure modes result in the termination of crane motion. Separate slow speed inching motors and controls have been provided for main hoist and trolley motion.

Limit switches, spring bumpers, and wheel stops have been provided for bridge and trolley motions. Centrifugal overspeed switches are provided to automatically terminate crane motion if the normal main hoist inching speed, main hoist normal high speed, trolley inching speed, trolley high speed, or bridge high speed are exceeded. A slack line lower limit switch, a geared type upper limit switch, and a weight type upper limit switch are provided for main hoist motion. A limit switch system is provided to sense gross movement of the equalizing bar and, in the unlikely event of a main hoist cable failure, to automatically terminate main hoist motion within 3 in. of vertical travel.

The main hoist is provided with a load sensing device which measures the load on the hook and provides digital readout in the cab. The load sensing system will automatically terminate hoisting motion in the event of main hoist overload or slack line conditions.

The main hoist drive is Whiting eddy current dynamic braking with 5-step hoisting and lowering through a 100-hp high-speed motor plus a single-speed regenerative lowering slow-speed motor with an electric clutch. In the high-speed mode, there are four points of eddy current braking in the lowering direction, and the fifth point is full-speed regenerative lowering. The first two points of high-speed hoisting use eddy current braking to provide speed control for light loads. The eddy current brake is interlocked with the hoist by a series relay, and current must be flowing in the eddy current brake circuit before power can be applied to the hoist motors and before the shoe brakes can be released. If excitation of the eddy current brake is lost on a control point which requires eddy current braking, then hoisting motors will automatically be terminated and the shoe brakes will set. There are two dc shoe brakes, and each brake has a separate rectifier panel. The dc brakes are connected to all three power phases which supply the main hoist motor in such a manner that a single phasing of the power supply will set at least one brake. The eddy current brake is energized, when the master switch is in the off position, to assist the holding brakes in stopping the load.

The main hoist slow-speed motor is energized from the same power reverser and master switch as the high-speed motor. The crane operator selects his mode of operation, either high speed or slow speed, by using a selector switch in the cab. An electric clutch is used to connect or disconnect the slow-speed motor from the hoist drive train. A series relay is used to sense that the clutch and slow-speed contactor are energized, thus ensuring that power is supplied to the slow-speed motor, before the holding brakes are released. It should be noted that the position of the holding brakes within the drive train is such that the same holding brakes are used for the slow-speed and high-speed motors. Two slow-speed overspeed switches are provided to sense overspeeding of the slow-speed motor and, in the event of overspeed, will lock out the slow-speed motor and set the holding brakes. Two high-speed overspeed switches are provided to sense overspeeding of the high-speed motor and, in the event of overspeeding, will lock out both high- and low-speed motors and set the load brakes.

The main hoist redundant reeving system is provided with a limit switch system which will, if the load is transferred excessively to one set of ropes, activate a red rotating light and automatically terminate all hoisting or lowering of the main hook.

Control circuit types of limit switches are provided to stop main hoist motion when the hook reaches a preset high-hook or low-hook condition. A power circuit type of high-hook limit switch is provided to terminate all hoisting motion, if the normal high-hook limit, as set by the control circuit switch mentioned above, is exceeded.

Overload protection for high- and low-speed main hoist motors is provided by individual thermal overload units on each power phase to provide running protection, and individual circuit breakers are provided for short-circuit protection. Operation of any of these overcurrent protection devices will open all three phases to the motor. Undervoltage protection is provided by undervoltage relays. A local cell type of weight sensing system is provided for the main hook. This weight sensing system has a digital readout provided in the cab for the crane operator. In the event that the load on the hook exceeds a preset maximum value, the hoisting motion will automatically be terminated. If the load on the hook becomes less than a preset minimum, the lowering will automatically be terminated.

The bridge is powered by two 10-hp wound rotor motors, one mounted on each end of the gantry, connected in a semisynchronized tie circuit. The rotors are tied together through a semisynchronized tie circuit. A common accelerating resistor is used with the master to provide four accelerating steps plus a shift point. Individual ac self-adjusting solenoid holding brakes are connected across each motor primary. A timer is provided which delays the starting motion of the bridge until the bridge motors have locked into synchronism. An overspeed switch is provided for bridge motion and, in the event of overspeed, shuts off power to the motors and sets the brakes. The manual rail clamps are interlocked with the bridge drive to prevent bridge motion unless the rail clamps are released. The bridge storage pins are also interlocked with the bridge drive circuitry to prevent bridge motion, unless the pins are released. A warning bell is provided on each end of the gantry to warn personnel of bridge motion whenever the bridge motors are energized. Extremes of bridge travel are prevented by control circuit limit switches. Motor overload protection is provided by thermal overloads on each phase plus a thermal magnetic circuit breaker for short-circuit protection. Undervoltage protection is provided by undervoltage relays. Timing relays are provided to prevent excessive motor torques during acceleration, and a plugging relay is provided to limit slugging torque when the drive is reversed.

The trolley drive is a Whiting five-step, magnetic type with a 5-hp, high-speed motor plus a single-speed, 1/4-hp, slow-speed motor with electric clutch. In the high-speed mode, there are four accelerating points, manually controlled, plus a shift point. A self-adjusting ac solenoid brake is controlled by a brake contactor. The slow-speed motor is energized from the same power reverser and master as the high-speed motor. The crane operator selects the mode of operation, either high speed or slow speed, by using a selector switch in the cab. A series relay is used to detect that the clutch, which connects the slow-speed motor to the trolley drive, is energized and that the slow-speed contactor is closed, thus ensuring that power is provided to the slow motor before the brake is released. An overspeed switch is provided to lock out the slow-speed motor and to set the holding brake if the low-speed motor overspeeds.

An overspeed switch is provided to shut off both the high-speed and low-speed motors and to set the holding brake if the high-speed motor overspeeds. The trolley storage lock is interconnected with the control circuitry to prevent trolley motion unless the lock is released. Extremes of trolley travel are prevented by control circuit limit switches. Thermal overloads and individual circuit breakers are provided for each bridge motor. Undervoltage protection is provided by undervoltage relays. Timing relays prevent excessive motor torques during acceleration, and plugging relays limit slugging torque when the trolley drive is reversed.

The spent-fuel cask crane was not designed to allow two-blocking. If a two-blocking test were required, block approach to the trolley underframe could result in cable and trolley frame damage. In actual operation, two-blocking is extremely unlikely due to the facts that redundant upper limit switches have been provided and that the crane operator in the trolley-mounted cab can easily verify whether the block has gone beyond its safe high-hook position.

The structural members of the spent-fuel cask crane have been fabricated in accordance with CMAA specification No. 70, and all welding was done in accordance with AWS D2.0 welding procedures. All weldments were given a visual inspection, and weld gauge sizes were checked on various welds throughout the structure.

During consideration of the necessity of performing notch toughness testing of the structural steel members of the crane, the following factors were taken into account:

A. Material types and thicknesses.

B. Loading and stress conditions of the structural members.

C. Temperature conditions during crane operation.

D. Past experience of failure of structural members of cranes attributed to brittle fracture.

The principal material used for the structural members of the crane was ASTM-A36 steel; however, ASTM-A242, a higher yield strength structural steel, was used in portions of the structure. Material thicknesses vary from 1/4 to 2 1/2 in. thick. The design conditions of the crane are based on the use of a factor of one-fifth the tensile strength or one-third the yield strength of the materials. Reference to the Pellini Fracture Analysis Diagram indicates that even below the nil ductility temperature (NDT) of the type of steels used, a preexisting defect 12 to 24 in. long is required to initiate a brittle crack when the stresses are in the range of 1/4 to 1/3 of the yield strength of the material. The lowest ambient temperature envisaged during operation of the crane is 30°F. While this temperature may be at or near the NDT of the thicker steels used, it is believed that the likelihood of having linear defects 12 to 24 in. long in the welds in the structural members is negligible. This reasoning is reinforced by the absence of failure of the brittle fracture mechanism of structural members of cranes made from these types of steels, which have been operating under temperature conditions far lower than 30°F.

In view of the considerations described above, it was decided that notch toughness testing of the structural members of the crane was not necessary.

Nondestructive examination using the visual method was performed on all welds and adjacent weld metal. Additional examinations for lamellar tearing were not performed, since lamellar tearing is a problem only on heavier weldments in joints where the principal loading is across the thickness of the base materials. None of the welds in the structural members of the crane falls into this category.

Preheat and postweld heat treatment was specified in the welding procedures used to fabricate the structural members of the crane; however, none of the welds was of sufficient size or thickness to necessitate the application of postweld heat treatment.

As outlined above, the spent-fuel cask crane has been designed with redundant load carrying devices, redundant main hoist ropes, redundant main hoist gear trains and load brakes between the main hoist motor and main drum, safety guards on the upper sheaves, safety housing main load block, and safety hub assemblies on the main hoist drum. A single failure of any element in the spent-fuel cask crane load carrying path will not cause a loss of load carrying ability.

9.1.4.3.3 Spent-Fuel Cask Crane Component Failure Evaluation

All members in the load carrying path of the spent-fuel cask crane have been designed with a minimum safety factor of 5 based on the 125-ton design rated load. In many instances, the calculated safety factors exceed the design safety value of 5.

Within the load carrying path, redundant protection is provided or a means is provided to capture and retain a failed component, thus preventing an uncontrolled descent of the load.

In the event of a failure of any load path component, plant personnel will make a careful investigation to determine the exact nature and extent of the malfunction. After inspection of the malfunction and the clearing away of any debris, careful continued operation may progress, at least in the lowering mode. If the failed component cannot be cleared or if it has jammed the load carrying path, four 35-ton come-alongs would be used to support the load from the bridge girders to allow clearing of the load carrying path. When the load carrying path is unjammed, it may be used to lower the load.

Beginning with the load block, the sister hook and lifting eye are redundant components, and the loss of either element will not result in loss of load carrying ability or render the crane inoperable. The load path continues upward through the hooks, hook nuts, and hook bearings and into the swivel, which is the next possible failure point. Although the swivel is a single element, it has been designed with a safety factor in excess of 7.5, which decreases the probability of a failure. In the event of a swivel failure, a loss of load would not occur since the block is provided with retainers to capture and hold the swivel. A swivel failure would require that raising motion be suspended, but the load could be safely lowered to a laydown area.

From the swivel, the load path continues into the block sheaves. The load block has been provided with retainers which will capture and retain a sheave in the event of a bearing or sheave failure. The failure of any given sheave will not result in a loss of load, and the system could continue to operate on the remaining reeving path.

The load path continues upward into the two cables of the redundant reeving system. The failure of either of the two cables will not result in loss of load or crane operability. In the event of a cable break, the displacement of the equalizing bar will trip the limit switch system and terminate hoisting motion. The broken cable should be cleared from the remaining reeving system prior to restoration of operation.

The next elements in the load path are the upper sheave nest, equalizer system, and load cells. A failure of the sheaves or sheave pins will not result in loss of load, in that retainers have been provided to capture the sheaves. In any event, operation could continue on the remaining rope and reeving system.

Failure of a load cell will not result in loss of load, and retainers have been provided to capture the affected parts. Failure of an equalizing bar pin will not result in loss of load, and crane operation could continue on the remaining reeving system.

The load carrying path continues upward to the drum, which is a single element within the design. A complete failure in the center of the drum would render the crane inoperable and would result in loss of load. A review of the drum dimensions show that the drum depth-to-length ratio falls far short of that necessary to consider it as a beam in bending. The loading on the drum is generally localized in nature and is compressive. As an added design conservatism, the drum has been designed with a safety factor in excess of 8.

Attached to and supporting either end of the drum are the other single elements of the design, the drum shafts. Retainers have been provided to hold the drum in the event of a drum shaft or bearing failure. The design of the retention system is such that operation could continue at least in the lowering direction.

The load path continues through the two gear trains, holding brakes, and input shafts to the main hoist motor. Each gear train is designed to handle safely the entire 125-ton load, and a failure in either gear train will not render the system inoperable. The two holding brakes provided are of a fail-safe design and automatically set upon a loss of power supply. Should the main hoist motor fail, the separate inching motor and drive could be used as an emergency means of operation. In the event that a mechanical or electrical failure renders the main hoist inoperable, the load could be lowered by manual operation of the load brakes. The lowering speed would be measured by a tachometer mounted on the motor shaft.

If an electrical or mechanical failure has rendered the trolley inoperable, the trolley could be moved by first releasing the brake and then pulling the trolley across the bridge with a come-along. The bridge could be moved in a similar manner. For short movements, the bridge or trolley could be moved by means of a hand- or air-operated wrench on the motor shaft. If a wheel bearing or axle has failed, it may be necessary to grease the rail in order to slide the broken wheel.

The crane controls and protective devices have been designed so that the load is left in a safe position in the event of a power failure or an electrical failure on the crane.

A loss of power supply to, or the failure of, the main hoist motor will result in termination of hoisting motion and setting of the holding brakes. If the main hoist motor has failed, the separate main hoist inching motor may be used to move the load. The two main hoist holding brakes are designed to set on a loss of power supply and are so wired that one phasing of the power supply to the main hoist motor will set at least one holding brake. If excitation to the eddy current brake is lost on a control point which requires the eddy current brake, the power supply to the main hoist motor will be automatically blocked and further hoisting using the main hoist motor will be prevented. However, if the eddy current brake is inoperative, the main hoist inching drive may be used to position the load, since eddy current braking is not required for the inching drive.

Redundant main hoist upper limit switches, one power type and one control type, have been provided. If the control type of limit switch, which is the first limit switch seen by the load block, fails, the second, or power type of limit switch, will stop main hoist motion. If both limit switches were to fail, continued upward motion of the load block will result in overloading, which will cause the load sensing system automatically to terminate the hoisting motion. It should be noted that with the crane's operator located in the cab, any violation of the upper limit switch setpoints is very unlikely. The main hoist is provided with a control type of lower limit switch to prevent slack line conditions. If this switch fails to function properly and lowering is continued, the weight sensing system will automatically stop hoist motion when the load on the hook becomes less than a preset minimum.

All motors have been provided with overspeed protection so that the overspeed will automatically cause the power supply to the motor to be terminated. All motors have undervoltage protection and both thermal and current overload protection, so that abnormalities will be sensed and motor operation automatically prevented.

The trolley drive has both a normal (or high-speed) motor and an inching (or slow-speed) motor. If the normal drive motor fails, the inching motor may be used to permit safe positioning of the load. Both bridge and trolley brakes are of a fail-safe design and will set on loss of power. Excesses of both bridge and trolley travel are prevented by redundant limit switches which are wired into separate portions of the control circuitry. Bumpers and wheel stops have been provided as an additional method of stopping bridge or trolley travel, if both redundant limit switches were to fail.

In the event that a contactor welds shut or a master switch becomes inoperative, the crane operator can activate the emergency stop button, which is on the control panel in the cab, and stop all crane motion. Opening the main disconnector will interrupt all power to the crane, stop all motions, and set all brakes.

9.1.4.3.4 Seismic Considerations

The fuel handling equipment is designed to withstand the forces of an operating basis earthquake (OBE) and an SSE. For normal conditions plus OBE loadings, the resulting stresses are limited to allowable working stresses as defined in the ASME Boiler and Pressure Vessel Code, Section III, Appendix XVII, for normal and upset conditions. For normal conditions plus SSE loadings, the stresses are limited to within the allowable values given by Subsection NA 2110 for critical parts of the equipment which are required to maintain the capability of the equipment to perform its safety function. Permanent deformation is allowed for the loading combination, which includes the SSE to the extent that there is no loss of safety function.

The seismic design categories for all fuel handling system components are in table 3.2-1.

9.1.4.3.5 Containment Pressure Boundary Integrity

The fuel transfer tube that connects the refueling canal (inside the reactor containment) and the spent-fuel pool (outside the containment) is closed on the refueling canal side by a blind flange at all times, except during refueling operations. Two seals are located around the periphery of the blind flange with leak-check provisions between them.

9.1.4.3.6 Radiation Shielding

During all phases of spent-fuel transfer, the gamma dose rate from the spent-fuel assembly is a small fraction of 2.5 mR/h at the surface of the water. This is accomplished by maintaining at least 9 ft of water above the active fuel in the assembly during all handling operations.

The two cranes used to lift spent-fuel assemblies are the refueling machine and the spent-fuel pool bridge hoist. The refueling machine contains positive stops that assure that the above shielding depth is maintained. The hoist on the spent-fuel pool bridge moves spent-fuel assemblies with a long-handled tool. Hoist travel and tool length likewise assure that the above shielding depth is maintained.

9.1.4.4 Tests and Inspections

As part of normal plant operations, the fuel handling equipment is inspected for operating conditions prior to each refueling operation. During the operational testing of this equipment, procedures are followed that will affirm the correct performance of the fuel handling system interlocks. Inspections credited for license renewal are summarized in the Overhead and Refueling Crane Inspection Program description in chapter 18, subsection 18.2.6.

The spent-fuel cask crane's redundant main hoist ropes shall be inspected and, if required, replaced to ensure compliance with ANSI B30.2.0 and with Whiting Corporation's recommendations. The inspection requirements of ANSI B30.2.0 and of Whiting are as follows:

A. ANSI B30.2.0

All running ropes which are in continuous service should be visually inspected once each working day. For continuous long term periods of operation, a thorough inspection of all ropes shall be made at least once a month and a full written, dated, and signed report outlining rope condition should be kept on file. Any signs of rope deterioration which could cause a loss of rope strength, such as those outlined below, shall be noted in the report and a determination made as to whether further use of the rope would create a safety hazard.

1. Reduction of rope diameter below the nominal diameter due to loss of core support, internal or external corrosion, or wear of outside wires.

2. A number of broken outside wires and the distribution of the broken wires.

3. Excessive wear of outside wires.

4. Corroded or broken wires at the rope end connections.

5. Corroded, cracked, bent, worn, or improper rope end connections.

6. Severe rope kinking, crushing, cutting, or unstranding.

B. Whiting Corporation

Replacement of the rope should be considered when any of the following conditions are present:

1. Twelve randomly distributed broken wires in one lay or four broken wires in one strand of one rope lay.

2. Wear of one-third the original diameter of outside individual wire.

3. Kinking, crushing, or any other damage resulting in distortion of the rope.

4. Evidence of any type of heat damage.

5. Reductions from nominal diameter of more than 1/16 in. for a rope diameter from 7/8 to 1 1/8 in., inclusive.

A cold-proof test will be performed to demonstrate that the spent-fuel cask crane can safely and adequately handle 125-ton full-rated capacity loads at minimum environmental temperatures. The cold-proof test shall be a 125-percent load test, conducted in accordance with ANSI B30.2.0 requirements, and performed at the available minimum site environmental temperature. After satisfactorily passing the cold-proof test, the environmental temperature at which the test was performed shall be the minimum temperature at which full capacity (125 tons) loads may be handled. If the environmental temperature drops below the previously established cold-proof temperature and if crane operation is required during such a period, then a new cold-proof test may be performed to establish a new cold-proof temperature or the crane may be temporarily derated until the temperature equals or exceeds the previously established cold-proof temperature.

Temporary derating of crane capacity shall be 1.5 percent of full-rated capacity per degree F temperature difference between the established cold-proof temperature and the colder existing temperature. The results of a cold-proof test shall be valid for a subsequent 40-month period and for all cask handling series started or performed during the 40-month interval. No new cask handling series will be initiated after expiration of the 40-month interval since performance of the last valid cold-proof test, until a new cold-proof test is performed.

The crane structure has been thoroughly examined to determine the calculated stress levels which exist in critical weldments when the crane is handling the full-rated load. For full-load operation, no critical load carrying welds are stressed in excess of two-thirds of their AWS allowable stress values. These weld stress values, which are well within AWS allowable values and far below yield, in conjunction with the successful performance of a cold-proof test, are sufficient to demonstrate the structural adequacy of the crane.

9.1.5 SPENT-FUEL LEAK DETECTION

Spent-fuel leak detection may be utilized either in the reactor containment building or fuel storage area when deemed necessary to provide an additional means of fuel performance evaluation.

9.1.5.1 Design Bases

The spent-fuel leak detection equipment is designed to provide for safe handling of spent-fuel assemblies while the equipment is being utilized.

One method of leak detection is ultrasonic testing (UT). In this case, an inspection device is temporarily mounted on top of a spent-fuel rack above empty cells. Then, the assembly to be tested is moved by the fuel handling equipment into the inspection device where individual rods are examined using a UT probe. The control and monitoring equipment associated with the inspection device is temporarily located on the spent-fuel pool deck for analyzing test results. The following design bases apply:

A. Movement of UT test equipment over the spent-fuel pool for temporary installation is bounded by the analysis of a dropped fuel assembly. Engineering analysis also verified that a drop of a typical UT inspection device weighing as much as 1470 lb (dry weight) from a height of up to 27 ft above the spent-fuel racks would not result in fuel rack damage which could lead to a spent-fuel pool criticality event. Use of spent-fuel handling tool restricts the height to which a fuel assembly may be lifted within the analyzed limit.

B. Structural analysis of the spent-fuel racks has shown that the temporary mounting of UT inspection equipment above the empty spent-fuel cells will not affect the structural integrity of the racks, even during a postulated seismic event.

C. Adherence to test procedure instructions assures no damage to either the test equipment or the fuel assembly during movement of fuel into the test equipment.

D. UT equipment does not enclose the fuel assembly and, therefore, does not affect assembly cooling.

Another method of leak detection involves placing the fuel assembly to be tested into an underwater inspection container. The following design bases apply to this leak detection method:

A. Leak detection equipment is designed to prevent damage to fuel assemblies during testing.

B. Fuel assembly overheating during leak testing while in underwater containers is prevented by 1) maintaining the water level at least 6 in. above the top of the fuel, and 2) inspection container overtemperature monitor.

C. Fuel assemblies may be removed from the underwater containers upon loss of system air or power supply.

Another method of leak detection involves the use of the in-mast sipping system. The refueling machine in Farley Unit 1 and Unit 2 has been equipped with in-mast sipping system hardware for detection of leaking fuel assemblies during normal core off-load operations. The in-mast sipping system injects air at the bottom of the mast, samples the fission gasses at the top of the mast, and directs the sample to a radiation monitoring system.

The following design bases apply to the use of the in-mast sipping system.

A. During fuel sipping, fuel assemblies are raised from the lower core plate to the refueling elevation above the core outlet but remain immersed in borated water. The minimum separation distance specified in the fuel handling guidelines will be maintained during fuel handling. The addition of air into the fuel assembly increases the void fraction in the water. An increase in void fraction will decrease the reactivity of the fuel assembly. The refueling water contains sufficient boron to provide a large amount of negative reactivity. The boron concentration during refueling is maintained within the limit specified in Farley Units 1 and 2 Technical Specifications.

B. The modifications to the refueling machine mast assembly are designed such that the safe fuel handling design function of the mast is not adversely affected. The modifications do not interfere with existing plant structures such as the reactor flange, reactor internals, cavity seal ring, or any fuel assemblies or components. The air nozzle manifold at the base of the fixed mast does not intrude into the envelope required for safe handling of the fuel assemblies. Use of the in-mast sipping system does not require any change to the fuel, reactor internals, or reactor vessel.

C. The process of in-mast sipping requires that air be delivered to the bottom of the fuel assembly by means of a stainless steel tube mounted to the side of the refueling machine mast. During this process, the supply tube is filled with air.

   Radiation shielding from the fuel assemblies is provided by a minimum of 10 ft of water cover above the fuel assembly. When sipping is not taking place, the tube fills with water because it is immersed in the refueling cavity water. During the sipping operation, radiation streaming through the air-filled tube was found to be negligible.

D. A seismic evaluation has been performed to demonstrate that with the addition of the in-mast sipping system, the refueling machine remains structurally adequate to withstand the seismic and dead weight loads. The seismic evaluation accounts for the weight of permanently installed hardware as well as the weight of temporary analysis equipment used during in-mast sipping.

E. An analysis of the thermal hydraulic effects on the fuel assemblies being leak-tested shows that there is no boiling in the fuel assembly as it is suspended in the enclosed refueling mast during the test. The sparging of air on the fuel assembly will not have an adverse effect during the leak test sequence.

9.1.5.2 System Description

The UT method of spent-fuel leak detection utilizes an inspection device containing a UT probe and visual monitor. The device with seismic supports is temporarily mounted on top of a spent-fuel rack above empty cells. The UT control and monitoring equipment is temporarily located on the spent-fuel pool deck.

Once the fuel assembly to be inspected is positioned in the inspection device, the probe begins scanning the rows of rods within the assembly, sending a signal to the monitoring equipment where it is recorded and displayed. The amplitude of this signal will indicate if any rods in the assembly are leaking. Operation of all leak detection equipment is consistent with the ALARA practices of Regulatory Guide 8.8.

The other spent-fuel leak detection method utilizes one or more systems, each having an underwater sipping container with associated controls and necessary utility connections, piping, and cabling for supply of required demineralized water, compressed air, electrical power, etc. The inspection container(s) is placed in a self supporting rack which may be placed in the refueling canal or the cask storage pit. A typical inspection cycle for a fuel assembly consists of assembly insertion into the underwater container, closing and sealing the container lid, flushing the container, sampling the radioactivity, opening the container lid, and removing the assembly.

The equipment may utilize a radiation detector as an integral part of the system or depend on water samples being taken from the container and analyzed for radioactivity to monitor radiation levels while the equipment is being utilized.

Fuel sipping is the process of identifying leaking fuel assemblies by detecting gaseous or solid fission products that have escaped from breached irradiated fuel rods. The in-mast sipping system provides a means of performing online, qualitative leak testing of fuel assemblies in the refueling mast during normal fuel handling operations. In-mast sipping system hardware is permanently installed on the refueling machine mast and includes an air collection manifold at the top of the mast, an air supply manifold at the bottom of the mast, an air supply tube and supports connected to the supply manifold, and covers installed on the mast to prevent crossflow and loss of air. Temporary equipment used to measure the quantity and type of gas and particulate material leaking from a fuel assembly is installed on the trolley of the refueling machine for the duration of the offload/leak detection activity, and is removed prior to resuming plant operation.

During fuel sipping, fuel assemblies are raised from the lower core plate to the refueling elevation but remain immersed in borated water. Air is delivered to the bottom of the fuel assembly by means of a stainless steel tube mounted to the side of the refueling machine mast. After the air rises through the fuel assembly, it is collected by the manifold at the top of the mast, where air samples are directed to a radiation monitoring system.

9.1.5.3 Safety Evaluation

The UT leak testing method does not create a criticality event because all the fuel assemblies are in spent-fuel racks except for the assembly being tested. These racks are already analyzed to ensure proper spacing to maintain $K_{eff} \leq 0.95$. The movement of the test assembly into the test device is conducted by a detailed procedure which assures that fuel assemblies will not be damaged.

The movement and setup of UT test equipment does not involve any unique plant configurations which could place the plant in an unanalyzed condition. The only potential accidents associated with the setup and movement of the fuel testing equipment involve physical damage to the spent-fuel racks, a scenario which has been previously considered.

The UT inspection device is seismically supported to prevent uncontrolled movement on top of the spent-fuel rack during a safe shutdown earthquake.

Pertaining to the alternate detection method, a criticality evaluation was performed. Operation of this equipment with fuel in the self supporting rack will not create the possibility of an accidental criticality. Since a 12-in. separation distance between the fuel assemblies is maintained and the separating material(s) is not air (i.e., steel and water), there are no criticality safety issues. Provided that the procedure takes place in refueling water, which typically contains greater than 1800-ppm soluble boron and the fuel enrichments are $\leq$ 5.0 w/o U-235, the 0.95 K_{eff} limit will not be exceeded.

The underwater inspection container(s) is designed to withstand overtemperature or overpressure events such that no fuel assembly damage will occur.

The in-mast sipping system is mounted on the refueling machine mast, which is designated Non-Nuclear Safety (NNS). The design of NNS equipment must resist failure that could prevent Safety Class equipment from performing its design function. In the case of the refueling machine, the potential adverse condition would be improper movement and handling of fuel. During fuel sipping, fuel assemblies are raised from the lower core plate to the refueling elevation but remain immersed in borated water. The minimum separation distance specified in the fuel handling guidelines will be maintained during fuel handling. The addition of air into the fuel assembly increases the void fraction in the water. An increase in void fraction will decrease the reactivity of the fuel assembly. The refueling water contains sufficient boron to provide a large amount of negative reactivity. The boron concentration is maintained within the limit specified in Farley Units 1 and 2 Technical Specifications.

The modifications to the refueling machine mast assembly are designed such that the safe fuel handling design function of the mast is not adversely affected. The refueling machines are structurally adequate to withstand seismic and dead weight loads, including the permanent in-mast sipping hardware and temporary equipment used during fuel sipping.

Analysis shows that there is no boiling in the fuel assembly as it is suspended in the enclosed refueling mast during the test. The sparging of air on the fuel assembly will not have an adverse effect.

9.1.6 DRY SPENT-FUEL STORAGE

In order to provide additional temporary spent-fuel storage capacity, Southern Nuclear Operating Company (SNC) elected to utilize the general license issued for storage of spent fuel in an ISFSI in accordance with the provisions of 10 CFR 72, subpart K. The general license is limited to storage of spent fuel which SNC is authorized to possess at the site under the specific license for the site and is restricted to use of spent-fuel casks that are approved by the NRC.

The ISFSI is located south of the diesel generator building inside the protected area as described in paragraph 1.2.10.4. The ISFSI consists of 5 concrete storage pads, each designed to accommodate 12 spent-fuel casks and support equipment. A list of acceptable spent-fuel casks for use at FNP and an evaluation for each is provided in the FNP ISFSI 10 CFR 72.212 Report.

9.1.6.1 Spent-Fuel Cask

SNC selected the Holtec HI-STORM 100 cask system for storage of spent fuel in the FNP ISFSI. The NRC reviewed and approved the HI-STORM 100 design and issued Certificate of Compliance (CoC) 1014 for the HI-STORM 100 cask system in accordance with the requirements of 10 CFR 72.

The HI-STORM 100 spent-fuel cask system is part of the Holtec family of MPC-based spent-fuel cask designs and utilizes the same MPC as the HI-STAR 100 storage and transport cask system. As such, the MPC for the HI-STORM 100 cask system is certified for both storage and transportation of spent fuel in accordance with 10 CFR 72 and 10 CFR 71, respectively. Each MPC is designed for storage of up to 32 spent-fuel assemblies. The HI-STORM 100 overpack is a steel and concrete cylindrical vessel that is certified for storage only in accordance with 10 CFR 72. The HI-STORM 100 overpack provides missile protection and shielding for the MPC during storage operations. MPCs used in conjunction with the HI-STORM 100 cask system will be transferred to HI-STAR 100 overpacks prior to shipment.

The HI-STORM 100 overpack is not designed to be placed in the spent-fuel pool during MPC loading operations but, instead, utilizes the HI-TRAC 125 transfer overpack for movement of the MPC to and from the spent-fuel pool. The HI-TRAC 125 transfer overpack is equipped with a removable bottom lid to facilitate MPC transfer from the HI-TRAC 125 transfer overpack to the HI-STORM 100 storage overpack.

The HI-TRAC 125 transfer overpack is equipped with two single-load path lifting trunnions which are rated for a combined maximum load of 125 tons. The lifting trunnions for the HI-TRAC 125 transfer overpack are designed, fabricated, tested, and inspected in accordance with ANSI N14.6 and NUREG-0612 and have a minimum safety factor of:

- Six times the weight of the cask to the yield strength of the materials of construction; and

- Ten times the weight of the cask to the ultimate strength of the materials of construction.

During MPC transfer operation, MPC lift cleats will be attached to the MPC lid for use with slings attached to the spent-fuel cask crane. The MPC lift cleats are designed, fabricated, tested, and inspected in accordance with ANSI N14.6(3) and NUREG-0612(6) and have a minimum safety factor of:

- Six times the weight of the cask to the yield strength of the materials of construction; and

- Ten times the weight of the cask to the ultimate strength of the materials of construction.

A detailed description of the HI-STORM 100 cask system is provided in Holtec Report HI-2002444, Final Safety Analysis Report (FSAR) for the Holtec HI-STORM 100 Cask System.(7)

9.1.6.2 Spent-Fuel Cask Lift Yoke

The spent-fuel cask lift yoke is a single-load path special lift device designed in accordance with ANSI N14.6(3) and NUREG-0612(4), and is rated for a maximum load of 125 tons. The spent-fuel cask lift yoke is used for:

- Vertical lifting of the HI-TRAC 125 transfer overpack.

- Remote underwater installation of the MPC lid.

- MPC transfer between the HI-TRAC 125 transfer overpack and the HI-STORM 100 storage overpack.

The spent-fuel cask lift yoke consists of two parallel strongbacks that sandwich the crane hook and connect to the spent-fuel cask crane sister hook and lifting eye. The spent-fuel cask lift yoke has two closed-loop arms that fit over the HI-TRAC 125 overpack trunnions located near the top of the HI-TRAC 125. Each lift yoke arm transmits the load to the strongbacks via a pair of actuation plates that allow the lift yoke arms to open and close. The actuation plates are attached to the strongbacks via solid steel via a slotted keyway. The spent-fuel cask lift yoke is designed such that it does not contain any load bearing welds. The weight of the HI-TRAC 125 overpack is transferred from the trunnions to the sister hook and lifting eye of the FNP cask crane as follows:

- Lift yoke arms.
- Actuation plates.
- Actuation plate pins.
- Strongbacks.
- Main lift yoke pins.

In addition to use for movement of the HI-TRAC 125 overpack, the spent-fuel cask lift yoke is equipped with four clevises which provide load attachment points designed in accordance with NUREG-0612 to support the weight of a loaded MPC during transfer operations. The weight of MPC is transferred from the MPC lift cleats to the sister hook and lifting eye of the spent-fuel cask crane as follows:

- MPC slings.
- Lift yoke clevises.
- Strongback.
- Main lift yoke pins.

Two spacers are used to position each pair of actuation plates. Four strongback spacers are provided to position the strongbacks.

The load bearing members of the spent-fuel cask lift yoke are designed to lift six times the rated load of the lift yoke which is 125 tons without generating a shear stress or maximum tensile stress at any point in the device in excess of the corresponding minimum yield strength of their materials of construction. Additionally, the spent-fuel cask lift yoke load bearing members are designed to lift ten times the rated load of the lift yoke without exceeding the ultimate strength of the materials of construction.

Structural fabrication of the spent-fuel cask lift yoke is performed to standards consistent with the service intended. All material is certified as to chemical and physical properties. In addition, all stressed members are inspected for internal defects.

Prior to first use, the spent-fuel cask lift yoke was subjected to a load test equal to 300% of the maximum load to which the device will be subjected. Following the load test, critical areas of the lift yoke were subjected to nondestructive testing in accordance with section 5.5 of ANSI N14.6.

For continued qualification of the spent-fuel cask lift yoke, the yoke is tested annually by one of the following methods:

A. After sustaining the test load equal to 300% of the maximum load to which the device is to be subjected for a period ≥10 min., critical areas are visually inspected for defects, and all components are inspected for permanent deformation.

B. If surface cleanliness and conditions permit, dimensional testing, visual inspection, and nondestructive testing are performed in accordance with section 5.5 of ANSI N14.6.

In addition, nonload bearing parts are tested annually according to written procedures to verify that they perform their design function. If the spent-fuel cask lift yoke has not been used for a period greater than 1 year, the above testing is not required. However, testing of the lift yoke as described above is required prior to subsequent use.

The HI-TRAC 125 overpack is equipped with lifting trunnions that are designed to mate with the elliptical loops of the lift arms of the spent-fuel cask lift yoke. Design of the HI-TRAC 125 overpack lift trunnions and the spent-fuel cask lift yoke with increased factors of safety described above in conjunction with use of the single-failure proof spent-fuel cask crane, precludes the accidental drop of a spent-fuel cask.

9.1.7 HEAVY LOADS

As per NUREG-0612, a heavy load is defined as any load, carried in a given area after a plant becomes operational, that weighs more than the combined weight of a single spent-fuel assembly and its associated handling tool for the specific plant in question.

9.1.7.1 Heavy Loads Safe Loads Path

A load path is a predetermined path and height above the floor a load must follow while suspended. A safe load path is a load path, including height above the floor, which has been identified by procedure or evaluated and determined that the load may travel near or over spent fuel, reactor core, or safe shutdown systems or components without affecting the ability to bring the plant to cold shutdown conditions and/or provide continued decay heat removal following the dropping of a heavy load. This includes the effect on equipment on floors below but does not consider single failure.

Safe load paths for heavy loads inside containment have been developed and incorporated into appropriate plant procedures. The safe load paths are documented in the following drawings; Unit 1: D-175511, D-175512, D-175513, D-175515, Sheet 1 and 2; Unit 2: D-205512, D-205513, D-205514, D-205516 Sheet 1 and 2. The safe loads paths are controlled by procedures. In the auxiliary building, only the demineralizer hatch monorail hoist is capable of carrying a heavy load over safe shutdown equipment. However, safe load paths are not considered necessary in this instance since the load pathway is restricted by the monorail track and safe shutdown functions will not be lost. For the spent-fuel bridge crane, the only heavy load handled is the spent-fuel pool transfer slot gate. Movement of this heavy load is directed by use of administrative controls which prevent movement of the transfer slot gate into a position where it may cause damage to spent fuel. Note that the spent-fuel cask crane is prevented from traveling over the spent-fuel pool by mechanical stops; therefore, it cannot carry heavy loads over spent fuel.

Safe load paths inside containment are clearly marked on drawings contained in procedures. Development of safe load paths in the containment and, as defined by procedure, over the spent pool area are consistent with NUREG-0612. In lieu of permanent floor markings, these procedures were modified to require the use of a signalman to direct movements of the polar crane. Use of a signalman is consistent with NUREG-0612 by providing the crane operator with suitable visual aids to ensure that load paths are followed. Also, deviations from safe load paths must be reviewed and approved.

The diesel generator building contains several hoists systems which are used to assist in lifting and rigging. However, these hoists are used for maintenance only when the diesel is not on standby. In addition, the diesels are separated by concrete walls, making it physically impossible for a hoist to drop a load on an adjacent diesel generator. The equipment separation in the diesel building assures that no heavy load can damage two trains of safety-related equipment. The Franklin Research Institute stated in its diesel generator hoist evaluation that "suitable precautions should be added to any existing procedures identifying the heavy loads and their respective handling systems or the Licensee should physically mark the component with a suitable warning." The Farley Nuclear Plant diesel generator hoists are mounted upon a monorail system. The placement of the fixed rails precludes the lifting of a heavy load over more than one train of safety-related equipment. Since the monorails are limited to only one path, identification of heavy loads is unnecessary.

A heavy load drop from the new fuel monorail hoist, new fuel bridge crane, spent-fuel cask crane, tendon surveillance areas, or the various maintenance monorail hoists would have no consequence to safe shutdown or decay heat removal equipment due to physical separation.

External portable maintenance cranes could drop loads onto the river water intake structure, service water intake structure, and outside buried service water piping. However, due to system redundancy, a heavy load drop on these structures or piping will not preclude a safe shutdown.

There are numerous cranes that were excluded from satisfying the criteria of the general guidelines of NUREG-0612. These handling systems included the diesel generator building hoists and external portable maintenance cranes, which are used for outside areas.

9.1.7.2 Load Handling Procedures

Load handling operations for heavy loads that are or could be handled over or in proximity to irradiated fuel or safe shutdown equipment are controlled by written procedures. As a minimum, procedures will be used for handling loads with spent-fuel cask bridge crane and polar crane, and for those loads listed in table 3-1 of NUREG-0612.

The slings used for rigging loads at FNP are installed and used per ANSI B30.9-1971. The ANSI standard was developed for lifting loads under dynamic conditions. Load limits for slings under ANSI B30.9-1971 are mass handling limits, not dead weight stress limits. The dynamic component is included in the standard through the application of significant safety factors. It is, therefore, inappropriate to apply additional dynamic stress criteria in the sling selection progress. The slings are developed for the load, not for a specific crane; therefore, the markings on slings contain load limits rather than a designation of the specific cranes for which they are used.

Safe load paths for the polar crane inside containment are defined in drawings and are contained in procedures. Components shall not go outside the designated boundaries as shown in the drawings. Deviations from defined safe load paths must be reviewed and approved.

9.1.7.3 Implementation of Standards

9.1.7.3.1 Training of Crane Operators

Crane operators involved in the lifting of heavy loads at FNP have been trained in accordance with ANSI B30.2-1976. The crane operator’s training includes specific instructions concerning the handling of loads within the defined safe load pathways inside containment. The requirements of ANSI B30.2-1976, Chapter 2-3 have been incorporated into the crane operator training, qualification, and conduct procedures.

9.1.7.3.2 Special Lifting Devices

There are three special lifting devices which carry heavy loads: reactor vessel head lifting device, core upper internals lifting device, and the spent-fuel cask lifting device. For Unit 2, a design review was performed which determined that both the reactor vessel head and core upper internals lifting devices were designed with safety factors of 5 for lifting loads under dynamic conditions. This factor provides confidence that the heavy load will not be dropped on the core. For Unit 1, the reactor vessel head lifting device was also designed with a safety factor of 5 for lifting loads under dynamic conditions. This factor provides confidence that the heavy load will not be dropped on the core. The replacement reactor internals lifting device for Unit 1 is designed to the allowable stress limits of ANSI N14.6 for non-single failure proof conditions (6*S<yield, 10*S<ultimate) for the upper internals lift. For the lower internals lift for Unit 1, the allowable stress limits of ANSI N14.6 without non-single failure proof penalty (3*S<yield, 5*S<ultimate) are met. The spent-fuel cask lift yoke is a single-load path special device designed in accordance with ANSI N14.6 and NUREG–0612, and is rated for a maximum load of 125 tons (the spent-fuel cask crane is discussed in FSAR subsection 9.1.6 and paragraphs 9.1.4.2.2.5, 9.1.7.4.3, and 9.1.7.4.4).

Following design and fabrication, a 125% load test was performed for each of the Unit 2 reactor vessel head and internals lifting devices. The devices were then visually inspected and found free of faults or distortion, and critical weld areas were nondestructively examined with satisfactory results. The Unit 1 reactor vessel head lifting device has been load tested to 113% of rated load. Load testing of the assembled Unit 1 internals lifting device was conducted in the factory before shipment. The Unit 1 internals lifting device was load tested to 150% of the dry weight required for the upper internals lifting arrangement and 125% of the dry weight required for the lower internals lifting arrangement. Proof of workmanship for Unit 1 devices is also provided based on welding which was performed in accordance with ASME Section XI, followed by appropriate nondestructive examination (NDE), dimensional tolerances, materials and heat treatment records, and radiography and ultrasonic test results which were also reviewed and verified to be in accordance with design specifications.

To establish continuing reliability of these devices, a program in which critical load bearing welds of these devices are nondestructively examined on a systematic basis are consistent with the Inservice Inspection Program (i.e., all welds examined over a 10-year period).

The cask lifting device will meet the requirements of ANSI N14.6-1978 as clarified by NUREG-0612.

9.1.7.3.3 Lifting Devices (Not Specifically Designed)

The slings used for rigging loads at FNP are based on the criteria established by NUREG-0612 and ANSI B30.9-1971 with the clarification that the dynamic loadings associated with the acceleration and deceleration of the load (based on maximum hoisting speeds) are a small fraction of the static load and that revising the selection criteria stated in ANSI B30.9-1971 to accommodate them would not have a substantial effect on the load handling reliability. The slings will be marked in accordance with ANSI B30.9-1971 requirements. Load handling procedures will specify the slings and other devices used with the slings to make a complete lifting device that is required for handling the load.

9.1.7.3.4 Slings

The slings used for rigging loads at FNP are installed and used per ANSI B30.9-1971. The ANSI standard was developed for lifting loads under dynamic conditions. Load limits for slings under ANSI B30.9-1971 are mass handling limits, not dead weight stress limits. The dynamic component is included in the standard through the application of significant safety factors. It is, therefore, inappropriate to apply additional dynamic stress criteria in the sling selection progress. The slings are developed for the load, not for a specific crane; therefore, the markings on slings contain load limits rather than a designation of the specific cranes for which they are used.

The hook speed for the load hook of the polar crane is 5 ft/min maximum. The cask crane's maximum load hook speed is 8 ft/min. These speeds are very slow and will not impart major dynamic loads on the rigging. The cask crane, which is a single-leg gantry running on one ground level track and one track on the auxiliary building roof, is not used to handle heavy loads over the spent-fuel area. The maximum hook speed for the spent-fuel bridge crane, which services the spent-fuel area, is 7 ft/min. This also constitutes a very slow hook speed.

Specific consideration of dynamic effects of loads is included in the sling's design safety factors and further consideration is not necessary. It is noted, however, that actual dynamic conditions experienced by these slings are not expected to be a consequence due to the relatively slow speeds of the cranes of concern. Therefore, no slings are marked for use on specific cranes.

9.1.7.3.5 Design, Inspection, Testing, and Maintenance of Cranes

Crane design, inspection, testing, and maintenance requirements have been revised to incorporate the requirements of Chapter 2-2 of ANSI B30.2-1976, except for certain test frequencies which cannot be met due to inaccessibility as noted in NUREG–0612.

9.1.7.4 <u>Load Drop Analysis</u>

For reactor vessel head lifts and spent-fuel cask lifts over the spent-fuel pool, a load drop analysis is provided that bounds the planned lifts with respect to load weight, load height, and medium present under the load, and is implemented into procedures for moving the load that reflect the applicable safety basis.

The following are the cranes at FNP which handle heavy loads in the vicinity of irradiated fuel or safe shutdown equipment and are, therefore, subject to NUREG-0612 criteria:

- Containment polar crane (bridge and jib).
- Demineralizer hatch monorail hoist.
- Spent-fuel pool bridge crane.
- Spent-fuel cask crane.

The following cranes were excluded from satisfying the guidelines of NUREG-0612 because no safety-related equipment is located at any elevation beneath the cranes:

- Drumming station bridge crane.
- Auxiliary building equipment hatch monorail hoist.
- Decontamination room monorail hoist.
- Blowdown drum storage area bridge crane

The following cranes were excluded from satisfying the guidelines of NUREG-0612 because these hoists are used solely for maintenance performed on the nonstandby diesel. In addition, the diesels are physically separated by concrete walls, precluding a load drop on an adjacent diesel generator:

- Diesel generator building hoists.

The following cranes were excluded from satisfying the guidelines of NUREG-0612 on the basis that load drops from these cranes onto the river water or service water structures or the outside buried service water piping would not preclude safe shutdown due to system redundancy:

- External portable maintenance cranes.

The following cranes were excluded from satisfying the guidelines of NUREG-0612 because sufficient physical separation exists between load impact points and safety-related components so that a load drop would be of no consequence to safe shutdown:

- New fuel monorail hoist.
- New fuel bridge crane.
- Tendon surveillance area hoists.
- Hot machine shop bridge crane.
- Filter hatch monorail hoist.
- Various maintenance monorail hoists.

9.1.7.4.1 Containment Polar Crane and Jib Cranes

The Unit 1 and 2 polar crane (bridge and jib) are the only cranes capable of carrying heavy loads over the reactor vessel or the rod cluster control (RCC) change fixture. The jib cranes have been administratively prevented from lifting heavy loads over the reactor vessel while the vessel head is removed. The only other cranes inside containment capable of carrying heavy loads over the reactor vessel have the power removed, in accordance with maintenance procedures, while the reactor vessel head is removed and fuel is in the reactor vessel. Since these cranes cannot lift heavy loads when the vessel head is removed with fuel in the reactor vessel, a signalman is not needed for these cranes. The provision for a signalman in accordance with the NRC guidance obviates the need for marking safe load paths on the floor. This approach is consistent with the guidelines provided by the NRC.

The prevention of heavy load drop onto the RCC change fixture is accomplished by administrative controls. The upper internals and the reactor vessel head will have been placed in the storage area before the fixture is put in use. The RCP motor, polar crane load block, and upper internals will be prevented from traveling over the RCC changing fixture during refueling since the fixture is an exclusion area and, as such, is not part of the safe load path for the polar crane.

The reactor vessel is also protected by administrative controls. When the reactor vessel missile shield/head is in place, the vessel is protected from potential heavy loads (reactor coolant pump

(RCP) motor or crane load block) by the shield. The reactor vessel head and internals will only be removed from the reactor vessel during refueling. Prior to removal of the internals, however, the reactor vessel missile shield/head must be removed and placed in the laydown area.

In the event a new fuel assembly in the RCC changing fixture is crushed, K_{eff} will remain < 0.95 since the refueling canal will be filled with 2000-ppm borated water during refueling.
For FNP, it has been determined that for a new core in 2000-ppm borated water with control rods fully inserted, the K_{eff} is ≤ 0.9. Per NUREG-0612 section 4.2.2, the maximum reactivity insertion due to crushing is 0.05. Therefore, the maximum achievable K_{eff} would be < 0.95.

In the containment building only the polar crane can carry heavy loads over safety-related equipment. The safety-related equipment in the containment which could be impacted by a heavy load drop is the pressurizer, steam generators, and the RCP. During modes 5 and 6, the pressurizer and steam generators are not required to maintain a safe shutdown condition. Therefore, no heavy load drops onto the pressurizer or steam generators during modes 5 and 6 have been considered. However, the RCP motor could be dropped onto the RCP while performing maintenance. For modes 1 through 4, the polar crane load block is the only heavy load which need to be considered since no other heavy loads in containment would be moved during these modes.

An analysis was performed for handling of heavy loads in containment. This analysis demonstrated that the moving of reactor head, reactor upper internals, reactor vessel missile shield (removed with the reactor head in 2003), RCPs, RCP motor, reactor vessel missile shield, RCP hatch covers, and polar crane load block within the established safe load paths was acceptable and would neither impact any safety function of safety-related equipment and components nor the structural integrity of affected structures. It has also been verified that the buckling load on affected fuel assemblies would not exceed design limits and that there will be no consequential damage to the structural integrity of the reactor vessel, reactor vessel nozzles, or RCS loop piping. Therefore, core cooling capability and the integrity of the fuel cladding will be maintained. Thus, the inadvertent drop of the reactor vessel head assembly at FNP would have no impact on the health or safety of the public.

In 2003, the reactor head was replaced on each unit with a new head package that included the missile shield. This increased the weight of the head, and the analysis was revised to show that the effects of dropping the heavier reactor head in the area defined as a safe load path were acceptable.

In 2008, a reactor vessel head drop evaluation was performed for Farley Units 1 and 2 in accordance with the Nuclear Energy guidelines of NEI 08-05, "Industry Initiative on Control of Heavy Loads." The reactor vessel head drop analysis was performed using the methodology and assumptions of WCAP-9198, Revision 1, "Reactor Vessel Head Drop Analyses." The conservative analysis assumed a drop height of 40 ft through air with a reactor head assembly weight of 270,000 lb. This evaluation was performed for the purpose of increasing the conservatism relative to the effect of the impact loads on the reactor vessel nozzles. The analysis concluded that the Farley Units 1 and 2 reactor vessel and reactor vessel nozzles are acceptable for the postulated 40-ft closure head assembly drop in air. The fuel assemblies will retain their structural integrity. In addition, a global assessment of the loop piping and the RV support structures below the nozzles confirmed that the structures are not susceptible to collapse or catastrophic failure and will retain the ability to cool the core.

An analysis was performed for the polar crane lifting the 9000-lb polar crane load block over the pressurizer and steam generators. A missile grating covers the pressurizer cavity to protect other equipment from possible pressurizer missiles. It has been shown by analysis that the missile shield will also withstand a free-fall drop of the polar crane load block. Therefore, the pressurizer is protected from a heavy load drop during modes 1 through 4. A heavy load drop on one steam generator would not prevent the plant from coming to a safe shutdown condition since the system could still perform the safety function.

An analysis was performed for the polar crane lifting the 77,300-lb RCP motors over the RCPs. It has been determined that a drop of the RCP motor block onto the RCP will not compromise the integrity of the RCS loop pressure boundary.

During refueling operations a postulated heavy load drop over the open reactor coolant pump (RCP) hatches would compromise RCS integrity. In MODES 5 and 6, with irradiated fuel in the reactor vessel, this would result in a LOCA. While the containment and core responses to this LOCA would be bounded by the analyses in subsections 6.2.1, 15.3.1, and 15.4.1, recovery and repairs would be greatly complicated by the presence of irradiated fuel in the reactor vessel. In MODE 6 this LOCA could uncover in-transit fuel in the refueling cavity or in the spent fuel pool (SFP) via the open transfer tube and SFP weir gate.

To preclude this occurrence, the following restrictions shall be placed on crane operations above the open RCP hatches in MODES 5 and 6 when there is irradiated fuel in the reactor vessel AND in MODE 6 while irradiated fuel is being moved inside containment or in the spent fuel pool with the transfer tube isolation valve and SFP weir gate open:

- Polar crane main or auxiliary hoist operation shall be prohibited.
- Temporary maintenance hoist operations shall be permissible, subject to administrative controls that will prevent RCS, CVCS, or RHR piping damage resulting from a load drop.

An analysis was performed for heavy load drops on the containment operating deck. The following assumptions were used in this calculation:

A. RCP motor drop onto the containment operating deck.

1. Weight of motor used was 80,000 lb.

2. Drop heights used were 5 ft onto the operating deck concrete, 38 ft into the transfer canal, and 60 ft onto the base slab (if dropped over grating, the motor would penetrate and go to the base slab).

3. These drops were determined to be acceptable

B. Reactor head drop onto the operating deck.

1. Weight of the reactor head is 265,000 lb (HAUP).

2. Safe load path is from reactor to head stand.

3. Drop height considered was 103 in. from el 155 ft or 72.5 in. from the top of the head stand.

4. Results of a drop from this height are structurally acceptable.

C. Polar crane block and hook assembly.

1. Weight of block and hook is 9,000 lb.

2. Drop onto concrete is acceptable from up to 60 ft.

3. Drop onto grating may not be acceptable from 60 ft. Grating may be perforated but slab below is acceptable. Grating would be acceptable from 10 ft 9.75 in.

D. Upper internals.

1. Upper internals weight is 140,000 lb.

2. Drop height of 3 ft 6 in. is assumed onto the operating deck.

3. Drop height of 26 ft 0 in. (additional) is assumed into the reactor cavity.

4. Cavity is assumed filled with water.

5. Drop is acceptable but will perforate cavity liner.

E. Reactor missile shield.

1. Missile shield is now part of the reactor head package.

F. Summary.

1. Load paths provided have been evaluated.

2. None of the objects will perforate the operating deck, although cracking and deflection may occur.

3. Any items dropped into the reactor cavity or transfer canal will perforate the liner but none will perforate the slab.

4. If either the load block or RCP motor is dropped onto the grating, the grating may not stop the object; however, the object will not perforate the slab below the grating.

9.1.7.4.2 Auxiliary Building

An analysis was completed for heavy load drops inside the auxiliary building onto the floor slabs. Section 2.0 describes the cranes subject to the NUREG-0612 criteria; therefore, some of the cranes listed in the analysis are not considered in the scope of NUREG-0612. The following assumptions are used in the calculation:

- Areas serviced by the following cranes/hoists are reviewed and evaluated.
  - New fuel bridge crane.
  - Drumming station bridge crane.
  - Auxiliary building equipment hatch bridge crane.
  - Decon room monorail hoist.
  - Hot machine shop bridge crane.
  - Demineralizer hatch monorail hoist.
  - Filter hatch monorail hoist.
  - Blowdown drum storage area bridge crane.
- All areas were reviewed for maximum drop height.
- Maximum drop heights for various loads are as follows:
  - 20,000 lb 2 ft 1 in.
  - 16,000 lb 2 ft 8 in.
  - 12,000 lb 3 ft 10 in.
  - 8,000 lb 6 ft 5 in.
  - 4,000 lb 21 ft 2 in.
- All drop heights prevent penetration through the floor.

For the auxiliary building, the demineralizer hatch monorail hoist could drop the demineralizer hatch onto portions of the boric acid transfer system. This is the only crane/load combination in the auxiliary building which could impact safety-related equipment.

An analysis was performed for the demineralizer hatch monorail hoist lifting the 18,250-lb demineralizer hatch over the boric acid transfer pump. Dropping the demineralizer hatch onto the boric acid transfer pump and its associated piping could at most disable one train of the system, thereby leaving one train to perform the required safety function.

9.1.7.4.3 Spent-Fuel Pool Bridge Crane

The only heavy load handled by the spent-fuel pool bridge crane is the spent-fuel pool transfer slot gate, which weighs approximately 3600 lb. Administrative controls prevent the transfer slot gate from being carried over the fuel assemblies in the spent-fuel pool. At the beginning of fuel transfer operations, the transfer slot gate is moved from its normal position directly to its stored position, which is located immediately adjacent to its normal position. This procedure is reversed at the end of fuel transfer operations. However, the racks are designed to withstand a gate drop from 10 ¼ in. The drop height is limited by a physical limitation in lifting capability. Additionally, administrative controls prevent handling equipment capable of carrying loads with a higher impact energy from transporting these loads over the fuel storage area.

9.1.7.4.4 Spent-Fuel Cask Crane

The cask crane is a single-leg gantry running on one ground level track and one track on the auxiliary building roof. The cask crane is not used to handle heavy loads over the spent fuel. The lifting device for a cask is special lifting device and meets the requirements of ANSI N14.6 as clarified by NUREG–0612. This provides assurance that a drop will not occur and, therefore, a drop analysis has not been performed.

To load a dry storage cask, the multipurpose canister (MPC) is placed in the cask loading pit next to the spent-fuel pool. During the process of loading the spent-fuel cask, after the fuel is in the MPC, the lid for the MPC is placed on the MPC using the cask crane. This is the only time that the spent-fuel cask crane can lift a heavy load over spent fuel. Movement of a heavy load over the MPC is acceptable based on the following:

- The single-failure proof spent-fuel cask crane being used in accordance with NUREG-0612.

- The special lift devices being designed in accordance with ANSI N14.6-1978.

- Slings meeting the requirements of ANSI B30.9-1971.

For general loads which the spent-fuel cask crane may move, an analysis was performed. A safety evaluation was performed to determine the consequences of a dropped load when using the spent-fuel cask crane main hoist without a single-failure proof lifting device (i.e., using slings) or the auxiliary hoist in order to ensure compliance with NUREG-0612. Curves of object weight verses drop height (figures 9.1-18 and 9.1-19) were developed and safe load path exclusion areas were identified for the auxiliary building roof. No heavy loads should be transferred over hatch “C” of the auxiliary building roof (figure 9.1-20).

- Roof hatch A is at column lines U to R and 11 to 14.
- Roof hatch B is at column lines N to R and 7 to 9.5.
- Roof hatch C is at column line P to U and 5 to 6.

A cask drop or tip into the spent-fuel pool is also prevented by permanently installed rail stops and mechanical bumpers which prohibit cask crane travel over or into the vicinity of the spent-fuel pool.

REFERENCES

1. (Deleted)

2. Letter from B. L. Siegel (Nuclear Regulatory Commission) to D. N. Morey (Southern Nuclear Operating Company), dated July 31, 1996, regarding exemption from the requirements of 10 CFR 70.24, “Criticality Accident Requirements,” for the Joseph M. Farley Nuclear Plant, Units 1 and 2.

3. ANSI-N14.6, American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More for Nuclear Material, February 15, 1978.

4. ANSI-B30.2, Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder), January 1, 1976.

5. ANSI-B30.9, Safety Standards for Cranes, Derricks, Hoists, Hooks, Jacks, and Slings, January 1, 1971.

6. NUREG-0612, Control of Heavy Loads at Nuclear Power Plants, Resolution of Generic Technical Activity A-36, Nuclear Regulatory Commission, July 1980.

7. HI-2002444, Final Safety Analysis Report (FSAR) for the Holtec International Storage and Transfer Operation Reinforced Module Cask System (HI-STORM 100 Cask System), NRC Docket 72-1014.

8. NEI 08-05, “Industry Initiative on Control of Heavy Loads,” July 2008.

TABLE 9.1-1 (SHEET 1 OF 2)

SPENT-FUEL POOL COOLING AND CLEANUP SYSTEM DESIGN PARAMETERS

Spent-fuel pool storage capacity	
Number of cores	8.96
Number of assemblies	1407
Nominal boron concentration of the spent-fuel pool water (ppm)	2300
Cooling characteristics	
Partial-core offload refueling case	50% of core plus 8.90 previous cores
Time after reactor shutdown to start core offload (h)	150
Number of cooling trains operable	1
Heat exchanger tube plugging level (%)	10
Decay heat production (Btu/h)	22.1×10^6
Spent-fuel pool water temperature with one cooling train in operation (°F)	≤ 150
Beginning of Cycle (BOC) Emergency full-core offload case	100% of core plus 8.40 previous cores
Time after reactor shutdown to start core offload (h)	150
Number of cooling trains operable	1
Heat exchanger tube plugging level (%)	10
Decay heat production (Btu/h)	37.0×10^6

TABLE 9.1-1 (SHEET 2 OF 2)

Spent-fuel pool water temperature with one cooling train in operation (°F)	≤ 180
End of cycle (EOC) full-core offload case cores	100% of core plus 8.40 previous cores
Time after reactor shutdown to start core offload (h)	150
Decay heat production (Btu/h)	36.5×10^6
Spent-fuel pool water temperatures with one cooling train in operation (°F)	≤ 180
"Best Estimate" full-core offload case	100% of core plus 8.40 previous cores
Time after reactor shutdown to start core offload (h)	150
Decay heat production (Btu/h)	30.3×10^6
Spent-fuel pool water temperature with one cooling train in operation (°F)	≤ 180[a]

a. Bounded by the emergency full-core offload case.

TABLE 9.1-2 (SHEET 1 OF 3)

SPENT-FUEL POOL COOLING AND CLEANUP SYSTEM DESIGN AND OPERATING PARAMETERS

Spent-fuel pool pump	
Number	2
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	2300
Total developed head (ft)	125
Material	Stainless steel
Spent-fuel skimmer pump	
Number	1
Design pressure (psig)	50
Design temperature (°F)	200
Design flow (gal/min)	100
Total developed head (ft)	50
Material	Stainless steel
Refueling water purification pump	
Number	1
Design pressure (psig)	200
Design temperature (°F)	200
Design flow (gal/min)	110
Total developed head (ft)	250
Material	Stainless steel

TABLE 9.1-2 (SHEET 2 OF 3)

Spent-fuel heat exchanger

Number	2	
Design heat transfer (Btu/h)	9.12×10^{6}[(a)]	
	Shell	Tube
Design pressure (psig)	150	150
Design temperature (°F)	200	200
Design flow (lb/h)	1.49×10^{6}	1.14×10^{6}
Inlet temperature (°F)	105	120
Outlet temperature (°F)	111.1	112
Fluid circulated	Component cooling water	Spent fuel pool water
Material	Carbon steel	Stainless steel

Spent-fuel pool demineralizer

Number	1
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	
Unit 1	109 max (27 min)
Unit 2	120 max (27 min)
Resin volume (ft^3)	30
Material	Austenitic stainless steel

Spent-fuel pool filter

Number	1
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	150
Filtration requirement	Greater than or equal to 98-percent retention of particles above 5 μ when the Cuno filter is used and Greater than or equal to 98-percent retention of particles above 6 μ when using the ultipor GF Plus filter
Material for vessel	Austenitic stainless steel

TABLE 9.1-2 (SHEET 3 OF 3)

Spent-fuel pool skimmer filter	
Number	1
Design pressure (psig)	250
Design temperature (°F)	200
Design flow (gal/min)	150
Filtration requirement	98-percent retention of particles above 5 µ when the Cuno filter is used and 98-percent retention of particles above 6 µ when using the ultipor GF Plus filter
Material for vessel	Austenitic stainless steel
Spent-fuel pool strainer	
Number	2
Rated flow (gal/min)	2300
Perforation (in.)	1/8
Material	Austenitic stainless steel
Spent-fuel pool skimmers	
Number	2
Design flow (gal/min)	50
Piping and valves	
Design pressure (psig)	150
Design temperature (°F)	200
Material	Stainless steel

a. Design value. Operational values are given in table 9.2-7.

TABLE 9.1-3 (SHEET 1 OF 2)

SPENT-FUEL CASK CRANE DATA

Bridge

Runway length of Units 1 and 2 (ft)	280
Bridge weight (lb)	330,000
Bridge span (ft-in.)	91-0
Bridge motor	2 at 10 hp
Number of wheels	8 (30-in.)
Maximum speed (ft/min)	30
Minimum incremental distance (in.)	0.10
Type of controls	Rev. plugging
Type of brake	1 (8-in. ac)
Type of bumper	Spring

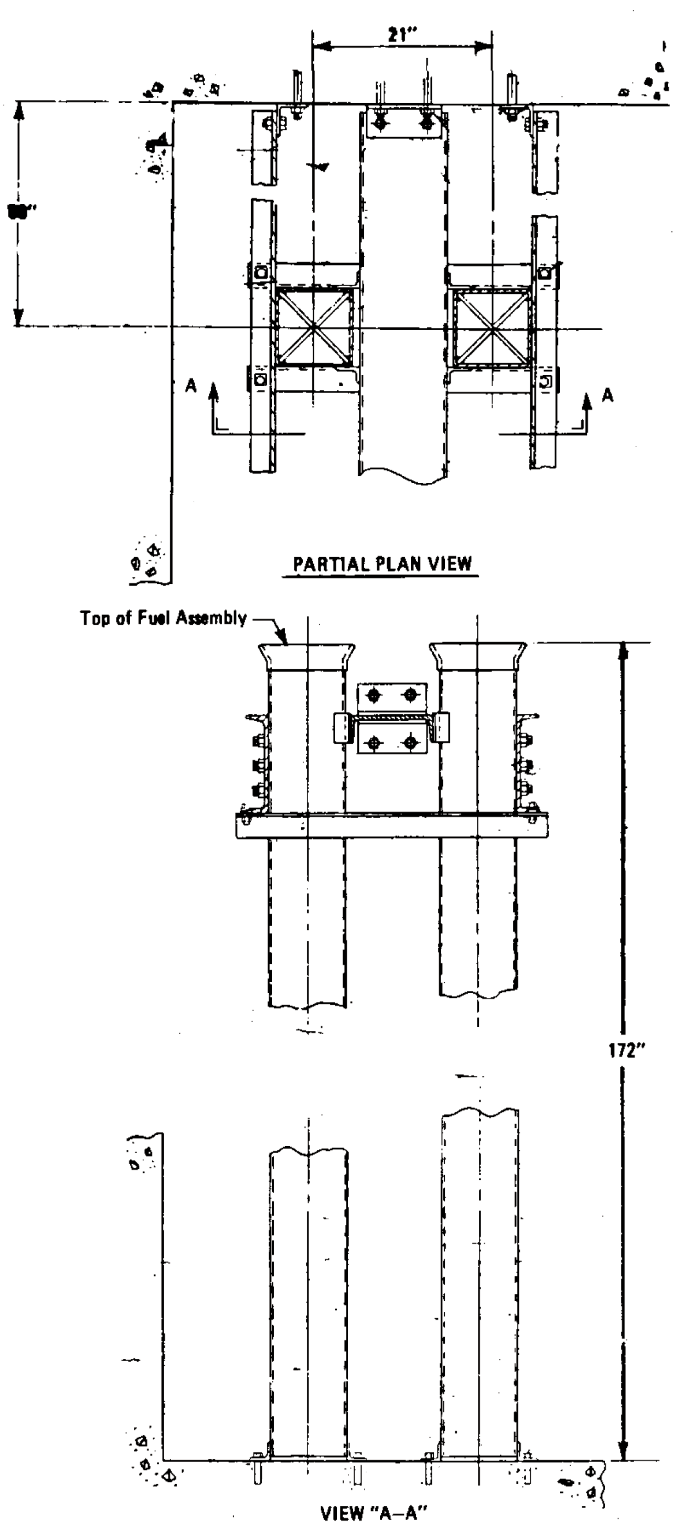
Trolley

Length of trolley travel (ft)	76
Trolley weight (lb)	140,000
Trolley gauge (ft-in.)	19-6
Trolley drive motor	5 hp
Number of wheels	4 (24-in.)
Maximum speed (ft/min)	25
Inching speed (in./min)	10
Type of controls	Rev. plugging
Type of brake	1 (6-in. ac)
Type of bumper	Spring

TABLE 9.1-3 (SHEET 2 OF 2)

Hoists

	Main	Auxiliary
Lifting capacity (tons)	125	15
Drum diameter (in.)	49.25	17
Rope type	6 x 37 IWRC	6 x 37 IWRC
Rope size diameter (in.)	1 1/8	1/2
Sheave diameter or pitch circle diameter (in.)	27,30,33	12
Hook material	ASTM-235	AISI-4130
Hook test load (tons)	250	30
Maximum hook travel (ft-in.)	96-6	102-0
Maximum hoist speed (ft/min)	8	30
Line speed (ft/min)	64	-
Inching speed (in./min)	6	-
Minimum incremental distance (in.)	0.03	0.1
Number parts rope	16	8
Block clearance in highest position (ft-in.)	7-6	11-5
Type load brake	Eddy current	Eddy current
Type holding brake	2 (16-in.)	2 (13-in.)
Type controls	Magnetic	Magnetic



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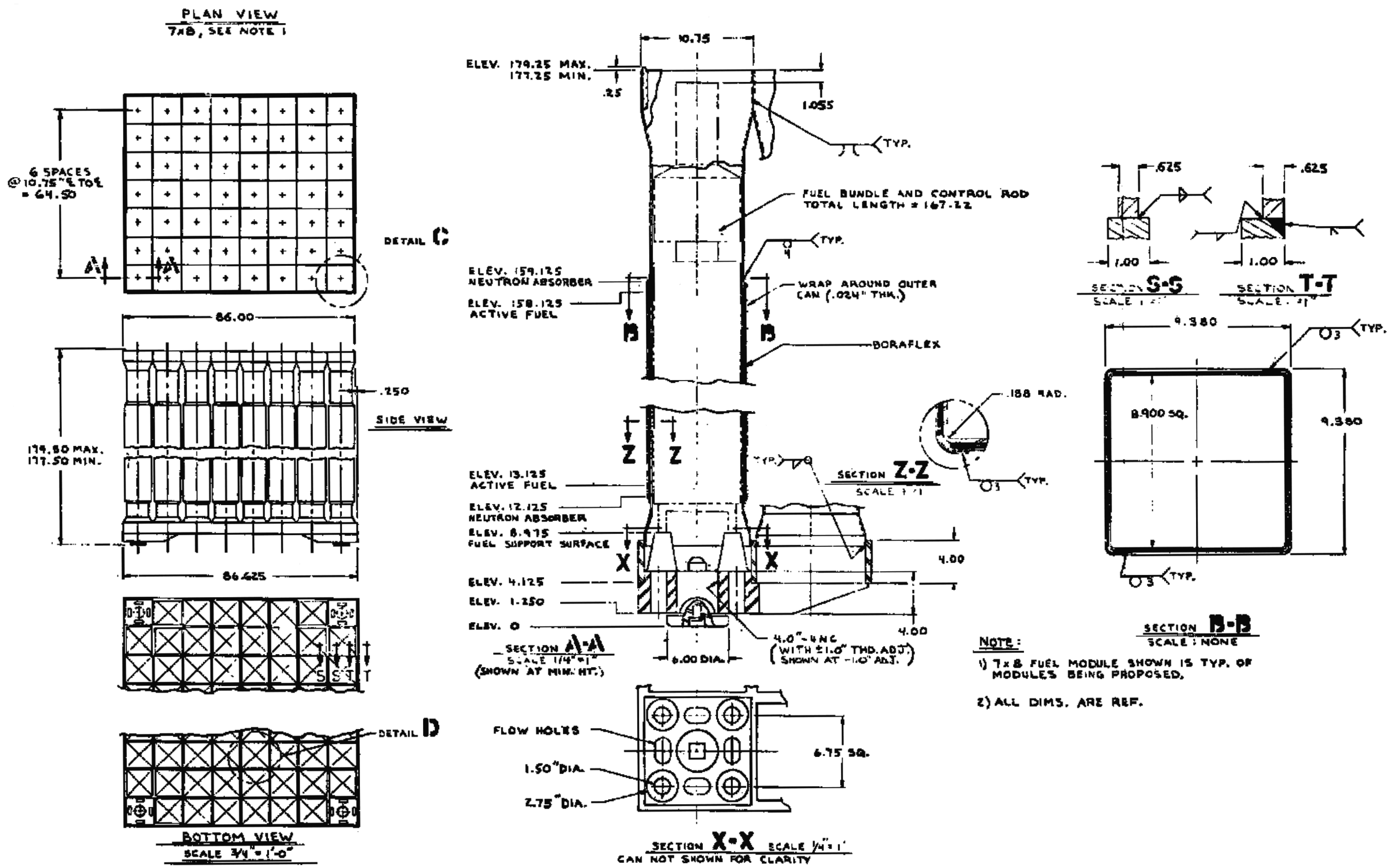
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	NEW FUEL STORAGE RACKS
		FIGURE 9.1-1



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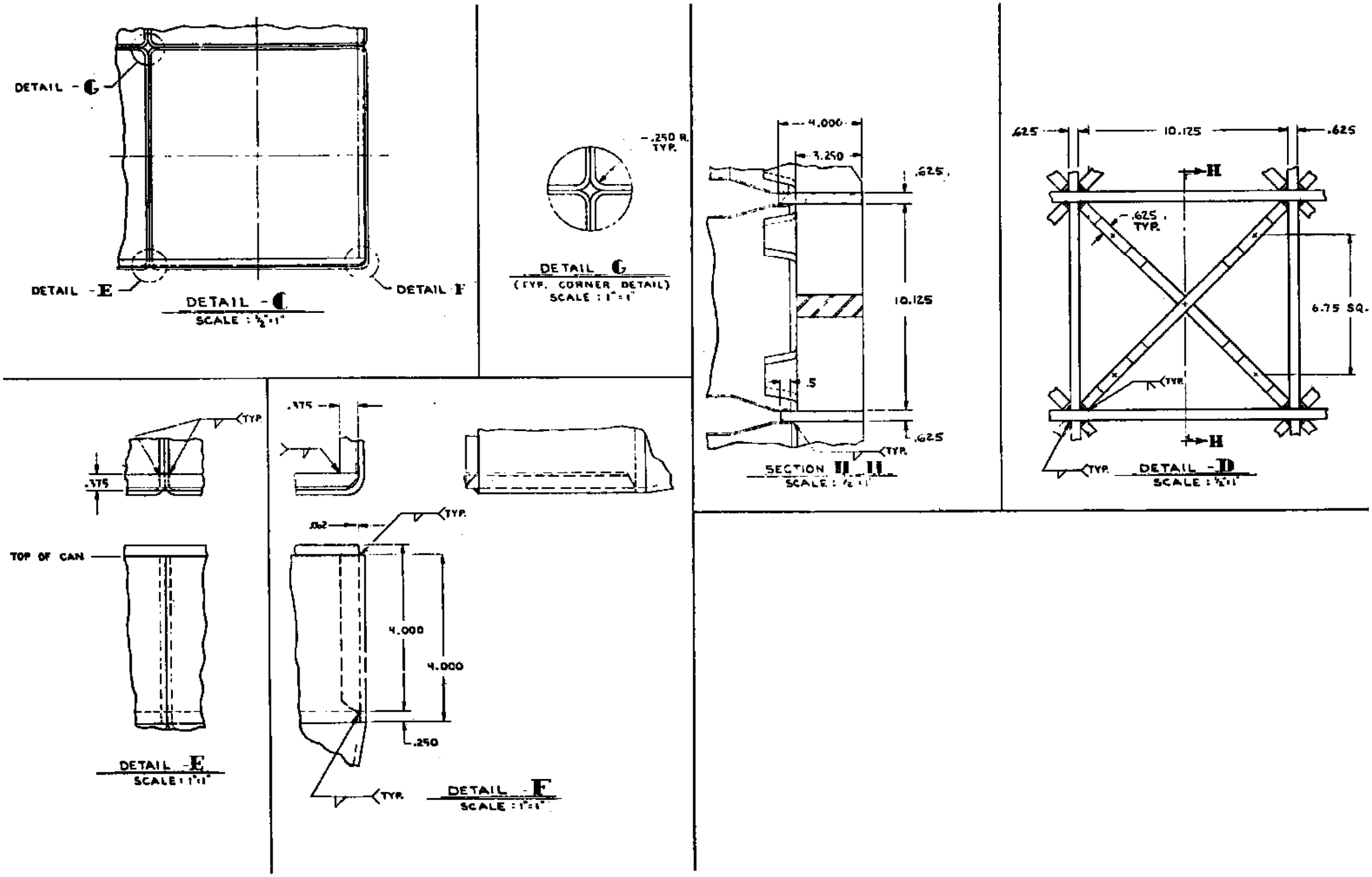
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL RACK MODULE

FIGURE 9.1-2 (SHEET 1 OF 2)



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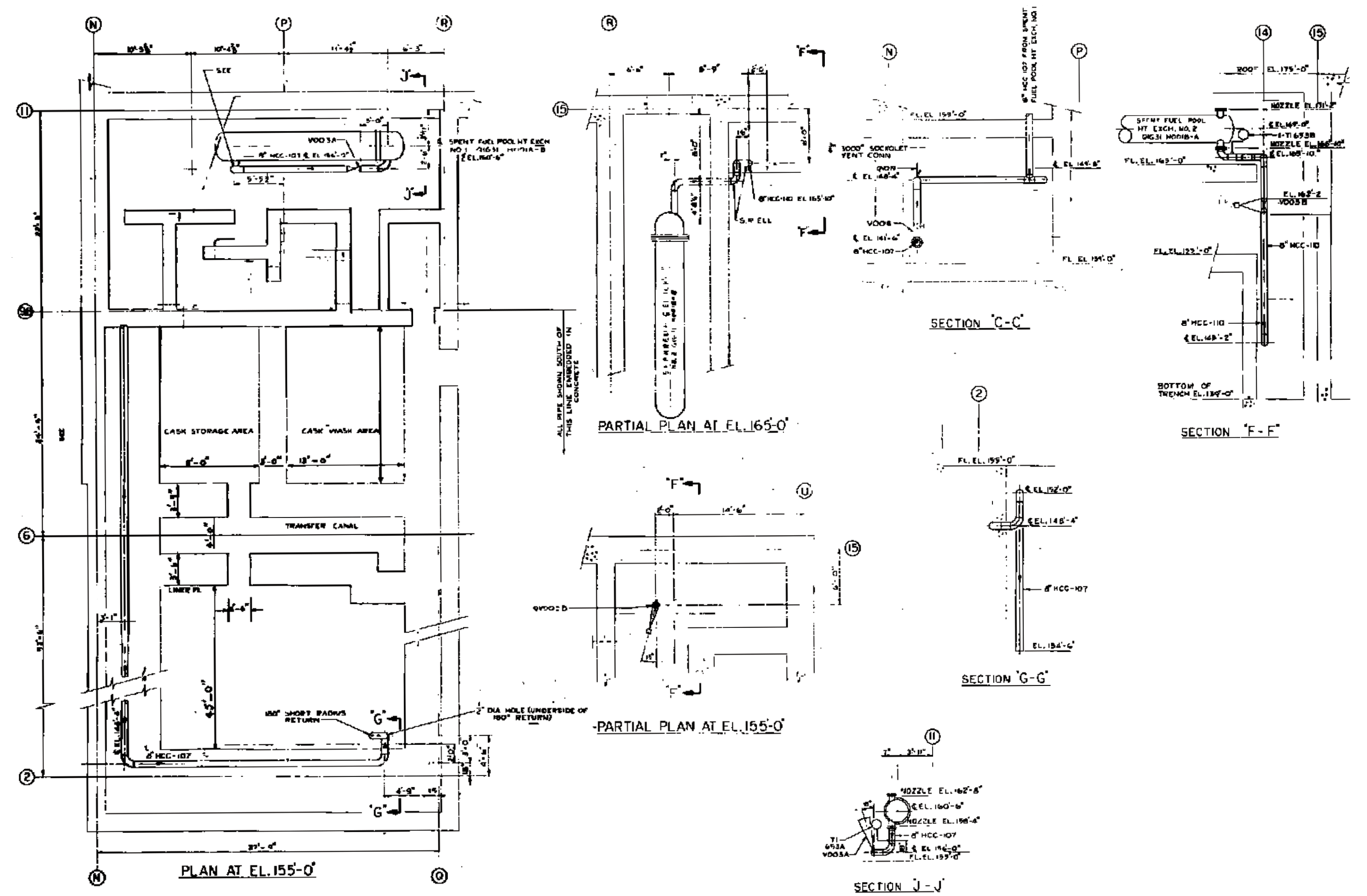
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL RACK MODULE

FIGURE 9.1-2 (SHEET 2 OF 2)



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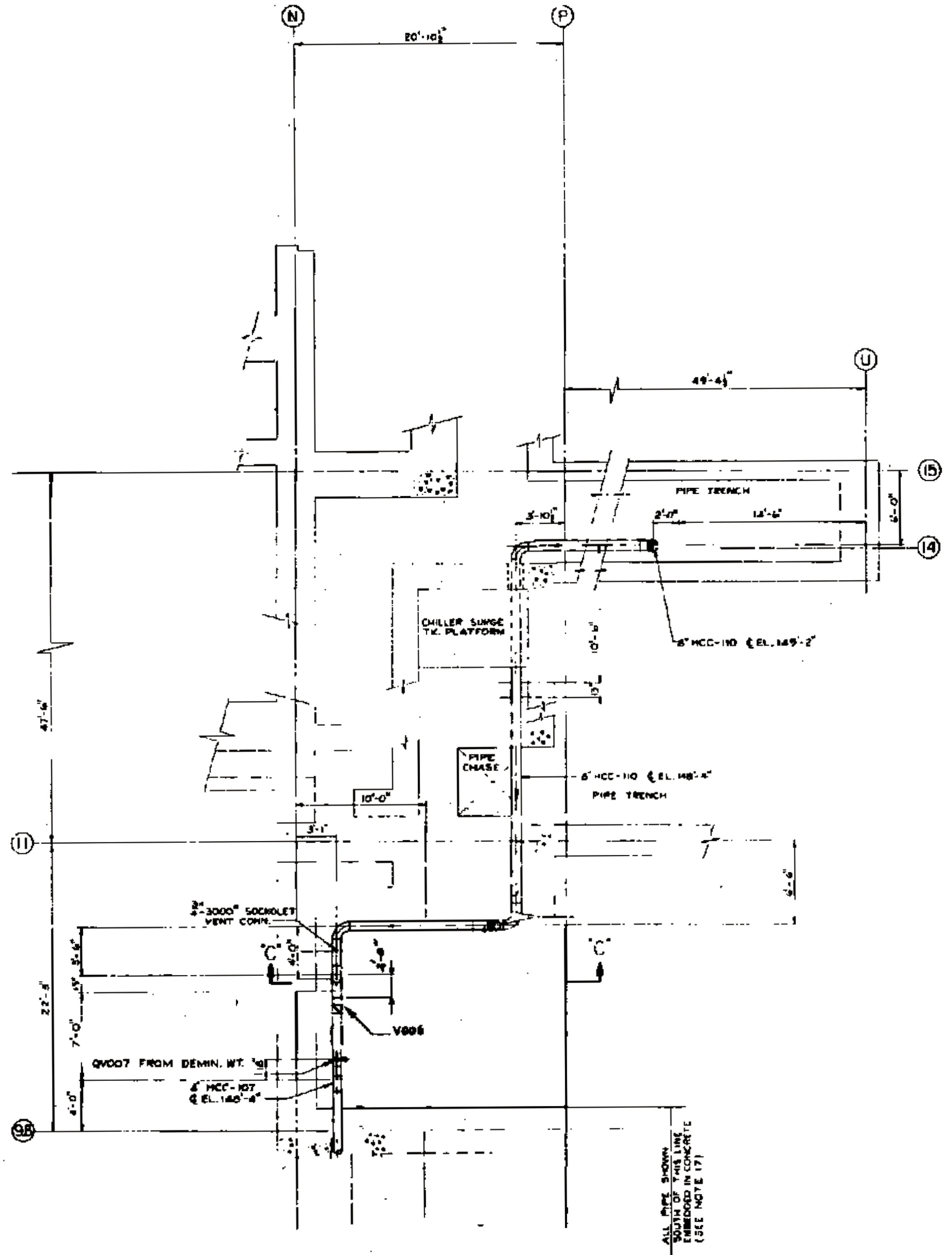
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL POOL COOLING SYSTEM
RETURN LINE PIPING ARRANGEMENT

FIGURE 9.1-3



PLAN AT EL. 139'-0"

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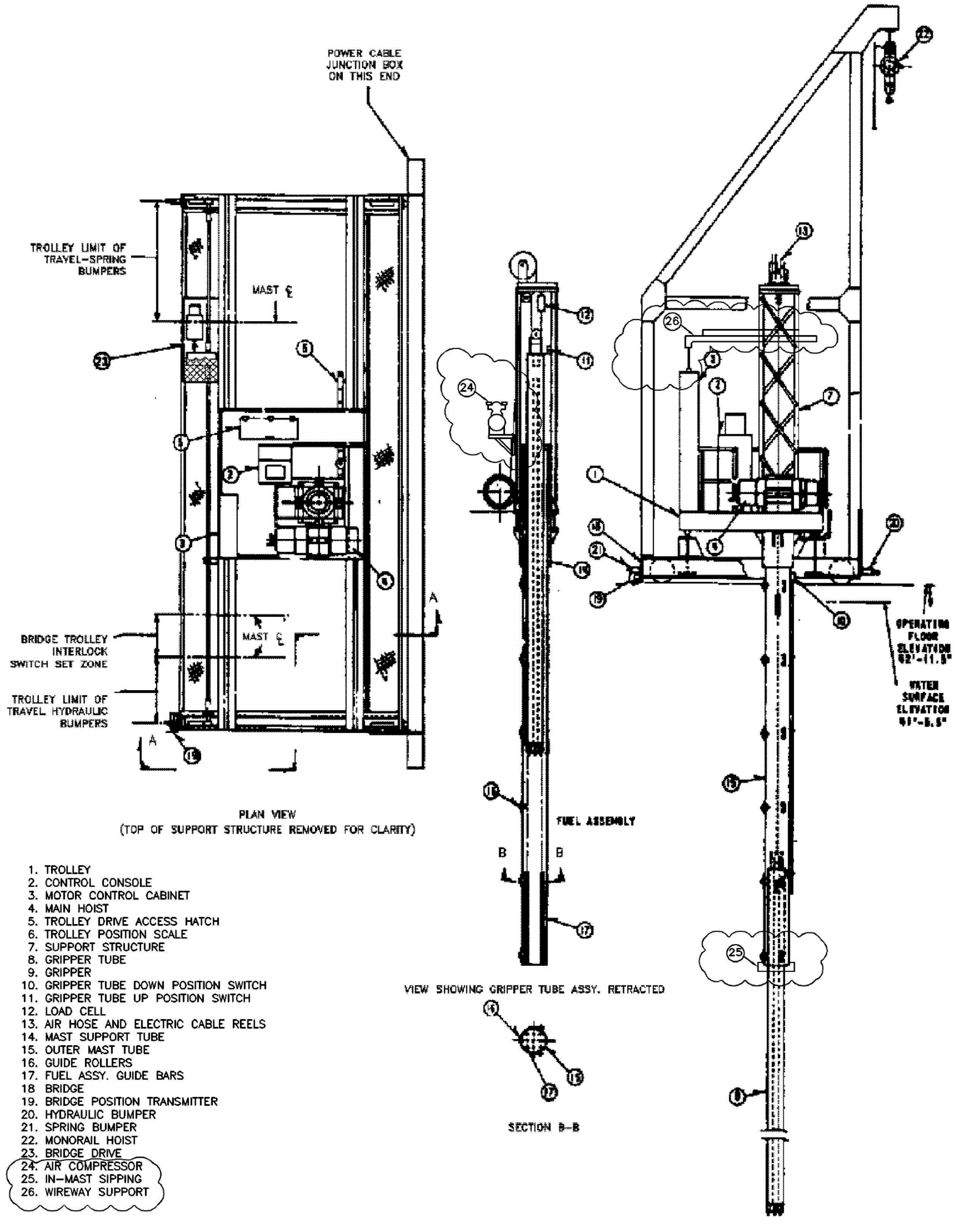
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL POOL COOLING SYSTEM
RETURN LINE PIPING ARRANGEMENT

FIGURE 9.1-4



1. TROLLEY
2. CONTROL CONSOLE
3. MOTOR CONTROL CABINET
4. MAIN HOIST
5. TROLLEY DRIVE ACCESS HATCH
6. TROLLEY POSITION SCALE
7. SUPPORT STRUCTURE
8. GRIPPER TUBE
9. GRIPPER
10. GRIPPER TUBE DOWN POSITION SWITCH
11. GRIPPER TUBE UP POSITION SWITCH
12. LOAD CELL
13. AIR HOSE AND ELECTRIC CABLE REELS
14. MAST SUPPORT TUBE
15. OUTER MAST TUBE
16. GUIDE ROLLERS
17. FUEL ASSY. GUIDE BARS
18. BRIDGE
19. BRIDGE POSITION TRANSMITTER
20. HYDRAULIC BUMPER
21. SPRING BUMPER
22. MONORAIL HOIST
23. BRIDGE DRIVE
24. AIR COMPRESSOR
25. IN–MAST SIPPING
26. WIREWAY SUPPORT

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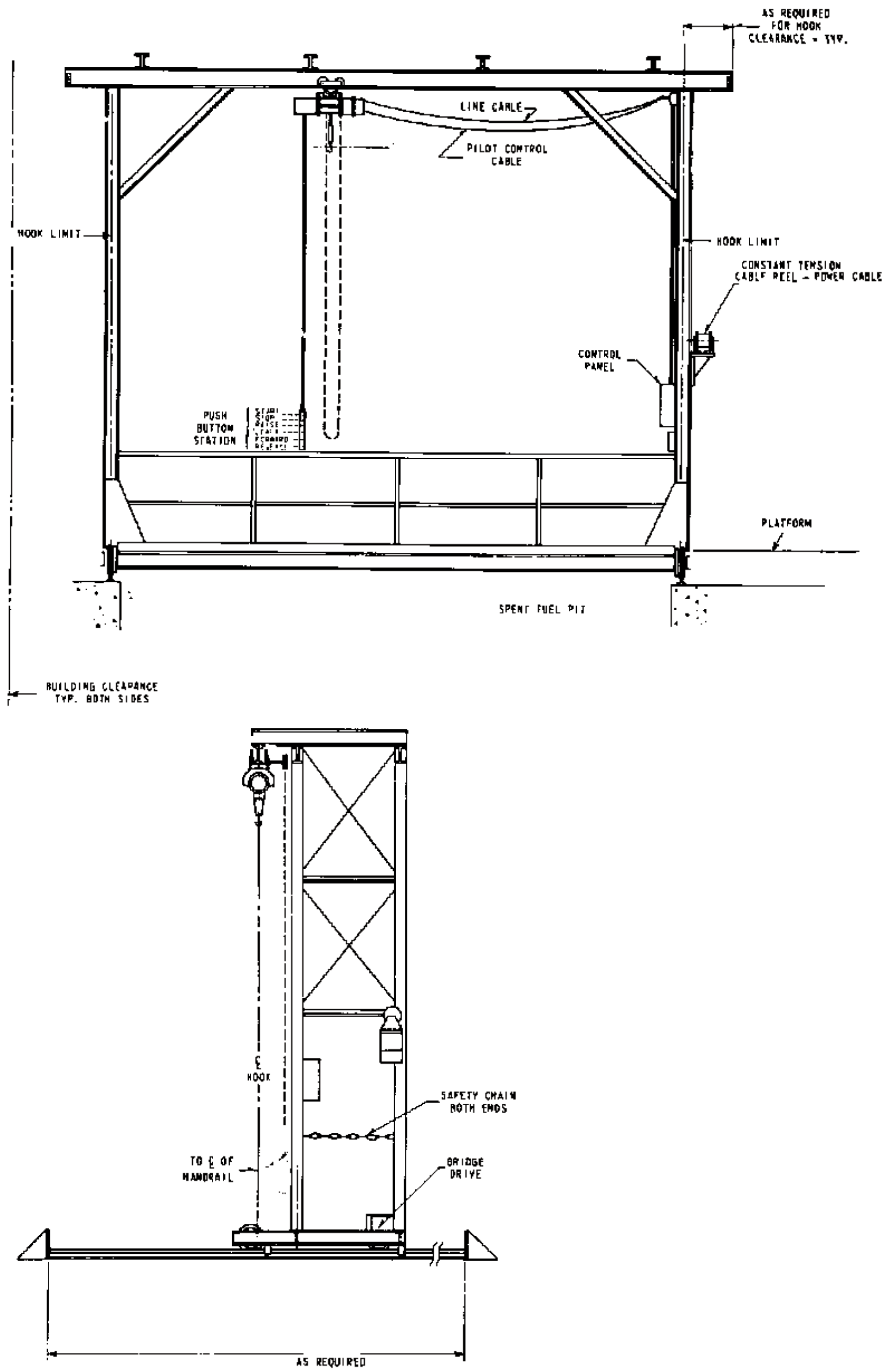
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	MANIPULATOR CRANE FIGURE 9.1-5



13

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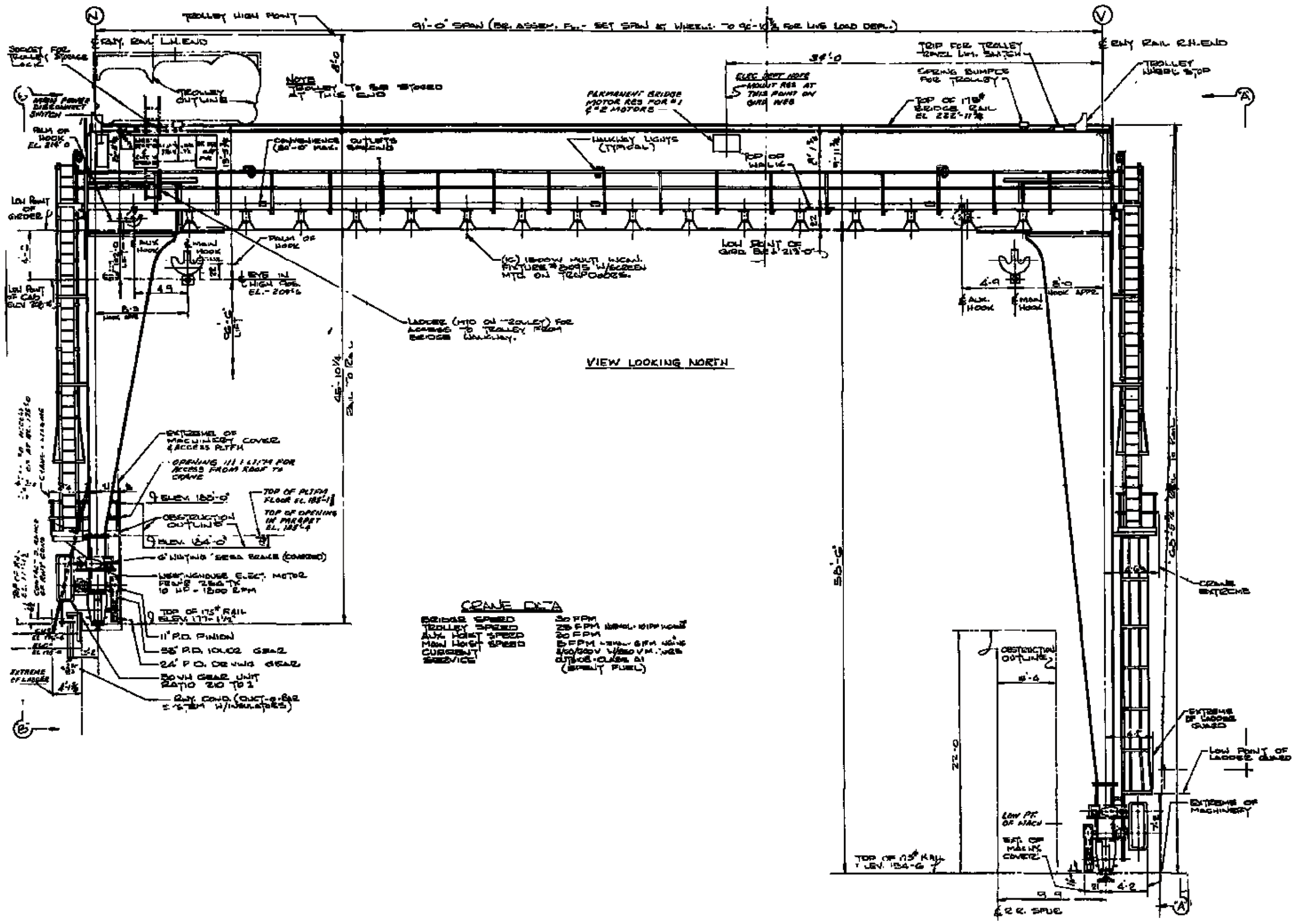
SPENT FUEL POOL BRIDGE

FIGURE 9.1-6



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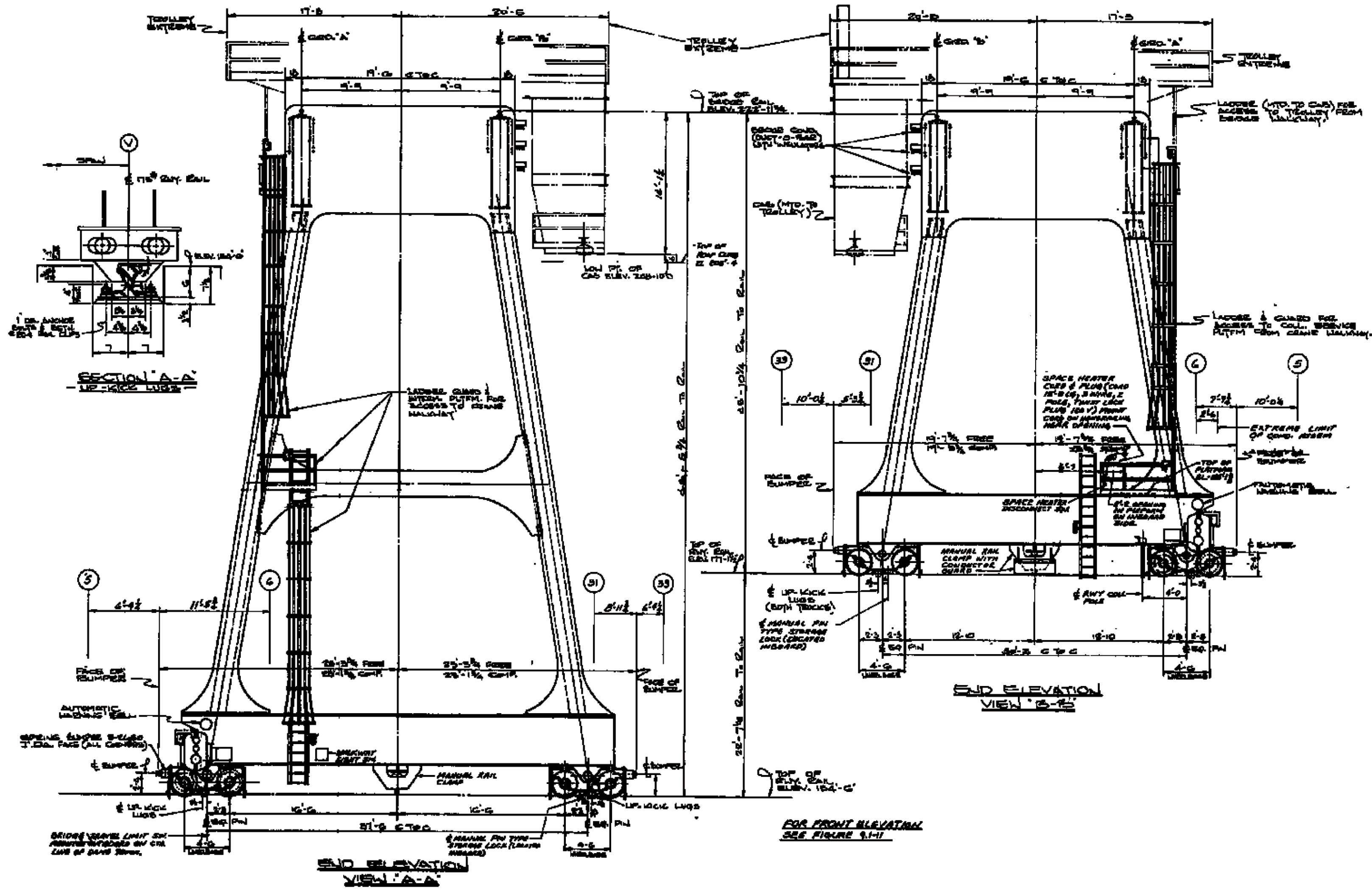
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL CASK CRANE
FRONT ELEVATION

FIGURE 9.1-7



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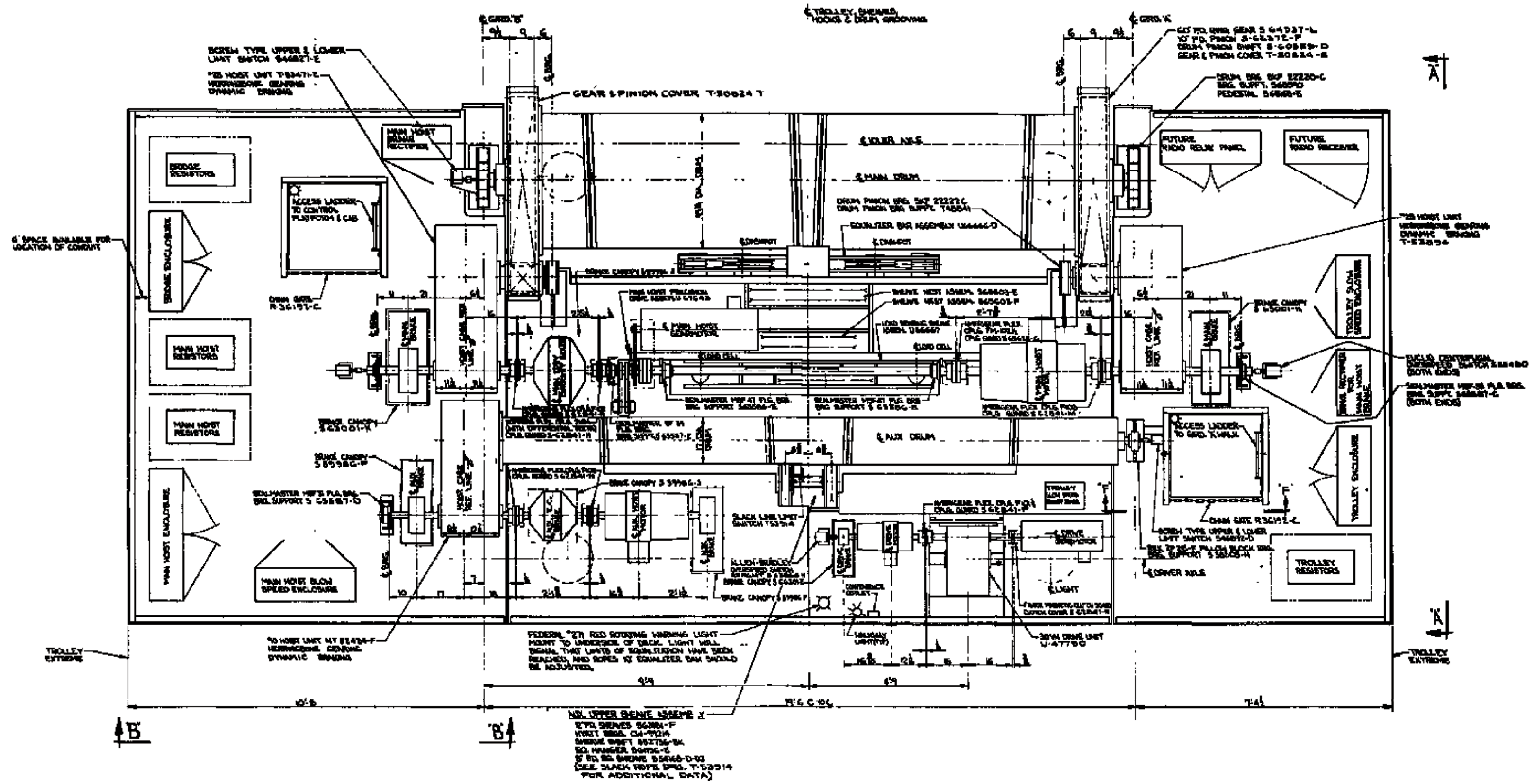
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL CASK CRANE
END ELEVATION

FIGURE 9.1-8



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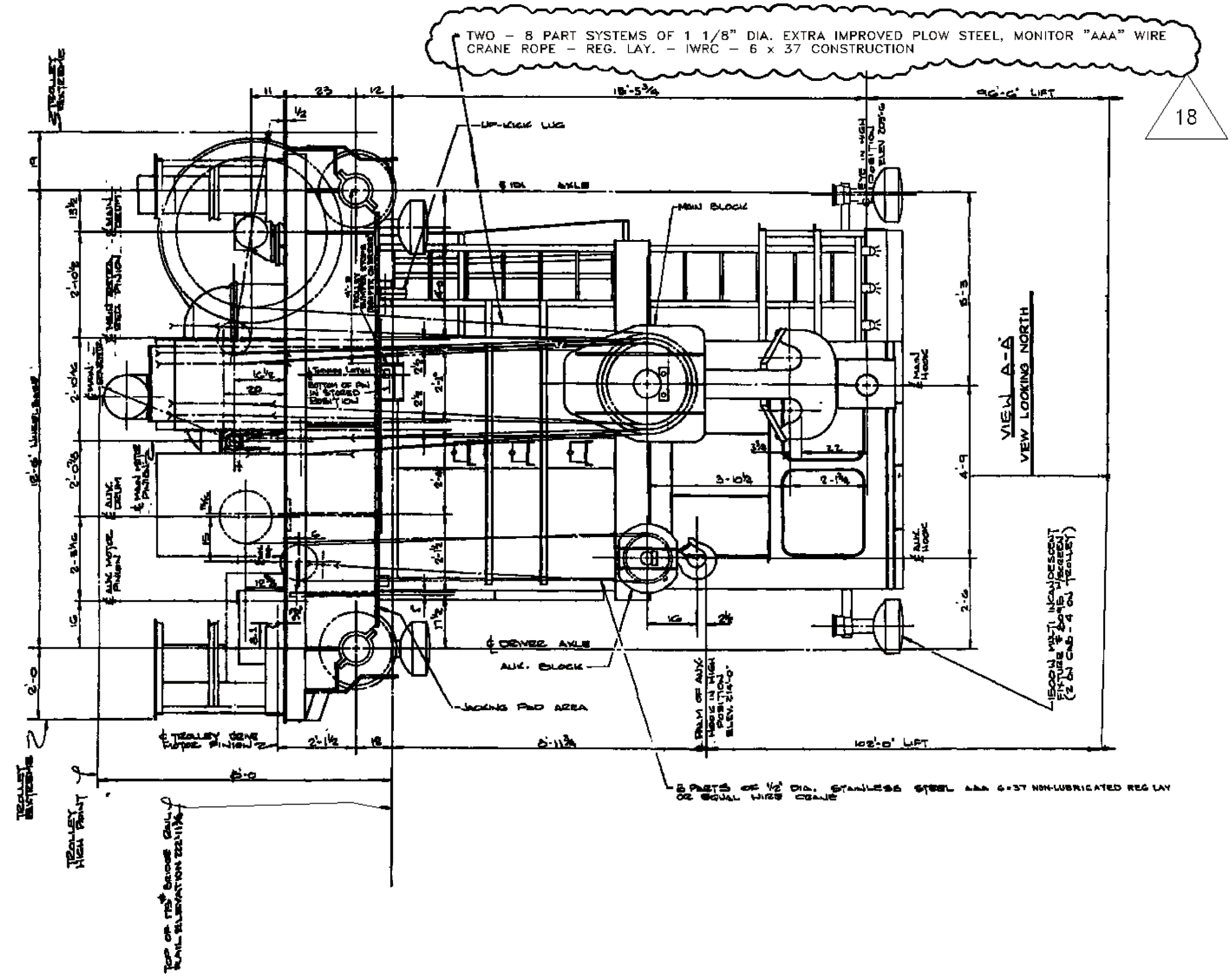
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL CASK CRANE
TROLLEY PLAN VIEW

FIGURE 9.1-9



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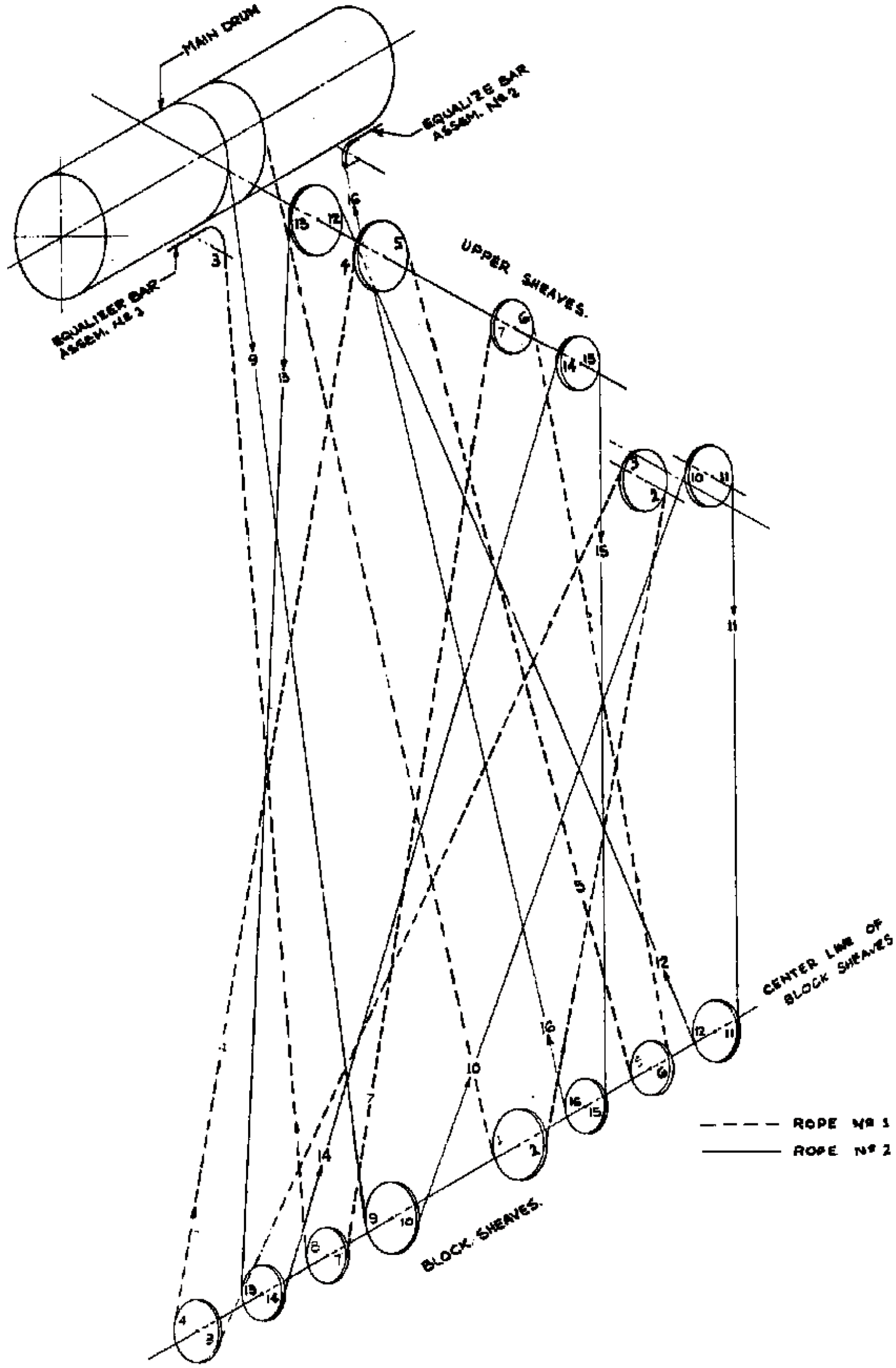
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL CASK CRANE TROLLEY
END ELEVATION

FIGURE 9.1-10



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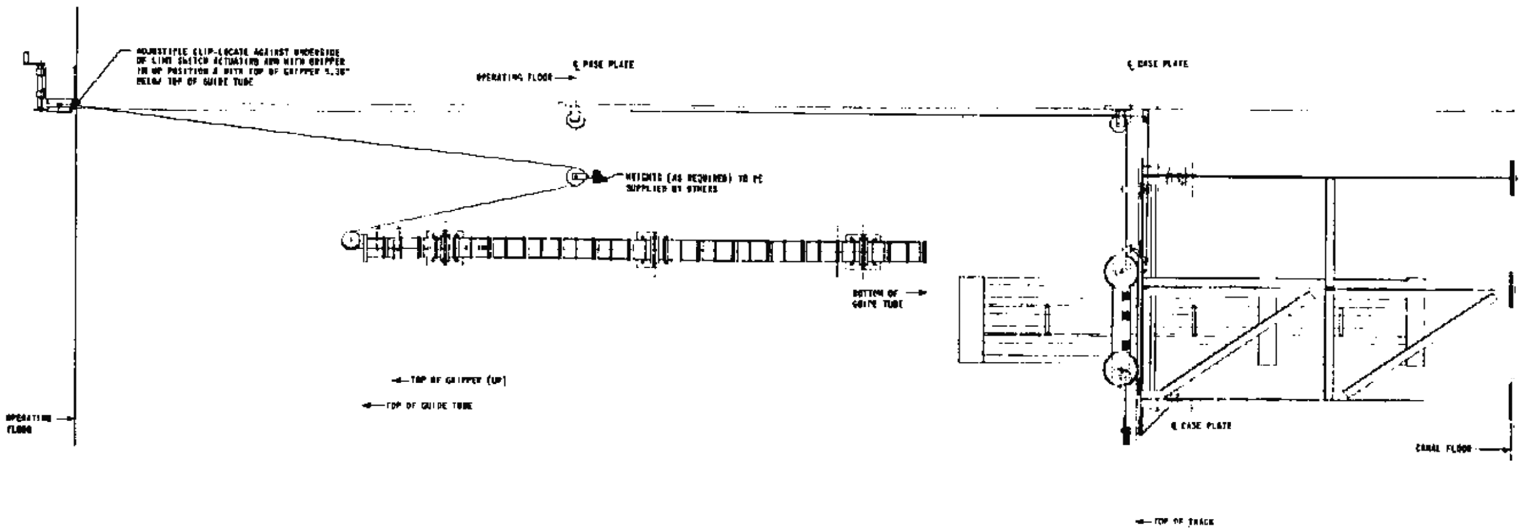
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	SPENT FUEL CASK CRANE MAIN HOIST 16-PART, 2-ROPE REEVING SKETCH
		FIGURE 9.1-11



13

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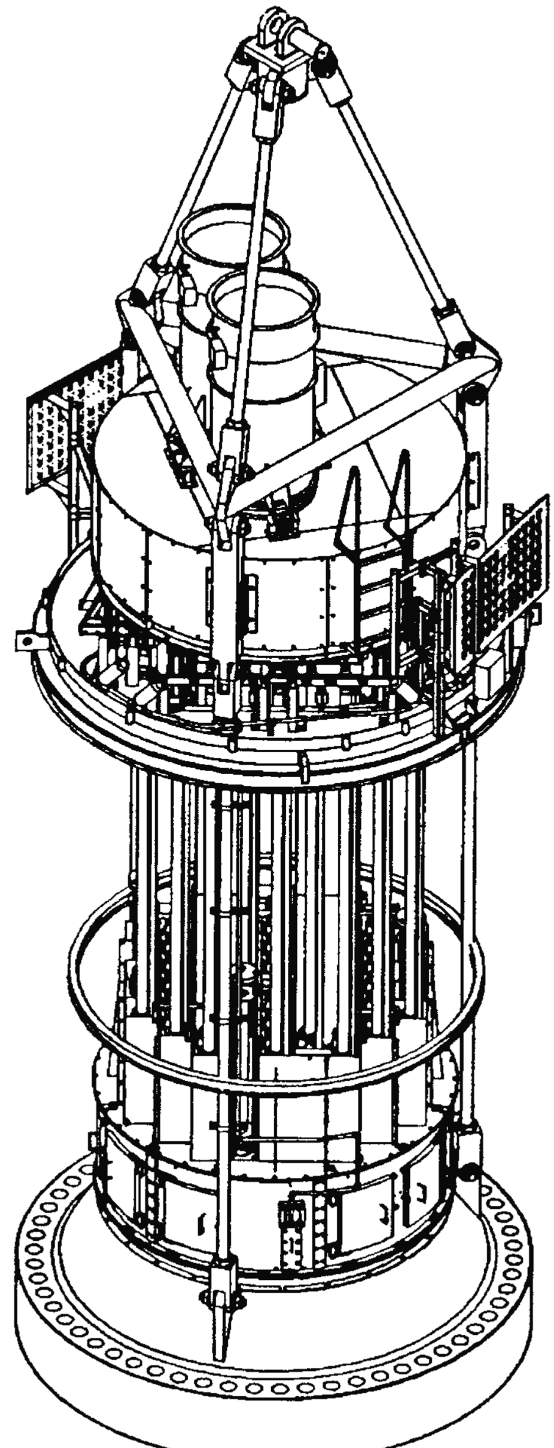
NUCLEAR PLANT
UNIT 1 AND UNIT 2

ROD CLUSTER CONTROL
CHANGING FIXTURE

FIGURE 9.1-12



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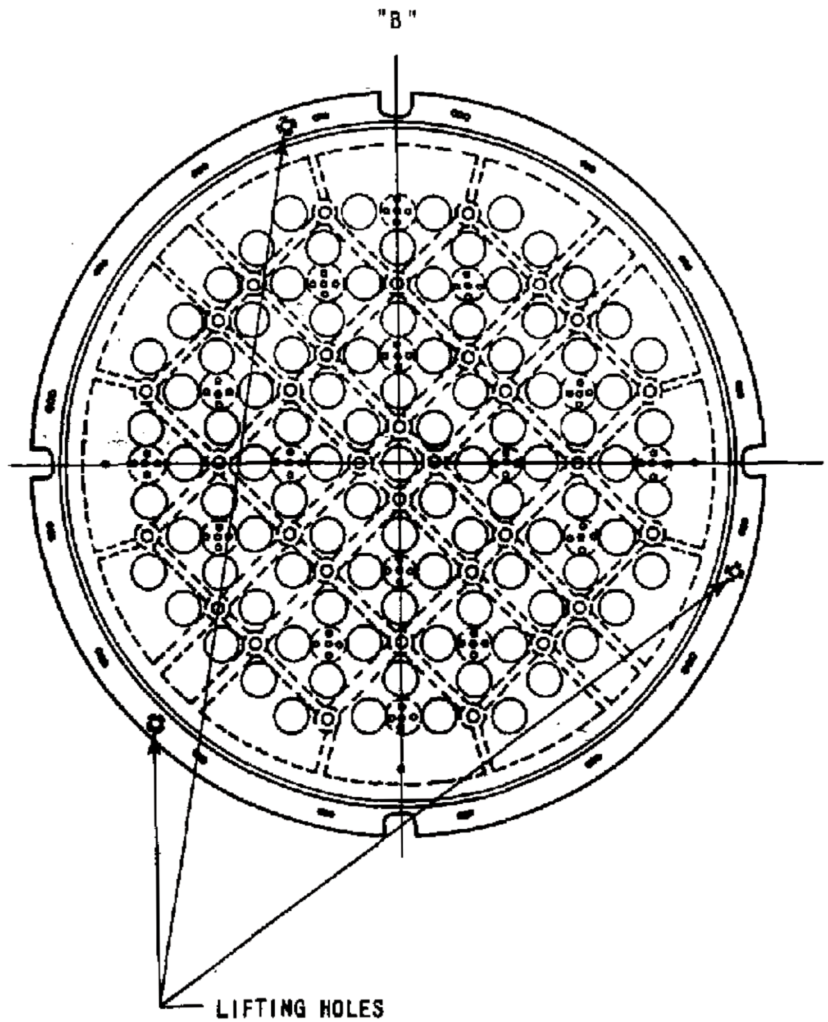
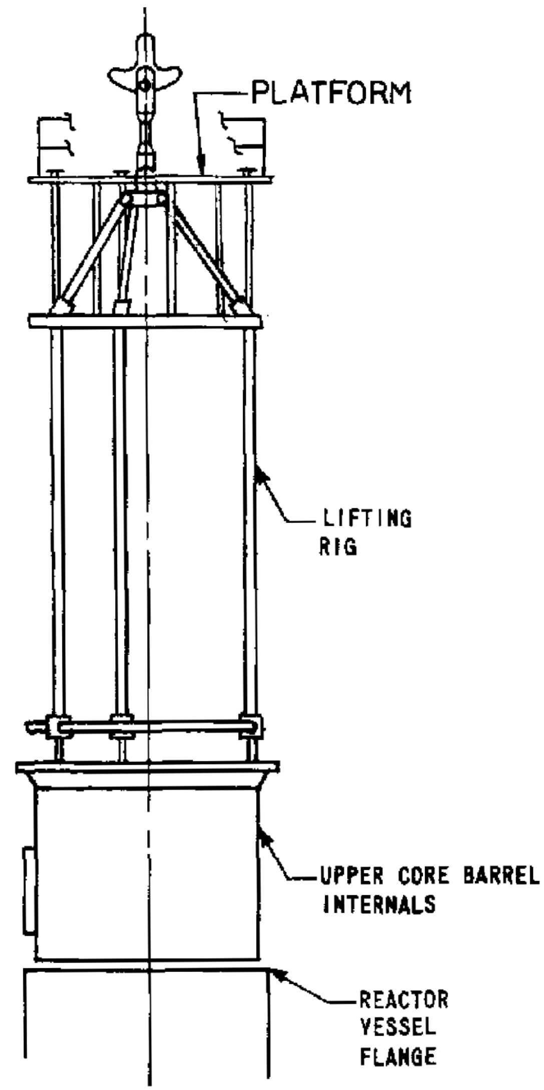
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

REACTOR VESSEL HEAD
LIFTING DEVICE

FIGURE 9.1-13



PLAN VIEW OF UPPER CORE SUPPORT STRUCTURES



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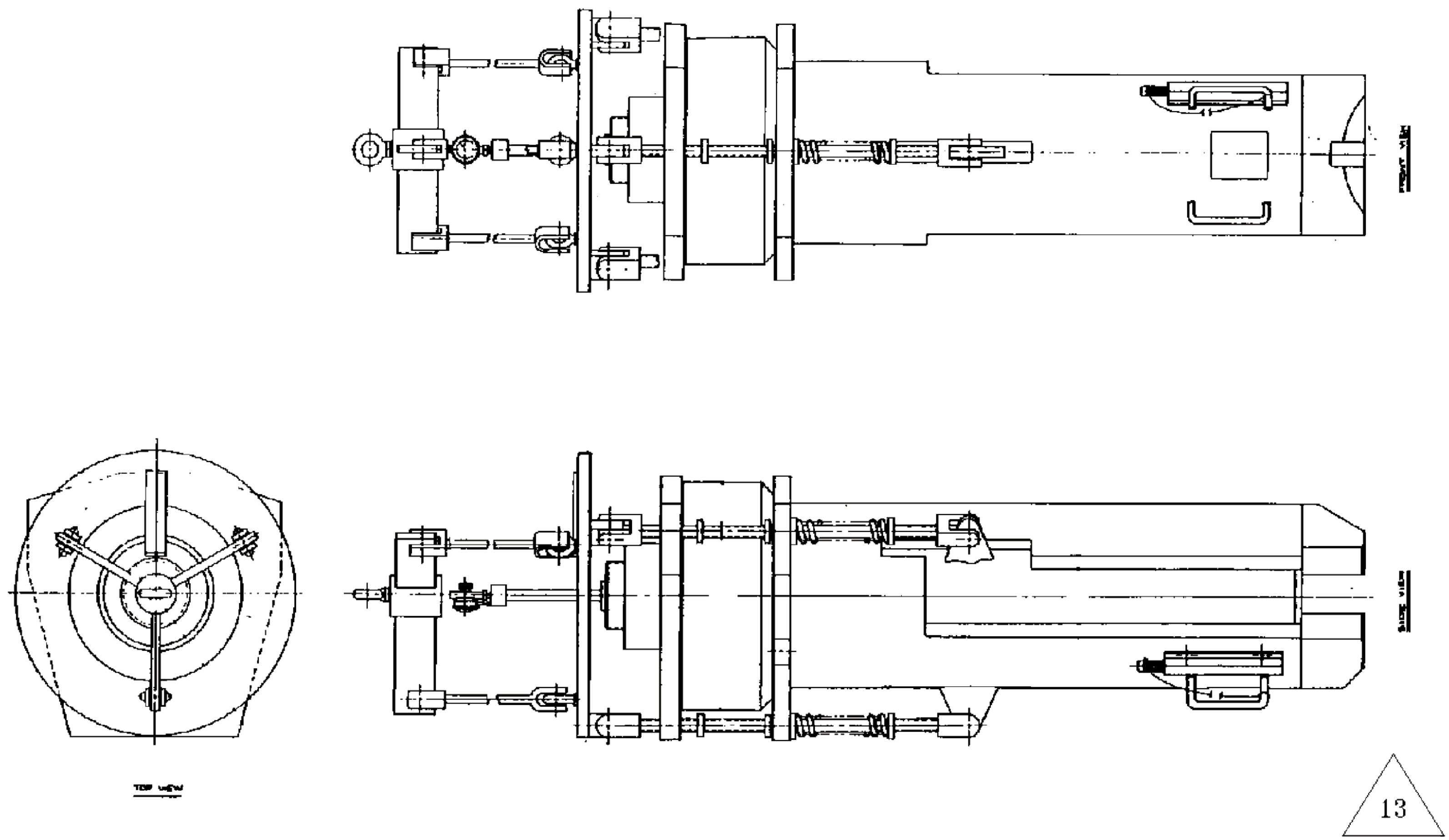
JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2

REACTOR INTERNALS LIFTING DEVICE

FIGURE 9.1-14



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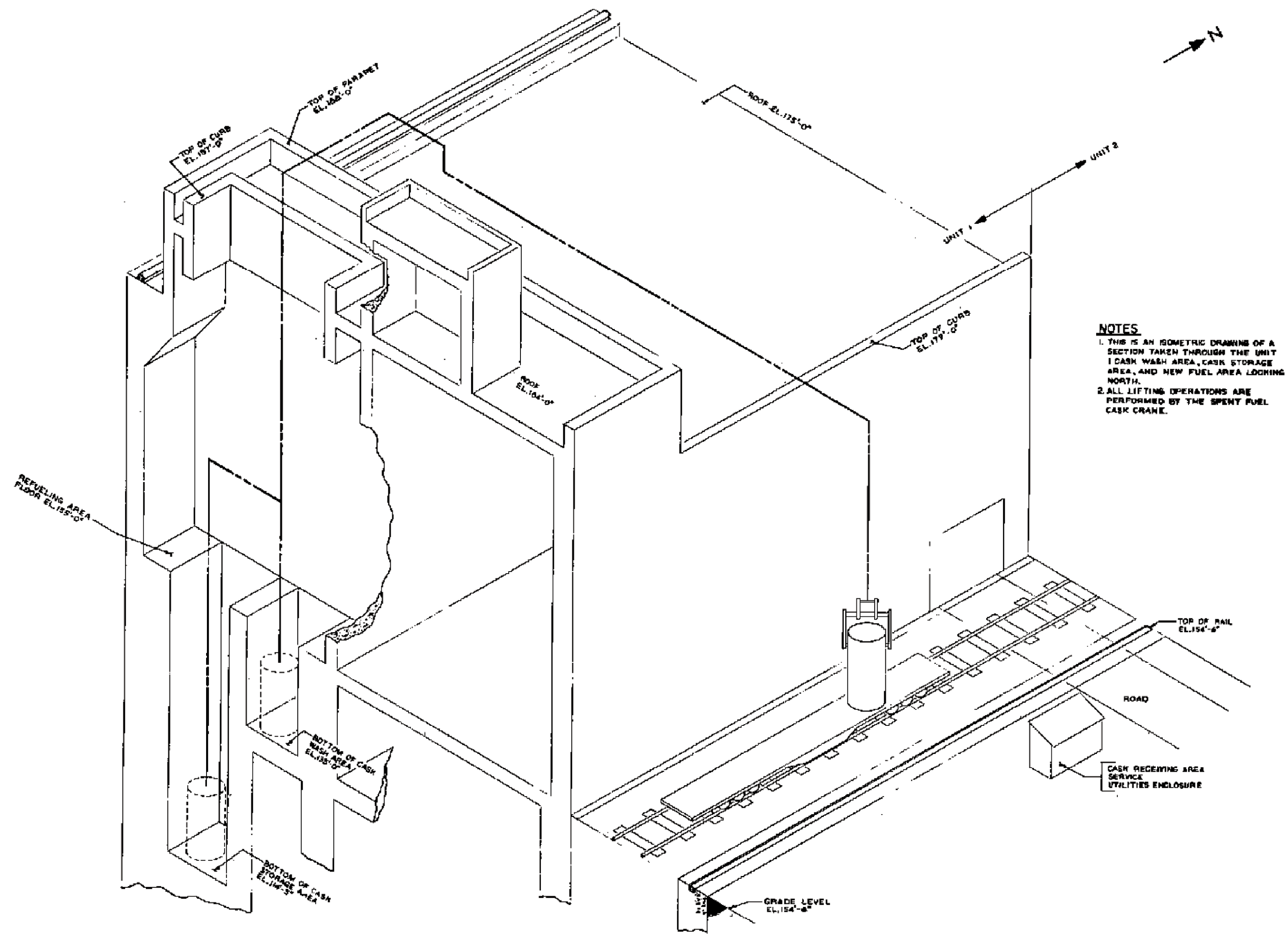
NUCLEAR PLANT
UNIT 1 AND UNIT 2

TYPICAL STUD TENSIONER

FIGURE 9.1-15



NOTES

1. THIS IS AN ISOMETRIC DRAWING OF A SECTION TAKEN THROUGH THE UNIT 1 CASK WASH AREA, CASK STORAGE AREA, AND NEW FUEL AREA LOOKING NORTH.
2. ALL LIFTING OPERATIONS ARE PERFORMED BY THE SPENT FUEL CASK CRANE.

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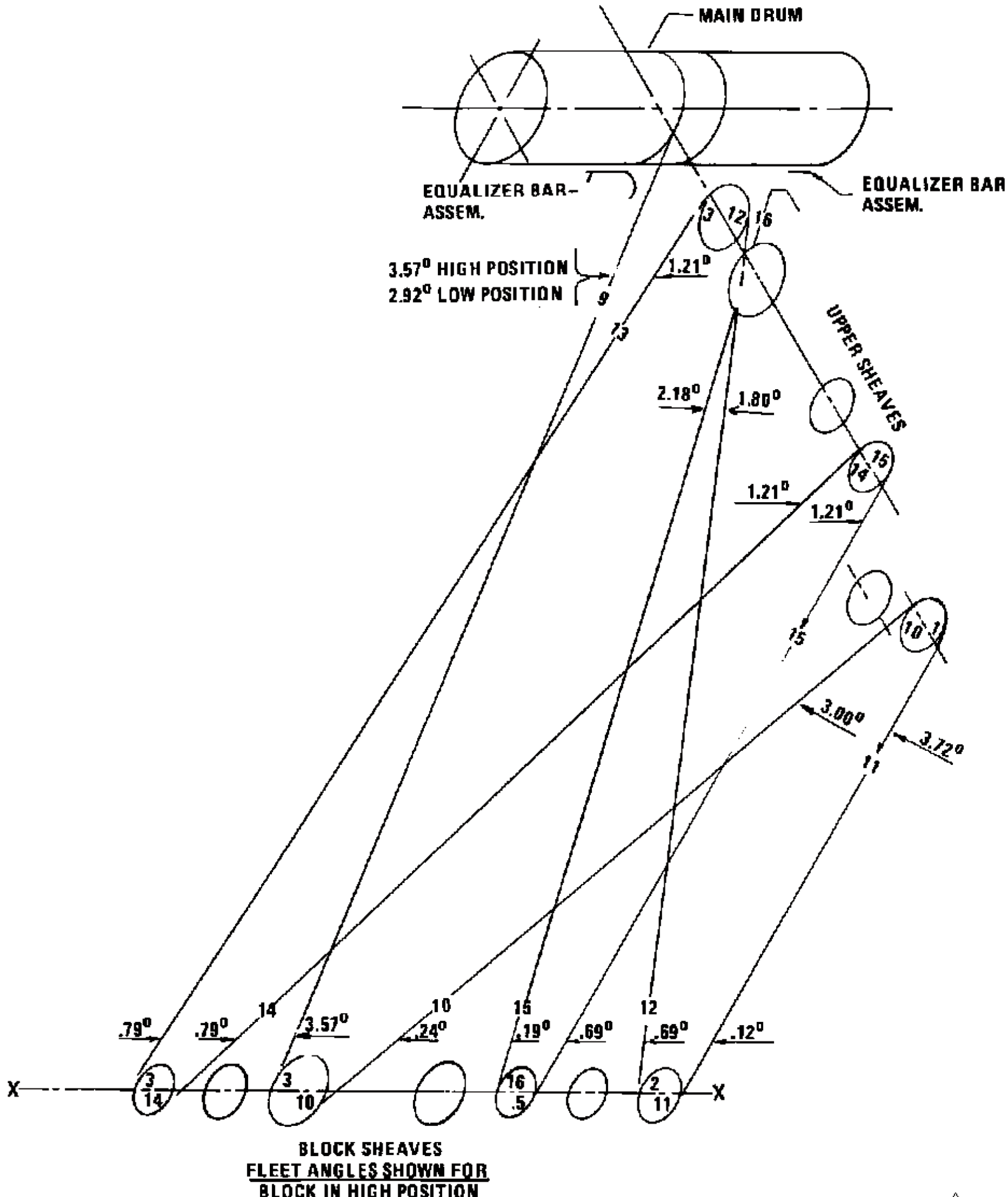
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL CASK
HANDLING PROCEDURE

FIGURE 9.1-16



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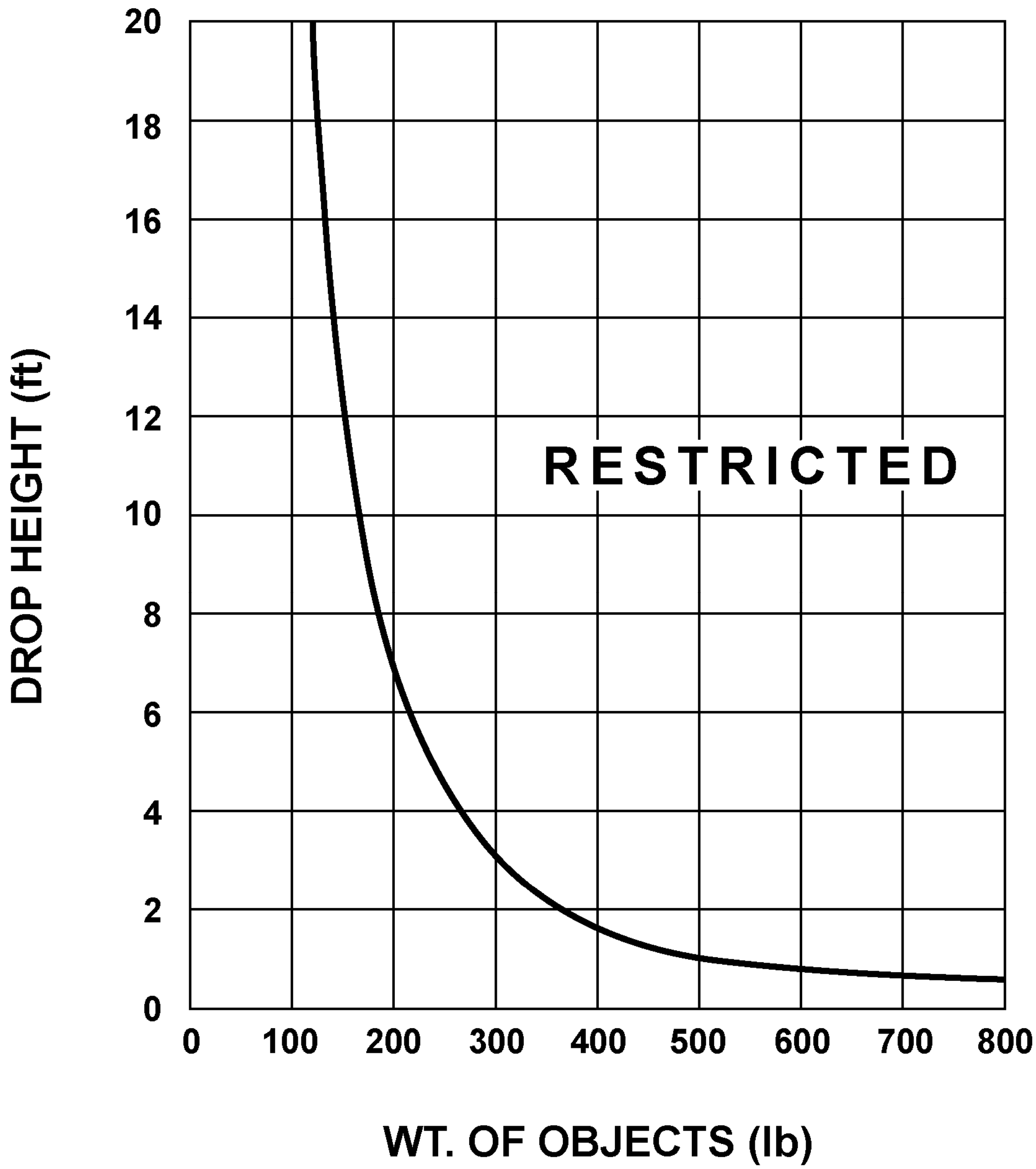
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SPENT FUEL CASK CRANE
FLEET ANGLES

FIGURE 9.1-17

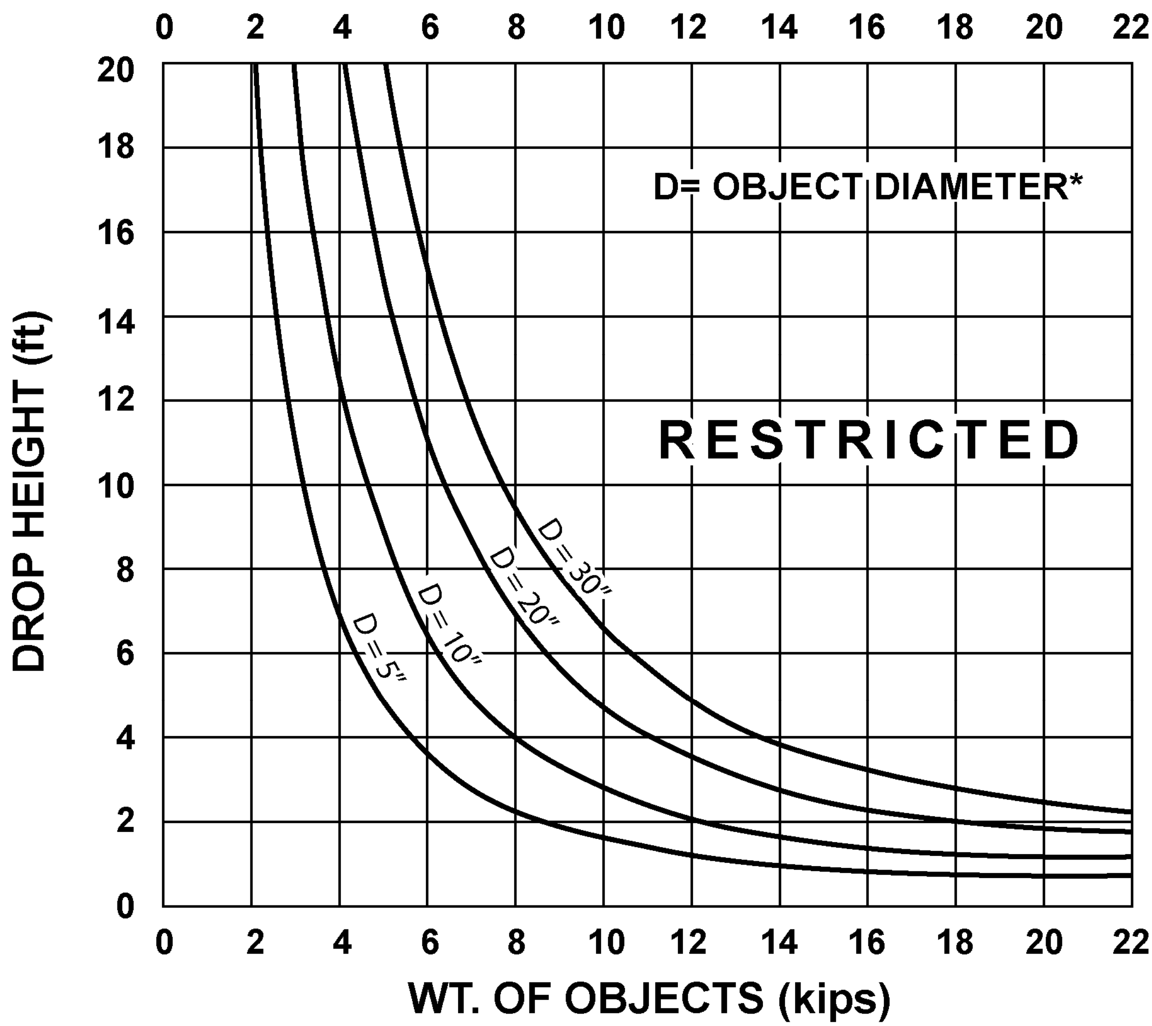


FOR HATCH “A” ONLY

NOTE: HATCH “A” is documented in drawing D-176007 for Unit 1 and D-206007 for Unit 2.

REV 22 8/09

SOUTHERN COMPANY Energy to Serve Your World®	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	HEAVY LOAD RESTRICTIONS FOR AUXILIARY HOOK – AUXILIARY BUILDING ROOF, HATCH “A” ONLY FIGURE 9.1-18



* For irregularly shaped objects, use equivalent diameter for a circle with the same contact or circumscribed contact area.

NOTE: HATCH "B" is documented in drawing D-176007 for Unit 1 and D-206007 for Unit 2.

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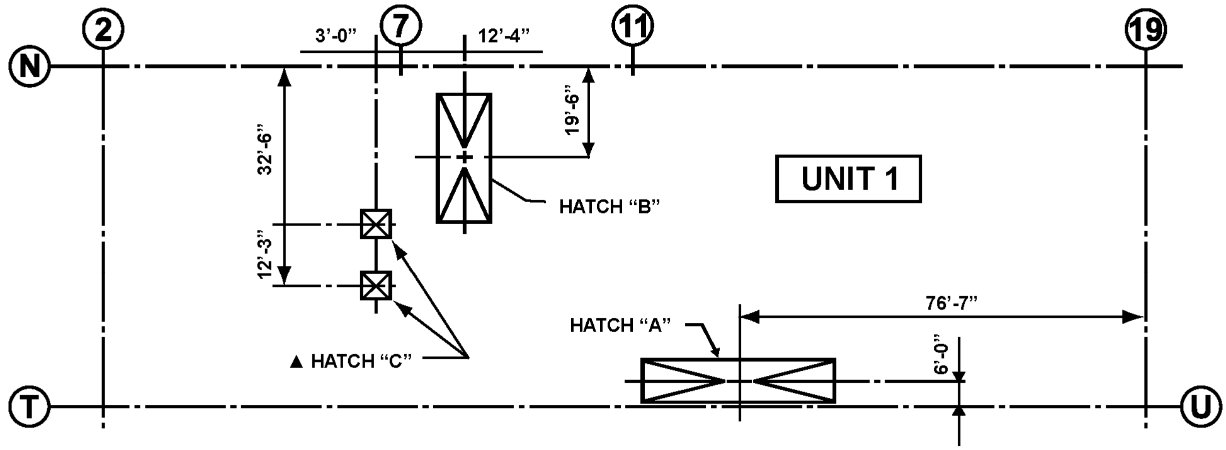
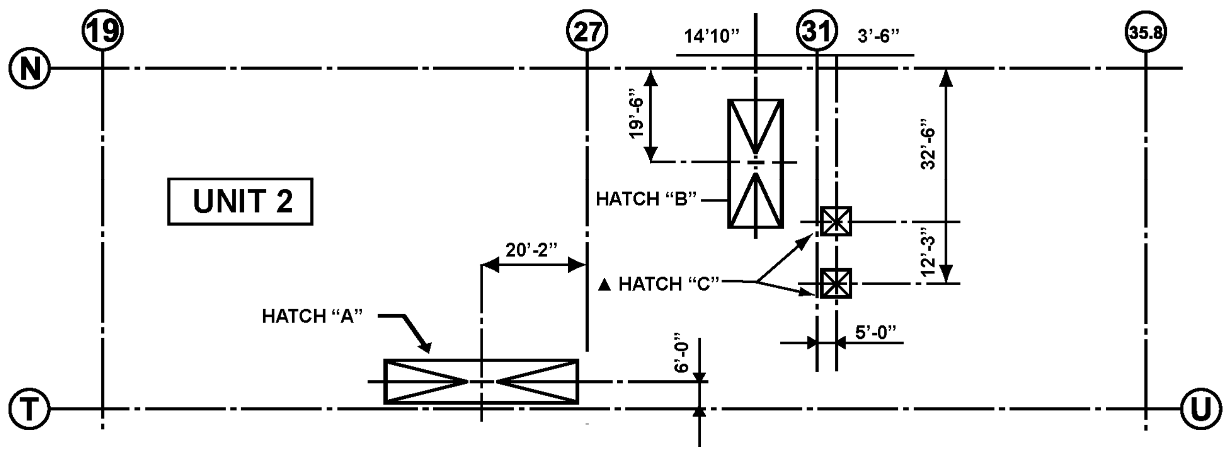
NUCLEAR PLANT
UNIT 1 AND UNIT 2

HEAVY LOAD RESTRICTIONS FOR AUXILIARY HOOK – AUXILIARY BUILDING ROOF AREA AND HATCH "B"

FIGURE 9.1-19



▲ NO HEAVY LOAD SHOULD BE TRANSFERRED OVER HATCH "C".



NOTE: HATCH "C" is documented in drawing D-176007 for Unit 1 and D-206007 for Unit 2.

REV 22 8/09

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NUCLEAR PLANT
UNIT 1 AND UNIT 2

HEAVY LOAD RESTRICTIONS FOR AUXILIARY HOOK – AUXILIARY BUILDING ROOF HATCH "C"

FIGURE 9.1-20

9.2 WATER SYSTEMS

9.2.1 STATION COOLING WATER SYSTEMS (RIVER WATER, SERVICE WATER, AND CIRCULATING WATER SYSTEMS)

9.2.1.1 Design Bases

The station cooling water systems provide cooling water for plant components during both normal and accident conditions. Component data for the river water and service water systems are listed in table 9.2-1.

The service water system is capable of delivering cooling water during all modes of plant operation to all equipment required to function under accident conditions. Safety-related portions of the system are designed to the following criteria:

A. Seismic Category I.

B. Safety Class 3.

C. Meets single-failure criteria.

D. Operable during:

1. A loss of offsite power (LOSP) on one unit or both units.

2. Loss of river water system with or without offsite power.

3. A loss-of-coolant accident (LOCA) in one unit while the other unit is in normal operating mode or normal shutdown mode with or without offsite power.

4. A safe shutdown earthquake (SSE) affecting the Farley Nuclear Plant (FNP) site with or without offsite power.

5. A fire in a single fire area of one unit while the other unit is in normal operating mode or normal shutdown mode with or without offsite power.

These accident conditions are discussed in further detail in FSAR paragraph 9.2.1.3.

E. No loss of function during adverse environmental conditions.

Table 9.2-2 delineates the number of river and service water pumps required per unit to provide adequate cooling for different plant conditions.

The service water system is designed to supply the flowrates listed in table 9.2-3.

Additionally, the service water system is designed to minimize leakage of radioactive material to the environment by maintaining system pressure above that of the medium being cooled where possible. Some system fluctuations and lineups may result in either component cooling water (CCW) or service water having the higher pressure of the two systems. The CCW system is typically operated at a higher pressure than the associated service water system. In the event of leakage from the CCW system to the service water system, the CCW surge tank will decrease in level. Control room alarms will alert the operators to this condition. Operator action will then be required to secure the leakage path.

9.2.1.2 System Description

The station cooling water systems for the FNP include a river water system which is shared by both units. The cooling system also includes a separate service water system for each unit and a circulating water system for each unit.

The river water system pumps water from the Chattahoochee River to the storage pond. Though the river water system has no safety-related functions, the pumps and many of the valves (as indicated on drawing D-170119, sheets 6 and 7) were originally designed to nuclear quality standards. Some designated instrumentation for the river water system, physically located in the service water intake structure, performs safety-related functions for the service water system as indicated on drawing D-170119, sheet 7. The service water system pumps water from the storage pond to various heat exchangers throughout the plant. A listing of service water design flowrates is provided in table 9.2-3. Safety-related portions of the service water system are indicated on drawings D-170119, sheets 1, 2, and 3 and D-175003, sheets 1, 2, 3, and 4. The overall relationship of the river and service water systems to plant arrangement is shown in figure 9.2-1. The circulating water system provides cooling water to the main turbine condensers and has no safety-related functions. The circulating water system is shown on drawings D-170119, sheets 9 and 10 and D-200013, sheet 6.

The river water intake structure is designed to prevent flooding from sources outside the building up to el 127 ft mean sea level (msl). Sump pumps are provided inside the structure to discharge the normally expected water accumulation from the various sources inside the building. However, the sump pumps are not large enough to handle the water volume that would result from a major line break of the river water system. To assure maximum availability of the river water system, the pump rooms (train A and train B) are separated by a watertight wall. Flooding on either side of the wall will be detected and alarmed by level switches.

The functions of the river water system, the service water system, and the circulating water system during various modes of operation are described in the following section.

9.2.1.2.1 Normal Power Operation

During normal operation, the river water system takes suction from the Chattahoochee River by means of river water pumps which discharge into a 60-in. header. The river water pump discharge header is divided into two separate trains by means of redundant isolation valves QSP25V511 and QSP25V512. The river water is then carried to a valve box located near the service water intake structure at the pond via two 60-in. pipes. From the valve box, the river water exits via two 54-in. lines which then combine into one 54-in. line which passes along the top of the pond dike and discharges into the storage pond through a discharge flume. The river water system is provided with ten river water pumps, five on each train.

Each pump is provided with a five-position control switch with reset, off, auto, run, and close positions. The reset and close positions are momentary positions which spring return to the off and run positions, respectively. During normal power operation the pumps will operate as follows:

A. Switch turned to reset or off position, pump will turn off.

B. Switch turned to auto position, pump will turn on and off responding to the water level fluctuations in the pond.

C. Switch turned to close or run position, pump should run. If the pump does not start, an alarm will result while the switch is in the run position or after the switch spring returns to run from the close position.

During normal operation the pond water level is controlled approximately between el 185 ft 6 in. and el 185 ft. With two units on line, it is expected that six to eight river water pumps will be required to maintain the pond water level. Typically, one or more river water pump(s) on each train will be placed in the auto position. When the water level in the pond drops down to el 185 ft, level switches QSP25LS510 and QSP25LS511 located in the wet pit will automatically turn on the river water pumps in auto position. When the pond level reaches el 184 ft 4 in., an alarm will be annunciated, alerting the control room operator. When the water level in the pond reaches el 185 ft 6 in., the same switches will turn off the river water pumps in the auto position. In the event that these level switches fail to operate, the level transmitters NSP25LT501 and NSP25LT502 located in the wet pit will give a service water structure alarm in the control room at el 185 ft 9 in., at which time the operator will take the appropriate action to shut off the necessary number of river water pumps. These level transmitters also feed into the control room pond level indicators.

The service water system takes suction from the service water intake structure located at the storage pond. Stop logs are provided in the service water intake structure which will prevent the water in the wet pit from dropping below el 180 ft. Five service water pumps are provided for each unit. The service water system is a nonshared system between the two units except for: the intake structure, the shared diesel generators, the recirculation line to the pond, the divert line to the wet pit, and the discharge piping and structure to the river. Therefore, the following discussion which is written for Unit 1 is the same for Unit 2. During normal operation, four service water pumps are required to maintain the plant service water requirements. These service water pumps discharge into a 42-in. header which is divided into 2 trains by means of valves Q1P16V506 and Q1P16V507, pumps 1A and 1B for one train, and pumps 1D and 1E for the other train. Pump 1C can be aligned to either train by means of the above valves. These valves are procedurally controlled so that when one is open the other must be closed, thereby maintaining the train separation. After the header, each train of the service water, supplied via 42-in. lines, proceeds to the service water strainers. The strainers are periodically manually backwashed so that the backwash flows to a sump and is then drained back to the pond. A differential pressure switch across the strainer inlet and outlet alarms in the control room upon an increase in differential pressure. A 36-in. bypass line is also provided around the strainers.

After the strainers, the service water from the intake structure proceeds via 42-in. lines to a valve box. Prior to entering the valve box, a 12-in. line branches off from each train to the diesel generator building. After entering the valve box, the following lines branch off from each train: (1) a 24-in. dilution bypass line, (2) a 24-in. supply line to the turbine building, (3) a 30-in. supply line to the auxiliary building, and (4) a 2-in. supply line to the air compressors located within the turbine building.

The lines going to the diesel generator building supply the cooling water requirements of the diesel generators. This is shown in drawings D-170119, sheet 3 and D-200013, sheet 3. A description of this portion of the service water system is given in subsection 9.5.5.

The dilution bypass line provides the bypass capability to prevent the overpressurization of the service water system.

The Train A and Train B lines to the turbine building combine into a 24-in. supply line just outside the valve box. Service water is supplied to the turbine oil coolers, the steam generator feed pump turbine oil coolers, the turbine building HVAC condensers, the hydrogen coolers, the plant instrument air compressors, the exciter coolers, the seal oil coolers, the generator bus cooling units, the EH fluid reservoir coolers, the condensate pumps, the heater drain pumps, the water analysis room HVAC condenser, and the water analysis room chiller. This portion of the service water system is nonsafety-related and is separated from the safety-related portion by means of redundant isolation valves on both the Train A and Train B supply lines. In the safety-related portion of each train, prior to combining into one 24-in. header, excess flow instrumentation (differential pressure switches Q1P16DPS565, DPS566, DPS568, and DPS569) is provided. This instrumentation automatically isolates the cooling water supply to the turbine building (valves Q1P16V514, V515, V516, and V517) should the flow exceed approximately 17,500 gal/min from either of the trains. These valves also automatically isolate upon receipt of a Phase A SI signal. Additionally, these valves throttle the supply flow to the turbine building during a LOSP event. This throttling function serves to provide a limited amount of cooling water to the turbine building during a LOSP event to support a controlled shutdown/cooldown of the secondary side, while at the same time ensuring maximum cooling water flow is available for the emergency diesel generators. A 2-in. line from each train upstream of these valves supplies cooling water to the air compressors when the turbine building is isolated.

The service water system inside the containment and the auxiliary building is shown on drawing D-175003, sheets 1 through 4. Each train supplies cooling water to at least one CCW system heat exchanger, two containment air coolers, one 600-V load center cooler, one battery charging room cooler, one motor control center room cooler, one residual heat removal pump room cooler, one containment spray pump room cooler, one auxiliary feedwater pump room cooler and high-head SI pump room cooler, and one CCW system pump room cooler. Service water is also supplied to the following nonsafety-related equipment: steam generator blowdown heat exchanger, BTRS chillers, and reactor coolant pump motor air coolers.

Service water discharging from the auxiliary building, the turbine building, the diesel generator building, and the dilution bypass line junctions in another valve box. Exiting from this valve box are the redundant 30-in. discharge headers supplying water to the circulating water canal and service water return to the river. Each line is equipped with an isolation valve (Q1P16V545 and 546). Service water is supplied to the circulating water makeup system via a 30-in. line. This line is equipped with an isolation valve (Q1P16V550) and a circulating water makeup control valve (Q1P16V560). The control valve is an automatic air-operated control valve, controlled by the level controller located in the circulating water pump structure wet pit. The service water return line to the river is a 36-in. line. It is equipped with an isolation valve (Q1P16V549) and a standpipe discharging into a surge tank. The standpipe maintains a backpressure on the service water return lines from the auxiliary building, containment, and turbine building. During normal operation the standpipe provides the necessary backpressure on the systems being serviced. The surge tank provides the volumetric capacity to allow for flow transients. Upstream of the standpipe/surge tank, cooling tower blowdown joins this stream and the line continues to the standpipe/surge tank across a flow measuring device. The flow proceeds from the surge tank through the 36-in. diameter pipe and joins with the Unit 2 service water system. The combined Unit 1 and Unit 2 discharge flow proceeds from this junction through the 60-in. diameter pipe to the discharge structure at the river.

The circulating water system takes suction from the circulating water pump structure wet pit via two circulating water pumps, each rated at about 327,000 gal/min. Fixed screens are provided at this pump intake structure to prevent possible debris from entering the pumps. Circulating water enters into the supply water passage which supplies cooling water to the turbine condensers. Cooling tower blowdown is branched from this supply passage with a flow controller and an air-operated control valve in order to control the solids buildup in the cooling tower basin and also to provide the river discharge from the cold side of the circulating water. Circulating water from the condensers enters the cooling towers and returns to the circulating water pump structure wet pit via the return water canal. Motor-operated butterfly valves which can be operated locally are provided at the discharge of the circulating water pumps, at the inlets and outlets of each condenser, and at the cooling tower supply lines. A cooling tower bypass system is provided for cold weather operation.

9.2.1.2.2 Startup and Shutdown

Operation and the flow path described above for normal operation is the same for the startup and shutdown operation. In this mode, the operator will manually adjust flows or shut off cooling paths to the various equipment as required by the normal operating procedures.

9.2.1.2.3 Emergency Modes of Operation

The design features facilitating the normal operation of the plant are described above. The following describes the provisions that have been made in the design to ensure the safe shutdown of the plant in the event of a failure in the system.

9.2.1.2.3.1 **Loss of River Water Intake Structure or River Water Pump Suction**. The station cooling water system is designed such that the safe shutdown of the plant is not dependent on the river as a cooling water source. The primary purpose of the river water system is to provide make up to the storage pond. The storage pond alone serves as the ultimate heat sink for the plant. However, the river water system is available as a cooling water source as long as offsite power is available for the river water pumps.

9.2.1.2.3.2 **Loss of Storage Pond Dam**. The storage pond dam was designed and constructed and is maintained in compliance with applicable industry standards. Additionally, a detailed analysis was performed to demonstrate the reliability of the pond dam and the results of this analysis indicated the possibility of a dam failure is approximately 1.9×10^{-7} failures per year. Therefore, the loss of the storage pond dam is not considered to be a credible event and such an event is not postulated as part of the design basis of the station cooling water system.

9.2.1.2.3.3 **Flood Protection**. The river water pumps are protected from flooding up to el 127 ft msl. At flood elevations above el 127 ft msl to maximum flood water level at el 144.2 ft msl, no provisions have been made to ensure river water pump operation. The service water pumps and pond are protected up to maximum flood level.

The service water pumps are operable at the maximum level the pond can maintain. The pond spillway is at el 186 ft, and the top of the pond dike is at el 195 ft. The probable maximum precipitation (PMP) flood of el 192 ft 2 1/2 in. will not flood the pump and equipment rooms, since the entrances are located above this elevation and the building is protected against flooding to el 195 ft 4 1/2 in. In addition, the pump and equipment rooms of the service water intake structure are drained by gravity to an area outside the PMP associated with the pond. The river basin PMP flood is el 144 ft 2 in. The nonsealed structure openings communicating to the outside of the structure are located above the pond PMP flood elevation, except for the sump drain mentioned above. Therefore, the station cooling water system and the ultimate heat sink would not be affected by a flood.

9.2.1.2.3.4 **Pump Minimum Submergence**. The minimum submergence given by the service water pump manufacturer is 5 ft, which corresponds to a minimum operating water level of 157 ft 6 in. msl. If the pond water level drops to el 184 ft, river water makeup is automatically directed to the service water pump wetpit. The wetpit has stoplogs to maintain the water level at el 180 ft. Therefore, in the highly unlikely event of a storage pond dam failure, the service water system could operate as long as the river water system remained available. Should the river water system become incapable of providing sufficient makeup to the service water pond, the service water system would be placed in the recirculation-to-pond mode of operation. If the pond level decreases due to loss of the river water system with the pond dam intact, the stoplogs must be removed to ensure that an adequate supply of water can enter the service water wetpit. For a discussion of the pond levels during recirculation mode of operation, refer to subsection 9.2.5. At all times the level in the wetpit sump would be greater than the minimum submergence.

The minimum submergence given by the river water pump manufacturer is 4 ft 6 in., which gives a minimum operating water level of 67 ft msl. With Jim Woodruff Dam in place, the minimum operating level normally maintained by the Corps of Engineers in the Chattahoochee River is el 76 ft msl. Therefore, the drought condition should not cause the water level to drop below the minimum submergence required for the pumps.

9.2.1.2.3.5 **Storage Pond Protection**. The design of the service water system is such that during normal operating conditions service water is not returned to the storage pond, but is returned to the river in the Seismic Category II service water dilution line. Pond level is maintained by makeup from the river through the river water pumps and piping. Therefore, the service water system is normally a once-through system. When the river water system is not available as makeup to the pond, the pond level will drop and initiate an alarm. The service water system is then placed in the recirculation mode by operator action. This is accomplished by opening the train-oriented valves in the recirculation line to the pond and isolating the Seismic Category II dilution line from the remainder of the system via the train-oriented isolation valves.

9.2.1.2.4 Service Water Equipment Room Drainage

The lowest elevation of the service water intake structure, excluding the wet pit area, is el 167 ft. The gravity sump drain extends from immediately below this elevation to a point 937 ft east of the structure, which is downhill from the structure and pond dike. It emerges to grade elevation at el 143 ft. Since it in no way communicates with the water contained in the storage pond, the only flooding condition that could enter the discharge end of the pipe is that associated with the river basin maximum flood. This flood elevation is el 144 ft 2 in., which is well below the lowest elevation of the service water intake structure. Therefore, means to prevent backflooding such as check valves are not necessary. However, the discharge of the drain is equipped with a 24-in. flap valve to prevent the entry of rodents or reptiles.

9.2.1.2.5 Service Water Pumps Internally Generated Missiles

The probability that a missile generated from the motor of one service water pump will damage another safety-related pump or other safety-related equipment is estimated to be $< 4.5 \times 10^{-9}$ per year. This extremely low value does not warrant additional design efforts to prevent damage. The design against missile damage has been adequately accomplished by the motor manufacturer. The most probable missile is a fan blade 6 in. x 4 in. x 1/8 in., which will not have sufficient energy to penetrate the 1/2-in., 2000-grade cast iron casing. A less probable missile is a 1/2-in. cap screw, 1 in. long, which also will not penetrate the casing. There are no physical barriers between redundant service water pumps for protection from internally generated missiles.

9.2.1.3 <u>Safety Evaluation</u>

All safety-related portions of the station service water system, including the service water intake structure and pumps, are Seismic Category I and meet the single-failure criteria, as analyzed in the failure analysis in table 9.2-5.

All structures containing station safety-related service water components are watertight up to the maximum external flood level.

In the event of storage pond low water level, the river water system will be valved to discharge directly into the service water pump wet pit. Should the river system become unavailable, the service water system will be valved to recirculate the cooling water to the storage pond in order to maintain pond level.

A discussion of the long term capability of the system to dissipate waste heat is found in subsection 9.2.5.

All safety-related piping located outdoors is covered by a minimum of 3 ft 10 in. of soil for missile protection. Redundant lines are physically separated so that the failure of one line will not affect the redundant line.

In the event of LOSP, the service water pumps will automatically be supplied power from the emergency diesel generators in order to supply the cooling water required to hold both units at hot shutdown conditions. Through operator action, the river water pumps can also be connected to the emergency diesel generators but no credit is assumed for their operation in the plant safety analysis.

The nonsafety-related portions of the service water system in the auxiliary building, containment, and turbine building, with the exception of the 2-in. lines supplying the air compressors on each unit, are automatically isolated on an SI signal by MOVs. Fire protection hose station service water valves inside containment are normally locked closed.

Because the service water operates continuously during normal plant operation, its availability is apparent to plant operators. Radiation monitors located in the return lines from the containment air coolers alarm in the main control room. If not previously opened, bypass valves on the service water lines exiting the containment air coolers would automatically open on an SI signal and increase post-LOCA flow to these coolers. Regardless of the initial position of the bypass valves, the containment air coolers would receive an increase in post-LOCA flow due to the automatic isolation of the nonsafety-related portions of the service water system on an SI signal.

Allowance has been made in the selection of pipe wall thickness for corrosion effects. All underground service water and river water piping is protected by a coal tar enamel coating on the exterior. A cathodic protection system is also provided but not credited for aging management.

In addition to the component failure analysis presented in table 9.2-5, the following is the failure modes and effects analysis of the service water system under various emergency modes of operation.

Case 1: The following discussion is the evaluation of system operation during LOSP for both units. The primary impact on the system is due to the loss of the river water and instrument air systems.

The LOSP results in the diesel generators starting and loading. As the river water pumps are not automatically loaded onto the diesel generators, a LOSP will result in the loss of the river water system which provides makeup water to the service water pond. Per FSAR paragraph 9.2.5.3, the loss of the river water system will result in the service water system being placed in the recirculation-to-pond mode before the pond level reaches el 184 ft-0 in.

A loss of instrument air causes air-operated valves (AOVs) in the service water system to go to their failed position. Although some AOVs fail open on a LOSP, the service water miniflow valves (Q1/Q2P16V577, V578, and V579) and the dilution bypass AOVs (Q1/Q2P16V562 and

V563) fail closed. Following a LOSP, the turbine building supply MOVs (Q1/Q2P16V514, V515, V516, and V517) move to a throttled position.

Once plant operators isolate the nonsafety-related loads (the turbine building, the steam generator blowdown heat exchanger, letdown chillers, and the reactor coolant pump motor air coolers) on the affected units, service water flowrates to the safety-related components in at least one train are sufficient for safe long-term operation. The isolated loads are the nonsafety-related loads on the service water system and are the same components automatically isolated by an SI-generated Phase A isolation signal following a LOCA.

The reduced flowrates to safety-related components prior to operator actions are adequate in at least one train per unit during the initial 15 min following this event. The manual operator actions along with the automatic actions discussed above result in acceptable service water flowrates to the diesel generators and other safety-related components, thus ensuring safe long-term operation. The loss of any single component will not render the system incapable of supplying sufficient service water flowrates.

<u>Case 2</u>: The following discussion is the evaluation of the system operation under loss of the river water system combined with LOSP, with both units operating and subsequently being brought to cold shutdown.

On loss of the river water system, the operator will divert service water return flow to the pond. The operator has more than ample time to make the diversion.

The loss of any single component, including diesel generator, electrical bus, etc., will not render the system incapable of supplying the required service water flow.

The service water makeup line to the service water wet pit is designed such that there is always a path for return flow to the pond and/or wet pit. The spurious closure of one of valves QSP16V508-B(13), QSP16V507-A(14), QSP16V506-B(15), or QSP16V505-A(16) in the pond recirculation lines will not render the system incapable of providing the required service water flow. In the event of a loss of the river water system, the operator will verify that valves QSP16V508-B(13) and QSP16V507-A(14) are fully open and that valves QSP16V506-B(15) and QSP16V505-A(16) are closed.

<u>Case 3</u>: The following discussion is the evaluation of the system operation under loss of the river water system with offsite power available, with both units operating and subsequently being brought to cold shutdown.

The evaluation of this case is identical to case 2 except that offsite power is used instead of the diesel generators.

<u>Case 4</u>: The following discussion is the evaluation of the system operation under LOSP, while one unit is operating and subsequently being brought to cold shutdown and the other unit is undergoing a LOCA.

The storage pond level will decrease due to the loss of flow to the pond from the river water system. When the pond level drops to el 184 ft 4 in., it will be alarmed in the control room. The operator will then divert the service water return flow to the storage pond by opening valves

Q1P16V539-A(5), Q2P16V538-B(6), Q1P16V538-B(11), and Q2P16V539-A(12) and by closing valves Q1P16V546-A(7), Q2P16V545-B(8), Q1P16V545-B(9), and Q2P16V546-A(10). The operator has more than ample time to make the diversion.

As discussed in Case 1, a loss of instrument air causes AOVs in the service water system to go to their failed position. Although some AOVs fail open on a LOSP, the service water miniflow valves (Q1/Q2P16V577, V578, and V579) and the dilution bypass AOVs (Q1/Q2P16V562 and V563) fail closed. The failed open AOVs result in a reduction of flow to the safety-related components. Following a LOSP, the turbine building supply MOVs (Q1/Q2P16V514, V515, V516, and V517) move to a throttled position.

The SI-generated Phase A isolation signal associated with a LOCA automatically isolates the major nonsafety-related loads (the turbine building, the steam generator blowdown heat exchanger, letdown chillers, and the reactor coolant pump motor air coolers). Implementation of the operator actions on the non-LOCA unit also reduces the demand on the service water system by isolating the major nonsafety-related loads. These actions increase the service water flowrates to safety-related components in at least one train per unit for safe long-term operation.

The reduced flowrates to safety-related components prior to operator actions on the non-LOCA unit are adequate in at least one train during the initial 15 minutes following this event.

The loss of any single component, including a diesel generator, electrical bus, etc., will not render the system incapable of supplying the required service water.

<u>Case 5</u>: The following discussion is the evaluation of the system operation with offsite power available, while one unit is operating and subsequently being brought to cold shutdown and the other unit is undergoing a LOCA.

The evaluation of this case is identical to Case 4 except that offsite power is available instead of only having the diesel generators to supply electrical power. With offsite power available, the river water pumps will be available to provide makeup to the pond. As shown in Case 4, operation of the river water system is not required to bring the plant to a cold shutdown condition.

<u>Case 6</u>: The following discussion is the evaluation of the system operation under LOSP, with one unit operating and subsequently being brought to cold shutdown while the other unit is being brought to cold shutdown with a major line break resulting from an SSE.

An SSE seismic event may be postulated to result in a single-line break on site in any Seismic Category II (nonseismic) line in the service water system or in any supporting system. Bounding breaks may be postulated to occur on the 24-in. supply line in either the Unit 1 or Unit 2 turbine building or on the 10-in. supply line to either the Unit 1 or Unit 2 steam generator blowdown heat exchanger and letdown chillers in the auxiliary building.

The primary impact on the system from the LOSP is due to the loss of the river water and instrument air systems. As discussed in Case 1, loss of the river water system terminates makeup water to the service water pond. However, the service water system will be placed in the recirculation to pond mode before the pond level decreases to el 184 ft-0 in.

As discussed in Case 1, a loss of instrument air causes AOVs in the service water system to go to their failed position. Although some AOVs fail open on a LOSP, the service water miniflow valves (Q1/Q2P16V577, V578, and V579) and the dilution bypass AOVs (Q1/Q2P16V562 and V563) fail closed. Along with the unisolated line break caused by the SSE, the failed open AOVs result in a reduction of flow to the safety-related components. Following a LOSP, the turbine building supply MOVs (Q1/Q2P16V514, V515, V516, and V517) move to a throttled position.

Operator actions to isolate the major nonsafety-related loads (the turbine building, the steam generator blowdown heat exchanger, letdown chillers, and the reactor coolant pump motor air coolers) on both units within 15 min will isolate any postulated line break and increase service water flowrates to safety-related components in at least one train per unit for safe long-term operation.

The reduced flowrates to safety-related components prior to operator actions are adequate in at least one train per unit during the initial 15 min following this event. The manual operator actions discussed above result in acceptable service water flowrates to the system's safety-related components, thus ensuring safe long-term operation. The loss of any single component will not render the system incapable of supplying sufficient service water flowrates.

<u>Case 7</u>: The following discussion is the evaluation of the system operation with offsite power available, with one unit operating and subsequently being brought to cold shutdown while the other unit is being brought to cold shutdown with a major line break resulting from an SSE.

This evaluation is identical to Case 6 except that offsite power is available instead of only having diesel generators to supply electrical power. With offsite power, the river water system will be available to provide makeup water to the service water pond. Additionally, all AOVs will continue operation due to availability of the instrument air system. As shown in Case 6, neither the river water system nor the instrument air system is required to bring the plant to a safe shutdown condition.

<u>Case 8</u>: The following discussion is the evaluation of the system operation under LOSP, with one unit operating and subsequently being brought to cold shutdown while the other unit is being brought to cold shutdown with a fire in a single fire area.

The performance of the service water system following a postulated LOSP is described in Case 1. The addition of a fire on one unit, concurrent with a LOSP on both units, decreases the flowrates to the safety-related components on the fire-related unit. Some valves used to isolate the major nonsafety-related loads (the turbine building, the steam generator blowdown heat exchanger, letdown chillers, and the reactor coolant pump motor air coolers) can no longer be remotely operated due to fire-related failures. Under these conditions, the service water system can supply sufficient flow to safety-related components in at least one train for safe long-term operation.

Implementation of the operator actions on the unit unaffected by the fire would reduce the demand on the service water system by isolating the major nonsafety-related loads. These actions increase the service water flowrates to safety-related components in at least one train for safe long-term operation.

The reduced flowrates to safety-related components prior to operator actions on the unit unaffected by the fire would be adequate in at least one train during the initial 15 min following this event.

There are no single component failures associated with a fire as only failures caused by the fire are assumed. These fire-related failures will not render the system incapable of supplying sufficient service water flowrates.

9.2.1.4 Tests and Inspections

The river and service water systems are in constant use during plant operation. Therefore, the availability and performance of all normally functioning components is evident to plant operators. In addition to normal maintenance, service water pumps, valves, piping, and supports will be tested/inspected per the requirements of the plant Technical Specifications, Inservice Inspection Program, and Inservice Testing Program. Service Water Program activities credited as a license renewal aging management program are described in chapter 18, subsection 18.2.1.

9.2.1.5 Instrumentation Applications

Instrumentation is provided to indicate whether the system is operating properly. In the event of a LOCA, automatic controls operate the service water system, as required for safety.

Redundant supply trains from the river to the pond are furnished with pressure switches which alarm in the control room in the event of a header break. Valves are manually controlled to isolate the break and divert flow to the redundant train. The service water intake structure has redundant level indicators to monitor and control the storage pond level as follows:

A. High level (el 185 ft 9 in.) - Alarms operator.

B. Normal high level (el 185 ft 6 in.) - Trips river water pumps if no LOSP.

C. Normal low level (el 185 ft) - Starts river water pump in auto if no LOSP.

D. Low level (el 184 ft 4 in.) - Alarms operator.

E. Divert level (el 184 ft) - Actuates valves to divert river water flow directly to the wet pit.

F. Divert level (el 180 ft) - Actuates valves to divert service water to pond recirculation directly to the wet pit.

G. Low-low level (el 170 ft) - Alarms operator.

9.2.1.6 Service Water Treatment Systems

Prevention of fouling in the plant service water system piping and equipment will be accomplished by intermittent treatment of the service water using appropriate biocides and by the use of other appropriate water treatment chemicals if necessary. These may include the systems described below.

A. A chlorine dioxide generator may be provided to feed both service water systems at once with the generator output split between units or to feed both units on an alternating basis.

   The generator produces chlorine dioxide from the reaction of appropriate precursor chemicals as they are mixed in a stream of service water. The resulting chlorine dioxide solution is diffused into the service water flow using the solution lines.

   The chlorine dioxide generator has a flow switch which shuts the generator down upon low service water flow.

   The control panel is designed to allow adjustments to the length and frequency of chlorine dioxide treatment cycles and to the chlorine dioxide feed rate, as experience deems necessary.

B. Sodium Hypochlorite Addition

   Sodium Hypochlorite solution may be added to both service water systems at once, or to a single service water system

9.2.2 COOLING SYSTEM FOR REACTOR AUXILIARIES

9.2.2.1 Design Bases

The component cooling system, a closed cooling water system, transfers heat to the service water system from components which process radioactive fluid. The system is designed to function during all modes of plant operation, including heat removal following a LOCA. Portions of the component cooling system which are required for postaccident heat removal are redundant. Separate headers and redundant pumps and heat exchangers are provided so that a single failure will not preclude the supply of sufficient cooling water to the engineered safeguards.

The system is continuously monitored for radioactivity, and all components can be isolated.

9.2.2.2 System Description

This system consists of three component cooling pumps, three component cooling heat exchangers, a surge tank, and interconnecting piping. One pump and one component cooling heat exchanger will normally be operated to provide cooling water for various components located in the auxiliary building and containment. Drawings D-175002, sheets 1 through 3, and D-205002, sheets 1 through 3 show the component cooling system. Equipment associated with the component cooling system is shown in figures 1.2-4 and 9.1-3.

Component cooling will be provided for the following heat sources:

A. Residual heat exchangers [residual heat removal system (RHRS)].

B. Reactor coolant pump oil coolers and thermal barrier cooling coil (reactor coolant system).

C. Letdown heat exchanger (chemical and volume control system).

D. Excess letdown heat exchanger (chemical and volume control system).

E. Seal water heat exchanger (chemical and volume control system).

F. Recycle evaporator condenser, vent condenser, and distillate cooler (chemical and volume control system).

G. Waste evaporator condenser, vent condenser, and distillate cooler (waste processing system).

H. Waste gas compressors (waste processing system).

I. Residual heat removal pump seal heat exchangers (RHRS).

J. SI/charging pump lube oil (bearing) and gear oil heat exchangers (emergency core cooling system).

K. Spent-fuel pool heat exchangers (spent-fuel pool cooling system).

L. Sample heat exchangers (sample system).

M. Reactor coolant drain tank heat exchanger (waste processing system).

N. Waste gas hydrogen recombiners (waste processing system).

The component cooling system acts as an intermediate heat transfer system between potentially radioactive heat sources and the service water system. This additional leakage barrier greatly reduces the probability of radioactive releases to the environment resulting from a leaking component. The CCW is constantly monitored for radioactivity by monitors located in the pump suction headers.

One component cooling pump and one component cooling heat exchanger are required to accommodate the heat loads for full power operation. During normal power operation, the on-service train of CCW consisting of one component cooling pump and one component cooling heat exchanger is in operation to deliver CCW to the charging pump bearing oil and gear oil heat exchangers, the shell of the spent-fuel pool heat exchanger, the RHR pump seal cooler, and the miscellaneous equipment header. The other train of CCW may be run to deliver CCW to its train associated charging pump bearing oil and gear oil heat exchangers, the shell of the spent-fuel pool heat exchanger, and the RHR pump seal cooler. The manual valves in the interconnecting piping between the component cooling pumps and the component cooling heat exchangers and in the crossover lines between redundant headers are prepositioned such that, if the operating component cooling pump trips, the train A/B (swing) component cooling pump lined up on the same train starts automatically and supplies CCW to the component cooling heat exchanger in operation. The redundant CCW train is completely isolated from the train in operation by the prepositioned manual block valves. A standby heat exchanger is available should it become necessary to isolate the operating heat exchanger.

Flowrates and heat loads for the component cooling system components are given in tables 9.2-6 and 9.2-7, respectively. CCW and service water inlet and outlet temperatures for the CCW heat exchangers are summarized in table 9.2-8. During the normal cooldown mode, two component cooling pumps and heat exchangers are available. However, the heat loads for the two CCW heat exchangers differ, as shown in table 9.2-7. The normal cooldown temperatures listed in table 9.2-8 are for the CCW heat exchanger aligned to the onservice train. In the limiting case of a LOCA in one unit, cooldown in the other unit, LOSP and loss of electrical bus in the cooldown unit, one component cooling pump and heat exchanger will be available in the cooldown unit with the CCW heat exchanger operating at the abnormal cooldown temperatures listed in table 9.2-8.

The surge tank accommodates expansion, contraction, and inleakage of water and, in addition, ensures a reserve CCW supply until a leaking cooling line can be isolated. The tank is normally vented to the atmosphere; however, a radiation monitor in each of the component cooling pump inlet headers actuates an annunciator in the control room and automatically closes the valve in the surge tank vent line in the unlikely event that the radiation level has reached a preset level above the normal background.

Demineralized makeup water is supplied as required and delivered to the component cooling surge tank. A backup source of water is provided from the reactor makeup water system (RMWS).

The following equipment is provided:

A. Component Cooling Heat Exchangers

The three component cooling heat exchangers are located in the auxiliary building and are of the shell and straight tube type. Service water circulates through the tubes while CCW circulates through the shell side. Parameters are presented in table 9.2-9.

B. Component Cooling Pumps

The three component cooling pumps which circulate CCW through the component cooling system are horizontal, centrifugal units. Parameters are presented in table 9.2-9.

The component cooling pumps are located at elevations high enough to avoid any damage or malfunction due to the maximum flooding condition in the component cooling heat exchanger room.

Pump room coolers are used to maintain air temperature in the pump rooms at or below 104°F during normal operation. Refer to table 9.4-6A for post-design basis accident (DBA) room temperatures. Component cooling pump room coolers are discussed in paragraph 9.4.2.1.9.

C. Component Cooling Surge Tank

The component cooling surge tank accommodates changes in CCW volume. Parameters are presented in table 9.2-9. Provisions are made for makeup and addition of the chemical corrosion inhibitor to the component cooling loop. The surge tank has two surge line connections separated by a partition.

D. Component Cooling Valves

The valves used in the component cooling system are of standard design. Self-actuated, spring-loaded relief valves are provided for overpressure protection.

All MOVs in the component cooling heat exchanger room are located at elevations high enough to avoid any damage or malfunction due to a maximum flooding condition in that room.

E. Component Cooling Piping

All component cooling system piping is carbon steel with welded joints and connections wherever practical to minimize the possibility of leakage.

The portion of the CCW system piping located in the component cooling heat exchanger room is Seismic Category I. The CCW piping is routed such that the larger diameter piping is located at lower elevations than the smaller diameter piping. A failure of any nonseismic piping from other systems in the component cooling heat exchanger room will not affect the operation of the safeguard component cooling system.

9.2.2.3 <u>Safety Evaluation</u>

All portions of the component cooling system that are safety related are Seismic Category I design. Valves in the supply and return lines for nonsafety-related equipment will be automatically closed by a low-low level signal in the surge tank or remote manually from the control room. System components are designed to the codes given in table 9.2-10.

During the recirculation phase following a LOCA, at least one of the three component cooling pumps delivers flow to at least one residual heat exchanger, one low-head SI pump, one high-head SI pump, and one spent-fuel pool heat exchanger. At least one of the three component cooling heat exchangers is in operation to transfer heat to the service water system.

A failure analysis of pumps, heat exchangers, and valves is presented in table 9.2-11. No single failure in one CCW system train can cause a loss of the redundant train. During normal operation, the two trains of the CCW system are isolated from each other by manual isolation valves. Critical components are elevated above floor level so that the water level resulting from the release of water inventory in either CCW system train into the CCW equipment room will not damage components in the other train. Pumps are driven by constant speed motors. Pumps and motors are designed for a 25-percent overspeed condition. Pump and motor internals are enclosed in housings which would act to contain any debris resulting from a postulated internal failure. The motor coupling is of a one-piece design without bolts or nuts. Pump or motor missiles are not postulated.

All portions of the component cooling system within the containment are designed as Seismic Category I. Cooling water is circulated through all equipment even though a component may not be in service. None of the equipment within the containment will require CCW during the recirculation phase following a LOCA, and the supply and return lines will be automatically isolated outside the containment on a containment isolation signal. The component cooling system containment isolation valves inside the containment are located outside the secondary shield at an elevation well above the anticipated post-LOCA water level in the containment.

Outside the containment, the residual heat removal pumps, the residual heat exchangers, the spent-fuel heat exchanger, the component cooling pumps and heat exchangers, and associated valves, piping, and instrumentation are accessible for maintenance and inspection during power operation. System design provides for the replacement of one pump or one heat exchanger while the other units are in service.

During the recirculation phase following a LOCA, makeup to the component cooling system will be available from the RMWSs described in subsection 9.2.7.

Except for the normally closed makeup line and equipment vent and drain lines, there are no direct connections between the cooling water and other systems. The equipment vent and drain lines have manual valves which will normally be closed, except when the equipment is being vented or drained for maintenance or repair operations, or for the periodic connection to temporary CCW fluid cleanup systems that meet CCW system design pressure and temperature. The vent lines are capped as an additional safety feature.

The relief valves on the cooling water lines downstream from the sample, excess letdown, seal water, letdown, spent-fuel pool, and residual heat exchangers are sized to relieve the volumetric expansion occurring if the exchanger shell side is isolated when cooling with high temperature coolant flowing through the tube side. The valve set pressure is equal to the design pressure of the shell side of the heat exchangers.

The relief valve on the component cooling surge tank is sized to relieve the maximum flowrate of water which will enter the surge tank following a rupture of a reactor coolant pump thermal barrier cooling coil. The relief valve set pressure equals the design pressure of the component cooling surge tank. Initial protection is provided by an isolation valve which is located to isolate a particular branch and which will close automatically in the event of a thermal barrier coil rupture.

System fluctuations and lineups may result in either CCW or service water having the higher pressure of the two systems.

Leakage from the component cooling system will be detected by a drop in the level of the component cooling surge tank. Nonsafeguard equipment will be automatically isolated on low-low level.

The leaking component will then be located by sequential isolation or inspection of equipment in the system. If the leak is in the online CCW heat exchanger, the standby exchanger would be put on the line and the leaking exchanger isolated and repaired. During normal operation the leaking exchanger could be left in service with leakage up to the capacity of the makeup line to the system from the demineralized makeup water source, until such time as an alternate heat exchanger is placed in service.

Should a large tube-side to shell-side leak develop in a residual heat exchanger, the water level in the component cooling surge tank would rise; thus, the operator would be alerted by a high water level alarm. The atmospheric vent on the tank will close automatically in the event of a high radiation level at the CCW pump suction headers. If the leaking residual heat exchanger is not isolated from the component cooling loop before the inflow completely fills the surge tank, the surge tank relief valve will discharge to the auxiliary building floor drain tank.

Provision is also made to connect and operate a temporary demineralizer for purification of one CCW train.

9.2.2.4 <u>Tests and Inspection</u>

Because the component cooling system is in constant use during plant operation, the availability and performance of all normally functioning components of the inservice train are evident to plant operators. The MOVs in the cooling water supply to the residual heat exchangers that are required to open for post-LOCA heat removal can be tested during power operation.

CCW pumps and valves are tested in accordance with the Technical Specifications.

9.2.2.5 <u>Instrumentation Applications</u>

Low flow alarms in the CCW return lines from the seal heat exchanger of the low-head SI pumps sound an alarm in the control room. Each of these pumps normally receives flow from that CCW pump which is powered from the associated emergency bus.

The component cooling pumps and heat exchangers are fully instrumented for flow, pressure, and temperature so that any degradation in performance can be noted and corrective action taken.

High pressure switches on the return line from each reactor coolant pump thermal barrier cooling coil and a high flow switch on the common return from all three pumps will initiate the rapid closure of isolation valves to isolate the reactor coolant pumps in the event of a leak in the thermal barrier.

Control room indication of surge tank level and high, low, and low-low level alarms in the control room keep the operator informed of any leakage into or out of the component cooling system.

Actuation of the remote manual makeup valves is normally initiated on a low level alarm. Should the surge tank reach low-low level, the cooling water lines for all nonsafety-related equipment are automatically isolated.

The CCW is constantly monitored for radioactive leaks into the system by radiation monitors in the pump suction headers.

9.2.3 DEMINERALIZED WATER MAKEUP SYSTEM

9.2.3.1 Design Bases

One demineralized water makeup system is designed to provide demineralized water for Units 1 and 2 during all phases of plant operations. This includes water for filling, flushing, and making up losses during startup, shutdown, refueling, power, and maintenance operations.

This system has no nuclear safety function. It is designed and installed to the requirements of nonnuclear safety (NNS) equipment under the American Nuclear Society safety criteria.

9.2.3.2 System Description

The piping and instrumentation diagram (P&ID) for the demineralized water makeup system is shown on drawings D-175047, sheets 1 and 2, and D-205047. During normal power operation this system receives demineralized water from the plant water treatment system and supplies it as makeup to the following components:

A. Reactor makeup water storage tanks.

B. Boric acid batching tanks.

C. Resin fill tanks.

D. Component cooling surge tanks.

E. Spent-fuel pools.

F. Condensate storage tanks.

G. Turbine building auxiliary boiler.

The demineralized water makeup system is also a source of cleaning and flushing water for demineralizers, evaporators, pumps, piping, tanks, and the high-pressure water spray decon unit.

The system is composed of one 200,000-gal demineralized water storage tank, 3 demineralized water makeup pumps, and associated valves, piping, and instrumentation.

9.2.3.2.1 Components

A. Demineralized Water Storage Tank

One 200,000-gal demineralized water storage tank provides the demineralized water requirements for Units 1 and 2 during all phases of plant operations. The vinyl-lined tank is constructed of carbon steel and is designed to the standards of the American Water Works Association D-100.

B. Demineralized Water Pumps

Three demineralized water pumps take suction from the demineralized water storage tank and supply demineralized water to both units. These centrifugal pumps are constructed of carbon steel.

C. Valves

Diaphragm valves and globe valves are used to regulate the flow of demineralized water to the various components. These valves are located adjacent to the components supplied with demineralized water to facilitate filling and maintenance operations.

D. Piping

Demineralized water makeup system piping does not handle radioactive liquid and is therefore constructed of carbon steel. Piping joints and connections are welded, except where flanged connections are required to facilitate equipment removal for maintenance.

9.2.3.3 Safety Evaluation

The demineralized water makeup system is not required for any safety-related functions. Consequently, the failure of any part of this system will not adversely affect the nuclear safety of the plant.

The demineralized water storage tank is located so that water from a tank rupture would flow into the yard drainage system without affecting any safety-related equipment.

9.2.3.4 Tests and Inspections

The demineralized water makeup system is operated intermittently during all phases of plant operations. The major components of the system are located in the yard and are easily accessible for inspection at any time.

9.2.3.5 Instrumentation Applications

The instrumentation that is available for the demineralized water makeup system is shown in drawings D-175047, sheets 1 and 2, and D-205047. Alarms are provided as noted.

9.2.4 POTABLE AND SANITARY WATER SYSTEM

9.2.4.1 Design Bases

The potable and sanitary water system will provide water for drinking and sanitary purposes. The system has no safety function and is Safety Class NNS.

The potable and sanitary water system is designed to supply 300 gal/min of water per unit. The water will be chemically treated in accordance with all State and Federal regulations.

9.2.4.2 System Description

The P&ID for the potable and sanitary water system is shown in drawing D-170127. The system water is supplied to a 20,000-gal capacity sanitary water storage tank from the well water system, which is discussed in subsection 9.2.9.

There are three 300-gal/min sanitary water pumps (one pump is a spare) which take their suction from the storage tank. Two of the pumps will be installed with Unit 1 and the third with Unit 2. The piping system is arranged to receive the third pump during the installation of the Unit 2 pump.

Chlorine will be added to meet State and Federal requirements. Residual chlorine content will be analyzed and regulated to maintain government standards.

9.2.4.3 Safety Evaluation

The design of the potable and sanitary water supply provides water that will meet all sanitary requirements. The design of the piping system ensures that impurities cannot enter the system by backflow. The system waste water does not contain any radioactive material and will be directed to a sewage treatment system.

There are no safety implications since this system is shared between Unit 1 and Unit 2.

9.2.4.4 Tests and Inspections

The system is proved operable by its use during normal plant operation. Periodic samples will be tested to ensure meeting water standards.

9.2.4.5 Instrumentation Applications

The sanitary water tank is provided with a level controller which maintains the level in the sanitary water storage tank. The sanitary water pump discharge supply header will be provided with a self-actuated, pressure reducing regulator to maintain system pressure limit.

Local and remote indications and alarms are provided as required for monitoring and protection of the components in the system.

9.2.5 ULTIMATE HEAT SINK

The ultimate heat sink consists of the storage pond described in paragraph 2.4.8.1 and the service water system described in subsection 9.2.1.

9.2.5.1 Design Bases

A. The ultimate heat sink is capable of providing sufficient cooling for at least 30 days, to permit simultaneous safe shutdown and cooldown of both nuclear reactor units and to maintain them in a safe shutdown condition or, in the event of an accident in one unit, to permit safe control of the accident and simultaneously permit safe shutdown and cooldown of the other unit and maintain it in a safe shutdown condition. These requirements are in conformance with Regulatory Guide 1.27.

B. Procedures for ensuring continued capability beyond the 30-day requirement are available in conformance with Regulatory Guide 1.27.

C. The ultimate heat sink has the capability to perform safety functions required by Design Basis A during and after any one of the following events, in conformance with Regulatory Guide 1.27:

   1. The most severe natural phenomena expected at the site, with appropriate ambient conditions, but with no two or more such phenomena occurring simultaneously.

   2. The site-related events (e.g., transportation accident, river diversion) that historically occurred or that may occur during the plant lifetime.

   3. Reasonably probable combinations of less severe natural phenomena and/or site-related events.

4. A single failure of nonseismic manmade structural features.

9.2.5.2 System Description

Figure 2.3-27 shows the location of the Seismic Category I pond, which stores water pumped from the river prior to its use in the plant service water system and cooling towers. Additional information on the pond may be found in paragraph 2.4.8.1. As described in subsection 9.2.1, the service water system provides cooling water during both normal and accident conditions. All components necessary to perform this function are Seismic Category I, meet single-failure criteria, are operable during LOSP, and sustain no loss of function during adverse environmental conditions.

Between el 184.0 and 185.0, up to approximately 100 acre-ft of water is in storage. Enough water is available between elevations 185.0 and 184.0 to operate two units for several hours at full power without the river water system in operation before implementing shutdown procedures. If the pond level drops below el 184 ft, shutdown procedures must begin. Indications of river pump operation and storage pond level are provided in the control room. Therefore, insofar as loss of the river intake structure and equipment is concerned, the need to shut down is indicated by the storage pond level. An alarm will sound in the control room when this pond is lowered to el 184 ft 4 in. Under two-unit operation, this will allow 90 min to evaluate the situation and shut down if required.

9.2.5.3 Safety Evaluation

The design of the ultimate heat sink provides sufficient capacity and reliability to ensure compliance with Regulatory Guide 1.27, Ultimate Heat Sink.

The storage pond has the capability to provide sufficient cooling for at least 30 days to permit simultaneous safe shutdown and cooldown of both nuclear reactor units and to maintain them in a safe shutdown condition or, in the event of an accident in one unit, to permit safe control of the accident and simultaneously permit safe shutdown and cooldown of the other unit and maintain it in a safe shutdown condition. The water in storage is sufficient to ensure that evaporation losses during the 30-day period will not reduce the water surface elevation to an unacceptable level. In evaluating the capability of the storage pond to meet its requirements, the following conservative assumptions have been made:

A. The surface of the pond at the beginning of the analysis is assumed to be at el 184 ft 0 in. This assumption is conservative as the pond level is normally maintained between el 185 ft 0 in and 185 ft 6 in.

B. Initial pond temperature is 95.3°F. Temperature records of the Chattahoochee River(1) reveal the maximum temperature of record is 93°F, recorded at West Point, Georgia, in August 1955. It is estimated that the water temperature can increase 2.3°F in the pond, bringing the maximum initial temperature to 95.3°F. Peirce(2) substantiates this value with his measurements of five Alabama reservoirs.

C. No makeup is available to the service water pond from the river water system, from rain, or from any other source for a period of 30 days consistent with Regulatory Guide 1.27. Makeup will be available following this 30-day period.

D. The service water system is placed in the recirculation to pond mode before the pond level decreases to el 184 ft 0 in. by closing valves Q1P16V545, Q1P16V546, Q2P16V545, and Q2P16V546, and opening valves Q1P16V538, Q1P16V539, Q2P16V538, and Q2P16V539. It is assumed these valves are used in the realignment of the system in order to prevent the potential loss of pond inventory through the makeup supply to the circulating water system. In the recirculation to pond mode, the heat loads from the service water system of both units are returned to the service water pond.

E. A loss of the pond dam is not considered to be a credible failure. A description of the seismic analysis used for the storage pond is given in section 2.5.

F. The divert system, which was originally intended to divert service directly to the service water intake structure following a loss of the dam, is either inoperable or will be defeated by operator action. Therefore, the service water system will not go into divert when the pond level drops to el 180 ft 0 in.

G. A LOSP is postulated to occur coincident with the beginning of the analyzed 30-day period and offsite power is not restored during the 30-day period. All five diesels are in operation throughout the 30-day period in order to provide the maximum probable heat load on the pond as further discussed in assumption H below.

H. The service water pond is subject to its maximum probable heat load during the 30-day period. The calculation of maximum probable heat loads is conservative and includes a 5,000,000-Btu/h heat load margin to account for uncertainties in actual heat loads and a 5,000,000-Btu/h margin for possible future service water system heat loads. As a point of reference, this total margin of 10,000,000 Btu/h is approximately equivalent to the heat load imposed on the service water system by one diesel generator.

Seven different heat load versus time profiles were evaluated as listed below:

<u>Service Water System Heat Load vs. Time Profiles</u>

Case 1: LOCA in one unit with a minimum ESF cooldown. Normal shutdown in the other unit with a 50°F/h cooldown rate.

Case 2: LOCA in one unit with a minimum ESF cooldown. Normal shutdown in the other unit with a 16-h cooldown.

Case 3: LOCA in one unit with a maximum ESF cooldown. Norma l shutdown in the other unit with a 50°F/h cooldown rate.

Case 4: LOCA in one unit with a maximum ESF cooldown. Normal shutdown in the other unit with a 16-h cooldown.

Case 5: Simultaneous normal shutdown of both units with a 50°F/h cooldown rate.

Case 6: Simultaneous normal shutdown of both units with a 16-h cooldown.

Case 7: Simultaneous normal shutdown of both units, one unit with a 50°F/h cooldown rate and the other unit with a 16-h cooldown.

NOTES

- Minimum ESF cooldown indicates that one train of residual heat removal, containment spray, and containment coolers is in service. Maximum ESF indicates that both trains of these systems are in service.

- The 50°F/h and 16-h cooldown refer to the rate of cooldown of the RCS from 350°F to 140°F. This is the temperature range in which the RHRS operates.

Multiple cases were analyzed because the function of heat input rate versus time can have an effect on the peak service water inlet temperature. Cases with less than the maximum integrated heat load were evaluated to ensure the calculation identified the peak service water inlet temperature. As an example, it is possible that a case with a high heat input rate near the end of the 30-day period may result in a higher peak service water inlet temperature than a case with a higher integrated heat load but with a lower heat input rate at the end of the 30-day period.

I. Varying service water system flowrates were assumed and evaluated to ensure that the UHS evaluation places no constraints on service water system flowrates. This evaluation was required as (1) the service water system flowrate during the 30-day shutdown/cooldown period may vary significantly depending on plant conditions and operator preference and (2) it is not obvious, due to the complexity of the pond heat transfer model, whether higher or lower flowrates would tend to result in higher peak service water inlet temperatures.

J. For all pond water evaluations, the volume of water in the pond and the surface area of the pond as assumed in the evaluation is defined by figure 9.2-2. These curves are estimates of the pond volume and area following 40 years of plant operation. The curves were prepared by extrapolating the pond volume and surface area measurements made yearly from 1985 to 1989. Based on these curves, at a pond elevation of 184 ft 0 in, the volume of the pond assumed in the evaluation is 1325 acre-ft, and the surface area of the pond assumed in the evaluation is 89 acres.

The renewed operating licenses authorize an additional 20-year period of extended operation for both FNP units, resulting in a plant operating life of 60 years. The pond volume calculation was evaluated as a time-limited aging analysis (TLAA) during the license renewal process in accordance with 10 CFR 54.21. It was determined that the current pond volume calculation remains conservative assuming a plant operating life of 60 years. See chapter 18, subsection 18.4.5.

K. A seismic event may result in one line break of any nonseismic (Seismic Category II) service water line on site. Should a line break occur during the 30-day shutdown/cooldown period, the analysis assumes it will be quickly isolated and any losses of pond volume through a service water pipe break will not be significant.

As discussed in paragraph 9.2.1.3, the service water system design basis assumes that a service water system line break in the nonseismic turbine building, containment, or auxiliary building service water piping will be isolated within 15 min. The largest break which can be postulated occurs at the turbine building inlet and results in a loss of not more than 36,750 gal/min. A break flowrate of 36,750 gal/min for a period of 30 min (twice the period of time assumed in the design basis of the system) results in an inventory loss of approximately 1,100,000 gal or 3.4 acre-ft. This is a small volume in comparison to the minimum initial pond volume of 1325 acre-ft and a small loss in comparison to other assumed plant losses (service water that is supplied to the plant but not returned to the pond when in recirculation mode) of 1145 gal/min for the entire 30-day period or a total loss of approximately 150 acre-ft.

L. The pond seepage rate is assumed to be 15 ft^3/s at the initial water level of 184 ft 0 in and to decrease as the pond level decreases. Testing has indicated the actual seepage rate to be less than 3 ft^3/s. However, due to problems associated with field verification of such low seepage rates, the higher value of 15 ft^3/s, which includes conservative allowances for measurement errors, was assumed for the analysis.

The assumption that seepage decreases as the level in the pond decreases is appropriate as actual seepage would decrease with decreasing pond depth and decreasing area of the pond bottom. The UHS evaluation models the pond as a grid of 200-ft x 200-ft cells. In the model, as the pond inventory decreases, cells in shallower areas of the pond become dry and are therefore "inactive." Seepage is modeled as a loss of 0.152 ft^3/s from each active cell. There are 99 cells that are active at el 184 ft 0 in (15 ft^3/s / 99 cells = 0.152 ft^3/s per cell).

Thus, as the pond level decreases and cells become inactive, the modeled seepage rate decreases.

M. Meteorological data from the National Oceanic and Atmospheric station at Columbus, Georgia, are sufficiently representative of the meteorological conditions at the Farley Nuclear Plant site to allow its use as the meteorological record for this analysis. A 42-year meteorological record (1948 to 1989) was examined which meets the Regulatory Guide 1.27, Revision 2, recommendation that a record of at least 30 years be evaluated.

N. Regulatory Guide 1.27, Section B, recommends that "meteorological conditions considered in the design of the sink should be selected with respect to the controlling parameters and critical time periods unique to the specific design of the sink."

Controlling parameters for the service water pond are dry bulb, wet bulb, and dewpoint temperatures; windspeed and direction; and solar radiation.

Critical time periods considered in the analysis are 1 day, 7 days, and 30 days for the maximum intake temperature and 30 days for maximum evaporation. The 1-day period was selected to maximize the intake temperature, the 30-day period was selected as it coincides with the 30-day Regulatory Guide 1.27 design period, and the 7-day period was selected as an intermediate value in anticipation of a pond response temperature on the order of 1 week.

O. The service water intake structure stoplogs, which extend from the bottom of the wetpit to el 180 ft 0 in, were assumed to be in place when the event begins. It was also assumed that the stoplogs are removed before the pond level drops below el 181 ft 10 in. This action is required to ensure that sufficient water can enter the service water wetpit.

P. A simplifying assumption is made that the heat transferred from heat exchangers to the service water system is equal to the maximum design heat transfer value independent of the service water system flowrate. This is conservative as lower flowrates would tend to reduce the heat input to the pond.

Q. See figure 3.8-28 for the service water intake structure and drawings D-171417 and D-171419 for the river water discharge to pond structures.

9.2.5.4 <u>Description of Analysis Method and Summary of Results</u>

An analysis of the ultimate heat sink was conducted to evaluate the ability of the Farley Nuclear Plant service water pond to function as an ultimate heat sink in accordance with NRC Regulatory Guide 1.27. The service water pond is considered to be an acceptable ultimate heat sink based on cooling water capacity and heat storage/dissipation capabilities if the following two criteria are met:

1. The maximum service water intake temperature does not exceed the maximum temperature acceptable for the continued operation of safety-related equipment during the accident.

2. The water losses over the 30-day cooldown period do not cause the pond level to drop below el 161 ft 0 in. This is the minimum pond level required to permit sufficient water to enter the service water intake structure.

The analysis consists of two parts. In one part, offsite meteorological data were examined and periods of maximum natural heating and evaporation were identified. Use was made of an offsite station because the onsite meteorological record was only 13 years in length, too short for the analysis suggested in Regulatory Guide 1.27. To select an appropriate offsite meteorological station from candidate sites, representative water temperatures (called response temperatures) for a pond with an average depth equal to that of the service water pond were calculated. Response temperature records at 1- or 3-h intervals were created--one based on Columbus, Georgia, meteorological data and one based on Tallahassee, Florida, data. These stations were the nearest National Oceanic and Atmospheric Administration (NOAA) stations reporting a full set of meteorological parameters; each station has a 42-year record (1948 to 1989) available on magnetic tape.

Daily averages of the computed response temperatures were then compared to measure pond temperatures, for which there were 13 years of record. Measured pond temperatures are influenced not only by meteorological conditions, but also by the pumping of water from the Chattahoochee River into the service water pond for normal operations and by the occasional recirculation of service water heat loads to the pond. Response temperatures were plotted against measured pond temperatures in order to provide a basis for comparison of the two candidate offsite meteorological stations and to demonstrate general agreement with the calculated response temperatures. The calculated response temperature record was then used to determine periods of maximum natural heating and maximum evaporation of the pond. These periods were determined to be mid-July 1980 and late June 1986, respectively, and to be based on the Columbus, Georgia, meteorological record.

The second part of the analysis was the detailed computation of pond hydraulics and heat transfer using a time-varying, three-dimensional finite difference code. The application of the code to the service water pond included gridding the pond into 200-ft x 200-ft horizontal cells and 3.3-ft vertical layers, mapping pond intake and discharge structures onto the resulting grid, and applying the time-varying boundary conditions of (1) meteorological data for the chosen period, (2) heat loads and pumping rates, and (3) seepage. The grid layout and the location of the pond inlet/outlet structures are shown on figure 9.2-8. The heat load and pumping data consisted of seven cases, four of which modeled a post-LOCA shutdown on one unit and a normal shutdown on the other unit, and three of which were two-unit normal shutdowns. These cases are listed in item H of paragraph 9.2.5.3.

Each of the boundary condition effects was integrated by the model as it simulated pond circulation, drawdown, and temperature at computational time steps of 7.5 min or less. For example, the code considered decreasing pond volume and area in response to seepage and evaporation, thereby reducing the amount of heat transferred to the atmosphere. Other transient events, such as the removal of the service water intake structure stoplogs as the water surface elevation reaches 181 ft 10 in. were also included in the simulation.

The final analysis showed that under historic meteorological conditions, maximum pond temperatures were reached 30 days after initiation of the shutdown. The following table shows the peak service water intake temperatures and minimum elevation at the end of 30 days:

1980 Columbus, GA, Meteorological Data for Maximum Temperature:

Heat Load Case No.	Peak Service Water Intake Temperature	Pond Elevation at End of 30 days
3 and 4	106.2°F	172 ft 4 in.

1986 Columbus, GA, Meteorological Data for Maximum Evaporation:

Heat Load Case No.	Peak Service Water Intake Temperature	Pond Elevation at End of 30 days
4	98.1°F	172 ft 1 in.

The calculated peak service water inlet temperature is 106.2°F, which is reached at the end of the 30-day period analyzed in accordance with Regulatory Guide 1.27. The design basis maximum service water temperature for safety-related components has been established as 106.2°F in accordance with this evaluation.

Two different cases both resulted in a 106.2°F peak temperature. These are cases 3 and 4, which involve maximum ESF cooldown on the LOCA unit and either a 50°F/h cooldown rate (case 3) or a 16-h cooldown (case 4) on the other unit. Figures 9.2-3 and 9.2-4 show the service water inlet temperature versus time curves for the 30-day post-LOCA period for cases 3 and 4.

Based on the meteorological data for maximum evaporation, at the end of the 30-day period, the pond elevation had dropped from el 184 ft 0 in. to 172 ft 1 in., which is a decrease of 11 ft 11 in. The final elevation is acceptable as it is above el 161 ft 0 in. The pond volume at the end of the 30-day period is 333 acre-ft, which is a reduction of 992 acre-ft (75-percent reduction) from the assumed initial volume of 1325 acre-ft. Of this 992 acre-ft loss, 88 acre-ft (9 percent of the total loss) are due to evaporation, 750 acre-ft (76 percent of the total loss) are due to seepage, and 154 acre-ft (16 percent of the total loss) are due to plant losses.

Therefore, it is concluded that the service water pond can supply the plant's DBA cooling requirements for the required 30-day period and that the recommendations of Regulatory Guide 1.27 have been met.

If the river water system were to be unavailable for pond makeup, continued capability of the pond after 30 days could be ensured by the use of portable pumps or water trucked to the pond.

A description of the seismic analysis used for the storage pond is given in section 2.5. A safety evaluation of the service water system is given in paragraph 9.2.1.3. An evaluation of the capability of the ultimate heat sink under adverse water conditions is given in section 2.4.

9.2.5.5 Tests and Inspections

Periodic inservice testing of the service water pond will be performed to demonstrate that the seepage rate does not exceed that used for the service water pond thermal analysis in subsection 9.2.5.

Additional testing and inspections for the station service water system are discussed in paragraph 9.2.1.4.

Periodically, the instrumentation described below can be checked for operability.

9.2.5.6 Instrumentation Applications

Instrumentation is provided to indicate whether the station service water system is operating properly. In the event of a LOCA, automatic controls operate the service water system (as required for safety) and the river water system.

The water level in the pond is continuously monitored in the service water pump wet pit, as discussed in subsection 2.4.8 and paragraph 2.4.11.6.

9.2.6 CONDENSATE STORAGE FACILITIES

9.2.6.1 Design Bases

The condensate storage facility provides makeup and surge capacity to compensate for changes in the turbine plant systems inventory and provides reserve supply for emergency shutdown decay heat removal, should the normal feedwater system fail.

The condensate storage tank and all piping and components required to supply the auxiliary feedwater pumps are Safety Class 2B and Seismic Category I.

9.2.6.2 System Description

The condensate storage facility consists of a 500,000-gal capacity steel tank, the bottom of which is at grade. The condensate makeup connection is located so that 164,000 gal remain in the tank for emergency use. The auxiliary feedwater pump intake lines are near the bottom of the tank. The tank is lined with a corrosion resistant coating and contains a diaphragm for water chemistry control.

9.2.6.3 Safety Considerations

The carbon steel tank fulfills the requirements for water chemistry and corrosion control. Radioactive concentrations are held to the limits of plant technical specifications. The

condensate makeup suction elevation ensures a reserve of 164,000 gal for emergency decay heat removal.
In order to ensure the 164,000-gal reserve, the lower 12 ft of the tanks are designed to withstand ruptures caused by missiles. Certain connections to the Unit 1 and Unit 2 CSTs, within the lower 12 ft of the tank, are protected by structures. The subject connections are: CST drain, vacuum degasifier tank connection, and the sensing lines for the level transmitters.

However, portions of the AFW pump's minimum flow recirculation line and the flow instrumentation lines attached to the AFW pump suction pipes are located outdoors and exposed to a potential tornado missile. An analysis was performed to ensure that adequate reserve margin in the CST water is available considering a rupture of these lines from missile impact. The result of the analysis showed that the reserve water margin available in the protected volume (164,000 gal) in the CST is sufficient to maintain the plant at hot standby for a 2-h period after a reactor trip, followed by a 4-h cooldown to 350°F, including the total water volume lost from the assumed ruptured lines (AFW pump recirculation lines isolated within 30 minutes, and four unisolated flow instrumentation lines). The assumptions used to determine this evaluation were: initial low-low steam generator water level, steam generator refilled to no-load programmed level at completion of cooldown to 350°F, and the feedwater source temperature at 110°F.

The Technical Specification basis is to ensure sufficient water is available to maintain the RCS at hot standby for 9 h with steam discharge to the atmosphere concurrent with a total loss of offsite power. Additional conservative assumptions were used in sizing the CST in conjunction with maintaining the plant at hot standby for 2 h, followed by a 4-h cooldown to 350°F.

9.2.6.4 Tests and Inspections

Only visual inspection is required.

9.2.6.5 Storage Tank Fill

The condensate storage tank main fill line is from the water treatment system. The condensate tank can also be filled from the demineralized water tank as a backup to the main fill line. During load changes and resulting condenser high level, the condensate/feedwater system may be manually aligned to overflow to the condensate storage tank.

9.2.6.6 Flooding Due to Storage Tank Rupture

The worst case to cause flooding of the new fuel storage building due to the rupture of the condensate storage tank is a 20-ft^2 round hole punched by a 4000-lb car hitting the tank at an elevation of 12 to 25 ft from the ground at the critical location. The lower 12 ft of the tank are protected against missile hazards as described in paragraph 9.2.6.3. For a 20-ft^2 hole with its center at 14 ft above the ground facing the entrance door of the new fuel storage building, a jet stream of up to 600 ft^3/s will hit the ground at a distance of 39 ft from the edge of the tank at a 36° angle from the horizontal plane with a jet diameter of 3.8 ft. The time required to empty the tank from full to 12 ft from the ground is about 160 s. If the location of the rupture hole is raised from 14 ft up to 25 ft above the ground, the discharge rate will decrease to 450 ft^3/s, and the horizontal distance the jet travels before it hits the ground will increase to 41 ft; the angle of the jet before hitting the ground will increase from 36° to 51°.

Because of the relative position of the storage tank and the new fuel storage building, it is possible that the large jet flowing out from the ruptured hole will impinge on the road in front of the entrance door of the new fuel storage building. This entrance is protected by a Seismic Category I door, designed to withstand tornado loads, which is normally closed. The door opens in a direction that would cause the door to deflect the water jet away from the building and will withstand the forces that would result from the water jet impinging directly on the door in any opened or closed position (figures 9.2-9 and 9.2-10). Therefore, little or no water is expected to enter the building during the postulated event. However, no safety-related equipment would be damaged by water entering the door from this source. The auxiliary building external wall would not be damaged by direct impingement of the water jet from the ruptured tank.

The 8 surface drainage grates in the vicinity of the storage tank can drain up to about 60 ft^3/s of water or 10 percent of the maximum discharge resulting from a 20-ft^2 ruptured hole. The rest of the water will be retained on the ground and cause flooding in the area up to el 154.5 ft, which is 6 in. below the floor slab elevation of the building. The flooding can last up to 9 min.

The maximum discharge rate can be 12 ft^3/s for an 8-in. ruptured hole at a height of 12 ft from the ground. This discharge rate will not cause flooding.

9.2.7 REACTOR MAKEUP WATER SYSTEM

9.2.7.1 Design Bases

The RMWS provides nonborated makeup water for the reactor coolant system and emergency makeup to the component cooling system.

The RMWS is also used to provide makeup and flushing water for various other components listed in paragraph 9.2.7.2.

All piping, valves, and other components shown in drawings D-175036 and D-205036 are Seismic Category I, with the exception of that piping shown with an HCD or HBD number (nonseismic).

The Category I portion of this system is designed, fabricated, and installed to the requirements of American Society of Mechanical Engineers Section III, Class 3 components.

9.2.7.2 System Description

The P&ID for the RMWS is shown in drawings D-175036 and D-205036.

The RMWS provides a source of recycled demineralized water which is used as makeup for the following components:

A. Boric acid blenders.

B. Chemical mixing tanks.

C. Pressurizer relief tanks.

D. Reactor coolant pump standpipes.

The RMWS provides a source of flushing water to the liner fill system and the fill system sampler for the solidification and dewatering facility. The RMWS also provides a source of cleaning and flushing water for various equipment such as evaporators, pumps, and tanks.

The Units 1 and 2 RMWS are cross-connected such that the reactor makeup water pumps and storage tank of one unit can supply reactor makeup water to the users of the other unit. This cross-connection provides for uninterrupted operation of the units when one of the RMWS is out of service.

The system is composed of one 200,000-gal reactor makeup water storage tank, two reactor makeup water pumps, and associated valves, piping, and instrumentation.

9.2.7.2.1 Components

A. Reactor Makeup Water Storage Tank

The 200,000-gal reactor makeup water storage tank provides the makeup water for the reactor coolant system and stores the distillate from the recycle and waste evaporators. These stainless steel tanks contain a diaphragm membrane and the Unit 1 tank contains a 150-gal/min recirculating vacuum degasifier to exclude oxygen from the makeup water.

B. Reactor Makeup Water Pumps

Two reactor makeup water pumps take suction from the reactor makeup water storage tanks. These pumps are used to feed dilution water to the boric acid blender and to supply makeup water for intermittent flushing of equipment and piping.

Each pump is sized to match the maximum letdown flow from the reactor coolant system. One pump serves as a standby for the other. These centrifugal pumps are constructed of austenitic stainless steel.

C. Valves

Diaphragm valves are used to regulate the flow of demineralized water to the various components. Air-operated globe valves are used to regulate the flow of makeup water to the reactor coolant system.

D. Piping

The RMWS piping is fabricated of austenitic stainless steel. Piping joints and connections are welded, except where flanged connections are required to facilitate equipment removal for maintenance.

9.2.7.3 Safety Evaluation

The sole safety function of the RMWS is to provide makeup water to the component cooling surge tank in the event of a low level in that tank resulting from a leak in the component cooling system and in the event that the demineralized water makeup system is unavailable.

The RMWS is provided with two pumps; each is a backup for the other, and each is on a separate emergency power bus.

Reactor makeup water pumps 1A and 1B (drawings D-175036 and D-205036) are supplied with emergency power through their motor control centers, 1A and 1B, respectively. The motor control centers are fed from the 4-kV emergency buses 1F and 1G, respectively, through the 600-V emergency load centers 1D and 1E, respectively.

Therefore, the CCW and other essential systems will receive makeup water from the reactor makeup water storage tank in the event of LOSP.

9.2.7.4 Tests and Inspections

The RMWS is operated intermittently during all phases of plant operations. The major components of the system are located in the yard and are easily accessible for inspection at any time.

9.2.7.5 Instrumentation Applications

The instrumentation that is available for the RMWS is shown in drawings D-175036 and D-205036. Alarms are provided as noted.

9.2.8 PLANT WATER TREATMENT SYSTEM

9.2.8.1 Design Bases

The plant water treatment system is designed to provide both Units 1 and 2 with normal demineralized water requirements during all phases of plant operations. This includes water for filling, flushing, and making up losses during startup, shutdown, refueling, power, and maintenance operations.

This system does not service any nuclear safety function and is Safety Class NNS .

9.2.8.2 System Description

A simplified flow diagram of the plant water treatment system is shown on figure 9.2-11.

The plant water treatment system equipment is housed in a building separated from the main power generation building. The system consists of a clarifier which receives its water supply from the nonsafety-related portion of the service water system and supplies a 200,000-gal capacity water storage tank with clarified water.

The filtered and demineralized water will be stored in storage tanks located in the yard before being pumped to plant systems.

The clarifier is designed to provide 700 gal/min of clarified water at full capacity but may be operated at lower rates depending on demand.

Each demineralized water plant is designed to produce 320 gal/min of demineralized water. Each plant may be operated at lower rates depending on the demand.

The following equipment is provided for the clarifier:

A. Clarifier Tanks

   The two clarifier tanks are each rated at 350 gal/min. The tanks each contain a flocculator, settling tube, and filter sections.

B. Chemical Feed Equipment

   Hypochlorite, alum, caustic, and polyelectrolyte chemical feed systems automatically feed the influent line to the clarifier tanks.

C. Clarifier System Pumps

   1. Clarifier supply pumps - Two pumps, rated at 800 gal/min and 50 ft total dynamic head (TDH), pump service water from the clarifier supply sump to the clarifier. During normal operation, one pump would be running with one pump as a spare.

   2. Clearwell pumps - Three pumps, rated at 400 gal/min and 60 ft TDH, pump clarified water from the clarifier clear well to the water storage tank. During normal operation, two pumps will be running with one pump as a spare.

   3. Backwash pump - One pump, rated at 1750 gal/min and 50 ft TDH, supplies clarified water from the water storage tank to the clarifier for backwash.

4. Surface wash pump - One pump, rated at 60 gal/min and 160 ft TDH, supplies clarified water from the water storage tank to the clarifier during backwash.

D. Waste Neutralization System

Waste water is collected in the waste neutralization sump and pumped into the 19,000-gal waste collection tank. The contents of the tank are released to the sediment pond by gravity flow. Since the demineralizer waste water cannot contain radioactive contamination, only the pH of the waste tank effluent is monitored.

Waste neutralization sump pumps - Two pumps, rated at 300 gal/min and 50-ft TDH, transfer water from the waste neutralization sump to the waste storage tank. Both pumps are normally controlled by a level controller in the sump.

The final plant effluent water is typically maintained at or below the following limits:

Conductivity	0.10 μmho/cm at 25°C
Average soluble silica	0.02 ppm
Oxygen	0.10 ppm

In an effort to improve the reliability and service life of the steam generators, a reverse osmosis unit has been installed to supplement or replace functions of the original water treatment facility. This system is sized at 360 gal/min maximum, utilizing three 120-gal/min parallel triple membrane reverse osmosis systems. This system features serial redundancy of major components and does not require the provision of purified water for resin regeneration and rinsedown.

The reverse osmosis unit receives its water supply from the 200,000-gal clarified water storage tank. The effluent of the reverse osmosis unit is connected to the discharge of one of the two independent, demineralized water plants. The reverse osmosis unit may be operated independently or in conjunction with one of the demineralized water plants.

The objectives of this facility are to decrease the quantity of organic material passing through the plant and to decrease the ongoing low level leakage of ionic species from the ion exchange resin system into the makeup water. In the long term, the consistent improvement anticipated in makeup water quality will lead to a decreased probability of corrosion for the secondary side of the steam generators, a decreased inventory of hideout return chemicals when the FNP units are shut down, and the elimination of chemistry related power holds during restarts.

9.2.8.3 Safety Evaluation

The plant water treatment system is not required for any safety-related functions. Consequently, the failure of any part of this system will not adversely affect the nuclear safety of the plant.

The possibility of radioactively contaminated water siphoning into the demineralized water system from the reactor makeup water storage tank is precluded by a check valve at the inlet of each reactor makeup water storage tank, as shown in figure 9.2-11.

9.2.8.4 Tests and Inspections

The plant water treatment system is operated intermittently during all phases of plant operations. The major components of the system are located in the water treatment building and are easily accessible for inspection at any time.

9.2.8.5 Instrumentation Applications

The clarifier has a control panel with all the instruments and alarms necessary to allow the early detection of abnormal conditions. The major instrumentation that is available for the water treatment plant is shown on figure 9.2-11.

9.2.9 WELL WATER SYSTEM

9.2.9.1 Design Bases

The well water system provides water for the potable and sanitary water system discussed in subsection 9.2.4, the fire protection system discussed in subsection 9.5.1, and the demineralized water system discussed in subsection 9.2.3. The system is Safety Class NNS and Seismic Category II.

9.2.9.2 System Description

The well water system is shown schematically in drawing D-170110, sheet 1. Two operational deep wells are located at the plant site. The 500-gal/min-capacity pump on deep well No. 2 and the 300-gal/min-capacity pump on deep well No. 4 serve as the primary supply to the 20,000-gal sanitary water tank and the two 300,000-gal fire protection tanks and serve as backup supply to the 200,000-gal filtered water storage tank. Depending on which pump is selected for the lead position, one of these two pumps is automatically initiated when there is demand for water in the sanitary or fire protection tanks. The other of these two pumps will start automatically (lag position) if the lead pump does not start after a short time delay, or may be started manually for additional well water supply. A third water well pump, No. 3, may be started manually, if needed.

The piping system is designed such that all three pumps are interconnected to ensure that proper levels are maintained in all tanks. No. 2 and No. 4 deep well pumps are capable of producing approximately 500 gal/min and 300 gal/min, respectively; well water pump No. 3 will produce approximately 100 gal/min. Refer to table 2.4-9 for additional well data.

Usage of the plant well water is described by paragraph 2.4.13.1.4.

9.2.9.3 Safety Evaluation

Deep well pump No. 2 (NSY36P501B) or No. 4 (NSY36P501F) serves as the primary supply to the fire protection system. Well water pump No. 3 (NSY36P501F) serves as a manual backup. Each well water pump is equipped with a safety relief valve to protect system piping and components. The discharge line of each pump is provided with a pressure switch which trips the pump to prevent it from operating at its shutoff head. A time delay on the pressure switches prevents the pumps from tripping due to momentary pressure surges that may occur during the starting or stopping of an adjacent pump.

The filtered water storage tank and fire protection tanks are located approximately 500 ft from the nearest safety-related equipment. Water resulting from the rupture of any of these tanks would flow into the yard drainage system without affecting any safety-related equipment.

9.2.9.4 Tests and Inspections

The well water system supply is periodically tested and certified as to quality.

9.2.9.5 Instrumentation Applications

Each tank that is provided water from the well water system is equipped with level instrumentation which ensures proper tank level. Additional system instrumentation (pressure switches) ensures that the pumps are running when they are required and tripped when they are not required.

REFERENCES

1. Avrett, J. R., "A Compilation of Surface Water Quality Data in Alabama," Geological Survey of Alabama, Circular 36, 1966.

2. Peirce, L. B., "Reservoir Temperatures in North Central Alabama," Geological Survey of Alabama, Bulletin 82, 1964.

[HISTORICAL]
[TABLE 9.2-1 (SHEET 1 OF 2)

RIVER WATER SYSTEM COMPONENT DATA

River water pumps installed with Unit 1	
Quantity	*5*
Manufacturer	*Byron Jackson*
Type	*One-stage vertical circulator*
Rated capacity (gal/min)	*9750*
Rated heat (ft)	*175*
Motor horsepower	*600*
Design pressure (psig)	*150*
Design temperature (°F)	*125*
River water pumps installed with Unit 2	
Quantity	*5*
Manufacturer	*Johnston*
Type	*Two-stage vertical circulator*
Rated capacity (gal/min)	*9750*
Rated head (ft)	*175*
Motor horsepower	*600*
Design pressure (psig)	*150*
Design temperature (°F)	*125*
River water piping and valves	
Design pressure (psig)	*150*
Design temperature (°F)	*125* ***]***

TABLE 9.2-1 (SHEET 2 OF 2)

SERVICE WATER SYSTEM COMPONENT DATA

Service water pumps (Unit 1)	
Quantity	5
Manufacturer	Sulzer
Type	Two-stage vertical circulator
Rated capacity (gal/min)	9000
Rated head (ft)	210
Motor horsepower	600
Design pressure (psig)	150
Design temperature (°F)	125
Service water pumps (Unit 2)	
Quantity	5
Manufacturer	Johnston
Type	Two-stage vertical circulator
Rated capacity (gal/min)	9000
Rated head (ft)	210
Motor horsepower	600
Design pressure (psig)	150
Design temperature (°F)	125
Service water piping and valves	
Design pressure (psig)	150
Design temperature (°F)	125

TABLE 9.2-2

NUMBER OF PUMPS REQUIRED PER UNIT TO PROVIDE ADEQUATE COOLING

Condition	River Water Pumps[a]	Service Water Pumps
Safe cold shutdown (normal)	0	4
Loss of offsite power	0	2
LOCA (minimum safeguards)	0	2
Probable maximum flood	0	4[b]

a. River water is available during normal operating conditions for use as makeup to the service water storage pond, which serves as the ultimate heat sink. However, river water is not required for any of the conditions listed in this table. When river water is not available, the service water system can be recirculated to the pond to minimize the pond's inventory losses.

b. At the probable maximum flood, the river water pump structure will be flooded; therefore, the service water pump flow will be supplied from storage pond volume. The number of pumps required (four) assumes a normal safe cold shutdown condition, recirculating the cooling water to the storage pond.

TABLE 9.2-3 (SHEET 1 OF 2)

SERVICE WATER SYSTEM DESIGN FLOWRATES

Component Description	Normal Operation		Loss of Offsite Power		Hot Shutdown		Cold Shutdown		LOCA Injection		LOCA Recirculation	
	Number of Components Receiving SW Flow	Flowrate/ Component (GPM)	Number of Components Receiving SW Flow	Flowrate/ Component (GPM)	Number of Components Receiving SW Flow	Flowrate/ Component (GPM)	Number of Components Receiving SW Flow	Flowrate/ Component (GPM)	Number of Components Receiving SW Flow	Flowrate/ Component (GPM)	Number of Components Receiving SW Flow	Flowrate/ Component (GPM)
Component Cooling Water Heat Exchangers	1	10,000	1	10,000	1	10,000	1	10,000	1	10,000	1	10,000
Containment Coolers	4	800	2	800	4	800	4	800	2	2,000	2	2,000
Pump Room Coolers:												
RHR (LHSI)	2	40	1	40	2	40	2	40	1	40	1	40
Charging (HHSI)	3	105	2	105	3	105	3	105	2	105	2	105
Containment Spray	2	105	1	105	2	105	2	105	1	105	1	105
Auxiliary Feedwater	2	105	1	105	2	105	2	105	1	105	1	105
Component Cooling	2	105	1	105	2	105	2	105	1	105	1	105
600V Load Center Room Cooler	2	75	1	75	2	75	2	75	1	75	1	75
Battery Charging Room Coolers	2	30	1	30	2	30	2	30	1	30	1	30
(Swing HX)	1	24	1	24	1	24	1	24	1	24	1	24
Motor Control Center Room Cooler	2	20	1	20	2	20	2	20	1	20	1	20
Diesel Generators:												
Small Diesel (2C & 1C)	2	540	1	540	2	540	2	540	1	540	1	950
Large Diesel (1B, 2B, & 1-2A) (SEE NOTE 3)	2	820	1	820	2	820	2	820	1	820	1	1,450
Letdown Chiller Condenser (SEE NOTE 5)	1	420	---	0	1	420	---	0	---	0	---	0
Steam Generator Blowdown Heat Exchanger (SEE NOTES 4 & 5)	1	1,800	---	0	---	0	---	0	---	0	---	0
Reactor Coolant Pump Motor Air Coolers (SEE NOTE 5)	3	162	---	0	3	162	3	162	---	0	---	0
Turbine Building Heat Exchangers (SEE NOTES 5 & 6)	---	12,000	---	4,615	---	12,000	---	200	---	0	---	0

TABLE 9.2-3 (SHEET 2 OF 2)

Notes:

1. These values are design flowrates for each component listed. Actual flowrates to individual components will vary depending on service water temperature and component operational conditions.

2. This table is applicable for one unit operation. The number of components receiving SW flow from one unit is indicated for each condition listed. For a single failure involving the loss of a train, this table assumes that the on-service train is available for each unit.

3. The number of diesels receiving SW flow from one unit is indicated for each condition listed. See FSAR section 9.5.5 for a description of SW cooling the diesel generators.

   Service water is normally supplied to all five diesel generators continuously, even though only one SW train/unit is required for safe shutdown.

   This requirement is fulfilled even though SW may supply between two and five diesel generators, depending upon which SW trains are assumed lost to a single failure.

   Diesel Generator 2C will not automatically start upon a LOSP as it has been designated the Alternate AC Supply during a Station Blackout.

4. The steam generator blowdown heat exchanger is operating during normal operation of the plant only. During intermittent blowdown operation, the service water flowrate to the heat exchanger may reach 3,200 GPM.

5. These loads are isolated either automatically following a LOCA or by operator action following a LOSP.

6. Following a LOSP, the Turbine Building inlet valves automatically throttle to allow minimum service water flow to aid in equipment cooldown. No equipment within the Turbine Building is required to operate following a LOSP.

TABLE 9.2-4

(This Table Intentionally Deleted)

TABLE 9.2-5

SINGLE FAILURE ANALYSIS SERVICE WATER SYSTEM

Component	Malfunction	Effect on Safety-Related Systems	Comments
Service water pump	Pump failure	No effect	Pump trip will be alarmed in the control room. Two pumps are the minimum required for post-LOCA operation. The failed pump will be isolated and repaired. The spare pump may be manually started to replace the failed pump.
Service water pump discharge header	Header break	No effect	Low pressure will be alarmed in the control room. The header is valved so that failure of the header will not result in less than two pumps supplying water.
Service water supply line	Line break	No effect	Low pressure will be alarmed in the control room. Redundant supply line will be used to supply the full flow required.
Isolation valve	Valve failure	No effect	Valves are arranged so that no single failure will render less than two pumps available.
Emergency recirculation line to pond	Line break	No effect	Redundant line available.

a. Analysis given above is for one pump, one valve, one line, etc. Analysis is similar for all other components. Analysis given is for one unit.

TABLE 9.2-6 (SHEET 1 OF 2)

COMPONENT COOLING WATER SYSTEM DESIGN FLOWRATES [Note a]
(For Each Plant Unit, gal/min)

	Normal Operation	Hot Shutdown	Cooldown [Note c]	LOCA [Note b] (Injection)	LOCA [Note b] (Recirculation)
Charging Pump(s)					
Lube Oil Cooler(s)	20 (2)	20 (2)	20 (2)	20 (2)	20 (2)
Gear Oil Cooler(s)	16/10 (2) [Note d, h]	16/10 (2) [Note d, h]	16/10 (2) [Note d, h]	16/10 (2) [Note d, h]	16/10 (2) [Note d, h]
Excess Letdown Heat Exchanger [Note j]	(230 gal/min during startup only)				
Hydrogen Recombiner(s)	20 (2)	20 (2)	N/A	N/A	N/A
Letdown Heat Exchanger [Note k]	240 [Note f]	530 [Note f]	240	N/A	N/A
Reactor Coolant Drain Tank Heat Exchanger [Note j]	230	230	N/A	N/A	N/A
Reactor Coolant Pump(s)	585 (3)	585 (3)	585	585 (3) [Note g]	N/A
Recycle Evaporator Package [Note j]	780	780	780	N/A	N/A
RHR Heat Exchanger(s)	N/A	N/A	5600	5600	5600
RHR Pump(s)	5	5	5	5	5
Sample System [Note j]	50	50	50	N/A	N/A
Seal Water Heat Exchanger	200	200	200	N/A	N/A
Spent Fuel Pool Heat Exchanger(s)	3000	3000	3000	3000 [Note i]	3000 [Note i]
Waste Evaporator Package [Note j]	780 [Note e]	780 [Note e]	780 [Note e]	N/A	N/A
Waste Gas Compressor(s) [Note j]	100 (2)	100 (2)	100 (2)	N/A	N/A

( ) Number of components if more than one

TABLE 9.2-6 (SHEET 2 OF 2)

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[a] These values are design flowrates for the components listed. Actual flowrates to individual components will vary depending on component operational conditions.

[b] Only one train of components are assumed in service following a LOCA.

[c] This column denotes components in operation during a single train cooldown. Both trains of CCW are normally placed in service during the cooldown period. However, only one train of CCW is required to operate during this cooldown period.

[d] Unit 1 flow given first (Unit 1/Unit 2).

[e] The waste evaporator is not currently used.

[f] With maximum purification, the flow requirement is 530 gpm.

[g] CCW flow to the RCPs is terminated on a Phase B isolation signal.

[h] Two charging pumps are normally aligned to the on-service train of CCW.

[i] The original CCW system design criteria assumed the Spent Fuel Pool Heat Exchangers were isolated during the initial phase of LOCA Recirculation. However, the current alignment would allow the on-service Spent Fuel Pool Heat Exchanger to receive CCW flow during LOCA Recirculation. When a Spent Fuel Pool Heat Exchanger and an RHR heat exchanger are aligned to the same train, as they could be during LOCA Recirculation, the CCW flow available to the Spent Fuel Pool Heat Exchanger will decrease.

(j) CCW flow to these components is isolated by a failed closed air-operated valve following a loss of offsite power (LOSP).

(k) Even though letdown flow to the letdown heat exchanger is isolated following a loss of offsite power (LOSP), CCW flow to this component could increase as the air operator flow control valve fails open.

TABLE 9.2-7 (SHEET 1 OF 2)

COMPONENT COOLING WATER SYSTEM HEAT LOADS
(For Each Plant Unit, 10^6 Btu/h)

	Normal Operation [Note l]	Hot Shutdown	Cooldown [Note h]	LOCA (Injection)	LOCA (Recirculation)
CCW Pump(s)	0.833	0.833	0.833	0.833	0.833
Charging Pump(s) [Note g]					
Lube Oil Cooler(s)	0.096 (2)	0.096 (2)	0.096 (2)	0.096 (2)	0.096 (2)
Gear Oil Cooler(s)	0.045 (2)	0.045 (2)	0.045 (2)	0.045 (2)	0.045 (2)
Excess Letdown Heat Exchanger [Note j]	(4.9 x 10^6 Btu/h during startup only)				
Hydrogen Recombiner(s)	0.14 (2)	0.07	N/A	N/A	N/A
Letdown Heat Exchanger [Note k]	5.37 [Note a]	11.67 [Note a]	4.8 [Note a]	N/A	N/A
Reactor Coolant Drain Tank Heat Exchanger [Note j]	2.23	2.23	N/A	N/A	N/A
Reactor Coolant Pump(s)	2.34 (3)	2.34 (3)	0.78	N/A	N/A
Recycle Evaporator Package [Note j]	8.8	8.8	8.8 [Note d]	N/A	N/A
RHR Heat Exchanger(s)	N/A	N/A	91.8 [Note b]	N/A	108.9 [Note i, m]
RHR Pump(s)	N/A	N/A	0.035	0.035	0.035
Sample System [Note j]	1.06 [Note e]	1.06 [Note e]	1.06 [Note e]	N/A	N/A
Seal Water Heat Exchanger	1.4	1.4	1.4	N/A	N/A
Spent Fuel Pool Heat Exchanger(s)	15.4 [Note c]	15.4 [Note c]	15.4 [Note c]	15.4 [Note c]	[Note c, m]
Waste Evaporator Package [Note j]	N/A [Note f]	N/A [Note f]	N/A [Note f]	N/A	N/A
Waste Gas Compressor(s) [Note j]	0.27 (2)	0.135	0.27 (2)	N/A	N/A

( ).No. of components if more than one.

TABLE 9.2-7 (SHEET 2 OF 2)

[a] With normal purification, the heat load is 5.37 x 10^6 Btu/hr. With maximum purification, the heat load is 11.67 x 10^6 Btu/hr. During cooldown, the heat load is 4.8 x 106 Btu/hr.

[b] Initial RHR heat load for a single train cooldown.

[c] The spent fuel pool heat load is based on a 79 assembly per cycle discharge schedule with 25 days decay time for the last discharge and was calculated using the NRC's uncertainty factors.

[d] The evaporator is not required to operate during the cooldown period. If it is necessary to reduce the heat load on the component cooling water system, the evaporator can be shut down and the cooling flow terminated.

[e] Maximum calculated heat load assuming that the Gross Failed Fuel Detector (GFFD), the Fine Cooling Chiller, and 9 sample coolers are in operation.

[f] The waste evaporator is not currently used. Therefore, the Waste Evaporator's heat load of 8.8 MBtu/Hr is not listed.

[g] Two charging pumps are normally aligned to the on-service train of CCW.

[h] This column denotes components in operation during a single train cooldown. Both trains of CCW are normally placed in service during the cooldown period. However, only one train of CCW is required to operate during the cooldown period.

[i] Initial RHR heat load for a single train cooldown for LOCA recirculation mode.

[j] CCW flow to these components is isolated by a failed closed air-operated valve following a loss of offsite power (LOSP). Therefore, should a LOSP occur, these heat loads would not be transferred to the CCW system.

[k] Letdown flow to the letdown heat exchanger is isolated following a loss of offsite power (LOSP). Therefore, should a LOSP occur, the letdown heat exchanger heat load would not be transferred to the CCW system.

[l] Represents "start-up" and "at-power" operation.

[m] The heat loads on the RHR and spent fuel pool (SFP) heat exchangers (HXs) vary during the LOCA recirculation event with a resultant heatup of the SFP. The combined heat loads do not exceed 115.3 MBTU/hr. The maximum RHR HX heat load occurs at the start of recirculation phase, and the maximum SFP HX heat load occurs after the peak SFP temperature is reached and SFP cooldown commences. The maximum SFP heat removal rate slightly exceeds the assumed decay heat load of 15.4 MBTU/hr.

TABLE 9.2-8

COMPONENT COOLING WATER/SERVICE WATER TEMPERATURES (°F)

CCW Heat Exchanger Nozzle	Normal Operation[a]	Hot Shutdown[b]	Normal[c][d] Cooldown	Abnormal[c][e] Cooldown	LOCA[c][f] Injection	LOCA[c][g] Recirculation
Component cooling water inlet	118.8	118.8	155.4	163.2	109.0	167.1
Component cooling water outlet	105.0	105.0	128.9	132.8	101.9	134.5
Service water inlet	95.0	95.0	97.3[h]	97.3[h]	97.3	97.3
Service water outlet	104.1	105.0	116.9	119.5	100.6	120.7

a. With maximum purification. Temperatures based on 6,600 gal/min CCW flow and 10,000 gal/min service water flow.

b. Temperatures based on 6,400 gal/min CCW flow and 8,340 gal/min service water flow.

c. All temperatures listed are based on 0.0028 hr. ft^2 °F/Btu overall fouling and 5% tube plugging (118) tubes for the CCW heat exchanger. Additionally, the CCW heat exchanger heat transfer area is assumed to be reduced from 13,052 ft^2 to 12,841 ft^2 due to the 12-inch Plasticor coating on the inside inlet tube end.

d. Temperatures based on 7,500 gal/min CCW flow and 10,000 gal/min service water flow.

e. Temperatures based on 7,419 gal/min CCW flow and 10,000 gal/min service water flow.

f. Temperatures based on 4,643 gal/min CCW flow and 10,000 gal/min service water flow.

g. Temperatures based on 7,299 gal/min CCW flow and 10,000 gal/min service water flow.

h. A LOCA is assumed to occur on the other unit causing the SW inlet temperature to rise from 95°F to 97.3°F.

TABLE 9.2-9 (SHEET 1 OF 2)

COMPONENT COOLING SYSTEM COMPONENT DATA

Component cooling pumps

Quantity	3
Type	Horizontal, centrifugal
Rated capacity (gal/min)	6700
Rated head (ft)	175
Motor horsepower	400
Casing material	Cast steel
Design pressure (psig)	150
Design temperature (°F)	200

Component cooling heat exchangers (per exchanger)

Quantity	3
Type	Shell and straight tube
Heat transferred (Btu/h) (normal operation with maximum letdown)	45.6×10^6
Shell side (component cooling water)	
Inlet temperature (°F)	118.8
Outlet temperature (°F)	105
Design flowrate (lb/h)	3.28×10^6
Design temperature (°F)	200
Design pressure (psig)	150
Material	Carbon steel
Tube side (service water)	
Inlet temperature (°F)	95
Outlet temperature (°F)	104.1
Design flowrate (lb/h)	4.96×10^6
Design pressure (psig)	150
Design temperature (°F)	200
Material	Admiralty

Note: An epoxy coating has been applied to the tubesheets, the first 12” of the tubes on the inlet end, channel head, channel head gasket surface, cover plate, and first 12” of the service water inlet piping for erosion/corrosion protection.

Component cooling surge tank

Quantity	1
Volume (gal)	2000
Design pressure (psig)	14
Design temperature (°F)	200
Construction material	Carbon steel

TABLE 9.2-9 (SHEET 2 OF 2)

Component cooling loop piping and valves

Design pressure (psig)	150
Design temperature (°F)	200

TABLE 9.2-10

COMPONENT COOLING SYSTEM CODE REQUIREMENTS

Component cooling pumps	ASME Pump and Valve Code
Component cooling heat exchangers	ASME Section VIII (Unit 1)
Component cooling heat exchangers	ASME Section III (Unit 2)
Component cooling surge tank	API 620
Component cooling piping	ASME Section III
Component cooling valves:	
Nuclear class valves, 2 1/2 in. and larger	ASME Pump and Valve Code
Nuclear class valves, 2 in. and smaller	ASME Section III
Butterfly valves	ASME Section III
Nuclear control valves	ASME Section III
Nuclear relief valves	ASME Section III

TABLE 9.2-11 (SHEET 1 OF 2)

COMPONENT COOLING SYSTEM FAILURE ANALYSIS

Component	Malfunction	Comments and Consequences
Component cooling pump	Fails to start	Three pumps are provided. One pump required for normal, hot shutdown or post-LOCA heat removal.
Motor-operated valve on RHR exchanger inlet	Unable to open post-LOCA	Two valves and heat exchangers are provided. One heat exchanger is required to operate post-LOCA.
Component cooling heat exchanger	Tube leakage	Each unit was hydrostatically tested and freon leak-tested prior to shipment. Leakage is detected by change in surge tank level. Each unit is isolable.
Component cooling system pressure boundary	Failure resulting in abnormal leakage of component cooling water	The system is always valved into two separate flow trains, each of which meets minimum safeguard requirements. Leakage cannot affect both trains. Low operating pressures make ruptures improbable.
Component cooling pumps	Manual valve on a pump suction or discharge line closed	This will be prevented by prestartup and operational check. Further, during normal operation, each pump will be checked on a periodic basis which would indicate if a valve were closed. Annunciation in the control room for low flow for certain equipment cooled by CCW.
Component cooling system vent or drain valve	Left open	This will be prevented by prestartup and operational checks. On the operating train such a situation will readily be assessed by makeup requirements to system. On the second train, such a situation will be ascertained by surge tank level alarms.

TABLE 9.2-11 (SHEET 2 OF 2)

Component	Malfunction	Comments and Consequences
Demineralized water makeup line check valve	Stick open	The check valve will be backed up by the motor-operated valve. Valve will normally be closed.

TABLE 9.2-12 (SHEET 1 OF 2)

SERVICE WATER SYSTEM HEAT LOAD: (e)
ONE UNIT LOCA WITH MAXIMUM ESF, (a)ONE UNIT SHUTDOWN/COOLDOWN

All heat loads are in 10^6 Btu/h

		Single Unit: Shutdown			Two Units: LOCA + Shutdown + Margin	
Time(s)	LOCA Unit (b)	50°F/h(b) Cooldown	16-h(b) Cooldown	Margin(c)	50°F/h(b) Cooldown	16-h(b) Cooldown
1	0	179	179	10	189	189
32	443	179	179	10	632	632
50	443	179	179	10	632	632
100	447	179	179	10	636	636
150	448	179	179	10	637	637
200	446	179	179	10	635	635
250	440	179	179	10	629	629
300	429	179	179	10	618	618
350	420	179	179	10	609	609
400	409	179	179	10	598	598
450	400	179	179	10	589	589
500	390	179	179	10	580	580
700	361	179	179	10	550	550
1.0×10^3	306	179	179	10	495	495
$1.50^- \times 10^3$	214	179	179	10	403	403
$1.50^+ \times 10^3$	405	179	179	10	594	594
2.0×10^3	350	179	179	10	539	539
3.0×10^3	340	179	179	10	529	529
5.0×10^3	321	179	179	10	510	510
7.0×10^3	289	179	179	10	478	478
$7.20^- \times 10^3$	287	179	179	10	476	476
$7.20^+ \times 10^3$	287	199	199	10	496	496
1.0×10^4	252	187	187	10	450	450
1.5×10^4	206	169	169	10	385	385
2.0×10^4	183	155	155	10	348	348
$2.16^- \times 10^4$	178	149	149	10	337	337
$2.16^+ \times 10^4$	178	364	296	10	552	484
3.0×10^4	161	346	279	10	517	450
$3.67^- \times 10^4$	156	332	265	10	498	431
$3.67^+ \times 10^4$	156	189	265	10	355	431
5.0×10^4	146	172	247	10	328	403
7.0×10^4	137	146	221	10	293	368
$7.92^- \times 10^4$	134	134	209	10	278	353
$7.92^+ \times 10^4$	134	134	134	10	278	278
1.0×10^5	129	118	118	10	257	257
1.5×10^5	122	113	113	10	245	245
2.0×10^5	117	109	109	10	236	236
3.0×10^5	112	101	101	10	223	223
5.0×10^5	104	96	96	10	210	210
7.0×10^5	99	92	92	10	201	201
1.0×10^6	95	86	86	10	191	191
2.59×10^{6}(d)	95	86	86	10	191	191

TABLE 9.2-12 (SHEET 2 OF 2)

a. Maximum ESF indicates that two RHR heat exchangers, two containment spray pumps, and four containment coolers are in service.

b. The heat load on the service water system from the shutdown/ cooldown of a unit that has experienced a LOCA is described in more detail in table 9.2-13.

The heat load on the service water system from the unit that is undergoing a shutdown/cooldown with a 50°F/h cooldown is described in more detail in table 9.2-14. 50°F/h cooldown refers to the rate of the cooldown of the RCS from 350°F to 140°F. This is the temperature range through which the RHRS operates.

The heat load on the service water system from the unit that is undergoing a shutdown/cooldown with a 16-h cooldown is described in more detail in table 9.2-15. Sixteen-hour cooldown refers to the length of time required to cool the RCS from 350°F to 140°F. This is the temperature range through which the RHRS operates. Sixteen hours is the normal time required to provide this cooldown using one train of RHR; however, to maximize heat input to the service water pond, this analysis assumes both trains of RHR are operating during the 16-h cooldown.

c. The UHS analysis includes a 10 million Btu/h heat load as a margin for possible future additional service water system heat loads.

d. The value of 2.59 x 10^6 s equals 30 days.

e. The heat loads rejected by individual components into the SWS were reevaluated to assess the impact of power uprating both FNP units on the projected maximum SW pond (UHS) temperature. While some component heat loads increase as a result of power uprate, many others decrease for reasons other than uprate. These include the reduction in the heat load from Diesel Generator 2C (SBO diesel which does not start on LOSP), from the Waste Evaporator Package (no longer in use at FNP), and from the control room air conditioner (no longer cooled by service water). The net of these changes to the overall UHS heat load, including changes related to power uprating and those unrelated to power uprating, is a decrease in the heat load beginning on the second day of the 30-day period of evaluation and continuing through the end of the 30-day period. As the reevaluated overall heat load into the UHS is lower than that described in the current UHS evaluation, the UHS remains capable of performing its safety-related function and the peak supply temperature from the service water pond will be below the current design basis value of 106.2°F.

TABLE 9.2-13 (SHEET 1 OF 2)

SERVICE WATER SYSTEM HEAT LOAD[e]
LOCA WITH MAXIMUM ESF[a]

	Sensible Heat + Decay Heat[b]			
Time(s)	RHR HXs (10^6 Btu/h)	Ctmt. Coolers (10^6 Btu/h)	Aux. Loads[c] (10^6 Btu/h)	Total Load (10^6 Btu/h)
1	0	0	0	0
32	0	368	75	443
50	0	368	75	443
100	0	372	75	447
150	0	374	75	448
200	0	371	75	446
250	0	365	75	440
300	0	355	75	429
350	0	345	75	420
400	0	334	75	409
450	0	325	75	400
500	0	316	75	390
700	0	286	75	361
1.0×10^3	0	232	75	306
$1.50^- \times 10^3$[b]	0	139	75	214
$1.50^+ \times 10^3$[b]	191	139	75	405
2.0×10^3	177	98	75	350
3.0×10^3	149	106	75	340
5.0×10^3	142	105	75	321
7.0×10^3	127	87	75	289
1.0×10^4	107	70	75	252
1.5×10^4	80	51	75	206
2.0×10^4	66	41	75	183
3.0×10^4	54	33	75	161
5.0×10^4	45	26	75	146
7.0×10^4	39	23	75	137
1.0×10^5	34	19	75	129
1.5×10^5	31	16	75	122
2.0×10^5	28	14	75	117
3.0×10^5	25	12	75	112
5.0×10^5	20	9	75	104
7.0×10^5	17	7	75	99
1.0×10^6	15	5	75	95
2.59×10^6[d]	15	5	75	95

TABLE 9.2-13 (SHEET 2 OF 2)

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a. Maximum ESF indicates that two RHR heat exchangers, two containment spray pumps, and four containment coolers are in service.

b. Sensible and decay heat loads are the sum of the heat loads of the RHR heat exchanger, the containment air coolers, and containment heat sinks. The RHRS begins operating in the recirculation mode at t = 1.50×10^3 s after the LOCA.

c. Auxiliary Loads:

Component	Heat Load (10^6 Btu/h)
ESF pump room coolers	1.4
Control room ac condensers**	1.2**
Other auxiliary building room coolers and air conditioning units	0.4
Loads on CCW HX (other than RHR HX)	
Spent-fuel pool heat exchanger	11.9
RHR pump seal cooler (2 pumps)	0.2
Charging pump seal cooler, gear oil cooler and bearing cooler (3 pumps)	0.9
Service water pumps (4 pumps)	6.1
Diesel generators (5 diesels)	52.6
Total auxiliary loads:	74.7×10^6 Btu/h

** The water cooled control room AC units have been replaced with air cooled AC units. Thus, the UHS analysis considers this heat load (1.2×10^6 Btu/h) as additional margin.

d. The value of 2.59×10^6 s equals 30 days.

e. The heat loads rejected by individual components into the SWS were reevaluated to assess the impact of power uprating both FNP units on the projected maximum SW pond (UHS) temperature. While some component heat loads increase as a result of power uprate, many others decrease for reasons other than uprate. These include the reduction in the heat load from Diesel Generator 2C (SBO diesel which does not start on LOSP), from the Waste Evaporator Package (no longer in use at FNP), and from the control room air conditioner (no longer cooled by service water). The net of these changes to the overall UHS heat load, including changes related to power uprating and those unrelated to power uprating, is a decrease in the heat load beginning on the second day of the 30-day period of evaluation and continuing through the end of the 30-day period. As the reevaluated overall heat load into the UHS is lower than that described in the current UHS evaluation, the UHS remains capable of performing its safety-related function and the peak supply temperature from the service water pond will be below the current design basis value of 106.2°F.

TABLE 9.2-14 (SHEET 1 OF 4)

SERVICE WATER SYSTEM HEAT LOAD[f]
SHUTDOWN WITH 50°F/h COOLDOWN[a]

Time (s)	RHR HXs[b] (10^6 Btu/h)	Other CCW[d] (10^6 Btu/h)	Auxiliary Loads[e] (10^6 Btu/h)	Total Load (10^6 Btu/h)
1	0	49	130	179
30	0	49	130	179
50	0	49	130	179
100	0	49	130	179
150	0	49	130	179
200	0	49	130	179
250	0	49	130	179
300	0	49	130	179
350	0	49	130	179
400	0	49	130	179
450	0	49	130	179
500	0	49	130	179
700	0	49	130	179
1.0×10^3	0	49	130	179
1.5×10^3	0	49	130	179
2.0×10^3	0	49	130	179
3.0×10^3	0	49	130	179
5.0×10^3	0	49	130	179
$7.20^- \times 10^3$[c]	0	49	130	179
$7.20^+ \times 10^3$[c]	0	49	150	199
1.0×10^4	0	49	138	187
1.5×10^4	0	49	120	169
2.0×10^4	0	49	106	155
$2.16^- \times 10^4$[c]	0	49	100	149
$2.16^+ \times 10^4$[c]	218	50	96	364
3.0×10^4	208	50	88	346
$3.67^- \times 10^4$[c]	199	50	83	332
$3.67^+ \times 10^4$[c]	80	30	79	189
5.0×10^4	74	30	68	172
7.0×10^4	64	30	52	146
1.0×10^5	56	30	32	118
1.5×10^5	51	30	32	113
2.0×10^5	47	30	32	109
3.0×10^5	39	30	32	101
5.0×10^5	34	30	32	96
7.0×10^5	30	30	32	92
1.0×10^6	24	30	32	86
2.59×10^6[c]	24	30	32	86

TABLE 9.2-14 (SHEET 2 OF 4)

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a. 50°F/h cooldown refers to the rate of the cooldown of the RCS from 350°F/h to 140°F/h. This is the temperature range through which the RHRS operates.

b. The RHRS removes reactor sensible and decay heat loads. The heat load due to the reactor coolant pumps is included in the sensible heat load value. In order to be conservative, it is assumed that all three RCPs are operating until the RCS temperature is 140°F.

c. The analysis assumes the unit is tripped from 100-percent power at time t = 0 s. Reactor power is reduced from 100-percent power to 0-percent power in 2 h (at t = 7200 s). Based on a 50°F/h cooldown from 547°F to 350°F, the unit is in hot shutdown and the RHRS is placed in service 4 h following attaining 0-percent power (at t = 21,600 s). With a 50°F cooldown rate, the unit is in cold shutdown 4.2 h later (at t = 36,720 s) when the RCS temperature has decreased to 140°F. The UHS analysis models a period of 30 days (2.59×10^6 s equals 30 days).

d. Other CCW loads (other than RHR HX):

	Heat Loads in 10^6 Btu/h		
Component	Trip to HSD	HSD to CSD	CSD
Spent-fuel pool heat exchanger	11.9	11.9	11.9
Letdown heat exchanger	12.0	14.3	0
RCP thermal barrier	3.6	3.6	0
Seal water heat exchanger	1.3	1.3	0
Recycle evaporator	8.8	8.8	8.8
Reactor coolant drain tank HX	1.7	0	0
Waste evaporator*	8.8	8.8	8.8
Waste gas compressor	0.3	0.3	0.1
RHR pump seal cooler (2 pumps)	0	0.2	0.2
Sample HX	0.3	0.3	0.3
Catalytic H_2 Recombiner	0.1	0	0
Charging pump seal HX, gear oil HX, and bearing HX (2 pumps)	0.6	0.6	0
Total other CCW loads ($\times 10^6$ Btu/h)	49.4	50.1	30.1

TABLE 9.2-14 (SHEET 3 OF 4)

* Though the waste evaporator package is not currently in use, its design heat load of 8.8 x 10^6 Btu/h is included as a conservatism.

e. Auxiliary Loads:

Component	Trip to HSD	HSD to CSD	CSD
	Heat Loads in 10^6 Btu/h		
Reactor coolant pump air coolers	4.0	4.0	0
BTRS chillers (Note 4)	4.5	0	0
Containment coolers	7.4	7.4	7.4
ESF pump room coolers	1.4	1.4	1.4
Other auxiliary building room coolers and air conditioning units	0.4	0.4	0.4
Blowdown heat exchanger		Note 2	
Service water pumps (4 pumps)	6.1	6.1	6.1
Diesel generators		Note 1	
Turbine building loads		Note 3	
Total Auxiliary Loads (x 10^6 Btu/h)	23.8	19.3	15.3
	(+ Steam generator blowdown + turbine building heat loads)		

Notes:

1. The heat load of these components is included in the heat loads for the unit that has experienced a LOCA.

2. The blowdown heat exchanger is in operation for 4 h following 0-percent reactor power. It is assumed that 0-percent reactor power is reached 2 h following the trip. From the trip until 0-percent power, the blowdown heat exchanger sees a blowdown flowrate of 75 gal/min and a heat load of 18.0 x 10^6 Btu/h. In the period from 2 h (t = 7200 s) to 6 h (t = 21,600 s) following the trip, the blowdown rate is increased to 200 gal/min. The heat load initially increases to 37.6 x 10^6 Btu/h due to the increased blowdown flowrate but then decreases with the decreasing RCS temperature. Blowdown is isolated when the RCS temperature reaches 140°F (at t = 21,600 s).

TABLE 9.2-14 (SHEET 4 OF 4)

3. It is assumed that the service water system sees the design turbine building heat load of 87.8×10^6 for the 2-h period from the trip until reactor power is reduced to 0 percent (at t = 7200 s). The turbine building heat load then drops linearly over a period of 24 h to 16.8×10^6 Btu/h (at t = 93,600 s). It then remains at 16.8×10^6 Btu/h for the remainder of the 30-day period.

4. The BTRS chillers have been retired in place and are no longer in use. The BTRS chiller heat load of 4.5×10^6 Btu/h is included to maintain margin.

f. The heat loads rejected by individual components into the SWS were reevaluated to assess the impact of power uprating both FNP units on the projected maximum SW pond (UHS) temperature. While some component heat loads increase as a result of power uprate, many others decrease for reasons other than uprate. These include the reduction in the heat load from Diesel Generator 2C (SBO diesel which does not start on LOSP), from the Waste Evaporator Package (no longer in use at FNP), and from the control room air conditioner (no longer cooled by service water). The net of these changes to the overall UHS heat load, including changes related to power uprating and those unrelated to power uprating, is a decrease in the heat load beginning on the second day of the 30-day period of evaluation and continuing through the end of the 30-day period. As the reevaluated overall heat load into the UHS is lower than that described in the current UHS evaluation, the UHS remains capable of performing its safety-related function and the peak supply temperature from the service water pond will be below the current design basis value of 106.2°F.

TABLE 9.2-15 (SHEET 1 OF 4)

SERVICE WATER SYSTEM HEAT LOAD[f]
NORMAL SHUTDOWN WITH 16-h COOLDOWN[a]

Time (s)	RHR HXs[b] (10^6 Btu/h)	Other CCW[d] (10^6 Btu/h)	Auxiliary Loads[e] (10^6 Btu/h)	Total Load (10^6 Btu/h)
1	0	49	130	179
30	0	49	130	179
50	0	49	130	179
100	0	49	130	179
150	0	49	130	179
200	0	49	130	179
250	0	49	130	179
300	0	49	130	179
350	0	49	130	179
400	0	49	130	179
450	0	49	130	179
500	0	49	130	179
700	0	49	130	179
1.0×10^3	0	49	130	179
1.5×10^3	0	49	130	179
2.0×10^3	0	49	130	179
3.0×10^3	0	49	130	179
5.0×10^3	0	49	130	179
$7.20^- \times 10^3$[c]	0	49	130	179
$7.20^+ \times 10^3$[c]	0	49	150	199
1.0×10^4	0	49	138	187
1.5×10^4	0	49	120	169
2.0×10^4	0	49	106	155
$2.16^- \times 10^4$[c]	0	49	100	149
$2.16^+ \times 10^4$[c]	151	50	96	296
3.0×10^4	140	50	88	279
5.0×10^4	125	50	68	247
7.0×10^4	116	50	52	221
$7.92^- \times 10^4$	111	50	48	209
$7.92^+ \times 10^4$	60	30	44	134
1.0×10^5	56	30	32	118
1.5×10^5	51	30	32	113
2.0×10^5	47	30	32	109
3.0×10^5	39	30	32	101
5.0×10^5	34	30	32	96
7.0×10^5	30	30	32	92
1.0×10^6	24	30	32	86
2.59×10^6[c]	24	30	32	86

TABLE 9.2-15 (SHEET 2 OF 4)

---

a. Sixteen-hour cooldown refers to the length of time required to cool the RCS from 350°F to 140°F. This is the temperature range through which the RHRS operates. Sixteen hours is the normal time required to provide this cooldown using one train of RHR; however, to maximize heat input to the service water pond, this analysis assumes both trains of RHR are operating during the 16-h cooldown.

b. The RHRS removes reactor sensible and decay heat loads. The heat load due to the reactor coolant pumps is included in the sensible heat load value. In order to be conservative, it is assumed that all three reactor coolant pumps are operating until the RCS temperature is 140°F.

c. The analysis assumes the unit is tripped from 100-percent power at time t = 0 s. Reactor power is reduced from 100-percent power to 0-percent power in 2 h (at t = 7200 s). Based on a 50°F/h cooldown from 547°F to 350°F, the unit is in hot shutdown and the RHRS is placed in service 4 h following attaining 0-percent power (at t = 21,600 s). The unit is then in cold shutdown 16 h (at t = 70,200 s) when the RCS temperature has decreased to 140°F. The UHS analysis models a period of 30 days (2.59×10^6 s equal 30 days).

d. Other CCW loads (other than RHR HX):

Component	Heat Loads in 10^6 Btu/h Trip to HSD	HSD to CSD	CSD
Spent-fuel pool heat exchanger	11.9	11.9	11.9
Letdown heat exchanger	12.0	14.3	0
RCP thermal barrier	3.6	3.6	0
Seal water heat exchanger	1.3	1.3	0
Recycle evaporator	8.8	8.8	8.8
Reactor coolant drain tank HX	1.7	0	0
Waste evaporator*	8.8	8.8	8.8
Waste gas compressor	0.3	0.3	0.1
RHR pump seal cooler (2 pumps)	0	0.2	0.2
Sample HX	0.3	0.3	0.3
Catalytic H_2 Recombiner	0.1	0	0
Charging pump seal HX, gear oil HX, and bearing HX (2 pumps)	0.6	0.6	0
Total other CCW Loads ($\times 10^6$ Btu/h)	49.4	50.1	30.1

TABLE 9.2-15 (SHEET 3 OF 4)

* Though the waste evaporator package is not currently in use, its design heat load of 8.8 x 106 Btu/h is included as a conservatism.

e. Auxiliary Loads:

Component	Trip to HSD	HSD to CSD	CSD
	Heat Loads in 10^6 Btu/h		
Reactor coolant pump air coolers	4.0	4.5	0
BTRS chillers (Note 4)	4.5	0	0
Containment coolers	7.4	7.4	7.4
ESF pump room coolers	1.4	1.4	1.4
Other auxiliary building room coolers and air conditioning units	0.4	0.4	0.4
Blowdown heat exchanger		Note 2	
Service water pumps (4 pumps)	6.1	6.1	6.1
Diesel generators		Note 1	
Turbine building loads		Note 3	
Total Auxiliary Loads (x 10^6 Btu/h)	23.8	19.3	15.3

(+ Steam generator blowdown + turbine building heat loads)

Notes:

1. The heat load of these components is included in the heat loads for the unit that has experienced a LOCA.

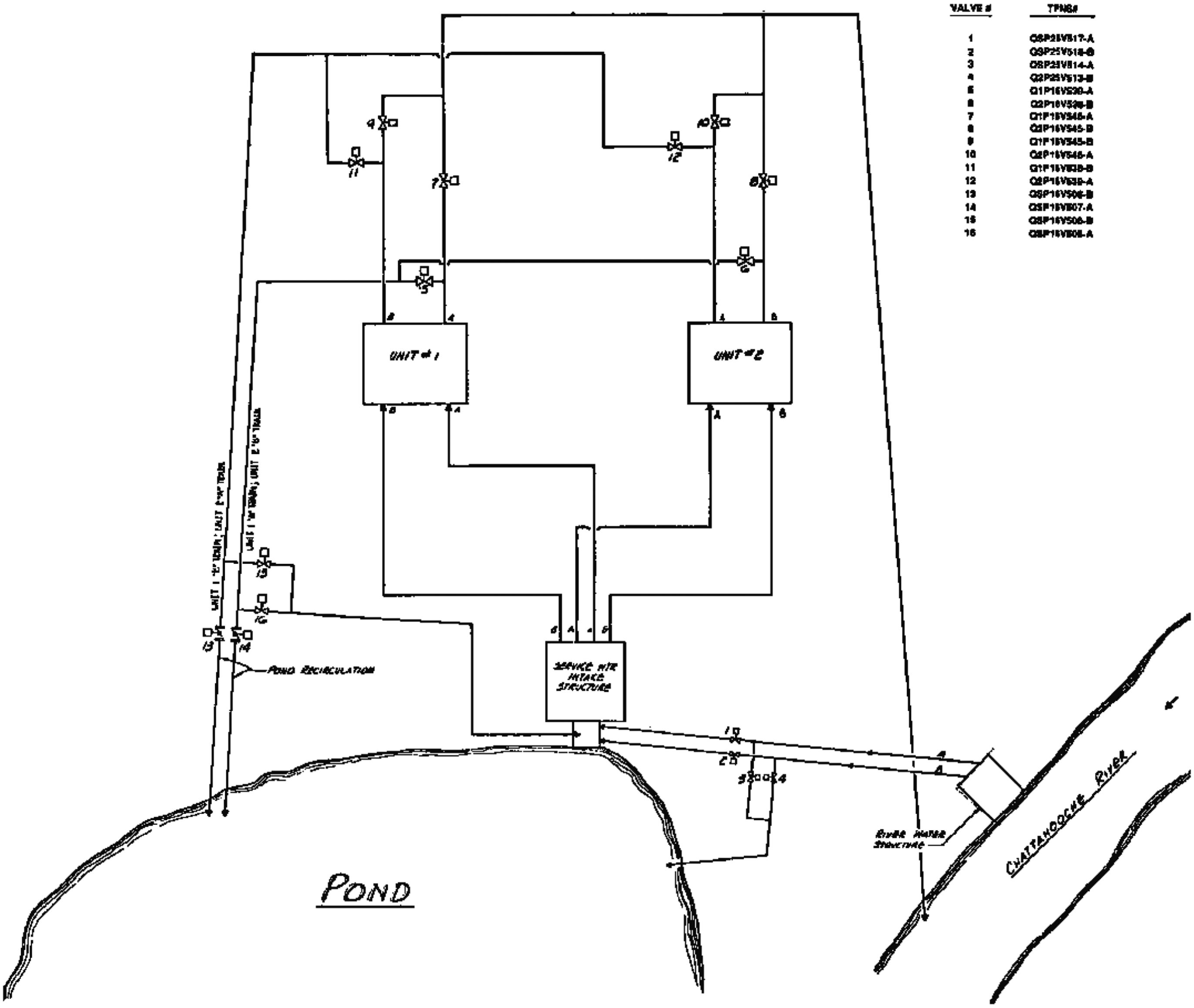
2. The blowdown heat exchanger is in operation for 4 h following 0-percent reactor power. It is assumed that 0-percent reactor power is reached 2 h following the trip. From the trip until 0-percent power, the blowdown heat exchanger sees a blowdown flowrate of 75 gal/min and a heat load of 18.0 x 10^6 Btu/h. In the period from 2 h (t = 7200 s) to 6 h (t = 21,600 s) following the trip, the blowdown rate is increased to 200 gal/min. The heat load initially increases to 37.6 x 10^6 Btu/h due to the increased blowdown flowrate, but then decreases with the decreasing RCS temperature. Blowdown is isolated when the RCS temperature reaches 140°F (at t = 21,600 s).

TABLE 9.2-15 (SHEET 4 OF 4)

3. It is assumed that the service water system sees the design turbine building heat load of 87.8×10^6 for the 2-h period from the trip until reactor power is reduced to 0 percent (at t = 7200 s). The turbine building heat load then drops linearly over a period of 24 h to 16.8×10^6 Btu/h (at t = 93,600 s). It then remains at 16.8×10^6 Btu/h for the remainder of the 30-day period.

4. The BTRS chillers have been retired in place and are no longer in use. The BTRS chiller heat load of 4.5×10^6 Btu/h is included to maintain margin.

f. The heat loads rejected by individual components into the SWS were reevaluated to assess the impact of power uprating both FNP units on the projected maximum SW pond (UHS) temperature. While some component heat loads increase as a result of power uprate, many others decrease for reasons other than uprate. These include the reduction in the heat load from Diesel Generator 2C (SBO diesel which does not start on LOSP), from the Waste Evaporator Package (no longer in use at FNP), and from the control room air conditioner (no longer cooled by service water). The net of these changes to the overall UHS heat load, including changes related to power uprating and those unrelated to power uprating, is a decrease in the heat load beginning on the second day of the 30-day period of evaluation and continuing through the end of the 30-day period. As the reevaluated overall heat load into the UHS is lower than that described in the current UHS evaluation, the UHS remains capable of performing its safety-related function and the peak supply temperature from the service water pond will be below the current design basis value of 106.2°F.



VALVE #	TPNS#
1	QSP25V517-A
2	QSP25V516-B
3	QSP25V514-A
4	Q2P25V513-B
5	Q1P16V530-A
6	Q2P16V530-B
7	Q1P16V545-A
8	Q2P16V545-B
9	Q1P16V545-B
10	Q2P16V545-A
11	Q1P16V530-B
12	Q2P16V530-A
13	QSP16V506-B
14	QSP16V507-A
15	QSP16V508-B
16	QSP16V505-A

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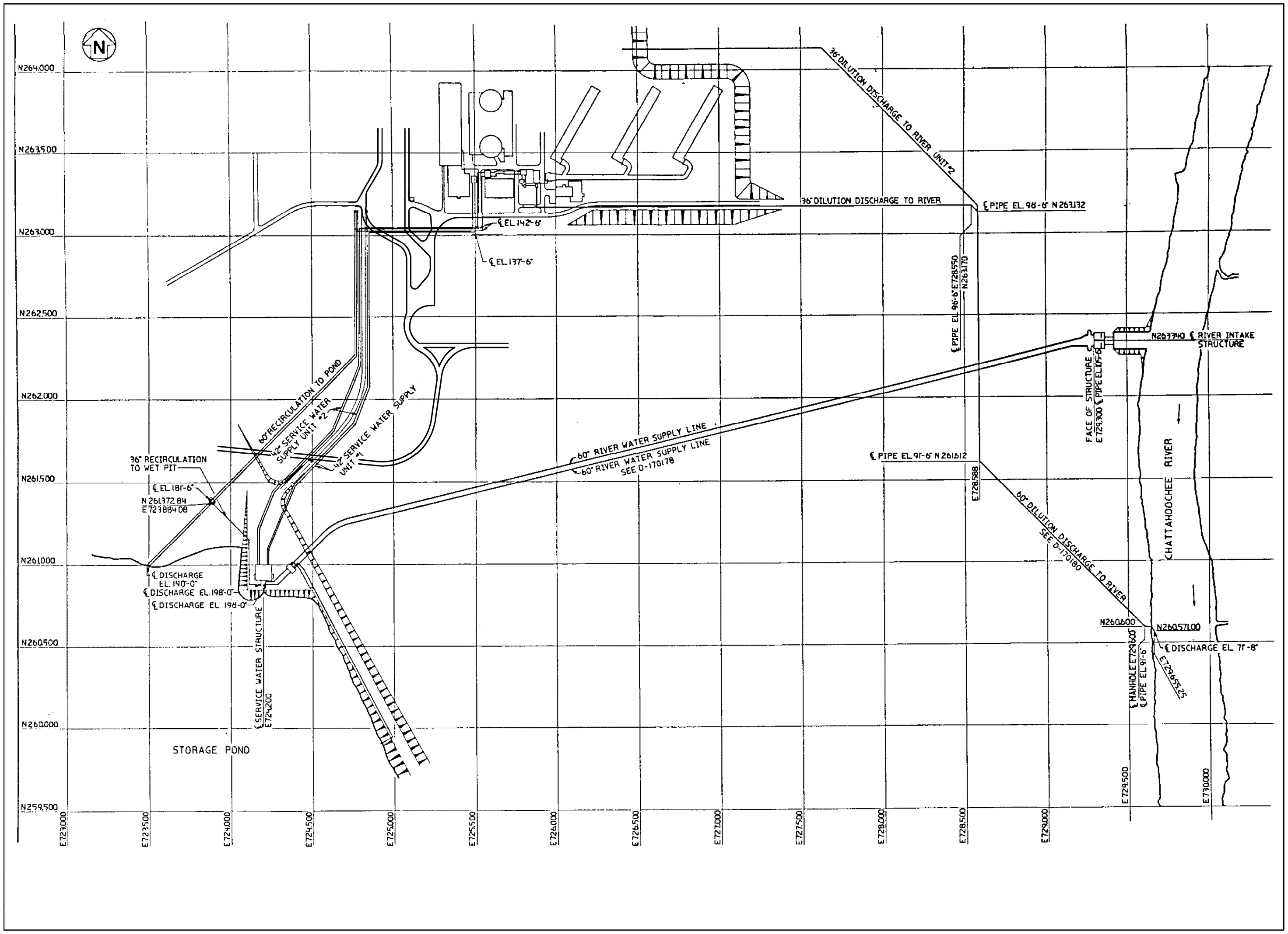
NUCLEAR PLANT
UNIT 1 AND UNIT 2

SERVICE WATER SYSTEM

FIGURE 9.2-1 (SHEET 1 OF 3)



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NUCLEAR PLANT
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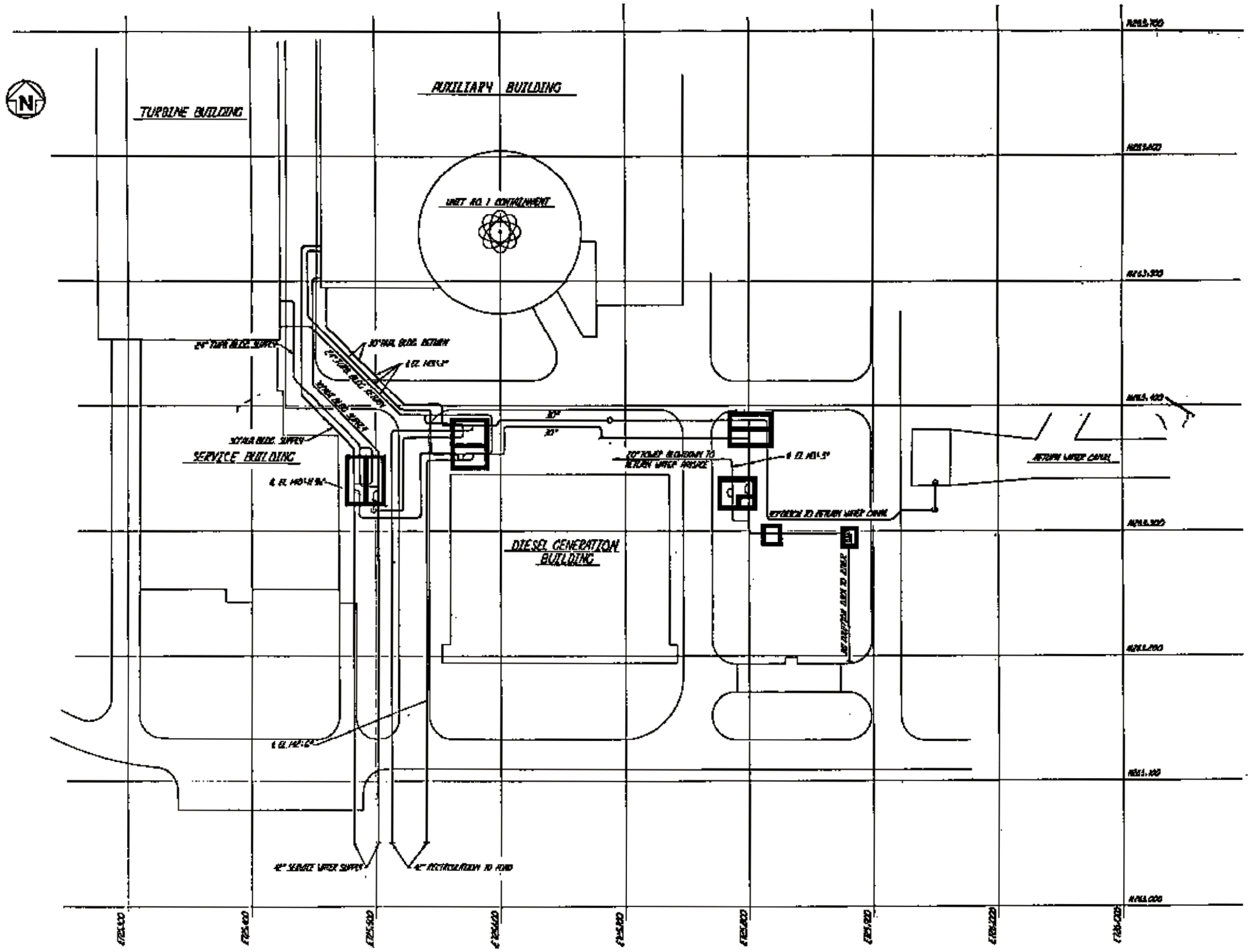
MAJOR SERVICE WATER SUPPLY
AND DISCHARGE PIPING

FIGURE 9.2-1 (SHEET 2 OF 3)



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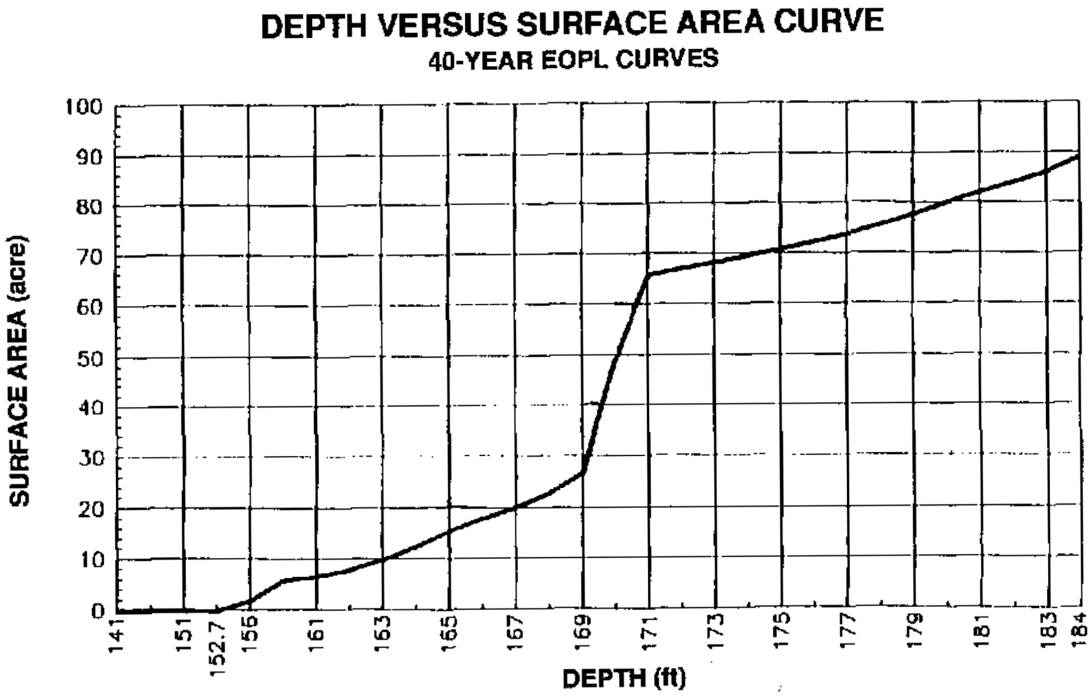
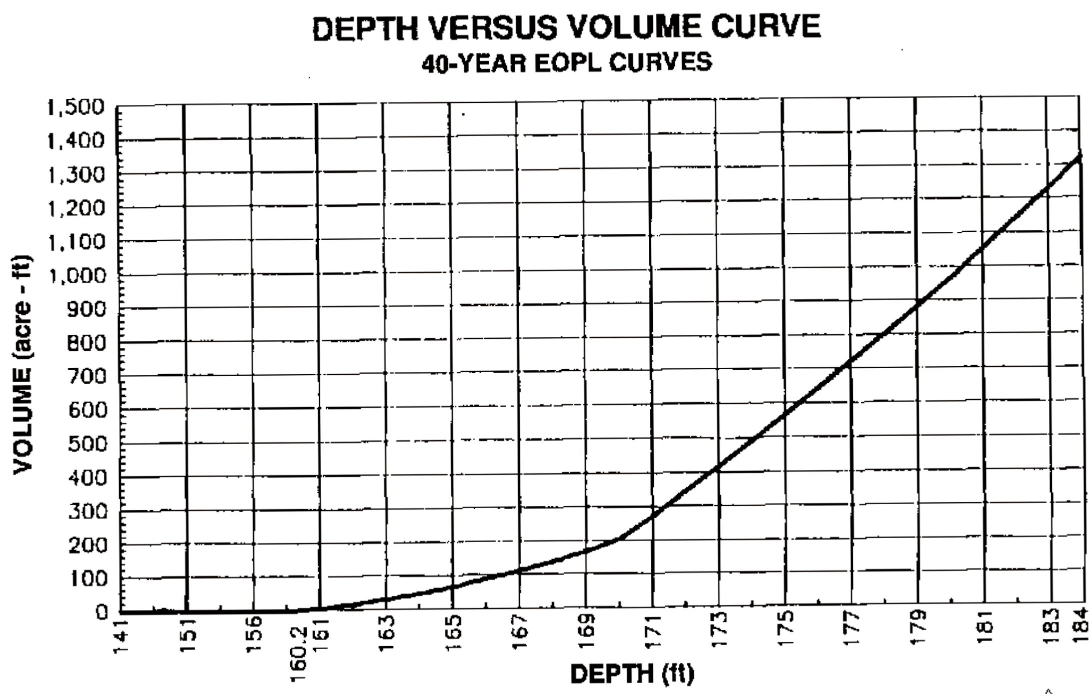
NUCLEAR PLANT
UNIT 1 AND UNIT 2

MAJOR SERVICE WATER SUPPLY AND DISCHARGE PIPING

FIGURE 9.2-1 (SHEET 3 OF 3)





13

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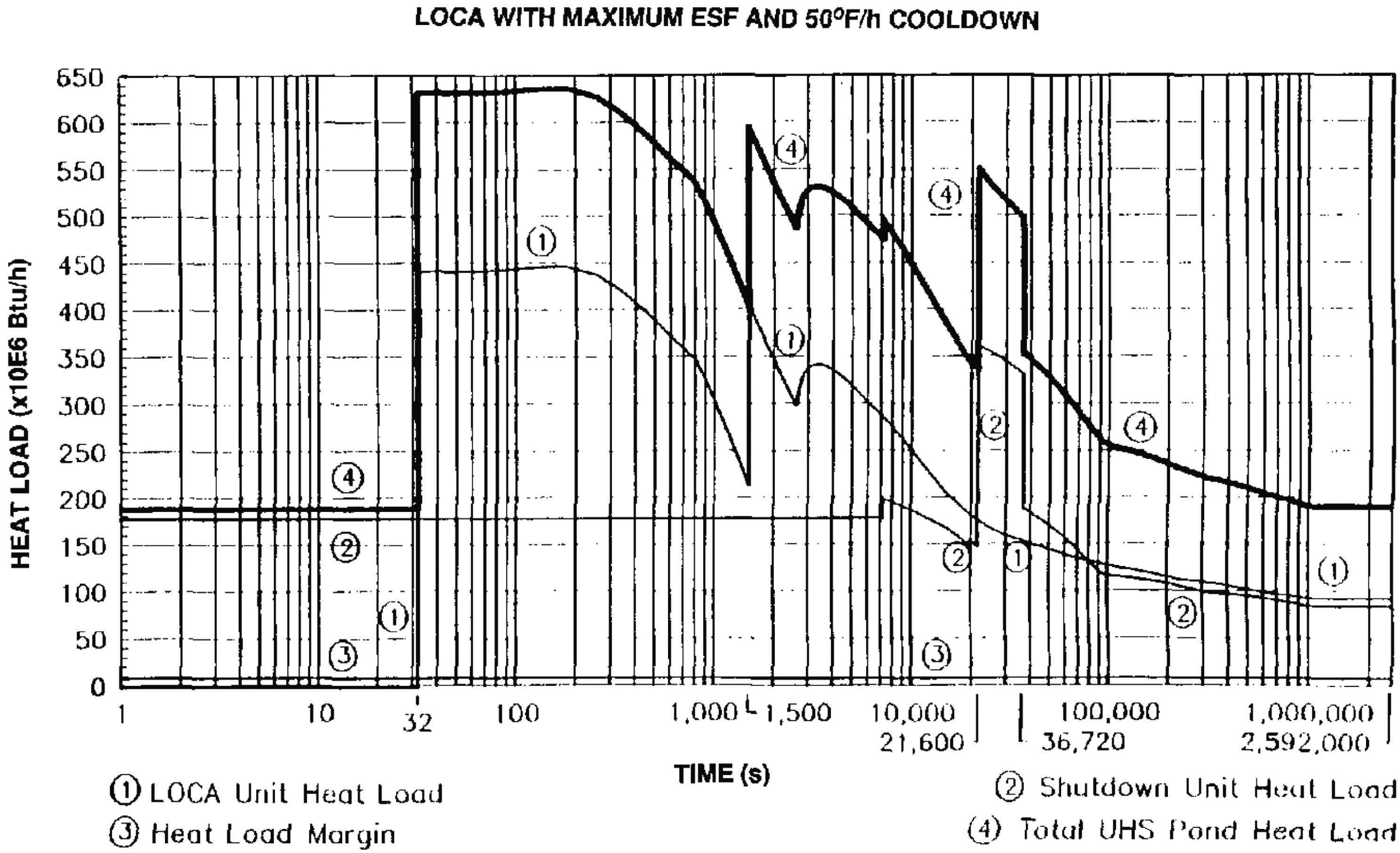
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	EMERGENCY COOLING POND ESTIMATED AREA AND VOLUME FOLLOWING 40 YEARS OF SERVICE
		FIGURE 9.2-2



13

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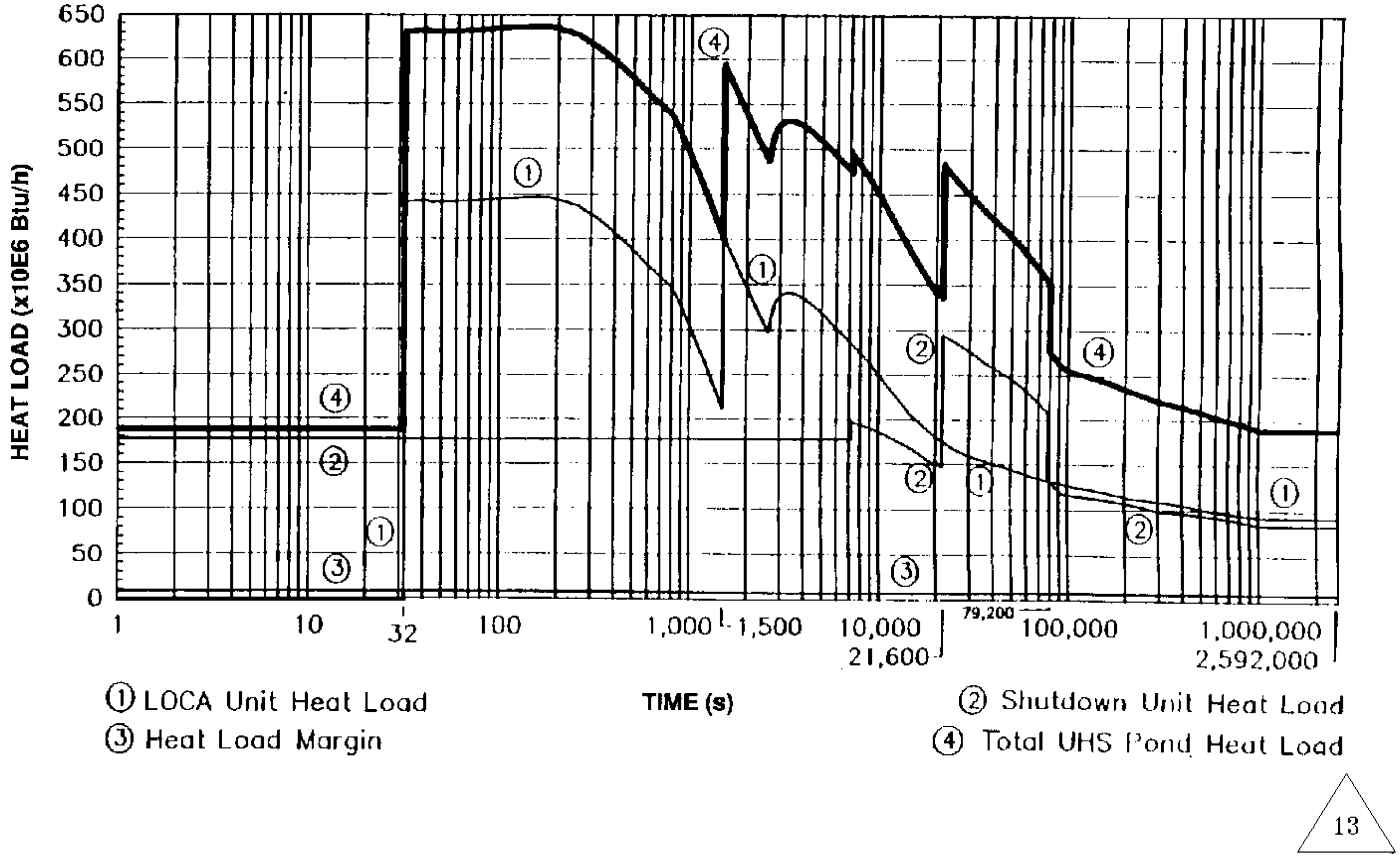
NUCLEAR PLANT
UNIT 1 AND UNIT 2

ULTIMATE HEAT SINK, HEAT INPUT VERSUS TIME, LOCA WITH MAXIMUM ESF AND NORMAL SHUTDOWN WITH 50° F/h COOLDOWN

FIGURE 9.2-3



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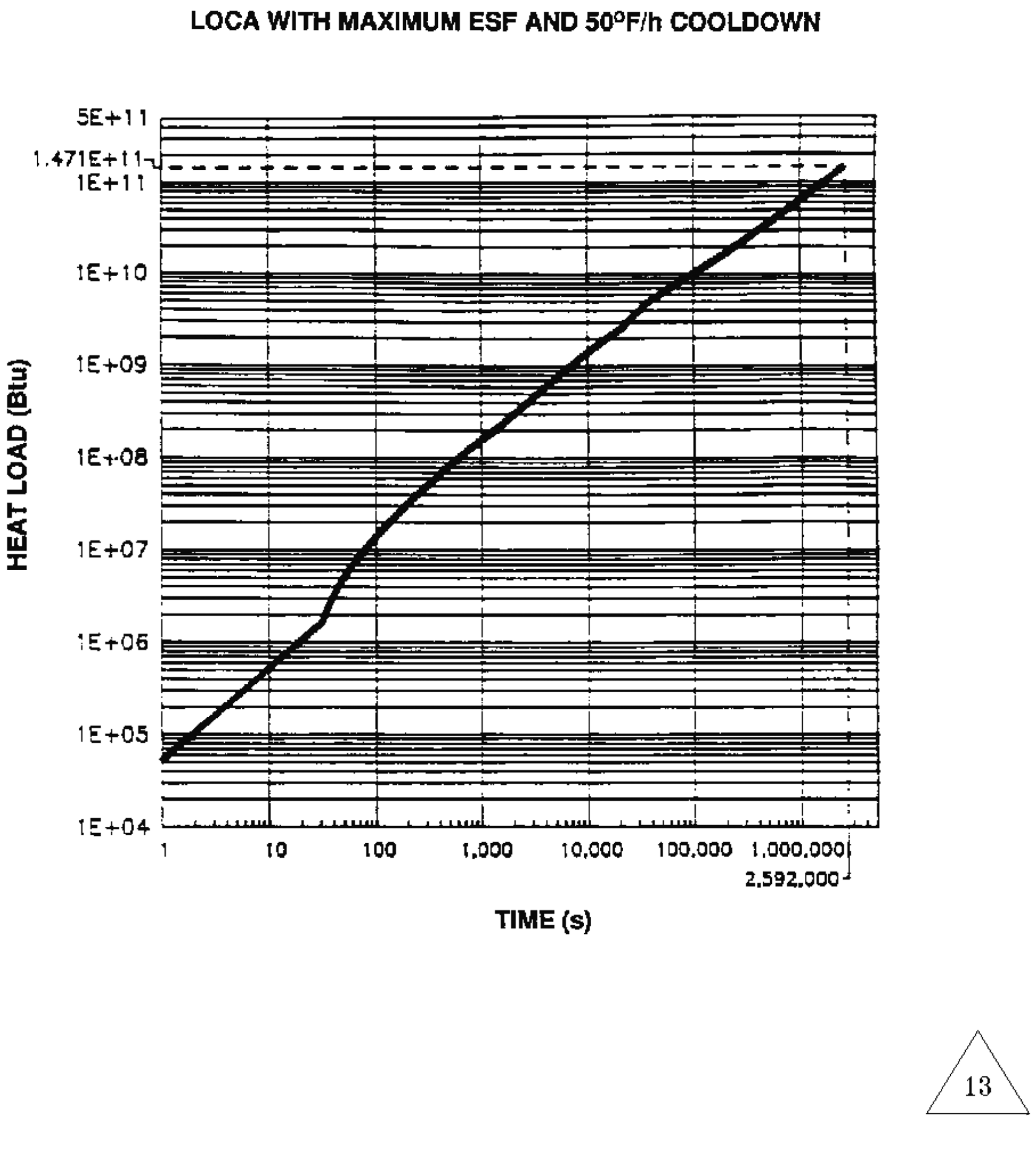
NUCLEAR PLANT
UNIT 1 AND UNIT 2

ULTIMATE HEAT SINK, HEAT INPUT VERSUS TIME, LOCA WITH MAXIMUM ESF AND NORMAL SHUTDOWN WITH 16-h COOLDOWN

FIGURE 9.2-4



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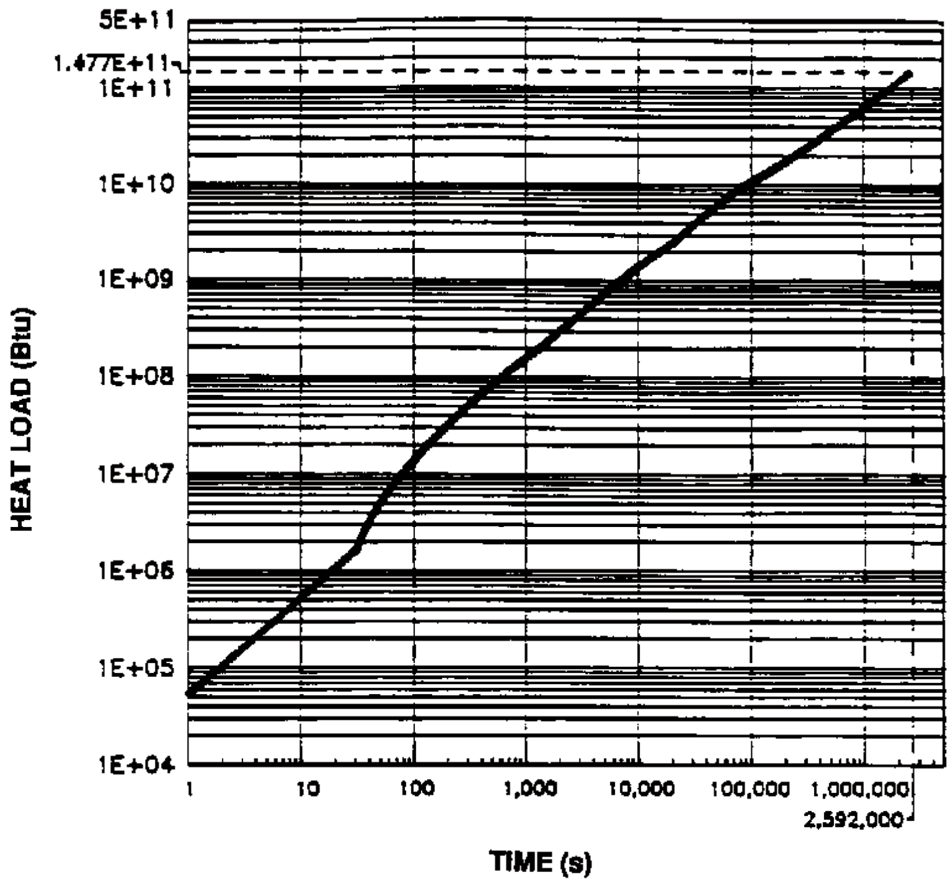
NUCLEAR PLANT
UNIT 1 AND UNIT 2

ULTIMATE HEAT SINK, INTEGRATED
HEAT LOAD, LOCA WITH MAXIMUM ESF AND
NORMAL SHUTDOWN WITH 50°F/h COOLDOWN

FIGURE 9.2-5

LOCA WITH MAXIMUM ESF AND 16-h COOLDOWN



13

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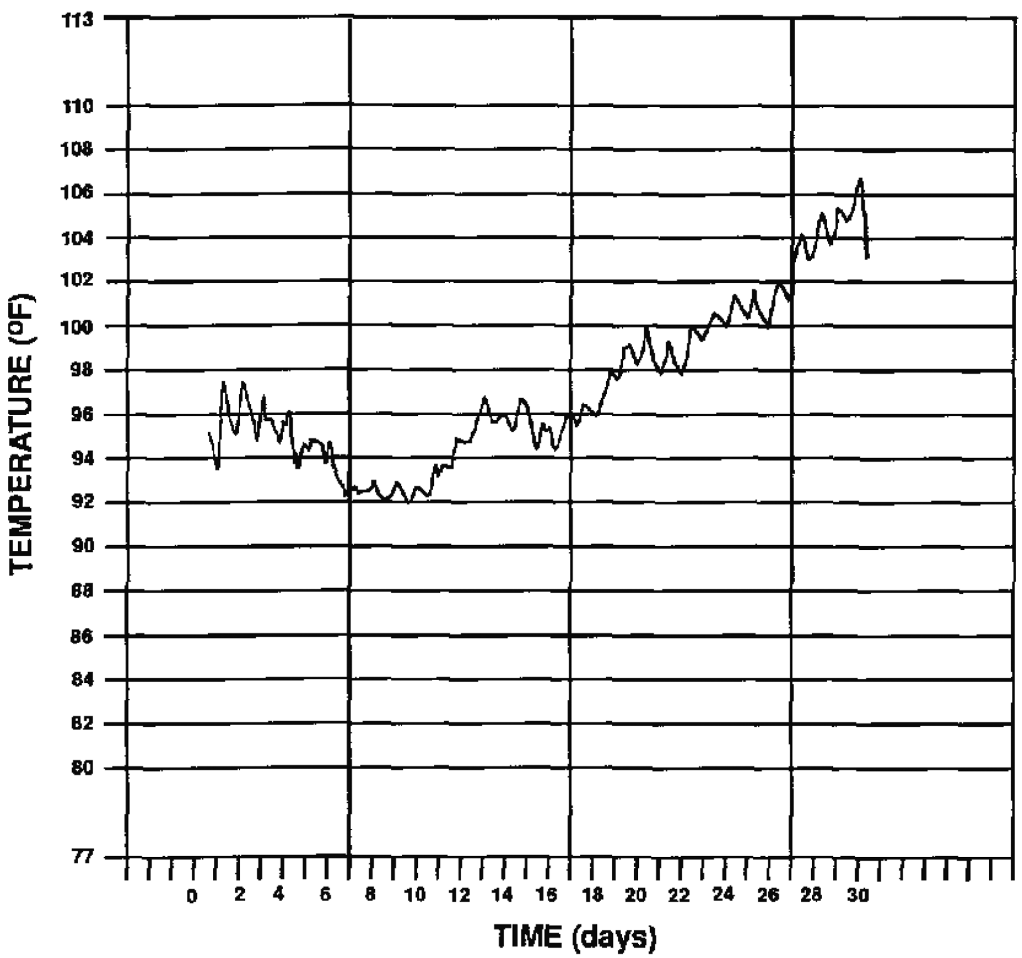
ULTIMATE HEAT SINK, INTEGRATED HEAT LOAD, LOCA WITH MAXIMUM ESF AND NORMAL SHUTDOWN WITH 16-h COOLDOWN

FIGURE 9.2-6

ULTIMATE HEAT SINK:
SERVICE WATER INLET TEMPERATURE vs. TIME
LOCA IN ONE UNIT WITH MAXIMUM ESF
NORMAL SHUTDOWN WITH 50°F/h COOLDOWN IN OTHER UNIT
INITIAL POND TEMPERATURE OF 95°F



13

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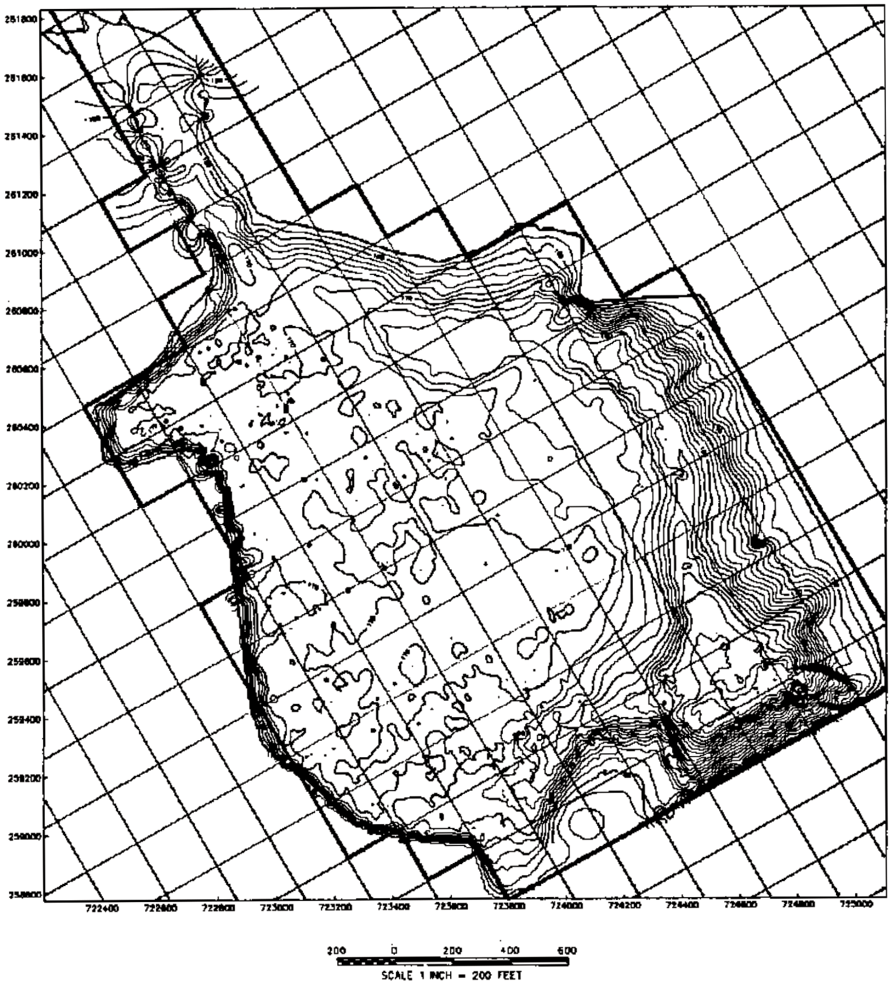
SOUTHERN COMPANY Energy to Serve Your World®	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	ULTIMATE HEAT SINK SERVICE WATER INLET TEMPERATURE VERSUS TIME
		FIGURE 9.2-7

1989 FARLEY STORAGE POND 2 FT. CONTOURS



NOTE:

1) CONTOURS CALCULATED FROM A DIGITAL TERRAIN MODEL USING GRID FILE 1101GRD-002
2) MAP SCALE 1" = 200'
3) 2 FOOT CONTOUR INTERVAL
4) GRID CALCULATIONS MADE FROM DATA COLLECTED 18 AUGUST 1989

PRODUCED BY: ALABAMA POWER COMPANY
POWER GENERATION TECHNICAL
SERVICES - CIVIL
DWG. NO. D-371374, SH. 2 OF 3

5) BASED ON SKETCH D-P55877

13

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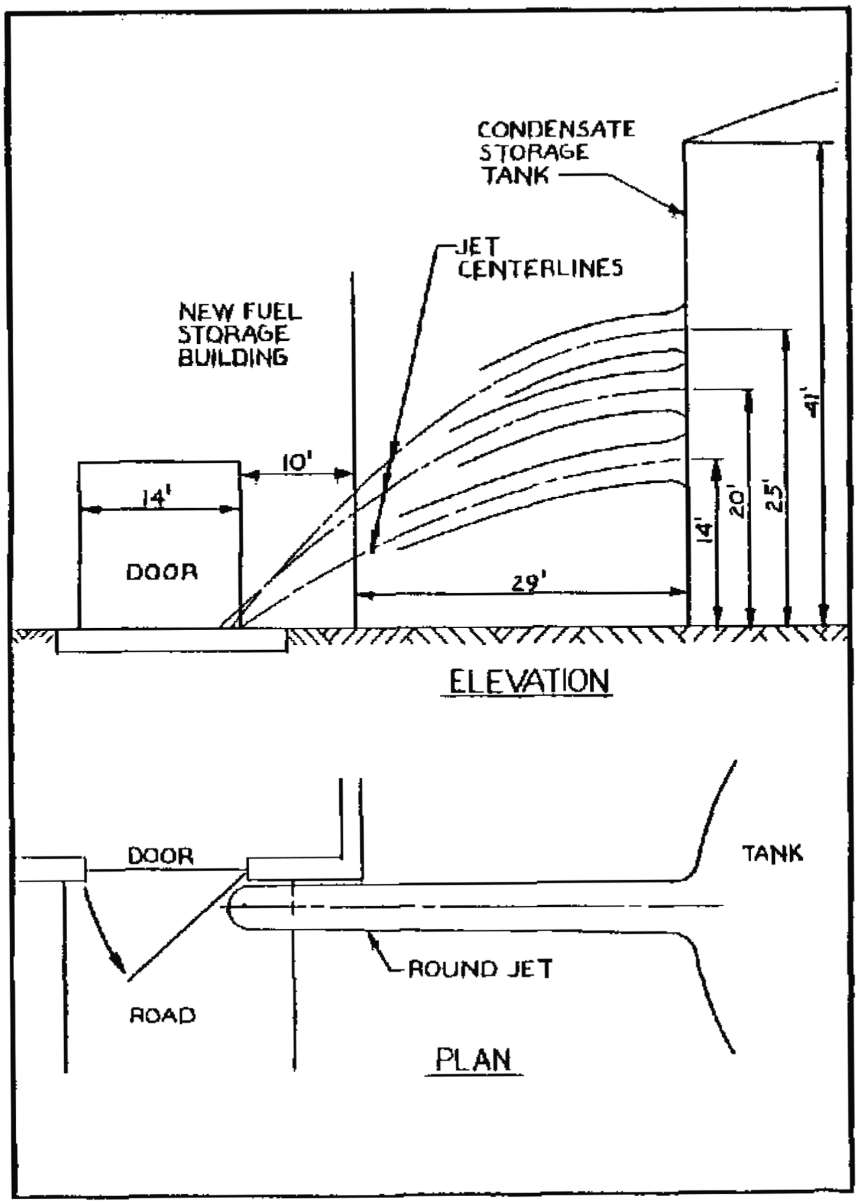
NUCLEAR PLANT
UNIT 1 AND UNIT 2

ULTIMATE HEAT SINK, POND CONFIGURATION AS MODELED IN THE UHS EVALUATION

FIGURE 9.2-8



13

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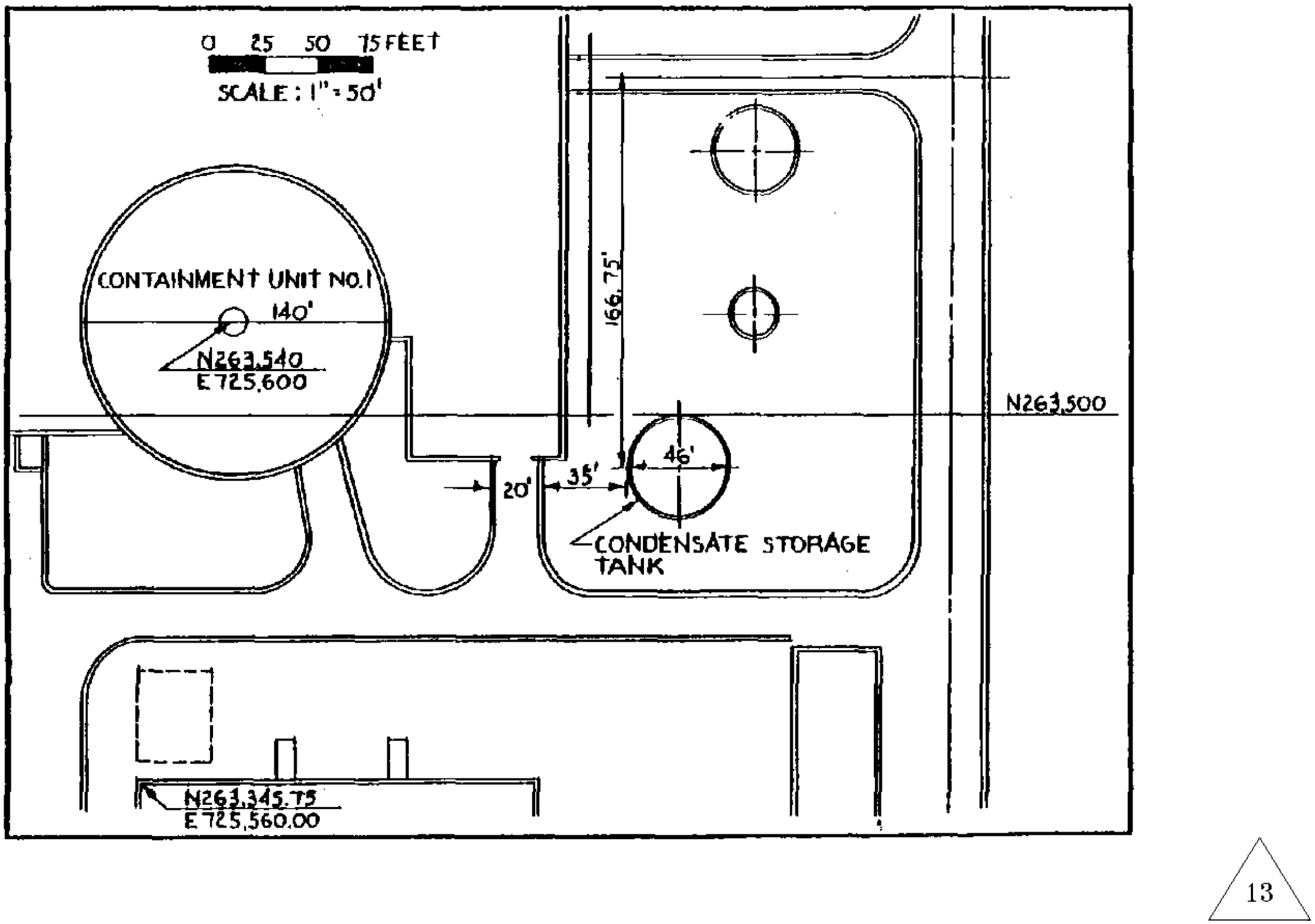
NUCLEAR PLANT
UNIT 1 AND UNIT 2

ROUND JET FROM A 20-FT^2
RUPTURED HOLE

FIGURE 9.2-9



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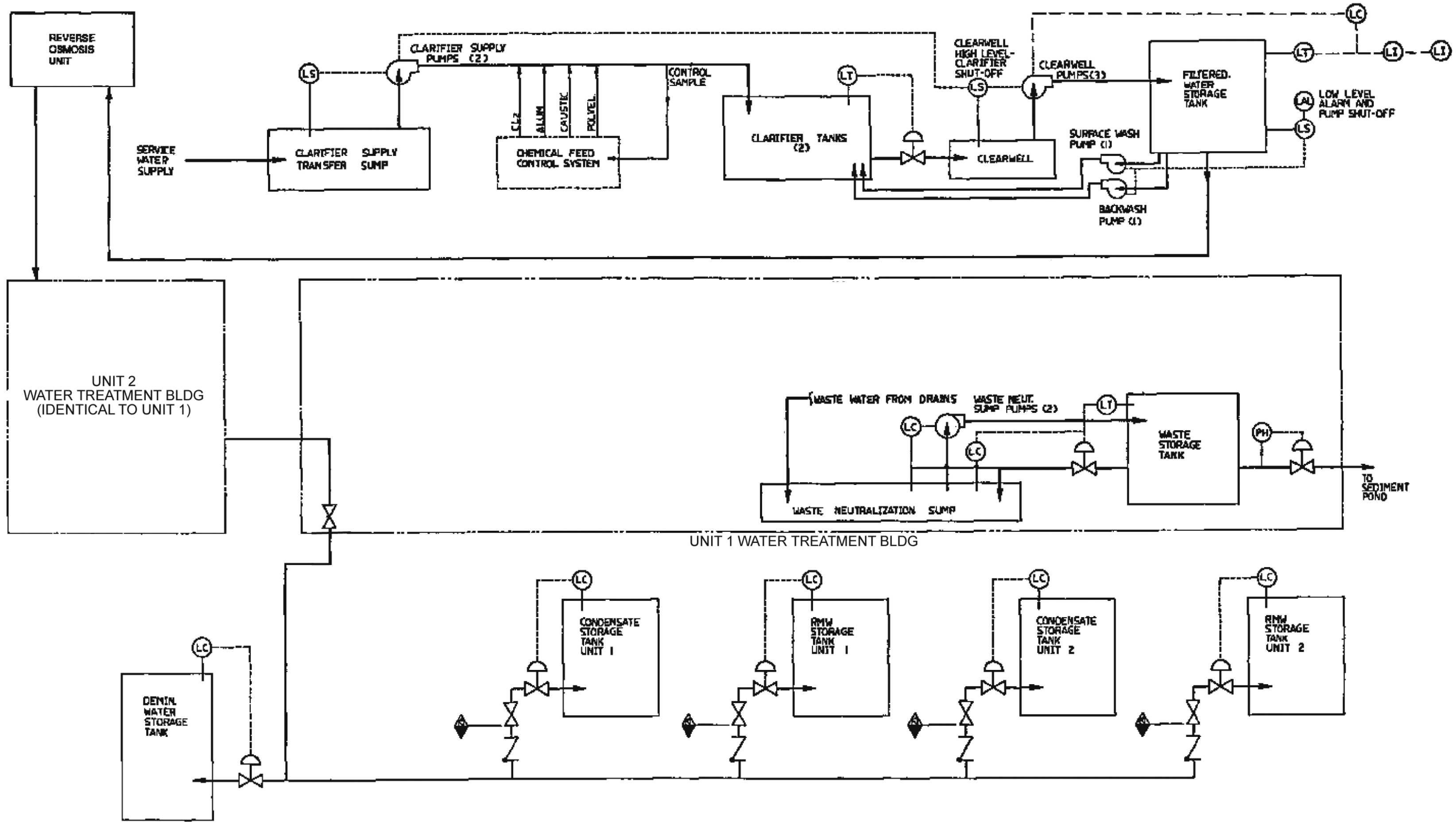
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

PLAN VIEW OF THE CONDENSATE STORAGE TANK AND ITS SURROUNDING FACILITIES

FIGURE 9.2-10



REV 22 8/09

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NUCLEAR PLANT
UNIT 1 AND UNIT 2

PLANT WATER TREATMENT SYSTEM

FIGURE 9.2-11

9.3 PROCESS AUXILIARIES

The process auxiliaries consist of those auxiliary systems associated with the reactor process system. These systems include the compressed air system, process sampling systems, equipment and floor drainage system, chemical and volume control system (CVCS), and failed fuel detection systems. The evaluations of radiological considerations are presented in chapter 12. Only the CVCS is necessary for safe shutdown of the plant.

9.3.1 COMPRESSED AIR SYSTEM

The compressed air system, as shown in drawings D-170131, sheets 1 and 2; D-200019, sheets 1 and 2; D-175035, sheet 1; D-205035; D-175034, sheets 1 through 3; and D-205034, sheets 1 through 4, provides all plant compressed air requirements for pneumatic instruments and valves and for service air outlets located throughout the plant. There are two primary trains of air compressors per unit with each unit having a spare air compressor which is arranged so that it may be used for either unit. The compressed air system is not required for the safe shutdown of the plant. The following subdivisions provide information on design bases, system descriptions, safety evaluation, tests and inspections, and instrumentation applications for the compressed air system.

9.3.1.1 Design Bases

The two primary trains of air compressors provided in the system are sized to furnish the total average instrument air requirements plus an allowance for service air use. Two parallel instrument air filtering and drying trains are provided to treat the normal maximum quantity of air required for instrument air and service air requirements and to deliver dry air having a dewpoint of -40°F or less at 100 psig. One filtering and drying train has sufficient capacity to accommodate normal operation of all three air compressors simultaneously.

The compressed air piping system which furnishes air inside the containment is equipped with containment isolation valving in accordance with the criteria for containment isolation systems as discussed in subsection 6.2.4.

All parts of the system located within the auxiliary building and containment, with the exception of the containment penetrations, are designed to meet Seismic Category II requirements. The air receivers and instrument air dryers were designed and fabricated in accordance with Section VIII of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. System piping, with the exception of the containment penetrations, was fabricated and installed in accordance with American National Standards Institute (ANSI) B31.1, Code for Pressure Piping. The containment penetration piping was fabricated and installed in accordance with Section III of the ASME Boiler and Pressure Vessel Code.

9.3.1.2 System Description

The compressed air system consists of three compressors, three aftercoolers, four air receivers, and instrument air filtering and drying equipment. The cooling water for aftercoolers and compressors is supplied from the service water system. The air receivers are connected to a common compressed air header that serves both instrument air and service air.

Each air header supplies branch lines which supply instrument air and service air to all parts of the plant. All instrument air lines penetrating the containment have isolation valves located outside the containment which are installed in series with check valves located inside the containment. All service air lines penetrating the containment have one locked closed globe valve on both sides of the containment penetration.

The three Unit 1 compressors and two of the Unit 2 compressors are two-stage, water-cooled, rotary screw compressors with a capacity of 800 scfm at 110-psig discharge pressure. Each of these compressors is equipped with an intercooler and aftercooler and discharge compressed air to a 150-ft^3-capacity air receiver tank. One of the Unit 2 compressors is a two-stage, water-cooled, rotary screw compressor with 789 scfm at 100-psig discharge pressure. This compressor is equipped with an intercooler and aftercooler and discharges compressed air to an 89-ft^3 air receiver tank. Each compressor takes suction from inside the turbine building through an air filter.

The compressor controls are designed to permit continuous operation of any number of the compressor motors with the compressors automatically loaded and unloaded in response to system pressure or automatic start and stop operation of any number of the compressor motors in response to system pressure. During normal plant operation, one of the compressors is selected for continuous motor operation, while the other compressors serve as standbys and start automatically if the continuously operating compressor cannot meet system demand.

Compressed air normally passes through one or two parallel filtering and drying trains before being distributed to the instrument air and service air piping systems. One filtering and drying train is sufficient to accommodate the normal operation of both the instrument air and service air systems. The arrangement of the filtering and drying equipment allows cleaning or changing of filters while the unit is in operation by diverting the airflow through the other parallel train. Each air dryer has two independent drying chambers connected in parallel. The air dryer automatically alternates airflow through each of the chambers to permit automatic drying of the desiccant in one chamber while the other chamber is in service.

9.3.1.3 Safety Evaluation

The compressed air system is required for normal operation and startup of the plant; however, all pneumatically operated devices in the plant essential for safe shutdown are designed to operate to the safe position upon loss of air pressure. Therefore, a supply of compressed air is not essential for safe shutdown of the plant, and the compressed air system is, accordingly, not designed to meet the single failure criterion. All pneumatically operated valves essential for safe shutdown and not used for containment isolation are listed in table 9.3-1. Those valves necessary for containment isolation are listed in table 6.2-31.

The isolation valves installed in the instrument air containment penetrations will prevent releases from the containment in the event of failure of the compressed air system pressure boundary inside the containment. The air-operated isolation valves automatically operate to the closed position upon initiation of a containment isolation signal and are designed to operate to the closed position upon failure of air pressure or electrical power to the valves.

Required air cleanliness is maintained by the following features:

A. Filters installed at the inlets to the compressors.

B. Filters at each end of the air dryer elements. The afterfilters are designed to remove particulates down to .9µm absolute.

C. Filters installed in all lines to instruments and valves essential for safe shutdown. The compressors and the air dryer units are designed for full capacity operation over the full range of environmental temperature and humidity conditions that can occur in the turbine building.

9.3.1.4 Tests and Inspections

The compressed air system will be tested in accordance with written procedures during the initial testing and operation program. All engineered safety features systems will be tested for performance capability under conditions of loss of instrument air as outlined in chapter 14.

9.3.1.5 Instrumentation Applications

For each operating unit, the air compressors can be controlled either by sequence control logic integrated into one air compressor or by remote hand switches located in the control room. The sequence control logic will make one compressor the master and the others will be slaves. The sequence control logic will load and unload the selected air compressors based on header pressure. Each compressor can be deselected from sequence control in order to be controlled by its remote hand switch. The hand switch can be placed in “off” or “auto”. When the switch is in the “auto” position the compressor will load and unload based on the compressor’s discharge pressure.

The following pressure switches (drawings D-170131, sheets 1 and 2; D-200019, sheets 1 and 2; D-175035, sheet 1; D-205035; D-175034, sheets 1 through 3; and D-205034, sheets 1 through 4) located in the system allow for an order of priority in removal of various compressed air loads in the event of a system failure:

Switch	Actuation Point	Function
N1P19PS503	80 psig decreasing	Closes N1P18V901; isolates service air header; must be manually reset
N1P19PS504	70 psig decreasing	Opens N1P19V902; bypasses air dryers and filters; must be manually reset

Switch	Actuation Point	Function
N1P19PS506	55 psig decreasing	Closes N1P19V904; isolates nonessential air header; must be manually reset
N1P19PS505A N1P19PS505B N1P19PS505C	45 psig decreasing 45 psig decreasing 45 psig decreasing	2/3 logic to close N1P19V903; isolates essential air header; must be manually reset

9.3.2 PROCESS SAMPLING SYSTEMS

9.3.2.1 Design Bases

The sampling systems are designed to permit liquid and gaseous sampling for analysis and chemistry control, both primary and secondary, of the plant primary and secondary fluids. Samples are used to provide information for monitoring the operational performance of plant equipment and for making operational decisions. The following description is for Unit I; the second unit is a separate but identical system, except as noted.

9.3.2.2 System Description

The sampling system is divided into two sections, the nuclear steam supply system (NSSS) sampling section and the turbine plant analyzer sampling section.

9.3.2.2.1 Nuclear Steam Supply System Sampling Stations

The NSSS sampling station, located in the auxiliary building sample room, provides sample streams for grab samples or collection in sample bombs as listed in table 9.3-2. Chemical and radiochemical analyses are performed on these samples, as appropriate, to determine boron concentration, fission and corrosion product concentration, and pH and conductivity levels. Analytical results are then used to regulate boron concentration, to evaluate fuel rod integrity, to evaluate ion exchanges and filter performance, and to specify chemical additions to related systems. The system is designed to permit remote collection of selected samples during all modes of operation, from full power to cold shutdown, without requiring access to the containment. Administrative procedures will ensure that precollection purging, sample collection time, and sample volume will provide representative samples for analysis.

Sample point locations have been selected to ensure that representative samples are obtained.

Also included in the design are provisions for local grab samples of liquid and gaseous fluid streams. These points, though not considered part of the sampling system, are listed in table 9.3-3.

At the NSSS sampling station, all radioactive and potentially radioactive sample streams are routed to a sampling facility contained within an exhaust ventilated, hooded enclosure. Process fluids at temperatures greater than 140°F will be cooled to < 100°F before being routed to sample pressure vessels or grab sample points.

From the sample station, purge recirculation, with appropriate pressure reduction, is routed to the volume control tank (VCT) for all points except the VCT gas sample. When operating conditions preclude purge recirculation to the VCT, i.e., CVCS system out-of-service, grab samples are obtained by directing sample system flush water to the waste holdup tank. The VCT gas sample is returned to the suction of the waste processing system gas compressor.

The sample lines are shielded to reduce radiation exposure to personnel in the sample room. Shielding is designed to reduce the radiation level to 15 mrem/h or less. Additional personnel protection is provided by an exhaust ventilation hood, sample coolers, pressure relief valves, and an area radiation monitor with high alarm.

A sample system control panel is provided and located inside the primary chemistry lab for Unit 1 and sample room for Unit 2. Control switches are provided on the panel for control of the sample isolation valves shown in drawings D-175009, sheets 1 through 3 and D-205009, sheets 1 through 3. The panel is designed to meet the requirements of Institute of Electrical and Electronics Engineers 279, 323, 344, and Seismic Category I criteria.

A remotely operated postaccident sample panel and shielded pass through (figure 9.3-1) have been added to obtain samples of highly radioactive reactor coolant. This system has the capability for taking a pressurized reactor coolant system (RCS) sample from the RCS hot leg and pressurizer and unpressurized samples from the residual heat exchangers. The postaccident sample system was installed to meet the requirements of NUREG 0578. Based on the results of the shielding design study, with subsequent modification and time studies from drawing postaccident samples, the estimated whole body or extremities radiation doses to any individual will not exceed 3 rem and 18 3/4 rem, respectively. The postaccident sample has both local and remote control panels independent of other sample system control panels. The postaccident sample panel is shown in drawing D-175009, sheet 3, with sample system connection points shown in sheet 1.

As documented in NRC SERs[1][2][3], postaccident sampling of reactor coolant either conforms to NRC acceptance criteria contained in NUREG-0578, NUREG-0737, and Regulatory Guide 1.97 or deviations have been justified.

Amendments 156 and 148 to the Facility Operating Licenses for Units 1 and 2, respectively, removed the PASS and related administrative controls from the Technical Specifications. The associated NRC SER[4] states that issuance of these amendments supersedes the PASS-specific requirements imposed by post-TMI confirmatory orders.

In addition to the enclosed sample station, there is also a sample station for process streams that will not contain radioactive materials. As shown in drawings D-175009, sheets 1 through 3 and D-205009, sheets 1 through 3, these streams include the steam line sample process streams and the steam generator sample streams.

Because of the potential for radioactively contaminated samples being drawn from the steam generators, the steam generator sample streams are routed to the enclosed sample station before being routed to the open sample station. These sample streams are continuously monitored for radioactivity by a scintillation counter and holdup tank assembly. Upon reaching a high radiation level, the isolation valves between the hooded and unhooded sample stations are automatically closed. Each steam generator is then individually sampled, within the hooded station, to determine the source of radioactivity. This procedure will minimize the amount of liquid containing radioactivity that is released to the environment through the steam generator blowdown treatment systems.

Steam generator sample temperature control is accomplished by two stages of cooling. The first stage of cooling is through roughing coolers, followed by a second stage of cooling in a refrigerator compressor condensing unit. The refrigerator compressor condenser rejects its heat through a closed cooling system to the component cooling water system.

All process sample lines penetrating the containment boundary are protected by automatic valves that close on the receipt of a high radiation signal on any one of the three steam generator blowdown sample lines. The valves are capable of remote closure from the control room.

Portions of the sample system as shown on drawings D-175009, sheets 1 through 3 and D-205009, sheets 1 through 3 are safety-related, Seismic Category I to provide for containment isolation and to interface with other safety-related systems. The remainder of the sample system is nonsafety related, nonseismic. The boundaries are specified on drawings D-175009, sheets 1 through 3 and D-205009, sheets 1 through 3. The safety-related portions of the sample system were designed to the following codes and standards:

Piping, tubing, and fittings	ASME III
Valves	ASME III

The nonsafety-related portions were designed to the following codes and standards:

Sample pressure vessels	ASME VIII
Piping, tubing, and fittings	ANSI B31.1
Valves	ANSI B31.1

The sample coolers are located in the nonsafety-related portion of the system. The design requirements for the sample coolers are identified in table 3.2-1.

The postaccident sampling system is nonseismic.

The NSSS sampling system is not necessary to ensure either the integrity of the reactor coolant pressure boundary or the capability to shut down the reactor.

The process sampling system is proved operable by its use during normal plant operation. Grab samples are taken to verify the proper operation of the continuous samplers. Portions of the system normally closed to flow can be tested to ensure the operability and integrity of the system.

Local temperature indicators after the high temperature and high pressure sample heat exchangers determine the sample temperature before a sample is drawn in a sample sink.

Local pressure indicators after the high temperature and high pressure sample heat exchangers guide the adjustment of any throttling valves. Pressure reduction valves are provided to protect the equipment and operators.

9.3.2.2.2 Turbine Plant Analyzer Sampling Section

The turbine plant analyzer sampling section draws continuous samples from the turbine cycle for automatic or manual water quality analysis. Sample inlet conditions are listed in table 9.3-4.

The turbine plant analyzer station is located in the turbine building. This station contains sample pressure reducing and cooling equipment including valves, pressure regulators, pressure indicators, flow regulators, piping grab sample sinks, and continuous analyzers for conductivity, dissolved oxygen, and pH. Recorders, indicators, and an annunciator to alarm abnormal conditions are also located at this station.

9.3.3 EQUIPMENT AND FLOOR DRAINAGE SYSTEM

9.3.3.1 Design Bases

The equipment and floor drainage system ensures that waste liquids, valve and pump leakoffs, tank drains, etc., are directed to the proper area for processing or disposal. The drains are separated according to their activity and quality. Drains containing tritiated water are collected and deposited in the waste processing system. Drains containing nontritiated water and nontritiated, chromated water are also collected and recycled or disposed of, according to the needs of the water system.

The system piping is designed to transport fluids during normal and abnormal conditions. Drain headers are large enough to accommodate the normal drain flow and minimize the possibility of fouling. Lower elevation sumps are sized to collect excess floor drainages; the sump pumps then transfer drainage to the waste processing system. An evaluation of radiological considerations of this system during normal operation is presented in chapter 11.

9.3.3.2 System Description

Each floor of the auxiliary building and containment (drawings D-175005; D-175004, sheets 1 and 2; and D-205004, sheets 1 and 2) is supplied with a separate drain header for the tritiated water drains and for the nontritiated water drains found on that level. The floor drain header and equipment drain header are provided with running traps to provide loop seals to prevent spreading of radioactive gasses in the auxiliary building. This gas migration can be further reduced by exhausting the equipment drain and the floor drain running traps located in the chemical drain tank room via negative pressure units to the radwaste area ventilation system. A maximum of three drain headers for each level are installed. The lower floor of the auxiliary building has two drain collection tanks, the floor drain tank and the waste holdup tank, which collect most of the drains from the floors above. Some drains are routed to sumps which pump to one or both of the drain collection tanks for processing. The sump contents are then pumped to the waste processing system. Drains in the containment flow to the reactor coolant drain tank or to the containment sump. They are then pumped to the waste processing system.

9.3.3.3 Design Evaluation

The equipment and floor drainage system accommodates the auxiliary building and containment drains during each normal mode of plant operation. It is mainly a passive system required to function at all times. Because the drain headers are not pressurized, a line rupture is unlikely. Plugging of the header is minimized by installing main headers large enough to accommodate more than the design flow and by making the flow path as straight as possible. Main headers are at least 4 in. in diameter.

The volume of the floor drain tank is 10,000 gal. ***[HISTORICAL] [****Under normal operation it is expected that 51,000 gal/year of liquid wastes will be processed through the tank for a single unit. This consists of the following flows:*

Decontamination water	*15,000 gal/year*
Laboratory equipment rinses	*16,000 gal/year*
Nonrecyclable reactor coolant	*7000 gal/year*
Nonreactor grade leaks	*13,000 gal/year*

This corresponds to a daily average flowrate of ~140 gal/day. With a single unit feeding the floor drain tank, and assuming filling for 30 days, the tank will be about half full at processing.

*In addition to the above, consideration was also given to fabrication, standardization, and layout criteria in finally sizing the tank.**]***

Sumps and sump pumps in the auxiliary building lower elevations collect drainage from the floor drain system and discharge to the waste processing system. Each of the low-head safety injection pump rooms, the containment spray pump rooms, and the high-head safety injection pump rooms is watertight and is protected by an individual sump containing two nonsafety-related sump pumps which are powered from the same electrical train as the pumps they are protecting. Each sump receives only drainage from the individual pump room that it is protecting.

Each sump pump has a design flowrate of 100 gal/min. Each sump is equipped with a mechanical alternator and high level alarm. When the level in the sump rises to within 13 in. of the cover, the leading pump is started. An indicator light on the control board signifies that one pump is running. If the leading pump cannot handle the full flow of incoming liquid and the level rises to within 12 in. of the cover, the lagging pump starts and an indicator light on the control board signifies that both pumps are running. If both pumps are unable to handle the load and the level rises to within 6 in. of the cover, an alarm is sounded in the control room. If the leading pump alone is able to reduce the level in the sump to the pump cutoff point, the mechanical alternator will then cause the lagging pump to become the leading pump for the next required operation. The liquid in these sumps is pumped to the waste processing system.

The watertight rooms protect each pump from flooding from outside the room. Frequency of sump pump operation, one-pump versus two-pump operation, and sump high level alarms will indicate leaks within the individual pump rooms and will provide the operator with a gross indication of the magnitude of the leak.

9.3.3.4 Tests and Inspections

[HISTORICAL] [*Each drain header is flushed and inspected with regard to leaktightness, flow capacity, and flow path. Pumps and level switches are tested for start and stop at the proper sump levels. Piping and valves are inspected for leaktightness, flow paths, and mechanical operability.****]***

9.3.3.5 Instrumentation and Control

Level switches and indicators are provided in the control room to control stopping and starting of pumps and to indicate a flood condition of a residual heat removal pump or containment spray system pump compartment. The waste processing system radiation monitor (R-18) is described in paragraph 11.4.2.2.11.

9.3.3.6 Nonradioactive Auxiliary Building Sump Transfer

A manual mode of operation exists which allows nonradioactive drainage in the auxiliary building sumps to be transferred to the turbine building sumps. This mode also allows for transfer of service water from containment components to the turbine building sump to support component maintenance during an outage. The transfer path to the nonradioactive sump is established using a CTMT service penetration under administrative controls. To accomplish a transfer, the handswitches for the nonradioactive auxiliary building sump pumps are placed in the "pull-to-lock" position. This overrides the automatic sump pump operation described in paragraph 9.3.3.3 and allows these sumps to be selectively aligned with turbine building sumps.

In order to align the auxiliary building nonradioactive sumps to the turbine building sumps, cross-connect valve N1G21V325/ N2G21V320 must be unlocked and opened. Subsequent to opening this cross-connect valve, the handswitch for the desired pump may be removed from the "pull-to-lock" position and started as required. After the nonradioactive drainage has been pumped to the turbine building sump, the pump is stopped and the handswitch returned to the "pull-to-lock" position. Cross-connect valve N1G21V325/N2G21V320 is then closed and locked to ensure that no fluid is unintentionally transferred to the turbine building sumps.

9.3.4 CHEMICAL AND VOLUME CONTROL SYSTEM AND LIQUID POISON SYSTEM

9.3.4.1 Chemical and Volume Control System

The CVCS shown in drawings D-175039, sheets 1 through 7 and D-205039, sheets 1 through 5 is designed to provide the following services to the RCS:

A. Maintenance of programmed water level in the pressurizer, i.e., maintain required water inventory in the RCS.

B. Maintenance of seal water injection flow to the reactor coolant pumps.

C. Control of water chemistry conditions, activity level, soluble chemical neutron absorber concentration, and makeup.

D. Processing of effluent reactor coolant to effect recovery and reuse of soluble chemical neutron absorber and makeup water.

E. Emergency core coolant [part of the system is shared with the emergency core cooling system (ECCS)].

9.3.4.1.1 Design Bases

Quantitative design bases are given in table 9.3-5 with qualitative descriptions given below.

A. Reactivity Control

The CVCS regulates the concentration of chemical neutron absorber in the reactor coolant to control reactivity changes resulting from the change in reactor coolant temperature between cold shutdown and hot full power operation, burnup of fuel and burnable poisons, and xenon transients.

Reactor makeup control is as follows:

1. The CVCS is capable of borating the RCS through any of three flow paths and from any of three boric acid sources.

2. The amount of boric acid stored in the CVCS always exceeds that amount required to borate the RCS to cold shutdown concentration, assuming that the control assembly with the highest reactivity worth is stuck in its fully withdrawn position. This amount of boric acid also exceeds the amount required to bring the reactor to hot shutdown and to compensate for subsequent xenon decay.

3. The CVCS is capable of counteracting inadvertent positive reactivity insertion caused by the maximum boron dilution accident (chapter 15).

B. Regulation of Reactor Coolant Inventory

The CVCS maintains the coolant inventory in the RCS within the allowable pressurizer level range for all normal modes of operation including startup from cold shutdown, full power operation, and plant cooldown. This system also has sufficient makeup capacity to maintain the minimum required inventory in the event of minor RCS leaks. (See the plant Technical Specifications for a discussion of maximum allowable RCS leakage.)

The CVCS flowrate is based on the requirement that it permit the RCS to be heated to or cooled from hot standby condition at the design rate and maintain pressurizer level within the limits of the operating band.

C. Reactor Coolant Purification

The CVCS removes fission and activation products (other than tritium) from the reactor coolant during operation of the reactor. The CVCS can also remove excess lithium from the reactor coolant, keeping the lithium concentration within the desired limits for pH control. (See table 5.2-22.)

Tritium is produced within the fuel by ternary fission and from neutron reactions with the soluble boron, the lithium used for the pH control, and naturally occurring deuterium within the coolant. The lithium concentration is maintained within the desired range by the addition of Li^7OH and by a cation or mixed-bed demineralizer that will remove any excess of lithium produced by the $B^{10}(n,\alpha)Li^7$ reaction. The $Li^6(n,\alpha)T$ reaction is controlled by limiting the Li^6 impurity to 0.1 atomic percent. The contributions from these sources are slight, as indicated in appendix 11A. As can be seen, the primary sources of tritium in the coolant are from ternary fission and the $B^{10}(n,2\alpha)T$ reaction with the boron in the coolant.

Once the tritium is in the coolant, the only method of controlling the concentration is by dilution of the primary coolant. There is a letdown from the primary coolant system to the CVCS of 135 gal/min (maximum). Thus tritium is distributed throughout the recycle holdup tanks, the boric acid tanks, and the reactor makeup water storage tank. During refueling operations some water is exchanged between the RCS and the refueling water storage tank. There is also some exchange of water with the spent-fuel pool. Without exchange of any of this water with the environment (complete holdup of tritium) the coolant concentration would reach the levels given in appendix 11A.1.5. Actual tritium concentrations will depend on plant operating parameters, such as leakage (requiring makeup) and planned releases of tritiated water.

The CVCS is capable of removing fission and activation products, in ionic form or as particulates, from the reactor coolant in order to provide access to those process lines carrying reactor coolant during operation and to reduce activity releases due to leaks.

D. Chemical Additions for Corrosion Control

The CVCS provides a means for adding chemicals (batch addition) to the RCS which control the pH of the coolant during initial startup and subsequent operation, scavenge oxygen from the coolant during startup, and control the oxygen level of the reactor coolant due to radiolysis during all operations subsequent to startup.

Chemicals may also be added on a continuous basis to control stress corrosion cracking in Alloy 600 materials and to reduce RCS radiation levels.

The CVCS is capable of maintaining the oxygen content and pH of the reactor coolant within limits specified in table 5.2-22.

The dilution effect of chemical addition (both batch and continuous) must be compensated for in selecting the proper reactor makeup boron concentration as discussed in paragraph 9.3.4.1.1A.

E. Seal Water Injection

The CVCS is able to supply filtered water continuously to each reactor coolant pump seal, as required by the reactor coolant pump design.

F. Emergency Core Cooling

The centrifugal charging pumps in the CVCS also serve as the high-head safety injection pumps in the ECCS. Other than the centrifugal charging pumps and associated piping and valves, the CVCS is not required to function during a loss-of-coolant accident (LOCA). During a LOCA, the CVCS is isolated except for the centrifugal charging pumps and the piping in the safety injection path.

9.3.4.1.2 System Description

The CVCS is shown in drawings D-175039, sheets 1 through 7 and D-205039, sheets 1 through 5, with design parameters listed in table 9.3-5. The CVCS consists of several subsystems: the charging, letdown, and seal water system; the chemical control, purification, and makeup system; and the boron recycle system.

9.3.4.1.2.1 <u>Charging, Letdown, and Seal Water System</u>. The charging and letdown functions of the CVCS are employed to maintain a programmed water level in the RCS pressurizer, thus maintaining proper reactor coolant inventory during all phases of plant operation. This is achieved by means of a continuous feed and bleed process, during which the feed rate is automatically controlled on the basis of pressurizer water level. The bleed rate can be chosen to suit various plant operational requirements by selecting the proper combination of letdown orifices in the letdown flow path. This selection is made through remote manual operation of valves located in the parallel orificed paths as discussed in paragraph 9.3.4.1.2.2.4.

Reactor coolant is discharged to the CVCS from the reactor coolant loop piping upstream of the reactor coolant pump; it then flows through the shell side of the regenerative heat exchanger, where its temperature is reduced by heat transfer to the charging flow passing through the tubes. The coolant then experiences a large pressure reduction as it passes through a letdown orifice and flows through the tube side of the letdown heat exchanger, where its temperature is further reduced to the operating temperature of the mixed-bed demineralizers (140°F). Downstream of the letdown heat exchanger a second pressure reduction occurs. This second pressure reduction is performed by the low-pressure letdown valve, the function of which is to maintain upstream pressure which prevents flashing downstream of the letdown orifices.

The coolant then flows through one of the mixed-bed demineralizers. The flow may then pass through the cation bed demineralizer, which is used intermittently when additional purification of the reactor coolant is required. The cation bed demineralizer flow is limited to a maximum of 60 gal/min.

During boric acid storage and release operations, especially during load follow, part or all of the letdown flow leaving the demineralizers is directed to the boron thermal regeneration system (BTRS), discussed in paragraph 9.3.4.2. The coolant then flows through the reactor coolant filter and into the volume control tank through a spray nozzle in the top of the tank. The gas space in the volume control tank may be continuously purged with hydrogen. Subsection 11.3.4 contains descriptions of operation with and without continuous purge. The partial pressure of hydrogen in the volume control tank determines the concentration of hydrogen dissolved in the reactor coolant.

The charging pumps normally take suction from the volume control tank and return the cooled, purified reactor coolant to the RCS through the charging line. Normal charging flow is handled by one of the three charging pumps. The bulk of the charging flow is pumped back to the RCS through the tube side of the regenerative heat exchanger. The letdown flow in the shell side of the regenerative heat exchanger raises the charging flow to a temperature approaching the reactor coolant temperature. The flow is then injected into a cold leg of the RCS. Two charging paths are provided from a point downstream of the regenerative heat exchanger. A flow path is also provided from the regenerative heat exchanger outlet to the pressurizer spray line. An air-operated valve in the spray line is employed to provide auxiliary spray to the vapor space of the pressurizer during plant cooldown. This provides a means of cooling the pressurizer near the end of plant cooldown, when the reactor coolant pumps are not operating.

A portion of the charging flow (nominally 8 gal/min per reactor coolant pump) is directed to the reactor coolant pumps through a seal water injection filter. It is directed down to a point between the pump shaft bearing and the thermal barrier cooling coil. Here the flow splits and a portion (nominally 5 gal/min per pump) enters the RCS through the labyrinth seals and thermal barrier. The remainder of the flow is directed up the pump shaft, cooling the lower bearing, and to the No. 1 seal leakoff. The No. 1 seal leakoff flow discharges to a common manifold, exits from the containment, and then passes through the seal water return filter and the seal water heat exchanger to the suction side of the charging pumps, or by alternate path to the volume control tank. A check valve in the spool piece between the reactor coolant pumps and the No. 1 seal leakoff line prevents reverse flow through the seal. A very small portion of the seal flow leaks through to the No. 2 seal. A No. 3 seal provides a final barrier to leakage to containment atmosphere. The No. 2 seal leakoff flow is discharged to the reactor coolant drain found in the waste processing system, and the No. 3 seal leakoff flow is discharged to the containment sump.

An alternate letdown path from the RCS is provided in the event that the normal letdown path is inoperable. Reactor coolant can be discharged from a cold leg and flows through the tube side of the excess letdown heat exchanger, where it is cooled by component cooling water flowing through the shell side. Downstream of the heat exchanger, a remote manual control valve controls the excess letdown flow. The flow normally joins the No. 1 seal discharge manifold and passes through the seal water return filter and heat exchanger to the suction side of the charging pumps. The excess letdown flow can also be directed to the reactor coolant drain tank. When the normal letdown line is not available, the normal purification path is also not in operation. Therefore, this alternate condition would allow continued power operation for limited periods of time dependent on RCS chemistry and activity. The excess letdown flow path is also used to provide additional letdown capability during the final stages of plant heatup. This path removes some of the excess reactor coolant due to expansion of the system as a result of the RCS temperature increase. In this case, the excess letdown is diverted to the reactor coolant drain tank.

Surges in RCS inventory due to load changes are accommodated for the most part in the pressurizer. The volume control tank provides surge capacity for reactor coolant expansion not accommodated by the pressurizer. If the water level in the volume control tank exceeds the normal operating range, a proportional controller modulates a three-way valve downstream of the reactor coolant filter to divert a portion of the letdown to the recycle holdup tanks in the boron recycle system. If the high level limit in the volume control tank is reached, an alarm is actuated in the control room and the letdown is completely diverted to the recycle holdup tanks.

The boron recycle system (paragraph 9.3.4.1.2.3) can be used to receive and process reactor coolant effluent for reuse of the boric acid and purified water. The system decontaminates the effluent by means of demineralization and gas stripping and uses evaporation to separate and recover the boric acid and reactor makeup water.

Low level in the volume control tank initiates makeup from the reactor makeup control system. If the reactor makeup control system does not supply sufficient makeup to keep the volume control tank level from falling to a lower level, an emergency low level signal causes the suction of the charging pumps to be transferred to the refueling water storage tank.

9.3.4.1.2.2 Chemical Control, Purification, and Makeup System. The pH control, oxygen control, reactor coolant purification, and chemical shim and reactor coolant makeup of this system are discussed below.

9.3.4.1.2.2.1 The pH Control. The pH control chemical employed is lithium hydroxide. This chemical is chosen for its compatibility with the materials and water chemistry of borated water/stainless steel/zirconium/inconel systems. In addition, Li^7 is produced in the core region due to irradiation of the dissolved boron in the coolant.

The concentration of Li^7 in the RCS is maintained in the range specified for pH control (table 5.2-22). If the concentration exceeds this range, as it may during the early stages of core life, the cation bed demineralizer is employed in the letdown line in series operation with a mixed bed demineralizer. Since the amount of lithium to be removed is small and its buildup can be readily calculated, the flow through the cation bed demineralizer is not required to be full letdown flow. As an alternate, a nonlithiated mixed-bed demineralizer may be used to remove the lithium. If the concentration of Li^7 is below the specified limits, lithium hydroxide can be introduced into the RCS via the charging flow. The solution is prepared in the laboratory and poured into the chemical mixing tank. Reactor makeup water is then used to flush the solution to the suction manifold of the charging pumps.

9.3.4.1.2.2.2 Oxygen Control. During reactor startup from the cold condition, hydrazine is employed as an oxygen scavenging agent. The hydrazine solution is introduced into the RCS in the same manner as described above for the pH control agent. Hydrazine is not employed at any time other than startup from the cold shutdown state.

Dissolved hydrogen is employed to control and scavenge oxygen produced due to radiolysis of water in the core region. Sufficient partial pressure of hydrogen is maintained in the volume control tank so that the specified equilibrium concentration of hydrogen is maintained in the reactor coolant. A pressure control valve maintains a minimum pressure in the vapor space of the volume control tank. This valve can be adjusted to provide the correct equilibrium hydrogen concentration (25 to 50 cm^3 hydrogen at STP/kg water for power operation). If operating without continuous VCT purge as described in subsection 11.3.4, the pressure control valve may be isolated and hydrogen pressure controlled by manual operation as necessary to maintain the required partial pressure of hydrogen.

9.3.4.1.2.2.3 Reactor Coolant Purification. Mixed-bed demineralizers are provided in the letdown line to provide cleanup of the letdown flow. The demineralizers remove ionic corrosion products and certain fission products. One demineralizer is in continuous service and can be supplemented intermittently by the cation bed demineralizer, if necessary, for additional purification. The cation resin removes principally cesium and lithium isotopes from the purification flow. The second mixed-bed demineralizer serves as a standby unit for use if the operating demineralizer becomes exhausted during operation.

A further cleanup feature is provided for use during cold shutdown and residual heat removal. A remotely operated valve admits a bypass flow from the residual heat removal system into the letdown line upstream of the letdown heat exchanger. The flow passes through the heat exchanger, through a mixed-bed demineralizer and the reactor coolant filter to the volume control tank. The fluid is then returned to the RCS via the normal charging route.

Filters are provided at various locations to ensure filtration of particulate and resin fines and to protect the seals on the reactor coolant pumps.

Fission gases can be removed from the system by purging the volume control tank gas space with hydrogen to the gaseous waste processing system.

9.3.4.1.2.2.4 Chemical Shim and Reactor Coolant Makeup. The soluble neutron absorber (boric acid) concentration is controlled by the BTRS and by the reactor makeup control system. The reactor makeup control system is also used to maintain proper reactor coolant inventory. For emergency boration and makeup, the capability exists to provide refueling water or 4-wt-percent boric acid to the suction of the charging pump.

The boric acid is stored in two boric acid tanks. Two boric acid transfer pumps are provided, with one pump normally aligned to provide boric acid to the boric acid blender and the second pump in reserve. On a demand signal by the reactor makeup control system, the pump starts and delivers boric acid to the boric acid blender. The pump can also be used to recirculate the boric acid tank fluid.

The reactor makeup water pumps, taking suction from the reactor makeup water storage tank, are employed for various makeup and flushing operations throughout the systems. One of these pumps also starts on demand from the reactor makeup control system and provides flow to the boric acid blender. For a description of the reactor makeup water system see subsection 9.2.7.

The flow from the boric acid blender is directed to either the suction manifold of the charging pumps or the volume control tank through the letdown line and spray nozzle.

During reactor operation, changes are made in the reactor coolant boron concentration for the following conditions:

A. Reactor startup - Boron concentration must be decreased from shutdown concentration to achieve criticality.

B. Load follow - Boron concentration must be either increased or decreased to compensate for the xenon transient following a change in load.

C. Fuel burnup - Boron concentration must be decreased to compensate for fuel burnup, except as offset by (E) below.

D. Cold shutdown - Boron concentration must be increased to the cold shutdown concentration.

E. Burnable poison depletion - Boron concentration must be increased to compensate for burned poison depletion.

The BTRS is used to control boron concentration to compensate for xenon transients during load follow operations. Boron thermal regeneration can also be used during dilution operations to reduce the amount of effluent to be processed by the boron recycle system portion of the CVCS.

The reactor makeup control system consists of a group of instruments arranged to provide a manually preselected makeup composition to the charging F1-6 pump suction header or the volume control tank. The makeup control functions are those of maintaining desired operating fluid inventory in the volume control tank and adjusting reactor coolant boron concentration for reactivity control.

A. Automatic Makeup (F1)

The automatic makeup mode of operation of the reactor makeup control system provides boric acid solution preset to match the boron concentration in the RCS. The automatic makeup compensates for minor leakage of reactor coolant without causing significant changes in the coolant boron concentration.

Under normal plant operating conditions, the mode selector switch and makeup stop valves are set in the automatic makeup position. A present low level signal from the volume control tank level controller causes the automatic makeup control action to start a reactor makeup water pump, start a boric acid transfer pump, open the makeup stop valve to the charging pump suction, open the concentrated boric acid control valve, and open the reactor makeup water control valve. The flow controllers then blend the makeup stream according to the preset concentration. Makeup addition to the charging pump suction header causes the water level in the volume control tank to rise. At a preset high level point, the makeup is stopped, the reactor makeup water pump stops, the reactor makeup water control valve closes, the boric acid transfer pump stops, the concentrated boric acid control valve closes, and the makeup stop valve to charging pump suction closes.

If the automatic makeup fails or is not aligned for operation and the tank level continues to decrease, a low-level alarm is actuated. Manual action may correct the situation, or, if the level continues to decrease, an emergency low level signal from both channels opens the stop valves in the refueling water supply line to the charging pumps and closes the stop valves in the volume control tank outlet line.

B. Dilution (F2)

The dilute mode of operation permits the addition of a preselected quantity of reactor makeup water at a preselected flowrate to the RCS. The operator sets the mode selector switch to dilute, the reactor makeup water flow controller setpoint to the desired flowrate, and the reactor makeup water batch integrator to the desired quantity, and he then initiates system start. This opens the reactor makeup water control valve to the volume control tank and starts a reactor makeup water pump which will deliver water to the volume control tank. From here the water goes to the charging pump suction header. Excessive rise of the volume control tank water level is prevented by automatic actuation (by the tank level controller) of a three-way diversion valve which routes the reactor coolant letdown flow to the recycle holdup tanks. When the preselected quantity of water has been added, the batch integrator causes the pump to stop and the control valve to close.

Dilution can also be accomplished by operating the BTRS in the boron storage mode.

C. Alternate Dilution (F3)

The alternate dilute mode of operation is similar to the dilute mode, except that a portion of the dilution water flows directly to the charging pump suction and a portion flows into the volume control tank via the spray nozzle and then flows to the charging pump suction. Dilution water can be directed entirely to the charging pump suction, if desired, by manually closing the makeup water control valve to the VCT.

D. Boration (F4)

The borate mode of operation permits the addition of a preselected flowrate to the RCS. The operator sets the mode selection switch to borate, the concentrated boric acid flow controller setpoint to the desired flowrate, and the concentrated boric acid batch integrator to the desired quantity, and he then initiates system start. This opens the makeup stop valve to the charging pumps suction and starts the boric acid solution to the charging pumps suction header. The total quantity added in most cases is so small that it has only a minor effect on the volume control tank level. When the preset quantity of concentrated boric acid solution is added, the batch integrator stops the boric acid transfer pump and closes the makeup stop valve to the suction of the charging pumps.

Boration can also be accomplished by operating the BTRS in the boron release mode.

E. Manual (F5)

The manual mode of operation permits the addition of a preselected quantity and blend of boric acid solution to the refueling water storage tank, the spent-fuel pool, or the recycle holdup tanks in the boron recycle system. While it is in the manual mode of operation, automatic makeup to the RCS is precluded. The discharge flow path must be prepared by opening manual valves in the desired path.

The operator then sets the mode selector switch to manual, the boric acid and reactor makeup water flow controllers to the desired flowrates, and the boric acid and reactor makeup water batch integrators to the desired quantities, and he then actuates the makeup start switch. The start switch actuates the boric acid flow control valve and the reactor makeup water flow control valve to the boric acid blender and starts the preselected reactor makeup water pump and the boric acid transfer pump.

When the preset quantities of boric acid and reactor makeup water have been added, the pumps stop and the boric acid and reactor makeup water flow control valves close. This operation may be stopped manually by actuating the makeup stop switch.

If either batch integrator is satisfied before the other has recorded its required total, the pump and valve associated with the integrator that has been satisfied will terminate flow. The flow controlled by the other integrator will continue until that integrator is satisfied.

F. Alarm Functions (F6)

The reactor makeup control is provided with alarm functions to call the operator's attention to the following conditions:

1. Deviation of reactor makeup water flowrate from the control setpoint.

2. Deviation of concentrated boric acid flowrate from control setpoint.

3. High level in the volume control tank. This alarm indicates that the level in the tank is approaching high level and a resulting 100-percent diversion

of the letdown stream to the recycle holdup tanks in the boron recycle system.

4. Low level in the volume control tank. This alarm indicates that the level in the tank is approaching emergency low level and resulting realignment of charging pump suction to the refueling water storage tank.

9.3.4.1.2.3 **Boron Recycle System.** The boron recycle system can be used to receive and recycles reactor coolant effluent for reuse of the boric acid and makeup water. The system decontaminates the effluent by means of demineralization and gas stripping and uses evaporation to separate and recover the boric acid and makeup water.

The system is designed to collect the excess reactor coolant that results from the following plant operation during one core cycle (approximately 1 year):

A. Dilution for core burnup from approximately 1200-ppm boron at beginning of a core cycle to approximately 100 ppm near the end of a core cycle (dilution from 100- to 10-ppm boron is handled by the thermal regeneration demineralizers in the BTRS).

B. Hot shutdowns and startups. Four hot shutdowns are assumed to take place during a core cycle.

C. Cold shutdowns and startups. Three cold shutdowns are assumed to take place during a core cycle.

D. Refueling shutdown and startup.

The boron recycle system is designed to process the total volume of water collected during a core cycle as well as short term surges. The design surge is that produced by a cold shutdown and subsequent startup during the latter part of a core cycle.

Water is also collected from the following sources:

A. Volume control tank pressure relief (CVCS).

B. Boric acid blender (CVCS) - Provides storage of boric acid if a boric acid tank must be emptied for maintenance. The boric acid solution is stored in a recycle holdup tank after first being diluted with reactor makeup water by the blender. The boric acid concentration is reduced to ensure against precipitation of the boric acid in the unheated recycle holdup tank.

C. ECCS flush - Accepts flush water from safety injection lines.

D. Waste processing system - Provides capability for using the recycle evaporator as a waste evaporator and vice versa.

E. Spent-fuel pool pumps (spent-fuel pool cooling and cleanup system) - Provide a means of storing the fuel transfer canal water in case maintenance is required on the transfer equipment.

F. Valve leakoffs and equipment drains.

The water collected by the boron recycle system contains dissolved gases, boric acid, and suspended solids. Based on reactor operations with 1 percent of the rated core thermal power being generated by fuel elements with defective cladding, the boron recycle system is designed to provide sufficient cleanup of the water to satisfy the chemistry requirements of the recycled reactor makeup water and 4-wt-percent boric acid solution.

The maximum radioactivity concentration buildup in the boron recycle system components is based on operation of the reactor at its engineered safeguards design rating, with defective fuel rods generating 1 percent of the rated core thermal power. For each component, the shielding design considers the maximum buildup on an isotopic basis including only those isotopes which are present in significant amounts. Filtration, demineralization, and evaporation are the means by which the activity concentrations are controlled.

All portions of the boron recycle system that contain concentrated boric acid solution are located within a heated area in order to maintain solution temperature at ≥ 65°F. This is 10°F above the solubility limit for the nominal 4 wt percent boric acid solution. If a portion of the system which normally contains concentrated boric acid solution is not located in a heated area, it must be provided with some other means (e.g., heat tracing) to maintain solution temperature at ≥ 65°F.

The boron recycle system is manually operated with the exception of a few automatic protection functions. These automatic functions protect the recycle evaporator feed demineralizers from a high inlet temperature and a high differential pressure, prevent a high vacuum from being drawn on the recycle holdup tank, and prevent high activity recycle evaporator condensate from being sent to the reactor makeup water storage tank. The boron recycle system has sufficient instrumentation readouts and alarms to provide the operator information to ensure proper system operation.

A. Evaporation

When water is directed to the boron recycle system for reprocessing, the flow passes first through the recycle evaporator feed demineralizers and filter and then into the recycle holdup tanks. The recycle evaporator feed pumps can be used to transfer liquid from one recycle holdup tank to the other, if desired. When sufficient water is accumulated to warrant evaporator operation, the recycle evaporator feed pumps take suction from the selected recycle holdup tank. The fluid then flows through the recycle evaporator package. Here hydrogen, nitrogen, and residual fission gases are removed in the stripping column before the liquid enters the evaporator shell.

These gases are directed to the gas portion of the waste processing system.

During evaporator operation, distillate from the evaporator flows continuously to the reactor makeup water storage tank. Also located in this flow path are the recycle evaporator condensate demineralizer and the recycle evaporator condensate filter.

The evaporator concentrates the boric acid solution until a 4-wt-percent solution is obtained. The accumulated batch is normally transferred directly to the boric acid tanks through the recycle evaporator concentrates filter. If, for some reason, this batch cannot be discharged to the boric acid tanks, it can be diverted back to the recycle holdup tanks or to the waste processing system.

Connections are provided so that, if necessary, the recycle evaporator can be used as a waste evaporator and vice versa.

B. Recycle Holdup Tank Venting

Because hydrogen is dissolved in the reactor coolant at approximately one atmosphere overpressure, a portion of the hydrogen along with fission gases will come out of solution in the recycle holdup tank under the diaphragm. The hydrogen and fission gases are vented to the waste processing system (gas portion) or the plant vent stack (via a portable pump) and the radwaste ventilation system as required. The total integrated flow of hydrogen-bearing water to the recycle holdup tanks is monitored. An alarm indicates when a sufficient amount of water has passed to the recycle holdup tanks to require venting of the accumulated gases.

C. Maintenance Drains

When large amounts of water must be drained from the RCS or the spent-fuel pool (or fuel transfer canal) to the boron recycle system, a recycle holdup tank is drained of water and vented to the waste processing system. The water can then be stored in this tank until maintenance is completed and, after checking the chemistry, returned. After returning the water, the recycle holdup tank is again vented to the waste processing system.

D. Reactor Makeup Water Cleanup

If the reactor makeup water requires purification, it can be recirculated through the recycle evaporator condensate demineralizer until its chemistry is within specifications. If further processing is necessary, water from the reactor makeup water storage tank can be directed through the recycle evaporator condensate demineralizer and into the recycle holdup tank for reevaporation. Alternatively, reactor makeup water can be directed to the recycle evaporator through its flush line, bypassing the demineralizer and holdup tank, provided that the reactor makeup water storage tank is maintained above established minimum level.

E. Waste Processing with the Recycle Evaporator

The recycle evaporator can be used to perform the function of the waste evaporator except that, since heat tracing is not provided for the recycle evaporator, the boric acid would be concentrated to no more than 4 wt%.

After using the recycle evaporator to process water from the waste processing system, it is thoroughly rinsed out. During initial recycle processing, the condensate is directed to the waste condensate tank for analysis prior to transfer to the reactor makeup water storage tank. Depending upon the purity of the evaporator bottoms, the concentrated boric acid can be transferred to the boric acid tanks or it can be drummed.

9.3.4.1.2.4 <u>Layout</u>. The volume control tank is located above the charging pumps to provide sufficient net positive suction head. All parts of the charging and letdown system are shielded as necessary to limit dose rates during operation with 1-percent fuel defects assumed. The regenerative heat exchanger, excess letdown heat exchanger, letdown orifices, and seal bypass orifices are located within the reactor containment. All other system equipment is located inside the auxiliary building.

9.3.4.1.2.5 <u>Component Description</u>. A summary of principal component design parameters is given in table 9.3-6, and safety classifications and design codes are given in section 3.2.

All CVCS piping that handles radioactive liquid is austenitic stainless steel. All piping joints and connections are welded, except where flanged connections are required to facilitate equipment removal for maintenance and hydrostatic testing.

9.3.4.1.2.5.1 Charging Pumps. Three charging pumps are supplied to inject coolant into the RCS. The charging pumps are all of the horizontal, multistage, centrifugal type. All parts in contact with the reactor coolant are fabricated of austenitic stainless steel or other material of adequate corrosion resistance. There is a minimum flow recirculation line to protect the centrifugal charging pumps from a closed discharge valve condition.

Charging flowrate is determined from a pressurizer level signal. Charging flow control is accomplished by a modulating valve on the discharge side of the centrifugal pumps. The centrifugal charging pumps also serve as high head safety injection pumps in the ECCS.

Only one charging pump will be operable at RCS temperatures below 180°F, except during pump swap operations. The remaining two charging pumps will have power removed from the pump. This procedure will reduce the likelihood of overpressurizing the RCS due to inadvertent operation of the charging pumps.

9.3.4.1.2.5.2 Boric Acid Transfer Pumps. Two horizontal, centrifugal pumps are supplied. One pump is normally aligned to supply boric acid to the boric acid blender, while the second serves as a standby. Manual or automatic initiation of the reactor coolant makeup system will start a pump to provide normal makeup of boric acid solution through the boric acid blender. Emergency boration, supplying 4-wt-percent boric acid solution directly to the suction of the charging pumps, can be accomplished by manually starting either pump. The transfer pumps also function to transfer boric acid solution from the batching tank to the boric acid tanks.

The pumps are located in a heated area to prevent crystallization of the boric acid solution. All parts in contact with the solution are of austenitic stainless steel.

9.3.4.1.2.5.3 Recycle Evaporator Feed Pumps. Two centrifugal pumps supply feed to the recycle evaporator package from the recycle holdup tanks. Two pumps are supplied for redundancy. A cross-connect pipe is provided between the pumps of Units 1 and 2. The cross-connect allows the pumps to be used to transfer liquid from one holdup tank to either unit's holdup tanks, to either unit's spent-fuel pool, and to either unit's charging pumps for transfer into the RCS. The pumps can also be used to recirculate water from the recycle holdup tanks through the recycle evaporator feed demineralizers for cleanup if required.

9.3.4.1.2.5.4 Regenerative Heat Exchanger. The regenerative heat exchanger is designed to recover heat from the letdown flow by reheating the charging flow, which reduces thermal shock on the charging penetrations into the reactor coolant loop piping.

The letdown stream flows through the shell of the regenerative heat exchanger, and the charging stream flows through the tubes. The unit is constructed of austenitic stainless steel and is of all welded construction.

The temperatures of both outlet streams from the heat exchanger are monitored with indication given in the control room. A high temperature alarm is given on the main control board if the temperature of the letdown stream exceeds desired limits.

9.3.4.1.2.5.5 Letdown Heat Exchanger. The letdown heat exchanger cools the letdown stream to the operating temperature of the mixed-bed demineralizers. Reactor coolant flows through the tube side of the exchanger, while component cooling water flows through the shell side. All surfaces in contact with the reactor coolant are austenitic stainless steel; the shell is carbon steel.

The low-pressure letdown valve, located downstream of the letdown heat exchanger, maintains the pressure of the letdown flow, upstream of the heat exchanger, in a range sufficiently high to prevent two-phase flow.

The letdown temperature control indicates and controls the temperature of the letdown flow exiting from the letdown heat exchanger. The temperature sensor, which is part of the CVCS, provides input to the controller in the component cooling system. The exit temperature is controlled by regulating the component cooling water flow through the letdown heat exchanger by using the control valve located in the component cooling water discharge line. Temperature indication is provided on the main control board. If the temperature of the letdown stream exceeds approximately 140°F, the flow is diverted to the volume control tank in order to avoid damaging the resin in the mixed bed demineralizer.

9.3.4.1.2.5.6 Excess Letdown Heat Exchanger. The excess letdown heat exchanger cools reactor coolant letdown flow at a rate which is equivalent to the nominal seal injection flow, which flows downward through the reactor coolant pump labyrinth seals.

The excess letdown heat exchanger can be employed either when normal letdown is temporarily out of service to maintain the reactor in operation or when it can be used to supplement maximum letdown during the final stages of heatup. The letdown flows through the tube side of the unit, and component cooling water is circulated through the shell. All surfaces in contact with reactor coolant are austenitic stainless steel, and the shell is carbon steel. All tube joints are welded.

A temperature detector measures temperature of excess letdown downstream of the excess letdown heat exchanger. Temperature indication and high temperature alarm are provided on the main control board.

A pressure sensor indicates the pressure of the excess letdown flow downstream of the excess letdown heat exchanger and excess letdown control valve. Pressure indication is provided on the main control board.

9.3.4.1.2.5.7 Seal Water Heat Exchanger. The seal water heat exchanger is designed to cool fluid from three sources: reactor coolant pump seal water returning to the CVCS, reactor coolant discharged from the excess letdown heat exchanger, and centrifugal charging pump bypass flow. Reactor coolant flows through the tube side of the heat exchanger, and component cooling water is circulated through the shell. The design flowrate is equal to the sum of the excess letdown flow, maximum design reactor coolant pump seal leakage, and bypass flow from one centrifugal charging pump. The unit is designed to cool the above flow to the temperature normally maintained in the volume control tank. All surfaces in contact with reactor coolant are austenitic stainless steel; the shell is carbon steel.

9.3.4.1.2.5.8 Volume Control Tank. The volume control tank provides surge capacity for part of the reactor coolant expansion volume not accommodated by the pressurizer. When the level in the tank reaches the high-level setpoint, the remainder of the expansion volume is accommodated by diversion of the letdown stream to the recycle holdup tanks. It also provides a means for introducing hydrogen into the coolant to maintain the required equilibrium concentration of 25 to 50 cm^3 hydrogen (at STP/kg water) for power operations, is used for degassing the reactor coolant, and serves as a head tank for the charging pumps.

A spray nozzle located inside the tank on the letdown line nozzle provides liquid to gas contact between the incoming fluid and the hydrogen atmosphere in the tank.

A remotely operated vent valve, discharging to the gaseous waste processing system, permits removal of gaseous fission products, which are stripped from the reactor coolant and collected in the gas space of this tank. Relief protection, gas space sampling, and nitrogen purge connections are also provided. The tank can also accept the seal water return flow from the reactor coolant pumps, although this flow normally goes directly to the suction of the charging pumps.

Volume control tank pressure and temperature are monitored with indication given in the control room. Alarm is given in the control room for high and low pressure conditions and for high temperature.

Two level channels govern the water inventory in the volume control tank. These channels provide local and remote level indication, level alarms, level control, makeup control, and emergency makeup control.

If the volume control tank level rises above the normal operating range, one channel provides an analog signal to a proportional controller which modulates the three-way valve downstream of the reactor coolant filter to maintain the volume control tank level within the normal operating band. The three-way valve can split letdown flow so that a portion goes to the recycle holdup tanks and a portion to the volume control tank. The controller would operate in this fashion during a dilution operation, when reactor makeup water is being fed to the volume control tank from the reactor makeup control system.

If the modulating function of the channel fails and the volume control tank level continues to rise, the high level alarm will alert the operator to the malfunction and the letdown flow can be manually diverted to the holdup tanks. If no action is taken by the operator and the tank level continues to rise, the full letdown flow will be automatically diverted.

During normal power operation, a low level in the volume control tank initiates automatic makeup which injects a preselected blend of boron and water into the charging pump suction header. When the volume control tank is restored to normal, automatic makeup stops.

If the automatic makeup fails or is not aligned for operation and the tank level continues to decrease, a low-level alarm is actuated. Manual action may correct the situation or, if the level continues to decrease, an emergency low-level signal from both channels opens the stop valves in the refueling water supply line and closes the stop valves in the volume control tank outlet line.

9.3.4.1.2.5.9 Boric Acid Tanks. The combined boric acid tank capacity is sized to store sufficient boric acid solution for a cold shutdown from full-power operation immediately following refueling with the most reactive control rod not inserted, plus operating margins.

The concentration of boric acid solution in storage is maintained between 4- and 4.4-wt-percent. Periodic manual sampling and corrective action, if necessary, ensure that these limits are maintained. As a consequence, measured amounts of boric acid solution can be delivered to the reactor coolant to control the concentration. The boron concentration limits are specified in the Technical Requirements Manual (TRM).

A temperature sensor provides temperature measurement of each tank's contents. Local temperature indication is provided, as well as high and low temperature alarms which are indicated on the main control board. The minimum solution temperature is specified in the TRM.

Two level detectors indicate the level in each boric acid tank. Level indication with high-, low-, and low-low-level alarms is provided on the main control board. The low-low alarm is set to indicate the minimum level of boric acid in the tank to ensure sufficient boric acid to provide for a cold shutdown with one stuck rod. The minimum contained borated water volume is specified in the TRM.

9.3.4.1.2.5.10 Batching Tank. The batching tank is used for mixing a makeup supply of boric acid solution for transfer to the boric acid tanks. The tank may also be used for solution storage.

A local sampling point is provided for verifying the solution concentration prior to transferring it out of the tank. The tank is provided with an agitator to improve mixing during batching operations and a steam jacket for heating the boric acid solution.

9.3.4.1.2.5.11 Chemical Mixing Tank. The primary use of the chemical mixing tank is in the preparation of caustic solutions for pH control and hydrazine solution for oxygen scavenging.

9.3.4.1.2.5.12 Recycle Holdup Tanks. Three recycle holdup tanks provide storage of excess reactor effluents for future reuse, disposal, or processing by the recycle evaporator package. Each tank has a diaphragm which prevents air from dissolving in the tank liquid and prevents the hydrogen and fission gases under the diaphragm from mixing with the air. The air space in the tank above the diaphragm is vented to the plant vent.

9.3.4.1.2.5.13 Recycle Evaporator Reagent Tank. This tank provides a means of adding chemicals to the recycle evaporator package, e.g., for cleanup.

9.3.4.1.2.5.14 Mixed-Bed Demineralizers. Two flushable, mixed-bed demineralizers assist in maintaining reactor coolant purity. A lithium or hydrogen form cation resin and hydroxyl form anion resin are charged into the demineralizers. Each form of resin removes fission and corrosion products. The resin bed is designed to reduce the concentration of ionic isotopes in the purification stream, except for cesium, yttrium, and molybdenum, by a minimum factor of 10.

In preparation for an outage and during an outage where a release of particulate and soluble corrosion products is anticipated, a specialty resin, such as a coated weak acid cation resin, may be added to a mixed-bed demineralizer for removal of particulate radio-cobalt and particulate nickel.

This demineralizer may be used during power operations for reactor coolant Lithium control during periods when the cation demineralizer or alternate mixed-bed demineralizer are not available for this purpose.

Each demineralizer has sufficient capacity for approximately one core cycle with 1-percent failed fuel. One demineralizer serves as a standby unit for use if the operating demineralizer becomes exhausted during operation.

A temperature sensor measures temperature of the letdown flow downstream of the letdown heat exchanger and controls the letdown flow to the mixed-bed demineralizers by means of a three-way valve. If the letdown temperature exceeds the allowable resin operating temperature, the flow is automatically bypassed around the demineralizers. Temperature indication and high alarm are provided on the main control board. The air-operated, three-way valve failure mode directs flow to the volume control tank.

9.3.4.1.2.5.15 Cation Bed Demineralizer. A flushable cation resin bed in the hydrogen form is located downstream of the mixed-bed demineralizers and is used intermittently to control the concentration of Li^7 which builds up in the coolant from the $B^{10}(n,\alpha)Li^7$ reaction. The demineralizer also has sufficient capacity to maintain the cesium-137 concentration in the coolant below 1.0 $\mu Ci/cm^3$ with 1-percent failed fuel. The resin bed is designed to reduce the concentration of ionic isotopes, particularly cesium, yttrium, and molybdenum, by a minimum factor of 10.

The cation bed demineralizer has sufficient capacity for approximately one core cycle with 1-percent failed fuel.

9.3.4.1.2.5.16 Recycle Evaporator Feed Demineralizers. Two flushable, mixed bed demineralizers remove fission products from the fluid directed to the recycle holdup tanks. The demineralizers also provide a means of cleaning the recycle holdup tank contents via recirculation.

9.3.4.1.2.5.17 Recycle Evaporator Condensate Demineralizer. A sluicable, mixed-bed resin demineralizer is used to remove any boric acid, other anionic impurities such as chloride and fluoride, cationic impurities such as sodium, calcium, magnesium, and aluminum and also any particulate activity carryover contained in the evaporator condensate. The mixed-bed resin provides the system with the capability to remove a wide range of chemical and radiochemical contaminants resulting in high quality water for plant operations. Although the bed may become saturated with boron at the normally low concentration (< 10 ppm) leaving the evaporator, it will still remove most of the boron if the concentration increases because of an evaporator upset. The demineralizer also provides a means of cleanup of the reactor makeup water storage tank contents.

9.3.4.1.2.5.18 Reactor Coolant Filter. The reactor coolant filter is located on the letdown line upstream of the volume control tank. The filter collects resin fines and particulates from the letdown stream. The nominal flow capacity of the filter is greater than the maximum purification flowrate.

Two local pressure indicators are provided to show the pressures upstream and downstream of the reactor coolant filter and thus provide filter differential pressure.

9.3.4.1.2.5.19 Seal Water Injection Filters. Two seal water injection filters are located in parallel in a common line to the reactor coolant pump seals; they collect particulate matter that could be harmful to the seal faces. Each filter is sized to accept flow in excess of the normal seal water flow requirements.

A differential pressure indicator monitors the pressure drop across each seal water injection filter and gives local indication with high differential pressure alarm on the main control board.

9.3.4.1.2.5.20 Seal Water Return Filter. The filter collects particulates from the reactor coolant pump seal water return and from the excess letdown flow. The filter is designed to pass flow in excess of the sum of the excess letdown flow and the maximum design leakage from the reactor coolant pump seals.

Two local pressure indicators are provided to show the pressures upstream and downstream of the filter and thus provide differential pressure across the filter.

9.3.4.1.2.5.21 Boric Acid Filter. The boric acid filter collects particulates from the boric acid solution being pumped from the boric acid tanks. The filter is designed to pass the design flow of two boric acid transfer pumps operating simultaneously.

Local pressure indicators indicate the pressure upstream and downstream of the boric acid filter and thus provide filter differential pressure.

9.3.4.1.2.5.22 Recycle Evaporator Feed Filter. This filter collects resin fines and particles from the fluid entering the recycle holdup tanks.

9.3.4.1.2.5.23 Recycle Evaporator Condensate Filter. This filter collects particulates from the boric acid evaporator condensate stream.

9.3.4.1.2.5.24 Recycle Evaporator Concentrates Filter. This filter removes particulates from the evaporator concentrate as it leaves the evaporator.

9.3.4.1.2.5.25 Boric Acid Blender. The boric acid blender promotes thorough mixing of boric acid solution and reactor makeup water for the reactor coolant makeup circuit. The blender consists of a conventional pipe tee fitted with a perforated tube insert. The blender decreases the pipe length required to homogenize the mixture for taking a representative local sample. A sample point is provided in the piping just downstream of the blender.

9.3.4.1.2.5.26 Letdown Orifices. The three letdown orifices are arranged in parallel and serve to reduce the pressure of the letdown stream to a value compatible with the letdown heat exchanger design. Two of the three are sized so that either can pass normal letdown flow of 60 gal/min; the third can pass 45 gal/min. One or both standby orifices may be used with the normally operating orifice in order to increase letdown flow, such as during reactor heatup operations and maximum purification. This arrangement also provides a full standby capacity for control of letdown flow. Orifices are placed in and taken out of service by remote manual operation of their respective isolation valves.

A flow monitor provides indication in the control room of the letdown flowrate. A high flow alarm is provided to indicate flowrates exceeding 140 gal/min.

A low pressure letdown controller controls the pressure downstream of the letdown heat exchanger to prevent flashing of the letdown liquid. Pressure indication and high pressure alarm are provided on the main control board.

9.3.4.1.2.5.27 Recycle Evaporator Package. The recycle evaporator package processes dilute boric acid and produces distillate and approximately 4-wt-percent boric acid stripped of hydrogen, nitrogen, and radioactive gases.

A boric acid solution is fed from the recycle holdup tanks to the evaporator by the recycle evaporator feed pumps. The feed first passes through a heat exchanger where condensing steam raises its temperature. The feed then passes into the top of the stripping column. Gases are stripped off as the feed passes over the packing in the tower in contraflow to stripping steam from the evaporator. After stripping, the feed is introduced into the evaporator as makeup. The vapors leaving the boiling pool are stripped of entrained liquid and volatile boron carryover. Pure vapors are then condensed in the condenser section and pumped from the system. When the desired concentration is reached in the boiling pool, the concentrates are pumped from the system.

Radioactive gases and other noncondensables are discharged from the system into the waste gas vent header.

The recycle and waste evaporators are identical units and are interconnected so that they serve as standbys for each other under abnormal conditions.

9.3.4.1.2.5.28 Recycle Holdup Tank Vent Eductor. The eductor is designed to pull gases from under the diaphragm in the recycle holdup tank. Nitrogen, provided by the waste gas compressor, provides the motive force.

9.3.4.1.2.5.29 Valves. Valves, other than diaphragm valves, that perform a modulating function are equipped with a stuffing box containing two sets of packing and an intermediate leakoff connection. Valves are normally installed so that, when closed, the high pressure is not on the packing. Basic material of construction is stainless steel for all valves that handle radioactive liquid or boric acid solutions.

Isolation valves are provided for all lines entering the reactor containment. These valves are discussed in detail in subsection 6.2.4.

Relief valves are provided for lines and components that might be pressurized above design pressure by improper operation or component malfunction.

A. Charging Line Downstream of Regenerative Heat Exchanger

If the charging side of the regenerative heat exchanger is isolated while the hot letdown flow continues at its maximum rate, the volumetric expansion of coolant on the charging side of the heat exchanger is relieved to the RCS through a spring-loaded check valve.

The spring in the valve is designed to permit the check valve to open in the event that the differential pressure exceeds the design pressure differential.

B. Letdown Line Downstream of Letdown Orifices

The pressure relief valve downstream of the letdown orifices protects the low-pressure piping and the letdown heat exchanger from overpressure when the low-pressure piping is isolated. The capacity of the relief valve exceeds the maximum flowrate through all letdown orifices. The valve set pressure is equal to the design pressure of the letdown heat exchanger tube side.

C. Letdown Line Downstream of Low Pressure Letdown Valve

The pressure relief valve downstream of the low pressure letdown valve protects the low-pressure piping, demineralizers, and filter from overpressure when this section of the system is isolated. The overpressure may result from leakage through the low-pressure letdown valve. The capacity of the relief valve exceeds the maximum flowrate through all letdown orifices. The valve set pressure is equal to the design pressure of the demineralizers.

D. Volume Control Tank

The relief valve on the volume control tank permits the tank to be designed for a lower pressure than the upstream equipment. This valve has a capacity greater than the summation of the following items: maximum letdown, maximum seal water return, excess letdown, and nominal flow from one reactor makeup water pump. The valve set pressure equals the design pressure of the volume control tank.

E. Charging Pump Suction

A relief valve on the charging pump suction header relieves pressure that may build up if the suction line isolation valves are closed or if the system is overpressurized. The valve set pressure is equal to the design pressure of the associated piping and equipment.

F. Seal Water Return Line (Inside Containment)

This relief valve is designed to relieve overpressurization in the seal water return piping inside the containment if the motor-operated isolation valve is closed. The valve is designed to relieve the total leakoff flow from the No. 1 seals of the reactor coolant pumps plus the design excess letdown flow. The valve is set to relieve at the design pressure of the piping.

G. Seal Water Return Line (Charging Pumps Bypass Flow)

This relief valve protects the seal water heat exchanger and its associated piping from overpressurization. If either of the isolation valves for the heat exchanger is closed and if the bypass line is closed, the piping could be overpressurized by the bypass flow from the centrifugal charging pumps. The valve is sized to handle full bypass flow with all centrifugal pumps running. The valve is set to relieve at the design pressure of the heat exchanger.

H. Steam Line to Batching Tank

The relief valve on the steam line to the batching tank protects the low-pressure piping and batching tank heating jacket from overpressure when the condensate return line is isolated. The capacity of the relief valve equals the maximum expected steam inlet flow. The set pressure equals the design pressure of the heating jacket.

9.3.4.1.2.5.30 Piping. All CVCS piping handling radioactive liquid is austenitic stainless steel. All piping joints and connections are welded, except where flanged connections are required to facilitate equipment removal for maintenance and hydrostatic testing.

9.3.4.1.2.6 <u>System Operation</u>. The reactor startup, power generation and hot standby operation, and reactor shutdown of the CVCS are discussed below.

9.3.4.1.2.6.1 Reactor Startup. Reactor startup is defined as the operations which bring the reactor from cold shutdown to normal operating temperature and pressure. It is assumed that:

A. Normal residual heat removal is in progress.

B. The RCS boron concentration is at the cold shutdown concentration.

C. The reactor makeup control system is set to provide makeup at the cold shutdown concentration.

D. The RCS is either water solid or drained to minimum level for the purpose of refueling or maintenance. If the RCS is water solid, system pressure is controlled by letdown through the residual heat removal system and through the low pressure letdown valve in the letdown line.

E. The charging and letdown lines of the CVCS are filled with coolant at the cold shutdown boron concentration. The letdown orifice isolation valves are closed.

If the RCS requires filling via dynamic venting, the procedure is as follows:

A. One charging pump is started, which provides blended flow from the reactor makeup control system at the cold shutdown boron concentration. Charging and letdown flows and seal injection flow to reactor coolant pumps are established.

B. The vents on the head of the reactor vessel and pressurizer are opened.

C. The RCS is filled and the vents closed.

The system pressure is raised using the charging pump and controlled by the low-pressure letdown valve. When the system pressure is adequate for operation of the reactor coolant pumps, seal water leakage flow from the pumps is verified and the pumps are operated and vented sequentially until all gases are cleared from the system. Final venting takes place at the pressurizer.

If the RCS requires filling and venting via use of the reactor coolant vacuum refill system (RCVRS), the procedure is as follows:

Air is removed from the RCS by the RCVRS via a connection to the pressurizer relief tank (PRT) inlet line. Initial conditions are as follows: the RCS level is at midloop and the PRT level is below the sparging header. The vacuum pump skid suction hose is connected to the PRT inlet line connection. The RHR flow is adjusted to prevent vortexing and to ensure adequate net positive suction head (NPSH). The air evacuation path is established by opening the reactor vessel head vent valves, the pressurizer spray valves, the power-operated relief valve (PORV) block valves and the PORVs.

After the filling and venting operations are completed, all pressurizer heaters are energized, and the reactor coolant pumps are employed to heat up the system. After the reactor coolant pumps are started, pressure control via the residual heat removal system and the low pressure letdown line is continued as the pressurizer steam bubble is formed. At this point, steam formation in the pressurizer is accomplished by manual control of the charging flow and automatic pressure control of the letdown flow. When the pressurizer water level reaches the no-load programmed setpoint, the pressurizer level control is shifted to control the charging flow to maintain programmed level. The residual heat removal system is then isolated from the RCS.

The reactor coolant boron concentration is now reduced either by operating the reactor makeup control system in the dilute mode or by operating the BTRS in the boron storage mode and, when the resin beds are saturated, washing off the beds to the recycle holdup tanks. The reactor coolant boron concentration is corrected to the point where the control rods may be withdrawn and criticality achieved. Nuclear heatup may then proceed, with corresponding manual adjustment of the reactor coolant boron concentration to balance the temperature coefficient effects and maintain the control rods within their operating range. During heatup, the appropriate combination of letdown orifices is used to provide necessary letdown flow.

Prior to or during the heating process, the CVCS is employed to obtain the correct chemical properties in the RCS. The reactor makeup control is operated on a continuing basis to ensure correct control rod position. Chemicals are added through the chemical mixing tank, as required, to control reactor coolant chemistry such as pH and dissolved oxygen content. Hydrogen overpressure is established in the volume control tank to ensure the appropriate hydrogen concentration in the reactor coolant.

9.3.4.1.2.6.2 Power Generation and Hot Standby Operation. Base load, load follow, and hot shutdown of this operation are discussed below.

A. Base Load

At a constant power level, the rates of charging and letdown are dictated by the requirements for seal water to the reactor coolant pumps and the normal purification of the RCS. One charging pump is employed, and charging flow is controlled automatically from pressurizer level. The only necessary adjustments in boron concentration are those to compensate for core burnup. These adjustments are made at infrequent intervals to maintain the control groups within their allowable limits. Rapid variations in power demand are accommodated automatically by control rod movement. If variations in power level occur and the new power level is sustained for long periods, some adjustment in boron concentration may be necessary to maintain the control groups within their maneuvering band.

During normal operation, normal letdown flow is maintained and one mixed-bed demineralizer is in service. Reactor coolant samples are taken periodically to check boron concentration, water quality, pH, and activity level. The charging pump flow to the RCS is controlled automatically by the pressurizer level control signal through the discharge header flow control valve.

B. Load Follow

A power reduction will initially cause a xenon buildup followed by xenon decay to a new, lower equilibrium value. The reverse occurs if the power level decreases and then increases to a new and higher equilibrium value associated with the amount of the power level change.

The BTRS is normally used to vary the reactor coolant boron concentration to compensate for xenon transients occurring when reactor power level is changed. The reactor makeup control system may also be used to vary the boron concentration in the reactor coolant.

The most important intelligence available to the plant operator, enabling him to determine whether dilution or boration of the RCS is necessary, is the position of the control rods within the maneuvering band. If, for example, the control rods are moving down into the core and are approaching the bottom of the maneuvering band, the operator must borate the reactor coolant to bring the rods outward. If not, the control rods may move into the core beyond the shutdown limit. If, on the other hand, the rods are moving out of the core, the operator dilutes the reactor coolant to keep the rods from moving above the top of the maneuvering band. Keeping the control rods at the top of the maneuvering band ensures the capability of immediate return to full power. However, violation of the upper limit of the maneuvering band is not safety related and is allowed.

With the control rods above the top of the maneuvering band the reactor cannot return to full power immediately; it can return to some rate determined by the xenon burnout transient.

During periods of plant loading, the reactor coolant expands as its temperature rises. The pressurizer absorbs most of this expansion as the level controller raises the level setpoint to the increased level associated with the new power level. The remainder of the excess coolant is let down and is stored in the volume control tank. During this period, the flow through the letdown orifice remains constant and the charging flow is reduced by the pressurizer level control signal, resulting in an increased temperature at the regenerative heat exchanger outlet. The temperature controller downstream from the letdown heat exchanger increases the component cooling water flow to maintain the desired letdown temperature.

During periods of plant unloading, the charging flow is increased to make up for the coolant contraction not accommodated by the programmed reduction in pressurizer level.

C. Hot Standby and Hot Shutdown

When the reactor is shutdown and the RCS temperature is ≥ 350°F, the plant is in the Hot Standby operational mode. When the reactor is shutdown and the RCS temperature is > 200°F and < 350°F, the plant is in the Hot Shutdown operational mode. RCS temperature is normally the result of RCP heat and decay heat additions. Normally RCS temperature is controlled by the steam dumps or atmospheric relief valves when at higher temperatures. When at lower temperatures, the RHR system is normally used to control RCS temperature. Technical Specifications provide additional details regarding plant operational modes.

Following a normal reactor shutdown or reactor trip, for a finite period of time, the reactor can be returned to some power using only the control rods. Through design, procedural reactivity management requirements, and Technical Specification requirements, the reactor maintains a minimum shutdown margin of 1.77% $\Delta k/k$. The shutdown reactivity (assuming no-load T_{avg} and no change in RCS boron) immediately following a normal reactor shutdown or reactor trip is a result of control rod and shutdown rod insertions, while also accounting for the reactivity associated with the pre-shutdown power. Subsequently, xenon buildup following reactor shutdown adds additional shutdown reactivity for approximately 8 h, returns to the initial post trip value in approximately 24 h, and then reduces shutdown reactivity over the next approximately 72 h. RCS boron additions/deletions can compensate for the effects of xenon decay/buildup and reduction in RCS temperature. The magnitude of xenon effects vary with pre-shutdown power history status and the operating cycle fuel characteristics. The core specific Nuclear Design and Core Management manuals should be referred to for specific information regarding reactivity effects associated with various plant operational modes.

9.3.4.1.2.6.3 Reactor Shutdown. Reactor shutdown is defined as the operations that bring the reactor to cold shutdown.

Before initiating a cold shutdown, the RCS hydrogen concentration is reduced by replacing the volume control tank hydrogen atmosphere with nitrogen by purging to the gaseous waste processing system. An alternate method of reducing the hydrogen concentration in the RCS is chemical degassing. Both methods are explained in detail in paragraph 11.3.4.1

Before cooldown and depressurization of the reactor plant is initiated, the reactor coolant boron concentration is increased to the cold shutdown value. The operator sets the reactor makeup control to borate, selects the volume of concentrated boric acid solution necessary to perform the boration, selects the desired flowrate, and actuates makeup start. After the boration is completed and reactor coolant samples verify that the concentration is correct, the operator resets the reactor makeup control system for leakage makeup and system contraction at the shutdown reactor coolant boron concentration.

Contraction of the coolant during cooldown of the RCS results in actuation of the pressurizer level control to maintain normal pressurizer water level. The charging flow is increased, relative to letdown flow, and results in a decreasing volume control tank level. The volume control tank level controller automatically initiates makeup to maintain the inventory.

After the residual heat removal system is placed in service and the reactor coolant pumps are shut down, further cooling of the pressurizer liquid is accomplished by charging through the auxiliary spray line. Coincident with plant cooldown, a portion of the reactor coolant flow may be diverted from the residual heat removal system to the CVCS for cleanup. Demineralization of ionic radioactive impurities and stripping of fission gases reduce the reactor coolant activity level sufficiently to permit personnel access for refueling or maintenance operations.

9.3.4.1.3 Safety Evaluation

9.3.4.1.3.1 <u>Reactivity Control</u>. Any time that the plant is at power, the quantity of boric acid retained and ready for injection always exceeds that quantity required for the normal cold shutdown, assuming that the control assembly of greatest worth is in its fully withdrawn position. This quantity always exceeds the quantity of boric acid required to bring the reactor to hot shutdown and to compensate for subsequent xenon decay. An adequate quantity of boric acid is also available in the refueling water storage tank to achieve cold shutdown.

When the reactor is subcritical (i.e., during cold or hot shutdown, refueling, and approach to criticality), the neutron source multiplication is continuously monitored and indicated. Any appreciable increase in the neutron source multiplication, including that caused by the maximum physical boron dilution rate, is slow enough to give ample time to start a corrective action (boron dilution stop and boration) to prevent the core from becoming critical.

Two separate and independent flow paths are available for reactor coolant boration, i.e., the charging line and the reactor coolant pump seal injection. A single failure does not result in the inability to borate the RCS.

As backup to the normal boric acid supply, the operator can align the refueling water storage tank outlet to the suction of the charging pumps, thus injecting 2300-ppm boron solution (minimum) into the RCS.

In Mode 6, with any valve used to isolate an unborated water source not secured in the closed position, the TRM ensures that at least one flow path is available for boron injection. When the unborated water source isolation valves are secured in the closed position in Mode 6, a boron dilution accident is precluded. In this case, plant procedures ensure the availability of at least one boron injection flow path.

In Mode 5, the TRM ensures that at least one flow path is available for boron injection and that the capability of such injection is adequate to ensure that cold shutdown can be maintained.

In Modes 1, 2, 3, and 4 the TRM ensures that redundant boration capability is available in quantity sufficient to ensure shutdown to cold conditions.

An upper limit to the boric acid tank boron concentration and a lower limit to the temperature for the tank and for flow paths from the tank are specified in order to ensure that solution solubility is maintained.

Since inoperability of a single component does not impair ability to meet boron injection requirements, plant operating procedures allow components to be temporarily out of service for repairs. However, with an inoperable component, the ability to tolerate additional component failure is limited. Therefore, operating procedures require immediate action to effect repairs of an inoperable component, restrict permissible repair time, and require demonstration of the operability of the redundant component.

9.3.4.1.3.2 **Reactor Coolant Purification.** The CVCS is capable of reducing the concentration of ionic isotopes in the purification stream as required in the design basis. This is accomplished by passing the letdown flow through the mixed-bed demineralizers that remove ionic isotopes, except those of cesium, molybdenum, and yttrium, with a minimum decontamination factor of 10. Through occasional use of the cation bed demineralizer, the concentration of cesium can be maintained below 1.0 $\mu Ci/cm^3$, assuming 1 percent of the rated core thermal power is being produced by fuel with defective cladding. The cation bed demineralizer is capable of passing the normal letdown flow, though only a portion of this capacity is normally utilized. Each mixed-bed demineralizer is capable of processing the maximum letdown flowrate. If the normally operating mixed-bed demineralizer's resin has become exhausted, the second demineralizer can be placed in service. Each demineralizer is designed, however, to operate for one core cycle with 1-percent defective fuel.

9.3.4.1.3.3 **<u>Seal Water Injection</u>.** Flow to the reactor coolant pumps' seals is ensured by the fact that there are three charging pumps, any one of which is capable of supplying the normal charging line flow plus the nominal seal water flow.

9.3.4.1.3.4 **<u>Leakage Provisions</u>.** The CVCS components, valves, and piping that see radioactive service are designed to limit leakage to the atmosphere. Leakage to the atmosphere is limited through: welding of all piping joints and connections except where flanged connections are provided to facilitate maintenance and hydrostatic testing, extensive use of leakoffs to collect leakage, and use of diaphragm valves where conditions permit.

The volume control tank in the CVCS provides an inferential measurement of leakage from the system as well as the RCS. Low level in the volume control tank actuates makeup at the prevailing reactor coolant boron concentration.

The amount of leakage can be inferred from the amount of makeup added by the reactor makeup control system.

9.3.4.1.3.5 **<u>Ability to Meet the Safeguards Function</u>.** A failure analysis of the portion of the CVCS which is safety related (used as part of the ECCS) is included as part of the ECCS failure analysis presented in appendix 6A.

9.3.4.1.4 Tests and Inspections

As part of plant operation, periodic tests, surveillance inspections, and instrument calibrations are made to monitor equipment condition and performance. Most components are in use regularly; therefore, assurance of the availability and performance of the systems and equipment is provided by control room and/or local indication.

The plant Technical Specifications and requirements in the TRM have been established concerning calibration, checking, and sampling of the CVCS.

9.3.4.1.5 Instrumentation Application

Process control instrumentation is provided to acquire data concerning key parameters about the CVCS. The location of the instrumentation is shown in drawings D-175039, sheet 1 through 7 and D-205039, sheets 1 through 5. The instrumentation furnishes input signals for monitoring and/or alarming purposes. Indications and/or alarms are provided for the following parameters: temperature, pressure, flow, water level, and radiation.

The instrumentation also supplies input signals for control purposes. Some specific control functions are:

A. Letdown flow is diverted to the volume control tank upon high temperature indication upstream of the mixed-bed demineralizers.

B. Pressure downstream of the letdown heat exchangers is controlled to prevent flashing of the letdown liquid.

C. Charging flowrate is controlled during charging pump operation.

D. Water level is controlled in the volume control tank.

E. Temperature of the boric acid solution in the batching tank is maintained.

F. Reactor makeup is controlled.

G. DELETED

9.3.4.2 Boron Thermal Regeneration System

The BTRS varies the RCS boron concentration to compensate for xenon transients and other reactivity changes which occur when the reactor power level is changed.

9.3.4.2.1 Design Basis

The BTRS is designed to accommodate the changes in boron concentration required by the design load cycle without requiring makeup for either boration or dilution.

9.3.4.2.2 System Description

During normal operation of the CVCS, the letdown flow from the RCS passes through the regenerative heat exchanger, letdown heat exchanger, mixed-bed demineralizers, reactor coolant filter, and volume control tank. The charging pumps then take suction from the volume control tank and return the purified reactor coolant to the RCS.

An alternate letdown path is provided which allows part or all of the letdown flow to pass through the BTRS (shown in drawings D-175040 and D-205040) when boron concentration changes are made to follow plant load. The letdown flow is directed to the BTRS from a point downstream of the mixed-bed demineralizers. After processing by the BTRS, the flow is returned to the CVCS at a point upstream of the reactor coolant filter.

Storage and release of boron during load follow operation is determined by the temperature of the fluid entering the thermal regeneration demineralizers. A group of heat exchangers is employed to provide the desired fluid temperatures at the demineralizer inlet for either storage or release operation of the system.

The flow path through the BTRS is different for boron storage and release operations. During boron storage, the letdown stream enters the moderating heat exchanger and from there it passes through the letdown chiller heat exchanger. The moderating heat exchanger cools the letdown stream prior to its entering the demineralizers. The letdown reheat heat exchanger is valved out on the tube side and performs no function during boron storage operations. After passing through the demineralizers, the letdown enters the moderating heat exchanger shell side, where it is heated by the incoming letdown stream before going to the volume control tank.

Therefore, for boron storage, a decrease in the boric acid concentration in the reactor coolant is accomplished by sending the letdown flow at relatively low temperatures to the thermal regeneration demineralizers. The resin, which was depleted of boron at high temperature during a prior boron release operation, is now capable of storing boric acid from the low temperature letdown stream. Reactor coolant with a decreased concentration of boric acid leaves the demineralizers and is directed to the CVCS. Procedures are also available to decrease the concentration of boric acid in the reactor coolant using BTRS demineralizers without using BTRS chillers.

During the boron release operation, the letdown stream enters the moderating heat exchanger tube side, bypasses the letdown chiller heat exchanger, and passes through the shell side of the letdown reheat heat exchanger. The moderating and letdown reheat heat exchangers heat the letdown stream prior to its entering the resin beds. The temperature of the letdown at the point of entry to the demineralizers is controlled automatically by the temperature control valve which controls the flowrate on the tube side of the letdown reheat heat exchanger. After passing through the demineralizers, the letdown stream enters the shell side of the moderating heat exchanger, passes through the tube side of the letdown chiller heat exchanger, and then goes to the volume control tank. Thus, for boron release, an increase in the boric acid concentration in the reactor coolant is accomplished by sending the letdown flow at relatively high temperatures to the thermal regeneration demineralizers. The water flowing through the demineralizers now releases boron that was stored by the resin at low temperature during a previous boron storage operation. The boron-enriched reactor coolant is returned to the RCS via the CVCS.

Although the BTRS is primarily designed to compensate for xenon transients occurring during load follow, it can also be used to handle boron swings far in excess of the design capacity of the demineralizers. During startup dilution, for example, the resin beds are first saturated, then washed off to the recycle holdup tanks in the CVCS, and then again saturated and washed off. This operation continues until the desired dilution in the RCS is obtained.

As an additional function, a thermal regeneration demineralizer can be used as a deborating demineralizer, which would be used to dilute the RCS down to very low boron concentrations toward the end of core life. To make such a bed effective, the effluent concentration from the bed must be kept very low, close to 0-ppm boron. This low effluent concentration can be achieved by using fresh resin. When RCS boron concentrations are low during the end of a core cycle, the four BTRS demineralizers are evaluated for boron removal capability. The boron removal efficiency of each demineralizer resin will determine when the demineralizer will be placed in service, and when the resin will be replaced with fresh resin.

A. Component Description

Component safety classifications and design codes are given in section 3.2, and a summary of principal component design parameters is given in table 9.3-7.

1. Chiller Pumps (ABANDONED)

   These centrifugal pumps circulate the water through the chilled-water loop. One pump is supplied for each chiller.

2. Moderating Heat Exchanger

   The moderating heat exchanger operates as a regenerative heat exchanger between incoming and outgoing streams to and from the thermal regeneration demineralizers.

   The incoming flow enters the tube side of the moderating heat exchanger. The shell-side fluid, which comes directly from the demineralizers, enters at low temperature during boron storage and enters at high temperature during boron release.

3. Letdown Chiller Heat Exchanger

   During the boron storage operation, the process stream enters the tube side of the letdown chiller heat exchanger after leaving the moderating heat exchanger.

4. Letdown Reheat Heat Exchanger

   The letdown reheat heat exchanger is used only during boron release operations and it is then used to heat the process stream. Water used for heating is diverted from the letdown line upstream of the letdown heat exchanger in the CVCS, passed through the tube side of the letdown reheat heat exchanger, and then returned to the letdown stream upstream of the letdown heat exchanger.

5. Chiller Surge Tank (ABANDONED)

   The chiller surge tank handles the thermal expansion and contraction of the water in the chiller loop. The surge volume in the tank also acts as a thermal buffer for the chiller.

6. Thermal Regeneration Demineralizers

   The function of the thermal regeneration demineralizers is to store the total amount of boron that must be removed from the RCS to accomplish the required dilution during a load cycle in order to compensate for xenon buildup resulting from a decreased power level. Furthermore, the demineralizers must be able to release the previously stored boron to accomplish the required boration of the reactor coolant during the load cycle in order to compensate for a decrease in xenon concentration resulting from an increased power level.

The demineralizers are of the type that can accept flow in either direction. The flow direction during boron storage is therefore always opposite to that during release. This provides much faster response when the beds are switched from storage to release, and vice versa, than would be the case if the demineralizers could accept flow in only one direction.

7. Chillers (ABANDONED)

The chillers are located in a chilled-water loop containing a surge tank, chiller pumps, the letdown chiller heat exchanger, piping, valves, and controls. The purpose of the chillers is twofold: to cool down the process stream during storage of boron on the resin and to maintain an outlet temperature from the BTRS at or below 115°F during release of boron.

B. System Operation

A master switch is provided which places the system in either the boron release or boron storage mode of operation or turns the system off. The operational modes determined by the thermal regeneration selector switch are boration, dilution, and off.

When the switch is set on off, the BTRS is isolated from the letdown line and the chiller and chiller pumps are stopped. Valve 1-8547 opens to permit normal letdown flow directly to the volume control tank.
With the switch set for dilution (boron storage), the following alignments occur:

1. Proper flow path to BTRS is established.

2. Tube side flow (hot letdown) of the letdown reheat heat exchanger is isolated.

3. The BTRS bypass valve (1-8547) diverts all letdown flow into the BTRS.

The chiller heat exchanger shell flow control valve (TCV-386) is set to control the temperature of the water leaving the tube side and going to the BTRS demineralizers. Valve 1-HCV-387 is adjusted to control the amount of water that flows through the demineralizer beds.

When the selector switch is set for boration (boron release), the system automatically:

1. Aligns the proper flow path in the BTRS.

2. Controls the temperature leaving the shell side and going to the BTRS demineralizers via the letdown reheat heat exchanger tube flow control valve (TCV-381).

3. Directs all letdown flow into the BTRS via bypass valve 1-8547.

The chiller heat exchanger flow control valve (TCV-386) is set to control the temperature of the water leaving the tube side and going to the volume control tank. Valve 1-HCV-387 is adjusted to control the amount of water that flows through the demineralizer beds.

After the mode of operation has been selected and the system prepared for operation by actuation of the master switch, flow is admitted to the BTRS by throttling back on the diversion valve in the letdown line. The flowrate through the BTRS is dictated by the desired reactor coolant dilution (boration) rate.

When the boron concentration of the reactor coolant reaches the desired level, the BTRS is shut down by placing the master switch in the off position.

Table 9.3-8 shows certain values associated with operation of the BTRS and their position in each operating mode.

9.3.4.2.3 Safety Evaluation

Any partial or total malfunction of the BTRS would result only in loss of plant load following capability. This system is nonsafety related. The postulated full power dilution accident considered in chapter 15 is not influenced by dilution with this system. The dilution flow depends solely upon the delivery capability of the charging pumps, which remains unchanged with or without BTRS operability.

9.3.4.2.4 Tests and Inspections

The BTRS is in intermittent use throughout normal reactor operation. Periodic visual inspection and preventive maintenance are conducted using normal industry practice.

9.3.4.2.5 Instrumentation Application

A. Temperature

Instrumentation is provided to monitor the chiller outlet temperature and to control chiller operation. Instrumentation is also provided to monitor the chiller surge tank temperature. Readout for both sets of instrumentation is located on the main control board.

Instrumentation is provided to control the temperature of the letdown flow passing through the demineralizers. During dilution, it controls a valve which throttles the letdown chiller heat exchanger shell-side flow. During boration, it controls the valves which throttle the letdown reheat heat exchanger tube side flow. Readout and a high temperature alarm are provided on the main control board.

Protection of the thermal regeneration demineralizer resins from high temperature flow is provided by instrumentation which, upon reaching the high temperature setpoint, operates a three-way valve in the letdown line upstream of the mixed-bed demineralizers in the CVCS in order to divert the letdown flow to the volume control tank. Readout is provided on the main control board.

Instrumentation is provided to monitor the temperature of the flow leaving the demineralizers. Temperature indication is provided on the main control board.

The temperature of the flow leaving the BTRS during boration (boron release) operations is controlled by instrumentation controlling a valve which throttles the letdown chiller heat exchanger shell-side flow. Thus the temperature of the fluid being routed to the volume control tank is prevented from becoming too high.

B. Pressure

Instrumentation is provided which monitors and gives local indication of the pressure at each chiller pump suction and discharge and at the inlet and outlet to the bank of demineralizers.

C. Flow

Instrumentation on the return line to the chiller surge tank maintains chiller loop flow at a constant value by controlling the valve which adjusts the amount of flow bypassing the letdown chiller heat exchanger. Thus, if the shell-side flow in the heat exchanger is restricted by the temperature controlled valve, the bypass valve is automatically adjusted to maintain full flow in the chiller loop.

Instrumentation is provided to monitor the flowrate through the BTRS. Indication is on the main control board.

D. Level

Instrumentation is provided to measure the fluid level in the chiller surge tank. Level readout and high and low level alarms are provided on the main control board.

9.3.5 FAILED FUEL DETECTION SYSTEM

9.3.5.1 Design Bases

The gross failed fuel detection system consists of equipment designed to detect gross fuel failure by the measurement of delayed neutron activity in the reactor coolant.

9.3.5.2 System Description

The gross failed fuel detector is connected to the hot leg of a primary coolant loop (figure 9.3-2). The coolant sample passes through a cooler and then into a coil containing a neutron detector and moderator, after which it flows back into the volume control tank. The sample delay time to the neutron detector is adjusted by means of a flow controller. The delay time also depends on the length of tubing used. Once set, the flow is kept relatively constant by the automatic flow control valve. A transmitting flowmeter is installed for periodic checks of the flowrate. A sensor monitors the temperature within the neutron coil.

Figure 9.3-3 shows the block diagram of the gross failed fuel detector channel. The detector, preamplifier, sample cooler, and associated flow controls are located outside the containment. The signal processing equipment and readout are mounted in a rack located in the control room. The delayed neutron signal of the detector is displayed on a recorder located in the rack. The response time for the gross failed fuel detector is on the order of 60 s.

9.3.5.3 Safety Evaluation

The gross failed fuel detection system does not perform a safety-related function and is not designed to satisfy any specific safety criteria. As shown in figure 9.3-2, the gross failed fuel detector is outside the containment and is installed in the primary coolant hot leg sample line. It is isolated from the containment by means of the sample system isolation valves. The safety evaluation of the sampling system, including the isolation valves, is discussed in subsection 9.3.2.

9.3.5.4 Tests and Inspections

The gross failed fuel detection system is equipped with a test oscillator in the preamplifier and a test oscillator in the electronics drawer, each of which can be used to test the proper operation of the signal processing circuitry. Routine tests and inspections will be performed in accordance with procedures described in section 13.5.

9.3.5.5 Instrument Applications

Instrumentation associated with the gross failed fuel detection system is described in paragraph 9.3.5.2.

REFERENCES:

1. NRC Safety Evaluation Report, J. M. Farley Nuclear Plant Unit 1 and Unit 2, NUREG-0117 Supplement No. 5 to NUREG-75/034, dated March 1981.

2. Letter from NRC, dated March 26, 1985, and enclosed SER related to the Post-Accident Sampling System.

3. Letter from NRC, dated January 7, 1987, and enclosed SER related to Regulatory Guide 1.97.

4. Letter from NRC, dated May 22, 2002, and enclosed SER related to FOL amendments 156 and 148 for Units 1 and 2, respectively.

TABLE 9.3-1 (SHEET 1 OF 3)

SAFETY-RELATED AIR-OPERATED VALVES

Item	Piping Diagram FSAR Drawing No.	Elementary Diagram Drawing No.	Location Drawing No.
Containment Isolation Phase A, Control Room Vent Motors			
3622	D-175012	177373	175144
3623	D-175012	177373	175144
3624	D-175012	177373	175144
3625	D-175012	177373	175144
3626	D-175012	177373	175144
3627	D-175012	177373	175144
3628	D-175012	177373	175144
3629	D-175012	177373	175144
3649A	D-175012	177373	175144
3649B	D-175012	177373	175144
3649C	D-175012	177373	175144
3234A	D-175033, Sheet 2	177857	175142
3234B	D-175033, Sheet 2	177857	175142
3772A	D-175000, Sheet 1	177373	175142
3772B	D-175000, Sheet 1	177373	175142
3772C	D-175000, Sheet 1	177373	175142
Electric Driven Auxiliary Feedwater Pumps and Flow Control Valves			
3227A	D-175007	177591	175142
3227B	D-175007	177591	175142
3227C	D-175007	177591	175142
3328	D-175009, Sheet 2	177844	175146
3329	D-175009, Sheet 2	177844	175146
3330	D-175009, Sheet 2	177844	175146
Steam Line Isolation			
3368AA	D-175033, Sheet 1	177864	175142
3368AB	D-175033, Sheet 1	177864	175142
3368BA	D-175033, Sheet 1	177864	175142
3976A	D-175033, Sheet 1	177866	175142
3976B	D-175033, Sheet 1	177866	175142
3976C	D-175033, Sheet 1	177866	175142
3369AA/AC	D-175033, Sheet 1	177863	175142
3369BA/BC	D-175033, Sheet 1	177863	175142

TABLE 9.3-1 (SHEET 2 OF 3)

Item	Piping Diagram FSAR Drawing No.	Elementary Diagram Drawing No.	Location Drawing No.
3369CA/CC	D-175033, Sheet 1	177863	175142
3370AA/AC	D-175033, Sheet 1	177867	175142
3370BA/BC	D-175033, Sheet 1	177867	175142
3370CA/CC	D-175033, Sheet 1	177867	175142
Safety Injection			
2229	D-175002, Sheet 2	177853	175147
3096A	D-175002, Sheet 2	177853	175147
3096B	D-175002, Sheet 2	177853	175147
LCV-115A	D-175039, Sheet 7	177604	175145
033A	D-175043, Sheet 1	507141	175146
033B	D-175043, Sheet 1	507141	175146
033A	D-205043, Sheet 1	356839	205145
033B	D-205043, Sheet 1	356839	205145
Supporting Systems			
444B	D-175037, Sheet 2	177381	175148
445A	D-175037, Sheet 2	177381	175148
8875A	D-175038, Sheet 2	177858	175150
8875B	D-175038, Sheet 2	177858	175150
8875C	D-175038, Sheet 2	177858	175150
Supporting Equipment			
0459	D-175039, Sheet 1	177585	175150
0460	D-175039, Sheet 1	177586	175150
8141A	D-175039, Sheet 1	177861	175149
8141B	D-175039, Sheet 1	177861	175149
8141C	D-175039, Sheet 1	177861	175149
8146	D-175039, Sheet 1	177861	175150
8147	D-175039, Sheet 1	177861	175150
8145	D-175039, Sheet 1	177858	175150
8153	D-175039, Sheet 1	177858	175150
8154	D-175039, Sheet 1	177858	175149
0113A	D-175039, Sheet 6	177379	175147
0113B	D-175039, Sheet 2	177509	175147
0114A	D-175039, Sheet 2	177510	175147
0114B	D-175039, Sheet 7	177511	175147

TABLE 9.3-1 (SHEET 3 OF 3)

Item	Piping Diagram FSAR Drawing No.	Elementary Diagram Drawing No.	Location Drawing No.
3009A	D-175003, Sheet 1	177856	175143
3009B	D-175003, Sheet 1	177856	175143
3009C	D-175003, Sheet 1	177856	175143
3028	D-175002, Sheet 1	177584	175140
3105	D-175009, Sheet 1		175143
3106	D-175009, Sheet 1		175143
3371A	D-175033, Sheet 1	177401	175324
3371B	D-175033, Sheet 1	177401	175324
3371C	D-175033, Sheet 1	177401	175324
7614A	D-175071, Sheet 1	177054	175146
7614B	D-175071, Sheet 1	177054	175146
7614C	D-175071, Sheet 1	177054	175146

TABLE 9.3-2 (SHEET 1 OF 2)

PRIMARY SAMPLE SYSTEM SAMPLE POINT DESIGN DATA

Sample Point	Sample Point Name	Sample Conditions Design/ Service (psig)	Sample Conditions Design/ Service (°F)
XE-3101	Reactor coolant hot leg, loop 2	2458/2235	650/600
XE-3102	Reactor coolant hot leg, loop 3	2485/2235	650/600
XE-3103	Pressurizer liquid	2485/2235	680/653
XE-3104	Pressurizer steam	2485/2235	680/650
XE-3105	Discharge residual heat exchanger 1	600/400	400/350
XE-3106	Discharge residual heat exchanger 2	600/400	400/350
XE-3117	Volume control tank gas space	150/60	500/120
XE-3162	Accumulator tank 1	700/650	650/150
XE-3163	Accumulator tank 2	700/650	650/150
XE-3164	Accumulator tank 3	700/650	650/150
XE-3127	Discharge letdown heat exchanger	370/200	650/127
XE-3151	Discharge mixed bed demineralizers	370/150	650/127
XE-3179A	Steam generator 1A, bottom	1085/775	600/517
XE-3180A	Steam generator 1B, bottom	1085/775	600/517

TABLE 9.3-2 (SHEET 2 OF 2)

Sample Point	Sample Point Name	Sample Conditions Design/ Service (psig)	Design/ Service (°F)
XE-3181A	Steam generator 1C, bottom	1085/775	600/517
XE-3182A	Main steam line 1A	1085/775	600/517
XE-3182B	Main steam line 1B	1085/775	600/517
XE-3182C	Main steam line 1C	1085/775	600/517

TABLE 9.3-3 (SHEET 1 OF 3)

LOCAL GRAB SAMPLES

Sample Point Name	Sample Conditions Design/ Service (psig)	 Design/ Service (°F)
Boric acid blender discharge to volume control tank	ATM/ATM	300/165
Boric acid tank 1	ATM/ATM	200/60-80
Boric acid tank 2	ATM/ATM	200/60-80
Boric acid batching tank	ATM/ATM	300/165
Discharge recycle evaporator feed demineralizer 1	150/75	200/115
Discharge recycle evaporator feed demineralizer 2	150/75	200/115
Recycle holdup tank 1 (bottom of diaphragm)	ATM/ATM	200/120
Recycle holdup tank 2 (bottom of diaphragm)	ATM/ATM	200/120
Recycle holdup tank 3 (bottom of diaphragm)	ATM/ATM	200/120
Discharge recycle evaporator feed pumps	150/140	200/120
Discharge recycle evaporator condensate demineralizer	150/100	200/115
Recycle evaporator package concentrates sample	150/135	500/120
Recycle evaporator package distillates sample	150/135	500/120
Recycle holdup tanks to WPS gas compressor	ATM/ATM	200/120

TABLE 9.3-3 (SHEET 2 OF 3)

Sample Point Name	Sample Conditions Design/ Service (psig)	Design/ Service (°F)
Floor drain tank pump discharge	150/110	200/120
Gas decay tanks (gas sample)	50/20	150/140
Water from spent fuel pool pump 1	150/30	200/120
Refuel water from demineralizer to spent fuel pool	200/120	150/60
Discharge residual heat removal pump 1	600/400	400/350
Discharge residual heat removal pump 2	600/400	400/350
Discharge thermal regenerative heat exchanger to modified heat exchanger	250/200	150/140
Letdown chiller heat exchanger discharge to chiller surge tank	25/100	150/100
Reactor coolant drain tank discharge	150/100	250/100
Vent from reactor coolant drain tank to WPS	100/10	200/100
Waste evaporator condensate from waste evaporator condition tank or demineralizer	150/100	200/120
Waste evaporator feed pump discharge to waste evaporator filter	150/110	200/120
Waste evaporator demineralizer discharge to waste evaporator condition tank	150/110	200/120
Waste condensate pump discharge	150/110	200/120
Waste evaporator concentrate sample	150/135	500/120

TABLE 9.3-3 (SHEET 3 OF 3)

Sample Point Name	Sample Conditions Design/ Service (psig)	Design/ Service (°F)
Waste evaporator distillate sample	150/135	500/120
Spent resin storage tank sluice filter discharge	150/110	200/120
Chemical drain tank pump discharge	150/110	200/120
Laundry and hot shower pump discharge	150/110	200/120
Discharge of waste monitor tank discharge pumps 1 and 2 to environment	150/110	200/120
Component cooling heat exchanger A (component cooling water)	150/100	200/120
Component cooling heat exchanger B	150/100	200/120
Component cooling heat exchanger C	150/100	200/120
Component cooling heat exchanger A (service water)	150/100	200/120
Component cooling heat exchanger B	150/100	200/120
Component cooling heat exchanger C	150/100	200/120
Reactor makeup water tank	ATM/ATM	200/120
Demineralized water tank	ATM/ATM	200/120
Boric acid transfer pump A discharge	150/120	500/80
Boric acid transfer pump B discharge	150/120	500/80

TABLE 9.3-4

TURBINE PLANT ANALYZER SAMPLING SECTION SAMPLE POINT DESIGN DATA

	Sample Conditions	
Sample Point Name	Design/ Service (psig)	Design/ Service (°F)
Makeup to condenser	50/35	150/121
Condensate pump discharge	550/466	300/121
Steam generator feedwater pump suction	550/466	470/121
Steam generator inlet	1180/775	470/442
Steam generator outlet 1	1085/775	600/517
Steam generator outlet 2	1085/775	600/517

TABLE 9.3-5

CHEMICAL AND VOLUME CONTROL SYSTEM DESIGN PARAMETERS

General Features	Parameter
Seal water supply flowrate for three reactor coolant pumps, nominal (gal/min)	24
Seal water return flowrate for three reactor coolant pumps, nominal (gal/min)	9
Letdown flow (gal/min)	
Normal	60
Maximum	135
Charging flow, excluding seal water (gal/min)	
Normal	45
Maximum	105[a]
Temperature of letdown reactor coolant entering system (°F)	543.5
Temperature of charging flow directed to reactor coolant system (°F)	485
Centrifugal charging pump bypass flow, each (gal/min)	60
Amount of 4 percent boric acid solution required to meet cold shutdown requirements shortly after full power operation (gal)	11,300

a. The original design value of 105 gal/min has been reevaluated for a flow controller limit increase to 130 gal/min and has been found acceptable.

TABLE 9.3-6 (SHEET 1 OF 9)

PRINCIPAL COMPONENT DATA SUMMARY

Centrifugal Charging Pumps

Number	3
Design pressure (psig)	3000
Design temperature (°F)	300
Design flow (gal/min)	150
Design head (ft)	5800
Material	Austenitic stainless steel

Boric Acid Transfer Pumps

Number	2
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	75
Design head (ft)	235
Material	Austenitic stainless steel

Recycle Evaporator Feed Pumps

Number	2
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	30
Design head (ft)	320
Material	Stainless steel

a. The 2A charging pump (Q2E21P002A), the 2B charging pump (Q2E21P002B), the 1C charging pump (Q1E21P002C), and the 2C charging pump (Q2E21P002C) design pressure is 3000 psig.

TABLE 9.3-6 (SHEET 2 OF 9)

Regenerative Heat Exchanger

Number	1
Heat transfer rate at design conditions (Btu/h)	8.2×10^6
Shell side	
Design pressure (psig)	2485
Design temperature (°F)	650
Fluid	Borated reactor coolant
Material	Austenitic stainless steel
Tube side	
Design pressure (psig)	2735
Design temperature (°F)	650
Fluid	Borated reactor coolant
Material	Austenitic stainless steel
Shell side (letdown, normal operation)	
Flow (lb/h)	29,826
Inlet temperature (°F)	543.5
Outlet temperature (°F)	290
Tube side (charging)	
Flow (lb/h)	22,370
Inlet temperature (°F)	130
Outlet temperature (°F)	485

Letdown Heat Exchanger

Number	1
Heat transfer rate at design conditions (Btu/h)	16.1×10^6
Shell side	
Design pressure (psig)	150
Design temperature (°F)	250
Fluid	Component cooling water
Material	Carbon steel

TABLE 9.3-6 (SHEET 3 OF 9)

Tube side		
Design pressure (psig)		600
Design temperature (°F)		400
Fluid		Borated reactor coolant
Material		Austenitic stainless steel
Shell side	Normal	Design - Heatup
Flow (lb/h)	117,733	551,000
Inlet temperature (°F)	105	105
Outlet temperature (°F)	150.7	134.3
Tube side (letdown)		
Flow (lb/h)	29,826	59,700
Inlet temperature (°F)	290	380
Outlet temperature (°F)	110.9	115

Excess Letdown Heat Exchanger

Number	1	
Heat transfer rate at design conditions (Btu/h)	5.03×10^6	
	Shell Side	Tube Side
Design pressure (psig)	150	2485
Design temperature (°F)	250	650
Design flow (lb/h)	125,700	12,400
Inlet temperature (°F)	105	547
Outlet temperature (°F)	145	165
Fluid	Component cooling water	Borated reactor coolant
Material	Carbon steel	Austenitic stainless steel

Seal Water Heat Exchanger

Number	1

TABLE 9.3-6 (SHEET 4 OF 9)

Heat transfer rate at design conditions (Btu/h)	1.5×10^6	
	<u>Shell Side</u>	<u>Tube Side</u>
Design pressure (psig)	150	150
Design temperature (°F)	250	250
Design flow (lb/h)	115,000	64,075
Inlet temperature (°F)	105	138.5
Outlet temperature (°F)	118	115
Fluid	Component cooling water	Borated reactor coolant
Material	Carbon steel	Austenitic stainless steel

Volume Control Tank

Number	1
Volume (ft^3)	300
Design pressure (psig)	75
Design temperature (°F)	250
Material	Austenitic stainless steel

Boric Acid Tanks

Number	2
Capacity	21,000
Design pressure (psig)	Atmospheric
Design temperature (°F)	170
Material	Austenitic stainless steel

Boric Acid Batching Tank

Number	1
Capacity (gal)	400
Design pressure (psig)	Atmospheric
Design temperature (°F)	300
Material	Austenitic stainless steel

TABLE 9.3-6 (SHEET 5 OF 9)

Recycle Holdup Tank

Number	3
Volume (gal)	28,000
Design pressure (psig)	Atmospheric
Design temperature (°F)	200
Material	Austenitic stainless steel

Recycle Evaporator Reagent Tank

Number	1
Volume (gal)	5
Design pressure (psig)	150
Design temperature (°F)	200
Material	Austenitic stainless steel

Mixed Bed Demineralizers

Number	2
Design pressure (psig)	300
Design temperature (°F)	250
Design flow (gal/min)	120
Resin volume, each (ft^3)	30 Typical/39 maximum
Material	Austenitic stainless steel

Cation Bed Demineralizer

Number	1
Design pressure (psig)	300
Design temperature (°F)	250
Design flow (gal/min)	60
Resin volume (ft^3)	20
Material	Austenitic stainless steel

TABLE 9.3-6 (SHEET 6 OF 9)

Recycle Evaporator Feed Demineralizers

Number	2
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	120
Resin volume (ft^3)	30
Material	Austenitic stainless steel

Recycle Evaporator Condensate Demineralizer

Number	1
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	30
Resin volume (ft^3)	20
Material	Austenitic stainless steel

Reactor Coolant Filter

Number	1
Design pressure (psig)	300
Design temperature (°F)	250
Design flow (gal/min)	150
Particle retention	Greater than or equal to 98-percent retention of particles for the applicable micron size
Material (vessel)	Austenitic stainless steel

Seal Water Injection Filters

Number	2
Design pressure (psig)	2735
Design temperature (°F)	200
Design flow (gal/min)	80

TABLE 9.3-6 (SHEET 7 OF 9)

Particle retention	Greater than or equal to 98-percent retention of particles for the applicable micron size
Material (vessel)	Austenitic stainless steel

Seal Water Return Filter

Number	1
Design pressure (psig)	150
Design temperature (°F)	250
Design flow (gal/min)	150
Particle retention	Greater than or equal to 98-percent retention of particles for the applicable micron size
Material (vessel)	Austenitic stainless steel

Boric Acid Filter

Number	1
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	150
Particle retention	98-percent retention of particles 25 μm and above for the Cuno filter and 98-percent retention of particles 6 μm and above for the ultipor GF Plus filter

TABLE 9.3-6 (SHEET 8 OF 9)

Material (vessel)	Austenitic stainless steel
Recycle Evaporator Feed Filter	
Number	1
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	150
Particle retention	98-percent retention of particles 5 μm and above for the Cuno filter and 98-percent retention of particles 1 μm and above for the ultipor GF Plus filter
Material (vessel)	Austenitic stainless steel
Recycle Evaporator Condensate Filter	
Number	1
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	35
Retention of 25-˜m particles	98 percent
Material (vessel)	Austenitic stainless steel
Recycle Evaporator Concentrates Filter	
Number	1
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	35
Retention of 25 ˜m particles	98 percent
Material (vessel)	Austenitic stainless steel
Boric Acid Blender	

TABLE 9.3-6 (SHEET 9 OF 9)

Number		1
Design pressure (psig)		150
Design temperature (°F)		250
Design flow (gal/min)		35
Boric acid solution		35
Reactor makeup water		85
Material		Austenitic stainless steel
Letdown Orifice	45 gal/min	60 gal/min
Number	1	2
Design flow (lb/h)	22,400	29,826
Differential pressure at design flow (psi)	1700 ± 100	1700 ± 100
Design pressure (psig)	2485	2485
Design temperature (°F)	650	650
Material	Austenitic stainless steel	Austenitic stainless steel
Recycle Evaporator Package		
Number		1
Concentration of concentrate, boric acid (wt percent)		4
Concentration of condensate		<10 ppm boron as H_3B_3
Material		Stainless steel
Recycle Holdup Tank Vent Eductor		
Number		1
Design pressure (psig)		150
Design temperature (°F)		200
Suction flow (sf^3/min)		1 of H_2
Motive flow (sf^3/min)		40 of N_2
Material		Carbon steel

TABLE 9.3-7 (SHEET 1 OF 3)

BORON THERMAL REGENERATION SYSTEM COMPONENT DATA

Chiller Pumps

Number	2
Design pressure (psig)	150
Design temperature (°F)	200
Design flow (gal/min)	500
Design head (ft)	150
Material	Carbon steel

Moderating Heat Exchanger

Number	1	
Design heat transfer (Btu/h)	2.53×10^6	
	Shell	Tube
Design pressure (psig)	300	300
Design temperature (°F)	200	200
Design flow (lb/h)	59,640	59,640
Design inlet temperature, boron storage mode (°F)	50	115
Design outlet temperature, boron storage mode (°F)	92.4	72.6
Inlet temperature, boron release mode (°F)	140	115
Outlet temperature, boron release mode (°F)	123.7	131.3
Fluid circulated	Reactor coolant	Reactor coolant
Material	Stainless steel	Stainless steel

TABLE 9.3-7 (SHEET 2 OF 3)

Letdown Chiller Heat Exchanger

Number	1	
Design heat transfer (Btu/h)	1.65×10^6	
	Shell	Tube
Design pressure (psig)	150	300
Design temperature (°F)	200	200
Design flow (lb/h)	175,000	59,640
Design inlet temperature, boron storage mode (°F)	39	72.6
Design outlet temperature, boron storage mode (°F)	48.4	45
Inlet temperature, boron release mode (°F)	90	123.7
Outlet temperature, boron release mode (°F)	99.4	96.1
Fluid circulated	Chromated water	Reactor coolant
Material	Carbon steel	Stainless steel

Letdown Reheat Heat Exchanger

Number	1	
Design heat transfer (Btu/h)	1.49×10^6	
	Shell	Tube
Design pressure (psig)	300	600
Design temperature (°F)	200	400
Design flow (lb/h)	59,640	44,730
Inlet temperature (°F)	115	280
Outlet temperature (°F)	140	246.7
Fluid circulated	Reactor coolant	Reactor coolant
Material	Stainless steel	Stainless steel

TABLE 9.3-7 (SHEET 3 OF 3)

Chiller Surge Tank

Number	1
Volume (gal)	400
Design pressure (psig)	Atmospheric
Design temperature (°F)	200
Material	Carbon steel

Thermal Regeneration Demineralizers

Number	4
Design pressure (psig)	300
Design temperature (°F)	250
Design flow (gal/min)	120
Resin volume (ft^3)	70
Material	Stainless steel

Chillers

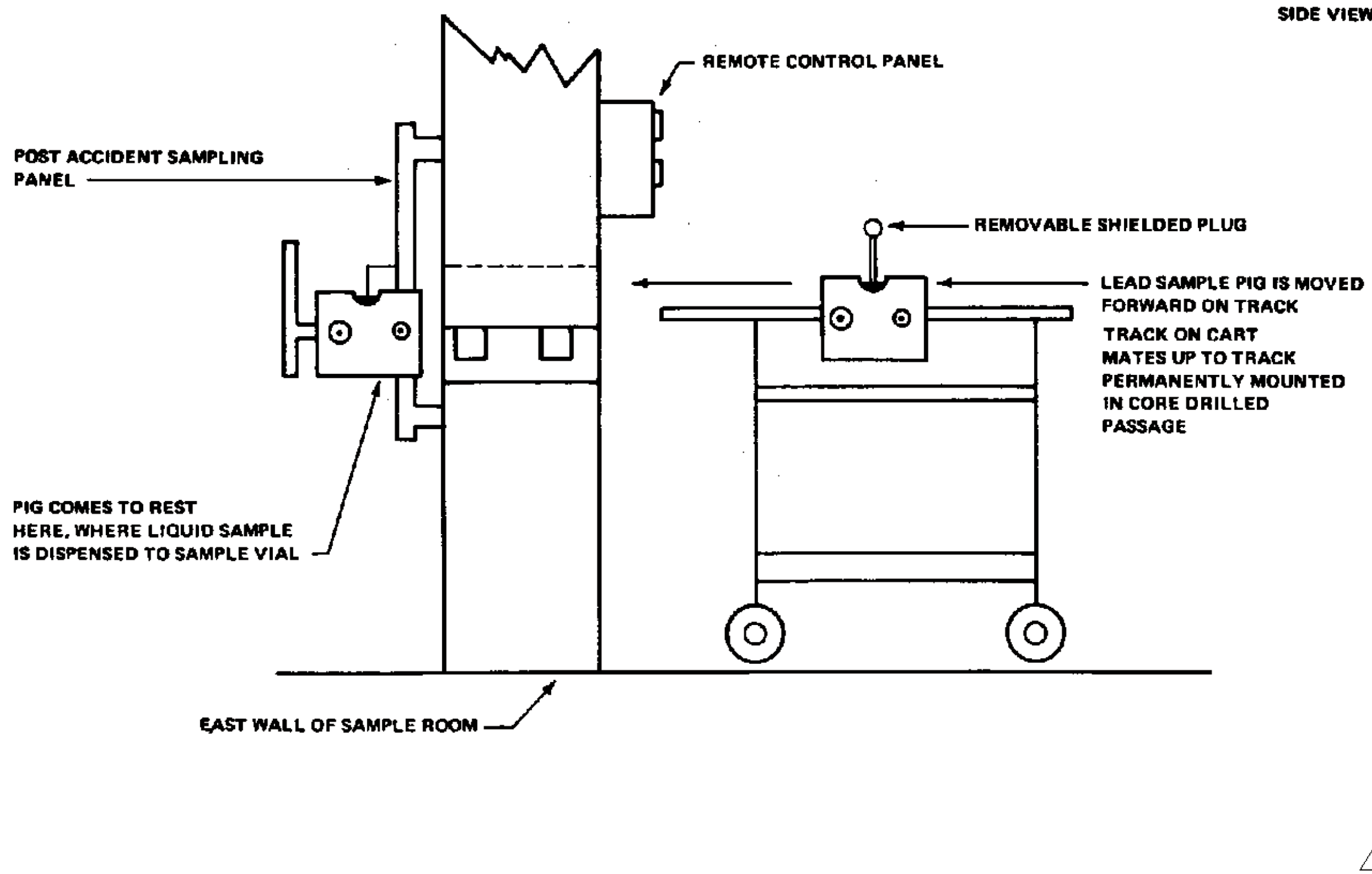
Number	2
Capacity (Btu/h)	1.66×10^6
Design flow (gal/min)	352
Inlet temperature (°F)	48.4
Outlet temperature (°F)	39

TABLE 9.3-8

VALVE POSITIONS FOR OPERATING MODES OF BORON THERMAL REGENERATION SYSTEM

Valve	Dilute	Off	Borate
7054	Open	Closed	Open
7002A	Open	Closed	Closed
7002B	Open	Closed	Closed
7022	Open	Closed	Closed
7040	Closed	Open	Open
7041	Closed	Open	Open
7045	Open	Open	Closed
7046	Closed	Closed	Open
TCV-381A	Closed	Closed	(a)
TCV-381B	Open	Open	(a)
TCV-386	(a)	Closed	(a)
HCV-387 (3-way)	(a)	Open	(a)
8547	Closed	Open	Closed

a. Limit switch indication not available, since position varies.



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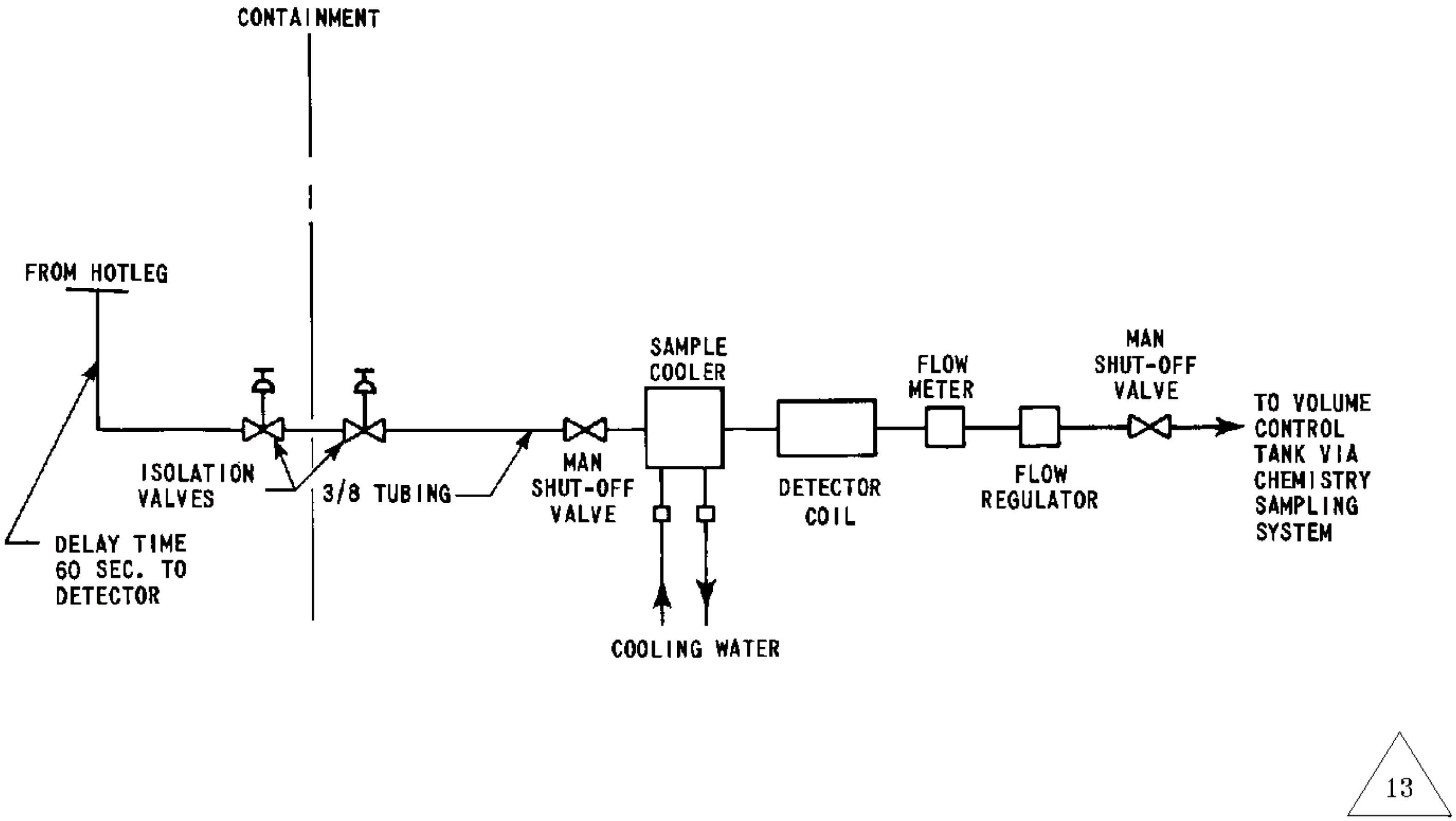
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

REACTOR COOLANT SAMPLING SYSTEM

FIGURE 9.3-1



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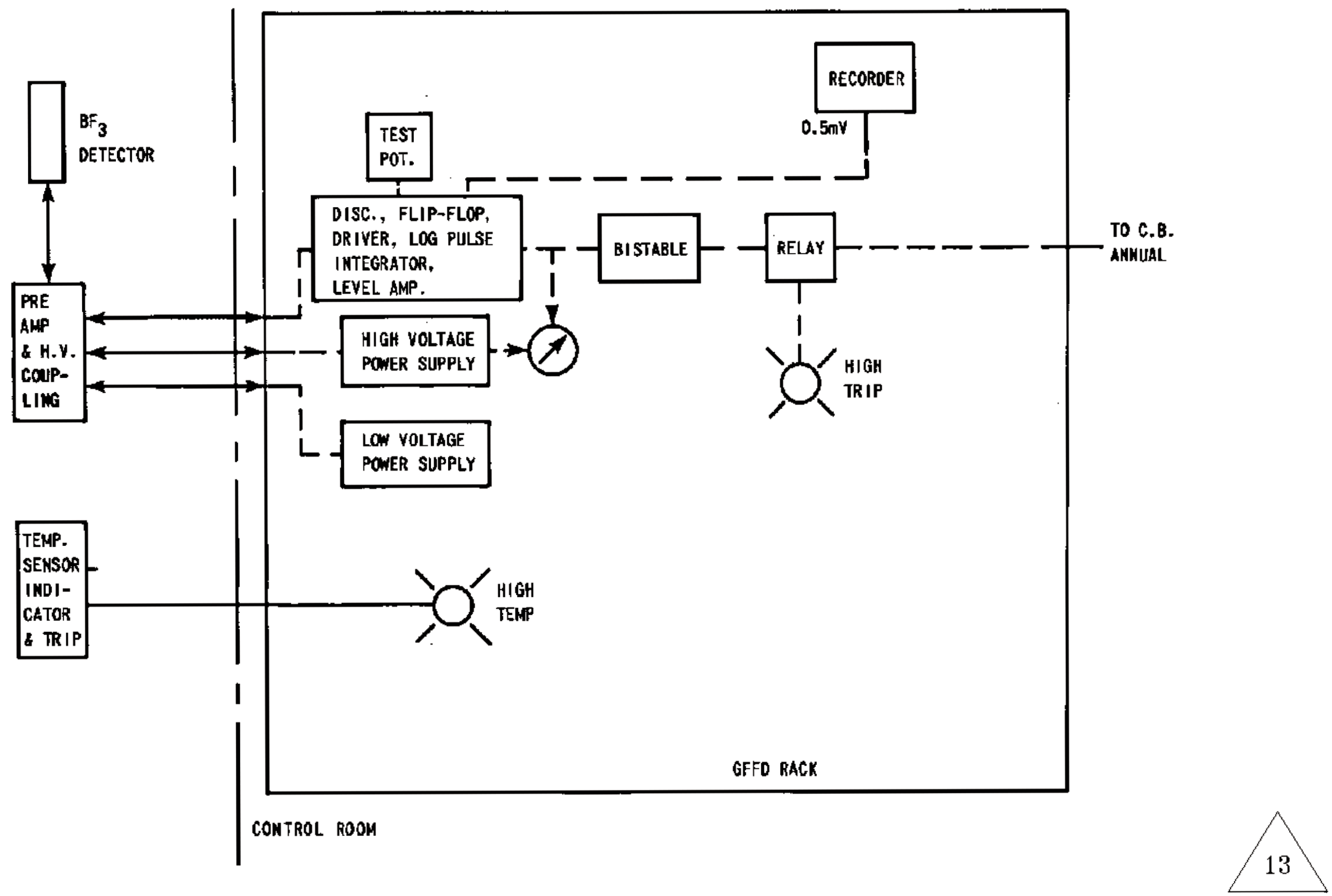
NUCLEAR PLANT
UNIT 1 AND UNIT 2

GROSS FAILED FUEL
DETECTOR FLOW DIAGRAM

FIGURE 9.3-2



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NUCLEAR PLANT
UNIT 1 AND UNIT 2

GROSS FAILED FUEL DETECTOR
ELECTRONICS DIAGRAM

FIGURE 9.3-3

9.4 AIR CONDITIONING, HEATING, COOLING, AND VENTILATION SYSTEMS

9.4.1 CONTROL ROOM

9.4.1.1 Design Bases

The control room air conditioning and filtration system is designed with sufficient redundancy and separation of components to provide reliable operation under normal conditions and to ensure operation under emergency conditions.

Two separate and redundant air conditioning systems are provided to maintain the temperature in the control room at approximately 78°F (db). Safety-related components in the control room are designed to withstand a maximum environmental temperature of 120°F. Therefore, control room temperatures will not approach the design limit of the safety-related components, even considering a single active or passive failure in the control room heating, ventilation, and air conditioning (HVAC) systems.

The control room was designed to meet the dose requirements of 10 CFR 50, Appendix A, General Design Criterion 19. The control room doses were analyzed based on the following design parameters:17

A. Containment isolation signal from the engineered safety features actuation system automatically switches the control room HVAC system from normal to emergency mode of operation.

B. High radiation levels entering the control room will automatically isolate the normal air systems with the pressurization and recirculation systems being manually initiated by the operator.

C. The control room is pressurized greater than all adjacent areas with a redundant air intake on the auxiliary building roof. The air intake rate is 300 ft^3/min in the emergency mode. Deep bed charcoal filters (6 in.) at the intake have 99 percent efficiency for removal of all forms of iodine. This design minimizes the possibility of any unfiltered leakage into the control room.

D. The control room recirculation system flowrate is 3000 ft^3/min. This system has a filter efficiency of 95 percent (2 in.) for all forms of iodine except particulates which are treated as in C above.

Provisions are made in the system to detect and limit the introduction of airborne radioactive material into the control room. Provisions are also made in the system for the removal of radioactive and foreign material from the control room environment.

The system is designed to provide an environment with controlled temperature and humidity to ensure both the comfort and safety of the operators and the integrity of the control room components. Design ambient conditions are approximately 78°F (db) and 50-percent relative humidity.

The system is designed to permit periodic inspection of the principal system components.

9.4.1.2 System Description

The control room air conditioning and filtration system is shown schematically in drawings D-175012 and D-205012. Principal system components are listed and described in Table 9.4-1. The conformance of the control room filtration units to Regulatory Guide 1.52 is presented in Table 9.4-2.

During normal plant operation, one of the two 100-percent capacity, Category I air handling units recirculates 21,000 ft^3/min of cooled, filtered air through the control room. Each air handling unit consists of a recirculation fan, prefilter, cooling coil, and the associated instrumentation and controls. One of four 100 percent capacity, Category I air-cooled condensing units rejects the control room heat to the atmosphere. Each condensing unit consists of compressors, condenser coils, condenser fans and controls. Should the operating unit fail to function in some way, the second 100-percent capacity unit can be manually started by the operator.

Two full capacity, redundant, Seismic Category I air pressurization systems are provided to maintain the control room at a positive pressure post accident. Each train is capable of supplying 300 ft^3/min through electric heating coils, prefilter, high efficiency particulate air (HEPA) filter, and 6-in., deep bed, charcoal filters, designed in accordance with the requirements of Regulatory Guide 1.52. Installed in parallel to the suction side of each control room main air conditioning unit are 1000-ft^3/min filtration units, consisting of prefilters, HEPA filters, and 2-in.charcoal filters, and a 2000-ft^3/min filtration unit incorporating the same composite filter elements as the 1000-ft^3/min units. Therefore, the overall recirculation filtration capacity is 3000 ft^3/min.

During normal operation, an air supply system delivers fresh outside air to the control room and to the computer room. (See drawings D-175012 and D-205012.) The makeup air supplied to the control room by this system maintains the control room at a slight positive pressure, thereby preventing the introduction of air into the control room from sources other than the design fresh air makeup system. The actuation logic for the emergency pressurization system is described in paragraph 9.4.1.5.

A smoke detector near the return air duct to each recirculation fan will sound an alarm in the control room on high smoke level. If necessary, the operator can exhaust air from the control room by manually opening the three pneumatically-operated exhaust isolation valves and starting one of the two 100-percent capacity exhaust fans. These exhaust fans and isolation valves are operated/opened only for purging smoke or toxic chemicals from the main control room. An area radiation monitoring system and redundant control room charcoal filter recirculation systems are provided to detect and reduce radiation levels in the control room. The filters are composite units and have been furnished to the same specifications as the filters for the penetration room filtration system (subsection 6.2.3). An area radiation monitor located in the control room alarms on high radiation level and alerts the operator to the need for filtration of recirculated air.

Redundant Category I process radiation monitors are provided at the control room normal fresh air intake. Redundant Category I smoke detectors are provided in the fresh air intake and return air duct of the computer room air handling unit. The air-operated isolation damper on the computer room recirculation line is interlocked with the computer room fire detectors and will automatically close in the event of smoke detection. The computer room fire detectors are also the means for actuating the halon release into this area. The halon storage tank is located outside the computer room. Inadvertent release of halon is discussed in paragraph 9.4.1.3 below. Tripping any one of the detectors will cause an alarm to sound in the control room and the closing of all air-operated and motor-operated isolation valves in the non-engineered safety features HVAC ducting penetrating the control room boundary, thereby isolating the control room. If required, and if contaminants are within safe levels, the operator can draw outside air by manually starting the emergency pressurization system, in which the air is filtered through deep bed filters.

A containment isolation actuation system (CIAS) phase A initiation signal or high radiation entering the control room causes the normal makeup air to be cut off and all control room isolation valves are closed. In this event, the positive pressure in the control room is maintained by the startup of one of the emergency pressurization systems, each consisting of an air inlet, an isolation valve, and a 300-ft^3/min, deep bed, charcoal filtration unit. Emergency pressurization is automatically initiated by a CIAS signal or manually initiated by the operator for the high radiation isolation condition. In like manner, the standby filtration units will be started and recirculate 3000 ft^3/min out of the 21,000 ft^3/min total room recirculation flowrate through charcoal filters.

Following CIAS a phase A signal, control room isolation, and charcoal filtration atmosphere cleanup will be initiated by the plant engineered safeguard instrumentation. High radiation levels entering the control room will also automatically initiate control room isolation; however, the pressurization and filtration systems must be manually initiated by the operator. During other situations requiring control room isolation, the operator manually initiates closure of the motor- and air-operated valves required to effect control room isolation.

All penetrations into the control room are sealed to minimize inleakage of outside air. Mechanical penetrations are sealed by the use of silicone rubber foam or by fiberglass impregnated boots. Electrical penetrations are sealed with silicone rubber foam. The HVAC system duct penetrations are provided with airtight automatic butterfly valves.

9.4.1.3 Safety Evaluation

The safety classification of the control room air conditioning and filtration system components is given in subsection 3.2.2. The redundant system has been designed to provide minimum filtering and ventilation and ensures that no single failure will prevent the safe occupancy of the control room under any mode of plant operation. A single-failure analysis is presented in table 9.4-3.

Power for the fan and condensing units of each air conditioner is supplied from emergency power supplies. A separate, independent system of distribution ducts is installed for each train.

The duct from the computer room air conditioning unit that normally supplies fresh makeup air to the control room contains two pneumatically operated valves in series. Two pneumatically operated valves in series are provided for the utility exhaust subsystem. These valves are powered from redundant power supplies and close automatically on a containment isolation signal to isolate the control room from outside air.

Since redundancy does not exist for the smoke purge exhaust isolation valves, the exhaust fans are normally not in operation and the isolation valves are normally closed to provide a passive isolation boundary. The exhaust fans and isolation valves are operated/opened only for purging smoke or toxic chemicals from the main control room.

The control room habitability is maintained by continually monitoring radiation levels and smoke concentration inside the room plus continually monitoring radiation levels, including monitoring smoke concentration, in the control room air intake duct and computer room return duct. To minimize inleakage, the control room is provided with normal and emergency pressurization systems designed to maintain positive pressure.

Upon smoke detection, an alarm is annunciated in the control room and all fail-safe, airtight isolation valves are closed automatically and remain closed until they are reopened manually. The normal makeup air is cut off and the operator can manually start the exhaust fan to purge smoke. If necessary, the operator can manually isolate the control room and make use of self-contained breathing apparatus. After a safe level of smoke concentration is reached, the operator can draw outside air either from the normal makeup air subsystem or from the emergency (pressurization system) makeup air subsystem.

Upon a high radiation signal from the makeup air inlet, an alarm is sounded in the control room and all isolation valves are closed automatically and remain closed until they are reopened manually. This will result in a loss of positive pressure in the control room. In this event, the operator will manually start one of the redundant pressurization systems and one of the redundant recirculation filtration systems (one 2000-ft^3/min and one 1000-ft^3/min system). The HEPA and 6-in., deep bed, charcoal filter unit in the pressurization system and the HEPA and 2-in. charcoal filters in the recirculation system provide additional assurance that the dose received by control room personnel will not exceed the guidelines of General Design Criterion 19.

Upon receipt of a containment isolation signal, the control room is automatically isolated as described above. The air pressurization system and recirculation system are automatically actuated to maintain the positive pressure and to provide control room cleanup, respectively. A flow control damper mounted on the bleedoff leg of the pressurization system will respond automatically to the pressure controller in the control room if in automatic, or may be manually positioned to achieve a slightly positive pressure. In automatic: if the positive pressure drops below 0.25-in. water gauge, the bleedoff damper will automatically restrict the bleedoff flow to divert maximum air supply into the room, in order to achieve a rapid pressure buildup. On a rising room pressure, the bleedoff damper will function in the opposite manner. Therefore, the control room pressure will be sensed and maintained, as well as exhibited for operator information.

Upon receipt of a smoke detection signal from the computer room smoke detector, the computer room HVAC is automatically isolated as described in paragraph 9.4.1.2. In addition, redundant Seismic Category I smoke detectors downstream of the return air subsystem from the computer room will automatically isolate redundant Seismic Category I isolation valves in the computer room recirculation line in the event of smoke recirculation following a computer room fire.

Radiation monitors are provided within the control room boundary. Radiation monitors are also provided within each of the various ventilation systems serving all radiation release points in the plant. These monitors provide indication in the control room and alarm whenever predetermined radiation levels are exceeded. These HVAC systems discharge through the plant vent stack. Additional radiation monitors are provided at the vent stack discharge which will provide a backup means of detecting abnormal plant releases. These monitors are designed to detect releases in excess of the maximum permissible concentrations guidelines established under column 1, Table II, Appendix B to 10 CFR 20.1 - 20.601. Based on the availability and sensitivity of the monitoring systems provided, the operator will have adequate indication and information to evaluate the magnitude of any abnormal plant releases and will manually isolate the control room if required.

An analysis of dose levels in the control room under accident conditions is presented in the applicable sections of chapter 15.

[HISTORICAL] *[An analysis of a chlorine release accident has been performed. This analysis is for historical purposes since single container quantities of gaseous chlorine are limited to 150 lbs. or less. (Locations and quantities of onsite chlorine storage are given in Table 2.2-3.) Because of the proximity of the closest circulating water chlorination house, the analysis was performed for the release of 2 tons of chlorine (the maximum amount of chlorine headered together at one time). Twenty-five percent of the chlorine was assumed to flash to gas. This is analyzed as a puff release. The remainder is assumed to form a 200-ft^2 pool where it evaporates due to the heat load from the sun and from ambient air and ground temperature.*

No credit is taken for the channeling of the dense chlorine gas around buildings and along ditches. No credit is taken for an elevated air intake, even though the intake is at an elevation of approximately 177 ft.

To evaluate the control room habitability, considering the closest circulating chlorination house, the following cases have been analyzed using the techniques outlined in references 1, 2, and 3:

A. Two-ton chlorine spill, 450 ft from control room air intake, 0.5 m/s wind, Pasquill Class F meteorology, shared Unit 1 and Unit 2 control room, 70-ft^3/min unfiltered inleakage, and no credit for building wake effect.

B. The same as case A except a wind speed of 1.0 m/s is used.

C. The same as case A except building wake effect is considered.

D. The same as case B except building wake effect is considered.

The time (after chlorine accident) required to reach 15, 30, 45, 60, and maximum chlorine concentration ppm by volume inside the control room is given in Table 9.4-4. This table also shows the peak chlorine concentration. The original analysis assumes a 5-s detector response time from 5 ppm setpoint (chlorine detector at air intake), a 5-s transport time of chlorinated air from air intake to the isolation valve, and a 6-s closing time of the isolation valve.

Plots of the chlorine concentration vs time for case A showing the time history for maximum chlorine concentration in the control room are presented in figure 9.4-1, sheets 1 and 2. Similar plots are presented in figure 9.4-1, sheets 3 and 4, for case B to show the least time required to reach 15 ppm.

In case B the operators will have over 2 min to put on self-contained breathing apparatus before a concentration of 15 ppm is reached in the control room, after allowing 5-s detection time at 5 ppm for the chlorine detectors at the chlorination house. This is in accordance with Regulatory Guide 1.78.

An inleakage rate of 70 ft^3/min is used based on 0.06 air exchange per hour for Type A control room defined in Regulatory Guide 1.78. Self-contained breathing apparatus with a minimum 30-min air supply are stored in the control room. Sufficient apparatus is provided to allow one spare per three units required. An additional 6-h air supply is provided in the auxiliary building as close as practical to the control room. An offsite source of air will also be available.]

An analysis of the halon 1301 concentration in the control room following an accidental spill in the computer room, without fire, has been performed. It is assumed that the total amount of halon 1301 flooding the computer room mixes with the air in the computer room. This yields a maximum initial concentration of 6 percent by volume in the computer room. Using the maximum control room makeup air quantity of 1650 ft^3/min, the maximum concentration of halon 1301 in the control room is 0.47 percent by volume after 15 min. This is well below the 7 percent maximum recommended concentration for normally occupied areas of National Fire Protection Association standard 12A. Figure 9.4-1, sheet 5, shows the time history of the halon 1301 concentration in the control room following the accidental release in the computer room.

9.4.1.4 Inspection and Testing Requirements

The control room filtration units, consisting of prefilters, HEPA filters, charcoal filters, and fans, are tested and qualified in the same manner as the filtration units furnished for the penetration system (subsection 6.2.3). Throughout plant life, periodic tests will be performed on all filters in the same manner as for the penetration room filtration units. Testing of this system is discussed in the Technical Specifications.

The control room air conditioning subsystem, consisting of redundant fans, coils, and air cooled condensing units, was tested before installation as follows:

Major Air Conditioning Components	Code or Standard
Fans	AMCA 210-67
Cooling coils	American Refrigeration Institute (ARI) standard 410-91
Air-cooled condensing units	ARI Standard 365-87

The filtration and air conditioning equipment, including refrigerant piping and distribution ductwork, was tested for leaks and balanced after installation in accordance with the Sheet Metal and Air Conditioning Contractors National Association, Low Velocity Duct Construction and Associated Air Balance Council, Standards for Field Measurement and Instrumentation, form 81266, Volume 1, 1970.

Isolation butterfly valves were subjected to leakage tests in accordance with standard MSS-SP-67, Type 1, Manufacturers Standardization Society of the Valve and Fitting Industry, and were found bubbletight against air at 25 psig.

Each component is inspected prior to installation and will be available for periodic inspection during plant operation. Instruments and controls are tested for actuation at the proper setpoints, and alarm functions are checked for operability and limits during pre-operational testing.

Because the control room air conditioning system is in use during normal plant operation, the availability of active components is evident to the plant operators, and there is no need for further online testing. Portions of the system normally closed to flow are periodically tested to ensure operability and integrity of the system. Periodic testing of the control room air conditioning system is discussed in the Technical Specifications.

9.4.1.5 Instrumentation

One train of the control room air conditioning system is operating during normal conditions and both trains are automatically started during post-LOCA conditions. Both trains of the control room recirculation filtration and emergency pressurization systems are automatically started upon receipt of a containment isolation A system signal. Instrumentation and associated analog and logic channels utilized for the initiation of the air conditioning, recirculation, filtration, and pressurization systems are described in chapter 7.

The following are displayed and/or located in the control room:

A. Control room air temperature.

B. Air intake smoke concentration indication.

C. Air intake radiation level.

D. Room smoke detectors.

E. Alarm for high differential pressure across each filter train.

F. Differential pressure between the control room and atmosphere.

Position indication of all isolation valves and dampers is locally displayed. Differential pressure across each filter train and fan is locally displayed in the control room mechanical equipment room.

9.4.1.6 Analysis of Site Boundary, Low Population Zone (LPZ) Boundary, and Control Room Operator Dose Following a LOCA

9.4.1.6.1 Assumptions and Conditions

In the evaluation of radiological consequences following a LOCA, the assumptions in Regulatory Guide 1.4 have been followed in the analysis (except for iodine model as noted):

A. Containment Parameters
See table 15.4-14.

B. Control Room Parameters
See table 15.4-16.

C. Atmospheric Dispersion Factors, X/Q (s/m^3)
See table 15B-2.

9.4.1.6.2 Justification of Assumptions and Conditions

9.4.1.6.2.1 Decontamination Factor. See table 15.4-14.

9.4.1.6.2.2 Air Transfer Rate. For this analysis, the air mixing rate of 2 unsprayed volume changes/h in the containment is assumed on the following basis.

The internal design of the containment structures permits air to circulate freely. All cubicles and compartments within the containment are open at the top and allow air circulation. Convective mixing in conjunction with containment spray ensures a high degree of mixing. Containment system experiment tests and the Marviken experiments have verified the adequate mixing of the containment atmosphere, due to the containment sprays and the blowdown in a highly compartmentalized configuration. The containment under present analysis is much less compartmentalized, ensuring even better mixing than in Marviken.

All subcompartments within the containment are provided with vents in the top (to provide pressure relief in the event of a LOCA in the subcompartment). These same vents provide for mixing between the subcompartments and the bulk containment. In the long term, the flow entering the compartment is approximately 3750 gal/min when recirculation core flooding is initiated. The sensible energy associated with the core recirculation flow is sufficient to provide mixing within the subcompartment and provides additional driving forces to mix the contents of the subcompartment through buoyancy effects.

This analysis assumes that the activity in the unsprayed region leaks at the same leak rate to the environment as that from the sprayed region.

9.4.1.6.2.3 <u>Control Room Atmospheric Dispersion Factors</u>. The atmospheric dispersion values (X/Q) were computed at the control room intake for each hour of meteorological data, for the years 2000 through 2004, using the ARCON96 computer code as described in Regulatory Guide 1.194.

ARCON96 evaluates ground level, vent, and elevated releases. A vent release is one that takes place through a rooftop vent with an uncapped vertical opening. Building wake effects are also considered in the model for estimating X/Q values from ground-level releases. Momentum rise and thermal plume rise are not considered in calculating the effective release height in the model. Additionally, under calm wind conditions, the receptor location is assumed to be directly downwind of the release point. Considering the release height, the receptor height, and the horizontal distance from the release point to the receptor, the model will calculate a “slant range distance” as the straight-line distance between the release point and the receptor. The values of X/Q for each averaging period were calculated and the 5-percent probable values determined. The values for each averaging time are shown in table 15B-2.

9.4.1.6.3 Results

The dose to control room operators is within the limits of 10 CFR 50, Appendix A, General Design Criterion 19, as shown in table 15.4-17.

9.4.2 AUXILIARY BUILDING

The auxiliary building ventilation system is designed to provide a suitable environment for equipment and personnel. The system provides maximum safety and convenience for operating personnel by arranging the ventilation equipment in zones so that potentially contaminated areas are separated from clean areas. The path of ventilating air is from areas of low activity toward areas of progressively higher activity.

Separate heating and ventilating systems serve the radwaste areas and nonradioactive areas, including the lower equipment rooms, technical support center, and fuel handling areas of the auxiliary building. The computer room, access control room, electrical equipment rooms, and technical support center have individual air conditioning systems.

Electrical equipment within nonengineered safety feature electrical equipment rooms, computer room, and cable spreading room is not required to mitigate the consequences of a postulated accident; therefore, failure of the associated air conditioning equipment will not affect the safe shutdown capability.

Each engineered safety feature electrical motor control center and 600-V load center room is provided with a Seismic Category I room air cooling unit powered from the same diesel as the motor control center or load center being served. These units are designed to limit the environmental temperature within the electrical equipment room under all postulated accident conditions. Any single failure will not affect safe shutdown capability. Table 9.4-6A depicts the maximum temperatures in the rooms cooled by service water post-DBA.

The radwaste area heating, ventilating, and filtration system is discussed in subsection 9.4.3. The remaining systems are discussed below.

9.4.2.1 Design Bases

9.4.2.1.1 Nonradioactive Area Heating and Ventilating System

The nonradioactive area heating and ventilating system is designed to perform the following functions:

A. Remove the sensible heat loss from all equipment and piping in the nonradioactive area during normal plant operation.

B. Limit the maximum ambient temperature to 110°F when the outdoor temperature is 95°F and minimize to 60°F when the outdoor temperature is 20°F.

The lower equipment rooms' heating and ventilating system is comprised of a supply air handling unit containing a fan, a prefilter, an electric heating coil, and an exhaust fan. The system provides and tempers outside air to ventilate the lower equipment rooms. These rooms are included in and are part of the nonradioactive ventilation area.

9.4.2.1.2 Fuel Handling Area Heating, Ventilating, and Filtration System

The fuel handling area heating, ventilating, and filtration system is designed to perform the following functions:

A. Remove the sensible heat loss from all equipment and piping in the fuel handling area during normal plant operation.

B. Limit the maximum ambient temperature to 110°F when the outdoor temperature is 95°F and minimize to 60°F when the outdoor temperature is 20°F.

C. Remove water vapors above the spent-fuel pool to improve visibility of fuel elements within the pool.

D. Provide filtering by routing 100 percent of the spent-fuel pool area exhaust air through pre-filter, HEPA, and charcoal filters during normal plant operation.

E. Provide filtering by routing exhaust air from the spent-fuel pool through the penetration room filtration system. Movement of new fuel over spent fuel with the spent fuel area roof new fuel access hatch open creates the potential for a fuel handling accident with a release pathway which bypasses the Fuel Handling Area Heating, Ventilating, and Filtration System. This configuration may also bypass the radiation monitors in the exhaust duct, and consequently bypass the PRF post- accident. This configuration is specifically analyzed in section 15.4.5.

F. Maintain a slightly negative pressure in the spent-fuel pool area with respect to the surrounding areas and outside at all times.

The conformance of the fuel handling area heating, ventilating, and filtration system is presented in table 9.4-5.

9.4.2.1.3 Computer Room HVAC System

The computer room HVAC system is designed to do the following:

A. Provide an environment with controlled temperature and humidity to ensure both the comfort and safety of the operators and the integrity of the computer room components.

B. Provide sufficient air capacity to maintain the computer room and control room at a slightly positive pressure.

The computer room environment is maintained between 60 and 80°F and 50-percent relative humidity. This ensures both the comfort and safety of the operators and the integrity of the computer room components.

9.4.2.1.4 Access Control Area HVAC System

The access control area HVAC system is designed to do the following:

A. Maintain ventilation and constant temperature and limit humidity in the “clean” zone to suit personnel working conditions.

B. Provide filtering of the exhaust air from controlled zones by directing the effluent to the radwaste area ventilating system HEPA/charcoal filters.

The design conditions for the air-conditioned rooms are 75°F and 50-percent relative humidity.

9.4.2.1.5 Electrical Equipment Room Air Conditioning Systems

The electrical equipment room air conditioning systems for the cable spreading room, the 600-V load center rooms, the 600-V load center 1M and 1N rooms in Unit 1, and the 600-V load center 2M room in Unit 2 are designed to remove the sensible heat loss from all equipment in the rooms to limit the ambient temperature to 95°F.

In addition to serving the 600-V load center 1M and 1N rooms in Unit 1 and the 600-V load center 2M room in Unit 2, the hot instrument shop is maintained at 75°F by the 600-V load center 1M and 1N air conditioning system.

Unit 1 and Unit 2 cable spreading rooms are provided with a smoke purge system. The smoke purge system has one exhaust fan with interconnecting ductwork to exhaust both units' cable spreading rooms. This exhaust fan is manually operated. An interlock is provided between the exhaust fan and the fire protection CO_2 system to prevent fan operation when the CO_2 system is in use.

9.4.2.1.6 Battery Room Exhaust System

The battery room exhaust system is designed to do the following:

A. Provide ventilation at the rate of at least 5 air changes/h.

B. Prevent hydrogen generation in the room from exceeding a 4-percent concentration by volume.

C. Prevent the room ambient temperature from exceeding 110°F.

9.4.2.1.7 Battery Charger Room, Motor Control Center, and 600-V Load Center Cooling Systems

The battery charger room, motor control center 1A, motor control center 1B, 600-V load center 1D, and 600-V load center 1E coolers are designed to maintain the ambient temperature in each respective room at or below 104°F during normal operation. Refer to Table 9.4-6A for post-DBA room temperatures.

An engineering analysis has been performed for all rooms with room coolers. This analysis demonstrates that the equipment in MCC 1A, 2A, 1B and 2B are capable of performing their specified function, during the temporary unavailability of the room cooler with the plant encountering a design basis accident (DBA). In battery charger room A, B, or C the analysis indicates that the room with the room cooler temporarily out of service must have the room door open (Reference 5) to the adjoining room with a room cooler in service for the equipment to be capable of performing its specified function, with the plant encountering a DBA.

All components of the battery charger room, motor control centers, and 600-V load center coolers are designed to meet Seismic Category I requirements. Power supplies and cooling water supplies to these units are arranged in a manner that will satisfy the single failure criterion. The single failure analysis is shown in table 9.4-7.

9.4.2.1.8 Sampling Room, Gas Analysis Room, Counting Room, and Radioactive Laboratory Heating and Air Conditioning System

A separate, individual heating and air conditioning system is provided for the sampling room, gas analysis room, counting room, and radioactive laboratory room. The system is designed to maintain each individual room ambient temperature at 75°F all year round, with the exception of the sampling room, which is maintained at 80°F.

The sampling room, gas analysis room, and radioactive laboratory exhaust systems are designed to draw air through the exhaust hood sufficient to convey entrained fumes through exhaust ducts connected to the main radioactive area filtration unit. The counting room is exhausted directly to the radwaste ventilation system without the use of an exhaust hood.

9.4.2.1.9 Engineered Safety Feature Pump Room Coolers

The pump room coolers are designed to maintain the ambient temperature in each of the charging/high head, residual heat removal, containment spray, component cooling, and auxiliary feedwater pump rooms at or below 104°F during normal operation of the pumps. Refer to Table 9.4-6A for post-DBA room temperatures.

An engineering analysis has been performed for all engineered safety feature pump rooms with room coolers. This analysis demonstrates that the equipment in the CCW pump rooms are capable of performing their specified function, during the temporary unavailability of one or both room coolers with the plant encountering a design basis accident (DBA).

Calculations show that with the safety-related room coolers out of service under accident conditions, temperature of the CCW pumps room will not exceed the continuous-duty rating of the ESF TS equipment in the room. Thus, the associated safety-related room coolers are not considered support equipment for the ESF TS equipment in this room and, as such, are not required for the ESF TS equipment in the room to remain operable. Therefore, other than for pressure boundary integrity, the safety-related room coolers for the CCW pumps room are not considered a required ESF room cooler subsystem.

All components of the pump room coolers that serve engineered safety feature pumps are designed to meet Seismic Category I requirements. Power supplies and cooling water supplies to these units are arranged in a manner that will satisfy the single failure criterion.

9.4.2.1.10 Technical Support Center HVAC System

The technical support center HVAC system is designed to maintain the center at 78°F and 50-percent relative humidity during the summer and 72°F during the winter. The system is designed so that the technical support center can be occupied by personnel during plant accident conditions. The system is designed to provide personnel protection from external airborne radiation. The system is powered by a safety-related power supply unit designed to meet safety-related system criteria. The technical support center HVAC system is not classified, however, as safety-related, nor is it redundant.

9.4.2.2 System Description

9.4.2.2.1 Nonradioactive Area Heating and Ventilating Systems

The nonradioactive area heating and ventilating system is independent of any other system and includes provisions to supply and exhaust air from the nonradioactive area. The system is shown in drawings D-175014, sheets 1 and 2; and D-205014, sheets 1 and 2, and principal components are listed in table 9.4-6. The system consists of one full capacity supply air handling unit complete with hot water heating coil, prefilter, and pneumatically operated dampers and one full capacity exhaust fan, connecting ductwork, and all controls.

The supply air handling unit provides once-through filtered and tempered outside air to the area through supply distribution ductwork when the outside air temperature is above 60°F. When the outside air temperature falls below 60°F, the supply unit will operate with approximately 20-percent outside air and approximately 80-percent recirculated air. A separate 100-percent capacity exhaust fan picks up the exhaust air through exhaust ductwork. A pneumatically operated damper located on the downstream side of the exhaust fan opens in proportion with the supply unit outside and return air dampers.

A. Heating and Ventilating Unit

The supply unit employed in the system is a floor-mounted, horizontal, drawthrough, cabinet type, single zone, air handling unit consisting of a centrifugal fan, hot water heating coil, flat type prefilter, outdoor return air dampers with pneumatic operators, and a mixing box designed to handle a nominal 24,000 sft^3/min, at 2.5-in. water gauge static pressure, 2.6 x 10^5 btu/h heating capacity. The fan motor is 20 hp.

B. Exhaust Fan

The system exhaust fan is of the centrifugal type, with a nominal design flowrate of 20,000 sft^3/min, at 1.7-in. water gauge static pressure. The fan motor is rated at 15 hp.

The fans used for the nonradioactive area heating and ventilating system supply air handling unit and exhaust system are designed in accordance with the applicable portions of Air Moving and Conditioning Association (AMCA) 99-67, Standards Handbook, and AMCA 210-67, Test Codes for Air Handling Devices.

Moreover, additional ventilation has been provided to certain rooms in Unit 1 (i.e., rooms 463, 464, 506) and Unit 2 (i.e., rooms 2462, 2463, 2464, 2506) to account for the heat produced by the electrical equipment installed in these rooms. The ventilation air to these rooms is supplied from outside by the nonradwaste air handling unit and the computer UPS supply fan. The computer UPS primary exhaust fan and secondary exhaust fan provide adequate exhaust from these rooms. Design parameters for the computer UPS supply fan and computer UPS primary and secondary exhaust fans are shown in table 9.4-6.

The computer UPS primary exhaust fan operates continuously to prevent hydrogen buildup in rooms 464 (Unit 1) and 2464 (Unit 2) and the adjacent areas. The computer UPS supply and secondary exhaust fans run only on an as-required basis during the summer.

9.4.2.2.2 Fuel Handling Area Heating, Ventilating, and Filtration Systems

The fuel handling area heating, ventilating, and filtration system is independent of any other system and includes provisions to ventilate and filter the area atmosphere by the use of a supply heating and ventilating unit, HEPA charcoal filter unit, and exhaust fans. The system is shown in drawings D-175045 and D-205045, and principal components are listed in table 9.4-6.

One 100-percent capacity supply air handling unit supplies filtered and tempered outside air to two sides of the fuel handling area, namely, the spent-fuel pool and the new fuel storage areas. The air supplied to the pool mixes with the water vapor emanating from the pool surface. An exhaust fan picks up air through a manifold located on the opposite side of the pool and draws it through pre-filters, HEPA, and charcoal filters prior to being released through the vent stack. Movement of new fuel over spent fuel with the spent fuel area roof new fuel access hatch open creates the potential for a fuel handling accident with a release pathway which bypasses the radiation monitors in the exhaust duct, and consequently a bypass of the PRF. This configuration is specifically analyzed in section 15.4.5. A separate gravity roof vent releases the air from the new fuel storage area.

This section describes the normal operation of the two 100% capacity penetration room filtration systems. During movement of irradiated fuel assemblies in the spent fuel room, if either of the penetration room filtration systems are inoperable for more than 7 days, the operable penetration filtration train must be immediately placed in operation or movement of irradiated fuel assemblies in the spent fuel pool room must be immediately suspended.

A single PRF system is capable of meeting all requirements of the fuel handling accident analyses.

Whenever irradiated fuel is in the spent-fuel storage pool, one of the penetration room filtration systems is aligned to the spent-fuel pool area. During movement of irradiated fuel assemblies in the spent fuel pool room, both of the penetration room filtration systems are aligned to the spent-fuel pool area to process automatically the spent-fuel area exhausts in the event of a fuel handling accident. During this mode of operation, a fuel handling accident signal from the redundant radiation monitors in the Seismic Category I exhaust line automatically de-energizes the supply and exhaust ventilation fans and isolates the fuel handling area. Isolation of the spent-fuel pool area is accomplished by the automatic closure of one of the redundant isolation dampers located in the Seismic Category I supply and exhaust ductwork that connects the spent-fuel pool area to the fuel handling ventilation mechanical equipment room. The automatic start of the penetration room filtration system and the isolation of the fuel handling area heating, ventilating, and filtration system occur prior to the time radioactive gases from a fuel handling accident can be transported beyond the isolation dampers. This arrangement represents the NRC acceptance criteria for the design of these systems. Two pneumatically operated dampers will normally be left open to connect the fuel handling area with the penetration room filtration system through Seismic Category I ducting. The Seismic Category I fan and filter subsystems of the penetration room filtration system maintain a slightly negative pressure in the fuel handling area. The exhaust air passes through the (This page intentionally left blank.) particulate, absolute, and charcoal filters prior to being released through the vent stack. The two pneumatically operated “fail closed” valves (air to open) with backup air accumulators, are manually shut remotely to isolate the fuel handling area from the penetration room filtration system during a LOCA.

A. Heating and Ventilating Unit

The supply unit employed in the system is a floor- mounted, horizontal, drawthrough, cabinet type, single zone, air handling unit consisting of centrifugal fan, hot water heating coil, flat prefilter, outdoor return air dampers with pneumatic operators, and mixing box designed to handle 16,000 sf^3/min at 2.75-in. water gauge static pressure, 8.65 x 10^5 btu/h heating capacity. The fan motor is 15 hp.

B. Fans

The exhaust fans (2) used in the spent fuel pool system are of the centrifugal type, with a design flowrate of 13,100 sf^3/min each. Fan motors are 30 hp each. The roof vent used in the fuel storage system is of the gravity type, with a design flowrate of 3500 ft^3/min. The fans are designed in accordance with the applicable portions of AMCA 99-67, Standards Handbook; AMCA 210-67, Test Codes for Air Handling Devices; and AMCA 211A-65, Certified Rating Program for Air Moving Devices.

C. Filters of the Spent Fuel Pool Filtration System

The filters of the spent fuel pool filtration system are composite units consisting of prefilter section, absolute filter section, and impregnated charcoal bed filter section. Each section is designed as follows:

1. The prefilters are designed to have a mean efficiency of 85 percent when tested in accordance with the National Institute of Standards and Technology (NIST) discoloration test method.

2. The HEPA filters are designed to be capable of removing 99.97 percent minimum of particulate matter 0.3 mm or larger in size. This particulate filter is water and fire resistant design.

3. The charcoal filters are impregnated, activated carbon beds designed to be capable of removing 99.9 percent minimum of inorganic iodine. Organic iodine is removed by impregnated charcoal filters, with an efficiency of at least 95.0 percent at relative humidities below the area design value of 70 percent.

The prefilter and absolute filters are designed for a nominal flowrate of 1000 $ft^3/min/ft^2$ face area. Charcoal filters are designed for 40 $ft^3/min/ft^2$ face area. Carbon weight is approximately 3800 lb.

9.4.2.2.3 Computer Room HVAC System

The computer room HVAC system is shown in drawings D-175012 and D-205012, and principal components are listed and described in table 9.4-6.

The computer room conditioned air is supplied by a single 100 percent capacity, air conditioning, air handling unit and a remotely located split type air-cooled condensing unit. A split type system consists of a condensing unit remotely located from the air handling unit being served. The system is provided with approximately 30 percent outside makeup to maintain a slight positive pressure in the control room and computer room. Supply ductwork conveys air from the conditioning equipment to the computer room, while air return is accomplished by a return fan through separate return ductwork.

A. Heating and Cooling Unit

The supply heating and cooling unit employed in the system is a floor-mounted, horizontal, drawthrough, cabinet type, single zone, air handling unit consisting of centrifugal fan, hot water heating coil, direct expansion cooling coil, angle prefilters, outdoor return air dampers with pneumatic motor operators designed to handle 5550 sf^3/min at 5.7-in. water gauge static pressure, 160,160 Btu/h sensible cooling capacity and 122,000 Btu/h heating capacity. The fan motor is 10 hp.

B. Return Fans

The fan used in the return subsystem of the computer room air conditioning unit is of the vane axial type with a design flowrate of 3600 sf^3/min. The fan motor is 2 hp.

C. Condensing Unit

The remotely located condensing unit used in the split type air conditioning system consists of an air-cooled, fan coil condenser and a refrigerant reciprocating compressor designed to handle 240,000 btu/h. The condenser unit has two fans with motor horsepower ratings of ½ hp each, for a total of 1 hp. The compressor power rating is 25 kW.

In addition to the 100-percent capacity air conditioning system described above, two recirculation type air handling units along with their associated condensing units have been provided. Normally, one of these units is operated in conjunction with the 100-percent capacity air conditioning unit. However, in the event the 100-percent capacity unit is out of service, both recirculation units operate in parallel to provide adequate cooling of the Unit 1 and Unit 2 computer rooms and the Unit 2 communication room. In this mode of operation, the airflow from each unit is estimated to be 4300 sf^3/min with a total cooling capacity of 278,300 btu/h.

A. Air Handling Units The air handling units employed in the system are the floor mounted, vertical draw-through type consisting of centrifugal fans, direct expansion cooling coils, prefilters, return air OBVDs, and parallel blade back-draft dampers, each designed to handle 7500 sf^3/min at 6.31 in. WG static pressure, and 193,000 btu/h cooling. The fan motor is 15 hp.

B. Condensing Units The remotely located condensing units used in the split type air conditioning system consist of air-cooled, fan coil condensers and refrigerant reciprocating compressors designed to handle 237,000 btu/h. The condenser motor and compressor motor horsepower ratings are 1 hp and 20 hp, respectively.

The fans are designed in accordance with the applicable portions of AMCA 99-67, Standards Handbook; AMCA 210-67, Test Codes for Air Handling Devices; and AMCA 211A-65, Certified Rating Program for Air Moving Devices.

The direct expansion cooling coils, air-cooled condensing unit, and refrigerant circuit components are designed in accordance with Air Conditioning and Refrigeration Institute (ARI) 410-64, 450, and 520-68.

9.4.2.2.4 Access Control Area HVAC System

The access control area HVAC system is shown in drawing D-175001, and principal components are listed and described in table 9.4-6. The access control area is divided into “clean” and “controlled” zones and consists of rooms such as offices, analysis rooms, laboratory, instrument calibration and storage room, and hot and clean restroom facilities. Both the “controlled” zones and “clean” zones are air conditioned.

A separate cooling and heating unit supplies conditioned air to the personnel dosimetry laboratory. The personnel dosimetry laboratory is served by a system which provides approximately 3 1/2 tons of cooling. The heating is provided from the plant hot water heating system. The dosimetry laboratory system provides the minimum required fresh outside air at all times. When outside air conditions are appropriate, the system’s enthalpy controlled economizer arrangement increases the proportion of outside air supplied while providing “free cooling.” The extra outside air provides added positive pressurization of the access control area while maintaining flow from the clean area to an area of relatively higher radioactivity. Fresh air for the dosimetry laboratory is drawn directly from the outside.

The balance of the access control area is supplied with conditioned air by an independent air handling unit, which provides approximately 23 tons of cooling. The heating for this area is provided by electric heaters mounted in the ducts supplying conditioned air to each space. The system serving this area is provided with outside air from the nonradwaste outside air supply system. The air is at ambient conditions in summer and tempered to 60°F in the winter. The outside airflow for this system is high due to the clean toilet ventilation requirements and because the exhaust air from potentially radioactive areas cannot be recirculated. The ventilation for the clean toilet areas is provided by an exhaust fan located on the roof.

The air from the clean zones is returned to the air handling units. Exhaust air from the controlled areas is directed through the HEPA and charcoal filters of the radwaste area filtration unit and then to the plant exhaust vent.

The direction of airflow between rooms is carefully controlled and moves from clean toward controlled areas. To ensure such airflow patterns at all times, a booster fan is utilized.

A. Heating and Cooling Unit (Dosimetry Laboratory)

The supply heating and cooling unit used in the system is a floor-mounted, horizontal, draw-through, cabinet type, single zone, air handling unit consisting of centrifugal fan, hot water heating coil, direct expansion cooling coil, flat prefilters, outdoor return air dampers with pneumatic motor operators designed to handle 1450 sf^3/min at 2.34-in. WG static pressure, 52,000 btu/h cooling, and 34,000 btu/h heating. The fan motor is 1.5 hp.

B. Cooling Unit (Access Control Area)

The supply cooling unit used in the system is a floor-mounted, horizontal, draw-through, cabinet type, single zone, air handling unit consisting of centrifugal fan, direct expansion cooling coil, flat prefilters, and outdoor and return air dampers with electric motor operators. This unit is designed to handle 4250 sf^3/min at 3.29-in. WG static pressure and 268,000 btu/h cooling. The fan motor is 5 hp.

C. Exhaust Fan

The exhaust fan used in exhausting the air from the clean areas is a roof exhaust fan, centrifugal type, with a design flowrate of 4530 sf^3/min at 1.2-in. WG static pressure. The fan motor is 2 hp.

D. Condensing Unit (Dosimetry Laboratory)

The remotely located condensing unit used in the split type air conditioning system consists of an air-cooled fan coil condenser and a refrigerant reciprocating compressor designed to handle 52,000 btu/h and 1450 sf^3/min of conditioned air. The condenser motor and compressor motor horsepower ratings are 1/2 hp and 7.5 hp, respectively.

E. Condensing Unit (Access Control Area)

The remotely located condensing unit used in the split type air conditioning system consists of an air-cooled fan coil condenser and a refrigerant reciprocating compressor designed to handle 279,000 btu/h and 25,200 sf^3/min. The condenser motors and compressor motor horsepower ratings are three at 1 hp each and 30 hp, respectively.

The fans are designed in accordance with the applicable portions of AMCA 99-67, Standards Handbook; AMCA 210-67, Test Codes for Air Handling Devices; and AMCA 211A-65, Certified Rating Program for Air Moving Devices.

The direct expansion cooling coil, air-cooled condensing unit, and refrigerant circuit components are designed in accordance with ARI 410-64, 450, and 520-68.

9.4.2.2.5 Electrical Equipment Room Air Conditioning Systems

A separate and independent air conditioning system is used for the electrical cable spreading room, the 600-V load center 1M and 1N rooms in Unit 1, the 600-V load center 2M room in Unit 2, and the 600-V load center rooms. The smoke purge system for cable spreading rooms provides a means of removing smoke and CO_2 as required by the fire brigade or operators. The air conditioning systems are shown in drawings D-175014, sheets 1 and 2; and D-205014, sheets 1 and 2, and principal components are listed and described in table 9.4-6.

The cable spreading room air conditioning unit is located inside the penetration room boundary. Conditioned air is recirculated in the cable spreading room through supply and return ductwork.

The 600-V load center 1M and 1N air conditioning unit is mounted in the ceiling of the hot instrument shop adjoining the load center rooms. Conditioned air is supplied to the load centers and the hot instrument shop through supply ductwork. The air from the load centers is recirculated and air from the instrument shop is exhausted to the radwaste ventilation system.

The 600-V load center air conditioning unit is located inside the nonradioactive area heating and ventilating mechanical equipment room. Conditioned air is recirculated in the 600-V load center rooms located on two different floor levels. Supply and return ductwork is used to supply the air to and draw the air from the 600-V load center rooms.

Each of the air conditioning units utilizes a roof-mounted, air-cooled condensing unit.

A. Air Conditioning Units

The air conditioning units used in the systems are vertical, floor-mounted (except the 600-V load center 1M, 1N, and 2M units which are horizontal, ceiling-mounted), drawthrough, cabinet type, single zone, air handling units consisting of centrifugal fan, direct expansion cooling coil, and flat prefilters.

B. Condensing Units

The remote condensing units used in the systems consist of air-cooled fan coil condensers and refrigerant reciprocating or scroll compressors.

The cable spreading room smoke purge system’s exhaust fan is a centrifugal type fan, mounted on the roof at el 190 ft-6 in.

The fans are designed in accordance with the applicable portions of AMCA 99-67, Standards Handbook; AMCA 210-67, Test Codes for the Air Handling Devices; and AMCA 211A-65, Certified Rating Program for Air Moving Devices.

The direct expansion cooling coil, air-cooled condensing units, and refrigerant circuit components are designed in accordance with the ARI 410-64, 450, and 520-68.

9.4.2.2.6 Battery Room Exhaust System

The battery room exhaust system is shown in drawings D-175014, sheets 1 and 2; and D-205014, sheets 1 and 2, and principal components are listed and described in table 9.4-6.

The air in each battery room is drawn out by an independent exhaust fan through Seismic Category I exhaust ducts during normal and accident modes of battery operation. Air is drawn from the high point of each battery room at the rate of at least 5 air changes/h. The makeup air to each battery room is directly supplied from the nonradioactive supply air handling unit.

All components of both systems are designed to meet Seismic Category I requirements. Power supplies to both fans are Class 1E electric systems.

9.4.2.2.7 Battery Charger Room, Motor Control Centers, and 600-V Load Centers Cooling Systems

Room coolers are floor- or ceiling-mounted, horizontal or vertical, air handling unit type, each containing a direct driven vaneaxial fan, finned tube water coils, and a return air plenum, all assembled in one package unit. The coolers recirculate conditioned air from the respective battery charger rooms, motor control centers, and 600-V load centers through short supply and return ducts. Cooling water supplied from the service water system is recirculated through the cooling coils of the coolers.

A temperature switch located in each battery charger room, motor control center, and 600-V load center area energizes the respective cooler serving the rooms upon detecting a rise in room ambient temperature beyond the predetermined setpoint. These cooling systems are shown in drawings D-175014, sheets 1 and 2; D-205014, sheets 1 and 2; D-175011, sheets 1 through 3; D-205011, sheets 1 through 4, and principal components are listed and described in table 9.4-6.

9.4.2.2.8 Sampling Room, Gas Analysis Room, Counting Room, and Radioactive Laboratory Heating and Air-Conditioning System

The heating and air-conditioning system is shown in drawings D-175011, sheets 1 through 3 and D-205011, sheets 1 through 4. An individual heating and air-conditioning unit supplies conditioned air to the sampling room, gas analysis room, counting room, and radioactive laboratory. Sufficient outside makeup air taken from the radwaste heating and ventilating system supply duct provides ventilation for room occupants and for makeup air for the exhaust system.

Each of the four air-conditioning units utilizes a roof-mounted, air-cooled condensing unit.

9.4.2.2.9 Engineered Safety Feature Pump Room Coolers

Drawings D-175011, sheets 1 through 3 and D-205011, sheets 1 through 4 show the entire HVAC system in the radioactive portion of the auxiliary building. Although pump room coolers are included in this flow diagram, they are a separate system and are not a part of the radwaste HVAC system. The seismic category of engineered safety feature pump room air cooling units is shown in table 3.2-1.

Each of the pump room coolers is an air handling unit type containing a direct driven vaneaxial fan, finned tube water coils, and a return air plenum, all assembled in one package unit. The coolers draw air from the respective pump rooms being served and supply cooled air back to the same room. No ductwork is used in the air distribution except that of the auxiliary feedwater pump room coolers which utilize short ducts.

Cooling water supplied from the service water system circulates continuously through the cooling coils of the pump room coolers. Each of the coolers serving engineering safety feature pumps is supplied with water from the same service water system train. The cooler fan starts and stops automatically as its respective pump starts and stops. The fan starter cannot control the pump. If either one of the pump cooler motors fails, then this group of engineered safety features equipment will be isolated for immediate action. The spare safety feature pump and pump room cooler would then be started from the spare emergency bus. Cooler operating parameters are tabulated under table 9.4-6. The single-failure analysis of the pump room coolers is described in table 9.4-7.

9.4.2.2.10 Technical Support Center HVAC System

The technical support center HVAC system is comprised of a safety-related bus, an air handling unit, DX coils, a charcoal filter with fan, and all associated ductwork.

During normal operation of the system, outside air is drawn into the system and is mixed with recirculated air. The air is then cooled (or heated) to maintain the design temperature of the technical support center. When high radiation is detected in the control room, the center's HVAC system automatically diverts the fresh/recirculated air mixture through the charcoal filter before directing this mixture back into the air handling unit just prior to entering the technical support center. A positive pressure is maintained in the technical support center at all times to prevent infiltration of the center. The technical support center HVAC system is shown on drawing D-205014 sheet 2.

9.4.2.3 Safety Evaluation

9.4.2.3.1 Nonradioactive Area Heating and Ventilating System

This system provides adequate capacity to ensure that proper temperatures are maintained in the various portions of the building under operating and shutdown conditions in all types of weather. The system is located within the auxiliary building and arranged for ease of access, control, and monitoring.

The nonradioactive area heating and ventilating system is not an engineered safeguard system, and no credit is taken for its operation in analyzing the consequences of any accident.

9.4.2.3.2 Fuel Handling Area Heating, Ventilating, and Filtration System

This system provides adequate capacity to ensure that proper temperatures are maintained in the various portions of the fuel handling area under operating and shutdown conditions in all types of weather and to ensure that effluent discharges are maintained within acceptable limits during normal operation.

Isolation of the spent-fuel pool area is achieved by quick closing, air-operated, low leakage, Seismic Category I dampers installed in all ducts that penetrate the spent fuel pool boundary, with those portions of the conventional ducts containing isolation dampers being Seismic Category I.

Redundant Seismic Category I radiation monitors are provided. Upon receipt of a high radiation signal in the spent-fuel area, the spent-fuel HVAC system will be automatically isolated and an alarm will sound in the control room, alerting the operator. The auxiliary building penetration room filtration system is automatically actuated by the high radiation signal. Also, redundant Seismic Category I pressure sensors monitor the differential pressure between the suction side of the fan and the spent-fuel pool area. A low differential pressure reading below the predetermined setpoint indicates a low or no-flow condition in the exhaust duct, which could make the radiation detectors ineffective in sampling effluent. Either a high radiation signal or a low differential pressure signal from these monitors will automatically shut off all operating ventilation fans associated with the spent-fuel pool supply and exhaust subsystems and automatically close all air-operated isolation dampers within the boundary. Fans will remain off and dampers closed until the activity level in the pool area is within safe limits. Switching of fans, valves, and dampers back to the normal mode is accomplished manually.

Movement of new fuel over spent fuel with the spent fuel area roof new fuel access hatch open creates the potential for a fuel handling accident with a release pathway which bypasses the radiation monitors in the exhaust duct, and consequently a bypass of the PRF. This configuration is specifically analyzed in section 15.4.5.

The design of the exhaust ductwork and the location of the radiation monitors relative to the isolation dampers are such that radiation levels above the radiation monitor setpoint will be detected and the isolation dampers closed before any contaminated exhaust reaches the isolation dampers, thus ensuring that all releases are retained within the spent fuel pool area.

The system is located within the auxiliary building and arranged for ease of access, control, and monitoring. This system is not used to reduce accident doses.

9.4.2.3.3 Computer Room, Access Control Area, and Electrical Equipment Rooms HVAC Systems

These systems provide adequate capacity to ensure that proper temperatures are maintained in the various portions of the building under operating and shutdown conditions in all types of weather. The systems are located within the auxiliary building and are arranged for ease of access, control, and monitoring.

These HVAC systems are not engineered safeguard systems, and no credit is taken for their operation in analyzing the consequences of any accident.

9.4.2.3.4 Battery Room Exhaust System

The exhaust fans provided for the two battery rooms will prevent the buildup of hydrogen concentration in the rooms by exhausting the air continually during normal and accident modes of operation.

Low air flow switches in each exhaust fan duct provide an alarm when either battery room exhaust fan is not operating. When either exhaust fan fails, it would take approximately 200 h for the battery room hydrogen concentration to approach 4.0 volume percent. The low air flow alarm will provide the operator with sufficient time to analyze the situation and take necessary measures to restore exhaust flow well before flammable limits would be approached.

As a safety precaution, each battery room is furnished with a temperature switch that will give an alarm in the control room once 110°F ambient temperature is reached. This signal will alert the operator to take corrective action.

9.4.2.3.5 Battery Charger Room, Motor Control Centers, and 600-V Load Centers Cooling Systems

The coolers provided to cool the battery charger rooms, motor control centers, and 600-V load centers will maintain the environmental conditions required for the integrity of the electrical equipment under failure conditions of the normal ventilation system due to loss of power or component failure. The arrangement of the power supplies and cooling water supplies to these coolers meets the single failure criterion. Coolers have safety functions in mitigating the consequences of an accident but are not required to control the release of radioactivity.

9.4.2.3.6 Sampling Room, Gas Analysis Room, and Radioactive Laboratory Heating and Air Conditioning

The system provides adequate capacity to ensure that proper temperatures are maintained in these rooms and laboratories under operating and shutdown conditions in all types of weather.

The system is located within the auxiliary building and is arranged for ease of access, control, and monitoring.

The heating and air conditioning system is not an engineered safety features system, and no credit is taken for its operation in analyzing the consequences of any accident.

9.4.2.3.7 Technical Support Center HVAC System

The technical support center HVAC system provides adequate cooling and heating capacity to meet the specified design temperatures for occupying personnel. It also provides adequate protection for occupying personnel from airborne radiation in accordance with 10 CFR 50, Appendix A, General Design Criterion 19, for radiation doses in the control room.

The technical support center HVAC system is located within the auxiliary building next to the control room. Access can be from either the control room or the auxiliary building.

All damper shafts, ducting, and other equipment within the system are provided with seals to minimize leakage. The filtration unit meets the design requirements of American National Standards Institute (ANSI) N509-1976.

9.4.2.4 Tests and Inspection

9.4.2.4.1 Nonradioactive Area Heating and Ventilating System

Each component is inspected prior to installation. Components of each system shall be accessible for periodic inspection during plant operation.

Instruments are calibrated during testing. Automatic controls are tested for actuation at the proper setpoints. Alarm functions will be checked for operability and limits during preoperational testing.

The system is operated and tested initially with regard to flow paths, flow capacity, and mechanical operability.

9.4.2.4.2 Fuel Handling Area Heating, Ventilating, and Filtration System

Each component is inspected prior to installation. Components of each system are accessible for periodic inspection during normal plant operation.

Instruments are calibrated during testing. Automatic controls are tested for actuation at the proper setpoints. Alarm functions are checked for operability and limits during preoperational testing.

The system is operated and tested initially with regard to flow paths, flow capacity, and mechanical operability.

After initial startup and filter replacements, the HEPA filters are tested using dioctylphtalate (DOP) smoke and the charcoal filters are tested for bypass using freon 112.

9.4.2.4.3 Computer Room, Access Control Area, and Electrical Equipment Rooms HVAC Systems

Each component is inspected prior to installation. Components of each system are accessible for periodic inspection during plant operation.

Instruments are calibrated during testing. Automatic controls are tested for actuation at the proper setpoints. Alarm functions are checked for operability and limits during preoperational testing.

Each system is operated and tested initially with regard to flow paths, flow capacity, and mechanical operability.

9.4.2.4.4 Battery Room Exhaust System

Battery room exhaust fans are tested in the manufacturer’s shop to verify their performance in accordance with AMCA 211A-65 and 300-67. Each component is inspected prior to installation. Each exhaust system is operated and tested with regard to flow paths, flow capacity, and mechanical operability.

9.4.2.4.5 Battery Charger Room, Motor Control Centers, and 600-V Load Centers Cooling Systems

Cooler components are tested in the factory. Fans are tested to verify their performance in accordance with AMCA 211A-65 and 300-67. Coils are pneumatically and hydrostatically tested in the shop to verify the pressure ratings specified in the procurement specification.

Systems acceptance tests are performed to demonstrate the proper mounting of components, proper hookup of circuits and connections, setting of instrumentation, and operation of interlocks. Equipment and system performance is monitored and rated.

9.4.2.4.6 Sampling Room, Gas Analysis Room, Counting Room, and Radioactive Laboratory Heating and Air Conditioning System

Fans are warranted to meet the requirements of AMCA 210-67, Test Codes for Air Handling Devices, and AMCA 211A-65, Certified Rating Programs for Air Moving Devices.

The split system heat pump units are certified in accordance with ARI 210/240.

Distribution ductwork is operated and tested with regard to flow paths, flow capacity, and mechanical operability.

9.4.2.4.7 Engineered Safety Feature Pump Room Coolers

Component qualification tests demonstrate the characteristics of material to be incorporated by the manufacturer into components for the coolers and ensure that they meet the requirements of procurement specification.

Component acceptance tests are factory tests that demonstrate the capability of the components incorporated into the coolers. Fans are tested in the manufacturer’s shop to verify their performance in accordance with AMCA 211A-65 and 300-67. Coils are pneumatically and hydrostatically tested to verify pressure ratings specified in the procurement specification.

Systems acceptance tests consist of deenergized and energized tests which demonstrate the proper mounting of components, proper hookup of circuits and connections, setting of instrumentation, and operation of interlocks. Equipment and system performance is monitored and rated.

9.4.2.4.8 Technical Support Center HVAC System

The filter is tested by the manufacturer in accordance with the ANSI N509 construction test. The pressure boundary leakage test is conducted in accordance with section 4.12 of ANSI N509-1976 for the filter housing by the manufacturer; leakage limits as stated in section 4.12 shall be met. The mounting frame pressure leakage test is conducted in accordance with section 7.0 of ANSI N510-1975 by the manufacturer. An in-place leakage test is performed in accordance with sections 10.0 and 12.0 of ANSI N510-1980 for the HEPA filter and the charcoal filters. All ducts are tested for leakage after initial startup and after major modifications to the ductwork.

9.4.2.5 Instrumentation Application

9.4.2.5.1 Nonradioactive Area Heating and Ventilating System

During power operation, temperature indications will verify the proper operation of the heating and ventilating system.

A pressure sensor is installed in each fan, as necessary. If an operating fan fails, the sensor detects the loss of pressure and an alarm is annunciated in the control room.

9.4.2.5.2 Fuel Handling Area Heating, Ventilating, and Filtration System

During power operation, temperature and pressure indications verify the proper operation of the heating, ventilating, and filtration system. The fuel handling area particulate and gas monitor indications of the activity levels in the system exhaust are used to determine routine releases from the area and are indicated in the control room. If a high radiation level is detected, an alarm is annunciated in the control room and automatically isolates the normally operating heating and ventilating equipment and automatically starts the penetration room filtration system. As a backup to the radiation monitors and to ensure that a representative sample is available to these monitors, Seismic Category I pressure sensors are installed in the exhaust duct serving the spent-fuel pool. They will automatically isolate the spent-fuel pool ventilation system and automatically start the penetration room filtration system, upon a low differential pressure signal which indicates low flow in the exhaust duct.

Seismic Category II differential pressure sensors are installed for each fan or fan group and filter. If the normal operating fan in the exhaust subsystem fails, this sensor detects the loss of pressure and initiates alarms in the control room. High differential pressure in the filters initiates alarms in the control room.

9.4.2.5.3 Computer Room, Access Control Areas, and Electrical Equipment HVAC Systems

During power operation, temperature indications verify the proper operation of the HVAC systems.

A pressure sensor is installed in each fan. If the operating fans fail, this sensor detects the loss of pressure and alarms are annunciated in the control room.

Each of the air handling units for the dosimetry laboratory and access control area is interlocked with the access control area fire protection system and will shut down upon receipt of a fire alarm signal. Each electric duct heater for the access control areas is equipped with an integral airflow switch that disables heater operation if airflow is not maintained.

9.4.2.5.4 Battery Room Exhaust System

A flow sensor is provided for each fan. If a fan fails, the sensor detects the loss of flow and alarms are annunciated in the control room. A temperature switch is located in each battery room. If the room ambient temperature goes beyond 110°F, the switch detects the high temperature and alarms are annunciated in the control room.

9.4.2.5.5 Battery Charger Room, Motor Control Centers, and 600-V Load Centers Cooling Systems

Each of the battery charger room coolers is provided with a pressure indicator mounted between the inlet and outlet sides of the fan for low differential indication in case of low airflow. Each cooler is controlled by a room thermostat designed to meet single failure criterion.

9.4.2.5.6 Sampling Room, Gas Analysis Room, Counting Room, and Radioactive Laboratory Heating and Air Conditioning System

During power operation, temperature indications verify the proper operation of the heating and air conditioning system.

9.4.2.5.7 Engineered Safety Feature Pump Room Coolers

Each of the pump room coolers is provided with a pressure indicator mounted between the inlet and outlet sides of the fan for local low differential pressure indication in case of low airflow.

9.4.2.5.8 Technical Support Center HVAC System

Upon receipt of a signal from the control room high radiation detectors located in the control room air intake, the technical support center HVAC system automatically switches into the emergency mode of operation. This action can also be accomplished by means of a manual switch located at the technical support center HVAC system control panel. If either the filter fan or the air handling unit fan stops, an alarm will sound in the technical support center.

A fire in the charcoal beds will be alarmed in the control room. Automatic fire extinguishing capability is provided for the room in which the charcoal beds are located. The position of all dampers is indicated at the HVAC system control panel in the technical support center.

9.4.2.6 <u>Materials</u>

A. Decomposition Products

Materials used in or on battery exhaust systems, battery charger room cooling systems, and engineered safety feature pump room coolers have been chosen so that the decomposition products, if any, of each material will not interfere with safe operation of any engineered safety feature.

B. Material Compatibility

Material compatibility of the battery room exhaust and battery charger room cooling systems is discussed in paragraph 6.2.3.6.

9.4.3 RADWASTE AREA

The heating, ventilating, and filtration system for the radwaste area is independent from that used in any other area and is designed to control and direct all potentially contaminated air to the vent stack via prefilter, HEPA, and charcoal filters.

9.4.3.1 <u>Design Bases</u>

The radwaste area heating, ventilating, and filtration system is designed to provide a suitable environment for equipment and personnel operation by performing the following functions:

A. Limit compartment temperature to 110°F when outdoor temperature is 95°F and maintain compartments above 65°F when outdoor temperature is 20°F.

B. Maintain compartments at a slightly negative pressure with respect to the surrounding corridors to prevent outleakage of contaminants.

9.4.3.2 System Description

The radwaste area heating, ventilating, and filtration system includes provisions to supply, exhaust, and filter air from the radwaste area. The system is shown in drawings D-175011, sheets 1 through 3, D-205011, sheets 1 through 4 and principal components are listed in tables 9.4-8 and 9.4-9. The system consists of one supply fan which is a full capacity air handling unit complete with hot water heating coil, prefilter, and pneumatically operated outside air damper, two full capacity exhaust fans, connecting ductwork, and all controls.

The supply air handling unit provides once-through filtered and tempered outside air to all personnel occupancy areas, the monitor tank compartments, and treated waste holdup tank areas when the outside air temperature is above 65°F. When the outside air temperature falls below 28°F for Unit 1 and 65°F for Unit 2, the supply unit will operate with approximately 90-percent outside air and approximately 10-percent recirculated air. The air is exhausted from lesser areas to areas of increasingly greater potential radioactive contamination. The exhaust air is exhausted through banks of prefilters, HEPA, and charcoal filters by one of the two full capacity, redundant exhaust fans before discharging to the plant vent stack. One exhaust fan is normally running and one is a standby fan.

The radwaste exhaust fan can be operated while the radwaste supply fan is inoperable by defeating the interlocks that prevent such operation. When initiating this mode of operation, a penetration room door must be held open during exhaust fan startup to avoid excessive differential pressure between the penetration room and the auxiliary building.

Air exhausted from the chemical and laundry drain tank room, the waste gas processing area, and the waste monitor tank room is processed by a charcoal filter unit on Unit 2 as the air leaves the area.

9.4.3.2.1 Heating and Ventilating Unit

The supply unit employed in the system is a floor-mounted, horizontal, drawthrough, cabinet type, single zone, air handling unit consisting of centrifugal fan, hot water heating coil, and flat type prefilter, designed to handle a nominal flowrate of 50,000 sf^3/min at 4.5-in. WG static pressure, 2.16×10^6 Btu/h heating capacity. The fan motor is 75 hp.

9.4.3.2.2 Fans

The fans used in the full capacity exhaust subsystem of the radwaste area filtration system are of the vane axial type with a nominal design flowrate of 50,000 sf^3/min each. Fan motors are 75 hp each.

The fans are designed in accordance with the applicable portions of AMCA 99-67, Standards Handbook; AMCA 210-67, Test Codes for Air Handling Devices; AMCA 211A-65, Certified

Rating Program for Air Moving Devices; and AMCA 300-67, Test Code for Sound Rating of Air Moving Devices.

9.4.3.2.3 Exhaust Filter Unit

The exhaust filter unit is a composite unit consisting of a prefilter section, absolute filter section, and impregnated charcoal filter section. Each section is designed as follows:

A. The prefilters are designed to have a mean efficiency of 85 percent when tested in accordance with the NIST discoloration test method.

B. The HEPA filter is designed to be capable of removing 99.97 percent minimum of particulate matter 0.3 mm or larger in size. This particulate filter is of water and fire resistant design.

C. The charcoal filter is an impregnated, activated, 6-in. deep carbon bed that is designed to be capable of removing 99.9 percent minimum of inorganic iodine and, at relative humidities less than 70 percent, 99.0 percent minimum of organic iodines.

The prefilter and absolute filter are designed for a nominal flowrate of 1000 $ft^3/min/ft^2$ face area. The charcoal filter is designed for a nominal face velocity of 40 ft/min and 0.75-s gas residence time. The weight of charcoal is approximately 23,000 lb.

The filters used in the radwaste area filtration system are designed and manufactured in accordance with the requirements of NRC Health and Safety Bulletin No.306 (Military Specification MIL-F-51068C, June 8, 1970, Filter, Particulate, High Efficiency, Fire Resistant) and NRC Health and Safety Bulletin No.297.

9.4.3.3 Safety Evaluation

The system provides adequate capacity to ensure that proper temperatures are maintained in the various portions of the building under operating and shutdown conditions in all types of weather.

Exhaust air is drawn from areas of progressively high potential radiation to prevent exfiltration of this air from the building and to provide rapid cleanup. On Unit 2, a charcoal filter unit connected to the radwaste exhaust system is provided for potentially radioactive rooms, such as chemical and laundry drain tank room, waste gas processing area, and waste monitor tank room. The filter unit processes the air as it leaves the area and discharges it to the radwaste exhaust ducts, thus preventing the spread of airborne contamination from the radioactive equipment in these rooms.

This system is not safety related, and system failure will not adversely affect safe operations of the plant as shown by table 9.4-10.

9.4.3.4 Inspection and Testing Requirements

Each component is inspected prior to installation. Components of each system shall be accessible for periodic inspection during plant operation.

Instruments are calibrated during testing. Automatic controls are tested for actuation at the proper setpoints. Alarm functions are checked for operability and limits during preoperational testing.

The system is operated and tested initially with regard to flow paths, flow capacity, and mechanical operability.

The radwaste area supply air handling units and exhaust fans are tested before installation in accordance with AMCA 210-67 and ARI 410-64.

Systems equipment, piping, and distribution ductwork are tested and balanced after installation in accordance with Sheet Metal and Air Conditioning Contractors National Association, for High Velocity Duct Construction and Associated Air Balance Council, Standards for Field Measurement and Instrumentation, form 81266, Volume 1, 1970.

The HEPA filters are tested before installation as follows:

A. Media tensile test.

B. Sequential test.

C. Efficiency penetration test (DOP) in accordance with MTL-STD-282. Penetration will not exceed 0.03 percent for 0.3-μm diameter homogeneous particle of DOP.

D. Shipped to quality assurance station (Oak Ridge) for acceptance test using the hot smoke (thermally generated DOP) test.

The HEPA filter banks are given an in-place test for leakage and element imperfection using DOP. This test is similar to that described in 136 300-175A, “Instruction Manual for the Installation, Operation, and Maintenance of Penetrometer, Filter Testing, DOP, Q107,” U. S. Army Edgewood Arsenal, Maryland, January 15, 1965, and in “Filter Testing Program Atomic Energy of Canada Limited,” by F. Panchuk and W. Rachuk, in Proceedings of the Ninth AEC Air Cleaning Conference, September 1966, CONF-660904, Volume 2, Harvard University and NRC, January 1967.

Charcoal tests data are made available before installation as required by the purchase specifications in order to satisfy the following criteria:

A. The charcoal bed filter is capable of removing 99.9 percent of molecular iodine-131 in the presence of a gaseous concentration of 50 mg/m^3 of nonradioactive molecular iodine (I_2-131) plus 5 mg/m^3 of nonradioactive methyl iodide. The integrated I_2-131 removal efficiency for the test unit, including both iodine feed and dilution periods, is no less than 95. 0 percent.

B. The charcoal bed filter is capable of removing at least 99.0 percent of the methyl iodide-131 (CH_3I-131). The integrated efficiency in the removal of CH_3I-131 by the test unit, including both iodine feed and dilution periods, is no less than 95.0 percent.

C. The carbon lot tests used consist of gas life, wash, ignition temperature, and carbon tetrachloride tests.

Each HEPA filter bank is given an in-place system integrity test with cold generated DOP to detect leaks in filter cells. The in-place testing of the prefilters consists of checking the completed installation for leaks due to damaged filters, faulty bolting, gasketing, etc.

The in-place testing of the charcoal beds is performed with freon 112, using similar portable equipment described in paragraph 7.5.1, pages 7.8 and 7.9, NRC Report ORNL-NSIC-65, 1970, by C. A. Burchsted and A. B. Fuller, “Design, Construction, and Testing of High Efficiency Filtration Systems for Nuclear Application.” The testing procedure is in accordance with “Standardized Non-Destructive Test of Carbon Beds for Reactor Containment Applications,” by D. R. Muhlbaier, DP-1082, July 1967. Test results show an efficiency of 99.5 percent.

9.4.3.5 Instrumentation Application

During power operation, temperature indications will verify the proper operation of the heating and ventilating system. The radwaste area particulate and gas monitor indications of the activity levels in the system exhaust are used to determine routine releases from the area.

A pressure sensor is installed across the exhaust fans. If the normal operating fan in the exhaust subsystem fails, this sensor will sense the loss of pressure, will automatically start the standby fan, and will initiate alarms in the control room.

Differential pressure switches are installed across the HEPA and charcoal filters. High pressure drop across either filter will initiate an alarm in the control room.

9.4.4 TURBINE BUILDING

The turbine building is provided with a recirculation cooling and heating system designed to achieve maximum safety and convenience for operating personnel and to maintain building temperature within acceptable limits for equipment operation. This system is discussed in this section.

9.4.4.1 Design Bases

9.4.4.1.1 Turbine Building Heating and Cooling System

The turbine building heating and cooling system performs the following functions:

A. Provides temperature and humidity control for personnel working conditions and optimum equipment performance.

B. Provides cooling during normal plant operation.

C. Provides recirculation of indoor air.

D. Limits maximum ambient temperature to 100°F on the operating floor during normal plant operation.

E. Limits maximum temperature to 95°F on floors below the operating floor during normal plant operation.

F. Provides temperature and humidity control for personnel comfort in the water analysis room.

9.4.4.1.2 Steam Jet Air Ejector Filtration System

This system filters the effluent of the steam jet air ejector through a separate charcoal filtration system, as shown in drawings D-175031, sheets 1 through 3; D-205031, sheets 1 through 3; and D-175027.

9.4.4.2 <u>System Description</u>

9.4.4.2.1 Turbine Building Heating and Cooling System

The turbine building heating and cooling system is shown in drawings D-175031, sheets 1 through 3; D-205031, sheets 1 through 3; and D-175027. The system is designed to air condition various areas of the three main zones of the turbine building: above the operating floor, between the mezzanine and operating floors, and below the mezzanine floor. Each of 14 areas in the 3 zones is air conditioned by a factory built air handling unit and associated distribution ductwork. Four units are located on the operating floor, six on the mezzanine floor, and four on the basement floor. There are no interconnections between ductwork of adjacent areas. Each unit is designed to permit air mixing between the hot and cold spots of the area being served. Supply ductwork is used with each air handling unit to transport the conditioned air to the hottest equipment locations. Discharge velocities are sufficient to disperse the conditioned air throughout the area and overcome any convective air currents which may be present.

The turbine building cooling system air handling units are supplied with demineralized, chilled water by a primary pump and a closed loop primary piping system. A second pump is provided for standby service. The piping system is protected by an air separator with strainer and a closed expansion tank. The system utilizes the primary secondary circuiting arrangement, the secondary chilled water circuit consisting of 2 parallel arrangement, 70 percent cooling capacity centrifugal water chillers, two 50 percent capacity chilled water pumps, and associated piping, valves, instruments, and controls.

Additional design data for the water and air systems are given in table 9.4-11.

A. Cooling Air Handling Unit

Each area cooling air handling unit is a ceiling or floor-mounted, horizontal or vertical, draw-through cabinet type, single zone unit consisting of a flat prefilter, finned tube water coils, and a centrifugal fan. Additional design parameters for the cooling units are given in table 9.4-11.

B. Coils

The water coils used for the air handling units are designed in accordance with ARI standard 410-64.

C. Fans

The fans used for the air handling units are double width, double inlet, centrifugal ones designed in accordance with the applicable portions of AMCA 99-67, Standards Handbook, and AMCA 210-67, Test Code for Air Handling Devices.

D. Motors

The motors used for the air handling units were designed in accordance with the applicable portions of National Electrical Manufacturers Association (NEMA) MG1-1967, Standards for Motors and Generators; ANSI C-50.20-1954, Polyphase Induction Motors and Generators; and Institute of Electrical and Electronics Engineers (IEEE) 85-1965, Test Procedure for Airborne Noise Measurements on Rotating Electric Machinery.

Replacement motors are designed in accordance with the applicable portions of the edition of NEMA MG-1 in effect at the time of purchase. The water analysis room air conditioning unit and associated ductwork and controls are designed to maintain comfort temperatures and humidity for personnel in the water analysis room on the basement floor of the turbine building. The air conditioning unit is a self-contained package with a water-cooled condenser and is controlled by a thermostat located in the room.

E. Smoke Vents

The open, passive smoke vents on the turbine building roof allow smoke and heat to exit the turbine building.

9.4.4.2.2 Steam Jet Air Ejector Filtration System

The steam jet air ejector filtration system is served by one full capacity exhaust fan and one full capacity filtration unit consisting of a prefilter, HEPA filter, and a charcoal filter. The fan and filters are located inside the turbine building. The gaseous releases from the steam jet air ejector vents are routed from the filtration unit to the exhaust line of the turbine building main filtration unit.

A. Fans

The exhaust fan for the steam jet air ejector filtration system is a direct-driven centrifugal fan. Additional design parameters for the fans are given in table 9.4-11. The fans are designed in accordance with the applicable portions of AMCA 99-67, Standards Handbook, and AMCA 210-67, Test Code Air Handling Devices. The flowrate through the steam jet air ejector filtration unit is 1000 sf^3/min, 60 sf^3/min of which is steam jet air ejector effluent.

B. Filters

The filters are composite units consisting of a prefilter section, absolute filter section, and impregnated charcoal filter section. Each section is designed as follows:

1. The prefilters have a mean efficiency of 85 percent when tested in accordance with the NIST discoloration test method.

2. The HEPA filter is capable of removing 99.97 percent minimum of particulate matter 0.3 mm or larger in size. This particulate filter is water and fire resistant in design.

3. The charcoal filter is an impregnated, activated 6-in., deep carbon bed, capable of removing 99.9 percent minimum of inorganic iodine. At relative humidities below 70 percent, all iodines, including organic, are removed with an efficiency of at least 99.0 percent.

Additional design parameters for the filters are given in table 9.4-11.

The filters used in each filtration subsystem are designed and manufactured in accordance with the requirements of NRC Health and Safety Bulletin No.306 (Military Specification MIL-F-51068C, June 8, 1970, Filter, Particulate, High Efficiency, Fire Resistant) and NRC Health and Safety Bulletin No.297.

C. Dampers

The damper in the ducting upstream of the filter trains and the dampers at the discharge of the fan are pneumatically operated, two-position, fail-open butterfly dampers.

D. Motors

The motors used for the air handling units and filtration unit were designed in accordance with the applicable portions of NEMA MG1-1967, Standards for Motors and Generators; ANSI C-50.20-1954, Polyphase Induction Motors and

Generators; and IEEE 85-1965, Test Procedure for Airborne Noise Measurements on Rotating Electric Machinery.

Replacement motors are designed in accordance with the applicable portions of NEMA MG-1 in effect at the time of purchase.

9.4.4.3 Safety Evaluation

9.4.4.3.1 Turbine Building Cooling System

The system provides adequate capacity to ensure that proper temperatures are maintained in the various portions of the building while the plant is operating. The system is located within the turbine building and arranged for ease of access, control, and monitoring.

The turbine building cooling system is not an engineered safety features system, and no credit is taken for its operation when analyzing the consequences of any accident. Failure of selective system components could temporarily cause system performance degradation to the extent that preferred airflow patterns could not be maintained.

9.4.4.3.2 Steam Jet Air Ejector Filtration System

The system provides charcoal filtration of radioisotopes that may have leaked from the secondary systems into the turbine building.

The steam jet air ejector filtration system is not used to reduce accident doses.

The ductwork conveying unfiltered air upstream of the filtration units is at negative pressure, barring the possibility of outleakage of contaminants.

Filter components receive factory and field test to ensure against bypass and to confirm specified efficiencies.

9.4.4.4 Inspection and Testing Requirements

9.4.4.4.1 Turbine Building Cooling System

Fans are tested and rated in accordance with the standards of the AMCA. Water coils are tested and rated in accordance with the standards of the ARI.

The main system pumps and the chilled water pumps are tested and rated in accordance with the standards of the Hydraulic Institute. The centrifugal chiller components are tested in accordance with the ANSI B9.1-1971, the ASME Code for Unified Pressure Vessels, Section VIII, and ARI 550-69.

Each component is inspected prior to installation, and all components of the system are accessible for periodic inspection during plant operation.

Instruments will be calibrated during testing; automatic controls will be tested for actuation at the proper setpoints; and alarm functions will be checked for operability and limits during preoperational testing.

The system will be operated and tested initially with regard to flow paths, flow capacity, and mechanical operability.

9.4.4.4.2 Steam Jet Air Ejector Filtration System

The fan is tested and rated in accordance with standards of the AMCA.

The steam jet air ejector filtration system, as well as its components, will be tested prior to startup and periodically during operation. Written test procedures establish minimum acceptance values for all tests. A record of test results will be useful in enabling early detection of faulty performance.

Instruments will be calibrated during testing. Automatic controls will be tested for actuation at the proper setpoints. Alarm functions will be checked for operability and limits during preoperational testing.

The steam jet air ejector filtration system is provided with testing facilities to demonstrate system operability.

Each HEPA filter is tested with DOP smoke. The charcoal filters are tested with freon for bypass.

9.4.4.5 Instrumentation Application

9.4.4.5.1 Turbine Building Cooling Systems

During power operation, temperature and pressure indicators verify the proper operation of the cooling system. The air handling unit fans are started manually, while chilled water flows constantly through the coils. Space temperatures are controlled by thermostats which cycle the unit fan motors.

9.4.4.5.2 Steam Jet Air Ejector Filtration System

The following instrumentation for the steam jet air ejector filtration system is displayed locally:

A. Position indication of all fan discharge and intake dampers.

B. Differential pressure across each filter.

9.4.5 SERVICE WATER INTAKE STRUCTURE

The heating and ventilation system for the service water intake structure consists of three types of subsystems:

A. Pump room heating and ventilation system.

B. Switchgear rooms heating and ventilation systems.

C. Battery rooms/battery charger rooms heating and ventilation systems.

There are a pump room, two switchgear rooms, and two battery rooms/battery charger rooms.

9.4.5.1 <u>Design Bases</u>

9.4.5.1.1 Pump Room Heating and Ventilation System

The pump room heating and ventilation system is designed to perform the following functions:

A. Maintain a maximum temperature of 125°F within the pump room.

B. Maintain a minimum temperature of 40°F within the pump room.

C. Exhaust heat and smoke from the pump room in the event of a fire.

9.4.5.1.2 Switchgear Rooms Heating and Ventilation Systems

The switchgear rooms heating and ventilation systems are designed to perform the following functions:

A. Maintain a maximum temperature of 105°F within the switchgear rooms.

B. Maintain a minimum temperature of 40°F within the switchgear rooms.

C. Exhaust heat and smoke from the switchgear room in the event of fire.

9.4.5.1.3 Battery Rooms/Battery Charger Rooms Heating and Ventilation System

The battery rooms/battery charger rooms heating and ventilation systems are designed to perform the following functions:

A. Maintain a minimum temperature of 40°F in the battery rooms/battery charger rooms.

B. Prevent a buildup of hydrogen gas within the battery rooms/battery charger rooms.

C. Exhaust heat and smoke from the battery rooms/battery charger rooms in event of fire.

9.4.5.2 <u>System Description</u>

The heating and ventilation system for the service water intake structure is shown in drawings D-170332 and D-170333 and is designed to meet Class 1 requirements.

9.4.5.2.1 Pump Room Heating and Ventilation System

The pump room heating and ventilation system consists of redundant power roof exhaust ventilators (six 33 percent units) for exhausting heat from the room, redundant roof air intake ventilators with connecting ductwork and motor-operated dampers for supplying air to the exhaust ventilators and for opening and closing the dampers, redundant electric resistance unit heaters (fourteen 15 percent units) for maintaining a minimum temperature within the rooms, controls for automatically activating the standby equipment in the event of failure of primary equipment, redundant controls for activating the ventilating systems in the event of fire within the room, and annunciation equipment for alarming the control room in the event of excessively high or low temperatures within the room.

It should be noted that 100 percent capacity is based on eight of ten service water pumps operating simultaneously.

The sequence of control is:

A. Upon a rise in temperature, ventilating thermostats activate their respective roof exhaust ventilators and open their respective motor-operated dampers upon reaching setpoint.

B. Upon a further rise in temperature, secondary ventilating thermostats activate their respective roof exhaust ventilators upon reaching setpoint.

C. Upon a drop in temperature, ventilating thermostats deactivate their respective exhaust ventilators and close their respective dampers upon reaching setpoint. Dampers will close only when all ventilating fans are deactivated.

D. Upon a drop in temperature, each heating thermostat activates its matching heater upon reaching setpoint.

E. Each heating thermostat will deactivate its matching heater when the room temperature rises above its setpoint.

F. Upon failure of any primary roof exhaust ventilator, the standby exhaust ventilator fan motors are started upon a room temperature rise above their respective thermostat's setpoint.

G. Either firestat, upon reaching its setpoint, activates all exhaust ventilator fan motors and opens all motor-operated dampers in the room.

H. Upon reaching setpoint, the high temperature thermostat will activate the high temperature indicator on the local annunciator and the service water intake building alarm in the control room.

I. Upon reaching setpoint, the low temperature thermostat will activate the low temperature indicator on the local annunciator and the service water intake building alarm in the control room.

Manual overrides are provided to activate or deactivate each exhaust ventilator fan motor and heater as required.

9.4.5.2.2 Switchgear Rooms Heating and Ventilation Systems

The switchgear rooms heating and ventilation systems include in each room a power roof exhaust ventilator, a nonpowered roof exhaust ventilator, and a power roof intake ventilator with connecting ductwork and redundant motor-operated dampers. Both the power intake and power exhaust ventilators are sized to individually provide 100 percent of the heat removal requirements and are totally redundant. Other equipment consists of controls for automatically activating and deactivating the power exhaust and intake ventilators and for opening and closing the dampers, redundant electric resistance unit heaters (three 50-percent units each room) for maintaining a minimum temperature within the rooms, controls for automatically activating the standby equipment in the event of failure of primary equipment, redundant controls for starting the ventilation systems in the event of fire within the rooms, and annunciation equipment for alarming the control room in the event of excessively high or low temperatures within the room.

The sequence of control is:

A. Upon a rise in temperature in each room the ventilating thermostat activates the power roof intake ventilator and opens all dampers in its respective room upon reaching its setpoint.

B. Upon a drop in temperature in each room, the ventilating thermostat deactivates the intake ventilator and closes all dampers in its respective room upon reaching its setpoint.

C. Upon a continued drop in temperature in each room, each heating thermostat activates its matching heater upon reaching its setpoint.

D. Each heating thermostat will deactivate its matching heater when the room temperature rises above its setpoint.

E. Upon failure of the power intake ventilator, the power exhaust ventilator fan motor is started upon a room temperature rise above its respective thermostat's setpoint.

F. Either firestat and/or carbon dioxide triggering device in each room, upon reaching its setpoint, activates the exhaust and intake ventilator fan motors and opens all motor-operated dampers in its respective room.

G. Upon reaching setpoint, the high temperature thermostat will activate the high temperature indicator on the local annunciator and the service water intake building alarm in the control room.

H. Upon reaching setpoint, the low temperature thermostat will activate the low temperature indicator on the local annunciator and the service water intake building alarm in the control room.

Manual overrides are provided to activate or deactivate each ventilator fan motor and heater as required.

9.4.5.2.3 Battery Rooms/Battery Charger Rooms Heating and Ventilation Systems

The battery rooms/battery charger rooms heating and ventilation systems consist of redundant power roof exhaust ventilators (two 100-percent units each battery room) for exhausting hydrogen fumes from the rooms, roof air intake ventilators with connecting ductwork and redundant motor-operated dampers (in battery charger rooms) for supplying air to the exhaust ventilators, controls for automatically activating and deactivating the exhaust ventilators and for opening and closing the dampers, redundant electric resistance unit heaters (two 100-percent units each battery charger room) for maintaining a minimum temperature within the rooms, controls for automatically activating and deactivating the heaters, a fire damper (in the divider walls between the battery rooms and battery charger rooms) for sealing the rooms from each other in the event of fire in either room, and redundant controls for activating the ventilation systems and closing the fire dampers in the event of fire within the battery rooms.

The control of the system is as follows:

A. Both exhaust ventilators are normally in service and each timer activates its matching roof exhaust ventilator for a period of 5 min every hour.

B. Upon a drop in temperature in each room, each heating thermostat activates its matching heater upon reaching its setpoint.

C. Each heating thermostat will deactivate its matching heater when the room temperature rises above its setpoint.

D. Either firestat in each room, upon reaching its setpoint, activates all exhaust ventilator fan motors, opens all motor-operated dampers, and automatically closes the fire damper in its respective room.

Manual overrides are provided to activate and deactivate each exhaust ventilator fan motor and heater as required.

9.4.5.3 Safety Evaluation

At worst, a single failure can render inoperable a subsystem of the heating and ventilation system which serves one of the redundant trains of safety-related equipment.

The air intakes and exhausts are mounted on the roof of the service water intake structure well above flood level.

9.4.5.4 Inspection and Testing Requirements

All components of the heating and ventilation system of the service water intake structure will be tested prior to placing the system in service.

Because the heating and ventilation system of the service water intake structure is in use during normal plant operation, the availability of active components is evident to the plant operators and there is no need for further online testing. Portions of the system normally not in use are periodically tested to ensure operability of the system.

9.4.6 RIVER WATER INTAKE STRUCTURE

The heating and ventilation system for the river water intake structure consists of two types of subsystems:

A. Pump rooms heating and ventilation systems.

B. Switchgear rooms heating and ventilation systems.

There are two pump rooms and two switchgear rooms.

9.4.6.1 Design Bases

9.4.6.1.1 Pump Rooms Heating and Ventilation Systems

The pump room heating and ventilation systems are designed to perform the following functions:

A. Maintain a maximum temperature of 125°F within the pump room.

B. Maintain a minimum temperature of 40°F within the pump room.

C. Exhaust heat and smoke from the pump room in the event of a fire.

9.4.6.1.2 Switchgear Rooms Heating and Ventilation Systems

The switchgear rooms heating and ventilation systems are designed to perform the following functions:

A. Maintain a maximum temperature of 105°F within the switchgear rooms.

B. Maintain a minimum temperature of 40°F within the switchgear rooms.

C. Exhaust heat and smoke from the switchgear rooms in the event of a fire.

9.4.6.2 <u>System Description</u>

The heating and ventilation system for the river water intake structure is shown in drawings D-170330 and D-170331. The system was originally designed to meet Seismic Class I requirements, but is no longer required to be designed or maintained as such.

9.4.6.2.1 Pump Rooms Heating and Ventilation System

The pump rooms heating and ventilation systems consist of redundant power roof exhaust ventilators (three 50 percent units each room) for exhausting heat from the rooms, redundant roof air intake ventilators with connecting ductwork and motor-operated dampers for supplying air to the exhaust ventilators, controls for automatically activating and deactivating the exhaust ventilators and for opening and closing the dampers, redundant electric resistance unit heaters (six 25 percent units each room) for maintaining a minimum temperature within the rooms, controls for automatically activating and deactivating the heaters, controls for automatically activating the standby equipment in the event of failure of primary equipment, redundant controls for activating the ventilation systems in the event of fire within the rooms, and annunciation equipment for alarming the control room in the event of excessively high or low temperatures within the rooms.

It should be noted that 100 percent capacity is based on all river water pumps operating simultaneously.

The sequence of control is:

A. Upon a rise in temperature in each room, each individual ventilating thermostat activates its respective roof exhaust ventilator upon reaching its individual setpoint. The first ventilator activated opens all motor-operated dampers in its respective room upon reaching its setpoint.

B. Upon a drop in temperature in each room, each individual ventilating thermostat deactivates its respective exhaust ventilator upon reaching its individual setpoint. The last ventilator deactivated closes all dampers in its respective room upon reaching its setpoint.

C. Upon a continued drop in temperature in each room, each heating thermostat activates its matching heater upon reaching its setpoint.

D. Each heating thermostat will deactivate its matching heater when the room temperature rises above its setpoint.

E. Upon failure of any primary roof exhaust ventilator, the standby exhaust ventilator fan motor is started upon a room temperature rise above its thermostat's setpoint.

F. Either firestat in each room, upon reaching its setpoint, activates all exhaust ventilator fan motors and opens all motor-operated dampers in its respective room.

G. Upon reaching its setpoint, the high temperature thermostat will activate the high temperature indicator on the local annunciator and the river intake structure alarm in the control room.

H. Upon reaching its setpoint, the low temperature thermostat will activate the low temperature indicator on the local annunciator and the river intake structure alarm in the control room.

Manual overrides are provided and activate or deactivate the exhaust ventilator fan motors and heaters as required.

9.4.6.2.2 Switchgear Rooms Heating and Ventilation Systems

The switchgear rooms heating and ventilation systems consist of redundant power roof exhaust ventilators (two 100 percent units each room) for exhausting heat from the rooms, roof air intake ventilators with connecting ductwork and redundant motor-operated dampers for supplying air to the exhaust ventilators, controls for automatically activating and deactivating the exhaust ventilators and for opening and closing the dampers, redundant electric resistance unit heaters (three 50 percent units each room) for maintaining a minimum temperature within the rooms, controls for automatically activating and deactivating the heaters, controls for activating the standby equipment in the event of failure of primary equipment, redundant controls for starting the ventilation systems in the event of fire within the rooms, and annunciation equipment for local alarm and alarming the control room in the event of excessively high or low temperatures within the rooms.

The sequence of control is:

A. Upon a rise in temperature in each room, the ventilating thermostat activates the primary roof exhaust ventilator and opens all motor-operated dampers in its respective room upon reaching its setpoint.

B. Upon a drop in temperature in each room, the ventilating thermostat deactivates the primary exhaust ventilators and closes all dampers in its respective room upon reaching its setpoint

C. Upon a continued drop in temperature in each room, each heating thermostat activates its matching heater upon reaching its setpoint.

D. Each heating thermostat will deactivate its matching heater when the room temperature rises above its setpoint.

E. Upon failure of any primary exhaust ventilator, the standby exhaust ventilator fan motor is started upon reaching its respective thermostat's setpoint.

F. The first firestat and/or carbon dioxide triggering device in each room, upon reaching its setpoint, activates all exhaust ventilator fan motors and opens all motor-operated dampers in its respective room.

G. Upon reaching its setpoint, the high temperature thermostat will activate the high temperature indicator on the local annunciator and the river intake structure alarm in the control room.

H. Upon reaching its setpoint, the low temperature thermostat will activate the low temperature indicator on the local annunciator and the river intake structure alarm in the control room.

Manual overrides are provided to activate and deactivate each exhaust ventilator fan motor and heater as required.

9.4.6.3 <u>Inspection and Testing Requirements</u>

All components of the heating and ventilation system at the river water intake structure will be tested prior to placing the system in service.

Because the heating and ventilation system at the river water intake structure is in use during normal plant operation, the availability of active components is evident to the plant operators, and there is no need for further online testing. Portions of the system normally not in use are periodically tested to ensure operability of the system.

9.4.7 DIESEL GENERATOR BUILDING

The heating and ventilation system for the diesel generator building consists of four types of subsystems:

A. Generator rooms heating and ventilation systems.

B. Switchgear rooms heating and ventilation systems.

C. Oil storage rooms ventilation systems.

D. Vestibule area heating system.

There are five generator rooms, two switchgear rooms, five oil storage rooms, and one vestibule area.

9.4.7.1 Design Bases

9.4.7.1.1 Generator Rooms Heating and Ventilation Systems

The generator rooms heating and ventilation systems are designed to perform the following functions:

A. Maintain a maximum temperature of 104°F during the generator shutdown cycle and 122°F during the generator operation cycle within the generator rooms.

B. Maintain a minimum temperature of 40°F within the generator room.

C. Prevent escape of carbon dioxide from the generator rooms in the event of the activation of the carbon dioxide flooding system in the generator rooms.

9.4.7.1.2 Switchgear Rooms Heating and Ventilation Systems

The switchgear rooms heating and ventilation systems are designed to perform the following functions:

A. Maintain a maximum temperature of 104°F within the switchgear rooms.

B. Maintain a minimum temperature of 40°F within the switchgear rooms.

C. Exhaust heat and smoke from the switchgear rooms in the event of a fire.

9.4.7.1.3 Oil Storage Rooms Heating and Ventilation Systems

The oil storage rooms heating and ventilation systems are designed to perform the following functions:

A. Operate continuously under normal conditions.

B. Prevent escape of carbon dioxide from the oil storage rooms in the event of the activation of the carbon dioxide flooding system in the oil storage rooms.

9.4.7.1.4 Vestibule Area Heating System

The vestibule area heating system is designed to maintain a minimum temperature of 40°F within the vestibule area.

9.4.7.2 System Description

The heating and ventilation system for the diesel generator building is shown in drawings D-170336; D-177337, sheet 1; D-170338, sheets 1 and 2;and D-170339, and is designed to meet Class 1 requirements.

9.4.7.2.1 Generator Rooms Heating and Ventilation Systems

The generator rooms heating and ventilation systems consist of one power roof exhaust ventilator in each room for exhausting heat from the rooms during the generator shutdown cycle, redundant power roof exhaust ventilators (two 100 percent units each room) for exhausting heat from the rooms during the generator operation cycle, one motor-operated wall air intake louver with redundant sections and redundant operators for each section in each room for supplying air to the exhaust ventilators, one rolling fire door in each room for sealing the louver opening in the event of fire within the room, controls for automatically activating and deactivating the exhaust ventilators and for opening and closing the wall louvers, redundant electric resistance unit heaters (three 50 percent units each room) for maintaining a minimum temperature within the rooms, controls for automatically activating and deactivating the heaters, controls for automatically activating the standby equipment in the event of failure of primary equipment, redundant controls for deactivating the ventilating systems in the event of fire within the rooms, and annunciation equipment for alarming the control room in the event of excessively high or low temperatures within the rooms.

The sequence of control is:

A. Upon a rise in temperature in each room, the ventilating thermostat for the small exhaust ventilator activates this ventilator and fully opens the wall louver in its respective room upon reaching its setpoint.

B. Upon a continued rise in temperature in each room, the ventilating thermostat for the primary exhaust ventilator activates the primary exhaust ventilator in its respective room upon reaching its setpoint.

C. Upon a drop in temperature in each room, the ventilating thermostats for the primary exhaust ventilator deactivates the primary exhaust ventilator in its respective room upon reaching its setpoint.

D. Upon a continued drop in temperature in each room, the ventilating thermostat for the small exhaust ventilator deactivates this ventilator and closes the wall louver in its respective room upon reaching its setpoint.

E. Upon an additional temperature drop in each room, each heating thermostat activates its respective heater upon reaching its setpoint.

F. Each heating thermostat will deactivate its respective heater when the room temperature rises above its setpoint.

G. Upon failure of the primary roof exhaust ventilator, the standby ventilator is activated upon its respective thermostat reaching its setpoint.

H. Any firestat in each room, upon reaching its setpoint, deactivates all exhaust ventilators, closes the wall louver, and closes the fire door in its respective room.

I. Prior to manually activating the fire protection system, a manual HVAC pushbutton station adjacent to the carbon dioxide pushbutton station is activated to provide positive shutdown of exhaust fans and intake louvers to preclude carbon dioxide purge.

J. Upon reaching its setpoint, the high temperature thermostat will activate the high temperature indicator on the local annunciator and the diesel generator building alarm in the control room.

K. Upon reaching its setpoint, the low temperature thermostat will activate the low temperature indicator on the local annunciator and the diesel generator building alarm in the control room.

Manual override is provided to activate or deactivate each exhaust ventilator fan motor, heater, and louver motor as required.

9.4.7.2.2 Switchgear Rooms Heating and Ventilation Systems

The switchgear rooms heating and ventilation systems include in each room a power roof exhaust ventilator, a nonpowered roof exhaust ventilator, and a power roof intake ventilator with connecting ductwork and redundant motor-operated dampers. Both the power intake and power exhaust ventilators are sized to individually provide 100 percent of the heat removal requirements and are totally redundant. Other equipment consists of controls for automatically activating and deactivating the power exhaust and intake ventilators and for opening and closing the dampers, redundant electric resistance unit heaters (three 50-percent units each room) for maintaining a minimum temperature within the rooms, controls for automatically activating and deactivating the heaters, controls for automatically activating the standby equipment in the event of failure of primary equipment, redundant controls for activating the ventilating systems in the event of fire within the rooms, and annunciation equipment for alarming the control room in the event of excessively high or low temperatures in the rooms.

The sequence of control is as follows:

A. Upon a rise in temperature in each room, a ventilating thermostat activates the roof intake ventilator and opens all motor-operated dampers in its respective room upon reaching its setpoint.

B. Upon a drop in temperature in each room, the ventilating thermostat deactivates the intake ventilator and closes all dampers in its respective room upon reaching its setpoint.

C. Upon failure of the roof intake ventilator, the roof exhaust ventilator is activated upon its respective thermostat reaching setpoint.

D. Upon a continued drop in temperature in each room, each heating thermostat activates its matching heater upon reaching its setpoint.

E. Each heating thermostat will deactivate its matching heater when the room temperature rises above its setpoint.

F. Either firestat and/or carbon dioxide triggering device in each room, upon reaching its setpoint, activates the exhaust and intake ventilator fan motors and opens all motor-operated dampers in its respective room.

G. Upon reaching its setpoint, the high temperature thermostat will activate the high temperature indicator on the local annunciator and the diesel generator building alarm in the control room.

H. Upon reaching its setpoint, the low temperature thermostat will activate the low temperature indicator on the local annunciator and the diesel generator building alarm in the control room.

Manual override is provided to activate and deactivate each ventilator fan motor, heater, and damper motor as required.

9.4.7.2.3 Oil Storage Rooms Heating and Ventilation Systems

The oil storage rooms ventilation systems consist of redundant power roof exhaust ventilators (two 100 percent units each room) for exhausting fumes from the rooms, one motor-operated wall air intake louver in each room for supplying air to the exhaust ventilators, one fire damper in each room for sealing the louver opening and one fire damper in each room sealing the roof exhaust opening in the event of fire within the room, controls for automatically activating the standby equipment in the event of failure of primary equipment, and controls for deactivating the ventilating systems, closing the wall louver, and closing the fire damper in the event of fire within the rooms.

The sequence of control is:

A. The primary and standby exhaust ventilator in each room operates continuously under normal operating conditions.

B. The wall louver in each room is fully open under normal operating conditions.

C. Upon failure of the primary roof exhaust ventilator, its matching standby exhaust ventilator fan motor in each room is already activated, providing 100 percent ventilation capacity.

D. Ventilation systems operating status is checked periodically according to a predetermined schedule to ensure operational capability.

E. The firestat in each room, upon reaching its setpoint, deactivates all exhaust ventilator fan motors and closes the wall louver and fire dampers in its respective room.

F. Manual actuation of the CO_2 system will result in automatic shutdown of the HVAC exhaust fans and intake louvers to preclude carbon dioxide purge.

Manual override is provided to activate and deactivate each exhaust ventilator fan motor and louver motor as required.

9.4.7.2.4 Vestibule Area Heating System

The vestibule area heating system consists of one electric resistance unit heater for maintaining a minimum temperature within the area and controls for automatically activating and deactivating the heater.

The sequence of control is:

A. Upon a drop in temperature in the area, the heating thermostat activates the heater upon reaching its setpoint.

B. The heating thermostat will deactivate the heater when the area temperature rises above its setpoint.

Manual override is provided to activate and deactivate the heater as required.

9.4.7.3 Safety Evaluation

At worst, a single failure can render inoperable a subsystem of the heating and ventilation system which serves one of the redundant trains of safety-related equipment.

Analyses have been performed to determine the concentrations of several types of gases. Twenty-eight cases have been analyzed, with the results presented in table 9.4-12.

9.4.7.3.1 Cases 1, 2, 5, and 6

A two stage diffusion model is used. The model includes a first-stage Gaussian plume and a second-stage wake plume.

9.4.7.3.1.1 First-Stage Gaussian Plume. The diffusion equation for a continuous ground level release is given below:

$$X = \frac{Q_c}{\pi \sigma_y \sigma_z u} \exp\left\{-1/2\left(\frac{y}{\sigma_y}\right)^2\right\} \exp\left\{-1/2\left(\frac{z}{\sigma_z}\right)^2\right\}$$

Where:

X	=	The short term concentration (g/m^3).
Q_c	=	Amount of chlorine as continuous release (g/s).
u	=	Wind speed (m/s).
σ_y	=	The horizontal standard deviation of the plume (m).
σ_z	=	The vertical standard deviation of the plume (m).

The diffusion equation for an instantaneous (puff) ground level release with a finite initial volume is given below:

$$X = \frac{Q_1}{7.87(\sigma_{x,y}{}^2 + \sigma_I{}^2)(\sigma_z{}^2 + \sigma_I{}^2)^{1/2}}$$

$$\exp\left[-1/2\left(\frac{x^2}{\sigma_x{}^2 + \sigma_I{}^2} + \frac{y^2}{\sigma_y{}^2 + \sigma_I{}^2} + \frac{z^2}{\sigma_z{}^2 + \sigma_I{}^2}\right)\right]$$

Where:

X	=	Concentration at coordinates x, y, z from the center of the puff (g/m^3).
Q_I	=	The puff release quantity (g).
σ_x σ_y σ_z	=	Standard deviations of the gas concentration in the horizontal alongwind, horizontal crosswind direction, respectively, (assuming $\sigma_x = \sigma_y$) (m).
7.87	=	$2^{1/2} \pi^{3/2}$
σ_1	=	Initial standard deviation of the puff (m).
	=	$\frac{Q_1}{7.87 x_o}$, where X is the density of chlorine at standard conditions (g/m^3).

9.4.7.3.1.2 **Second-Stage Wake Plume.** The diffusion equation is given below:

$$X = \frac{QK}{Au}$$

Where:

X	=	Concentration (g/m^3).
K	=	Shape factor (K = 2 is used).
A	=	Projected area of the structure (m^2).
U	=	Wind speed (m/s).
Q	=	Total amount of chlorine release at the interstage line (g/s).
	=	$Q_c + Q_l$

9.4.7.3.2 **Cases 3, 4, 7, and 8**

The Bureau of Census, 1972, estimated 220,000 service stations in the U. S. The American Petroleum Institute estimated two to five underground storage tanks per station (assume an average of three). The National Fire Protection Association has no record of an active underground gasoline storage tank burning or exploding. The upper bound probability of this event is estimated at much less than 1/(220,000 x 3) or much less than 1.5×10^{-6}.

A more reasonable fire would be from a large tank truck during filling operations. Assume a truck containing 8000 gal of fuel with the spill and fire restricted to the area above the underground emergency fuel storage area, about 7500 ft^2. Using this hypothetical fire, a plume rise was calculated by:

$$\Delta h = 1.6\, F^{1/3}\, u^{-1}\, x^{2/3}$$

Where:

Δh	=	Plume rise (m).
u	=	Wind speed (m/s^{-1}).
X	=	Distance between fire and intake (m).
F	=	Buoyancy flux parameter (m^4/s^{-3}).
	=	$3.7 \times 10^{-5}\, Q_H$, where 3.7×10^{-5} has units m^4/s, cal^{-1}/s.
Q_H	=	Heat production rate (cal/s^{-1}).

9.4.7.3.3 Cases 9 through 28

All deal with actuation of a carbon dioxide fire protection system within an inside room equipped with redundant trains of safety-related equipment. The following steps are taken:

A. Calculate the pressure buildup within the room and the venting rate of carbon dioxide from the room. The calculation is based on a modification of Bechtel computer program PRESS,[4] a mass and energy balance taking into account the liquid, solid, and gaseous carbon dioxide phases and the venting area. The output provides the amount of carbon dioxide escaping from the room under consideration. It is assumed that all of the carbon dioxide released is evaporated to constitute the source.

B. Estimate reasonable dilutions following the escaped carbon dioxide along a path it must follow until it reaches the most critical diesel air intake. The buildup of the concentration of carbon dioxide inside the parapet walls (see figure 9.4-2) is limited by the intake rate of the diesel generator air intakes. The assumptions below are reasonably conservative.

   1. Carbon dioxide leaking from fire doors, louvers, etc. , will have an equal opportunity to go either way in the corridor. Assume one-half goes each direction and is diluted into the volume of the corridor.

   2. Wind speed is 10 mph. At 10 mph, about one-third of the carbon dioxide will aerodynamically get over the parapet wall and be diluted in the volume of the space inside the parapet. The other two-thirds will split on the wall and go the other two ways. At the density of a cold mixture of carbon dioxide and air, this is conservative.

   3. A buildup of carbon dioxide inside the parapet wall is allowed to continue as long as the source is continued, but it is limited by the intake rate of the diesel generator air intakes.

   4. Wind direction is always from the point where it escapes to the outside directly toward the air intake that would produce the worst case.

9.4.7.3.4 Chlorine Accident

The peak chlorine concentration of the diesel generator air intake is 82,000 ppm at 136 s after the incident. The plot of the concentration is shown in figure 9.4-3.

According to the information supplied by the diesel generator manufacturer, the effect of chlorine on the diesel general performance will not be observed until the chlorine concentration reaches about 15 percent by volume or 150,000 ppm. Since the peak is well below this value, no effect on diesel generator performance is expected.

Also, based on the information supplied by the manufacturer, effects of 86,000 ppm chlorine on engine lube oil, seals, or other organic materials are negligible, due to the short time period of this concentration at the diesel generator intake locations.

9.4.7.3.5 Combustion Products Due to a Fire

Because the plume rise at the intake is much greater than the diesel generator intake height, the combustion products due to a fire will have no effect on diesel generator performance.

9.4.7.3.6 Combustion Products Due to Diesel Exhaust

The result of recirculation from the diesel exhaust to the intake of diesel generators is given in case 7 in table 9.4-12. (See table 9.4-13 for assumptions.) The worst case is the small diesel generator where the total concentration of combustion products is 4939 mg/m^3 or about 26,000 ppm. Effects of such gaseous contaminants are discussed specifically for carbon dioxide in paragraph 9.4.7.3.7 below; there will be no effect on diesel generator performance.

9.4.7.3.7 Carbon Dioxide from the Fire Protection System

According to data supplied by the diesel manufacturer, the combined effect of carbon dioxide on the diesels from both oxygen starvation due to displacement of air from carbon dioxide acting as a combustion depressant is provided in the following table:

Concentration of Carbon Dioxide (percent volume)	Maximum Output of Diesel (percent)
15	100
20	90
25	80

The maximum carbon dioxide concentration is conservatively calculated to be 22,167 ppm as given in table 9.4-14 for case 16. Since this is well below the 150,000 ppm level, no effect on the performance of the diesel generators is expected.

Carbon dioxide is utilized in three types of areas within the diesel generator building:

A. Oil storage rooms (total flooding).

B. Diesel generator rooms (total flooding).

C. Switchgear rooms (local application).

The location of roof ventilators from these rooms with respect to the diesel air intakes is shown in figure 9.4-2.

9.4.7.4 Testing and Inspection Requirements

All components of the heating and ventilation system at the diesel generator building will be tested prior to placing the system in service and periodically thereafter.

Because the heating and ventilation system at the diesel generator building is in use during normal plant operation, the availability of active components is evident to operators, and there is no need for further online testing. Portions of the system not normally in use are periodically tested to ensure operability of the system.

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3. Slade, D.H., Meteorology and Atomic Energy. U.S. Nuclear Regulatory Commission DTI, 1968.

4. Bechtel Computer Program PRESS (modified for this safety evaluation), 1974. A mass and energy balance model, taking into account the solid, liquid, and gaseous carbon dioxide phases and the venting area. Output gives the amount of carbon dioxide escaping from the room under consideration.

5. NRC letter (SNC LC #14794) Joseph M. Farley Nuclear Plant, Units 1 and 2, Re: Addition of Engineered Safety Features Room Cooler Technical Specification, June 27, 2008.

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WASH-1400 (draft), Appendix III, page 37, August 1974.

TABLE 9.4-1 (SHEET 1 OF 4)

CONTROL ROOM AIR CONDITIONING AND FILTRATION SYSTEM - COMPONENT DESCRIPTION

Air Conditioning Units	
Fans	
Type	Centrifugal
Quantity (100 percent capacity)	2
Capacity (ft^3/min each)	21,000
Total static pressure (in. WG)	3.5
Drive	Belt
Motor (hp)	20
Condensing unit	
Condenser	
Type	Air-cooled
Quantity per train	2 (100% capacity)
Total cooling (Btu/h each)	600,000
Compressor	
Type	Refrigerant, scroll
Quantity per condensing unit (100 percent capacity)	4
Drive	Direct
Exhaust Fans	
Type	Vane axial
Quantity (100 percent capacity)	2
Capacity (ft^3/min each)	7200
Total static pressure (in. WG)	2.5
Drive	Direct
Motor (hp)	7.5

TABLE 9.4-1 (SHEET 2 OF 4)

Control Room Filtration Units (1000 ft^3/min)

Fans	
Type	Centrifugal
Quantity (100 percent capacity)	2
Capacity (ft^3/min each)	1000
Total static pressure (in. WG)	4.8
Drive	Direct
Motor (hp)	1.5
HEPA filters	
Type	High efficiency, dry
Media	Glass fiber (waterproof, fire retardant)
Design Efficiency, removal of 0.3 μm DOP smoke (percent)	99.97
Efficiency, 0.3 μm DOP smoke removal credit allowed by the NRC (percent)	99.5
Pressure drop, clean (in. WG)	1.0
Charcoal filters	
Type	2-in. tray
Media	Activated, impregnated carbon
Design Efficiency, elemental iodine (percent)	99.9
Testing Efficiency, methyl iodide (percent)	97.5
Efficiency, elemental and organic iodine removal credit allowed by the NRC (percent)	94.5
Pressure drop, clean (in. WG)	1.1

TABLE 9.4-1 (SHEET 3 OF 4)

Control Room Recirculation Filtration Units (2000 ft^3/min)

Fans	
Type	Vane axial
Quantity (100 percent capacity)	2
Capacity (ft^3/min each)	2000
Total static pressure (in. WG)	8
Drive	Direct
Motor (hp)	7.5
HEPA filters	
Type	High efficiency, dry
Media	Glass fiber (water-proof, fire retardant)
Design efficiency, removal of 0.3 μm DOP smoke (percent)	99.97
Efficiency, 0.3 mm DOP smoke removal credit allowed by the NRC (percent)	99.5
Pressure drop, clean (in. WG)	1.0
Charcoal filters	
Type	2-in. HECA™
Media	Activated, impreg-nated carbon
Design efficiency, elemental iodine (percent)	99.9
Testing efficiency, methyl iodide (percent)	97.5
Efficiency, elemental and organic iodine removal credit allowed by the NRC (percent)	94.5
Pressure drop, clean (in. WG)	1.25

TABLE 9.4-1 (SHEET 4 OF 4)

Control Room Filtration Units (Air Pressurization System)

Fans	
Type	Centrifugal
Quantity (100 percent capacity)	2
Capacity (ft^3/min each)	300
Total static pressure (in. WG)	9
Drive	Direct
Motor (hp)	1.5
HEPA filters	
Type	High efficency, dry
Media	Glass fiber (water-proof, fire retardant)
Design efficiency, removal of 0.3 μm DOP smoke (percent)	99.97
Efficiency, 0.3 μm DOP smoke removal credit allowed by the NRC (percent)	99.5
Pressure drop, clean (in. WG)	1.0
Charcoal filters	
Type	6-in. deep bed, HECA™
Media	Activated, impreg-nated carbon
Design efficiency, elemental iodine (percent)	99.9
Testing efficiency, methyl iodide (percent)	99.5
Efficiency, elemental and organic iodine removal credit allowed by the NRC (percent)	98.5
Pressure drop, clean (in. WG)	2.7
Electric heater	
Type	Finned tube
Capacity (kW)	2.5

TABLE 9.4-2 (SHEET 1 OF 9)

REGULATORY GUIDE 1.52, REV. 0 APPLICABILITY FOR THE CONTROL ROOM FILTRATION SYSTEM (PRESSURIZATION)

Reg. Guide Section	Applicability to This System	Note Index	Reg. Guide Section	Applicability to This System	Note Index
C.1.a	Yes	1	C.3.h	Yes	9
C.1.b	Yes	-	C.3.i	Yes	-
C.1.c	Yes	-	C.3.j	No	10
C.1.d	Yes	-	C.3.k	Yes	-
C.1.e	Yes	-	C.3.l	Yes	11
C.2.a	No	2	C.3.m	Yes	12
C.2.b	No	3	C.3.n	Yes	-
C.2.c	Yes	-	C.4.a	Yes	-
C.2.d	Yes	-	C.4.b	Yes	-
C.2.e	Yes	-	C.4.c	Yes	13
C.2.f	Yes	-	C.4.d	Yes	-
C.2.g	Yes	4	C.4.e	Yes	-
C.2.h	No	5	C.4.f	Yes	-
C.2.i	Yes	-	C.4.g	Yes	-
C.2.j	No	6	C.4.h	Yes	14
C.2.k	Yes	-	C.4.i	Yes	-
C.2.l	Yes	-	C.4.j	Yes	-
C.2.m	Yes	-	C.4.k	Yes	-
C.3.a	No	7	C.4.l	Yes	-
C.3.b	Yes	-	C.4.m	Yes	-
C.3.c	Yes	-	C.5.a	Yes	-
C.3.d	Yes	-	C.5.b	Yes	15
C.3.e	Yes	8	C.5.c	Yes	15
C.3.f	Yes	-	C.6.a	Yes	-
C.3.g	Yes	-	C.6.b	Yes	-

TABLE 9.4-2 (SHEET 2 OF 9)

NOTES

1. The design basis accident is the postulated LOCA.

2. No demister is provided because the unit is located outside the containment and no entrained water droplets are anticipated. No HEPA filters are provided downstream of the charcoals, since radioactive fines carryover is very unlikely. This is true because the charcoal trays are pressure tested at high velocity in the manufacturer's shop prior to delivery, thereby removing fines. Also, during system operation, air is passing through the charcoal at a very low velocity.

3. No physical separation is provided, since these units are located in a room where no missiles are postulated.

4. Pressure drops across the prefilters, HEPA, and charcoal filters are instrumented to indicate in the equipment room. Pressure drops across the HEPA and charcoal filters are instrumented to alarm in the control room. No recording of these signals is provided. Fan loss of flow is also instrumented to signal in the equipment room and alarm in the control room.

5. Fan motors and motor-operated valves installed outside containment and in a nonradioactive area are not in conformance with IEEE 323.

6. The size of the engineered safety feature filtration units precludes replacement as a single unit. The unit components are replaced individually.

7. Demisters are not provided.

8. Mounting frames for filter and charcoals are constructed of carbon steel coated with an inorganic nuclear grade paint.

9. Internal welds are carbon steel coated with an inorganic nuclear grade paint.

10. The deluge and drain system has been eliminated due to recurring problems experienced at other facilities associated with inadvertent wetting of the absorber. Temperature gauges have been installed to monitor any heat rise in the filter housing.

TABLE 9.4-2 (SHEET 3 OF 9)

11. Environmental conditions for systems considered are those specified under outside containment and nonradioactive area.

12. Duct construction guidelines follow SMACNA, in addition to ORNL-NSIC-65.

13. Vacuum breakers are not used. This prevents the probability of system leakage from pressure relieving device leakage or failure.

14. Test probes are not manifolded and are located in readily accessible locations with minimum piping.

15. Periodic testing to confirm a penetration of less than 0.5% at rated flow.

TABLE 9.4-2 (SHEET 4 OF 9)

REGULATORY GUIDE 1.52, REV. 0 APPLICABILITY FOR THE CONTROL ROOM FILTRATION SYSTEM (RECIRCULATION)

Reg. Guide Section	Applicability to This System	Note Index	Reg. Guide Section	Applicability to This System	Note Index
C.1.a	Yes	1	C.3.h	Yes	9
C.1.b	Yes	-	C.3.i	Yes	-
C.1.c	Yes	-	C.3.j	No	10
C.1.d	Yes	-	C.3.k	Yes	-
C.1.e	Yes	-	C.3.l	Yes	11
C.2.a	No	2	C.3.m	Yes	12
C.2.b	No	3	C.3.n	Yes	-
C.2.c	Yes	-	C.4.a	Yes	-
C.2.d	Yes	-	C.4.b	Yes	-
C.2.e	Yes	-	C.4.c	Yes	13
C.2.f	Yes	-	C.4.d	Yes	-
C.2.g	Yes	4	C.4.e	Yes	-
C.2.h	No	5	C.4.f	Yes	-
C.2.i	Yes	-	C.4.g	Yes	-
C.2.j	No	6	C.4.h	Yes	14
C.2.k	Yes	-	C.4.i	Yes	-
C.2.l	Yes	-	C.4.j	Yes	-
C.2.m	Yes	-	C.4.k	Yes	-
C.3.a	No	7	C.4.l	Yes	-
C.3.b	No	-	C.4.m	Yes	-
C.3.c	Yes	-	C.5.a	Yes	-
C.3.d	Yes	-	C.5.b	Yes	15
C.3.e	Yes	8	C.5.c	Yes	15
C.3.f	Yes	-	C.6.a	Yes	-
C.3.g	Yes	-	C.6.b	Yes	-

TABLE 9.4-2 (SHEET 5 OF 9)

NOTES

1. The design basis accident is the postulated LOCA.

2. No demister is provided because the unit is located outside the containment and no entrained water droplets are anticipated. No HEPA filters are provided downstream of the charcoals, since radioactive fines carryover is very unlikely. This is true because the charcoal trays are pressure tested at high velocity in the manufacturer's shop prior to delivery, thereby removing fines. Also, during system operation, air is passing through the charcoal at a very low velocity.

3. No physical separation is provided, since these units are located in a room where no missiles are postulated.

4. Pressure drops across the prefilters, HEPA, and charcoal filters are instrumented to indicate in the equipment room. Pressure drops across the HEPA and charcoal filters are instrumented to alarm in the control room. No recording of these signals is provided. Fan loss of flow is also instrumented to signal in the equipment room and alarm in the control room.

5. Fan motors and motor-operated valves installed outside containment and in a nonradioactive area are not in conformance with IEEE 323.

6. The size of the engineered safety feature filtration units precludes replacement as a single unit. The unit components are replaced individually.

7. Demisters are not provided.

8. Mounting frames for filter and charcoals are constructed of carbon steel coated with an inorganic nuclear grade paint.

9. Internal welds are carbon steel coated with an inorganic nuclear grade paint.

10. The deluge and drain system has been eliminated due to recurring problems experienced at other facilities associated with inadvertent wetting of the absorber. Temperature gauges have been installed to monitor any heat rise in the filter housing.

TABLE 9.4-2 (SHEET 6 OF 9)

11. Environmental conditions for systems considered are those specified under outside containment and nonradioactive area.

12. Duct construction guidelines follow SMACNA, in addition to ORNL-NSIC-65.

13. Vacuum breakers are not used. This prevents the probability of system leakage from pressure relieving device leakage or failure.

14. Test probes are not manifolded and are located in readily accessible locations with minimum piping.

15. Periodic testing to confirm a penetration of less than 0.5% at rated flow.

TABLE 9.4-2 (SHEET 7 OF 9)

REGULATORY GUIDE 1.52, REV. 0 APPLICABILITY FOR THE CONTROL ROOM FILTRATION SYSTEM (FILTRATION)

Reg. Guide Section	Applicability to This System	Note Index	Reg. Guide Section	Applicability to This System	Note Index
C.1.a	Yes	1	C.3.h	Yes	9
C.1.b	Yes	-	C.3.i	Yes	-
C.1.c	Yes	-	C.3.j	No	10
C.1.d	Yes	-	C.3.k	Yes	-
C.1.e	Yes	-	C.3.l	Yes	11
C.2.a	No	2	C.3.m	Yes	12
C.2.b	No	3	C.3.n	Yes	-
C.2.c	Yes	-	C.4.a	Yes	-
C.2.d	Yes	-	C.4.b	Yes	-
C.2.e	Yes	-	C.4.c	Yes	13
C.2.f	Yes	-	C.4.d	Yes	-
C.2.g	Yes	4	C.4.e	Yes	-
C.2.h	No	5	C.4.f	Yes	-
C.2.i	Yes	-	C.4.g	Yes	-
C.2.j	No	6	C.4.h	Yes	14
C.2.k	Yes	-	C.4.i	Yes	-
C.2.l	Yes	-	C.4.j	Yes	-
C.2.m	Yes	-	C.4.k	Yes	-
C.3.a	No	7	C.4.l	Yes	-
C.3.b	No	-	C.4.m	Yes	-
C.3.c	Yes	-	C.5.a	Yes	-
C.3.d	Yes	-	C.5.b	Yes	15
C.3.e	Yes	8	C.5.c	Yes	15
C.3.f	Yes	-	C.6.a	Yes	-
C.3.g	Yes	-	C.6.b	Yes	-

TABLE 9.4-2 (SHEET 8 OF 9)

NOTES

1. The design basis accident is the postulated LOCA.

2. No demister is provided because the unit is located outside the containment and no entrained water droplets are anticipated. No HEPA filters are provided downstream of the charcoals, since radioactive fines carryover is very unlikely. This is true because the charcoal trays are pressure tested at high velocity in the manufacturer's shop prior to delivery, thereby removing fines. Also, during system operation, air is passing through the charcoal at a very low velocity.

3. No physical separation is provided, since these units are located in a room where no missiles are postulated.

4. Pressure drops across the prefilters, HEPA, and charcoal filters are instrumented to indicate in the equipment room. Pressure drops across the HEPA and charcoal filters are instrumented to alarm in the control room. No recording of these signals is provided. Fan loss of flow is also instrumented to signal in the equipment room and alarm in the control room.

5. Fan motors and motor-operated valves installed outside containment and in a nonradioactive area are not in conformance with IEEE 323.

6. The size of the engineered safety feature filtration units precludes replacement as a single unit. The unit components are replaced individually.

7. Demisters are not provided.

8. Mounting frames for filter and charcoals are constructed of carbon steel coated with an inorganic nuclear grade paint.

9. Internal welds are carbon steel coated with an inorganic nuclear grade paint.

10. The deluge and drain system has been eliminated due to recurring problems experienced at other facilities associated with inadvertent wetting of the absorber. Temperature gauges have been installed to monitor any heat rise in the filter housing.

TABLE 9.4-2 (SHEET 9 OF 9)

11. Environmental conditions for systems considered are those specified under outside containment and nonradioactive area.

12. Duct construction guidelines follow SMACNA, in addition to ORNL-NSIC-65.

13. Access doors are not used.

14. Test probes are not manifolded and are located in readily accessible locations with minimum piping.

15. Periodic testing to confirm a penetration of less than 0.5% at rated flow.

TABLE 9.4-3

CONTROL ROOM AIR CONDITIONING AND FILTRATION SYSTEM - SINGLE FAILURE ANALYSIS

Component	Malfunction	Comments and Consequences
Air handling unit	Component failure	Two units provided; operation of one required
Condensing unit	Component failure	Four units provided; operation of one required
Filter train	Failure resulting in high differential pressure across the train	Two filter trains provided; operation of one required
Isolation valve, fresh air supply and utility exhaust	Fails to close after high radiation signal, safety injection signal, containment isolation signal, or smoke detection signal	Two valves in series; operation of one required for isolation
Duct system	Failure resulting in loss of air recirculation	Two full capacity systems provided; operation of one required
Outside air supply valve	Fails to open	Two provided; operation of one required
Isolation valve, smoke purge exhaust	N/A	Single isolation valves are maintained in closed position during normal operation to provide control room isolation boundary (passive component)

TABLE 9.4-4

TIME CALCULATIONS FOR VARIOUS CHLORINE CONCENTRATIONS

	Time Required to Reach the Following Cl_2 Concentration (s)					Maximum Concentration (ppm by volume)
Case	15 ppm	30 ppm	45 ppm	60 ppm	Maximum	
A	264.5	268.25	271	273.61	9392	368.8
B	134.0	137.0	139.5	143	9254	184.4
C	274	286	2736	6451	9433	70.3
D	455	7377	--	--	9318	33.5

TABLE 9.4-5 (SHEETS 1 THROUGH 3)

REGULATORY GUIDE 1.52
APPLICABILITY FOR THE SPENT FUEL POOL FILTRATION SYSTEM

(This Table has been deleted.)

TABLE 9.4-6 (SHEET 1 OF 9)

AUXILIARY BUILDING VENTILATION, AIR CONDITIONING, AND FILTRATION SYSTEM DESIGN PARAMETERS

Item	Non-Radwaste Area	Computer Room	Access Control Area	Cable Spreading Area	600-V Load Center 1M and 1N	600-V Load Center Room
Air Handling Unit (Supply) (Access Control Area)						
Type	None	None	Horizontal, draw through, floor mounted	None	None	None
Number			1			
Flowrate each, sf^3/min			4250			
Static Head, in. WG			3.29			
Heating capacity, Btu/h			NA			
Cooling capacity, Btu/h			2.68×10^5			
Mtr horsepower, each			5			
Air Handling Unit (Supply) (Dosimetry Lab)						
Type	Horizontal, draw through, floor mounted	None	Horizontal, draw through, floor mounted	None	None	None
Number	1		1			
Flowrate each, sf^3/min	24,000		1450			
Static head, in. WG	2. 5		2.34			
Heating capacity, Btu/h	2.6×10^5		0.34×10^5			
Cooling capacity, Btu/h	NA		0.52×10^5			
Mtr horsepower, each	20		1.5			
Air Conditioning Unit (Supply)						
Type	None	Horizontal, draw through floor mounted	None	Horizontal, draw through, floor mounted	Horizontal, draw through, floor mounted	Horizontal, draw through, ceiling mounted
Number		1		1	1 1	
Flowrate, sf^3/min		5550		2010	5620	16,000
Static head, in. WG		5.7		1.74	1.85	3.95
Heating capacity, Btu/h		1.22×10^5		NA	NA	NA
Cooling capacity, Btu/h		1.60×10^5		0.54×10^5	1.79×10^5	6.17×10^5
Mtr horsepower, each		10		1.0	5	25

TABLE 9.4-6 (SHEET 2 OF 9)

Item	Non-Radwaste Area	Computer Room	Access Control Area	Cable Spreading Area	600-V Load Center 1M and 1N	600-V Load Center Room
Air Conditioning Condensing Unit (Access Control Area)						
Type	None	None	Split, roof mounted air cooled	None	None	None
Number			1			
Cooling capacity, Btu/h			2.79×10^5			
Refrigerant type			R-22			
Fan motor, hp			Three at 1 hp each			
Compressor motor power, hp			30			
Air Conditioning Condensing Unit						(Unit 1)
Type	None	Split, roof mounted air cooled	Split, roof mounted air cooled	Split, roof mounted air cooled	Split, roof mounted air cooled	Split, roof mounted air cooled
Number		1	1 1	1	1	1
Cooling Capacity, Btu/h		2.4×10^5	0.52×10^5	1.21×10^5	3.29×10^5	5.83×10^5
Refrigerant type		R-22	R-22	R-22	R-22	R-22
Fan motor, hp		1	1/2	½	7 1/2	4
Compressor motor power, kW input or hp		25 kW	7. 5 hp	15 hp	30 hp	45 hp
Air Handling Unit (Recirculation)		(Recirculation)				
Type	None	Vertical, draw through, floor mounted	None	None	None	Horizontal, draw through, floor mounted
Number		2				1
Flowrate each, sf^3/min		7500				1300
Static head, in. WG		6.31				4
Cooling capacity, Btu/h		1.93×10^5				4.98×10^5
Motor horsepower, each		15				15

TABLE 9.4-6 (SHEET 3 OF 9)

Item	Non-Radwaste Area	Computer Room	Access Control Area	Cable Spreading Area	600-V Load Center 1M and 1N	600-V Load Center Room
Air Conditioning Condensing Unit						(Unit 2)
Type	None	Split, roof mounted, air cooled	None	None	None	Split, roof mounted, air cooled
Number		2				1
Cooling capacity, Btu/h		2.37×10^5				5×10^5
Refrigerant type		R-22				R-22
Fan motor, hp		1				4
Compressor motor power, hp		20				40
Filtration Unit						
Type	None	None	None	None	None	None
Number						
Prefilter media						
Prefilter efficiency, %						
HEPA media						
HEPA efficiency, %						
Charcoal media						
Charcoal efficiency, %						
Pressure drop, in. WG						
Exhaust Fan						
Type	Centrifugal	None	None	Centrifugal	None	None
Number	1			1		
Flowrate each, sf^3/min	20,000			4200		
Static head, in. WG	1.7			0.75		
Motor horsepower, each	15			2		
Roof Exhaust Fan						
Type	None	None	Power roof, exhaust	None	None	None
Number			1			
Flowrate each, sf^3/min			4530			
Static head, in. WG			1.2			
Motor horsepower, each			2			

TABLE 9.4-6 (SHEET 4 OF 9)

Item	Non-Radwaste Area	Computer Room	Access Control Area	Cable Spreading Area	600-V Load Center 1M and 1N	600-V Load Center Room
Return Fan						
Type	None	Vaneaxial	None	None	None	None
Number		1				
Flowrate each, sf ^{3}/min		3600				
Static head, in. WG		1.5				
Motor horsepower, each		2				

TABLE 9.4-6 (SHEET 5 OF 9)

Item	Fuel Handling Area	Battery Room Exhaust	Battery Charger Room	Charging High Head Pump Room	RHR Pump Room	Ctmt. Spray Pump Room	Compo. Cooling Pump Room	Aux Feedwater Pump Room
Air Handling Unit (Supply)		None						
Type	Horizontal draw through, floor mounted		Horizontal, axial ceiling mounted	Horizontal, axial ceiling mounted	Horizontal, axial ceiling mounted	Horizontal, axial ceiling mounted	Horizontal, axial ceiling mounted	Horizontal, axial ceiling mounted
Number	1		3	3 2		2	2	2
Flow rate each, scfm	16,000		16,000	30,260	9,440	12,600	23,000	17,150
Static head, in. w.g.	2.75		1.7	3.2	1.4	1.5	1.55	1.47
Heating capacity, Btu/hr	8.65×10^5		None	None	None	None	None	None
Cooling capacity, Btu/hr	NA		48,000 (Swing) 58,100 (Non-Swing)	202,000	63,000	83,800	156,300	108,120
Motor horsepower, each	15		5	25	5	5	15	7-1/2
Air Conditioning Unit (Supply)	None	None	None	None	None	None	None	None
Type								
Number								
Flow rate, scfm								
Static head, in w.g.								
Cooling capacity, Btu/hr								
Motor horsepower, each								
Air Conditioning Condensing Unit	None	None	None	None	None	None	None	None
Type								
Number								
Cooling capacity Btu/hr								
Refrigerant type								
Fan motor horsepower								
Compressor mtr power, hp								
Filtration Unit		None	None	None	None	None	None	None
Type	Composite Prefilter-HEPA-charcoal							
Number	1							

TABLE 9.4-6 (SHEET 6 OF 9)

Item	Fuel Handling Area	Battery Room Exhaust	Battery Charger Room	Charging High Head Pump Room	RHR Pump Room	Ctmt. Spray Pump Room	Compo. Cooling Pump Room	Aux Feedwater Pump Room
Prefilter media	Dry, replaceable cartridge							
Prefilter efficiency, %	85, NBS Dust Spot							
HEPA media	Dry extended							
HEPA efficiency, %	99.97, DOP @ 0.3							
Charcoal media	Coconut, active, impregnated							
Charcoal efficiency, %	99.9 I_2, 95.0 CH_3 I							
Pressure drop, in. w.g.	3.0							
Exhaust Fan		N	one	None	None	None	None	None
Type	Centrifugal	Centrifugal						
Number	2	2						
Flow rate each, scfm	13,100	350						
Static head, in. w.g.	6.64	0.375						
Motor horsepower, each	30 HP							
Roof Exhaust Fan	None	None	None	None	None	None	None	None
Type								
Number								
Flow rate each, scfm								
Static head, in. w.g.								
Motor horsepower, each								
Return Fan	None	None	None	None	None	None	None	None
Type								
Number								
Flow rate each, scfm								
Static head, in. w.g.								
Motor horsepower, each								

TABLE 9.4-6 (SHEET 7 OF 9)

Item	MCC 1A	MCC 1B (MCC 2B)	600 V Load Center ID	600 V Load Center 1E	600 V Load Center 2M	Unit 2 Lub. Oil Storage Area
Air Handling Unit (Supply)						
Type	Vertical, axial floor mounted	Vertical, axial floor mounted	Vertical, axial floor mounted	Vertical, axial floor mounted	None	Centrifugal
Number	1	2 (1)	1	1		1
Flow rate each, scfm	4,000	3,000 (4000)	11,500	11,500		945
Static head, in. w.g.	1.5	1.0 (1.5)	2.5	2.5		0.625
Heating capacity, Btu/hr	NA	NA (NA)	NA	NA		NA
Cooling capacity, Btu/hr	24,750	11,000 (24,750)	74,200	74, 200		NA
Motor horsepower, each	2	2 (2)	10	10		1.0
Air Conditioning Unit (Supply)						
Type	None	None	None	None	Horizontal, drawn through suspended	None
Number					1	
Flow rate, scfm					1,300	
Static head, in. w.g.					0.67	
Cooling capacity, Btu/hr					51,200	
Motor horsepower, each					1/2	
Air Conditioning Condensing Unit						
Type	None	None	None	None	Split roof mounted air cooled	None
Number					1	
Cooling capacity Btu/hr					51,200	
Refrigerant type					R-22	
Fan motor horsepower					1/4	
Compressor motor power, hp					7.1	

TABLE 9.4-6 (SHEET 8 OF 9)

Item	MCC 1A	MCC 1B (MCC 2B)	600 V Load Center ID	600 V Load Center 1E	600 V Load Center 2M	Unit 2 Lub. Oil Storage Area
Filtration Unit						
Type	None	None	None	None	None	None
Number						
Prefilter media						
Prefilter efficiency, %						
HEPA media						
HEPA efficiency, %						
Charcoal media						
Charcoal efficiency, %						
Pressure drop, in w.g.						
Exhaust Fan						
Type	None	None	None	None	None	None
Number						
Flow rate each, scfm						
Static head, in. w.g.						
Motor horsepower, each						
Roof Exhaust Fan						
Type	None	None	None	None	None	None
Number						
Flow rate each, scfm						
Static head, in. w.g.						
Motor horsepower, each						
Return Fan						
Type	None	None	None	None	None	None
Number						
Flow rate each, scfm						
Static head, in. w.g.						
Motor horsepower, each						

TABLE 9.4-6 (SHEET 9 OF 9)

NON-RADWASTE AREA

Item	Unit 1	Unit 2
Computer UPS Supply Fan		
Type	Centrifugal	Centrifugal
Number	1	1
Flowrate each (sf^3/min)	7060	8980
Static head (in. WG)	2.2	3.0
Motor horsepower, each	5.0	7.5
Computer UPS Primary		
Exhaust Fan	Tubular	Tubular
Type	Centrifugal	Centrifugal
Number	1	1
Flowrate each (sf^3/min)	1425	1425
Static head, (in. WG)	0.65	1.0
Motor horsepower, each	0.5	1.0
Computer UPS Secondary		
Exhaust Fan		
Type	Centrifugal	Centrifugal
Number	1	1
Flowrate each (sf^3/min)	7060	8980
Static head, (in. WG)	1.1	1.5
Motor horsepower, each	3.0	5.0

TABLE 9.4-6A

AUXILIARY BUILDING ROOM TEMPERATURES FOR POST-ACCIDENT HEAT LOADS

Room No.	Room Description	Rm. Temp.[(a)(b)] at end of post-accident period
173/174/181 (2173/2174/2181)	CH/HH Safety Inject. Pump Rms.	119°F
129/131 (2129/2131)	RHR/LH Injection Pump Rms.	129°F
111/125 (2111/2125)	Containment Spray Pump Rms.	122°F
185 (2185)	Component Cooling Pump Room	126°F
191/192 (2191/2192)	Auxiliary Feedwater Pump Rms.	116°F
224/226 (2224/2226)	Battery Charger Rooms (A & B)	114°F
225 (2225)	Battery Charger Rooms (C)	114°F
332 (2332)	MCC 1A (2A) Areas	121°F
209	MCC 1B Area	131°F
2209	MCC 2B Area	129°F
229/335 (2229/2335)	600 V Load Center 1D, 2D, 1E, & 2E Area	130°F

(a) The room and area temperatures listed are based on assumptions of design service water flow rates, design air flow rates and design fouling factor for the associated air coolers.

(b) The room temperatures listed in this column are at the end of a 30 day accident and are based on service water temperature of 106.2°F, equipment in operation and loss of normal non-safety related HVAC for all 30 days.

TABLE 9.4-7 (SHEET 1 OF 2)

BATTERY ROOM EXHAUST, BATTERY CHARGER ROOM, MOTOR CONTROL CENTERS, AND 600-V LOAD CENTERS AND ENGINEERED SAFETY FEATURES PUMP ROOM COOLING SYSTEMS - SINGLE FAILURE ANALYSIS

Component	Malfunction	Comments and Consequences
Battery room exhaust fan	Fan failure	One exhaust fan is provided for each battery room; one battery is required during post-LOCA operation The failed exhaust fan will be isolated and repaired
Battery room exhaust duct	Duct failure	Low flow will be alarmed locally The failed exhaust fan will be isolated and repaired
Battery charger room cooler	Component failure	One cooler is provided for each battery charger; two battery chargers operate and one is spare during post-LOCA operation The failed cooler will be isolated and repaired; the spare battery charger will be started, including the associated cooler
Battery charger room cooling system duct	Duct failure	Low differential pressure will be alarmed locally The failed duct will be isolated and repaired; the spare cooler will be started

TABLE 9.4-7 (SHEET 2 OF 2)

Component	Malfunction	Comments and Consequences
Engineered safety features pump room coolers	Component failure	One cooler is provided for each charging high head, residual heat removal, containment spray, and auxiliary feedwater pump; two coolers for three component cooling pumps; each spare pump has its own spare pump room cooler The failed cooler will be isolated and repaired; the spare pump and cooler will be started
Motor control center cooler	Component failure	One cooler each is provided for motor control center 1A, 2A and 2B and two coolers are provided for motor control center 1B; each of the coolers operates during post-LOCA operation The failed cooler will be isolated; the ambient temperature in the room being served by the failed cooler will rise but not exceed the design basis temperature of the service equipment
600-V load center cooler	Component failure	One cooler each is provided for 600-V load center 1D and 1E; both 600-V load centers operate The failed cooler will be isolated; the room ambient temperature associated with the failed cooler will rise until the cooler is repaired and reenergized

TABLE 9.4-8

RADWASTE AREA HEATING, VENTILATING, AND FILTRATION SYSTEMS DESIGN PARAMETERS

Item	Radwaste Area
Air handling unit (supply)	
Type	Horizontal, drawthrough, floor-mounted
Number	1
Flowrate (sf^3/min)	50,000
Static head (in. WG)	4.5
Heating capacity (Btu/h)	2.16×10^6
Motor hp, each	75
Exhaust fan	
Type	Vaneaxial
Number	2
Flowrate, each (sf^3/min)	50,000
Static head (in. WG)	6.5
Motor hp, each	75
Filtration unit	
Type	Composite prefilter, HEPA charcoal
Number	1
Prefilter media	Dry, cartridge
Prefilter efficiency (percent)	85, NIST dust spot
HEPA media	Dry, extended
HEPA efficiency (percent)	99.97, DPO at 0.3 m
Charcoal media	Coconut, activated, impregnated
Charcoal efficiency (percent)	99.9 - I_2; 99.0 - CH_3I

TABLE 9.4-9

UNIT 2 RADWASTE AREA HEATING, VENTILATING, AND FILTRATION SYSTEMS DESIGN PARAMETERS

Item	Waste Gas Area Filtration Unit[(a)]
Air handling unit (supply)	None
Exhaust fan	
Type	Centrifugal
Number	1
Flowrate, each (sf^3/min)	3000
Static head (in. WG)	4.0
Motor hp, each	10.0
Filtration unit	
Type	HEPA, charcoal filter, totally enclosed, refillable
Number	2
Prefilter media	Dry cartridge
Prefilter efficiency (percent)	85, NIST discoloration
HEPA media	-
HEPA efficiency (percent)	-
Charcoal media	Coconut, activated, impregnated charcoal
Charcoal efficiency (percent)	99.9 - I_2; 99.0 - CH_3I

a. Exhaust airflow from the chemical and laundry drain tank room, waste monitor tank room, and the waste gas area processing area.

TABLE 9.4-10

RADWASTE HEATING, VENTILATION, AND FILTRATION SYSTEM FAILURE ANALYSIS

Component	Malfunction	Comments and Consequences
Air handling unit supply fan	Failure of fan, resulting in loss of airflow	Loss of airflow actuates an annunciation system until corrective action is taken
Ventilation exhaust fans	Failure of fans, resulting in loss of airflow	Loss of airflow actuates an annunciation system; after 10 s have elapsed, standby fan will automatically start
Radwaste area filter unit	Filter overload, resulting in increased air filter pressure drop	Increase in filter pressure drop has - no sudden effect on system capability; local filter pressure drop display provides alarm for corrective action
Instrumentation	Instrumentation power failure	Control actuators assume fail-safe position until corrective action is taken
Ventilation supply duct	Failure of or leakage from exhaust duct, resulting in decreased or loss of airflow	Decreased or loss of airflow indicates low pressure; system loss of or decrease in air capacity actuates an annunciation system; after 10 s have elapsed, standby will automatically start
Ventilation exhaust duct	Failure of or leakage from exhaust duct, resulting in decreased or loss of airflow	Decrease or loss of airflow indicates low pressure; system loss of or decrease in air capacity actuates an annunciation system; after 10 s have elapsed, standby fan will automatically start

TABLE 9.4-11 (SHEET 1 OF 2)

TURBINE BUILDING HEATING, COOLING, AND STEAM JET AIR EJECTOR FILTRATION SYSTEMS COMPONENT DESIGN PARAMETERS

Cooling and Heating System

Water analysis room air condition unit

Number of units	1
Unit type	Single package
Fan type	Centrifugal
Airflow (ft^3/min)	2300
Total pressure (in. WG)	1.27
Motor (hp)	1
Total cooling (Btu/h)	100,000
Refrigerant	22
Condenser type	Water-cooled
Waterflow (gal/min)	28

Air handling units

Service	Operating floor, el 189 ft
Number of units	4
Unit type	Horizontal, single zone, drawthrough
Components	Fans, coil, filter
Fan type	Centrifugal
Airflow (ft^3/min)	15,350
Total pressure (in. WG)	2.5
Motor (hp)	10
Water coil	Finned tube, chilled water
Total load (Btu/h)	493,000 (cooling)
Waterflow (gal/min)	55 (cooling)
Service	Mezzanine floor, el 155 ft
Number of units	6
Unit type	Horizontal or vertical, single zone, draw-through
Components	Fan, coil, filter
Fan type	Centrifugal
Airflow (ft^3/min)	16,400
Total pressure (in. WG)	2.5
Motor (hp)	15
Water coil	Finned tube, chilled water
Total load (Btu/h)	530,100 (cooling)
Waterflow (gal/min)	59 (cooling)

TABLE 9.4-11 (SHEET 2 OF 2)

Service	Basement floor, el 137 ft
Number of units	4
Unit type	Horizontal or vertical, single zone, draw-through
Components	Fan, coil, filter
Fan type	Centrifugal
Airflow (ft^3/min)	24,000
Total pressure (in. WG)	2.25
Motor (hp)	15
Water coil	Finned tube, chilled water
Total load (Btu/h)	1,176,700 (cooling)
Waterflow (gal/min)	130 (cooling)

Steam Jet Air Ejector Filtration Unit

Fans	
Number	1
Type	Centrifugal
Rated flow (ft^3/min)	1000
Rated head (in. WG)	3.5
Filter train	
Number	1
Type	Single pass, high efficiency
Rated flow (ft^3/min)	1000
Components	Prefilter, HEPA, 6-in. fixed bed charcoal filter
Design efficiency (percent)	
Prefilter	80-85 NIST dust spot
High efficiency particulate	99.97 DOP test on 0.3 μm particles
Charcoal	99.0 for iodine removal

Smoke and Heat Vents

Service	Operating floor, el 189 ft
Number of units	13
Unit type	Passive roof gravity exhaust ventilator

TABLE 9.4-12 (SHEET 1 OF 4)

DESCRIPTION OF CASES EVALUATED IN SAFETY EVALUATION OF THE DIESEL GENERATOR BUILDING

Case	Location and Event	Assumptions	Intakes	Maximum Concentration
[HISTORICAL]				
[1	*Chlorine spill, 2 tons at circulating water house about 900 ft NNW of generator building*	*Wind speed 0.5 mps, direction toward intake, Pasquill F stability*	*Large*	*1684 ppm or 5 mg/m^3*
2	*Chlorine spill, 2 tons at circulating water house about 200 ft NE of generator building]*	Wind speed 0.5 mps, direction toward intake, Pasquill F stability	Large	81,969 ppm or 242 mg/m^3
3	Combustion products due to fire at underground fuel storage tanks, 8000-gal spill from a tank truck and resulting fire	Wind speed 10 mph, direction toward intakes	Nearest	Insignificant, plume rise is about 192 ft in the distance between fire and intake; intake is at 22 ft above ground
4	Heat or air temperature due to fire at underground fuel storage tanks, 8000-gal spill from a tank truck and resulting fire	Wind speed 10 mph, direction toward intakes	Nearest	Insignificant, plume rise is about 192 ft in the distance between fire and intake; intake is at 22 ft above ground
[5	*Same as case 1*	*Same as case 1*	*Small*	*1684 ppm or 5 mg/m^3*
6	*Same as case 2*	*Same as case 2*	*Small*	*80,929 ppm or 239 mg/m^3]*
7	Combustion products considering effect of diesel exhaust pipes	Wind speed 5 m/s, direction from nearest exhaust to intakes	Both large and small	CO_2 at large intake - 793 mg/m^3 CO_2 at small intake - 903 mg/m^3 H_2O at large intake - 297 mg/m^3 H_2O at small intake - 338 mg/m^3 SO_2 at large intake - 1.2 mg/m^3 SO_2 at small intake - 1.3 mg/m^3 N_2 at large intake - 3246 mg/m^3 N_2 at small intake - 3697 mg/m^3

TABLE 9.4-12 (SHEET 2 OF 4)

Case	Location and Event	Assumptions	Intakes	Maximum Concentration
8	Air temperature rise considering effect of diesel exhaust pipes	Same as case 7, except ambient outside temperature 90°F	Both large and small	ΔT rise at large intake - 8°F ΔT rise at small intake - 5°F
9	Actuation of CO_2 fire protection system in the large diesel generator room, 2800 lb CO_2 re-leased in 1 min	Ventilators, doors, louvers etc., operate normally, wind speed 10 mph, direction toward intake	Large	11,280 ppm
10	Same as case 9	Same as case 9, except roof ventilators fail to turn off	Large	15,412 ppm
11	Same as case 9	Same as case 9, except failure of fire doors (behind louvers) to close	Large	2807 ppm
12	Same as case 9	Same as case 9, except failure of louvers to close	Large	13,495 ppm
13	Actuation of CO_2 fire protection system in the small diesel generator room, 2800 lb CO_2 released in 1 min	Same as case 9	Small	22,157 ppm
14	Same as case 13	Same as case 9, except roof ventilators fail to turn off	Small	18,469 ppm
15	Same as case 13	Same as case 9, except failure of fire doors (behind louvers) to close	Small	12,877 ppm
16	Same as case 13	Same as case 9, except failure of the louvers in fire door to close	Small	22,167 ppm

TABLE 9.4-12 (SHEET 3 OF 4)

Case	Location and Event	Assumptions	Intakes	Maximum Concentration
17	Actuation of the CO_2 fire protection system in the large oil storage room releases 136 lb CO_2 in 1 min	Wind speed 10 mph, direction toward intake, rest of system operates normally	Large	2150 ppm
18	Case as case 17	Same as case 17, except roof ventilators fail to turn off	Large	8169 ppm
19	Same as case 17	Same as case 17, except failure of fire door (behind louvers) to close	Large	1308 ppm
20	Same as case 17	Same as case 17, except failure of louvers in fire door to close	Large	2139 ppm
21	Actuation of the CO_2 fire protection system in the small oil storage room; release 136 lb CO_2 in 1 min	Wind speed 10 mph, direction toward intake, rest of system operates normally	Small	1433 ppm
22	Same as case 21	Same as case 21, except roof ventilators fail to close	Small	8876 ppm
23	Same as case 21	Same as case 2, except failure of fire door (behind louvers) to close	Small	876 ppm
24	Same as case 21	Same as case 21, except failure of louvers in fire door to close	Small	1433 ppm
25	Actuation of the CO_2 fire protection system in the large diesel generator room, 10,000 lb CO_2 released in 3.65 min	Wind speed 10 mph, direction toward nearest intake	Large	6281 ppm

TABLE 9.4-12 (SHEET 4 OF 4)

Case	Location and Event	Assumptions	Intakes	Maximum Concentration
26	Actuation of the CO_2 fire protection system in the small diesel generator room, 10,000 lb CO_2 released in 3.65 min	Same as case 25	Small	17,995 ppm
27	Actuation of the CO_2 fire protection system in the large oil storage room, 10,000 lb CO_2 released in 33.9 min	Same as case 25	Large	2515 ppm
28	Actuation of the CO_2 fire protection system in the small oil storage room, 10,000 lb of CO_2 released in 33.9 min	Same as case 25	Small	6824 ppm

TABLE 9.4-13

RECIRCULATION OF EXHAUST GAS TO INTAKES - ASSUMPTIONS

Wind speed of 5 m/s

Wind direction from closest exhaust directly to diesel air intake

Complete combustion of fuel

Vertical thermal jet

Final Plume rise calculated by

$$\Delta h \quad = \quad 1.6\ F^{1/3}\ (3.5x)^{2/3}\ (u)^{-1}$$

Where:

X	=	Distance to final rise (m)
U	=	Wind speed (m/s)
F	=	Buoyancy Flux (m^4/s^3)

Plume rise at diesel intake is calculated by:

$$\Delta h = \left[\left(\frac{3}{b^2{}_m} \right) \left(\frac{F_m}{u} \right) \left(\frac{x}{u} \right) + \left(\frac{3}{2b^2} \right) \left(\frac{F}{u} \right) \left(\frac{x}{u} \right)^2 \right]^{1/3}$$

Where:

β_m	=	Entrainment Coefficient (Momentum)
β	=	Entrainment Coefficient (Buoyancy)
F_m	=	Momentum Flux (m^4/s^2)
F	=	Buoyancy Flux (m^4/s^3)
u	=	wind speed (m/s)
x	=	Distance between Exhaust and Intake (m)

TABLE 9.4-14

CONCENTRATION OF CARBON DIOXIDE AT DIESEL AIR INTAKE FROM VENTILATORS

		Maximum Concentration at Air Intake	
Case	No. of Times Fan Vents Open	Duration (s)	Amount from Vent (ppm)
9	4	4	11,280
10	Stay open	--	15,412
11	0	0	0
12	5	18	13,495
13	5	8	22,157
14	Stay open	--	18,469
15	0	0	0
16	5	8	22,167
17	1	6	2150
18	Stay open	--	8169
19	1	6	1308
20	1	6	2139
21	1	2	1433
22	Stay open	--	8876
23	1	2	876
24	1	2	1433
25	3	30	6281
26	3	15	614
27	(a)	~1900	2515
28	(a)	~2000	6824

a. The ventilators have stayed closed all the time.

TABLE 9.4-15 (SHEET 1 OF 14)

CONFORMANCE TO ASME N510-1989
CONTROL ROOM EMERGENCY FILTRATION SYSTEM (CREFS)
FILTRATION FILTER UNITS

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5 VISUAL INSPECTION			
5.5.1 Guidance for Visual Inspection			
5.5.1.1(a)	Adequate access to housing.	Yes	Yes
5.5.1.1(b)*	Adequate space for personnel and equipment for maintenance and testing.	No (Not required)	Yes
5.5.1.1(c)*	Doors of rigid construction to resist unacceptable flexure under operating conditions. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(d)	Adequate seal between door and casing. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(e)	Gasket joints are dovetail type with seating surface suitable for accommodating a knife edge sealing device. *Note: The design does not include this feature. Gaskets will be inspected when housing is disassembled.*	No (See note)	Yes (See note)
5.5.1.1(f)*	Provision for opening doors from inside and outside of housing. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(g)	Adequate number and acceptable condition of operable latches on access doors to achieve uniform seating. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(h)*	Provision for locking doors. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)

TABLE 9.4-15 (SHEET 2 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.1(i)*	Adequate structural rigidity of housing to resist unacceptable flexure during operating conditions.	No (Not required)	Yes
5.5.1.1(j)*	Access to upper tiers, (above the 7 ft level), provided with permanent ladders and platforms. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(k)*	At least 3 ft clearance between banks of components for maintenance and testing. *Note: The design does not include this feature throughout the housing.*	No (Not required)	N/A (See note)
5.5.1.1(l)*	Door provided on each side, (upstream and downstream), of each component bank. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(m)*	No back-to-back installation of components. *Note: Inspection only with filter housing disassembled.*	No (Not required)	Yes (See note)
5.5.1.1(n)	Sample ports located and labeled upstream and downstream of each HEPA filter and adsorber bank.	Yes	Yes
5.5.1.1(o)	Challenge injection ports located and labeled.	Yes	Yes
5.5.1.1(p)	Sample and injection ports equipped with leak-tight caps or plugged.	Yes	Yes
5.5.1.1(q)	Housekeeping in and around housing adequate for maintenance, testing, and operation.	Yes	Yes
5.5.1.1(r)	Adequate guards provided on fans for personnel safety.	Yes	Yes
5.5.1.1(s)	Condition of flexible connection between housing and fan located external to housing adequate to prevent leakage of untreated air.	Yes	Yes
5.5.1.1(t)	Fan-shaft seals installed where required.	Yes	Yes

TABLE 9.4-15 (SHEET 3 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.1(u)	Airtight seals for conduits, electrical connections, plumbing, drains, or other conditions that could result in bypassing of the housing or any component therein. *Note: Inspect accessible/visible items. Air tightness of components that could cause bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.1(v)	No sealant or caulking of any type on/in housings or component frames. Caulking on/in ducts may be permissible depending on project specifications. *Note: Inspect only external to ducts and housing where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.1(w)	Loop seals have adequate water level. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(x)	Satisfactory condition of fire protection components (if provided). *Note: The design does not include this feature. No fire protection provided for the filtration unit filter.*	N/A (See note)	N/A (See note)
5.5.1.2 Local Instrumentation			
5.5.1.2(a)	No unacceptable damage to instrumentation (e.g., gages, manometers, thermometers, etc.).	Yes	Yes
5.5.1.2(b)	All connections complete.	Yes	Yes
5.5.1.3 Lighting, Housing			
5.5.1.3(a)	Adequate lighting provided for visual inspection of housing and components. *Note: The design does not include this feature. Temporary lighting utilized, as necessary, to perform internal, visual inspections.*	N/A (See note)	N/A (See note)

TABLE 9.4-15 (SHEET 4 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.3(b)*	Flush mounted fixtures serviceable from outside the housing. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.4 Mounting Frames for Filters and Moisture Separators			
5.5.1.4(a)*	Continuous seal weld between members or frames and between frame and housing. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (Not required)	Yes (See note)
5.5.1.4(b)*	Adequate structural rigidity for supporting internal components during operating conditions without flexure. *Note: Inspect only where accessible during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(c)	No unacceptable damage to the frames that may interfere with proper seating of components. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (See note)	Yes (See note)
5.5.1.4(d)	Sample canisters installed and unused connections capped or plugged leak-tight.	Yes	Yes
5.5.1.4(e)	No penetrations of the mounting frame except for test canisters. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes
5.5.1.4(f)	No sealant or caulking of any type. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes (See note)

TABLE 9.4-15 (SHEET 5 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Testing Conformance Following Major Modification or Repair
5.5.1.5 Filter Clamping Devices			
5.5.1.5(a)	Sufficient number of devices of adequate size to assure specified gasket compression. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (See note)	Yes (See note)
5.5.1.5(b)*	Individual clamping of filters and adsorbers. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (Not required)	Yes (See note)
5.5.1.5(c)	All clamping hardware complete and in good condition. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (See note)	Yes (See note)
5.5.1.5(d)*	Adequate clearances provided between filter and adsorber units in same bank to tighten clamping devices. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (Not required)	Yes (See note)
5.5.1.6 Moisture Separators			
5.5.1.6(a)	No unacceptable damage to media, frame, or gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(b)	No dirt or debris loading which creates higher than the specified pressure drop across the bank of components at the design airflow rate. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(c)	Proper installation of moisture separators. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)

TABLE 9.4-15 (SHEET 6 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.7 Air Heating Coils - Inside Housing			
5.5.1.7(a)	No unacceptable damage to coils which may affect operability of the heaters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.7(b)	No unacceptable dirt or debris on or between coils. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.8 Prefilters			
5.5.1.8(a)	No damage to media, frame, or gaskets which may affect operability of prefilters. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes (See note)
5.5.1.8(b)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Pressure drop will be checked by installed gauges.*	No (See note)	Yes (See note)
5.5.1.8(c)	Proper installation of prefilters. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes (See note)
5.5.1.9 HEPA Filters			
5.5.1.9(a)	No unacceptable damage to filter media. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (See note)	Yes (See note)
5.5.1.9(b)	Acceptable condition and seating of gaskets with at least 50% compression. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (See note)	Yes (See note)

TABLE 9.4-15 (SHEET 7 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.9(c)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Pressure Drop will be checked by installed pressure gauges.*	No (See note)	Yes (See note)
5.5.1.9(d)	No sealant or caulking of any type. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes (See note)
5.5.1.9(e)	Filters are properly installed with pleats vertical. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes (See note)
5.5.1.10 Adsorbers			
5.5.1.10(a)	No unacceptable damage to adsorbers or adsorbent beds. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (See note)	Yes (See note)
5.5.1.10(b)	Acceptable condition and seating of gaskets with at least 50 % compression. *Note: Not Accessible. Inspection only with filter housing disassembled. Bypass leakage will be checked by in-place testing.*	No (See note)	Yes (See note)
5.5.1.10(c)	No through bolts on Type II adsorbers or other structure that could cause bypass in an adsorber bank where visible. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes (See note)
5.5.1.10(d)	No sealant or caulking of any type. *Note: Not Accessible. Inspection only with filter housing disassembled.*	No (See note)	Yes (See note)

TABLE 9.4-15 (SHEET 8 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.11 Dampers - Housing and Associated Bypass Duct			
5.5.1.11(a)	No unacceptable damage to or distortion of frame or blades. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(b)	No missing seats or blade edging. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(c)	No unacceptable damage to shaft, pivot pins, operator linkages, operators, or packing. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(d)	Linkage connected and free from obstruction. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(e)	No unacceptable damage to gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12 Manifolds			
5.5.1.12(a)	No unacceptable damage to test manifolds. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12(b)	Adequate clearance between permanent manifolds and filters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
6.0 DUCT AND HOUSING LEAK AND STRUCTURAL CAPABILITY TESTS			
6.5 Duct and Housing Leak and Structural Capability Tests - Procedure			
6.5.1*	Structural Capability Test *Note: Testing to be conducted only on affected components.*	No (Not required)	Yes (See note)

TABLE 9.4-15 (SHEET 9 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
6.5.2*	Duct and Housing Leak Rate Test (Constant Pressure Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.3*	Duct and Housing Leak Rate Test (Pressure Decay Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.4	Bubble Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)
6.5.5	Audible Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)
6.6 Acceptance Criteria			
6.6.1	Structural Capability Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (Not required)	No (See note)

TABLE 9.4-15 (SHEET 10 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
6.6.2	Duct and Housing Leak Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (See notes for 6.5.2 and 6.5.3)	No (See note)
7.0 Mounting Frame Pressure Leak Test (Optional)		No (Optional)	No (Optional)
8 AIRFLOW CAPACITY AND DISTRIBUTION TESTS			
8.5.1. Airflow Capacity Test Procedure			
8.5.1.1	Start system fan and verify stable (no surging) fan operation for 15 min.	Yes	Yes
8.5.1.2	Measure system airflow in accordance with 2.2 or equivalent. *Note: Reference 2.2 "Industrial Ventilation: A Manual of Recommended Practice (20th Edition)" excluding figure 9-5.*	Yes (See note)	Yes (See note)
8.5.1.3*	Clean System Airflow. With the new housing components installed, or simulated, operate at the clean differential pressure and compare measured flow rate (using methods of para. 8.5.1.2) with the value specified by the test program or project specification. If the specified value cannot be achieved, report to owner.	No (Not required)	Yes

TABLE 9.4-15 (SHEET 11 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
8.5.1.4*	Maximum Housing Component Pressure Drop Airflow. After successful completion of Para. 8.5.1.3, increase housing component resistance (artificially by blanking off portions of the filter bank or by adjusting throttling dampers) until the maximum housing component pressure drop for the system (as specified in the test program or project specifications) is achieved. Measure flow rate per para. 8.5.1.2. If the maximum housing component pressure drop airflow cannot be achieved, report to owner.	No (Not required)	Yes
8.5.1.5*	Return system to “clean” condition.	No (Not required)	Yes
8.5.2	Airflow Distribution Test Procedure *NOTE: Airflow distribution tests are not required for a filter bank containing a single HEPA filter.*		
8.5.2.1*	Airflow Distribution Through HEPA Filter Banks. The minimum number of velocity measurements shall be one in the center of each filter. All measurements should be made an equal distance away from the filters. Velocity measurements should be made downstream of the filters to take advantage of the airflow distribution dampening effects of the HEPA filters. *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)

TABLE 9.4-15 (SHEET 12 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
8.5.2.2*	Airflow Distribution Through Adsorber Banks. For banks containing Type I adsorbers, the air distribution test shall follow the same procedures specified for HEPA filter banks in para. 8.5.2.1. For banks containing Type II modular trays, the air distribution test shall follow the same procedure specified for filter banks in para. 8.5.2.1, except that all velocity measurements shall be made in the plane of the face of the air channels, in the center of every open channel and an equal distance away from the adsorbers. For type III adsorbers, velocity measurements shall be made in the plane of the face of the air channels. These measurements shall be made in centers of equal area that cover the entire open face, not in excess of 12 in. between points on a channel, and an equal distance away from the adsorber. *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)
8.5.2.3*	Calculate the average of the velocity readings (Section 3) *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)
8.5.2.4*	Note the highest and lowest velocity readings and calculate the percentage they vary from the average found in para. 8.5.2.3. If acceptance criteria are exceeded, notify owner. *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)

TABLE 9.4-15 (SHEET 13 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
8.6.0 Acceptance Criteria			
8.6.1	Acceptance Criteria for Airflow Capacity Test. Airflow shall be within ± 10% of the value specified in the test program or project specifications. Maximum housing component pressure drop airflows shall be ± 10% of the value specified in the test program or project specifications with the pressure drop greater than or equal to the maximum housing component pressure drop. For systems with carbon adsorbers, the maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15). *Notes:* *(1) Applies only to sections 8.5.1.1 and 8.5.1.2.* *(2) Maximum housing component pressure drops will be based on those that result in the system maintaining the TS flowrate ±10%.*	Yes (See note 1)	Yes (See note 2)
8.6.2*	Airflow Distribution Test. No velocity readings shall exceed ± 20% of the calculated average. For system with carbon adsorbers, maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test. (Section 15) *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)
9.0	AIR-AEROSOL MIXING UNIFORMITY TEST *Note: This is a single HEPA system and this test does not apply.*	N/A (See note)	N/A (See note)
10.0	HEPA FILTER BANK IN-PLACE TEST	Yes	Yes
11.0	ADSORBER BANK IN-PLACE LEAK TEST	Yes	Yes

TABLE 9.4-15 (SHEET 14 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
12.0	DUCT DAMPER BYPASS TEST *Note: System design does not include bypass damper.*	N/A (See note)	N/A (See note)
13.0	SYSTEM BYPASS TEST *Note: Tests performed per Section 10 satisfy Section 13 test requirements.*	N/A (See note)	N/A (See note)
14.0	Air Heater Performance Test *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
15.0	LABORATORY TESTING OF ADSORBENT *Note: Laboratory testing will be performed in accordance with ASTM D3803-1989.*	Yes (See note)	Yes (See note)

* ASME N510-1989 clearly delineates these steps are intended for acceptance tests performed after any major system modification or major repair.

TABLE 9.4-16 (SHEET 1 OF 14)

CONFORMANCE TO ASME N510-1989
CONTROL ROOM EMERGENCY FILTRATION SYSTEM (CREFS)
PRESSURIZATION FILTER UNITS

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5 VISUAL INSPECTION			
5.5.1 Guidance for Visual Inspection			
5.5.1.1(a)	Adequate access to housing.	Yes	Yes
5.5.1.1(b)*	Adequate space for personnel and equipment for maintenance and testing.	No (Not required)	Yes
5.5.1.1(c)*	Doors of rigid construction to resist unacceptable flexure under operating conditions. *Note: The pressurization unit has bolted access panels.*	No (Not required)	Yes (See note)
5.5.1.1(d)	Adequate seal between door and casing. *Note: The pressurization unit has bolted access panels.*	Yes (See note)	Yes (See note)
5.5.1.1(e)	Gasket joints are dovetail type with seating surface suitable for accommodating a knife edge sealing device. *Note: Gaskets are not dovetail type. The pressurization unit has bolted access panels with flat gaskets with flat surface seal on filter housing.*	Yes (See note)	Yes (See note)
5.5.1.1(f)*	Provision for opening doors from inside and outside of housing. *Note: The design does not include this feature. The pressurization unit has bolted access panels.*	No (Not required)	N/A (See note)
5.5.1.1(g)	Adequate number and acceptable condition of operable latches on access doors to achieve uniform seating. *Note: The design does not include this feature. The pressurization unit has bolted access panels.*	N/A (See note)	N/A (See note)

TABLE 9.4-16 (SHEET 2 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.1(h)*	Provision for locking doors. *Note: The design does not include this feature. The pressurization unit has bolted access panels.*	No (Not required)	N/A (See note)
5.5.1.1(i)*	Adequate structural rigidity of housing to resist unacceptable flexure during operating conditions.	No (Not required)	Yes
5.5.1.1(j)*	Access to upper tiers, (above the 7 ft level), provided with permanent ladders and platforms. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(k)*	At least 3 ft clearance between banks of components for maintenance and testing. *Note: The pressurization units have less than 3 feet between some banks by design.*	No (Not required)	N/A (See note)
5.5.1.1(l)*	Door provided on each side, (upstream and downstream), of each component bank. *Note: The pressurization unit has bolted access panels. There is no door downstream of the HEPA filter.*	No (Not required)	Yes (See note)
5.5.1.1(m)*	No back-to-back installation of components.	No (Not required)	Yes
5.5.1.1(n)	Sample ports located and labeled upstream and downstream of each HEPA filter and adsorber bank.	Yes	Yes
5.5.1.1(o)	Challenge injection ports located and labeled.	Yes	Yes
5.5.1.1(p)	Sample and injection ports equipped with leak-tight caps or plugged.	Yes	Yes
5.5.1.1(q)	Housekeeping in and around housing adequate for maintenance, testing, and operation.	Yes	Yes
5.5.1.1(r)	Adequate guards provided on fans for personnel safety.	Yes	Yes

TABLE 9.4-16 (SHEET 3 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.1(s)	Condition of flexible connection between housing and fan located external to housing adequate to prevent leakage of untreated air. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(t)	Fan-shaft seals installed where required.	Yes	Yes
5.5.1.1(u)	Airtight seals for conduits, electrical connections, plumbing, drains, or other conditions that could result in bypassing of the housing or any component therein. *Note: Inspect accessible/visible items. Air tightness of components that could cause bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.1(v)	No sealant or caulking of any type on/in housings or component frames. Caulking on/in ducts may be permissible depending on project specifications. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.1(w)	Loop seals have adequate water level. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(x)	Satisfactory condition of fire protection components (if provided). *Note: The design does not include this feature. No fire protection provided for the pressurization unit filter.*	N/A (See note)	N/A (See note)
5.5.1.2 Local Instrumentation			
5.5.1.2(a)	No unacceptable damage to instrumentation (e.g., gages, manometers, thermometers, etc.).	Yes	Yes
5.5.1.2(b)	All connections complete.	Yes	Yes

TABLE 9.4-16 (SHEET 4 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.3 Lighting, Housing			
5.5.1.3(a)	Adequate lighting provided for visual inspection of housing and components. *Note: The design does not include this feature. Temporary lighting utilized, as necessary, to perform internal, visual inspections.*	N/A (See note)	N/A (See note)
5.5.1.3(b)*	Flush mounted fixtures serviceable from outside the housing. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.4 Mounting Frames for Filters and Moisture Separators			
5.5.1.4(a)*	Continuous seal weld between members or frames and between frame and housing. *Note: Inspect only where accessible during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(b)*	Adequate structural rigidity for supporting internal components during operating conditions without flexure. *Note: Inspect only where accessible during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(c)	No unacceptable damage to the frames that may interfere with proper seating of components.	Yes	Yes
5.5.1.4(d)	Sample canisters installed and unused connections capped or plugged leak-tight. *Note: Pressurization unit contains internal sample canisters. Check that internal unused connections are sealed.*	Yes (See note)	Yes (See note)
5.5.1.4(e)	No penetrations of the mounting frame except for test canisters.	Yes	Yes
5.5.1.4(f)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)

TABLE 9.4-16 (SHEET 5 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.5 Filter Clamping Devices			
5.5.1.5(a)	Sufficient number of devices of adequate size to assure specified gasket compression.	Yes	Yes
5.5.1.5(b)*	Individual clamping of filters and adsorbers.	No (Not required)	Yes
5.5.1.5(c)	All clamping hardware complete and in good condition.	Yes	Yes
5.5.1.5(d)*	Adequate clearances provided between filter and adsorber units in same bank to tighten clamping devices.	No (Not required)	Yes
5.5.1.6 Moisture Separators			
5.5.1.6(a)	No unacceptable damage to media, frame, or gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(b)	No dirt or debris loading which creates higher than the specified pressure drop across the bank of components at the design airflow rate. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(c)	Proper installation of moisture separators. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.7 Air Heating Coils - Inside Housing			
5.5.1.7(a)	No unacceptable damage to coils which may affect operability of the heaters.	Yes	Yes
5.5.1.7(b)	No unacceptable dirt or debris on or between coils.	Yes	Yes

TABLE 9.4-16 (SHEET 6 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.8 Prefilters			
5.5.1.8(a)	No damage to media, frame, or gaskets which may affect operability of prefilters	Yes	Yes
5.5.1.8(b)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Inspect for visible loading - pressure drop will be checked by installed gauges.*	Yes (See note)	Yes (See note)
5.5.1.8(c)	Proper installation of prefilters.	Yes	Yes
5.5.1.9 HEPA Filters			
5.5.1.9(a)	No unacceptable damage to filter media.	Yes	Yes
5.5.1.9(b)	Acceptable condition and seating of gaskets with at least 50% compression. *Note: HEPAs have self adjusting clamps-inspect clamps and visually confirm that gaskets appear tight. Bypass leakage will be checked by in-place leak testing.*	Yes (See note)	Yes (See note)
5.5.1.9(c)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Inspect upstream side for visible loading - pressure drop will be checked by installed pressure gauges.*	Yes (See note)	Yes (See note)
5.5.1.9(d)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.9(e)	Filters are properly installed with pleats vertical.	Yes	Yes
5.5.1.10 Adsorbers			
5.5.1.10(a)	No unacceptable damage to adsorbers or adsorbent beds.	Yes	Yes

TABLE 9.4-16 (SHEET 7 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.10(b)	Acceptable condition and seating of gaskets with at least 50 % compression. *Note: The pressurization unit design is Type III adsorbers. Bypass leakage will be checked by in-place leak testing.*	N/A (See note)	N/A (See note)
5.5.1.10(c)	No through bolts on Type II adsorbers or other structure that could cause bypass in an adsorber bank where visible. *Note: The pressurization unit design does not have through-bolts. Type III adsorbers.*	N/A (See note)	N/A (See note)
5.5.1.10(d)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.11 Dampers - Housing and Associated Bypass Duct			
5.5.1.11(a)	No unacceptable damage to or distortion of frame or blades. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(b)	No missing seats or blade edging. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(c)	No unacceptable damage to shaft, pivot pins, operator linkages, operators, or packing. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(d)	Linkage connected and free from obstruction. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(e)	No unacceptable damage to gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12 Manifolds			
5.5.1.12(a)	No unacceptable damage to test manifolds. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)

TABLE 9.4-16 (SHEET 8 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.12(b)	Adequate clearance between permanent manifolds and filters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
6.0 DUCT AND HOUSING LEAK AND STRUCTURAL CAPABILITY TESTS			
6.5.1*	Structural Capability Test *Note: Testing to be conducted only on affected components.*	No (Not required)	Yes (See note)
6.5.2*	Duct and Housing Leak Rate Test (Constant Pressure Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.3*	Duct and Housing Leak Rate Test (Pressure Decay Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.4	Bubble Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)
6.5.5	Audible Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)

TABLE 9.4-16 (SHEET 9 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
6.6 Acceptance Criteria			
6.6.1	Structural Capability Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (Not required)	No (See note)
6.6.2	Duct and Housing Leak Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (See Notes for 6.5.2 and 6.5.3)	No (See note)
7.0 Mounting Frame Pressure Leak Test (Optional)		No (Optional)	No (Optional)
8.0 AIRFLOW CAPACITY AND DISTRIBUTION TESTS			
8.5.1 Airflow Capacity Test Procedure			
8.5.1.1	Start system fan and verify stable (no surging) fan operation for 15 min.	Yes	Yes
8.5.1.2	Measure system airflow in accordance with 2.2 or equivalent. *Note: Reference 2.2 "Industrial Ventilation: A Manual of Recommended Practice (20th Edition)" excluding figure 9-5.*	Yes (See note)	Yes (See note)

TABLE 9.4-16 (SHEET 10 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
8.5.1.3*	Clean System Airflow. With the new housing components installed, or simulated, operate at the clean differential pressure and compare measured flow rate (using methods of para. 8.5.1.2) with the value specified by the test program or project specification. If the specified value cannot be achieved, report to owner.	No (Not required)	Yes
8.5.1.4*	Maximum Housing Component Pressure Drop Airflow. After successful completion of para. 8.5.1.3, increase housing component resistance (artificially by blanking off portions of the filter bank or by adjusting throttling dampers) until the maximum housing component pressure drop for the system (as specified in the test program or project specifications) is achieved. Measure flow rate per para. 8.5.1.2. If the maximum housing component pressure drop airflow cannot be achieved, report to owner.	No (Not required)	Yes
8.5.1.5*	Return system to “clean” condition.	No (Not required)	Yes
8.5.2	Airflow Distribution Test Procedure *NOTE: Airflow distribution tests are not required for a filter bank containing a single HEPA filter.*		
8.5.2.1*	Airflow Distribution Through HEPA Filter Banks. The minimum number of velocity measurements shall be one in the center of each filter. All measurements should be made an equal distance away from the filters. Velocity measurements should be made downstream of the filters to take advantage of the airflow distribution dampening effects of the HEPA filters. *Note: This test will not be performed due to a single HEPA.*	No (Not required)	N/A

TABLE 9.4-16 (SHEET 11 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
8.5.2.2*	Airflow Distribution Through Adsorber Banks. For banks containing Type I adsorbers, the air distribution test shall follow the same procedures specified for HEPA filter banks in para. 8.5.2.1. For banks containing Type II modular trays, the air distribution test shall follow the same procedure specified for filter banks in para. 8.5.2.1, except that all velocity measurements shall be made in the plane of the face of the air channels, in the center of every open channel and an equal distance away from the adsorbers. For type III adsorbers, velocity measurements shall be made in the plane of the face of the air channels. These measurements shall be made in centers of equal area that cover the entire open face, not in excess of 12 in. between points on a channel, and an equal distance away from the adsorber. *Note: This test will not be performed due to a single HEPA.*	No (Not required)	N/A (See Note)
8.5.2.3*	Calculate the average of the velocity readings (Section 3) *Note: This test will not be performed due to a single HEPA.*	No (Not required)	N/A (See Note)
8.5.2.4*	Note the highest and lowest velocity readings and calculate the percentage they vary from the average found in para. 8.5.2.3. If acceptance criteria are exceeded, notify owner. *Note: This test will not be performed due to a single HEPA.*	No (Not required)	N/A (See Note)

TABLE 9.4-16 (SHEET 12 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Testing Conformance Following Major Modification or Repair
8.6.0 Acceptance Criteria			
8.6.1	Acceptance Criteria for Airflow Capacity Test. Airflow shall be within + 10% of the value specified in the test program or project specifications. Maximum housing component pressure drop airflows shall be + 10% of the value specified in the test program or project specifications with the pressure drop greater than or equal to the maximum housing component pressure drop. For systems with carbon adsorbers, the maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15). *Notes:* *(1) Applies only to sections 8.5.1.1 and 8.5.1.2.* *(2) Maximum housing component pressure drops will be based on those that result in the system maintaining the TS flowrate ±10%.* *(3) Air flow shall be within +25% to -10% of specified value.*	Yes (See Notes 1 and 3)	Yes (See Notes 2 and 3)
8.6.2*	Airflow Distribution Test. No velocity readings shall exceed + 20% of the calculated average. For system with carbon adsorbers, maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test. (Section 15) *Note: This test will not be performed due to a single HEPA*	No (Not required)	N/A (See Note)
9.0	AIR-AEROSOL MIXING UNIFORMITY TEST *Note: This is a single HEPA system and this test is not applicable.*	N/A (See Note)	N/A (See Note)
10.0	HEPA FILTER BANK IN-PLACE TEST	Yes	Yes

TABLE 9.4-16 (SHEET 13 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
11.0	ADSORBER BANK IN-PLACE LEAK TEST	Yes	Yes
12.0	DUCT DAMPER BYPASS TEST *Note: System design does not include bypass damper.*	N/A (See Note)	N/A (See Note)
13.0	SYSTEM BYPASS TEST *Note: Tests performed per Section 10 satisfy Section 13 test requirements.*	N/A (See Note)	N/A (See Note)
14.0 AIR HEATER PERFORMANCE TEST			
14.3 Prerequisites			
14.3.1	Prerequisite: Visual inspection of the heater is completed (para. 5.5.1.7).	Yes	Yes
14.3.2	Prerequisite: Electrical control and feed power is available and all safety interlocks have been checked.	Yes	Yes
14.5 Procedure			
14.5.1	With power on, and system operating at rated flow, measure the voltage and current of all power circuits.	Yes	Yes
14.5.2	With heater energized and system operating at rated airflow, measure the temperature of the entering and leaving air. A sufficient number of measurements shall be taken to determine average entering and leaving temperatures.	Yes	Yes
14.5.3	If measured values do not meet acceptance criteria, notify the owner.	Yes	Yes

TABLE 9.4-16 (SHEET 14 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Testing Conformance Following Major Modification or Repair
14.6 Acceptance Criteria			
14.6.1	Operating currents, voltages and change in temperature shall be within the limits of test program or project specifications.	Yes	Yes
15.0	LABORATORY TESTING OF ADSORBENT *Note: Laboratory testing will be performed in accordance with ASTM D3803-1989.*	Yes (See note)	Yes (See note)

* ASME N510-1989 clearly delineates these steps are intended for acceptance tests performed after any major system modification or major repair.

TABLE 9.4-17 (SHEET 1 OF 13)

CONFORMANCE TO ASME N510-1989
CONTROL ROOM EMERGENCY FILTRATION SYSTEM (CREFS)
RECIRCULATION FILTER UNITS

		Testing Conformance	
N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Routine Surveillance	Following Major Modification or Repair
5 VISUAL INSPECTION			
5.5.1 Guidance for Visual Inspection			
5.5.1.1(a)	Adequate access to housing.	Yes	Yes
5.5.1.1(b)*	Adequate space for personnel and equipment for maintenance and testing.	No (Not required)	Yes
5.5.1.1(c)*	Doors of rigid construction to resist unacceptable flexure under operating conditions.	No (Not required)	Yes
5.5.1.1(d)	Adequate seal between door and casing.	Yes	Yes
5.5.1.1(e)	Gasket joints are dovetail type with seating surface suitable for accommodating a knife edge sealing device. *Note: Gaskets are not dovetail type - inspect gaskets for seating surface.*	Yes (See note)	Yes (See note)
5.5.1.1(f)*	Provision for opening doors from inside and outside of housing.	No (Not required)	Yes
5.5.1.1(g)	Adequate number and acceptable condition of operable latches on access doors to achieve uniform seating.	Yes	Yes
5.5.1.1(h)*	Provision for locking doors.	No (Not required)	Yes
5.5.1.1(i)*	Adequate structural rigidity of housing to resist unacceptable flexure during operating conditions.	No (Not required)	Yes

TABLE 9.4-17 (SHEET 2 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Testing Conformance Following Major Modification or Repair
5.5.1.1(j)*	Access to upper tiers, (above the 7 ft level), provided with permanent ladders and platforms. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(k)*	At least 3 ft clearance between banks of components for maintenance and testing. *Note: Units have less than 3 feet between some banks by design.*	No (Not required)	N/A (See note)
5.5.1.1(l)*	Door provided on each side, (upstream and downstream), of each component bank. *Note: No door upstream of prefilter.*	No (Not required)	Yes (See note)
5.5.1.1(m)*	No back-to-back installation of components.	No (Not required)	Yes
5.5.1.1(n)	Sample ports located and labeled upstream and downstream of each HEPA filter and adsorber bank.	Yes	Yes
5.5.1.1(o)	Challenge injection ports located and labeled.	Yes	Yes
5.5.1.1(p)	Sample and injection ports equipped with leak-tight caps or plugged.	Yes	Yes
5.5.1.1(q)	Housekeeping in and around housing adequate for maintenance, testing, and operation.	Yes	Yes
5.5.1.1(r)	Adequate guards provided on fans for personnel safety. *Note: The design does not include this feature (direct drive vane axial fan).*	N/A (See note)	N/A (See note)
5.5.1.1(s)	Condition of flexible connection between housing and fan located external to housing adequate to prevent leakage of untreated air. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(t)	Fan-shaft seals installed where required. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)

TABLE 9.4-17 (SHEET 3 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.1(u)	Airtight seals for conduits, electrical connections, plumbing, drains, or other conditions that could result in bypassing of the housing or any component therein. *Note: Inspect accessible/visible items. Air tightness of components that could cause bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.1(v)	No sealant or caulking of any type on/in housings or component frames. Caulking on/in ducts may be permissible depending on project specifications. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.1(w)	Loop seals have adequate water level. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(x)	Satisfactory condition of fire protection components (if provided). *Note: The design does not include this feature. No fire protection provided.*	N/A (See note)	N/A (See note)
5.5.1.2 Local Instrumentation			
5.5.1.2(a)	No unacceptable damage to instrumentation (e.g., gages, manometers, thermometers, etc.).	Yes	Yes
5.5.1.2(b)	All connections complete.	Yes	Yes
5.5.1.3 Lighting, Housing			
5.5.1.3(a)	Adequate lighting provided for visual inspection of housing and components.	Yes	Yes
5.5.1.3(b)*	Flush mounted fixtures serviceable from outside the housing.	No (Not required)	Yes

TABLE 9.4-17 (SHEET 4 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.4 Mounting Frames for Filters and Moisture Separators			
5.5.1.4(a)*	Continuous seal weld between members or frames and between frame and housing. *Note: Inspect only where accessible during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(b)*	Adequate structural rigidity for supporting internal components during operating conditions without flexure. *Note: Inspect only where accessible during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(c)	No unacceptable damage to the frames that may interfere with proper seating of components.	Yes	Yes
5.5.1.4(d)	Sample canisters installed and unused connections capped or plugged leak-tight. *Note: Filter unit contains internal sample canisters. Check that unused connections are sealed.*	Yes (See note)	Yes (See note)
5.5.1.4(e)	No penetrations of the mounting frame except for test canisters.	Yes	Yes
5.5.1.4(f)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.5 Filter Clamping Devices			
5.5.1.5(a)	Sufficient number of devices of adequate size to assure specified gasket compression.	Yes	Yes
5.5.1.5(b)*	Individual clamping of filters and adsorbers. *Note: Adsorber is type III filter.*	No (Not required)	Yes (See note)
5.5.1.5(c)	All clamping hardware complete and in good condition.	Yes	Yes

TABLE 9.4-17 (SHEET 5 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.5(d)*	Adequate clearances provided between filter and adsorber units in same bank to tighten clamping devices.	No (Not required)	Yes
5.5.1.6 Moisture Separators			
5.5.1.6(a)	No unacceptable damage to media, frame, or gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(b)	No dirt or debris loading which creates higher than the specified pressure drop across the bank of components at the design airflow rate. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(c)	Proper installation of moisture separators. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.7 Air Heating Coils - Inside Housing			
5.5.1.7(a)	No unacceptable damage to coils which may affect operability of the heaters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.7(b)	No unacceptable dirt or debris on or between coils. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.8 Prefilters			
5.5.1.8(a)	No damage to media, frame, or gaskets which may affect operability of prefilters.	Yes	Yes

TABLE 9.4-17 (SHEET 6 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Testing Conformance Following Major Modification or Repair
5.5.1.8(b)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Inspect for visible loading - pressure drop will be checked by installed gauges.*	Yes (See note)	Yes (See note)
5.5.1.8(c)	Proper installation of prefilters.	Yes	Yes
5.5.1.9 HEPA Filters			
5.5.1.9(a)	No unacceptable damage to filter media.	Yes	Yes
5.5.1.9(b)	Acceptable condition and seating of gaskets with at least 50% compression. *Note: Visually confirm that gaskets appear tight. Bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.9(c)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Inspect upstream side for visible loading - pressure drop will be checked by installed pressure gauges.*	Yes (See note)	Yes (See note)
5.5.1.9(d)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.9(e)	Filters are properly installed with pleats vertical.	Yes	Yes
5.5.1.10 Adsorbers			
5.5.1.10(a)	No unacceptable damage to adsorbers or adsorbent beds.	Yes	Yes
5.5.1.10(b)	Acceptable condition and seating of gaskets with at least 50 % compression. *Note: Adsorber is Type III. Bypass leakage will be checked by in-place testing.*	N/A (See note)	N/A (See note)

TABLE 9.4-17 (SHEET 7 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.10(c)	No through bolts on Type II adsorbers or other structure that could cause bypass in an adsorber bank where visible. *Note: Adsorber is type III.*	N/A (See note)	N/A (See note)
5.5.1.10(d)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.11 Dampers - Housing and Associated Bypass Duct			
5.5.1.11(a)	No unacceptable damage to or distortion of frame or blades. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(b)	No missing seats or blade edging. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(c)	No unacceptable damage to shaft, pivot pins, operator linkages, operators, or packing. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(d)	Linkage connected and free from obstruction. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(e)	No unacceptable damage to gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12 Manifolds			
5.5.1.12(a)	No unacceptable damage to test manifolds. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12(b)	Adequate clearance between permanent manifolds and filters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)

TABLE 9.4-17 (SHEET 8 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
6.0 DUCT AND HOUSING LEAK AND STRUCTURAL CAPABILITY TESTS			
6.5 Duct And Housing Leak And Structural Capability Tests - Procedure			
6.5.1*	Structural Capability Test *Note: Testing to be conducted only on affected components.*	No (Not required)	Yes (See note)
6.5.2*	Duct and Housing Leak Rate Test (Constant Pressure Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.3*	Duct and Housing Leak Rate Test (Pressure Decay Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.4	Bubble Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)
6.5.5	Audible Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)

TABLE 9.4-17 (SHEET 9 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
6.6 Acceptance Criteria			
6.6.1	Structural Capability Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (Not required)	No (See note)
6.6.2	Duct and Housing Leak Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (See notes for 6.5.2 and 6.5.3)	No (See note)
7.0 MOUNTING FRAME PRESSURE LEAK TEST (OPTIONAL)		No (Optional)	No (Optional)
8 AIRFLOW CAPACITY AND DISTRIBUTION TESTS			
8.5.1 Airflow Capacity Test Procedure			
8.5.1.1	Start system fan and verify stable (no surging) fan operation for 15 min.	Yes	Yes
8.5.1.2	Measure system airflow in accordance with 2.2 or equivalent. *Note: Reference 2.2 "Industrial Ventilation: A Manual of Recommended Practice (20th Edition)" excluding figure 9-5.*	Yes (See note)	Yes (See note)
8.5.1.3*	Clean System Airflow. With the new housing components installed, or simulated, operate at the clean differential pressure and compare measured flow rate (using methods of para.	No (Not required)	Yes

TABLE 9.4-17 (SHEET 10 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
	8.5.1.2) with the value specified by the test program or project specification. If the specified value cannot be achieved, report to owner.		
8.5.1.4*	Maximum Housing Component Pressure Drop Airflow. After successful completion of para. 8.5.1.3, increase housing component resistance (artificially by blanking off portions of the filter bank or by adjusting throttling dampers) until the maximum housing component pressure drop for the system (as specified in the test program or project specifications) is achieved. Measure flow rate per para. 8.5.1.2. If the maximum housing component pressure drop airflow cannot be achieved, report to owner.	No (Not required)	Yes
8.5.1.5*	Return system to “clean” condition.	No (Not required)	Yes
8.5.2 Airflow Distribution Test Procedure *NOTE: Airflow distribution tests are not required for a filter bank containing a single HEPA filter*.			
8.5.2.1*	Airflow Distribution Through HEPA Filter Banks. The minimum number of velocity measurements shall be one in the center of each filter. All measurements should be made an equal distance away from the filters. Velocity measurements should be made downstream of the filters to take advantage of the airflow distribution dampening effects of the HEPA filters.	No (Not required)	Yes

TABLE 9.4-17 (SHEET 11 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
8.5.2.2*	Airflow Distribution Through Adsorber Banks. For banks containing Type I adsorbers, the air distribution test shall follow the same procedures specified for HEPA filter banks in para. 8.5.2.1. For banks containing Type II modular trays, the air distribution test shall follow the same procedure specified for filter banks in para. 8.5.2.1, except that all velocity measurements shall be made in the plane of the face of the air channels, in the center of every open channel and an equal distance away from the adsorbers. For type III adsorbers, velocity measurements shall be made in the plane of the face of the air channels. These measurements shall be made in centers of equal area that cover the entire open face, not in excess of 12 in. between points on a channel, and an equal distance away from the adsorber.	No (Not required)	Yes
8.5.2.3*	Calculate the average of the velocity readings (Section 3).	No (Not required)	Yes
8.5.2.4*	*Note the highest and lowest velocity readings and calculate the percentage they vary from the average found in para. 8.5.2.3. If acceptance criteria are exceeded, notify owner.*	No (Not required)	Yes

TABLE 9.4-17 (SHEET 12 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Following Major Modification or Repair
8.6.0 Acceptance Criteria			
8.6.1	Acceptance Criteria for Airflow Capacity Test. Airflow shall be within ± 10% of the value specified in the test program or project specifications. Maximum housing component pressure drop airflows shall be ± 10% of the value specified in the test program or project specifications with the pressure drop greater than or equal to the maximum housing component pressure drop. For systems with carbon adsorbers, the maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15). *Notes:* *(1) Applies only to sections 8.5.1.1 and 8.5.1.2.* *(2) Maximum housing component pressure drops will be based on those that result in the system maintaining the TS flowrate ±10%.*	Yes (See note 1)	Yes (See note 2)
8.6.2*	Airflow Distribution Test. No velocity readings shall exceed ± 20% of the calculated average. For system with carbon adsorbers, maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15).	No (Not required)	Yes
9.0	AIR-AEROSOL MIXING UNIFORMITY TEST *Note: Test will be performed only following relocation of the challenge gas injection port or upstream sample port or major modifications or repair that may affect flow distribution.*	No (Not required)	Yes (See note)
10.0	HEPA FILTER BANK IN-PLACE TEST	Yes	Yes

TABLE 9.4-17 (SHEET 13 OF 13)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
11.0	ADSORBER BANK IN-PLACE LEAK TEST	Yes	Yes
12.0	DUCT DAMPER BYPASS TEST *Note: System design does not include bypass damper.*	N/A (See note)	N/A (See note)
13.0	SYSTEM BYPASS TEST *Note: Tests performed per Section 10 satisfy Section 13 test requirements.*	N/A (See note)	N/A (See note)
14	Air Heater Performance Test *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
15.0	LABORATORY TESTING OF ADSORBENT *Note: Laboratory testing will be performed in accordance with ASTM D3803-1989.*	Yes (See note)	Yes (See note)

* ASME N510-1989 clearly delineates these steps are intended for acceptance tests performed after any major system modification or major repair.

TABLE 9.4-18 (SHEET 1 OF 14)

CONFORMANCE TO ASME N510-1989
PENETRATION ROOM FILTRATION (PRF)
SYSTEM FILTER UNITS

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5 VISUAL INSPECTION			
5.5.1 Guidance for Visual Inspection			
5.5.1.1(a)	Adequate access to housing.	Yes	Yes
5.5.1.1(b)*	Adequate space for personnel and equipment for maintenance and testing.	No (Not required)	Yes
5.5.1.1(c)*	Doors of rigid construction to resist unacceptable flexure under operating conditions.	No (Not required)	Yes
5.5.1.1(d)	Adequate seal between door and casing.	Yes	Yes
5.5.1.1(e)	Gasket joints are dovetail type with seating surface suitable for accommodating a knife edge sealing device. *Note: Gaskets are not dovetail type - inspect gaskets for seating surface.*	Yes (See note)	Yes (See note)
5.5.1.1(f)*	Provision for opening doors from inside and outside of housing.	No (Not required)	Yes
5.5.1.1(g)	Adequate number and acceptable condition of operable latches on access doors to achieve uniform seating.	Yes	Yes
5.5.1.1(h)*	Provision for locking doors.	No (Not required)	Yes
5.5.1.1(i)*	Adequate structural rigidity of housing to resist unacceptable flexure during operating conditions.	No (Not required)	Yes

TABLE 9.4-18 (SHEET 2 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.1(j)*	Access to upper tiers, (above the 7 ft level), provided with permanent ladders and platforms. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(k)*	At least 3 ft clearance between banks of components for maintenance and testing. *Note: PRF units have less than 3 feet between some banks by design.*	No (Not required)	N/A (See note)
5.5.1.1(l)*	Door provided on each side, (upstream and downstream), of each component bank. *Note: None provided for section between HEPA and carbon filters.*	No (Not required)	Yes (See note)
5.5.1.1(m)*	No back-to-back installation of components.	No (Not required)	Yes
5.5.1.1(n)	Sample ports located and labeled upstream and downstream of each HEPA filter and adsorber bank.	Yes	Yes
5.5.1.1(o)	Challenge injection ports located and labeled.	Yes	Yes
5.5.1.1(p)	Sample and injection ports equipped with leak-tight caps or plugged.	Yes	Yes
5.5.1.1(q)	Housekeeping in and around housing adequate for maintenance, testing, and operation.	Yes	Yes
5.5.1.1(r)	Adequate guards provided on fans for personnel safety.	Yes	Yes
5.5.1.1(s)	Condition of flexible connection between housing and fan located external to housing adequate to prevent leakage of untreated air.	Yes	Yes
5.5.1.1(t)	Fan-shaft seals installed where required.	Yes	Yes

TABLE 9.4-18 (SHEET 3 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.1(u)	Airtight seals for conduits, electrical connections, plumbing, drains, or other conditions that could result in bypassing of the housing or any component therein. *Note: Inspect accessible/visible items. Air tightness of components that could cause bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.1(v)	No sealant or caulking of any type on/in housings or component frames. Caulking on/in ducts may be permissible depending on project specifications. *Note: Inspect only where accessible during inspections. Adhesive on flexible fan boot is acceptable.*	Yes (See note)	Yes (See note)
5.5.1.1(w)	Loop seals have adequate water level. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(x)	Satisfactory condition of fire protection components (if provided). *Note: The design does not include this feature. No fire protection provided for PRF filter.*	N/A (See note)	N/A (See note)
5.5.1.2 Local Instrumentation			
5.5.1.2(a)	No unacceptable damage to instrumentation (e.g., gages, manometers, thermometers, etc.).	Yes	Yes
5.5.1.2(b)	All connections complete.	Yes	Yes
5.5.1.3 Lighting, Housing			
5.5.1.3(a)	Adequate lighting provided for visual inspection of housing and components. *Note: The design does not include this feature. Temporary lighting utilized, as necessary, to perform internal, visual inspections.*	N/A (See note)	N/A (See note)

TABLE 9.4-18 (SHEET 4 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Following Major Modification or Repair
5.5.1.3(b)*	Flush mounted fixtures serviceable from outside the housing. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.4 Mounting Frames for Filters and Moisture Separators			
5.5.1.4(a)*	Continuous seal weld between members or frames and between frame and housing. *Note: Inspect only where accessible during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(b)*	Adequate structural rigidity for supporting internal components during operating conditions without flexure. *Note: Inspect only where accessible during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(c)	No unacceptable damage to the frames that may interfere with proper seating of components.	Yes	Yes
5.5.1.4(d)	Sample canisters installed and unused connections capped or plugged leak-tight.	Yes	Yes
5.5.1.4(e)	No penetrations of the mounting frame except for test canisters.	Yes	Yes
5.5.1.4(f)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.5 Filter Clamping Devices			
5.5.1.5(a)	Sufficient number of devices of adequate size to assure specified gasket compression.	Yes	Yes
5.5.1.5(b)*	Individual clamping of filters and adsorbers.	No (Not required)	Yes
5.5.1.5(c)	All clamping hardware complete and in good condition.	Yes	Yes

TABLE 9.4-18 (SHEET 5 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.5(d)*	Adequate clearances provided between filter and adsorber units in same bank to tighten clamping devices.	No (Not required)	Yes
5.5.1.6 Moisture Separators			
5.5.1.6(a)	No unacceptable damage to media, frame, or gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(b)	No dirt or debris loading which creates higher than the specified pressure drop across the bank of components at the design airflow rate. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(c)	Proper installation of moisture separators. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.7 Air Heating Coils - Inside Housing			
5.5.1.7(a)	No unacceptable damage to coils which may affect operability of the heaters.	Yes	Yes
5.5.1.7(b)	No unacceptable dirt or debris on or between coils.	Yes	Yes
5.5.1.8 Prefilters			
5.5.1.8(a)	No damage to media, frame, or gaskets which may affect operability of prefilters.	Yes	Yes
5.5.1.8(b)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Inspect for visible loading - pressure drop will be checked by installed gauges.*	Yes (See note)	Yes (See note)

TABLE 9.4-18 (SHEET 6 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
5.5.1.8(c)	Proper installation of prefilters.	Yes	Yes
5.5.1.9 HEPA Filters			
5.5.1.9(a)	No unacceptable damage to filter media.	Yes	Yes
5.5.1.9(b)	Acceptable condition and seating of gaskets with at least 50% compression. *Note: HEPAs have self adjusting clamps-inspect clamps and visually confirm that gaskets appear tight. Bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.9(c)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Inspect upstream side for visible loading - pressure drop will be checked by installed pressure gauges.*	Yes (See note)	Yes (See note)
5.5.1.9(d)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.9(e)	Filters are properly installed with pleats vertical.	Yes	Yes
5.5.1.10 Adsorbers			
5.5.1.10(a)	No unacceptable damage to adsorbers or adsorbent beds.	Yes	Yes
5.5.1.10(b)	Acceptable condition and seating of gaskets with at least 50 % compression. *Note: Visually confirm that gaskets appear tight. Bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.10(c)	No through bolts on Type II adsorbers or other structure that could cause bypass in an adsorber bank where visible. *Note: PRF design does not have through-bolts.*	N/A (See note)	N/A (See note)

TABLE 9.4-18 (SHEET 7 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
5.5.1.10(d)	No sealant or caulking of any type. *Note: Inspect only where accessible during inspections.*	Yes (See note)	Yes (See note)
5.5.1.11 Dampers - Housing and Associated Bypass Duct			
5.5.1.11(a)	No unacceptable damage to or distortion of frame or blades. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(b)	No missing seats or blade edging. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(c)	No unacceptable damage to shaft, pivot pins, operator linkages, operators, or packing. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(d)	Linkage connected and free from obstruction. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(e)	No unacceptable damage to gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12 Manifolds			
5.5.1.12(a)	No unacceptable damage to test manifolds. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12(b)	Adequate clearance between permanent manifolds and filters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
6.0 DUCT AND HOUSING LEAK AND STRUCTURAL CAPABILITY TESTS			
6.5 Duct And Housing Leak And Structural Capability Tests - Procedure			

TABLE 9.4-18 (SHEET 8 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
6.5.1*	Structural Capability Test *Note: Testing to be conducted only on affected components.*	No (Not required)	Yes (See note)
6.5.2*	Duct and Housing Leak Rate Test (Constant Pressure Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.3*	Duct and Housing Leak Rate Test (Pressure Decay Method) *Note: This test will be performed only following major modification or repair and conducted on affected components only. Either constant pressure method (6.5.2) or pressure decay method (6.5.3) will be utilized.*	No (Not required)	Yes (See note)
6.5.4	Bubble Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)
6.5.5	Audible Leak Location Method *Note: This method is not a test but rather a leak detection method typically used for identifying leaks during the performance of the leak rate test of 6.5.2 or 6.5.3 or after minor repair. It does not prohibit the use of other detection methods.*	No (Not required)	No (See note)
6.6 Acceptance Criteria			
6.6.1	Structural Capability Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (Not required)	No (See note)

TABLE 9.4-18 (SHEET 9 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
6.6.2	Duct and Housing Leak Test. Meets the requirements of ASME N509, test program, and project specifications. *Note: Specific acceptance criteria will be developed for testing following major modification or repair based on the extent of the work scope and the system functional requirements.*	No (See notes for 6.5.2 and 6.5.3)	No (See note)
7.0 MOUNTING FRAME PRESSURE LEAK TEST (OPTIONAL)		No (Optional)	No (Optional)
8.0 AIRFLOW CAPACITY AND DISTRIBUTION TESTS			
8.5.1 Airflow Capacity Test Procedure			
8.5.1.1	Start system fan and verify stable (no surging) fan operation for 15 min.	Yes	Yes
8.5.1.2	Measure system airflow in accordance with 2.2 or equivalent. *Note: Reference 2.2 “Industrial Ventilation: A Manual of Recommended Practice (20th Edition)” excluding figure 9-5.*	Yes (See note)	Yes (See note)
8.5.1.3*	Clean System Airflow. With the new housing components installed, or simulated, operate at the clean differential pressure and compare measured flow rate (using methods of para. 8.5.1.2) with the value specified by the test program or project specification. If the specified value cannot be achieved, report to owner.	No (Not required)	Yes

TABLE 9.4-18 (SHEET 10 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
8.5.1.4*	Maximum Housing Component Pressure Drop Airflow. After successful completion of para. 8.5.1.3, increase housing component resistance (artificially by blanking off portions of the filter bank or by adjusting throttling dampers) until the maximum housing component pressure drop for the system (as specified in the test program or project specifications) is achieved. Measure flow rate per para. 8.5.1.2. If the maximum housing component pressure drop airflow cannot be achieved, report to owner.	No (Not required)	Yes
8.5.1.5*	Return system to “clean” condition.	No (Not required)	Yes
8.5.2	Airflow Distribution Test Procedure *NOTE: Airflow distribution tests are not required for a filter bank containing a single HEPA filter.*		
8.5.2.1*	Airflow Distribution Through HEPA Filter Banks. The minimum number of velocity measurements shall be one in the center of each filter. All measurements should be made an equal distance away from the filters. Velocity measurements should be made downstream of the filters to take advantage of the airflow distribution dampening effects of the HEPA filters.	No (Not required)	Yes

TABLE 9.4-18 (SHEET 11 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Following Major Modification or Repair
8.5.2.2*	Airflow Distribution Through Adsorber Banks. For banks containing Type I adsorbers, the air distribution test shall follow the same procedures specified for HEPA filter banks in para. 8.5.2.1. For banks containing Type II modular trays, the air distribution test shall follow the same procedure specified for filter banks in para. 8.5.2.1, except that all velocity measurements shall be made in the plane of the face of the air channels, in the center of every open channel and an equal distance away from the adsorbers. For type III adsorbers, velocity measurements shall be made in the plane of the face of the air channels. These measurements shall be made in centers of equal area that cover the entire open face, not in excess of 12 in. between points on a channel, and an equal distance away from the adsorber.	No (Not required)	Yes
8.5.2.3*	Calculate the average of the velocity readings (Section 3).	No (Not required)	Yes
8.5.2.4*	Note the highest and lowest velocity readings and calculate the percentage they vary from the average found in para. 8.5.2.3. If acceptance criteria are exceeded, notify owner.	No (Not required)	Yes

TABLE 9.4-18 (SHEET 12 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Major Modification or Repair
8.6.0 Acceptance Criteria			
8.6.1	Acceptance Criteria for Airflow Capacity Test. Airflow shall be within ± 10% of the value specified in the test program or project specifications. Maximum housing component pressure drop airflows shall be ± 10% of the value specified in the test program or project specifications with the pressure drop greater than or equal to the maximum housing component pressure drop. For systems with carbon adsorbers, the maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15). *Notes:* *(1) Applies only to sections 8.5.1.1 and 8.5.1.2.* *(2) Maximum housing component pressure drops will be based on those that result in the system maintaining the TS flowrate ±10%.*	Yes (See note 1)	Yes (See note 2)
8.6.2*	Airflow Distribution Test. No velocity readings shall exceed ± 20% of the calculated average. For system with carbon adsorbers, maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15).	No (Not required)	Yes
9.0	AIR-AEROSOL MIXING UNIFORMITY TEST *Note: Test will be performed only following relocation of the challenge gas injection port or upstream sample port or major modifications or repair that may affect flow distribution.*	No (Not Required)	Yes (See note)
10.0	HEPA FILTER BANK IN-PLACE TEST	Yes	Yes
11.0	ADSORBER BANK IN-PLACE LEAK TEST	Yes	Yes

TABLE 9.4-18 (SHEET 13 OF 14)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Major Modification or Repair
12.0	DUCT DAMPER BYPASS TEST *Note: System design does not include bypass damper.*	N/A (See note)	N/A (See note)
13.0	SYSTEM BYPASS TEST *Note: Tests performed per Section 10 satisfy Section 13 test requirements.*	N/A (See note)	N/A (See note)
14 AIR HEATER PERFORMANCE TEST			
14.3 Prerequisites			
14.3.1	Prerequisite: Visual inspection of the heater is completed (para. 5.5.1.7).	N/A	N/A
14.3.2	Prerequisite: Electrical control and feed power is available and all safety interlocks have been checked.	N/A	N/A
14.5 Procedure			
14.5.1	With power on, and system operating at rated flow, measure the voltage and current of all power circuits.	N/A	N/A
14.5.2	With heater energized and system operating at rated airflow, measure the temperature of the entering and leaving air. A sufficient number of measurements shall be taken to determine average entering and leaving temperatures.	N/A	N/A
14.5.3	If measured values do not meet acceptance criteria, notify the owner.	N/A	N/A

TABLE 9.4-18 (SHEET 14 OF 14)

		Testing Conformance	
N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Routine Surveillance	Following Major Modification or Repair
14.6 Acceptance Criteria			
14.6.1	Operating currents, voltages and change in temperature shall be within the limits of test program or project specifications.	N/A	N/A
15.0 LABORATORY TESTING OF ADSORBENT *Note: Laboratory testing will be performed in accordance with ASTM D3803-1989.*		Yes (See note)	Yes (See note)

* ASME N510-1989 clearly delineates these steps are intended for acceptance tests performed after any major system modification or major repair.

TABLE 9.4-19 (SHEETS 1 THROUGH 6)

CONFORMANCE TO ASME N510-1989 (SECTION 5)
CONTAINMENT PURGE EXHAUST FILTRATION (CPEF) SYSTEM FILTER UNITS

(This table has been deleted.)

TABLE 9.4-20 (SHEET 1 OF 12)

CONFORMANCE TO ASME N510-1989
POST-ACCIDENT PURGE FILTRATION SYSTEM

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Modification or Repair
5 VISUAL INSPECTION			
5.5.1 Guidance for Visual Inspection			
5.5.1.1(a)	Adequate access to housing.	Yes	Yes
5.5.1.1(b)*	Adequate space for personnel and equipment for maintenance and testing.	No (Not required)	Yes
5.5.1.1(c)*	Doors of rigid construction to resist unacceptable flexure under operating conditions.	No (Not required)	Yes
5.5.1.1(d)	Adequate seal between door and casing.	Yes	Yes
5.5.1.1(e)	Gasket joints are dovetail type with seating surface suitable for accommodating a knife edge sealing device. *Note: Gaskets are not dovetail type - inspect gaskets for seating surface only when accessible.*	Yes (See note)	Yes (See note)
5.5.1.1(f)*	Provision for opening doors from inside and outside of housing. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(g)	Adequate number and acceptable condition of operable latches on access doors to achieve uniform seating.	Yes	Yes
5.5.1.1(h)*	Provision for locking doors.	No (Not required)	Yes
5.5.1.1(i)*	Adequate structural rigidity of housing to resist unacceptable flexure during operating conditions.	No (Not required)	Yes

TABLE 9.4-20 (SHEET 2 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Modification or Repair
5.5.1.1(j)*	Access to upper tiers, (above the 7 ft evel), provided with permanent ladders and platforms. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.1(k)*	At least 3 ft clearance between banks of components for maintenance and testing. *Note: Units have less than 3 feet between some banks by design.*	No (Not required)	N/A (See note)
5.5.1.1(l)*	Door provided on each side, (upstream and downstream), of each component bank. *Note: No door upstream of HEPA or charcoal filters are proved in design. (Housing is a pressure vessel with limited access.)*	No (Not required)	N/A (See note)
5.5.1.1(m)*	No back-to-back installation of components.	No (Not required)	Yes
5.5.1.1(n)	Sample ports located and labeled upstream and downstream of each HEPA filter and adsorber bank.	Yes	Yes
5.5.1.1(o)	Challenge injection ports located and labeled.	Yes	Yes
5.5.1.1(p)	Sample and injection ports equipped with leak-tight caps or plugged. *Note: Valves may be used for the sample and injection ports. Outlets are capped.*	Yes	Yes
5.5.1.1(q)	Housekeeping in and around housing adequate for maintenance, testing, and operation.	Yes	Yes
5.5.1.1(r)	Adequate guards provided on fans for personnel safety. *Note: The design does not include this feature (no fan).*	N/A (See Note)	N/A (See Note)
5.5.1.1(s)	Condition of flexible connection between housing and fan located external to housing adequate to prevent leakage of untreated air. *Note: The design does not include this feature (no fan).*	N/A (See Note)	N/A (See Note)

TABLE 9.4-20 (SHEET 3 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Modification or Repair
5.5.1.1(t)	Fan-shaft seals installed where required. *Note: The design does not include this feature (no fan).*	N/A (See Note)	N/A (See Note)
5.5.1.1(u)	Airtight seals for conduits, electrical connections, plumbing, drains, or other conditions that could result in bypassing of the housing or any component therein. *Note: Inspect accessible/visible items. Air tightness of components that could cause bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.1(v)	No sealant or caulking of any type on/in housings or component frames. Caulking on/in ducts may be permissible depending on project specifications. *Note: Inspect only normally accessible areas without disassembly during inspections.*	Yes (See note)	Yes (See note)
5.5.1.1(w)	Loop seals have adequate water level. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.1(x)	Satisfactory condition of fire protection components (if provided). *Note: The design does not include this feature. No fire protection provided.*	N/A (See note)	N/A (See note)
5.5.1.2 Local Instrumentation			
5.5.1.2(a)	No unacceptable damage to instrumentation (e.g., gages, manometers, thermometers, etc.).	Yes	Yes
5.5.1.2(b)	All connections complete.	Yes	Yes

TABLE 9.4-20 (SHEET 4 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Modification or Repair
5.5.1.3 Lighting, Housing			
5.5.1.3(a)	Adequate lighting provided for visual inspection of housing and components. *Note: The design does not include this feature. Temporary lighting utilized, as necessary, to perform internal visual inspections.*	N/A (See note)	N/A (See note)
5.5.1.3(b)*	Flush mounted fixtures serviceable from outside the housing. *Note: The design does not include this feature.*	No (Not required)	N/A (See note)
5.5.1.4 Mounting Frames for Filters and Moisture Separators			
5.5.1.4(a)*	Continuous seal weld between members or frames and between frame and housing. *Note: Inspect only normally accessible areas without disassembly during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(b)*	Adequate structural rigidity for supporting internal components during operating conditions without flexure. *Note: Inspect only normally accessible areas without disassembly during inspections.*	No (Not required)	Yes (See note)
5.5.1.4(c)	No unacceptable damage to the frames that may interfere with proper seating of components. *Note: Not accessible. Inspect only normally accessible areas without disassembly during inspections. Bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.4(d)	Sample canisters installed and unused connections capped or plugged leak-tight. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.4(e)	No penetrations of the mounting frame except for test canisters. *Note: Inspect only normally accessible areas without disassembly during inspections.*	Yes (See note)	Yes (See note)

TABLE 9.4-20 (SHEET 5 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Modification or Repair
5.5.1.4(f)	No sealant or caulking of any type. *Note: Inspect only normally accessible areas without disassembly during inspections.*	Yes (See note)	Yes (See note)
5.5.1.5 Filter Clamping Devices			
5.5.1.5(a)	Sufficient number of devices of adequate size to assure specified gasket compression.	Yes	Yes
5.5.1.5(b)*	Individual clamping of filters and adsorbers. *Note: Adsorber is type III Filter.*	No (Not required)	Yes (See note)
5.5.1.5(c)	All clamping hardware complete and in good condition.	Yes	Yes
5.5.1.5(d)*	Adequate clearances provided between filter and adsorber units in same bank to tighten clamping devices.	No (Not required)	Yes
5.5.1.6 Moisture Separators			
5.5.1.6(a)	No unacceptable damage to media, frame, or gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(b)	No dirt or debris loading which creates higher than the specified pressure drop across the bank of components at the design airflow rate. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.6(c)	Proper installation of moisture separators. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.7 Air Heating Coils - Inside Housing			
5.5.1.7(a)	No unacceptable damage to coils which may affect operability of the heaters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)

TABLE 9.4-20 (SHEET 6 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Modification or Repair
5.5.1.7(b)	No unacceptable dirt or debris on or between coils. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.8 Prefilters			
5.5.1.8(a)	No damage to media, frame, or gaskets which may affect operability of prefilters *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.8(b)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.8(c)	Proper installation of prefilters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.9 HEPA Filters			
5.5.1.9(a)	No unacceptable damage to filter media.	Yes	Yes
5.5.1.9(b)	Acceptable condition and seating of gaskets with at least 50% compression. *Note: Visually confirm that gaskets appear tight. Bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.9(c)	No dirt or debris loading which creates higher than the specified pressure drop across the filter bank at the design flow rate. *Note: Inspect only normally accessible areas without disassembly during inspections. Pressure drop will be checked by installed pressure gauges.*	Yes (See note)	Yes (See note)
5.5.1.9(d)	No sealant or caulking of any type. *Note: Inspect only normally accessible areas without disassembly during inspections.*	Yes (See note)	Yes (See note)

TABLE 9.4-20 (SHEET 7 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Modification or Repair
5.5.1.9(e)	Filters are properly installed with pleats vertical.	Yes	Yes
5.5.1.10 Adsorbers			
5.5.1.10(a)	No unacceptable damage to adsorbers or adsorbent beds.	Yes	Yes
5.5.1.10(b)	Acceptable condition and seating of gaskets with at least 50 % compression. *Note: Visually confirm that gaskets appear tight.* *Adsorber is type III. Bypass leakage will be checked by in-place testing.*	Yes (See note)	Yes (See note)
5.5.1.10(c)	No through bolts on Type II adsorbers or other structure that could cause bypass in an adsorber bank where visible. *Note: Adsorber is type III.*	N/A (See note)	N/A (See note)
5.5.1.10(d)	No sealant or caulking of any type. *Note: Inspect only normally accessible areas without disassembly during inspections.*	Yes (See note)	Yes (See note)
5.5.1.11 Dampers - Housing and Associated Bypass Duct			
5.5.1.11(a)	No unacceptable damage to or distortion of frame or blades. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(b)	No missing seats or blade edging. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(c)	No unacceptable damage to shaft, pivot pins, operator linkages, operators, or packing. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.11(d)	Linkage connected and free from obstruction. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)

TABLE 9.4-20 (SHEET 8 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Modification or Repair
5.5.1.11(e)	No unacceptable damage to gaskets. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12 Manifolds			
5.5.1.12(a)	No unacceptable damage to test manifolds. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
5.5.1.12(b)	Adequate clearance between permanent manifolds and filters. *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
6 DUCTWORK AND HOUSING LEAK AND STRUCTURAL CAPABILITY TESTS	*Note: The design does not include this feature. Piping is utilized for the flow path and the filter housing is a pressure vessel.*		
8 AIRFLOW CAPACITY AND DISTRIBUTION TESTS			
8.5.1 Airflow Capacity Test Procedure			
8.5.1.1	Start system fan and verify stable (no surging) fan operation for 15 minutes. *Note: The design does not include this feature (no fan).*	N/A (See note)	N/A (See note)
8.5.1.2	Measure system airflow in accordance with 2.2 or equivalent. *Note: The design does not include this feature (no field measurement points provided in piping). Air flow will be measured with in-place instrumentation and associated accuracy or with external instrumentation in the supply line from a temporary air source.*	Yes (See note)	Yes (See note)

TABLE 9.4-20 (SHEET 9 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Modification or Repair
8.5.1.3*	Clean System Air flow. With the new housing components installed, or simulated, operate at the clean differential pressure and compare measured flow rate (using methods of para. 8.5.1.2) with the value specified by the test program or project specification. If the specified value cannot be achieved, report to owner.	No (Not required)	Yes
8.5.1.4*	Maximum Housing Component Pressure Drop Airflow. After successful completion of para. 8.5.1.3, increase housing component resistance (artificially by blanking off portions of the filter bank or by adjusting throttling dampers) until the maximum housing component pressure drop for the system (as specified in the test program or project specifications) is achieved. Measure flow rate per para. 8.5.1.2. If the maximum housing component pressure drop airflow cannot be achieved, report to owner. *Note: The design does not include this feature (no fan)*	No (Not required)	N/A (See note)
8.5.1.5*	Return system to “clean” condition.	No (Not required)	N/A
8.5.2 Airflow Distribution Test Procedure			
	Note: Airflow distribution tests are not required for a filter bank containing a single HEPA filter.		
8.5.2.1*	Airflow Distribution Through HEPA Filter Banks. The minimum number of velocity measurements shall be one in the center of each filter. All measurements should be made an equal distance away from the filters. Velocity measurements should be made downstream of the filters to take advantage of the airflow distribution dampening effects of the HEPA filters. *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)

TABLE 9.4-20 (SHEET 10 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	 Following Modification or Repair
8.5.2.2*	Airflow Distribution Through Adsorber Banks. For banks containing Type I adsorbers, the air distribution test shall follow the same procedures specified for HEPA filter banks in para 8.5.2.1. For banks containing Type II modular trays, the air distribution test shall follow the same procedure specified for filter banks in para. 8.5.2.1, except that all velocity measurements shall be made in the plane of the face of the air channels, in the center of every open channel and an equal distance away from the adsorbers. For type III adsorbers, velocity measurements shall be made in the plane of the face of the air channels. These measurements shall be made in centers of equal area that cover the entire open face, not in excess of 12 in. between points on a channel, and an equal distance away from the adsorber. *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)
8.5.2.3*	Calculate the average of the velocity readings (Section 3). *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)
8.5.2.4*	Note the highest and lowest velocity readings and calculate the percentage they vary from the average found in para. 8.5.2.3. If acceptance criteria are exceeded, notify owner. *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)

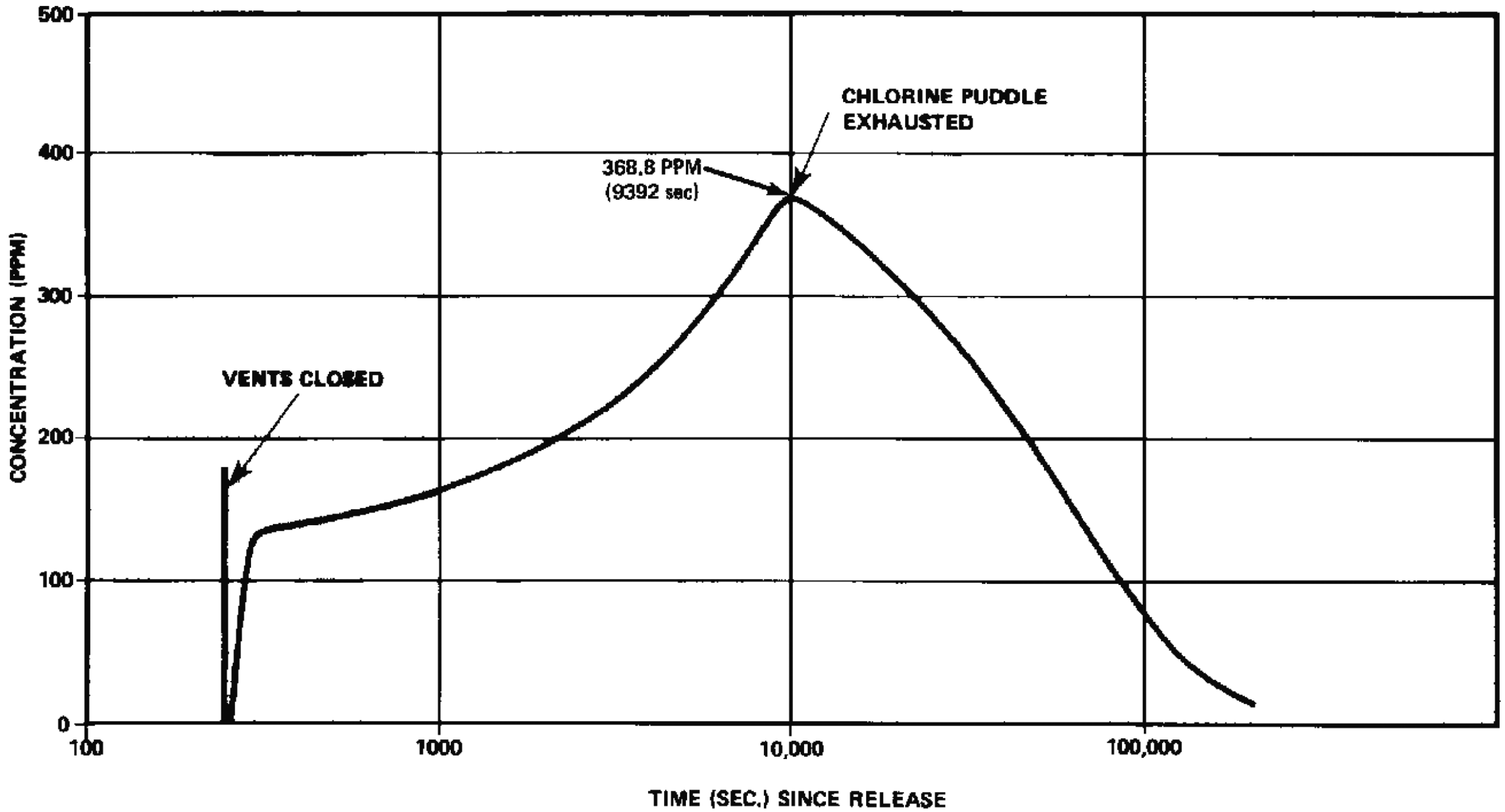
TABLE 9.4-20 (SHEET 11 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance Routine Surveillance	Testing Conformance Following Modification or Repair
8.6.0 Acceptance Criteria.			
8.6.1	Acceptance Criteria for Airflow Capacity Test. Airflow shall be within the values specified in the test program or project specifications. Maximum housing component pressure drop airflows shall be less than or equal to the values specified in the test program or project specifications with the pressure drop greater than or equal to the maximum housing component pressure drop. For systems with carbon adsorbers, the maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15). *Note: Applies only to section 8.5.1.2.*	Yes (See note)	Yes
8.6.2*	Airflow Distribution Test. No velocity readings shall exceed ±20% of the calculated average. For system with carbon adsorbers, maximum velocity of air through the carbon beds shall be limited to that value specified in the laboratory test (Section 15). *Note: This test will not be performed since a single HEPA filter is present.*	No (Not required)	N/A (See note)
9 AIR-AEROSOL MIXING UNIFORMITY TEST *Note: This is a single HEPA system and this test does not apply.*		N/A (See note)	N/A (See note)
10 HEPA FILTER BANK IN-PLACE TEST *Note: In-place leak testing will be performed following HEPA filter replacement.*		Yes	Yes (See note)
11 ADSORBER BANK IN-PLACE TEST		Yes	Yes

TABLE 9.4-20 (SHEET 12 OF 12)

N510-1989 Paragraph	Description of N510-1989 Testing Requirement	Testing Conformance: Routine Surveillance	Testing Conformance: Following Modification or Repair
12	DUCT DAMPER BYPASS TEST *Note: The design does not include bypass damper.*	N/A (See note)	N/A (See note)
13	SYSTEM BYPASS TEST *Note: Tests performed per Section 10 satisfy Section 13 requirements.*	N/A (See note)	N/A (See note)
14	AIR HEATER PERFORMANCE TEST *Note: The design does not include this feature.*	N/A (See note)	N/A (See note)
15	LABORATORY TESTING OF ADSORBENT *Notes:* *1. Laboratory testing will be performed in accordance with ASTM D3803-1989.* *2. Laboratory testing will be performed following adsorber replacement, at approximately 18-month intervals or following exposure to solvent, paints, or other organic fumes or vapors which exceed the administrative limit.*	Yes (See notes)	Yes (See notes)

* ASME N510-1989 clearly delineates these steps are intended for acceptance tests performed after any major system modification or repair.



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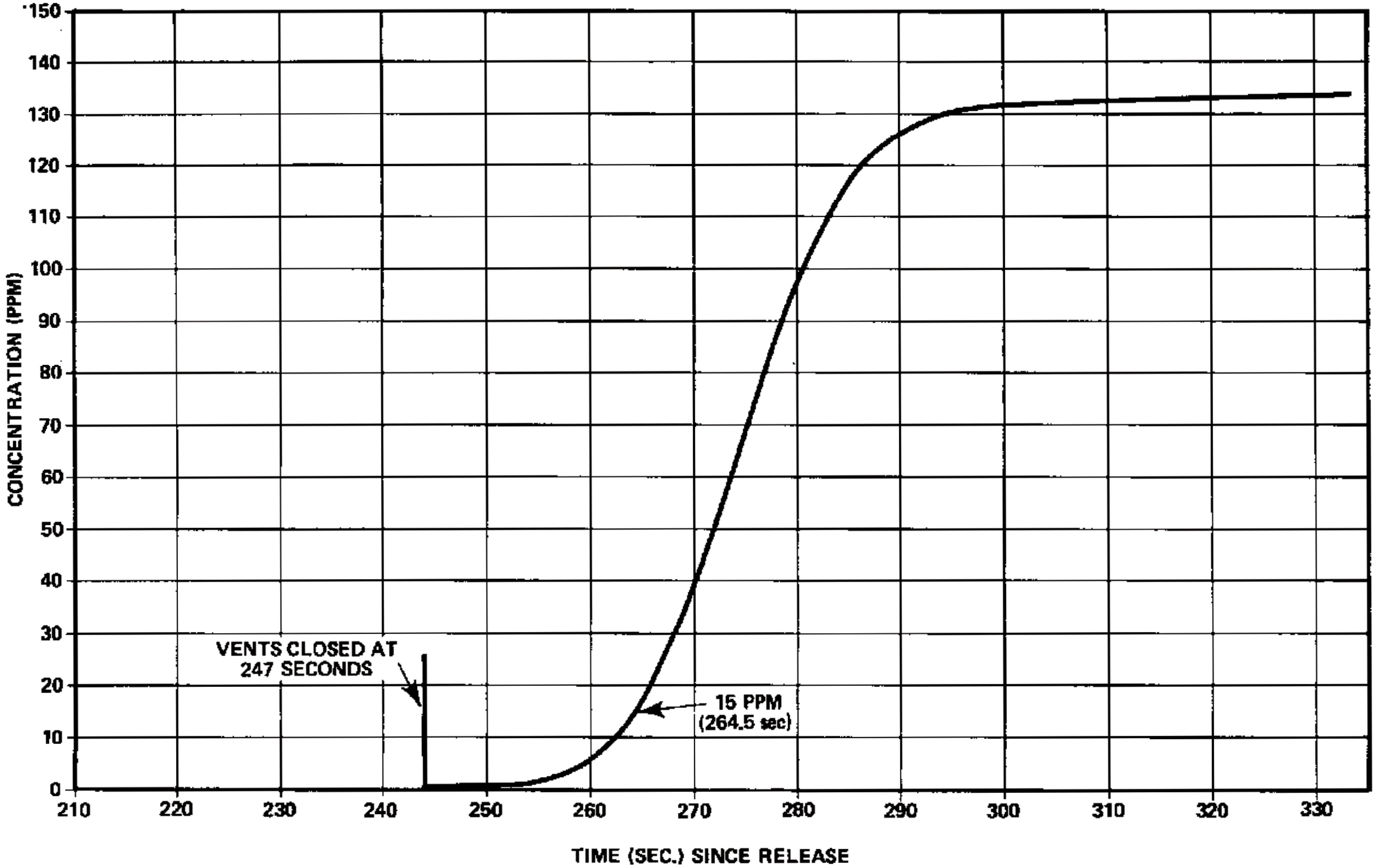
NUCLEAR PLANT
UNIT 1 AND UNIT 2

[CONCENTRATION OF CHLORINE IN CONTROL ROOM AFTER ONSITE CHLORINE RELEASE – CASE A (SMALL SCALE)

FIGURE 9.4-1 (SHEET 1 OF 5)]



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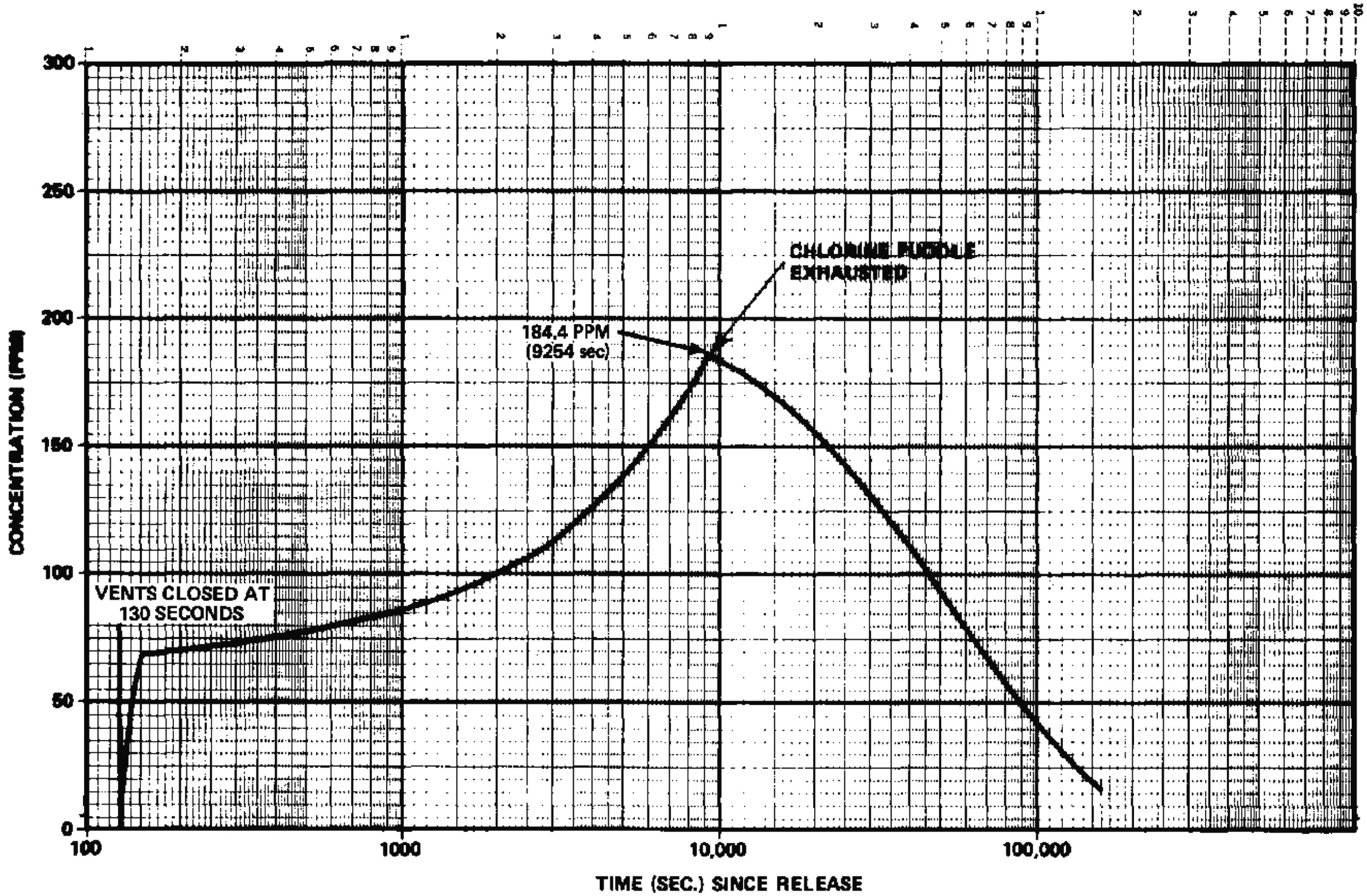
[CONCENTRATION OF CHLORINE IN CONTROL ROOM AFTER ONSITE CHLORINE RELEASE – CASE A (LARGE SCALE)

FIGURE 9.4-1 (SHEET 2 OF 5)]



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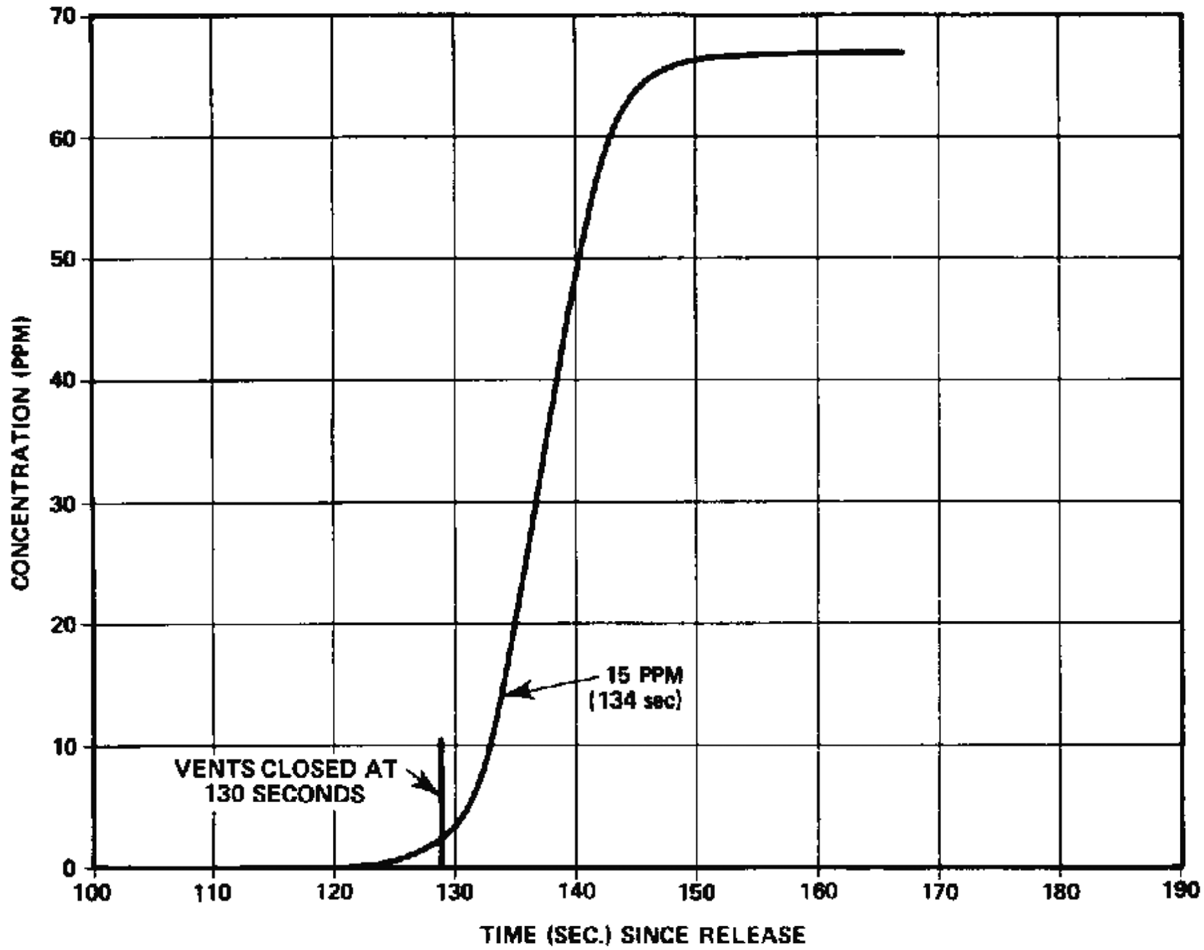
[CONCENTRATION OF CHLORINE IN CONTROL ROOM AFTER ONSITE CHLORINE RELEASE – CASE B (SMALL SCALE)

FIGURE 9.4—1 (SHEET 3 OF 5)]



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$$[HISTORICAL]$$

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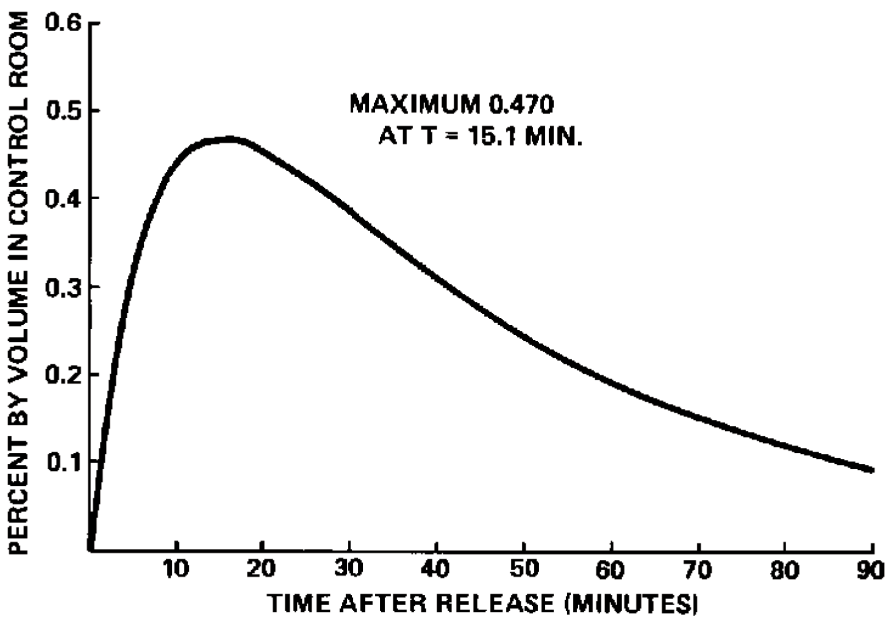
[CONCENTRATION OF CHLORINE IN CONTROL ROOM AFTER ONSITE CHLORINE RELEASE – CASE B (LARGE SCALE)

FIGURE 9.4-1 (SHEET 4 OF 5)]



13

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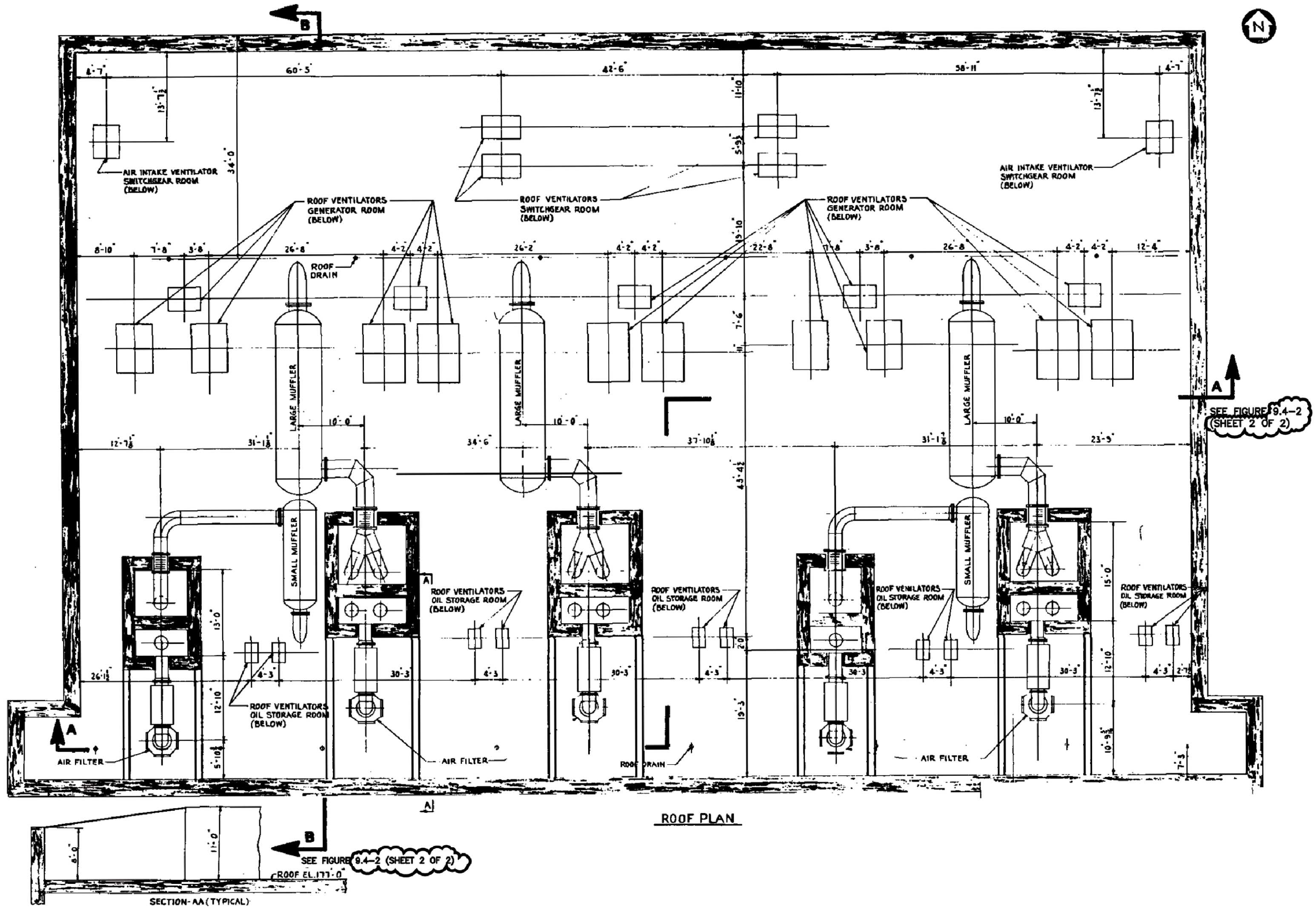
SOUTHERN COMPANY
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

HALON 1301 CONCENTRATION
IN CONTROL ROOM

FIGURE 9.4-1 (SHEET 5 OF 5)



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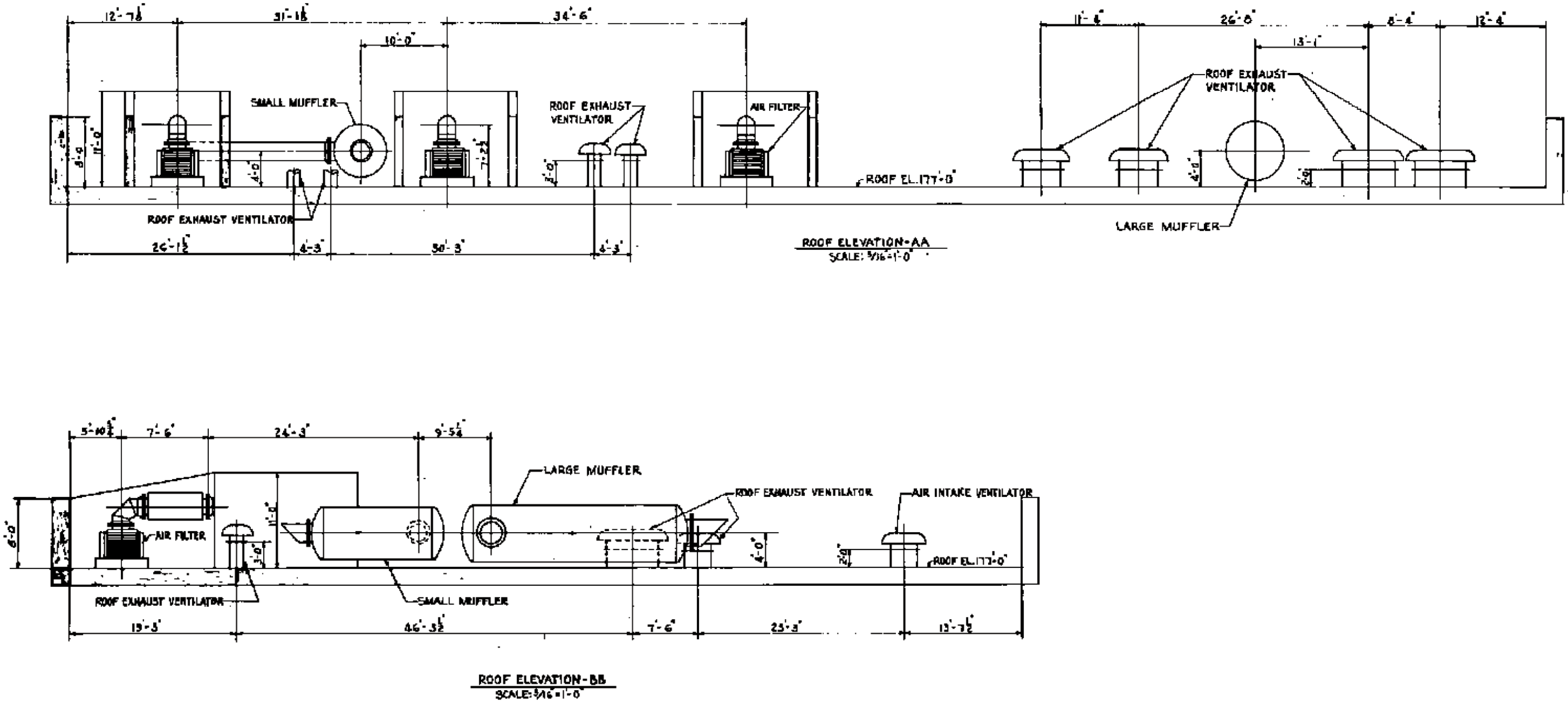
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

UNITS 1 AND 2 DIESEL GENERATOR
BUILDING EQUIPMENT LOCATION ON ROOF

FIGURE 9.4-2 (SHEET 1 OF 2)



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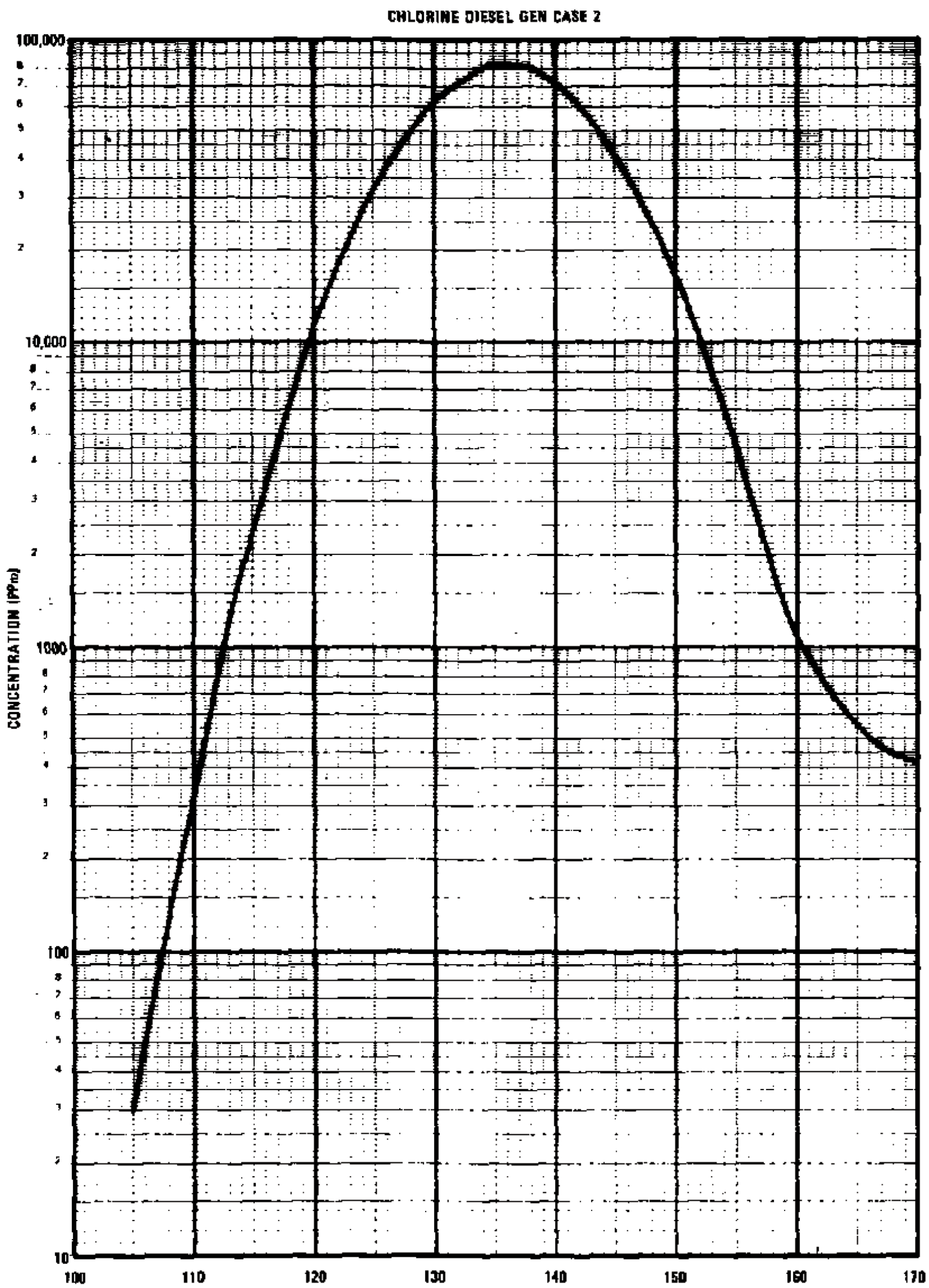
JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2

DIESEL GENERATOR BUILDING EQUIPMENT ON ROOF (ELEVATION AS SHOWN)

FIGURE 9.4-2 (SHEET 2 OF 2)



13

REV 21 5/08

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JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

CHLORINE CONCENTRATION VERSUS
TIME DIESEL GENERATOR

FIGURE 9.4-3

9.5 OTHER AUXILIARY SYSTEMS

9.5.1 FIRE PROTECTION SYSTEM

The fire protection program is based on the NRC requirements and guidelines, Nuclear Electric Insurance Limited (NEIL) Property Loss Prevention Standards and related industry standards. With regard to NRC criteria, the fire protection program meets the requirements of 10 CFR 50.48(c), which endorses, with exceptions, the National Fire Protection Association's (NFPA) 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants" - 2001 Edition. Farley Nuclear Plant has further used the guidance of NEI 04-02, "Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program under 10 CFR 50.48(c)" as endorsed by Regulatory Guide 1.205, "Risk-Informed, Performance Fire Protection for Existing Light-Water Nuclear Power Plants."

Adoption of NFPA 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," 2001 Edition in accordance with 10 CFR 50.48(c) serves as the method of satisfying 10 CFR 50.48(a) and General Design Criterion 3. Prior to adoption of NFPA 805, General Design Criterion 3, "Fire Protection" of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," was followed in the design of safety and nonsafety-related structures, systems, and components, as required by 10 CFR 50.48(a).

NFPA 805 does not supersede the requirements of GDC 3, 10 CFR 50.48(a), or 10 CFR 50.48(f). Those regulatory requirements continue to apply. However, under NFPA 805, the means by which GDC 3 or 10 CFR 50.48(a) requirements are met may be different than under 10 CFR 50.48(b). Specifically, whereas GDC 3 refers to SSCs important to safety, NFPA 805 identifies fire protection systems and features required to meet the Chapter 1 performance criteria through the methodology in Chapter 4 of NFPA 805. Also, under NFPA 805, the 10 CFR 50.48(a)(2)(iii) requirement to limit fire damage to SSCs important to safety so that the capability to safely shut down the plant is satisfied by meeting the performance criteria in Section 1.5.1 of NFPA 805.

A License Amendment and Safety Evaluation were issued on March 10, 2015 and October 17, 2016, by the NRC, that transitioned the existing fire protection program to a risk-informed, performance-based program based on NFPA 805, in accordance with 10 CFR 50.48(c).

9.5.1.1 Design Basis Summary

9.5.1.1.1 Defense-in-Depth

The fire protection program is focused on protecting the safety of the public, the environment, and plant personnel from a plant fire and its potential effect on safe reactor operations. The fire protection program is based on the concept of defense-in-depth. Defense-in-depth shall be achieved when an adequate balance of each of the following elements is provided:

(1) Preventing fires from starting.

(2) Rapidly detecting fires and controlling and extinguishing promptly those fires that do occur, thereby limiting fire damage.

(3) Providing an adequate level of fire protection for structures, systems, and components important to safety so that a fire that is not promptly extinguished will not prevent essential plant safety functions from being performed.

9.5.1.1.2 NFPA 805 Performance Criteria

The design basis for the fire protection program is based on the following nuclear safety and radiological release performance criteria contained in Section 1.5 of NFPA 805:

- Nuclear Safety Performance Criteria. Fire protection features shall be capable of providing reasonable assurance that, in the event of a fire, the plant is not placed in an unrecoverable condition. To demonstrate this, the following performance criteria shall be met:

  (a) Reactivity Control. Reactivity control shall be capable of inserting negative reactivity to achieve and maintain subcritical conditions. Negative reactivity inserting shall occur rapidly enough such that fuel design limits are not exceeded.

  (b) Inventory and Pressure Control. With fuel in the reactor vessel, head on and tensioned, inventory and pressure control shall be capable of controlling coolant level such that subcooling is maintained such that fuel clad damage as a result of a fire is prevented for a PWR.

  (c) Decay Heat Removal. Decay heat removal shall be capable of removing sufficient heat from the reactor core or spent fuel such that fuel is maintained in a safe and stable condition.

  (d) Vital Auxiliaries. Vital auxiliaries shall be capable of providing the necessary auxiliary support equipment and systems to assure that the systems required under (a), (b), (c), and (e) are capable of performing their required nuclear safety function.

  (e) Process Monitoring. Process monitoring shall be capable of providing the necessary indication to assure the criteria addressed in (a) through (d) have been achieved and are being maintained.

- Radioactive Release Performance Criteria. Radiation release to any unrestricted area due to the direct effects of fire suppression activities (but not involving fuel damage) shall be as low as reasonable achievable and shall not exceed applicable 10 CFR, Part 20 limits.

Chapter 2 of NFPA 805 establishes the process for demonstrating compliance with NFPA 805.

Chapter 3 of NFPA 805 contains the fundamental elements of the fire protection program and specifies the minimum design requirements for fire protection systems and features.

Chapter 4 of NFPA 805 establishes the methodology to determine the fire protection systems and features required to achieve the nuclear safety performance criteria outlined above. The methodology shall be permitted to be either deterministic or performance-based. Deterministic requirements shall be “deemed to satisfy” the performance criteria, defense-in-depth, and safety margin and require no further engineering analysis. Once a determination has been made that a fire protection system or feature is required to achieve the nuclear safety performance criteria of Section 1.5, its design and qualification shall meet the applicable requirement of Chapter 3.

9.5.1.1.2 Codes of Record

The codes, standards, and guidelines used for the design and installation of plant fire protection systems are listed in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document.

9.5.1.2 System Description

9.5.1.2.1 Required Systems

Nuclear Safety Capability Systems, Equipment, and Cables

Section 2.4.2 of NFPA 805 defines the methodology for performing the nuclear safety capability assessment. The systems equipment and cables required for the nuclear safety capability assessment are contained in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document.

Fire Protection Systems and Features

Chapter 3 of NFPA 805 contains the fundamental elements of the fire protection program and specifies the minimum design requirements for fire protection systems and features. Compliance with Chapter 3 is documented in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document.

Chapter 4 of NFPA 805 establishes the methodology and criteria to determine the fire protection systems and features required to achieve the nuclear safety performance criteria of Section 1.5 of NFPA 805. These fire protection systems and features shall meet the applicable requirements of NFPA 805 Chapter 3. These fire protection systems and features are documented in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document.

Radioactive Release

Structures, systems, and components relied upon to meet the radioactive release criteria are documented in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document.

9.5.1.2.2 Definition of "Power Block" Structures

Where used in NFPA 805 Chapter 3, the terms "Power Block" and "Plant" refer to structures that contain equipment required for nuclear plant operations. For the purposes of establishing the structures included in the fire protection program in accordance with 10 CFR 50.48(c) and NFPA 805, the plant structures listed in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document, are considered to be a part of the 'power block'.

9.5.1.3 Safety Evaluation

DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document documents the achievement of the nuclear safety and radioactive release performance criteria of NFPA 805 as required by 10 CFR 50.48(c). This document fulfills the requirements of Section 2.7.1.2, "Fire Protection Program Design Basis Document" of NFPA 805. The document contains the following:

- Identification of significant fire hazards in the fire area. This is based on NFPA 805 approach to analyze the plant from an ignition source and fuel package perspective.
- Summary of the Nuclear Safety Capability Assessment (at power and non-power) compliance strategies.
  - Deterministic compliance strategies.
  - Performance-based compliance strategies (including defense-in-depth and safety margin).
- Summary of the Non-Power Operations Modes compliance strategies.
- Summary of the Radioactive Release compliance strategies.
- Summary of the Fire Probabilistic Risk Assessments.
- Key analysis assumptions to be included in the NFPA 805 monitoring program.

9.5.1.4 Fire Protection Program Documentation, Configuration Control, and Quality Assurance

In accordance with Chapter 3 of NFPA 805, a fire protection plan documented in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document, defines the management policy and program direction and defines the responsibilities of those individuals responsible for the plan's implementation. This includes:

- Designating the senior management position with immediate authority and responsibility for the fire protection program.
- Designating a position responsible for the daily administration and coordination of the fire protection program and its implementation.
- Defining the fire protection interfaces with other organizations, assigning responsibilities for the coordination of activities, and identifying the various plant positions having the authority for implementing the various areas of the fire protection program.
- Identifying the appropriate authority having jurisdiction for the various areas of the fire protection program.
- Identifying the procedures established for the implementation of the fire protection program, including the post-transition change process and the fire protection monitoring program.
- Identifying the qualifications required for various fire protection program personnel.
- Identifying the quality requirements of Chapter 2 of NFPA 805.

Detailed compliance with the programmatic requirements of Chapters 2 and 3 of NFPA 805 is contained in DWG A-181805, NFPA 805 Fire Protection Program Design Basis Document.

9.5.2 COMMUNICATION SYSTEMS

The communication systems include internal (in-plant) and external communications designed to provide convenient and effective operational communications among various plant locations and between the plant and locations external to the plant.

The communication systems are not required for the safe shutdown of the reactor except in response to fires as discussed in appendix 9B and after incidents that require hot shutdown as discussed in paragraph 7.4.1.3.F.

9.5.2.1 Design Bases

Various communication systems are provided in the plant to ensure reliable communications during plant startup, operation, shutdown, and maintenance under normal conditions.

9.5.2.2 Description

Interplant and intraplant communications systems consist of telephones, handsets, and loudspeakers. These systems include a plant address system, an intraplant telephone system, an intraplant sound-powered telephone system, microwave communication system, two-way radio communication, an emergency alarm system, the Gra-Ceba Telephone Company system, an intracompany computer network, and the ftS-2000 emergency telecommunications system.

The plant public address system operates from an ac bus which is powered by the diesel generators upon loss of offsite power. This ensures communication to all areas of the plant, and that the plant alarm may be sounded. The system uses noise canceling dynamic microphone handsets located in strategic positions. Loudspeakers located throughout the plant are powered by individual amplifiers. Muting facilities are provided where required. In the event of a plant alarm, individual volume control is overridden and the speaker amplifiers are automatically set to the maximum volume. The system has one paging and five party line channels.

The intraplant telephone system employs handsets at strategic areas for private conversation and supports a Pico-Cellular cordless telephone system. The Pico-Cellular System provides wireless telephone coverage for strategic areas of the plant.

The intraplant sound-powered telephone system employs a multiple set of circuits based on operating systems to aid in startup and checkout procedures.

The microwave communication is connected to the intraplant telephone switchboard to enable the plant personnel to have dial service to other Alabama Power Company (APC) locations, including the general office in Birmingham, Alabama.

The two-way radio communication system permits communications in strategic areas of the plant via an antenna system comprised of leaky coaxial cable and regular antennae. This system also provides communication capability outside of the plant within the coverage area of the outside antenna. Individual radio power is controlled to 5 watts or less of output. Administrative controls ensure the radio will not be used near EMI sensitive equipment or in EMI sensitive areas. Each portable radio must be keyed before transmission occurs.

The commercial telephone is available in the plant, providing service through connecting (Gra-Ceba Telephone Company) companies to the South Central Bell System.

The Southern Company Computer network provides communication between the high voltage substation switchhouse, the APC load dispatcher, the Southern Company power pool, and other Southern Company plants.

Emergency telecommunications are provided through the Federal Government's ftS-2000 phone system. This system consists of dedicated circuits from within the plant to the NRC Operations Center in Bethesda, MD, and is used in the event of a plant emergency. The circuits are listed below:

ENS	-	Emergency Notification System
HPN	-	Health Physics Network
RSCL	-	Reactor Safety Counterpart Link
PMCL	-	Protective Measures Counterpart Link
MCL	-	Management Counterpart Link
LAN	-	Local Area Network

The above circuits are all telephone circuits. ERDS transmits specified plant parameters directly from the Unit 1 and Unit 2 plant computers to the NRC Operations Center in Bethesda, MD.

9.5.2.3 Inspection and Tests

All communication systems with the exception of the sound-powered telephone and emergency alarm system are in operation daily; this allows for testing to ensure that the system is operable. The sound-powered system and emergency alarm system are tested periodically to ensure that they remain operable (excluding the sound powered phone circuits in CTMT).

9.5.2.4 Safety Evaluation

The communication system allows maximum flexibility and redundancy to prevent loss of either offsite or intraplant communication from a single failure. Five channels are available for offsite communications: direct microwave telephone lines to general office and APC communication network, Gra-Ceba Telephone Company system, two-way radio, intracompany computer network, and ftS-2000 emergency telecommunications to the NRC. Each of these systems is separate; therefore, failure of any one system does not result in loss of offsite communication. The intraplant system consists of an emergency alarm, public address system, intraplant telephone system, two-way radio system, and an intraplant sound-powered telephone system. These systems are separated so that a failure in any one system does not result in a failure of any other system. However, only the Public Address System (PA), the Intrasite Telephone System (PAX), and the Sound Powered Phone System have been evaluated for operability due to a fire in a given fire area. Note that the two-way radio communications system has not been evaluated for the effects of a fire. Reference A-180583 and A-203583 for locations evaluated.

Refer to drawings D-177331; D-177334, sheets 1 through 3; D-177335; D-177336; D-177337, sheets 1 through 3; D-177338; D-177339; D-207331; D-207334, sheets 1 and 2; D-207336; D-207337, sheets 1 and 2; and D-207339, for the communication system.

9.5.3 LIGHTING SYSTEMS

Plant lighting is divided into three categories: normal, essential, and emergency. Normal and essential lighting are both ac, with essential lighting capable of operation from the plant diesels. Emergency lighting is either dc, supplied from station batteries and individual battery packs, or is ac, supplied from emergency lighting transformers. Essential lighting levels are designed to be either equal to or in excess of the levels stipulated in the seventh edition of the Illuminating Engineering Society (IES) standards (1972).

9.5.3.1 Normal Lighting

Power for normal lighting in the auxiliary and containment buildings is provided from 600-V load centers A, B, and C. All fixtures and lamps are rated for 277 V, except for underwater lamps and lamps associated with cranes, which are rated for 120 V. Incandescent lamps are used in areas with floor drains. Fluorescent lamps are used in areas without floor drains.

Industrial and commercial aluminum fixtures are used in the auxiliary building. Steel and epoxy-coated cast iron fixtures are used in the containment.

Normal lighting outside of the auxiliary and containment buildings is powered from local ac supplies. The rating of the lamps depends on the voltage of the available local power. The type of fixtures used is dependent on application and location.

9.5.3.2 Essential Lighting

Power for essential ac lighting in the Unit 1 auxiliary building and in the areas shared between Units 1 and 2 is provided from the shared 600-V motor control centers 1F and 1G. Power for essential lighting in the Unit 2 auxiliary building is supplied from 600-V motor control centers 2CC and 2DD. Essential lighting in the auxiliary building is in operation at all times. The fixtures are located in close proximity to equipment necessary for safe shutdown of the plant. In case of a loss of offsite power, the essential lighting power is supplied by plant diesels.

Essential ac lighting in buildings other than the auxiliary building is also located in close proximity to equipment necessary for safe shutdown of the plant and is fed from local diesel backed motor control centers.

9.5.3.3 Emergency Lighting

Emergency dc lighting is designed for personnel safety and plant shutdown. Direct current lighting for the control room is supplied from station batteries. In the event of loss of ac power, the dc lights will automatically switch on to provide the required lighting.

All other dc lighting receives its power from individual self-contained battery packs.

Battery packs in Category I structures are recharged from ac emergency buses. Battery packs in other structures are recharged from local ac supplies. The battery pack units are capable of providing light for a minimum of 90 min at illumination levels either equal to or in excess of the requirements stipulated in the seventh edition of the IES standards (1972).

Each individual battery pack unit is connected to a 277-V, or 120-V single-phase, 60-Hz unswitched power supply. In Category I structures, emergency lights are designed as Category I equipment. In the event of loss of ac power, the battery pack is switched on automatically to provide the required lighting.

The ac emergency lighting systems for the Unit 1 and Unit 2 containments are each comprised of two uninterruptible power supply units, two step-down distribution transformers, and multiple 120 V-ac sealed-beam units. The UPS units are connected to emergency lighting transformers that supply power to the sealed-beam units. Upon loss of power from a lighting transformer, the associated UPS units will switch on emergency power to the sealed-beam units.

9.5.4 DIESEL GENERATOR FUEL OIL SYSTEM

9.5.4.1 Design Bases

The emergency diesel generator fuel oil system is a Safety Class 2B system designed to supply the minimum number of diesels required for 7 days of operation with 10 percent excess capacity for testing using the deliverable capacity of four of the five underground storage tanks. The minimum number of required diesels is described in paragraph 8.3.1.1.7.2. The required storage tank capacities are based on the following values:

A. Diesel fuel oil heating capacity of 135,000 Btu/gal at 60°F.

B. Diesel generator fuel oil consumption rates as identified in manufacturer's data.

The diesel generator fuel oil system meets the requirements of the single-failure criteria and is Seismic Category I.

The total diesel fuel oil storage capacity is divided as follows:

A. Day tanks for each diesel generator sized with a capacity sufficient for at least 4 h of operation.

B. Five shared underground storage tanks for the diesel generators are sized such that four tanks provide sufficient capacity for the 7-day requirement, plus an additional 10 percent of the 7-day requirement.

The following design data are applicable to the diesel generator fuel oil system:

Number of storage tanks	5
Storage tank capacity	40,000 gal/tank
Storage tank design pressure	Atmospheric
Storage tank design temperature	Ambient
Number of transfer pumps	10 (2 per storage tank)
Transfer pump capacity	20 gal/min
Transfer pump head	40 ft
Number of day tanks	5 (1 per diesel)

The emergency diesel generators use Grade No. 2 fuel oil:

Day tank capacity	1000 gal (2 tanks) 1325 gal (3 tanks)
Day tank design pressure	Atmospheric
Day tank design temperature	Ambient

The diesel generator fuel oil storage tanks are buried. The specification for these tanks required that they be designed to Article ND-3800 of the American Society of Mechanical Engineers (ASME) Section III nuclear code. Since this article does not specifically cover underground tanks subjected to external soil pressure, the tanks were designed in accordance with the spirit of the article. Section VIII, Division I, was used to obtain allowable external pressure on the tanks.

No code gives specific instructions for calculating the external pressure caused by soil cover. Therefore, the methods developed by the American Water Works Association (AWWA) were used because they have been proven by experience to be adequate. The ASME Section VIII code is much more conservative with regard to required shell thickness than the methods used by the AWWA. Thus, the methods used by AWWA to calculate soil pressure, combined with use of the ASME Section VIII code for shell thickness, give a very safe margin.

Underground piping is protected by a wrapping system which conforms to AWWA C203-66 (standard for coal tar enamel protective coatings for steel pipe). Corrosion protection for the underground storage tank consists of a bitumastic coating, similar to that used for the piping. A cathodic protection system is also provided for all underground piping and the underground storage tanks but not credited for aging management. Provision is made on each tank for periodic draining of any water which might collect.

All tanks, pumps, valves, and piping conform to the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Class 3, with the exception of the day tanks and the storage tank vent lines. The day tanks conform to the requirements of Section VIII of the code and the vent lines meet B 31.1 criteria.

9.5.4.2 Description

The diesel generator fuel oil system is shown in drawing D-170060, and additional drawings further describing the physical layout and dimensions of the system are D-170210, sheet 1; D-170211; D-170357, sheet 1; D-170357, sheet 2; and figure 9.5-1. The shared fuel oil storage system consists of five underground storage tanks interconnected with piping, valves, and redundant capacity fuel transfer pumps.

The diesel engine day tanks are replenished from the onsite storage tanks by individual supply lines with cross-connecting capability to the other day tanks. Each tank has the necessary fittings required for the following:

A. Truck fill and water removal.
B. Venting.
C. Instrument connections.
D. Mounting flanges for transfer pumps.

Each storage tank has two vertical, centrifugal transfer pumps that provide a redundant means for transferring fuel oil from the storage tanks to the day tanks and other storage tanks. These transfer pumps can also be aligned for fuel oil recirculation. The minimum recirculation time necessary for representative sampling can be established by dye tracer testing. Wye strainers fitted with type 316 stainless steel screen with 0.045-in. perforations are installed in the discharge line of each pump. System instrumentation and control are provided on the tanks and pumps as stated below.

Each day tank is equipped with level switches for starting and stopping one transfer pump with a switch at the low level giving an alarm and a second switch at the low-low level giving a second alarm so that the other pump can be started manually.

Local control stations, located in switchgear rooms, allow the transfer pumps to be individually started or stopped by the operator. All controls are powered from the respective pump's motor control center via control transformers that reduce the control voltage to a nominal 120 V-ac.

Day tank high-level and low-level alarms actuate in both the diesel generator building and the main control room. Alarms are powered from the 125 V-dc system.
Each day tank has the capacity for at least 4 h of operation of its respective diesel generator at rated continuous load. The tank has the fittings required for the following:

A. Water removal and drain valve.
B. Venting.
C. Instrument connections.
D. Suction and recirculation line connections and valves.

9.5.4.3 Evaluation

The minimum onsite fuel storage capacity has been determined to be adequate based on 7 days of operation of the minimum required diesels as described in paragraph 3.8.1.1.7.2.

Allowing an additional storage capacity of 10 percent for periodic testing of the diesel generators ensures that 7 days of useable fuel oil is always available.

The underground storage tanks can be filled directly from tank trucks. The possibility that delivery trucks could not reach the site under adverse weather conditions is very remote, since hard-surfaced roads for year-round transportation exist between the site and the metropolitan areas of Dothan and Columbia, Alabama. If road transportation cannot be provided, barge delivery can be used, as could delivery by helicopter.

Sizing criteria of each day tank were selected to provide adequate capacity to preclude excessive cycling of the transfer pump and at least 2 h of operation after the low-level alarm to allow sufficient time for manual operator action(s) in response to system or equipment problems. The low-low level alarm will warn the operator that at least a 1-h supply remains in the tank. A failure analysis of the system is presented in table 9.5-1.

9.5.4.4 Tests and Inspections

All components of the system are tested in accordance with applicable codes and standards.

The entire diesel generator fuel oil system is flushed with oil and then functionally tested in accordance with the procedure outlined in chapter 14. The fuel oil in the storage tanks and the day tanks will be periodically tested to detect any contamination or deterioration.

The diesel generator fuel oil system is required to supply acceptable quality diesel oil to the emergency diesel generators in an emergency condition for safe shutdown of the plant. The surveillance requirements of the diesel fuel oil system are delineated in the plant technical specifications. The Fuel Oil Chemistry Control Program credited as a license renewal aging management program is described in chapter 18, subsection 18.2.9.

9.5.4.5 Instrumentation Application

The diesel generator fuel oil system is provided with required level switches for automatic operation of the pumps.

The underground storage tanks are equipped with level transmitters which provide indication on the main control board. An insertion point for a manual dipstick gauge is also provided for each underground storage tank.

The emergency diesel generator fuel oil day tank instrumentation consists of: a liquid level control switch for controlling the operation of the automatic transfer pump and to provide a local and main control room low-low level alarm; a liquid level switch to provide local and main control room high-low level alarm; a level transmitter to provide main control room indication; and a sight glass. The sight glass is normally isolated to assure inadvertent breakage of the glass will not result in loss of fuel oil.

Control switches located on local panels can be used for starting or stopping the automatic and the manual transfer pumps. These control switches can also be aligned for automatic operation of the automatic transfer pump.

9.5.5 DIESEL GENERATOR COOLING WATER SYSTEM

9.5.5.1 Design Bases

The diesel generator cooling water system is a Safety Class 2B system designed to supply a continuous flow of cooling water to the heat exchangers on all diesel generators. The system meets the requirements of the single failure criteria and is Seismic Category I. Some replacement tube bundles for the diesel generator cooling water heat exchangers have been procured under the provisions of NRC Generic Letter 89-09, “ASME Section III Component Replacements.” Replacement tube bundles procured per GL 89-09 are indicated by an “X” in the appropriate column of table 9.5-3.

9.5.5.2 Description

The diesel generator cooling water system which supplies all diesel generator heat exchangers is shown in drawings D-170119, sheet 3 and D-200013, sheet 3.

Each diesel generator has a separate closed cooling water system. The assured Category I makeup source for diesel generator's closed cooling water system is from the Seismic Category I service water system. The normal operating source is from demineralized water, with the service water providing emergency backup.

9.5.5.3 Evaluation

The diesel generator cooling water system provides a completely redundant supply of cooling water to each diesel. Since the diesels themselves are redundant, this provides a complete backup. Valving is arranged so that no single failure renders the diesel generator system incapable of performing its safety function.

As shown in drawings D-170119, sheet 3 and D-200013, sheet 3, check valves are provided in the cooling water supply lines to the three shared diesels, so that cooling water is available from either of the operating units.

The isolation valves in the supply lines from both Unit 1 and Unit 2 to the shared diesels (1-2A, 1C, and 2C) will be left open. The nonshared diesels (1B and 2B) will be supplied only from the unit to which that diesel generator furnishes electrical power. The isolation valves in the line from the other unit are normally closed.
All diesels on one train are supplied with cooling water from the same train. Following a postulated failure of the common header supply piping of train B of Unit 1, diesel generator 2B will be receiving cooling water from train B of Unit 2, which is its designated supply source,

since the isolation valve in the Unit 1 supply line will be closed. In addition, diesel generator 2C will be receiving cooling water from train B of Unit 2.

Since the isolation valves in the discharge lines from the shared diesels will be left open during operation, these diesels will always have a cooling water discharge path to either Unit 1 or Unit 2.

A single-failure analysis is presented in table 9.5-2.

All piping is located in the diesel generator building or buried with a minimum of 3 ft 10 in. of cover. All valves are located inside the diesel generator building.

9.5.6 DIESEL GENERATOR STARTING SYSTEM

9.5.6.1 Design Basis

The diesel generator starting system is designed to:

- Supply sufficient compressed air at sufficient pressure which, introduced into the cylinder above the pistons in the normal firing order, cranks the engine at a speed sufficient for engine starting and reaching rated speed within the licensing basis time of 12 s after receipt of the initial start signal.

- Provide two redundant air starting trains for each engine so that no single active failure renders the diesel generator starting system inoperable.

- Meet Seismic Category I requirements for the portions of the diesel generator starting system which are required to start the diesel upon receipt of an actuation signal.

9.5.6.2 Description

The diesel generator starting air system is shown in drawings D-170806, sheets 1 and 2; D-170807, sheets 1 and 2; and D-200212. The starting system includes two completely redundant trains consisting of an air compressor large enough to recharge an accumulator in 30 min. The accumulator is of sufficient size to furnish air for five engine starts without recharging. The starting air system configuration differs slightly between the 3 large diesel engines and the 2 small diesel engines as described below.

A. PC-2 Diesel Engines 1-2A, 1B, and 2B (large engines)

For the large diesel engines, the starting air is piped from the accumulator to the air start valve (air operated). Upon an automatic start or a manual start signal from the control room, a solenoid valve is energized to admit air to open the air start valve which pressurizes the starting air header. The starting air from the header is distributed to each air start check valve on the cylinders in the right bank. The starting air distributor is driven from the free end of the camshaft and delivers air as it rotates to open the starting air check valves in the correct firing order. As air enters the cylinders and pushes on the pistons, the engine rotates until it starts. The redundant air starting train, which is also energized simultaneously with the first train by the same signal, consists of the same components and configuration except air is supplied to the left bank of cylinders.

B. 38TD8-1/8 Diesel Engines 1C and 2C (small engines)

For the small diesel engines, the starting air is piped from the accumulator to the air start valve (solenoid operated). Upon an automatic start or a manual start signal from the control room, the air start valve is energized to admit air to the starting air header and starting air distributor. The starting air distributor is driven from the free end of the camshaft and delivers air in the correct firing order to open the air start check valves for cylinders 1 through 6. As air enters the cylinders and pushes on the pistons, the engine rotates until it starts. The redundant air starting train, which is also energized simultaneously with the first train by the same signal, consists of the same components and configuration except air is supplied to cylinders 7 through 12.

9.5.6.3 Safety Evaluation

The two complete starting trains ensure that the failure of any one component will not affect the starting of the engine.

9.5.7 DIESEL GENERATOR LUBRICATION SYSTEM

9.5.7.1 Design Basis

The engine is equipped with a pressure lubrication and piston cooling system which supplies a continuous flow of oil to all surfaces requiring lubrication and to the pistons for cooling when the engine is running and a standby system to warm and circulate the oil when the engine is not running.

9.5.7.2 Description of External Oil System

9.5.7.2.1 Engine PC-2

The built-in lubricating oil pump is driven from the engine drive gear and draws oil from the oil sump through a mesh intake screen. The oil is then forced through an external cooler and strainer and back into the engine through the lower oil header. The lubricating oil temperature is regulated by means of a temperature regulator which bypasses more or less oil around the cooler. An electrically operated "keep-warm" pump runs continuously to circulate the oil through a thermostatically controlled heater and then through a 5-μm filter and back to the engine lower oil header. An additional electrically operated prelube pump is used to prelube the rocker arm system according to manufacturer's recommendations prior to any start other than automatic.

9.5.7.2.2 Engine 38TD8-1/8

The built-in lubricating oil pump is driven by the engine through a flexible drive coupling and draws oil from the oil sump through a mesh intake screen. The oil is then forced through an external filter, cooler, and strainer then back into the engine through the lower oil header. The lubricating oil temperature is regulated by means of a temperature regulator which bypasses more or less oil around the cooler. When the engine is not running, an electrically operated keep-warm pump circulates oil from the sump through a thermostatically controlled heater and is introduced back into the lube oil system at the discharge side of the engine-driven lube oil pump. An additional electrically operated prelube pump is used to prelube all engine bearings according to manufacturer's recommendations prior to any start other than automatic.

9.5.7.3 Description of Internal Oil System 38TD8-1/8 Engines 1C and 2C

Oil flows through the lower header toward the blower end where a vertical pipe carries the oil to the upper header so that the header will not readily drain. Through supply pipes from both lower and upper headers, oil is forced to each main bearing and thence through tubes swagged into the crankshaft to each crankpin bearing. From each crankpin bearing, oil passes through the drilled passage in the connecting rod to the piston pin bearings and to the pistons.

The cooling oil from each lower piston is discharged through a hole in the insert. Oil from each upper piston is discharged through a hole in the insert into the compartment around the upper ends of the cylinders. This oil then drains either toward the blower or the control end and down to the oil pan or subbase.

The two camshafts receive lubrication from the upper oil header. The camshafts are hollow, and small openings at each bearing allow oil to reach the bearing surfaces. An opening in the end of each camshaft supplies oil to the camshaft sprockets and to the overspeed governor.

During engine startup, a lube oil accumulator supplies oil to the upper crankcase oil system. The accumulator fills with oil during normal engine operation. The next time the engine is started, the oil accumulated in the cylinder is forced by starting air pressure into the bearings. As documented in the NRC SER for Design of Diesel Generator Lubrication Modifications for Diesel Generators 1C and 2C Farley Unit 2, dated 120/28/9982, the lubrication system of these engines conforms to the NRC acceptance criteria contained in the recommendations of NUREG/CR-0660 and will prevent a dry start during automatic starting.

9.5.7.4 Description of Internal Oil System PC-2 Engines 1-2A, 1B, and 2B

On the PC-2 engine 1-2A, 1B, and 2B, oil flows through the oil header and individual pipes distribute the oil to each of the crankshaft main bearings. Oil is then fed to the crankpin bearings through holes drilled to the crankshaft. Special drilling in the connecting rod allows the oil to flow up to the piston pin bushing, around the cooling tubes cast in the piston crown, and down the connecting rod to return to the engine sump.

Separate feeds are also taken into the camshaft drive gear, the governor drive, the end camshaft bearings, overspeed trip, and water pump bearings. Oil is also fed to a header along each side of the engine situated behind the fuel pumps. Individual pipes from these headers lubricate the intermediate camshaft bearings, push rods, rollers, and injection pump rollers.

A separate lubricating oil system is provided for lubrication of the valve rocker gear on the cylinder heads. This system incorporates its own pump, driven from the engine camshaft, and a small reservoir tank in which the oil level is automatically controlled. A duplex filter is provided in this system.

9.5.7.5 Safety Evaluation

A failure of one component of the lubricating oil system will not jeopardize the availability of onsite generation for safe shutdown requirements. The lubricating system for each diesel is located totally within the compartment of its associated diesel. Therefore, failure of this system associated with a particular diesel will not affect the integrity of the other diesel generators.

TABLE 9.5-1

FAILURE MODE AND EFFECTS ANALYSIS OF DIESEL GENERATOR FUEL OIL SYSTEM

Items Description	Function	Failure Mode	Cause of Failure	Effect on Subsystem	Method of Failure Detection	Effect on System
1. Diesel oil storage tank	Each tank stores 3 1/2 days supply of fuel per tank for 1 diesel	Leaks	Crack, corrosion	Loss of insignificant oil supply	Level indicator and periodic inspection	None: Tanks still available
2. Transfer pump	Pump fuel to day tank or storage tanks	No output	(1) Motor fail	Cannot pump fuel oil	Level alarm	None: Use redundant diesel
			(2) Pump fail	Cannot pump fuel oil	Level alarm	None: Use redundant diesel
			(3) Loss of power	Cannot pump fuel oil	Level alarm	None: Use redundant diesel
3. Transfer line	Pipe fuel to day tank	Rupture	Crack, corrosion	Only 3 hours of available fuel oil to the diesel it serves	Level alarm	None: Use redundant diesel
4. Day tank	Stores 4-hour fuel supply at diesel	Rupture	Crack, corrosion	Loss of fuel supply to the diesel it serves	Level alarm	None: Use redundant diesel
5. Valve	Isolate portion of line to transfer fuel	Leaks	Crack, corrosion	Loss of part of oil supply	Level indicator	None: Four tanks still available
6. Valve	Unisolate portion of line to transfer fuel	Frozen in place	Valve disc to stem separation	Cannot transfer oil supply	Operator identified	None: Use redundant diesel

TABLE 9.5-2

SINGLE FAILURE ANALYSIS DIESEL GENERATOR COOLING WATER

Component	Malfunction	Effect on Safety-Related Systems	Comments
Diesel generator	Diesel failure	No effect	Redundancy of the diesel generators is provided.
Cooling water supply header	Line break	No effect	Failure of either cooling water train of either unit can result in the disabling of no more than one large and one small diesel generator. One large diesel per unit is capable of furnishing the required safety-related power to its assigned unit. A total of two small and three large diesels is provided.
Supply header	Header isolation valve fails closed	No effects	During two-unit operation, no single train supplies cooling water to more than one small diesel and one large diesel. Therefore, any train failure affects only these diesels. During one-unit operation, the above statement is also true. Only a total of four diesels is considered operational during one-unit operation. The large diesel assigned to the nonoperating unit will be isolated. The nonshared large diesel will be isolated from the unit not required to furnish cooling water to that diesel.
Discharge header	Header isolation valve fails closed	No effects	During two-unit operation, each diesel will have a discharge path to either of the units. Therefore, this single failure will not result in loss of flow to the diesels. During one-unit operation, this failure will result in the loss of flow to the diesel of the failed cooling water train only. The remaining train will provide cooling water to the required number of diesels in that train.

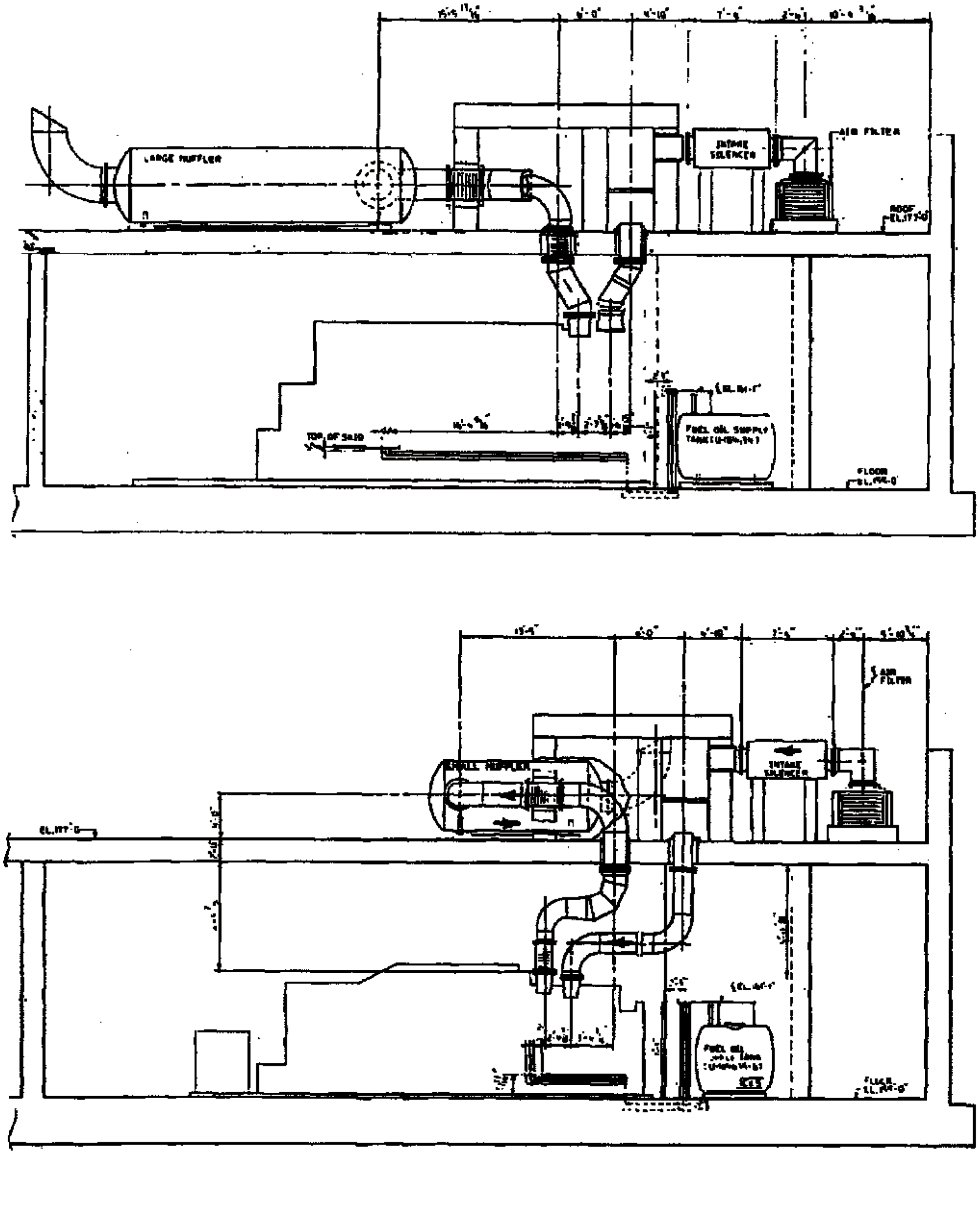
TABLE 9.5-3

DIESEL GENERATOR COOLING WATER SYSTEM HEAT EXCHANGER TUBE BUNDLE REPLACEMENT

The following Diesel Generator Cooling Water System Heat Exchanger Tube Bundles have been replaced with tube bundles procured under the provisions of NRC Generic Letter 89-09 (i.e., the replacement bundles are like-for-like replacements meeting the original ASME Section 3 requirements except for the Code Stamp):

Heat Exchanger	TPNS Number	Generic Letter 89-09 Replacement Tube Bundle Installed
1-2A Lube Oil Cooler	QSR43H0505	*Note 1
1-2A Jacket Water Cooler	QSR43H0511	X
1B Lube Oil Cooler	Q1R43H0501	*Note 1
1B Jacket Water Cooler	Q1R43H0503	X
2B Lube Oil Cooler	Q2R43H0501	*Note 1
2B Jacket Water Cooler	Q2R43H0503	X
1C Lube Oil Cooler	QSR43H0504	*Note 1
1C Inter-Cooler	QSR43H0514	X
1C Jacket Water Cooler	QSR43H0510	X
2C Lube Oil Cooler	QSR43H0503	*Note 1
2C Inter-Cooler	QSR43H0513	X
2C Jacket Water Cooler	QSR43H0509	X

*Note 1: These diesel generator cooling water system heat exchanger tube bundles have been subsequently replaced with new tube bundles which are manufactured using more erosion resistant materials. These replacement tube bundles meet all of the ASME Section 3 requirements including the code stamp.



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DIESEL GENERATOR FUEL OIL
SYSTEM PHYSICAL LAYOUT

FIGURE 9.5-1

**APPENDIX 9A ULTIMATE HEAT SINK EVALUATION -
RESIDUAL DECAY HEAT**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX 9A

ULTIMATE HEAT SINK ELEVATION - RESIDUAL DECAY HEAT

9A.1 DECAY HEAT

The decay heat generation for the Farley units is given in figure 9A-1. These curves are provided in Westinghouse Specification No. BOP-FR-8, Rev. 1, Functional Requirements and Design Criteria-Residual Decay Heat Standard. The decay heat values for the Farley units are taken from these curves. The finite irradiation time assumes a three-region core with equal mass regions irradiated for 8000, 16,000, and 24,000 h (effective full power), respectively.

These data have been compared to those which result from an application of the American Nuclear Society standard (ANS-5) for finite times using, for the contribution from fission products, the formula:

$$P/Po(t) = (1+u)\left\{1/3\sum_{i=1}^{3}\left[P/Po\,(\infty, t) - P/Po\left(\infty, t + t_i\right)\right]\right\}$$

Where:

I	=	Core region of interest.
t_i	=	Irradiation time of region i (8000 h for region 1, 16,000 h for region 2, and 24,000 h for region 3).
P/Po (t)	=	Decay heat fraction of initial power at time t.
P/Po (∞,t)	=	Decay heat fraction for infinite irradiation time from ANS-5 curve.
u	=	Recommended uncertainties per ANS-5 (20 percent t is 10^3 s, 10 percent 10^3 s < t < 10^7 s).

The result, within the accuracy of reading two values from the ANS-5 curve for infinite irradiation and the accuracy of plotting the difference plus prescribed uncertainties, agrees with the fission product decay curve in figure 9A-1.

The U-238 capture decay (due to U-239 and Np-239 decay) contribution shown in figure 9A-1 was calculated with equations prescribed by ANS-5 plus a 10-percent uncertainty.

The contribution from delay neutron-induced fissions is excluded from consideration by ANS-5.

A sample of the decay heat values used in the evaluation of the ultimate heat sink is given in table 9A-1. These values are based on the residual decay heat curves provided in NUREG-0800, Standard Review Plan, Revision 2, July 1981, Branch Technical Position ASB

9-2 (pages 9.2.5-11 to 9.2.5-13). Figure 9A-2 compares the Westinghouse total decay heat curve to the curve obtained using the total decay heat values from the updated ultimate heat sink evaluation. The curve formed using the total residual decay heat values from the UHS envelopes the Westinghouse curve; hence, the values used in the UHS calculation are conservative.

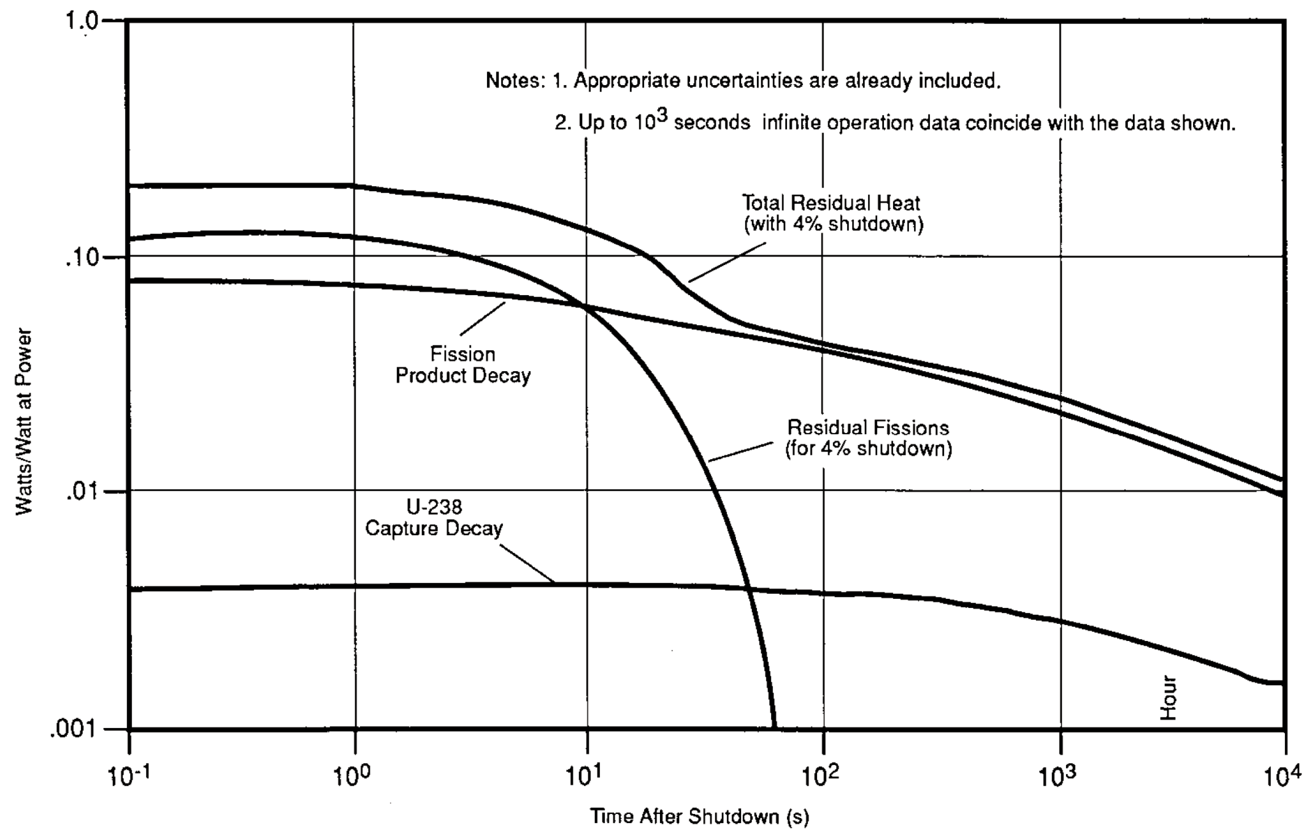
NUREG-0800 was employed in the heat sink calculation because it provides an added conservatism in the determination of residual decay heat and, subsequently, to the heat load to the ultimate heat sink. Furthermore, in no way does the use of NUREG-0800 in the ultimate heat sink calculation alter the existing design basis provided by the Westinghouse curves.

TABLE 9A-1

RESIDUAL DECAY HEAT USED IN THE UPDATED UHS CALCULATION

The total residual decay heat values used in the updated heat sink calculation are based on the residual decay heat curves provided in NUREG-0800 (page 9.2.5-11 to 9.2.5-13). The curves provide residual decay heat values in terms of fractions of full power. The value for full power that is used to determine the megawatt value of residual decay heat is 2774 MW. This MW decay heat is then converted to Watts and, finally, to Btu/h. The decay heat values are reported relative to the time when the reactor is shutdown.

$T_{shutdown\ (s)}$	Residual Decay Heat Rate (10^7 Btu/h)
14800	9.8
34800	7.7
54800	6.8
74800	5.9
92800	5.5
112800	5.3
132800	5.2
152800	5.0
172800	4.8
192800	4.7
217800	4.4
242800	4.2
267800	4.0
292800	3.8
317800	3.7
342800	3.6
392800	3.5
442800	3.4
492800	3.3
542800	3.2
592800	3.0
642800	2.9
692800	2.7
792800	2.5
992800	2.3
2584800	2.3



* Finite defined as three-region core with 8000, 16,000, and 24,000 h, respectively, of full-power operation.

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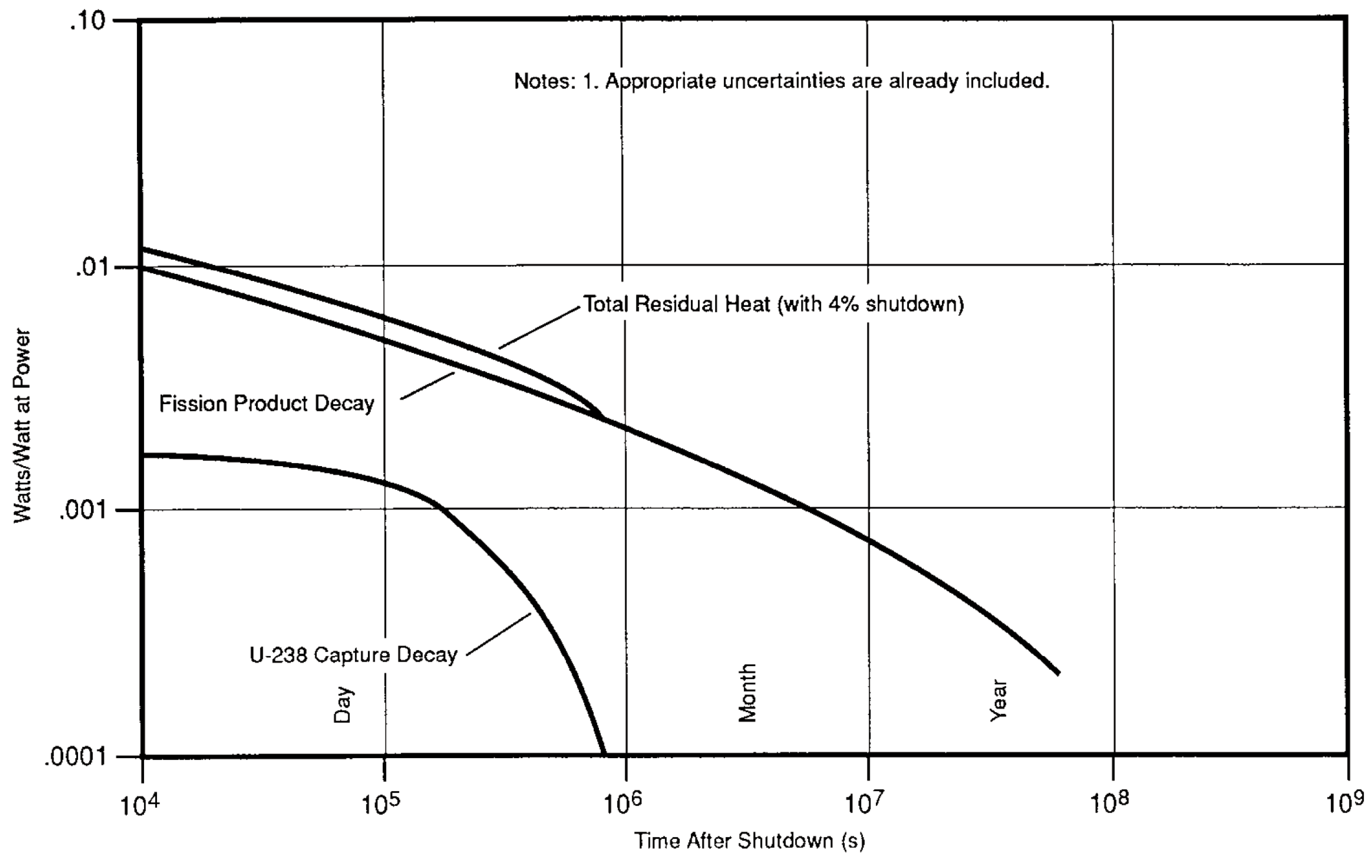
RESIDUAL DECAY HEAT FINITE IRRADIATION OF THREE-REGION CORES

FIGURE 9A-1 (SHEET 1 OF 2)



Finite defined as three-region core with 8000, 16,000, and 24,000 h, respectively, of full-power operation.

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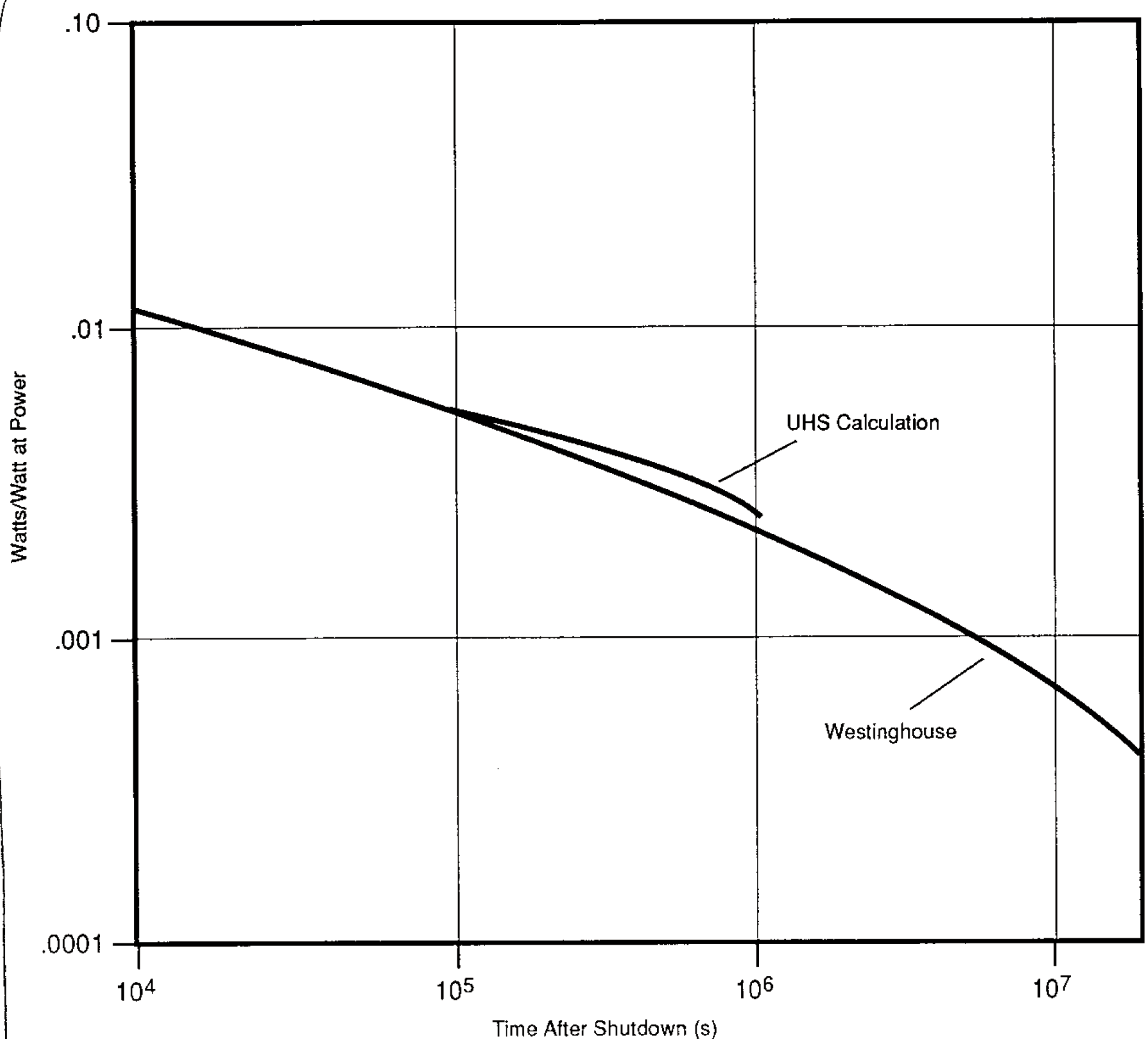
RESIDUAL DECAY HEAT FINITE IRRADIATION OF THREE-REGION CORES

FIGURE 9A-1 (SHEET 2 OF 2)



Finite defined as three-region core with 8000, 16,000, and 24,000 h, respectively, of full-power operation.

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COMPARISON OF WESTINGHOUSE AND UHS CALCULATION RESIDUAL DECAY HEAT CURVES

FIGURE 9A-2

APPENDIX 9B FIRE PROTECTION PROGRAM

Refer to A-181805, NFPA 805 Fire Protection Program Design Basis Document.

10.0 STEAM AND POWER CONVERSION SYSTEM

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

10.0 - STEAM AND POWER CONVERSION SYSTEM

10.1 SUMMARY DESCRIPTION

The steam and power conversion system is designed to accept steam from the nuclear steam supply system (NSSS) and convert its thermal energy into electrical energy. It consists of the turbine-generator, main steam supply system, main condenser, turbine bypass system, condensate and feedwater system, steam generator blowdown system, main condenser evacuation system, turbine gland sealing system, and circulating water system. The steam and power conversion system has a capability of 2785 MWt and 920 MWe. A flow diagram is provided for the main steam supply system in drawings D-175033, sheet 1, D-175033, sheet 2, D-170114, sheet 1, D-170114, sheet 2, D-205033, sheet 1, D-205033, sheet 2, and D-200007. A summary of major equipment is provided in table 10.1-1. Heat balances are shown in figures 10.1-1 and 10.1-2 for both normal and maximum volumetric flow rates, respectively.

The turbine is a Westinghouse (modified by Siemens) 1800 rpm, tandem compound, 4-flow exhaust with 45.5-in. last-stage blades. It is equipped with an automatic stop and emergency trip system which will trip the stop and control valves to a closed position in the event of turbine overspeed, low bearing oil pressure, low vacuum, or thrust bearing failure. (See section 10.2.)

The main steam supply system includes the associated piping and valves required to conduct the steam through the steam and power conversion system. Steam generated in the three steam generators will be conducted through the containment wall in three lines. Isolation valves and spring-loaded safety valves will be located outside of containment in each of the three steam lines, with the safety valves being located upstream of the isolation valves. Beyond the isolation valves, the three main steam lines join in a header, and downstream of the header, the flow splits into two separate lines which both lead to the turbine. At the turbine, flow from each of these two main steam supply lines will feed the turbine. Steam to the auxiliary feedwater pump turbine will be taken in separate lines from two of the three main steam lines. Steam will be supplied to the steam reheaters, the gland steam sealing system, the auxiliary steam system, the steam generator feedwater pump turbine, and other components and systems. (See section 10.3.)

The main condenser serves as a heat sink for the main turbine exhaust, feed pump turbine exhaust, turbine bypass steam, and other flows. It also provides for deaeration and storage for the condensate. Each low-pressure turbine casing is connected by the use of a single-convolution, stainless steel expansion joint to its condenser. (See subsection 10.4.1.)

The turbine bypass system provides a route for throttle steam to bypass the turbine and enter the condenser directly. This route is provided for the case of large turbine load reduction which could cause an undesired magnitude of nuclear system transients. The bypass system is capable of allowing a 50-percent load decrease in the turbine load without reactor trip. (See subsection 10.4.4.)

The condensate and feedwater system is a closed cycle which serves to conduct condensed steam from the main condenser to the steam generators located inside the containment.

Deaeration of the condensate is performed in the hot well of the main condenser. The condensate is then pumped through five stages of low-pressure feedwater heaters, followed by one stage of high-pressure feedwater headers, before entering the steam generators. (See subsection 10.4.7.)

The steam generator blowdown system is designed to maintain the water chemistry in the secondary coolant system at an optimum purity level. Blowdown liquid is taken off at the steam generator stage and processed with the use of ion exchange resins to remove impurities which may have been added through leaks in the steam and power conversion system. This system also removes radioactive contaminants which may enter the secondary side of the steam generator through defects in the steam generator tubing. After the contaminants have been removed for offsite disposal, the purified blowdown liquid is recycled to the main condenser.

The main condenser evacuation system, by the use of hogging ejectors during startup and steam jet air ejectors during normal running, creates a vacuum on the main condenser to ensure proper flow of the condensing steam. (See subsection 10.4.2.)

The turbine gland sealing system acts to seal the turbine shaft from leakage of air into the turbine interior or leakage of steam out of the turbine into the turbine building. (See subsection 10.4.3.)

The circulating water system is designed to remove the waste heat from the thermal cycle. It will also remove the heat released into the condenser by the steam dump system during plant startup, cooldown, or during steam dump operation following a large load reduction. (See subsection 10.4.5.)

Portions of the main steam supply system and the condensate and feedwater system are safety related. There is an extremely small amount of radioactivity in the steam and power conversion system during normal operation; therefore, no radiation shieldings (besides piping and housing) are required for this system. The portion of the steam and power conversion system which is located outside containment is continuously accessible under normal operating conditions.

TABLE 10.1-1 (SHEET 1 OF 2)

MAJOR STEAM AND POWER CONVERSION EQUIPMENT SUMMARY DESCRIPTION

Number of units	2
Reactor core (net MWt, each unit)	2,775
Reactor coolant pump heat input (MWt, each unit)	10
Total NSSS power (MWt, each unit)	2,785
NSSS total steam flow (lb/h, at maximum calculated, each unit)	12.26 E+06
Steam generator design pressure (psia)	1,100.0
Steam generator design temperature (°F)	600.0
NSSS steam outlet moisture (%)	0.10
NSSS inlet feedwater temperature (°F, at maximum calculated) (T)	444.0

Turbine-Generator Ratings[1,3]

Number of units	2
Turbine	
Throttle steam pressure (psia)	739.69
Throttle steam temperature (°F)	509.3
Throttle steam moisture (%)	0.27
Throttle steam flow (lb/h, each unit)	11,855,179
Exhaust pressure (in. Hg abs)	2.2
Generator	
Nameplate output (kW, each unit)	947,147
Power factor (pf)	0.85 (note 2)

TABLE 10.1-1 (SHEET 2 OF 2)

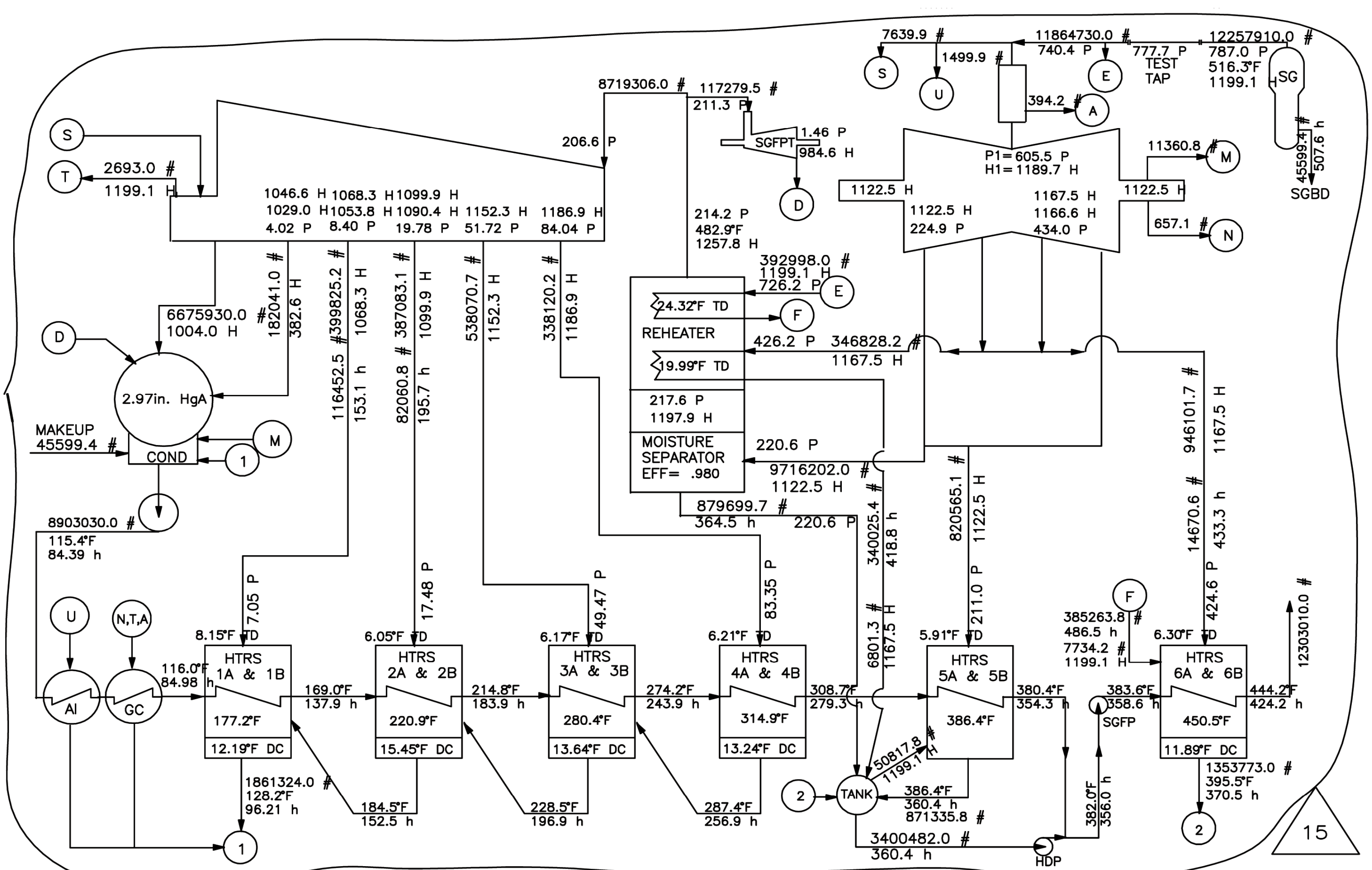
Generator rating (kVA)	1,045,000.0
Voltage	22,000.0
H_2 pressure (psig)	75.0

Notes:

(1) Ratings unchanged for power uprate. Uprate was evaluated based on the representative conditions reflected in figures 10.1-1 and 10.1-2.

(2) The Units operate near a power factor of 1.0.

(3) Nameplate output (kW, each unit) changed as a result of LP turbine replacement. Other ratings including throttle steam pressure, throttle steam temperature, throttle steam moisture, throttle steam flow, and exhaust pressure were not changed as a result of the LP turbine replacement but were revised by Siemens with the vendor manual transmittal for the LP turbine replacement.



Note: Flow conditions downstream of the LP turbine to the condenser have changed as a result of the LP turbine replacement.

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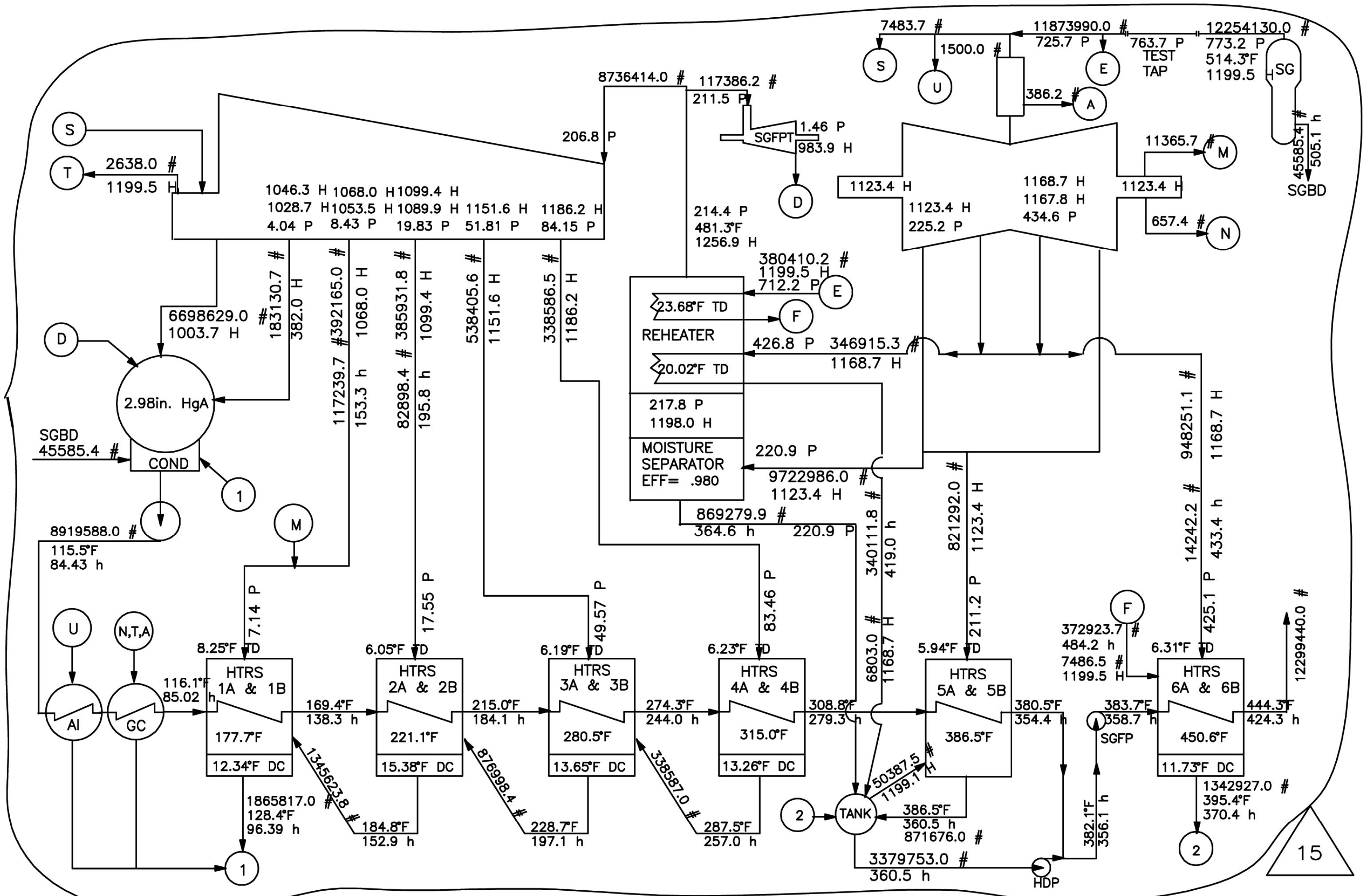
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	HEAT BALANCE – NORMAL FIGURE 10.1-1



Note: Flow conditions downstream of the LP turbine to the condenser have changed as a result of the LP turbine replacement.

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SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	HEAT BALANCE – MAXIMUM FIGURE 10.1-2

10.2 TURBINE-GENERATOR

10.2.1 DESIGN BASES

The turbine-generator is designed to convert the thermal energy of the steam generated by the nuclear steam supply system (NSSS) into electrical energy. As stated in section 10.1, it is a Westinghouse (modified by Siemens) 1800 rpm, tandem compound, 4-flow exhaust with 45.5-in. last-stage blades. The turbine is designed at maximum flow to accept up to 11,701,421 lb/h of throttled steam at a pressure of 750 psia, a temperature of 510.8°F, and 0.4-percent moisture for a maximum output of 895,534 kW by the generator. Modifications for power uprate conditions (representative data presented in figures 10.1-1 and 10.1-2) have increased expected output to approximately 910 MWE (gross). The LP turbine replacements increased expected output to approximately 933.4 MWE (gross). It is intended for a base-loaded operation with capabilities for load following when required.

The turbine-generator is designed to accommodate a 100-percent step-load reduction with the use of the turbine bypass system.

This capability is limited by the reactor coolant system (RCS) which is designed to accommodate a step change of 10 percent of full power step and a 5-percent per minute ramp up to and including but not exceeding 100 percent of full power without reactor trip. The reactor coolant system can accept a complete loss of load from full power with reactor trip. In addition, the steam dump system makes it possible to accept a 50-percent load rejection from full power without reactor trip.

The turbine is considered a machine and Westinghouse and Siemens have developed their own internal proprietary standards and specifications which are continuously updated in comparison to ASME codes and standards. The generator is designed to ANSI C50 standards.

10.2.2 DESCRIPTION

Saturated steam is supplied to the turbine throttle from the steam generators through four stop valves and four control valves. The steam flows through a two-flow, high-pressure turbine and then through four combination moisture separators reheaters in parallel to two double-flow, low-pressure turbines which exhaust to the main condenser. There are two stages of feedwater reheating off the high-pressure turbine and four stages of feedwater reheating off the low-pressure turbines; the steam supplied to these stages of feedwater reheating is provided by the extraction steam system. This extraction steam system is designed to supply steam from various stages of the high-pressure and low-pressure turbines to the moisture separators, high-pressure heaters, low-pressure heaters, auxiliary steam system, and condensate recovery system. The extraction steam provisions are shown in drawings C-170072, C-170073, C-170074, C-170075, C-170076, D-170076, D-170077, and D-200009.

The turbine-generator system and auxiliaries are capable of accepting a greater instantaneous or rate-of-load change than can be supplied by the reactor coolant system. Therefore, load transients which may occur are dictated by the reactor coolant system rather than the turbine generator.

The ac generator is a direct-coupled, 60-cycle, 3-phase, 22,000-V unit rated at 1,045,000 kVA at 0.85 power factor (the units operate near a power factor of 1.0); it has a short-circuit ratio of 0.58. The generator shaft seals are oil sealed to prevent hydrogen leakage. The generator has its own shaft-driven excitation equipment.

The turbine lubricating oil system supplies oil for lubricating the bearings. A bypass stream of turbine lubricating oil will flow continuously through an oil conditioner to remove water and other impurities.

The turbine is equipped with an automatic stop and emergency trip system which will trip the stop and control valves to a closed position in the event of turbine overspeed, low bearing oil pressure, low vacuum, or thrust bearing failure. An electric solenoid trip is provided for remote manual trips and for various automatic trips. The occurrence of a turbine trip from any of the above when operating at approximately 50-percent power or greater will cause a reactor trip signal to be supplied to the reactor protection system thus tripping the reactor.

High-pressure steam enters the turbine through four turbine throttle valves and four governor valves. Two turbine throttle and two governor valves form a single assembly. The steam exhausts from the high-pressure cylinder, flows through the reheaters, and reenters the turbine through the four reheat stop valves and the four reheat intercept valves.

The turbine-generator system is equipped with a digital electrohydraulic (DEH) control system to control steam flow through the turbine. The DEH control system performs two main functions--control of turbine speed and control of turbine load.

The spring-loaded valves are positioned by hydraulic actuators which receive their motive fluid from a high-pressure fluid supply system.

The digital controller positions the throttle and governor valves by means of electrohydraulic servo loops. In the event of a partial loop drop, the interceptor valves are closed by energizing a solenoid valve on the appropriate valve actuators.

The digital controller receives three feedbacks from the turbine--speed, generator megawatt output, and first-stage pressure, which is proportional to turbine load.

For Unit 1 Only

The operator controls the turbine and receives his information from the human machine interface (HMI) installed on the operator workstation (OWS) in the main control room (MCR).

The Ovation DEH turbine controller contains a redundant OA/OPC (operator auto/overspeed protection controller) drop to perform all base DEH functions. If the primary OA/OPC distributed processing unit (DPU) fails, the backup OA/OPC DPU will automatically take over for reliability. If both primary and backup OA/OPC drops should fail, the turbine will be tripped. This ensures that the turbine overspeed protection features of the DEH control system are continuously available during automatic or manual turbine operation.

For Unit 2 Only

The operator controls the turbine and receives his information from the manual OIM panel or the operator's/alarm CRT and keyboard along with an alarm and message printer. Preassembled cables connect the operator's man-machine interface (MMI) and printer to the operator's DPU.

The WDPF DEH MOD III turbine controller contains a redundant OPC (overspeed protection controller) drop and a redundant OAC (operator auto controller) drop to perform all base DEH functions. If the primary OPC DPU fails, the backup OPC DPU will automatically take over for reliability. If both primary and backup OPC drops should fail, the turbine will be tripped. This ensures that the turbine overspeed protection features of the DEH control system are continuously available during automatic or manual turbine operation. Additionally, if the OAC drop in control (primary or backup) fails, then the controller will transfer to Turbine Manual.

For Unit 1 and 2

The high-pressure fluid supply system is of the constant pressure type and is completely separate from the lubricating oil system. A dual pump system is used with one pump serving as a complete backup. The backup pump starts automatically from low header oil pressure.

The high-pressure fluid trip headers connected to each valve actuator assembly are controlled by a diaphragm-operated emergency trip valve and solenoid valves.

The mechanical overspeed trip arrangement is also retained. When the trip valve is opened, either by overspeed or other emergency conditions, the pressure in the two headers is released initiating quick closing of all steam valve actuators. A solenoid valve actuated by a pressure switch on the autostop oil trip header serves as an electrical backup for the interface valve. This redundant solenoid valve arrangement controls the trip header for all steam valves.

The servoposition loop previously described is optimized to obtain a steady-state position accuracy of less than 0.005 in., a transient response of approximately 10 Hz at 90-degree phase lag, and a valve closing time for dump conditions of 0.1 to 0.15 s. This performance assures adequate overspeed protection and stable operation for the changes in steam forces or fluid supply pressure.

Turbine overspeed is prevented by the rapid cutoff of steam admission to the turbine. Main steam and reheat steam admission are both controlled by series alignments of stop and control valves which are held open against strong spring pressure by high-pressure hydraulic fluid. Overspeed control is by trip valve release of the hydraulic fluid pressure. Redundant shaft-speed sensors and trip valving systems assure a highly reliable prevention of turbine overspeed.

The digital electrohydraulic control system contains a turbine shaft-speed transducer and is the basic control system for turbine overspeed. At 103 percent of rated shaft speed, this system releases the actuating hydraulic fluid pressure to move the main steam control and reheat intercept valves toward the closed position in an attempt to maintain shaft speed at less than 103 percent of rated speed.

Backup control is supplied by an overspeed trip valve and mechanical overspeed mechanism which consists of a spring-loaded eccentric weight mounted in the end of the turbine shaft. At 111 percent of rated shaft speed, centrifugal force moves the weight outward to mechanically actuate the overspeed trip valve which dumps autostop oil pressure, and in turn releases the actuating hydraulic fluid pressure to close the main steam stop and control valves and the reheat steam stop and intercept valves. The supply steam pressure acts to hold the stop valves closed.

Upon loss of the actuating hydraulic fluid pressure, an air pilot valve closes the extraction nonreturn valves to all feedwater heaters.

The secondary backup overspeed control is provided by the electrohydraulic control system if the turbine speed exceeds approximately 111.5 percent of rated speed. At this point, the solenoid trip is energized to dump the autostop oil, which in turn dumps the actuating hydraulic fluid pressure, to ensure closing of the main steam stop and control valves and the reheat steam stop and intercept valves.

Alabama Power Company (APC) has developed a comprehensive program for maintenance calibration and testing of the turbine overspeed protection system with the overall objective of maintaining the high reliability of this system. The program, which is entitled "Turbine Overspeed Reliability Assurance Program," is based on recommendations by Westinghouse regarding valve maintenance and on operating experience at FNP.

The maintenance program includes provisions for inspections and maintenance of the throttle, governor, reheat stop and intercept valves.

The calibration program includes provisions for the calibration of the turbine overspeed protection system. Calibration is performed during each refueling outage or following major maintenance on the turbine generator or the overspeed protection system.

The testing program includes provisions for turbine valve and turbine overspeed protection system testing. Testing is performed during each turbine startup, unless tested within the previous 7 days, including startup after each refueling outage. This program also includes a test of all the turbine valves on an approximate 6-month interval. The turbine overspeed trip system functional test is performed each refueling outage or when major maintenance is performed on the turbine. This test involves manually controlling turbine speed up to the trip set points to observe actual turbine overspeed trips.

SNC will monitor the reliability information of the turbine valves as results are obtained from the Westinghouse Nuclear Plant fleet experience and the FNP valve experience.

This comprehensive program is the subject of ongoing review and evaluation. The schedules and/or scope of the maintenance, calibration, and testing programs are subject to revision as appropriate, based on operating experience or changes to the manufacturer's recommendations. This program and any subsequent changes will be reviewed and approved as specified in existing plant administrative procedures. The program will be performed in accordance with procedures, maintenance work orders, and/or outage work schedules as appropriate. All deviations from the program and deficiencies identified through the specified maintenance, calibration, or testing activities will be evaluated by SNC to determine appropriate action to be taken such as correcting the deviation or deficiency, performing compensatory action, or removing the turbine from service.

10.2.3 TURBINE MISSILES

Nondestructive examination (NDE) of low pressure (LP) turbine rotor discs is performed to confirm that, if cracks exist, they do not pose an unacceptable risk for continued operation. Assessment of the NDE data is performed to determine the next required inspection interval. This assessment may be based on approved deterministic or probabilistic methods (References 3, 4, and 5).

The Siemens methodology presented in TP-04124 (reference 6) justifies the external missile generation probability in extending the disc inspections of the Siemens 13.9 m^2 retrofit design of LP rotors for up to 100,000 operating hours with quarterly test frequency for the main turbine stop and control valves as outlined in FSAR subsection 10.2.2. The results of this methodology demonstrate the turbine missile probability, P1, to be well below the NRC's acceptance criteria of 1E-05 per turbine year at a quarterly control valve surveillance interval provided that no crack is detected in the disc. Siemens further extended the recommended maximum valve surveillance interval to 6 months in Service Bulletin SB3-13-0009-ST-EN-01 (reference 7).

10.2.4 EVALUATION

The turbine generator and related steam-handling equipment is a concept of proven design that is capable of handling the plant load requirements. During normal operation, this system is designed to have an extremely small level of radioactivity.

Assuming steam generator tube leakage, the small amount of radioactivity which may enter the turbine generator is monitored in the steam jet air ejector discharge. Radioactivity which may be present in the secondary coolant loop is also monitored in the steam generator blowdown system and the steam generator sample system. Because of the low activity levels, sufficient shielding is provided by the piping, turbine casing, and other components. There is continuous access to the turbine area. (Refer to section 11.4 for monitoring and shielding information.)

REFERENCES

1. Regulatory Guide 1.115, Revision 1, dated July 1977, titled “Protection Against Low-Trajectory Turbine Missiles.”

2. Letter from Charles E. Rossi of NRC to James A. Martin of Westinghouse dated February 2, 1987, transmitting approval of various topical reports related to calculating probability of turbine missiles.

3. Letter from H.C. Bissell of Westinghouse to Don Mansfield of Southern Nuclear dated May 25, 1994, titled “Turbine Valve Testing Frequency.”

4. Letter from S. A. Varga of NRC to F. L. Clayton of APC dated August 24, 1981, titled “Turbine Disc Cracking.”

5. Letter from F. L. Clayton of APC to S. A. Varga of NRC dated September 21, 1981, titled “Turbine Disc Inspection Intervals.”

6. Siemens-Westinghouse Topical Report TP-04124 dated June 7, 2004, titled “Missile Probability Analysis for the Siemens 13.9M^2 Retrofit Design of Low-Pressure Turbine by Siemens AG.”

7. Siemens Service Bulletin SB3-13-0009-ST-EN-01 dated April 16, 2013, titled “Nuclear Steam Turbine Inlet Valve Testing Frequency.”

10.3 MAIN STEAM SUPPLY SYSTEM

The main steam supply system (MSSS) carries the steam generated in the three steam generators through the containment to the following components and systems:

A. Turbine-generator.

B. Moisture separator reheaters.

C. Steam jet air ejector system.

D. Turbine shaft gland seals.

E. Steam generator feedwater pump turbines.

F. Turbine-driven auxiliary feedwater pump.

G. Turbine bypass system.

Drawings D-175033, sheet 1, D-175033, sheet 2, D-170114, sheet 1, D-170114, sheet 2, D-205033, sheet 1, D-205033, sheet 2, and D-200007 show the schematic arrangement of the MSSS piping. The main steam piping up to and including the isolation valves in the main steam lines to the turbine-generator and the main steam piping to the auxiliary feedwater pump turbine have safety-related functions.

10.3.1 DESIGN BASES

10.3.1.1 Functional Requirements

The MSSS conducts the generated steam from the outlet of the steam generators to the various system components. The steam is used for various operational auxiliary services such as shaft steam seals, turbine drives for main and auxiliary feedwater pumps, and steam jet air ejectors, as well as for its principal purpose of supplying the main turbine and reheaters. This system also provides steam to other systems associated with steam generator pressure relief heat removal from the nuclear steam supply system (NSSS), such as the steam generator safety valves, relief valves, and steam dump valves.

The performance requirements for the MSSS are as follows:

A. Optimum pressure drop between steam generators and turbine valves.

B. Similar steam conditions between each turbine stop valve and between each steam generator must be maintained. The maximum pressure variance between one steam generator and any other is 50 psi. To ensure even steam pressure at all loads, the main steam piping is interconnected downstream of the isolation valves and also prior to the turbine stop valves.

C. Adequate piping flexibility is provided to limit forces and moments at the anchor points and upon all plant components to acceptable levels. Stress levels within the piping itself are within the limits specified in the applicable piping codes.

D. Adequate draining provisions for startup and for operation with saturated steam are provided. All low points and closed-end lines are drained to preclude any water accumulation.

10.3.1.2 <u>Safety Requirements</u>

The safety aspects of the main steam system are concentrated on the portions of main steam lines from the steam generators, out through the containment, and up to and including the main steam line isolation valves.

The safety requirements for the MSSS are as follows:

A. The steam lines and the shell side of the steam generator are basically considered as an extension of the containment boundary and, as such, must not be damaged as a consequence of reactor coolant system (RCS) damage. The steam generator shell and steam lines within the containment are therefore protected against a reactor coolant system missile. The reverse is also true in that a steam line break will not cause damage to the reactor coolant system.

B. The measured steam flowrate has a functional requirement. Functionally, the flowrate signal is used by the three-element feedwater controller and as a load index signal for the plant's variable speed main feedwater pumps. It is also used in the development of a steam flow-feed flow mismatch alarm.

   The flowrate is determined by measuring the dynamic pressure losses between the steam generator and a downstream point in the steam line before the containment.

C. The portion of the MSSS up to and including the main steam isolation valves is necessary for the safe shutdown of the plant and is Safety Class 2A and Category I Seismic.

D. Uncontrolled steam release as a result of a steam line failure is limited to the contents of one steam generator in order to keep the related effect upon the reactor core within prescribed bounds.

E. The failure of any main steam line or malfunction of a valve installed therein will not:

   1. Render inoperable any engineered safety feature (ESF).

   2. Result in the containment pressure exceeding the design value or impairing its integrity.

Other safety-related design provisions include:

A. The steam generator safety valves.

B. The steam generator relief valves.

C. The steam supply to the turbine-driven auxiliary feedwater pump. The steam supply to this turbine has a safety classification because of the safety-related functions of the auxiliary feedwater system. The turbine steam supply lines are connected to two steam generator steam lines upstream of the steam line protective valving to provide both redundancy and dependability of supply. Isolation valves in each line maintain the separation of the main steam lines by preventing any interconnecting backflow.

D. Each steam generator includes an internal restriction which acts to limit the maximum flow and the resulting thrust forces created by a main steam line break.

10.3.1.3 **Design Data**

A.	Number of steam generators 3	
B.	Total flow (lb/h)	12.26 E+06
C.	Design pressure (psig)	1085
D.	Design temperature (°F)	600
E.	Percent moisture (original design value; replacement steam generators outlet moisture is 0.10% or less)	0.25
F.	Number of safety valves	15
G.	Number of relief valves	3

10.3.1.4 **Design Codes**

The piping and components from the steam generators up to and including main steam line isolation valves are designed to meet Seismic Category I requirements and are in accordance with the ASME Code, Section III, Class 2. The remainder of the piping downstream of the main steam isolation valves is designed to meet Seismic Category II requirements and is in accordance with ANSI B31.1.0.

10.3.2 DESCRIPTION

10.3.2.1 General Description

Saturated steam generated in the three steam generators flows out through the containment wall in three 32-in. main steam lines to a common header.

A flow restrictor integral with the steam generator is provided in each of the three main steam lines inside the containment to limit steam blowdown in the event of a main steam line break. A description of these flow restrictors is presented in subsection 5.5.4, Main Steam Line Flow Restrictors.

The main steam line from each steam generator is provided with five spring-loaded safety valves and one power-operated relief valve. These are located between the containment penetration and the corresponding main steam line isolation valve. The power-operated relief valves are set to open before the first spring-loaded safety valve opens. The power-operated relief valves and the spring-loaded safety valves discharge to the atmosphere.

Two quick-acting, pneumatic-cylinder-operated isolation valves are installed in each main steam line outside the containment and downstream of the safety valves. A full description of these valves is included in subsection 5.5.5, Main Steam Line Isolation System, and in subsection 10.3.9, Main Steam Isolation Valves.

Connections for supplying main steam to the auxiliary feedwater pump turbine are provided on the main steam lines from steam generators B and C. These connections are outside the containment and before the isolation valves. This piping is described in section 6.5, Auxiliary Feedwater System.

The three main steam lines combine into a common header downstream of the isolation valves. Two 36-in. lines conduct the steam from this header, which is located in the auxiliary building, to the turbine building. Both of these lines branch into two 24-in. lines which conduct the steam to the high-pressure turbine. Upstream of the point where the 36-in. lines branch into 24-in. lines, there is a 24-in. crosstie between the 36-in. lines. Lines branch off this crosstie pipe to conduct steam to the following systems:

A. Turbine steam bypass system.

B. Moisture separator reheaters second-stage reheat.

C. Feedwater pump turbines.

D. Turbine gland sealing system.

E. Steam jet air ejectors.

F. Auxiliary steam supply system.

10.3.2.2 Components

10.3.2.2.1 Isolation Valves

See subsections 5.5.5 and 10.3.9 for a detailed description.

10.3.2.2.2 Flow Restrictor

See subsection 5.5.4 for a detailed description.

10.3.2.2.3 Safety Valves

Five spring-loaded safety valves are installed on each main steam line upstream of the main steam isolation valves and outside the containment. These valves are Safety Class 2A and Category I Seismic.

The range of pressure settings of the safety valves on each line is in equal increments from 1075 psig to 1129 psig. The maximum actual capacity of a single valve fully open at 1085 psig is 890,000 lb/h.

10.3.2.2.4 Relief Valves

Installed on each main steam line upstream of the main steam isolation valves and downstream of the safety valve is one atmospheric relief valve. The valves are pneumatically actuated and sized to pass 405,500 lb/h of steam at 1025 psig. They are capable of going from fully closed to fully open within 35 seconds or less. The valves are also capable of being modulated over the pressure range of 1085 psig to 100 psig. Valve control is automatic by steam line pressure with remote manual control of the setpoint. A local manual operator is provided for valve operation in the event of complete loss of automatic control. An emergency source of control air is provided to enable remote manual operation.

10.3.3 EVALUATION

Following a sudden load rejection of up to 50 percent, the MSSS prevents a reactor trip by bypassing the steam directly to the condenser as described in subsection 10.4.4. Following a turbine trip or load rejection above 50 percent or when the turbine bypass system is not available, the MSSS effects a safe reactor trip by removing excessive heat from the reactor coolant through the exhausting of secondary steam through atmospheric power-operated relief valves and the spring-loaded safety valves. The power-operated relief valves and the spring-loaded safety valves also protect the steam generator and the main steam piping from overpressure.

In the unlikely event of a main steam line rupture, the isolation valves in the main steam lines provide steam line isolation, as described in subsection 5.5.5. The valving safety requirements are established to cover the following situations:

A. Break in the Steam Line From One Steam Generator Inside Containment

The steam generator associated with the damaged line will discharge completely into the containment. Without reverse flow protection, the other steam generators would act to feed steam through the interconnecting header to reverse flow through the damaged line and into the containment, resulting in a significant pressure rise in the containment. To prevent discharge of more than one steam generator, the main steam isolation valves are capable of closing within 7 s against a steam flow in the forward direction with a differential pressure across the valve of 775 psig.

Two redundant main steam isolation valves are installed in each main steam line and are designed to stop flow in the forward direction. Both isolation valves are Safety Class 2A and Category I Seismic.

B. Break in the Steam Header Downstream of the Isolation Valve

The time requirement established in A above is the limiting case and is satisfactory for requirements resulting from this situation.

C. Steam Generator Tube Rupture

This requirement is not limiting. A fast-acting valve is not required nor is valve redundancy. The isolation valve serves to limit the total amount of primary coolant leakage during the shutdown period by isolating the damaged steam generator after primary coolant pressure is reduced below steam generator shell-side design pressure.

Automatic operation of the isolation valves is initiated by a steam break or high-high containment pressure signal. Provision is also made for remote manual operation from the control room.

The steam generated in the three steam generators is normally not radioactive; however, in the event of primary to secondary leakage due to a steam generator tube leak, it is possible for the main steam to become radioactively contaminated. A full discussion of the radiological aspects of primary to secondary leakage, including anticipated releases to the environment as a result of the opening of the power-operated relief valves and the safety valves, is contained in chapter 11.

10.3.4 INSPECTION AND TESTING REQUIREMENTS

The MSSS safety valves located in the main steam piping at the outlet from each steam generator were individually tested during initial startup by checking the actual pop and closing pressures of the valve as indicated by pressure gauges mounted in the steam piping as compared to the required design opening and closing pressures specified for the safety valves.

The opening and closing of the atmospheric power relief valves were likewise checked during initial startup by comparing design opening and closing pressures with the actual values as measured by a pressure gauge mounted in the steam line.

The atmospheric relief valves and their associated manual isolation valves are tested in accordance with the Technical Specifications.

The main steam line isolation valves were checked for closing time prior to startup and after each shutdown. A complete discussion of tests and inspections provided for the main steam line isolation valves is given in subsection 5.5.5.

The various alarm and trip pressure setpoints used to isolate the steam generator feedwater pumps to prevent overpressurization were checked by comparing design setpoints versus actual measured trip settings.

Before placing the systems into service, all foreign material and loose oxides were removed from the piping. During cleaning, entry of any fluid into the steam generator was prevented.

The MSSS piping was hydrostatically tested in accordance with the applicable codes.

Power conversion system thermal expansion and vibration measurement tests were conducted as outlined in subsection 14.1.3.

As required by the Technical Specifications, the three main steam lines from the rigid anchor points of the containment penetrations downstream to and including the main steam header shall be inspected in accordance with the Main Steamline Inspection Program.

10.3.5 WATER CHEMISTRY

The primary objective of secondary system water chemistry control is to minimize corrosion of the steam generator internals.

Secondary objectives include:

A. Avoiding or minimizing turbine deposits due to carryover from the steam generator.

B. Reducing corrosion in the feedwater cycle ahead of the steam generator.

C. Elimination of sludge from its point of concentration, the steam generator.

D. Preventing scale deposits on the steam generator heat transfer surfaces and in the turbine.

E. Minimizing feedwater oxygen content prior to entry into steam generator.

F. Controlling condenser air ejector radioactive iodine effluent releases.

These objectives are met by exercising careful chemistry control over the systems, including comprehensive sampling and analysis (inline and laboratory), chemical injection at selected points, continuous system blowdown from the steam generator, and effective protection of the steam generator and feedwater train internals during periods of inactivity.

The method of secondary water chemistry control used is monoethanolamine/hydrazine, morpholine/hydrazine, morpholine/hydrazine/boric acid, or monoethanolamine/hydrazine/ boric acid. Morpholine and monoethanolamine have proven in both laboratory and field experience to be beneficial for reducing erosion-corrosion of secondary side components and subsequent corrosion product transfer to steam generators. Hydrazine is added to scavenge dissolved oxygen to within appropriate limits. The decomposition of hydrazine produces ammonia in sufficient quantity such that the intentional addition of ammonia for pH control is not required. Boric acid is injected as needed into the secondary system to inhibit stress corrosion cracking of steam generator tubes.

Controlling system pH to achieve proper alkaline conditions reduces general corrosion and decreases the release of soluble corrosion products from metal surfaces. Ensuring the absence of free caustic eliminates the possibility of caustic stress corrosion. Ammonium chloride may be added to the secondary system, when necessary, for molar ratio control to change crevice pH.

Reducing dissolved oxygen to the lowest possible levels also contributes to diminished rates of general corrosion. Oxygen in the system is removed from the condenser by the steam jet air ejectors and is further reduced by scavenging with hydrazine introduced at the condensate pump discharge.

Excluding other impurities from the steam generator reduces scale formation on heat transfer surfaces and prevents corrosion caused by concentration of the reactant products of these impurities. Addition of impurities to the steam generator is limited by the careful control of feedwater purity. Of prime importance in this regard is an aggressive program of condenser maintenance to ensure its leak-tight integrity. The concentration effect of the impurities in the steam generator is minimized through continuous blowdown.

A steam generator partition factor of 0.1 and a condenser air ejector partition factor of 10^{-4} have been used in the evaluation of environmental consequences of postulated accidents (e.g., Steam Generator Tube Rupture, subsection 15.4.3.4). These are conservative values for the range of water chemistry allowed by WCAP-7452 based on measurements made at operating Westinghouse plants.

10.3.6 INSTRUMENTATION APPLICATIONS

The steam flow restrictors installed in the steam generators are also used for steam flow measurements during normal operation. Two flow transmitters and two pressure transmitters are installed in the main steam line from each steam generator. The steam flow and pressure signals are fed into reactor protection and feedwater control system circuits to control the feedwater flow to each steam generator, to close the isolation valves in case of rupture in main steam lines, and to open the power-operated relief valves in case of overpressure.

10.3.7 MAIN STEAM SAFETY VALVES

Overpressure protection for the three steam generators is provided by the main steam safety valves. The design basis for the main steam safety valves is that they must have sufficient capacity so that main steam pressure does not exceed 110% of the steam generator shell-side design pressure. Based on this requirement, the valves are sized to relieve 105% of the maximum calculated steam flow at an accumulation pressure not exceeding 110% of the steam generator shell design pressure.

Design parameters for the main steam safety valves are given in table 10.3-1.

Due to the large mass flowrate, each steam generator is protected by a number of valves. The maximum actual capacity of a single valve fully open at 1085 psi gauge does not exceed 890,000 lb/h. This provision serves to limit steam release if any one valve inadvertently sticks open.

The main steam safety valves are located on the main steam lines outside the containment and upstream of the main steam isolation valves. Each of the three main steam lines is equipped with five safety valves. To prevent chattering during operation of the safety valves, each of the five valves on a steam line is set at a different set pressure. The first valve set pressure is 1075 psig, which corresponds to the steam generator shell design pressure minus the pressure loss from the steam generator to the valve. Each of the remaining valves is set at a higher pressure such that all valves are open and at full relief without exceeding 110 percent of the steam generator shell design pressure.

The design of the main steam header where the safety valves are located is described in subsection 3.9.2.

Umbrella-type vent stacks route steam discharge from the safety valves to the atmosphere through penetrations in the auxiliary building roof. These vent stacks have been analyzed for seismic loadings in addition to the normal operating loads.

Prior to shipment, all safety valves were hydrostatically tested in the manufacturer's facilities in accordance with the applicable code. No leakage was observed. In addition, each valve was given a setpoint test and a seal-leakage test. The popping point tolerance did not exceed plus or minus 1 percent of the setpoint pressure. During normal plant operation, the valves are accessible for inspection.

10.3.8 MAIN STEAM ATMOSPHERIC POWER RELIEF VALVES

The steam generator atmospheric relief valves provide the capability for the removal of reactor decay heat during periods when the main heat sinks are not available. Such periods are when the turbine-generator or condenser is not in service, when the plant is being started up or following shutdown, during physics testing, in the event of turbine trip as a result of the loss of condenser vacuum, or when there is a loss of offsite electrical power. Design parameters for the atmospheric power relief valves are given in table 10.3-2.

A single power relief valve is provided on each main steam line upstream of the main steam isolation valves outside of the containment and exhausts to the atmosphere. The valves are of the modulating type and are under the automatic control from a steam line pressure controller with provisions for adjustment of the pressure setpoint from the control room. Additionally, a control scheme similar to that available from the control room is provided at the hot shutdown feedwater panel. Thus, control of the valve is provided in the event of control room evacuation. Each valve is provided with a manual operator so that the valves can be opened or closed locally, even in the event of a loss of all power sources (electric and air).

In the event of a high-energy line break which prohibits operator access to the manual handwheel located on each power-operated relief valve and the simultaneous loss of offsite power and valve air supply, an alternate air supply is located in the el 100-ft area in room 189 as shown in figure 1.2-4 for Unit 1 and in room 2189 for Unit 2 directly beneath the EL 127-ft main steam and feedwater valve room. This area is isolated from the main steam and feedwater valve room and would be accessible following any main steam or feedwater line break that makes the atmospheric dump valves inaccessible for manual control. The alternate air supply consists of two redundant, seismic, self-contained, nonlubricated cylinder type air compressors rated at 41.6 ft^3/min at 100 psig.

The alternate Seismic Category I air supply connections are as shown in drawing D-175035, sheet 2. The three-way solenoid valves (SV3371 AA, BA, CA) between each valve positioner output and the valve actuator selects positioner or alternate air supply control of the atmospheric steam dump valves. When the solenoid valve is energized, the atmospheric steam dump valve is controlled by the valve positioner. When the solenoid valve is deenergized, the atmospheric steam dump valve is controlled by the alternate air supply. The solenoid valve is energized automatically only when there is a signal to the valve positioner to open the atmospheric steam dump valve. Hand switches, one for each steam dump valve, are provided to maintain solenoid valves (SV3371 AA, BA, CA) deenergized when alternate air control is required. The hand switches also control solenoid valves (SV3371 AB, BB, CB). Solenoid valves (SV3371 AB, BB, CB), located with the alternate air supply outside the main steam room, provide for alternate air supply control of the atmospheric steam dump valves. A manual means is available to provide for alternate air supply operation of the atmospheric steam dump valves without electrical power to the solenoid valves (SV3371 AA, BA, CA, AB, BB, CB).

Each valve fails closed on loss of electrical or air supply. They are capable of modulating over the pressure range of 100 to 1085 psig with a stroke time of 35 seconds or less. Each valve is sized to pass a total of approximately 405,500 lb/h of steam (10 percent of plant maximum calculated steam flow) at the no-load pressure of 1025 psig. Additionally, the maximum actual capacity of any single valve at an inlet steam pressure corresponding to the steam generator shell design pressure (1085 psig) shall not exceed 890,000 lb/h steam. This provision serves to limit the steam release if any one valve inadvertently sticks open.

Discharge from the power-operated relief valves is piped to the atmosphere through penetrations in the auxiliary building roof. The discharge piping was analyzed for seismic and dynamic loads in addition to the normal operating conditions.

During emergency conditions, the main steam atmosphere power relief valves provide a means to control non-faulted steam generator pressures, and, or cool down the plant. During normal plant conditions these relief valves also give the plant flexibility of operation and the capability for a controlled cooldown. Isolation valves are provided upstream of each valve to allow maintenance. During a period when all other valves are out of service, the steam generator safety valves provide the necessary relieving capability.

Prior to shipment, each valve was hydrostatically tested in the manufacturer's facilities in accordance with the applicable code. Leakage was 40 cm^3/h in the valves that were tested. During plant operation, the valves are accessible for inspection. The operability of the alternate air supply system may be demonstrated during refueling shutdowns by using the alternate air supply to cycle open and closed each of the power-operated relief valves.

10.3.9 MAIN STEAM ISOLATION VALVES

The main steam isolation valves consist of two swing-disc check valves in each of the three main steam lines. These valves are located outside of the containment downstream of the main steam safety valves.

The main steam line isolation valves and their bypass valves are designed to stop forward flow and to isolate the steam generators and the main steam lines on signal initiated by engineered safety features actuation system under any of the following conditions:

A. High steam line flow (2/3) in coincidence with low-low T_{avg} (2/3) or low steam line pressure (2/3 break in main steam line).

B. High-high (2/3) pressure in the containment.

C. Manually from the control room.

The main steam isolation valves and bypass valves are designed in accordance with the requirements of the ASME Code for Pumps and Valves for Nuclear Power draft, November 1968 edition including March 1970 addenda, for Class II valves. These valves are classified as Safety Class 2A. The valves are of fail closed design and are designed to meet Seismic Category I requirements. Main steam isolation valve material specifications are listed in table 10.3-4.

Valve design conditions and steam line break flow values are given in table 10.3-3.

The swing-disc trip valves are designed to withstand a single event closing following a postulated rupture of a main steam line. Table 10.3-3 gives the maximum calculated flowrates obtainable at the valve in the event of a steam line break. Case A is based on assumed dry saturated steam flow and case B is based on assumed maximum moisture content. It was conservatively assumed that the steam generator outlet pressure at the time of the break was 1020 psia.

The main steam isolation valve line break design flow conditions were calculated using the Moody critical flow model for FL/D = 0[1]. Assumptions used include:

A. Isentropic flow from reservoir (steam generator) to valve level.

B. Choked flow occurs in the flow restrictor prior to initiation of valve movement.

C. System pressure is equal to no-load pressure at initiation of transient, and reservoir pressure remains constant at this pressure (1020 psia) throughout the transient.

D. Main steam line restrictor throat diameters are 14 in.

This flow is seen by the steam line isolation valve after the expansion wave generated by the break travels from the valve to the flow restrictor and back. This time is simply t = 2L/c, where L is the length (one way) and c is the sonic velocity. The most conservative time was found to be 0.68 s. A 1.0-s time delay has therefore been introduced before valve actuation to ensure that the time will be > 0.68 s.

The swing-disc trip valve, figure 10.3-1, is a 32-in., 600-lb, swing check valve with bolted bonnet and welding ends. An air-actuated cylinder operator is mounted where the disc shaft penetrates the valve body. This piston operator uses instrument air pressure to hold the valve disc in the open position against the force of a spring. Removal of instrument air pressure from the piston allows the spring to close the valve.

In the normal open position, the disc is held well out of the steam flow by the air operator. An air test cylinder is provided on the trip valve. This test cylinder can be remote manually actuated from the control room to stroke the trip valve disc through a small arc to ensure that the disc is not stuck in the open position. This motion is limited to a region within the bonnet of the valve and will not lower the disc into the steam flow. Position switches in the control room indicate the test position of the valve.

The instrument air supply and exhaust schematic drawing for the isolation valves is shown in figure 10.3-2.

Plant instrument air at 80-100 psig pressure is supplied to the actuator cylinder. Each of the redundant isolation valves has its own means of closing and venting the air supply to relieve the cylinder pressure and close the valve.

Each isolation valve is provided with a normally open, three-way solenoid valve which, when deenergized, provides instrument air to the actuator cylinder. As the solenoid valves are normally deenergized, loss of dc power will not cause the valves to close. An air reservoir is also provided for each isolation valve, to allow it to remain open upon loss of instrument air. Each solenoid valve receives a separate signal from the engineered safety features actuation system and has a separate 125-volt dc power supply. When the solenoid valve is energized, it vents the air reservoir and actuator cylinder to the atmosphere and closes the main steam isolation valves.

A 3-in. bypass line is provided around each pair of trip valves for warming the steam line and for equalizing pressure across the trip valves prior to opening. Each bypass line contains two air-operated, fail closed, redundant bypass valves. Each of the redundant bypass valves has its own means of closing and venting the air supply to relieve cylinder pressure and close the valve. Each redundant bypass valve receives a separate signal from the engineered safety features actuation signal.

REFERENCES

1. Moody, F. S., "Transactions of the ASME," Journal of Heat Transfer, p 134, figure 3, February 1965.

TABLE 10.3-1

MAIN STEAM SAFETY AND RELIEF VALVES DESIGN DATA

Main Steam Safety Valves

Quantity	15 (5 per steam generator)
Design pressure (psig)	1085
Design temperature (°F)	600
Capacity	Each bank of 5 valves relieves 4,328,230 lb/h from 1 steam generator (105% of maximum steam flow)
Set pressure (psig)	1075 (for first valve)
Full relieving pressure (psig)	1173 (including tolerance and accumulation)
Limiting flow (per valve) (lb/h)	890,000 at 1085 psig
Applicable code	ASME Section III, Class 2

Main Steam Atmospheric Relief Valve

Quantity	3 (1 per steam generator)
Design pressure (psig)	1085
Design temperature (°F)	600
Capacity (lb/h)	405,500 at 1025 psig 610,000 at 1085 psig
Setpoint (psig)	1025 (adjustable from control room)
Limiting flow (lb/h)	890,000 at 1085 psig
Applicable code	ASME Section III, Class 2

TABLE 10.3-2

ATMOSPHERIC POWER RELIEF VALVES

Valve Design Data

Design pressure (psig)	1085
Design temperature (°F)	600
Nuclear Class	ASME Section III, Class 2
Seismic	Class I
Design flow (lb/h)	405,500 at 1025 psig 610,000 at 1085 psig
Limiting flow (lb/h)	890,000 at 1085 psig

TABLE 10.3-3

MAIN STEAM ISOLATION VALVES FUNCTIONAL REQUIREMENTS

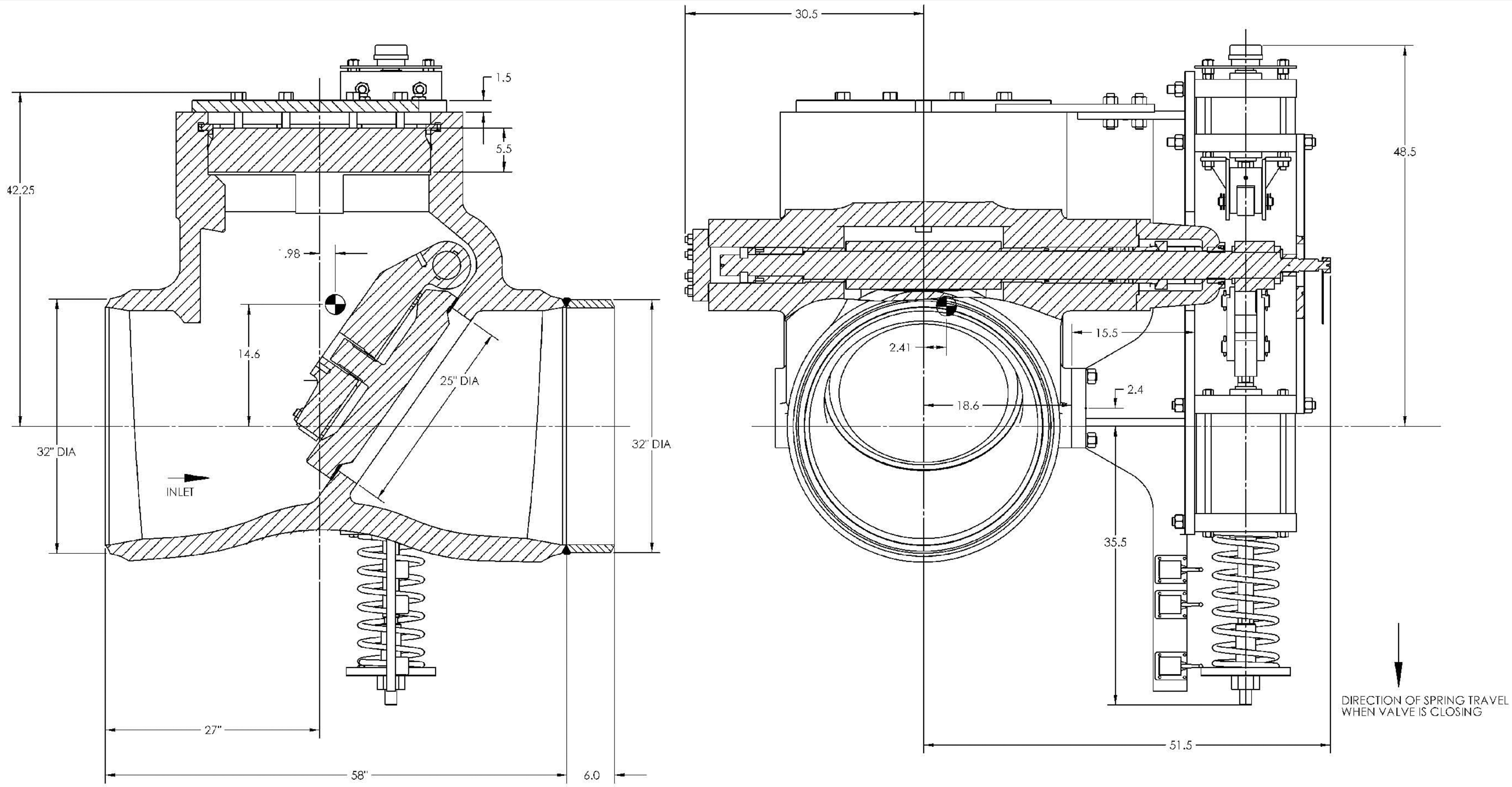
Valves	
Quantity	6
Design pressure (psig)	1085
Design temperature (°F)	600
Operator (trip valve)	Air piston
Full-Load Steam Conditions[1]	
Flow (per valve) (lb/h)	3.875×10^6
Pressure (psig)	775
Temperature (°F)	517
Steam Line Break Design Flow Conditions	
Case A (dry saturated steam flow through valve) (lb/s)	2300
Case B (4% quality steam flow through valve) (lb/s)	7800

(1) MSIVs have been evaluated for steam flows up to 4.10×10^6 lb/h for power uprate.

TABLE 10.3-4

MAIN STEAM ISOLATION VALVES MATERIALS

Component	Materials
Body	A-216 WCB
Disc arm	A-216 WCB
Disc	SA-182 Gr. 304F
Cover	A-515 Gr. 70
Shaft	A-564 Gr. 630
Locking plate studs	A-193 Gr. B7
Locking plate nuts	A-194 Gr. 2H
Load key	A-182 Gr. F6a CL2



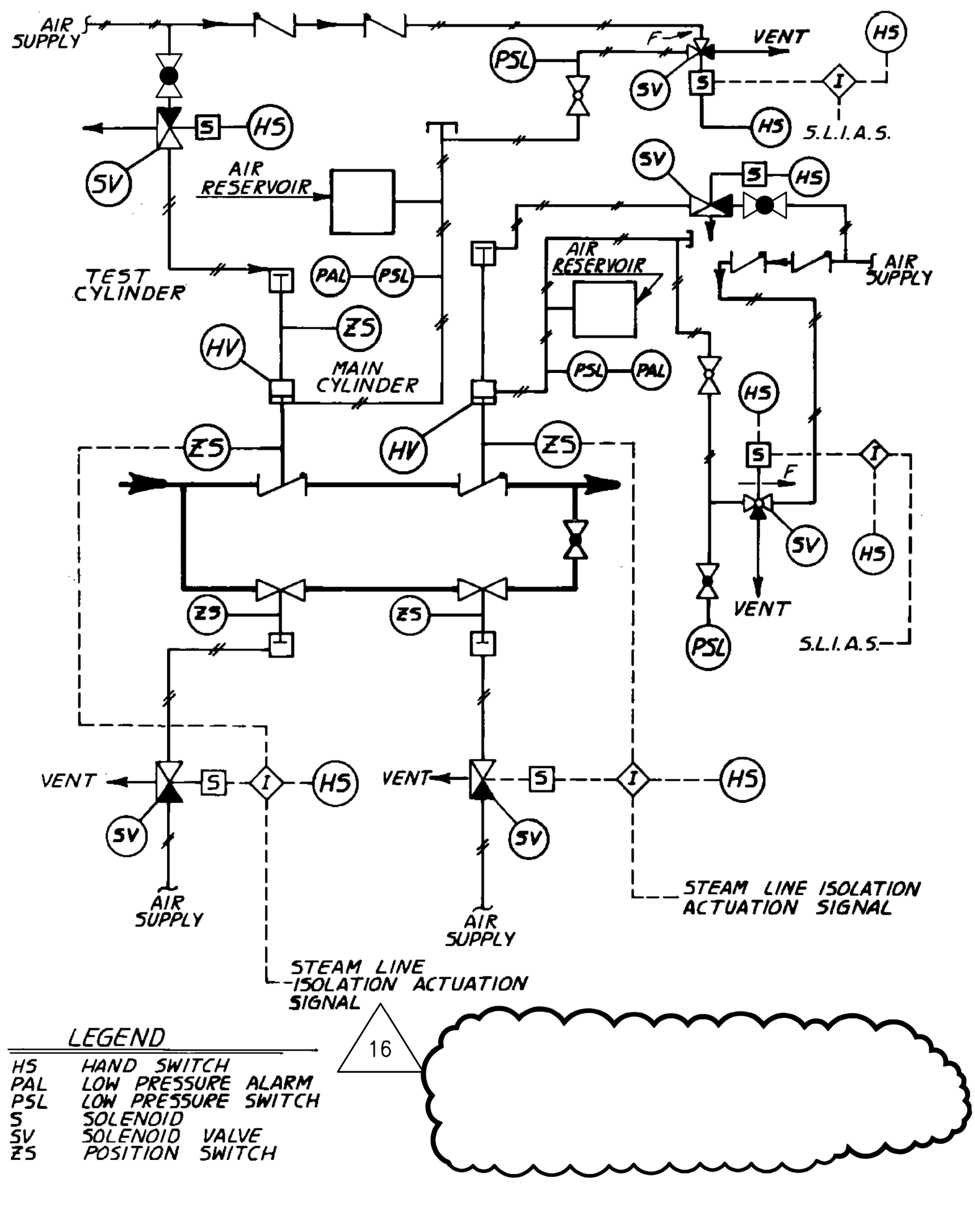
REV 23 5/11

SOUTHERN COMPANY
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

MAIN STEAM SWING-DISC
TRIP VALVE

FIGURE 10.3-1



LEGEND

HS	HAND SWITCH
PAL	LOW PRESSURE ALARM
PSL	LOW PRESSURE SWITCH
S	SOLENOID
SV	SOLENOID VALVE
ZS	POSITION SWITCH

REV 21 5/08

MAIN STEAM
ISOLATION VALVES

FIGURE 10.3-2

10.4 OTHER FEATURES OF THE STEAM AND POWER CONVERSION SYSTEM

This section provides information on the principal design features and subsystems of the steam and power conversion system.

10.4.1 MAIN CONDENSER

10.4.1.1 Design Bases

The main condenser is designed to function as the steam cycle heat sink and collection point for the following flows:

A. Main turbine exhaust.

B. Feedwater heater drains and vents.

C. Steam generator feedwater pump turbine exhaust.

D. Turbine steam bypass system flow.

E. Condensate and steam generator feedwater pump recirculation flow.

F. Condensate and feedwater system makeup flow.

G. Steam jet air ejector intercondenser and aftercondenser drains.

H. Gland steam condenser drain.

I. Miscellaneous equipment drains and vents.

The function of the main condenser is to provide a heat sink for the main turbine exhaust, feed pump turbine exhaust, turbine steam bypass, and other flows. It also deaerates and provides storage capacity for secondary system condensate.

10.4.1.2 System Description

The condenser is a two-shell, radial-flow, single-pass unit which is connected to the exhaust opening of each low-pressure turbine casing by single-convolution, stainless steel expansion joints. Each condenser shell is supported from the turbine building base slab by four concrete pads, and there are pressure-equalizing lines between the shells. These lines ensure that the maximum differential temperature between turbine exhausts will not exceed 30°F.

The condenser has two (one each shell) 3600 ft^3 hot wells which provide sufficient water storage capacity to accommodate system surges and condensate makeup during moderate transients without relying upon reserve condensate storage.

Each circulating water inlet and outlet line to the condenser is provided with a motor-operated shutoff valve.

The condenser has approximately 52,164 tubes giving it an effective surface area of approximately 680,000 ft^2.

During normal operation, the condenser uses 690,000 gal/min of cooling water to remove 67.9 x 10^8 Btu/h of energy from the main turbine exhaust, feed pump turbines exhaust, heater drains, and various other sources.

The noncondensable gasses are concentrated in the air cooling section of the condenser shells, from which they are removed by the steam jet hogging ejectors during startup and by the steam jet air ejectors during normal operation (see subsection 10.4.2). The condenser is designed to have no air leakage and will limit the free oxygen content in the condensate to a maximum of 0.0005 cc/liter at the hot well.

In addition to serving the usual function of a condenser, each shell is capable of accepting 2,432,840 lb/h of turbine bypass steam at an enthalpy of 1192.2 Btu/lb and a pressure of 250 psia without exceeding an exhaust hood temperature of 175°F and a back pressure of 6 in. Hg abs.

10.4.1.3 Safety Evaluation

The main condenser is normally used to remove residual heat from the reactor coolant system (RCS) during the initial cooling period after plant shutdown when the main steam is bypassed to the condenser by the turbine steam bypass system. The condenser is also used to condense the main steam bypassed to the condenser in the event of sudden load rejection by the turbine-generator or a turbine trip.

In the event of load rejection above 50 percent (including 100-percent load rejection due to turbine trip), the condenser will condense 40 percent of full-load main steam flow bypassed to it by the turbine bypass system, and the power-operated relief valves and spring-loaded safety valves will discharge remaining main steam flow to atmosphere to effect safe reactor shutdown and to protect the main steam supply system from overpressure.

If the main condenser is not available during normal plant shutdown, sudden load rejection, or turbine-generator trip, the power-operated relief valves and the spring-loaded safety valves can discharge full main steam flow to the atmosphere and effect a safe reactor shutdown. Nonavailability of the main condenser considered here includes failure of circulating water pumps to supply cooling water, failure of condenser evacuation system to remove noncondensable gases, excessive leakage of air through turbine gland packings due to failure of the gland seal system, or failure of the condenser due to any other reason.
Leakage of condensate from the condenser is not considered possible during operation since the condenser is at a vacuum and any leakage will be into the condenser. A tube leak occurring during operation will not cause a sudden decrease of condenser performance.

During normal operation and shutdown, the main condenser will have no radioactive contaminants inventory. Radioactive contaminants can only be obtained through primary to secondary system leakage due to a steam generator tube leak. A full discussion of the radiological aspects of primary to secondary leakage, including anticipated operating concentrations of radioactivity contaminants, is included in chapter 11. No hydrogen buildup in the main condenser is anticipated.

10.4.1.4 Tests and Inspections

The condenser is basically a welded structure. Air leaks, if any, will probably be found at valve stems or flanged joints. To test for leaks, the condenser will be filled with water prior to startup. Any tubes that develop leaks will be plugged at each end until an opportune time arises for their replacement. Condenser water boxes were hydrostatically tested in accordance with applicable codes.

10.4.1.5 Instrumentation Applications

The main condenser hot wells are equipped with level control devices for automatic control of system water makeup and reject as described in subsection 9.2.6.

The condenser and the steam system auxiliaries are centrally controlled and operation of the system is practically automatic. However, the condenser pressure and temperature will be monitored to see that they remain normal. Local and remote indicating devices are also provided for monitoring water levels in the condenser shells.

There is negligible influence of condenser functions on the reactor coolant system operation, and there is negligible potential for hydrogen buildup in the condenser.

10.4.2 MAIN CONDENSER EVACUATION SYSTEM

10.4.2.1 Design Bases

The main condenser evacuation system is designed to establish the initial condenser vacuum and to maintain it during operation by removing all noncondensable gasses from the condenser. The air ejectors are designed to meet Heat Exchange Institute standards.

10.4.2.2 System Description

The main condenser evacuation system is shown in drawings D-170064 (Unit 1) and D-200003 (Unit 2). The following components are included:

A. Steam Jet Hogging Ejectors

Two steam jet hogging ejectors are used to establish condenser vacuum during startup. Each hogging ejector requires 8,060 lb/h of driving steam at a pressure of 100 psig. The auxiliary steam system supplies this required steam up to approximately 215 psig and pressure-regulating valves reduce the pressure to 100 psig. The discharge from the hogging ejectors is vented directly to the atmosphere.

B. Steam Jet Air Ejectors

For maintaining condenser vacuum, two (one standby) twin-element, two-stage, 100-percent capacity steam jet air ejector systems are used. Each system is capable of removing 40 ft^3/min of saturated air at 71.5°F with 1-in. HgA back pressure.

Each system requires 2640 lb/h driving steam at 100 psig. During normal operation, this steam is extracted from the main steam supply header. An alternate steam source coming from the auxiliary steam system can be used to drive the air ejectors when the main steam is not available.

The steam gas mixture discharge from the ejector elements enters the intercondenser/aftercondenser where 700,000 lb/h of condensate condenses the steam.

The noncondensable gases are normally exhausted to the atmosphere while the condensed steam is drained to the condenser. Noncondensable gases can be exhausted through a charcoal filter system in the event of primary to secondary leakage

10.4.2.3 <u>Safety Evaluation</u>

The main condenser evacuation system can be used during reactor cooldown following a turbine-generator or reactor trip when the main steam is bypassed to the condenser. The air ejectors can be operated with the low-pressure steam generated in the steam generators during reactor cooldown. However, in the event that the main condenser evacuation system is not operable, it is possible that the bypassed steam is not condensed after accumulation of noncondensable gases and inleaking air in the condenser. This is considered a main condenser failure; safe shutdown of the reactor in such an event is discussed in subsection 10.4.1.

The noncondensable gases and vapor mixture discharged to atmosphere from the main condenser evacuation system is not normally radioactive. However, in the event of primary to secondary system leakage due to a steam generator tube leak, it is possible for mixture discharged to become radioactively contaminated. A full discussion of radiological aspects of a primary to secondary leakage and limiting conditions for operation is included in chapter 11.

10.4.2.4 Tests and Inspections

The system was tested in accordance with written procedures during the initial testing and operation program.

Operation of air ejectors is simple and dependable, requiring minimum maintenance at the designed steam conditions. Redundancy allows inspection on one ejector while the other is in service.

10.4.2.5 Instrumentation Applications

The steam jet air ejectors and hogging ejectors are controlled by operator manual selection. Local indicating devices such as pressure, temperature, and flow indicators are provided as required for monitoring the system operation. There are no control functions of the system which could influence operation of the reactor coolant system.

10.4.3 TURBINE GLAND SEALING SYSTEM

10.4.3.1 Design Bases

The gland steam seal system controls the gland steam pressure to maintain adequate sealing of both the main turbine and the steam generator feed pump turbine under all conditions of plant operation. The system is Safety Class Nonnuclear Safety (NNS) and Category II Seismic.

10.4.3.2 System Description

The annulus space where the turbine shaft penetrates the casings is sealed by steam supplied to labyrinth packings. Where the packing seals against vacuum, the sealing steam leaks outward to a vent annulus that is maintained at a slight vacuum. The vent annulus also receives air leakage from the outside. The air-steam mixture is conducted to the gland condenser. Where the packing seals against positive pressure, the sealing steam connection acts as a leak off.

The steam supplied to seals is automatically regulated at approximately 1 to 5 psig using auxiliary steam at low loads. At higher loads, when leak off from pressure packings is more than that required by vacuum packings, the excess is discharged to the gland condenser. The gland condenser returns seal leak off to the condenser as condensate. Noncondensable gasses are discharged to the atmosphere by the gland exhauster.

The gland steam seal system for each Unit can receive steam directly from its corresponding main steam system or via the auxiliary steam system.

10.4.3.3 Safety Evaluation

The system can be used during reactor cooldown following a turbine-generator or reactor trip when the main steam is bypassed to the condenser. The turbine gland seals can be supplied with the low-pressure steam generated in the steam generators during reactor cooldown. However, in the event that the turbine gland sealing system is not operable, it is possible that the bypassed steam is not condensed due to accumulation of inleaking air in the main condenser. This is considered as a main condenser failure, and safe shutdown of the reactor in such an event is discussed in subsection 10.4.1.

The condensable gases and vapor mixture discharged to the atmosphere by the steam packing exhauster fan are not normally radioactive. However, in the event of primary to secondary system leakage due to a steam generator tube leak, it is possible for the mixture discharged to be radioactively contaminated. A full discussion of the radiological aspects of primary to secondary system leakage, including anticipated releases from the turbine gland sealing system and limiting conditions for operation, is included in chapter 11.

10.4.3.4 Tests and Inspections

The system will be tested in accordance with written procedures during the initial testing and operation program. Because the gland sealing system is in constant use during plant operation, the availability and performance of all components is evident to plant operators.

10.4.3.5 Instrumentation Applications

A pressure controller is provided to maintain the gland seal steam pressure. In case of high pressure, the pressure controller signal opens the steam packing unloading valves and excess steam is bypassed to the main condenser. During startup or in case of low gland seal steam pressure, the controller signal opens a pressure-reducing valve to supply steam from the main steam line or the auxiliary steam system.

Local and remote indicating and alarm devices are provided, as required, for monitoring the system.

10.4.4 TURBINE BYPASS SYSTEM

The turbine bypass system, shown in drawings D-175033, sheet 1, D-175033, sheet 2, D-170114, sheet 1, D-170114, sheet 2, D-205033, sheet 1, D-205033, sheet 2, and D-200007, bypasses main steam directly to the main condenser during the transient conditions of a sudden load rejection by the turbine-generator or a turbine trip and during plant startup and shutdown. The system is not an engineered safety features (ESF) system.

10.4.4.1 Design Bases

The turbine bypass system is designed with a capacity to bypass up to 40 percent of the full-load main steam flow directly to the main condenser. The system thus provides an artificial load on the reactor coolant system during the transient conditions of a sudden load rejection by the turbine-generator or a turbine trip.

The capacity of the turbine bypass system, combined with the 10-percent step-load change characteristics of the reactor, provides the capability of accepting a sudden load rejection of up to 50 percent without reactor trip or operation of the spring-loaded safety valves or power-operated relief valves.

In the event of a load rejection above 50 percent, the reactor will trip and the turbine bypass system will bypass 40 percent of full-load main steam flow to the main condenser. Operation of the power-operated relief and the spring-loaded safety valves will prevent system pressure from exceeding design pressure of the main steam supply system.

The system is also used to bypass steam to the main condenser during plant startup and to remove residual heat from the reactor core during the initial cooling period after plant shutdown by bypassing the steam to the main condenser.

The turbine bypass system piping is designed to Seismic Class II requirements and in accordance with ANSI B31.1.0. The design pressure rating is the same as for the main steam supply system as described in section 10.3.

The turbine bypass system is Safety Class NNS.

10.4.4.2 System Description

The turbine bypass system is shown in drawings D-175033, sheet 1, D-175033, sheet 2, D-170114, sheet 1, D-170114, sheet 2, D-205033, sheet 1, D-205033, sheet 2, and D-200007. The turbine bypass piping branches off from the main steam crosstie piping with a 26-in. header which breaks down into eight 12-in. lines with a condenser dump valve located in each. Downstream of the dump valves, the eight 12-in. lines combine into four 18-in. lines before entering the condenser.

During modulating service, the eight dump valves open two at a time in sequence, with equal flow always going to each condenser shell. This allows fine control of flow and an even heat distribution throughout the condenser. On a large step-load reduction or plant trip, the valves will all open within 3 s after receiving a trip open signal. The condenser dump valves will fail closed automatically with instrument air failure, loss of condenser vacuum, or loss of circulating water pumps.

The steam dump valves reduce the main steam line pressure to a maximum of 250 psia before the steam enters the condenser. These valves are capable of going from full closed to full open within 3 s after receiving a trip open signal, and of going from full open to full closed within 5 s after deenergization of their solenoid valves. The valves can also be positioned automatically to pass required flows during modulating service resulting from a gradual steam supply load change. The valves will fail closed on loss of instrument air.

The maximum capacity of each of the eight dump valves is 890,000 lb/h with an inlet pressure of 1100 psia.

10.4.4.3 Safety Evaluation

The steam bypassed to the main condenser is not normally radioactive. However, in the event of primary to secondary leakage due to a steam generator tube leak, it is possible for the bypassed steam to become radioactively contaminated. A full discussion of the radiological aspects of primary to secondary leakage is contained in chapter 11.

The turbine bypass system protects the reactor by maintaining an artificial load on the reactor coolant system during a turbine trip or a sudden load rejection. In the event the bypass system is not operable because of failure of the main condenser or system malfunction, the spring-loaded safety valves and the power-operated relief valves on the main steam lines will discharge the required amount of steam to the atmosphere to effect a safe reactor shutdown and prevent system pressure from exceeding design pressure of the main steam supply system.

The dump system is not essential to the safe operation of the plant. However, it is required to give the plant flexibility of operation and a controlled cooldown.

10.4.4.4 Tests and Inspections

Before placing the system in service, the dump valves will be tested to confirm opening and closing times, and all foreign material and loose oxides will be removed from the piping.

As the valves are subjected to modulating control, maintenance is quite possible, and isolation valves are provided for each control valve.

10.4.4.5 Instrumentation Applications

The dump system during normal operating transients for which the plant is designed is automatically regulated by the reactor coolant temperature control system to maintain the programmed coolant temperature.

Reactor coolant temperature is controlled by a programmed load temperature relationship. Turbine impulse chamber pressure establishes the programmed load temperature.

During a load variation, there will be a deviation between the reactor and turbine outputs. Turbine steam flow and impulse chamber pressure will change with load. Steam generator steam flow and, therefore, pressure will also change. This will result in a change in heat transfer due to the change in steam pressure from the reactor coolant to the steam generator water. There will be a corresponding change in reactor coolant temperature resulting from the transient. Reactor coolant actual temperature will deviate from the programmed temperature derived from the turbine impulse chamber. The magnitude and rate of change of the deviation will depend on the transient.

A signal derived from turbine impulse chamber pressure establishes a rate of load change and unblocks the dump control, provided there is no other block signal (such as loss of condenser vacuum) present.

Reference T_{avg}, derived from impulse chamber pressure, and T_{avg} actual signals are used to activate the control rods and steam dump system. These signals select the number and mode of operation of the dump valves.

On large step-load reductions or plant trip, the valves open rapidly in 3 s. During the 3-s period, while the turbine valves are closing and dump valves are closed, there is a pressure rise in the nuclear steam supply system (NSSS). In the initial part of a large step-load transient, all dump valves are fully open. Then the valves are modulated closed at a design load change in the reactor of 5 percent per minute. The valves are fully closed when the reactor power matches the turbine power.

Steam system header pressure is used when the plant is at no load. The control signal is derived from a point in the steam piping between the steam generator valves and turbine valves.

10.4.5 CIRCULATING WATER SYSTEM

10.4.5.1 Design Bases

The objective of the circulating water system is to provide the main condenser with the continuous water supply required to remove the heat load rejected to the main condenser.

All pumps in the circulating water system are designed and constructed in accordance with the standards of the Hydraulic Institute. The piping of the system is designed in accordance with ANSI B31.1.

The cooling towers are designed and constructed in accordance with all applicable regulations and codes.

All components of the circulating water system are designed to meet Category II Seismic requirements.

10.4.5.2 System Description

This system, shown in drawings D-170119, sheet 9, D-170119, sheet 10, D-200013, sheet 6 and D-200013, sheet 7, circulates water from the cooling tower basins, through the main condenser, and back through the cooling towers. The systems are basically identical for Units 1 and 2.

There are two circulating water pumps, each rated at 327,200 gal/min and 70 ft TDH, which are housed in a separate structure between the turbine building and cooling towers. Fixed screens located at the pump intake structure prevent possible debris from entering the pumps. The circulating water system is treated as necessary to control organic fouling.

The circulating water system is constructed of open concrete flumes, reinforced concrete pipe, large diameter steel pipe, rubber expansion joints, and butterfly valves.

System makeup water is supplied by utilizing the service water discharge flow from the turbine building, auxiliary building, containment, and diesel heat exchangers as shown in drawings D-170119, sheet 2 and D-200013, sheet 8.

Motor-operated butterfly valves which can be operated locally are provided at the discharge of the circulating water pumps and at the inlets and outlets of the condenser.

10.4.5.3 Safety Evaluation

The circulating water system is normally used to supply cooling water to the main condenser to remove residual heat from the reactor coolant system during the initial cooling period of plant shutdown when the main steam is bypassed to the condenser. However, if the circulating water system fails to supply cooling water due to either failure of circulating water pumps, cooling tower, or circulating water piping, the bypassed main steam cannot be condensed in the main condenser. This is considered a condenser failure and safe shutdown of the reactor in such an event is discussed in subsection 10.4.1.

Passage of condensate from the condenser to the circulating water system through a condenser tube leak is not considered possible during operation since the circulating water system will be at a greater pressure than the condenser and any leakage will be into the condenser.

In the event of a rupture of the circulating water piping or condenser water boxes which would cause flooding in the turbine building, the system provides no automatic means of shutting off the circulating water pumps. If the total volume of the circulating water system (including the water in the cooling tower basin, circulating water pump wet pit, the canals leading from the cooling towers to the pump wet pit, the risers at the cooling towers, and the water in transit in the cooling towers), plus a 10-min supply of the 20,000 gal/min makeup from the service water system normally added to the circulating water system to replace the cooling tower losses, were discharged into the turbine building, the water level would reach el 149 ft 0 in. in Units 1 and 2 approximately 6 ft below grade. There are no passageways, pipe chases, cableways, or other flow paths below this elevation leading to other spaces containing essential systems and components. Since there are no essential electrical trains or safety-related equipment located within the turbine building, a circulating water system failure of this nature and extreme magnitude would not damage any systems necessary for safe shutdown of the plant.

There would be no damage to other plant structures in the unlikely event of collapse of the cooling towers.

10.4.5.4 Tests and Inspections

System components will be tested and inspected during preoperational activities to ensure proper operational integrity.

10.4.5.5 Instrumentation Application

The circulating water pumps are arranged for manual startup and shutdown using a control switch located in the control room.

The circulating water pump and discharge valve motor controls are provided with an interlock to assure that the pump motor will start with the discharge valve in the closed position. As the pump motor is started, the discharge valve motor operator will be energized by a relay in the pump motor control circuit. After a time delay, the pump motor will be automatically tripped if the discharge valve fails to open. Adjacent pumps and associated discharge valves will not be interlocked; however, when a pump is shut down, the discharge valve will automatically close and remain closed unless manually opened by operator action.

Indicating lights are provided in the circulating water pit to indicate open and closed positions of the circulating water pump discharge motor-operated butterfly valves.

Pressure indicators are provided at the inlet of each condenser shell. Local and remote indicators are provided for circulating water temperature at the inlet and outlet to each condenser shell.

10.4.5.6 Chemical Treatments

Chemicals are added as necessary to the circulating water system to control corrosion, deposition, and biofouling and to improve the cooling tower efficiency.

Addition rates and blowdown rates are controlled to ensure that the chemicals discharged to the river via the cooling tower blowdown meet the criteria of the National Pollutant Discharge Elimination System (NPDES) permit, as issued by the State of Alabama. Treatment chemicals may be added by the following methods:

A. Direct addition to the circulating water.

B. Direct application to cooling towers.

C. Addition to the service water system (circulating water makeup).

The blowdown rate may be varied or periodically terminated provided the solids content of the circulating water is maintained within acceptable limits.

The blowdown flow is diluted with plant cooling water discharge which is in excess of that required for makeup to the circulating water system (approximately 10,900 gal/min).

A circulating water sample is analyzed periodically to determine the chemistry of the circulating water. Adjustments to the chemical feed are based on sample analysis to maintain the residuals within acceptable limits.

10.4.6 CONDENSATE AND FEEDWATER RECIRCULATION AND CLEANUP SYSTEM

10.4.6.1 Design Bases

The objective of the condensate/feedwater recirculation and cleanup system is to provide recirculation and cleanup capability for the condensate/feedwater system prior to startup of the plant following an extended plant shutdown.

The components of the system located in the auxiliary building are constructed to meet Seismic Category I requirements and the components of the system located outside auxiliary building and inside the turbine building are constructed to meet Seismic Category II requirements.

The piping of the system is designed in accordance with ANSI B31.1.0. The piping and miscellaneous components are designed for 9,750 gal/min. The design flow of one condensate pump is 9,680 gal/min at 1,120 ft.

10.4.6.2 System Description

The condensate and feedwater recirculation and cleanup system is shown on drawings D-200011, sheet 1; D-200011, sheet 2; D-200011, sheet 3; and D-205073.

The system for Unit 2 consists of 14-in. piping which ties into the existing feedwater flow control valve bypass lines and recirculates condensate flow to condensers A and B. This system is no longer applicable to Unit 1.

One condensate pump is used to pump condensate from the hotwell of the condensers through the condensate/feedwater system and back to the condensers via the recirculation line.

10.4.6.3 Safety Evaluation

This system is operated only during modes 5 and 6 of plant operation. The isolation valves to the steam generator feed regulators and steam generator feed regulators bypass loop are closed during operation of this system. The closure of these valves diverts the condensate flow from the feedwater piping through the recirculation line and to the condensers. Since the isolation valves are closed during modes 1 through 4 of plant operation, these modes are not affected by the existence of the recirculation/cleanup system. Because the system operates only during modes 5 and 6, the system is not essential to the safe operation of the plant, and the basic function of the existing condensate/feedwater system is not affected.

The structural integrity of the system is such that it is compatible with and does not compromise the structural integrity of the existing condensate/feedwater system. That is, the system is designed to Seismic Class I for the portion of the system located in the auxiliary building and down-graded to Seismic Class II for the portion of the system located in the turbine building since no Seismic Class I system would be compromised due to the structural failure of the system.

The design of this system incorporates the appropriate criteria such that it is consistent with the plant safety analysis.

10.4.7 CONDENSATE AND FEEDWATER SYSTEMS

10.4.7.1 Design Bases

The condensate and feedwater systems return the condensed steam from the turbine condenser and drain from the regenerative feed heating cycle to the steam generators while maintaining the water inventories throughout the cycle.

These systems automatically maintain the steam generator water level during steady-state and transient operation.

The steady-state flow varies with Unit load as calculated by the turbine heat balances. During steam generator blowdown, the feed flow will be in excess of the heat balance flow by the rate of blowdown. When steam is extracted from the nuclear steam supply system ahead of the turbine cycle for other processes, the condensate and feed systems will recover this process flow and return it to the steam generators.

The pressurized water nuclear steam supply system steam pressure varies with load. The pressure in the steam generators drop with increased thermal output. This characteristic, combined with the lower feed system frictional resistance at lower flow, results in a small increase in total pumping head required from full load to no load. There is sufficient margin allowed above the system required head/flow for feed control, pump wear, design and testing, and system fouling to ensure adequate flow to the steam generators during steady-state and transient operation.

Uniform feedwater temperature to all steam generators is ensured under all operating conditions. A continuous steady feed flow will be maintained at all loads.

Sufficient feedwater storage capacity is maintained within the condensate feed systems to accommodate the mass transfer of fluid due to the expansion and contraction arising from the thermal and pressure effects on steam generator fluid inventory and condensate feed systems during load changes. This will also compensate for loss of fluid from the system during load changes or plant cooldown by atmospheric steam dump.

The feed system from the steam generators, back to and including the first stop and nonreturn valve outside the containment, is Safety Class 2A and Category I Seismic system. This portion of the feed system is an integral part of the auxiliary feed system described in section 6.5. The remainder of the condensate and feedwater systems is Safety Class NNS.

Provision is made for inservice inspection of all piping and components that are Safety Class 2A.

10.4.7.2 System Description

The condensate and feedwater system is shown in drawings D-170117, sheet 1, D-170117, sheet 2, D-170117, sheet 3, D-170117, sheet 4, D-175073, D-200011, sheet 1, D-200011, sheet 2, D-200011, sheet 3, and D-205073.

The system is composed of two low-pressure turbines; one twin- shell condenser; three 50-percent condensate pumps; two 50-percent variable-speed, turbine-driven feed pumps; two 50- percent heater drains pumps; two strings of feedwater heaters; two 100-percent steam jet air ejectors; and one turbine gland steam condenser.

The condensate pumps take their suction from the condenser hot well and pump through the air ejector condensers, gland steam condenser, and five stages of low-pressure feed heating to the feed pump suction.

The feed pump discharges through one stage of high-pressure feed heating into a common header. Each of the three steam generators is supplied through a single line taken from the common header.

The individual steam generators are supplied with feed regulators and flow elements. A bypass loop containing a feedwater bypass control valve is installed in parallel with the main feed regulator for each steam generator.

To allow plant maintenance, bypasses are provided around feed heaters. The bypass around the final feed heater joins the common steam generator feed header to ensure adequate mixing and equal temperature feed to the individual steam generators.

As the plant is designed for condenser dump only and 50-percent load rejection without reactor trip, no fluid loss to the atmosphere is considered while the main feed system is operating. The feed pump turbines exhaust into the main condenser. On loss of the condenser vacuum or main feed system, the plant will trip; maintaining steam generator inventory is no longer a requirement for the main feed system. Under these circumstances, the auxiliary feed system takes over. Sufficient water is stored in the condenser hot well to make up system fluid inventories on a 50-percent load rejection. The makeup pipe between the condenser and condensate tank is sized to provide flow to make up fluid inventory during a ramp load change of 5 percent per minute.

Uniform feed temperature to all steam generators is assured by the length and routing of the common feed header after the high-pressure heater bypass.

10.4.7.3 Safety Evaluation

All pieces of major equipment in the condensate and feedwater systems are bypassed so that their individual failure will not affect the basic functions of the systems. If multiple pump failures or loss of ac power results in loss of feedwater flow, the reactor will trip and the auxiliary feedwater system will provide feedwater to remove the residual heat.

Major breaks in the condensate and feedwater systems would cause flow and pressure losses great enough to trip the reactor. Upon reactor trip, the feedwater control valves and the feedwater bypass control valves will automatically close and the auxiliary feedwater system described in section 6.5 will supply the feedwater necessary to insure a safe reactor shutdown.

During normal operation, condensate and feedwater contain no radioactive contaminants. However, in the event of primary to secondary system leakage due to a steam generator tube leak, it is possible for the condensate and feedwater to become radioactively contaminated. A full discussion of the radiological aspects of primary to secondary leakage, including anticipated operating concentrations of radioactive contaminants, means of detection of radioactive contamination, anticipated releases to the environment, and limiting conditions for operation, is included in section 11.3.

Samples of the condensate and feedwater are taken from condenser hot wells, condensate pump discharge, feedwater line to the steam generators, and steam generator blowdown lines; they are analyzed as described in subsection 9.3.2, Process Sampling System, to control the quality of the condensate and feedwater. Samples from the steam generator blowdown lines are analyzed to detect radioactivity.

As a result of water hammer associated with feedwater flow instabilities at operating pressurized water reactors (PWRs), efforts have been initiated to identify the causes of water hammer and to determine its effect on the Farley feedwater system. As a result of the early efforts in this program, the Farley feedwater piping was modified to minimize the length of the horizontal run of piping attached to the steam generator feedwater nozzle. Figure 10.4-1 shows the piping modification.[a] The dotted line shows the original layout, which consisted of approximately 9 to 13 ft of horizontal piping between the steam generator nozzle and the 90-degree elbow. The current layout, shown as the solid line, utilizes a 45-degree elbow immediately adjacent to the 16-in. x 14-in. reducer which connects directly to the steam generator nozzle.[b]

Indications based on our efforts to date are that these modifications have reduced the energy which would be associated with a postulated water hammer by a factor of about 2-1/2 to 4, on a relative basis. Likewise, the peak pressure which would be associated with a postulated water hammer is estimated to have been reduced by approximately 20 percent , again on a relative basis.

10.4.7.4 Tests and Inspections

The feedwater stop valves, control valves, and bypass control valves are tested in accordance with the Technical Specifications and the Inservice Testing Program.

All foreign material and loose oxides will be removed from the piping prior to plant operation.

All of the components of the system will be continually monitored during operation to ensure satisfactory operation.

10.4.7.5 Instrumentation Applications

The steady-state steam generator water level is controlled by the feedwater control valves. In steady-state, the feedwater control valves (one for each steam generator) adjust the individual water levels and compensate for different pressure drops through the steam generators, feedwater, and steam pipes resulting from different piping layouts. Steam generator water level control at low-power levels is achieved by a feedwater control valve installed in a parallel loop around the main feedwater control valve for each steam generator.

Since the feed pump speed is variable, the steady-state throttling in the feedwater control valve shares its duty to maintain level with the ability of the speed control system to increase the pump speed and head above the initial steady-state values.

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a. For all Units except 2B.

b. Figure 10.4-2 shows the piping modification for steam generator 2B feedwater line. This unit's feedwater line utilizes a 45-degree elbow down and a 90-degree bend to the horizontal immediately adjacent to the 16-in. x 14-in. reducer. This results in a horizontal run of about 12 ft of pipe whose top is 6.5 in. below the bottom of the horizontal section connected to the steam generator nozzle.

The feedwater control valves and the feed pump speed control are considered as two complementary parts of the feed flow control system, whose purpose is to maintain the level in all steam generators within limits required for safe and continued plant operation.

A large-load reduction is the governing transient in the design of the feed control system. The closing of the turbine governing valve results in a pressure increase and a level decrease in the steam generators. To limit this level decrease, the feed flow should be increased. The increased pressure results in a decreasing flowrate from the feed pumps as long as the valves position and the pump speed remain unchanged.

To minimize the duty of the valve, the control system increases the speed of the pump so that the pump discharge pressure increases at least as much as the pressure in the steam generator. To achieve this, the pressure difference between feed header (after the last heater) and steam header is used as a control variable and is compared with a setpoint in order to generate a pump speed signal.

The feed pump speed control system consists of the following three interrelated parts:

A. The setpoint calculators which sum the three steam flows and contain the basic scaling adjustments.

B. The differential pressure controller (board mounted) which compares the steam header pressure, feedwater header pressure, and the calculated setpoint to determine the speed signal required.

C. The feed pump manual/auto stations (board mounted, one per pump) which provide the operator with the flexibility of choosing various operating modes.

Instrumentation, including pressure indicators, flow indicators, and temperature indicators, are provided in the control room to monitor the system.

10.4.8 STEAM GENERATOR BLOWDOWN PROCESSING SYSTEM

As part of the comprehensive steam-side chemistry control program employed in this plant, the steam generator blowdown processing system functions to eliminate harmful concentrations of chemical deposits from accumulating in the steam generators.

The effluents from the secondary side of the steam generators are normally dispersed to the environment following dilution with cooling tower blowdown water.

In the event the secondary side becomes contaminated with primary-side coolant, the blowdown processing system conditions the water such that it can be reused on the secondary side, and collects the radioactive contaminants and other solids for offsite disposal.

The use of multiple forms of instrumentation to detect primary/secondary leakage and the use of the steam generator blowdown processing system are provided to assure that the public health and safety is not compromised.

10.4.8.1 Design Bases

Secondary-side water chemistry control specifications require a minimum of 5 gal/min blowdown from each steam generator to achieve optimum effectiveness from the steam generator chemistry control program.

The steam generator blowdown processing system is designed to accommodate blowdown under a wide range of conditions.

Under conditions of steam generator tube leakage and/or condenser leakage, a continuous blowdown rate of 12.5 gal/min maximum per generator may be required to maintain proper chemistry control in the generator. The design basis of the processing portion of the blowdown processing system is 50 gal/min total. This permits 12.5 gal/min continuous blowdown for each generator plus some additional capacity as margin.

To facilitate the removal of any accumulated solids from the tube sheet when no tube leaks exist, the system is designed to accommodate, through the bypass portion of the system, an intermittent blowdown rate of 50 gal/min per generator or 150 gal/min total. If solids removal is required coincident with steam generator tube leakage, the processing system can accommodate only one steam generator blowing down at the maximum rate.

Processed system effluent will ordinarily be released to the environment. The system is also designed to permit recycling of processed steam generator blowdown to the main condenser. The average discharge concentration will not exceed 2×10^{-8} μCi/cm^3.

Sampling of blowdown fluid for radioactive elements will be based on the criteria presented in subsection 11.4.3. Sampling of blowdown fluid for secondary-side chemistry control purposes will be performed on a once-per-day basis.

The blowdown processing equipment is located in the auxiliary building. The ventilation system for this building is designed to provide temperatures not exceeding 110°F during the summer, which is well below the temperature limitations for this equipment.

The system is not essential to nuclear plant safety downstream of the blowdown isolation valves; therefore, the various components of the system are classified NNS and will be designed, fabricated, and tested in accordance with ASME Section VIII. The exceptions are the blowdown isolation valves and the associated piping between these valves and the steam generators. These items are classified ANS Safety Class 2A, and are designed, fabricated, tested, and inspected in accordance with ASME Section III.

10.4.8.2 System Description and Operation

Each reactor Unit has three steam generators and each generator has its own blowdown and sample lines.

The flow of blowdown fluid from each of the three steam generators is individually flowrate-controlled before the blowdown lines are manifolded outside of the containment barrier, as the blowdown requirements for each generator may not be the same. The system flow diagrams are shown in drawings D-175071, sheet 1; D-205071, sheet 1; D-175071, sheet 2; D-205071, sheet 2; D-175071, sheet 3; and D-205071, sheet 3. The flow diagrams show a typical series flow path with all four demineralizers bypassed. Although typically not used, if required, various combinations of two demineralizers, aligned in series, would be utilized as directed by plant procedures to process the blowdown fluid through the demineralizer processing portion of the system prior to being released to the environment. For the purpose of describing system operation, it is assumed that processing is initially not required and the demineralizers are therefore bypassed.

Fluid from the steam generator manifold enters under pressure into a shell and tube heat exchanger, where the fluid temperature is reduced by plant service cooling water. The cooling water flowrate is modulated to maintain a constant blowdown fluid exit temperature. The pressure is then reduced across a pressure control valve to the level required to overcome system resistance. The blowdown fluid is then directed through a radiation monitor and into a surge tank. From the surge tank, the fluid is pumped through a second radiation monitor to the discharge line by the discharge pumps. The rate of discharge is controlled by level instrumentation in the surge tank so that tank level is maintained at a nearly constant level.

For the path described above, the blowdown fluid receives no processing except cooling. In the event activity is transmitted to the secondary side of the steam generator, it will show up in the blowdown fluid. If the activity level is above 1.0×10^{-5} $\mu Ci/cm^3$, the radiation monitor located upstream of the surge tank will alarm in the control room and trip closed the control valve downstream of the heat exchanger, providing automatic isolation of the system. As the surge tank level decreases, the control valve will throttle down the discharge flow, and a low-surge tank level switch will shut off the pumps.

If the first radiation monitor fails to detect the activity, a redundant monitor is located on the discharge side of the surge tank that trips, isolating the system discharge. The system may also be automatically isolated by low service water dilution flow during normal plant operation. Plant procedures allow for bypass of the low dilution flow automatic isolation feature during certain operational conditions, such as plant outages. When system isolation is accomplished by closure of the discharge valve, the pumps are protected by mini flow lines.

The surge tank level will increase until a high-level switch trips, thereby terminating blowdown. Operator action can also shut off the pumps and operate the valves.

For the events described above, an amount of contaminated blowdown fluid may be in the surge tank which is unsuitable for discharge. This fluid can be processed through the processing portion of the system to provide the necessary decontamination to permit discharge. All subsequent steam generator blowdown will be automatically processed through the processing system.

The processing portion of the system consists of four mixed bed demineralizers, a filter, and instrumentation that provides process-related information used to monitor system performance. After processing, the fluid can be recycled to the main condenser, but may be discharged through the discharge line when required.

The processing system is designed such that it can be operated continuously, if needed, provided the resin beds are periodically renewed. Resin bed exhaustion is detected by periodic sample analysis. Resin beds are normally series aligned with the fresher bed downstream. Sampling analysis may be used to determine the acceptability of using other configurations. Normally, various series combinations of two resin beds are used. If breakthrough of the upstream bed occurs, the downstream bed continues to process the flow. Normally, process flow will then be realigned through one of the other series flow paths available. Spent resin is transferred from the exhausted bed to the spent-resin storage tank and new resin installed as determined by plant scheduling. The new resin is now available as a new downstream bed. The spent resin in the storage tank is transferred to the solidification and dewatering facility as determined by plant scheduling.

The resin is removed from the storage tank by first loosening the resin by applying nitrogen gas to the bottom of the tank through six sparger pipes. The spent-resin sluice pump can also be used to fluidize or loosen the resin by taking water from the storage tank and pumping it back into the bottom of the tank through the six sparger pipes.

Nitrogen gas pressure is then applied to the top of the resin, and it is this pressure head that moves the fluidized resin to its disposal point. The system also incorporates provisions for backflushing the valves and piping with demineralized water or sluice water when this operation is completed.

Each plant unit has its own processing system (demineralizers, filters).

10.4.8.2.1 Component Description

10.4.8.2.1.1 Steam Generator Blowdown Heat Exchangers. One heat exchanger cools the steam generator blowdown before it is discharged from the plant or sent to the demineralizers for cleanup. The heat exchangers are shell and tube design, with blowdown water in the tubes being cooled by service water on the shell side.

10.4.8.2.1.2 Steam Generator Blowdown Inlet Filter. This filter removes particulate matter from the steam generator blowdown fluid before it flows to the demineralizers. This filter assures maximum utilization of the demineralizer resins.

10.4.8.2.1.3 Steam Generator Blowdown Surge Tank. The surge tank collects the blowdown water prior to its being discharged from the system. The tank provides the necessary suction head for the discharge pumps.

10.4.8.2.1.4 Steam Generator Blowdown Discharge Pumps. The horizontal, centrifugal pumps are provided to pump the treated blowdown water from the surge tank to the main condenser, for plant discharge, or to recycle the blowdown water through the demineralizer train. Only one pump is operated normally, with the second serving as an installed spare.

10.4.8.2.1.5 Deleted.

10.4.8.2.1.6 **Steam Generator Blowdown Mixed Bed Demineralizer**. Four flushable, mixed bed demineralizers are provided in the blowdown treatment system. Exhausted resin beds are replaced based upon periodic sample analysis and plant scheduling.

10.4.8.2.1.7 **Steam Generator Blowdown Outlet Filter**. This filter removes particulate matter that may be carried over from the demineralizer beds. This protects the discharge pumps and prevents accumulation buildup in the surge tank.

10.4.8.2.1.8 **Steam Generator Blowdown Spent- Resin Storage Tanks.** These tanks are used to collect and store the spent resin from the steam generator blowdown demineralizers until it is transferred to the solidification and dewatering facility.

10.4.8.2.1.9 **Steam Generator Blowdown Spent-Resin Sluice Pump**. This canned, centrifugal pump is provided to sluice the spent resin from the demineralizers to the spent-resin storage tanks. The pump draws water from either spent-resin storage tank through a screen and directs it to the demineralizers. A resin slurry is formed and directed to the spent-resin storage tank.

10.4.8.2.1.10 **Steam Generator Blowdown Sluice Filter**. This filter removes resin fines from the sluice water flow directed to the demineralizers.

10.4.8.3 Design Evaluation

10.4.8.3.1 Radioactivity Discharge Rates

When operating without steam generator leakage or when the system effluent is being recycled back to the main condenser, there will be essentially zero release of radioactivity from this system. When the system effluent is discharged to the environment while operating with concurrent fuel defects and steam generator leakage, radioactivity discharge rates will depend on the combinations of these parameters which are assumed. The system is designed to limit average discharge concentrations under these conditions to 2×10^{-8} μCi/cm^3 or less. This average has been taken as being the average quarterly and the average annual discharge concentration for release to the environment. For the conditions of 20-gal/day steam generator leakage and 0.2-percent fuel defects, the average discharge concentration will be considerably below the above limits ($\sim 1.1 \times 10^{-9}$ μCi/cm^3). If conditions of higher tube leakage are postulated, the system could meet the average quarterly release limits, assuming 2 months of operation at 20-gal/day steam generator leakage at 1-percent fuel defects, and 1 month of operation at

144-gal/day steam generator leakage at 1-percent fuel defects. Following this period, the plant would require shutdown for steam generator tube repair if such were the case.

The radiological evaluation analysis for normal operating conditions is given in subsection 12.1.6.

10.4.8.3.2 Failure Analysis of Components

The blowdown processing system can be isolated by the action of two isolation valves activated by two separate radiation monitors. Sample points located throughout the system can be used as a means of checking the activity level in the blowdown fluid if necessary.

Piping and valving inside and outside containment to the containment isolation valve are designed and fabricated to ANS Safety Class 2A requirements. As this system performs no function related to safe shutdown of the plant, all components downstream of the containment isolation valve are classified as NNS Safety Class. The rupture of components downstream of the containment isolation valve will generally require shutdown of the plant.

10.4.8.3.3 Analysis of Shell-Side Radioactivity Concentration During Blowdown Processing System Isolation

The operation criteria for the secondary-side blowdown system are dictated by the need for limiting the secondary-side buildup of dissolved solids.

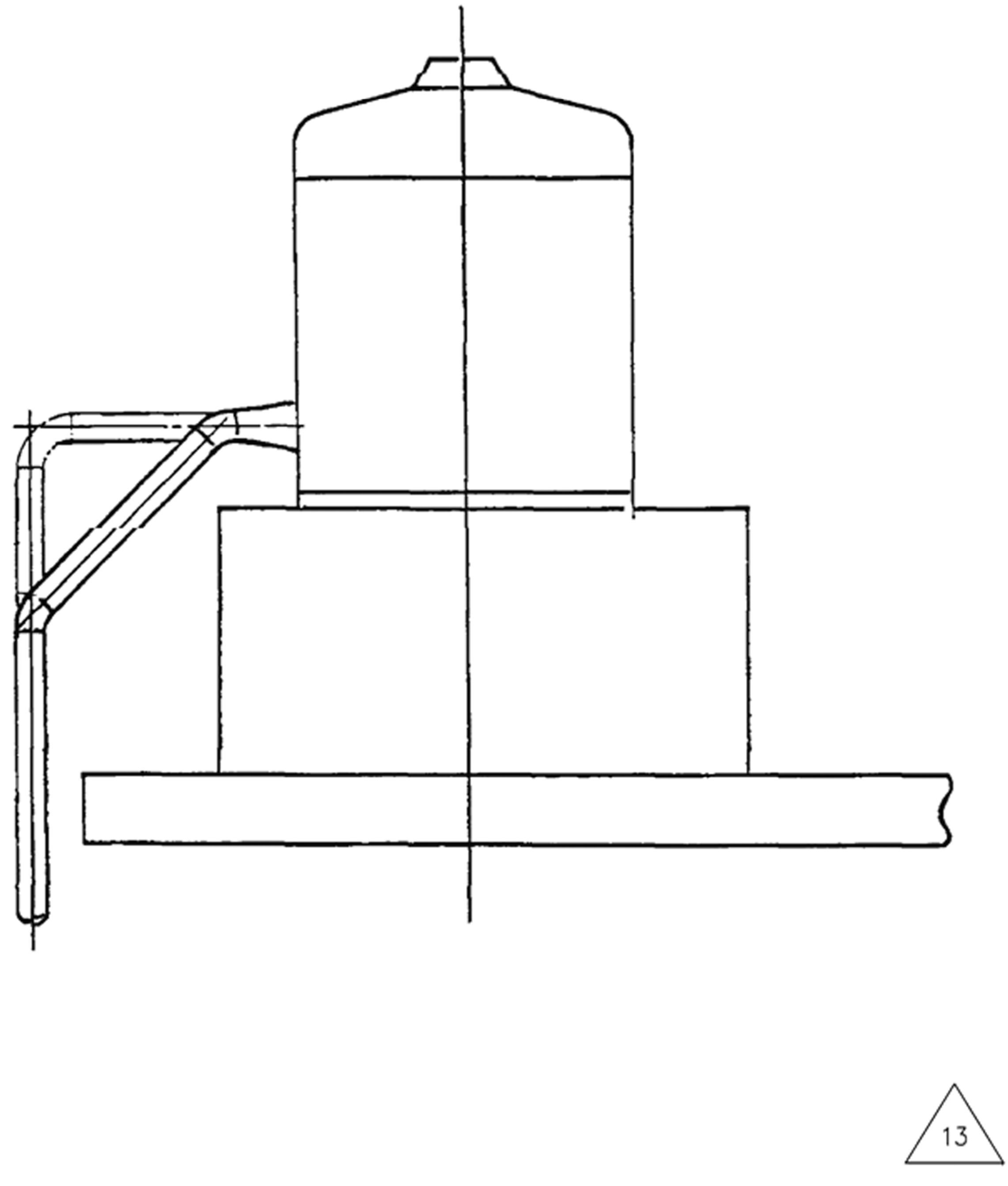
Hence, it is unlikely that the plant may operate with the blowdown system isolated. However, assuming system isolation coincident with 1-percent fuel defects and 144-gal/d primary-to-secondary-side leakage, the secondary-side activity will build up to approximately 5×10^{-2} $\mu Ci/cm^3$ in one 24-h period.

10.4.8.4 Tests and Inspections

Periodic tests and recalibration will be required on the radiation monitors in the blowdown processing system as described in the technical specifications. Periodic tests of the blowdown isolation valve functioning will be performed to check operability. Periodic visual inspections and preventive maintenance can be conducted as necessary when all components are available for inspection.

10.4.8.5 Safety Evaluation

The limiting conditions for operation and surveillance requirements for secondary water monitoring as defined in the Farley Technical Specifications assure that steam generator tube integrity is not reduced below an acceptable level for adequate margins of safety.



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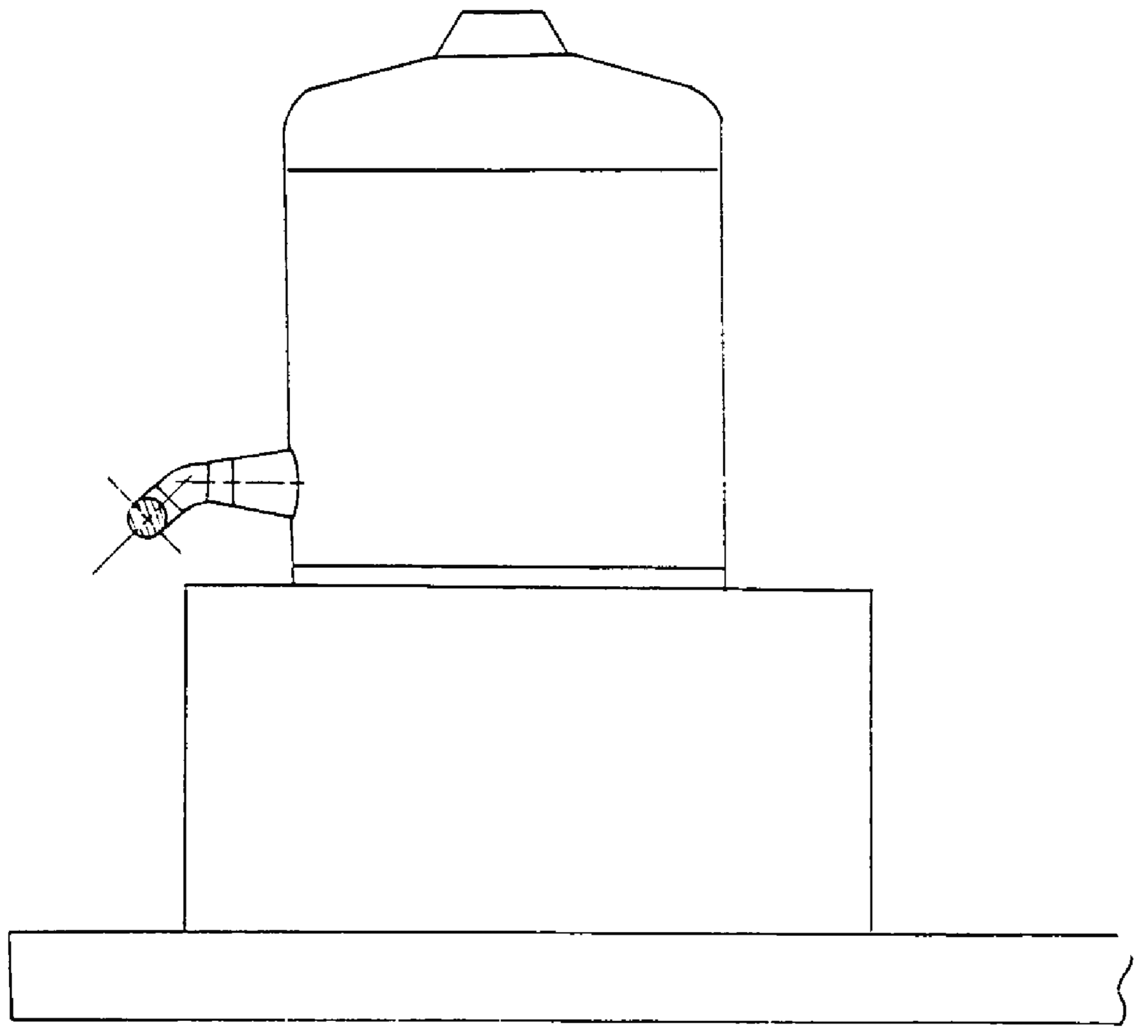
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

STEAM GENERATOR 1A, 1B, 1C, 2A,
AND 2C FEEDWATER CONNECTION

FIGURE 10.4-1



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JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

STEAM GENERATOR 2B
FEEDWATER CONNECTION

FIGURE 10.4-2

APPENDIX 10A

DYNAMIC ANALYSIS OF MAIN STEAM SWING DISC TRIP VALVE FOR FAULTED CONDITIONS

TABLE OF CONTENTS

Page

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

APPENDIX 10A

DYNAMIC ANALYSIS OF MAIN STEAM SWING DISC TRIP VALVE FOR FAULTED CONDITIONS

10A.1 INTRODUCTION

Prior to performing the closure impact analysis described herein, Teledyne Materials Research (TMR) performed two preliminary closure impact analyses for the disc of a main steam swing-disc trip valve intended for service in the Joseph M. Farley Nuclear Plant. In both of the preliminary analyses, it was conservatively assumed that the valve body would remain rigid during impact. The objective of the preliminary analyses was to demonstrate the structural adequacy of the disc before proceeding with a more comprehensive analysis in which the valve body would be allowed to deform. The assumption of a rigid valve seat was considered to yield a conservative evaluation of the disc because of the implied requirement that the kinetic energy stored in the disc and swing arm would be dissipated solely through plastic-strain energy absorption in the disc. This report contains the final analysis in which both the disc and the body are allowed to deform during the closure impact.

Large impact-induced strains in the disc were predicted on the basis of the conservative results of the first preliminary analysis. This led to a decision to substitute a more ductile material for the disc. For this reason, the A516 Gr. 70 steel disc considered in the first preliminary analysis was replaced by a type 304 stainless steel disc in the second preliminary analysis. The choice of type 304 stainless steel was justified on the basis of available high-strain rate tensile test data for the temperature of interest (600°F). Data presented in reference 2 reveals that the material had excellent ductility at strain rates as high as 100 s^{-1}, both in terms of the uniform elongation at ultimate stress and the reduction of area at fracture. Therefore, this material was considered to have excellent energy absorption characteristics for impact conditions. Another consideration in the selection of the stainless steel was the ability to construct stress-strain diagrams for various rates of straining by means of information available from reference 3. This information originated from the same testing program described in reference 2.

To reduce the high strains predicted in the first preliminary analysis for the disc rim region, a disc geometry modification was introduced prior to performance of the second preliminary analysis. The modification consisted of adding material to the backside of the disc in the rim region. Because the material change and geometry change were made simultaneously, it was not possible to determine to what degree the geometry change was effective toward reducing high local strains in the contact region. However, the geometry change, if nothing more, reduced the shear strains averaged across the disc thickness. Therefore, the ability of the redesigned disc to resist gross shearing at the internal seat diameter was improved.

The final analysis reported here is an axisymmetric simulation of the problem. That is, the structure was modeled axisymmetrically and the swinging motion of the disc was replaced by a translational motion. The problem was solved for a disc impact velocity of 150 ft/s. This velocity was obtained by equating the kinetic energy of the translating disc to that of the swinging disc.

A pressure of 705 psig was assumed to act on the upstream side of the disc for the duration of the impact event and the temperature of the valve was assumed to be 600°F.

The computer program used for the final analysis of the impact problem under faulted conditions was the PISCES code. This Lagrangian finite-difference code permits the dynamic response of a structure to be analyzed as a function of time under conditions of substantial plastic deformation and gross geometric distortion.

Strain criteria are introduced in the report for evaluating the results of the impact analysis. On the basis of testing the results against these criteria, it is concluded in section 10A.2 that the valve body and disc are structurally adequate to withstand the postulated faulted-condition event.

To acquaint the reader with the general appearance of the valve under consideration, a sketch of the longitudinal cross-section is shown in figure 10A-1. The figure was obtained by tracing Atwood and Morrill drawing No. 21261-H and shows the disc in the closed position. Under normal operating conditions, the disc will be fully open and steam will flow from left to right. As indicated on figure 10A-1, the downstream and upstream surfaces of the disc will be referred to as the front surface and back surface, respectively.

Figure 10A-1 shows the component configurations considered for the final analysis reported herein. With this design, the disc is subjected to a concentrated load at its center at the time of impact. This load is due to the inertia of the disc arm, post, and nut. For the purpose of analysis, a conservative approach was taken whereby the kinetic energy in the disc arm was forced to be dissipated through plastic deformation of the disc and body. As discussed later, this was accomplished by adding the kinetic energy of the disc arm to the kinetic energy of the disc through an increase in the density of the material near the center of the disc.

Following completion of the analysis reported herein, the disc arm was redesigned to the configuration indicated in figures 10A-2 and 10A-3. For the redesigned disc arm, the kinetic energy of the arm is transferred to the disc via four points located along the disc rim. The modified arm design results in less severe disc loading than that presented in this report. Consequently, the analysis performed in the original arm design (as shown in figure 10A-1) may be viewed as a conservative evaluation for the modified disc arm design.

Table 10A-1 shows the nomenclature used in the report.

10A.2 SUMMARY AND CONCLUSIONS

The complete impact analysis of the disc required two tasks. Fluid dynamics were used to calculate the forces on the disc and the disc closing velocity (attachment D). The impact analysis was based on converting the angular velocity calculated in attachment D to an equivalent uniform translational velocity and evaluating the impact response by means of an axisymmetric representation of the disc and valve body.

10A.2.1 SUMMARY OF FLUID DYNAMICS RESULTS

Addendum 8 to Bechtel Inquiry SS-1102-32 (reference 1) specifies the initial steam pressure and quality for the two cases of main steam flow conditions to be considered in the swing-disc, trip-valve closure analysis. Denoting these as cases 1 and 2, the fluid flow states vary between saturated steam in case 1, and 4-percent quality steam in case 2. The flow conditions for case 1 and case 2 are outlined in attachment D.

The elapsed time from pipe break detection to dump valve actuation is 0.5 s, and an additional 1.0 s is required for the air cylinder to depressurize from the nominal 100-psig pressure to the disc balance pressure. During this 1.5-s delay, the 32-in. main steam line blows down and outflow is established by the upstream flow restrictor. Thus, the disc is not exposed to the initial blowdown through the 32-in. pipe.

Atwood and Morrill weight and center of gravity data were used to compute a moment of inertia for the disc assembly. Relations for the torques acting on the swing disc were formulated, including those due to gravity, pressure, and the closing spring. Also considered was a constant shaft counter torque due to gland packing friction and based on Atwood and Morrill data.

A calculation was made to determine the choking angle across the disc at which the dihedral area between the disc plane and the plane of the valve seat is exactly equal to the flow area across the valve seat. The choke angle was computed as 24.5 degrees, measured from the valve seat.

In computing flow conditions across the valve, the conservative assumption was made that the break occurs just downstream of the valve, resulting in a choked-flow condition across the valve seat. This determined the flow velocity to which the disc was subjected. A dynamic analysis of the disc motion was conducted for five angular segments between the normal "open" position (65 degrees) and the closed position. The net torque acting on the disc was computed for each included angular segment, and the results were used to solve the equations of motion. Included in each calculation were ΔP, torque (T), α, ω, Δ, and Σt.

Upon onset of choking at θ = 24.5 degrees, a static pressure of 995 psia was taken at the back of the disc. A critical pressure ratio of 0.578 applied to this yielded a valve throat pressure of 575 psia, and a ΔP across the disc of 419.9 psid. This pressure differential was held constant during the remaining 24.5 degrees of disc travel to impact. To account for the steam hammer specified for cases 1 and 2, the steam hammer was averaged with ΔP of 419.9 psid over the last 10 degrees of disc travel to impact, and the result then used in the torque calculation.

The results of the fluid flow analysis, as contained in attachment D, indicate a disc center impact velocity of 117 ft/s for case 1 (saturated steam), and a 102.7 ft/s disc center impact velocity for case 2 (x = 4 percent). Closure times were 0.146 s and 0.158 s, respectively.

Using the more conservative case 1 disc center impact velocity, a modified disc center velocity was determined by equating the kinetic energy for the assumed translational rotational mode (KE_t) to the kinetic energy computed for the actual rotational mode (KE_r). As shown in attachment C, this computation gives the disc center a velocity of V_t = 150 ft/s used in the impact analysis. This approach to the choice of a uniform impact velocity was in accordance with the conservative assumption that the kinetic energy must be dissipated solely through plastic deformation of the valve body and disc.

10A.2.2 SUMMARY OF IMPACT ANALYSIS RESULTS

The dynamic solution formulated in section 10A.3 permitted the structural behavior of the valve under impact conditions to be investigated as a function of time. Both the disc and the valve body were allowed to deform plastically. Pertinent results obtained in the investigation are discussed in section 10A.4. Evaluation of the results against acceptance criteria is the subject of section 10A.5. The following is a summary of key results obtained in the analysis:

A. The duration of the impact event as measured by dissipation of the kinetic energy in the moving parts of the valve is approximately 1300 μs (1.3×10^{-3} s). The dynamic solution covers the first 1150 μs. Extrapolation to 1300 μs produces only minor changes in the results.

B. Following impact at 150 ft/s, the center of the disc continues to accelerate before it slows down. The highest velocity of 180 ft/s is reached 350 μs after impact.

C. Impact of the disc on the body seat results in substantial permanent geometric distortion of the valve, but not in the creation of a steam path past the disc. Consideration of the deformed shape shows rotation of the seating surfaces of both body and disc, as well as large-scale bending in the central portion of the disc. The center of the disc deflects 1.84 in., which is equivalent to a displacement of half the thickness of the disc (3.75 in.).

D. The largest value of the effective strain in the body is 15 percent. Because it is accompanied by a compressive hydrostatic stress state, an effective strain of up to 29 percent is considered acceptable. (Had the hydrostatic stress state been tensile, only 11-percent strain would have been acceptable.)

E. The largest value of the effective strain in the rim region of the disc is 17 percent. This is a localized strain for which an effective strain of 30 percent is considered acceptable (regardless of whether the hydrostatic stress state is tensile or compressive).

F. The largest value of the radial and hoop-bending strains in the disc which occur at the center of the front surface is 8.5 percent for both. Because of the constant volume conditions associated with plastic deformation, the bending strains are accompanied by a strain in the thickness direction of -17 percent. The effective strain for this state of strain is 17 percent. An effective strain of up to 18 percent is considered acceptable by a strain criterion for limiting geometric distortion by bending.

10A.2.3 CONCLUSIONS

A. The impact analysis shows that the body and disc are structurally adequate to withstand the dynamic forces produced by valve closure under the postulated faulted conditions.

B. The axisymmetric method of solution adopted for the dynamic analysis was confirmed as an acceptable analytical approach by the results obtained. That is, a sufficient margin exists between the imposed strain limits and maximum strains computed for the contact region of body and disc to provide protection against any deviations from the computed results attributable to the initially nonuniform impact velocity along the circumference of the disc.

C. The conclusions of A and B above are not invalidated by the redesign of the disc arm which followed the investigation.

10A.3 IMPACT ANALYSIS - FAULTED CONDITIONS

10A.3.1 METHOD OF ANALYSIS

The valve impact analysis reported herein is based on the method of solution incorporated in the PISCES computer code. This code permits the solution of stress-wave propagation problems by solving equations of motion and constitutive equations expressed in finite-difference form. Thus, the code is especially well suited for analyzing the response of structures to impact, and explosion and penetration conditions. Such response normally involves both elastic-plastic deformation of the material and gross distortion of the structural geometry. A solution is generated by calculating the response at each of many small time steps, also called cycles. The magnitude of the time step is automatically calculated within the program by means of a criterion that controls numerical stability.

Printout of the solution is available for any of the time steps. The user of the program preselects the times at which printout is desired. A standard output format is provided, but the user can also develop additional output by writing his own subroutine and appending it to the PISCES code. Because strain components, effective strain, and effective stress are not part of the standard output, TMR developed its own subroutine for the computation and printing of these variables. Plotting routines are available in PISCES for plotting the standard output, but TMR adapted its own plotting routines to PISCES to facilitate plotting of standard and nonstandard output.

References 4 through 6 are the manuals used in generating the PISCES solutions for the valve problem. They may be consulted for additional information on the computer code.

The following units used in the PISCES solutions are needed to interpret the printed and plotted results:

A. Unit of length = centimeter (cm).

B. Unit of time = microsecond (μs).

C. Unit of force = 10^{12} dyn.

D. Unit of pressure = mbar (1 mbar = 10^{12} dyn/cm^2).

E. Unit of mass = (g).

F. Unit of energy = 10^{12} dyn/cm.

Note that 1 psi is equal to 6.89 x 10^{-8} mbar.

10A.3.2 DISC MODEL

The overall disc dimensions used for constructing the PISCES model are given in figure 10A-4. The dimensions are shown in inches and in centimeters, the latter in parentheses. Attention is called to the undercut fillet at A. For reasons explained below, two fillet geometries were investigated. Figures 10A-5 and 10A-6 show the first PISCES model analyzed. The fillet in this model approximates the original design in that the outer radius of the fillet coincides with the inside diameter of the body seat. This coincidence led to computational difficulties with the PISCES code, apparently triggered by the local strain concentration in the disc resulting from indentation of the disc corner by the body seat corner. To circumvent this problem, the fillet geometry was changed to that shown in figures 10A-7 and 10A-8. The modification consists of increasing the outer radius of the fillet by 0.1 in. while leaving the outside diameter of the disc unchanged. As a consequence, the radial dimension of the contact face on the disc is reduced by the same amount, from 1.25 in. to 1.15 in.[a]

A dashed outline is used in figure 10A-4 to indicate the configuration of the original carbon steel disc which was considered in the first preliminary analysis. It was mentioned in section 10A.1 that when the disc material was changed from carbon steel to stainless steel, additional material was added to the disc backside to improve the shear strength of the disc. Because the chamfer at B has little bearing on the structural behavior of the disc, it was not included in the PISCES model.

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a. This modification has been incorporated into the design of the stainless steel disc. After completion of the analysis reported herein, the fillet depth was increased by 0.1 in. The rationale for this later modification is discussed in section 10A.5.

It was mentioned in section 10A.1 that a fictitious higher-density material was assumed to occupy the central portion of the disc. As explained in subsection 10A.3.6, the value of this higher-density material is determined from the imposed requirement that the kinetic energy of the disc post, nut, and disc arm be transferred to the disc on impact. In section 10A.1 it was stated that subsequent to the performance of this analysis, the disc arm was redesigned to add four adjustable points of attachment between the disc arm, and the disc post was redesigned to become an integral part of the discs (figures 10A-2 and 10A-3). The modified disc arm and postarrangement facilitates the field replacement and alignment of the stainless steel disc in the valve body and simplifies the machining of the replacement disc. The modified disc arm design will create a more favorable impact loading on the disc so that the impact analysis reported herein will remain valid.

10A.3.3 BODY MODEL

The valve body has a complex three-dimensional geometry. Considerable geometric simplification was necessary to permit an axisymmetric representation of the body. Modeling was facilitated by the massive proportions of the body relative to the disc so that it could be predicted that plastic deformation would be confined to the immediate vicinity of the seat area. However, even in this region, the geometry is not axisymmetric apart from the seat itself. Therefore, the choice was made to model the body seat region in such a way that it would best simulate the structural response at the location where the impact velocity of the disc is highest during the swing motion.

This choice led to the body geometry seen in figures 10A-5 through 10A-8. The model dimensions are defined in figure 10A-9.

The PISCES model of the body consists of two cylinders of unequal diameters but equal wall thickness separated by a transition region that contains the valve seat. The wall thickness of the two cylinders was made equal to the valve's allowed minimum wall thickness. The most characteristic aspect of the geometry is the feature of having the inside diameter on the downstream side match the diameter of the seat opening. The resulting 90-degree angle between the shell wall and the valve seat is representative of the geometry immediately adjacent to the point of maximum impact velocity mentioned above. This will be evident by comparing the model geometry with the actual geometry sketched in figure 10A-10, obtained by tracing part of Atwood and Morrill drawing No. 21322-F.

Only part of the PISCES model is shown in figures 10A-5 through 10A-8. As indicated on figure 10A-9 the model is 200 in. long, 100 in. each way from the seating surface. This much length was included in the model to assure that elastic stress waves reflected at the ends of the model would not return to the contact region in less than 1000 μs. Based on the preliminary analyses, it had been estimated that the conversion of kinetic energy to plastic-strain energy would, for all practical purposes, be completed in this timespan. To limit the number of zones in the model, a transition from six zones across the wall to two zones was made 12 in. downstream and 5 in. upstream from the seat surface. Moreover, the length of the zones was increased to 10 in. starting at axial positions located 20 in. downstream and 10 in. upstream. At distances this far from the impact surface, the use of zones with an aspect ratio of 10 can be justified on the assumption of uniform wave fronts.

10A.3.4 DISC MATERIAL

The material properties employed for the disc, which are for type 304 stainless steel at 600°F, are summarized below:

A. Elastic Constants

For Young's modulus (E), the value provided in Appendix I of ASME Section III was selected. Poisson's ratio (ν) was assumed to be 0.3, and the shear modulus (G) and bulk modulus (K) were computed from E and ν. Thus,

1. $E = 25.4 \times 10^6$ psi = 1.75 mbar.

2. $\nu = 0.3$.

3. $G = (E/2)/(1 + \nu) = 0.673$ mbar.

4. $K = (E/3)/(1 - 2\nu) = 1.46$ mbar.

B. Stress-Strain Diagram

The Liquid Metal Fast Breeder Reactor Materials Handbook (reference 3) was the source for the stress-strain diagrams for different strain rates shown in figure 10A-11. The pertinent page of the reference cited is included as attachment A. It provides a transcendental equation that gives, as a function of temperature and strain rate, the relationship between the true stress (σ_t) and the true plastic strain (ε_p). The equation is valid to 25-percent strain and strain rates from 10^{-5} to 10^2 s^{-1}. Total true strain (ε_t) may be obtained by adding the elastic strain such that $\varepsilon_t = \varepsilon_p + \sigma_t/E$. The diagram for a strain rate of 10^3 s^{-1} was expected to be encountered in the solution.

The PISCES code permits the use of a bilinear stress-strain diagram together with a specified maximum on stress. Figure 10A-12 defines the diagram used in the analysis. It consists of an elastic portion, a strain-hardening elastic-plastic portion, and a perfectly-plastic portion. It is also superposed on the curves in figure 10A-11 to indicate the reasoning employed in defining figure 10A-12. That is, since the effect of strain rate could not be modeled in the PISCES computer solution, a diagram was selected which would approximate high-strain behavior at large strains and low-strain rate behavior at small strains. Because the yield strength at the low-strain rate of 10^{-5} s^{-1} was less than the specified minimum value in Appendix I of ASME Section III, no downward adjustment of the curve to account for minimum properties was needed.

Denoting the yield stress (or proportional limit), true ultimate stress and tangent modulus in the strain-hardening range by σ_y, σ_{ut} and E_t, respectively, the values of these parameters associated with figures 10A-11 and 10A-12 are:

1. σ_y = 25,000 psi = 1.72 x 10^{-3} mbar.

2. σ_{ut} = 80,000 psi = 5.51 x 10^{-3} mbar.

3. E_t = 0.314 x 10^6 psi = 0.0216 mbar.

C. Ductility Parameters

The results of the PISCES solution will be evaluated on the basis of strain criteria expressed in terms of the ductility parameters ε_{ut} and ε_f. Here, ε_{ut} is the true uniform elongation (the true strain at the maximum load in a tension test) and ε_f is the true fracture strain. If ε_u is the measured engineering strain at maximum load, and RA is the measured reduction of area at the fracture location, then ε_{ut} and ε_f may be computed with the relations $\varepsilon_{ut} = \ln(1+\varepsilon_u)^{ut}$ and $\varepsilon_f = \ln [1/(1-RA)]$.

Referring to the HEDL data reported in reference 2 and reproduced in attachment B, the uniform elongation (figure B.1 of attachment B) and the reduction of area (figure B.2 of attachment B) for type 304 stainless steel at 600°F are not very dependent on strain rate. Based on the information contained in the two diagrams, appropriate choices for ε_{ut} and RA are 30-percent and 65-percent true absolute strain, respectively. The value of RA yields $\varepsilon_f/3$ = 35-percent true absolute strain.

D. Stellite Overlay

The contact surface of the disc is protected against wear by a stellite overlay. This layer of different material was not modeled as a separate material in the present analysis. While it would have been possible to do so, omitting the layer is justifiable on the ground that larger strains will be predicted without the stellite and that this will lead to a conservative evaluation.

10A.3.5 BODY MATERIAL

The body material is A-216, Gr. WCB steel, which is listed in Appendix I of ASME Section III as a carbon steel for casting purposes. Because no published data were available pertaining to the effect of strain rate on the stress-strain characteristics of material, a number of tension tests were performed on specimens machined from a blank of the casting material (supplied to TMR by Atwood and Morrill).

The tests furnished the information on stress-strain diagrams and ductility summarized below. (A report on the test program will be issued separately.[7])

A. Elastic Constants

For Young's modulus (E), the value provided in Appendix I of ASME Section III was selected. Poisson's ratio (ν) was assumed to be 0.3, and the shear modulus (G) and bulk modulus (K) were computed from E and ν. Thus, at 600 F,

1. $E = 25.4 \times 10^6$ psi = 1.77 mbar.

2. $\nu = 0.3$.

3. $G = (E/2)/(1 + \nu) = 0.682$ mbar.

4. $K = (E/3)/(1 - 2\nu) = 1.48$ mbar.

B. Stress-Strain Diagram

Stress-strain diagrams obtained at different strain rates and in three orthogonal directions of the test blank are shown in figures 10A-13, 10A-14, and 10A-15. The testing conditions are summarized in table 10A-2, which gives the dimensions of the blank as well as the nominal strain rate and the direction of loading for each of 11 test specimens. The Z-direction is the thickness direction of the cast material, whereas the x and Y directions are arbitrary inplane directions, metallographic examination of samples normal to the three directions furnished evidence of a uniform grain structure without a preferred orientation.

Inspection of the stress-strain diagrams in figures 10A-13 through 10A-15 reveals only a minor dependence of the results on loading direction and strain rate. The material appears to soften slightly with increase in strain rate, but for analytical purposes, the material can be assumed to be isotropic and strain-rate insensitive.

Also depicted in figures 10A-13 through 10A-15 is the trilinear stress-strain diagram assumed for the PISCES solution. The reader will note that the diagram is chosen well below the measured diagrams. One reason for this choice was that the material characterization should be conservative in view of the fact that the tests were few in number and that strain rates as high as 1000 s-1 could not be achieved. Here it should be recognized that lowering the stress-strain curve will lead to increased strains. This, in turn, leads to a conservative evaluation because of the use of criteria that place limits on strain. A second reason for lowering the stress-strain curve was the need to compensate for a yield strength measured at room temperature that was higher than the minimum yield strength given in Appendix I of ASME Section III.

The assumed stress-strain diagram is also shown in figure 10A-12, where it can be compared to the diagram for the disc material. The values of σ_y, σ_{ut}, and E_t for the body material are:

1. σ_y = 30,000 psi = 2.07×10^{-3} mbar.

2. σ_{ut} = 62,000 psi = 4.28×10^{-3} mbar.

3. $E_t = 0.320 \times 10^6$ psi = 0.0221 mbar.

C. Ductility Parameters

As mentioned in the discussion of the disc material, the ductility parameters to be used in the evaluation of the PISCES solution are ε_{ut} and ε_f. Table 10A-2 furnishes the measured values of ε_u and RA, and also the values of ε_{ut} and ε_f derived from ε_u and RA. Inspection of the tabulated values reveals a slight tendency for increased ductility at higher strain rates. (The low value of ε_{ut} for specimen No. 14 appears to be a spurious result.)

By averaging the values from all 11 tests, the following result is obtained: ε_{ut} = 11-percent true absolute strain, and ε_f = 88-percent true absolute strain. The strain criteria for the body will be based on these averages.

D. Stellite Overlay

The contact surface of the body seat is protected against wear by a stellite overlay. This overlay was not modeled in the body as a separate material for the same reasons that it was not in the disc.

10A.3.6 INITIAL CONDITIONS AND BOUNDARY CONDITIONS

A. Initial Positions of Body and Disc

It is assumed in the PISCES solution that the moving disc will first contact the stationary body at time t = 0, the starting point of the solution. It is also assumed that the still undeformed contact faces will at that point in time meet in the plane defined by the axial position x = 0.

B. Constraint on Body Motion

During the impact event, axial motion of the body is rigidly constrained at the upstream end of the model (at x = 100 in.). No such constraint is imposed at the downstream end (at x = -100 in.) so that the total length of the model is permitted to change.

C. Initial Disc Velocity

The disc velocity at impact is 150 ft/s (4.58 cm/μs). This velocity was determined in attachment C by matching the kinetic energy of disc translation to the kinetic energy of disc rotation. The rotational energy was known from the fluid dynamics analysis reported in attachment D.

D. Pressure Loading

A constant pressure of 705 psig (4.86×10^{-5} mbar) is maintained on the upstream side of the valve for the duration of the impact event.

E. Initial Material Densities

The initial density of model materials in the PISCES code is entered as a relative density (the density relative to that of water). Hence, for the steels used in the disc and body, the relative density (ρ_s) is 7.85. In the analysis performed, the mass of the post, nut, and arm attached to the disc was accounted for by assuming that a higher-density material normally occupies the threaded hole in the center of the disc. The density of this material was selected such that its mass was equivalent to that of the post, nut, and arm combined. With reference to attachment C, the relative density of the equivalent material (ρ_e) is found from the relation $\rho_e = 14.6\ \rho_s$. The equivalent material is occupied by the first five rows of zones in the disc model. The higher density derived in attachment C pertains to the original disc arm design reflected in figure 10A-1. As stated in section 10A-1, the redesigned disc arm shown in figures 10A-2 and 10A-3 will result in less severe loading of the disc by the disc arm. That is, the disc arm load is now applied in the rim region where its contribution to disc loading is insignificant. Loading at the center of the disc has been reduced to that due to the mass of the post, which is integral with the disc in the modified disc arm design. The mass of the post is less than the equivalent mass of post, arm, and nut in the original arm design so that the analysis as performed will be conservative.

10A.3.7 PISCES SOLUTION

A trial solution with the full model provided the value of the stable step between computation cycles as 0.385 µs. The initial time step was specified as 0.025 µs, a value computed by means of a formula provided in the PISCES Input Manual (reference 5). Subsequent time steps are determined internal to the code to ensure numerical stability in the computation. The stable time step was reached in 13 cycles.

The final solution was executed for 3000 cycles. The associated elapsed time was 1150 µs. Standard computer output was printed at intervals of 200 cycles; nonstandard output was printed at intervals of 50 cycles. The nonstandard output was acquired by means of a specially-written subroutine (called EXOUT). It furnished the following results: effective strain ($\bar{\varepsilon}$), axial strain (ε_x), radial strain (ε_y), hoop strain (ε_z), shear strain (ε_{xy}), and effective stress ($\bar{\sigma}$). Effective stress and effective strain are computed from stress and strain components with the following formulas from plasticity theory:

$$\bar{\sigma} = \left(1/\sqrt{2}\right)\left[\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + \left(\sigma_z - \sigma_x\right)^2 + 6\tau_{xy}^{\ 2}\right]^{1/2}$$

$$\bar{\varepsilon} = \left(\sqrt{2}/3\right)\left[\left(\varepsilon_x - \varepsilon_y\right)^2 + \left(\varepsilon_y - \varepsilon_z\right)^2 + \left(\varepsilon_z - \varepsilon_x\right)^2 + 6\varepsilon_{xy}^{\ 2}\right]^{1/2}$$

It should be noted that the geometry of the PISCES model is continually updated (following each computation cycle) so that the stress components σ_x, σ_y, σ_z, and τ_{xy} are true stresses and the strain components ε_x, ε_y, ε_z, and ε_{xy} are true strains. Consequently, $\bar{\sigma}$ and $\bar{\varepsilon}$ are also true quantities. It should further be noted that ε_{xy} is the tensorial shear strain, which is twice the engineering shear strain.

10A.4 PISCES RESULTS

Pertinent information extracted from the PISCES solution is presented in this section of the report.

At this point, an introduction is needed to explain the convention employed in the PISCES code for identifying grid points and grid zones. The grid is defined by columns and rows, indexed I and J, respectively. Figures 10A-16 and 10A-17 show the column and row numbering schemes adopted for the disc and body. A particular grid point in the model is defined by the values of I and J of the row and column that intersect at that point. For instance, point 11, 31 refers to outermost point on the front face of the disc. A grid zone is bounded by two columns, I and J + 1 and by two rows J and J + 1. A zone is defined by the values of I + 1 and J + 1. Thus, as an example, zone 12, 31 is the outermost zone on the front side of the disc.

10A.4.1 DISSIPATION OF KINETIC ENERGY

In table 10A-3, the kinetic energy in the model is tabulated versus the time elapsed since impact. To facilitate the interpretation of the results, the kinetic energy is also given as a percent of its initial value. The latter results furnish the curve plotted in figure 10A-18. It is apparent from the diagram that the kinetic energy is dissipated at a rate that decreases with time from t = 0 to t = 300 μs, and again from t = 700 μs on. In the timespan from t = 300 μs to t 700 μs, the rate of energy dissipation is practically constant. At solution termination time, t = 1150 μs, 97.2 percent of the kinetic energy has been dissipated. The graphical extrapolation of the curve in figure 10A-18 indicates that for practical purposes the duration of the impact is approximately 1300 μs.

10A.4.2 MAXIMUM DEFLECTION OF DISC

The position of various points on the disc as a function of time is given in table 10A-17. The data tabulated for the axial position of the surface points on the disc centerline yield the axial displacement curves portrayed in figure 10A-19. At the extrapolated time of 1300 μs, the displacement (U_x) is 1.77 in. at the front surface and 1.84 in. at the back surface.

Also shown in figure 10A-19 is a straight line which depicts the axial displacement of the disc in free motion (no impact). Since the computed displacement curves are initially above the line, it is clear that following impact, the center of the disc accelerates before it slows down.

10A.4.3 MAXIMUM VELOCITY IN DISC

A plot of axial velocity versus time is shown in figure 10A-20 for the two surface points on the centerline of the disc. The axial velocity (x) reaches a maximum value of 175 ft/s at the front surface and 179 ft/s at the back surface.

10A.4.4 GEOMETRIC DISTORTION

The progressive geometric distortion of the valve model may be observed in figures 10A-21, 10A-22, and 10A-23 where grid plots obtained at 300, 700, and 1150 μs after impact are shown. Figure 10A-24 is a superposition of the distorted shape at the end of the solution (t = 1150 μs) on the undistorted shape (t = 0).

Inspection of the geometry plot in figure 10A-21 reveals that the disc fillet below the contact zone has flattened out. As a consequence, the corner of the body starts to indent the zone of the disc just opposite this corner. The PISCES code permits this to happen. Evidence of such indentation is evident in figures 10A-22 and 10A-23 where the body grid appears to overlap the disc grid. The overlap is not a physical reality. It is a consequence of the plotting routine, which is based on connecting grid points by straight lines and which does not recognize indentation of a zone located in a contact region. The actual geometric distortion is sketched in figure 10A-24.

In the PISCES code, penetration can occur only at contact surfaces. The contact surfaces have to be columns. The column on the stationary part of the model is usually the so-called master column, and the column on the moving part is the slave column. Grid points on the master column can indent the slave column, but grid points on the slave column cannot indent the master column. An optional feature of the master slave approach in the PISCES code permits the formation of voids between the contacting surfaces. While this option was demonstrated to work in a preliminary computer run and then exercised in the full PISCES solution, the results obtained produced no clear evidence that any separation between disc and body occurred in the contact zone.

10A.4.5 STRAIN HISTORY PLOTS

The accumulation of strain as time progresses is best illustrated by means of history plots. All plots to be presented contain four curves, each portraying the strain in a given zone. The applicable zones are identified by column and row numbers in the manner explained at the beginning of section 10A.4.

A. Body Strains

The largest body strains occur in the two columns of zones adjacent to the contact surface. Representative history plots for this region are shown in figures 10A-25 and 10A-26. They indicate that effective strains in the body reach stable values in about 900 μs. The maximum effective strain in the body is 14.7 percent and occurs at zone 9, 17.

B. Disc Strains

Effective strains in the rim region are largest in the four rows of zones for which the results are plotted in figures 10A-27 through 10A-30. It is seen that the strains tend to stabilize faster than in the body, although complete stabilization again requires about 900 µs. The maximum strain in the rim region is 17.4 percent and is found at zone 13, 27.

Results for the central portion of the disc are plotted in figures 10A-31 through 10A-38. Figures 10A-31 through 10A-34 give the effective strain ($\bar{\varepsilon}$), the axial strain (ε_x), the radial strain (ε_y), and the hoop strain (ε_z), respectively, for four zones spaced along the front surface of the disc. Likewise, figures 10A-35 through 10A-38 give the corresponding results for the back surface. The two sets of results show that the front surface is more severely strained than the back surface. A comparison with the results for the rim region indicates that strains in the central region do not begin to accumulate significantly until after most of the strain accumulation in the rim region is over. At solution termination time, the effective strain reaches a maximum of 14.3 percent at the center on the front side and 10.4 percent at the center on the back side. Extrapolation to time t = 1300 µs increases these values to 14.6 percent and 10.6 percent, respectively.

10A.4.6 STRESS HISTORY PLOTS

Because of the severe straining of the body and disc, strains are of considerably more interest and importance than stresses. For this reason, only two history plots were obtained. These pertain to the effective surface stress in the central region of the disc. Figures 10A-39 and 10A-40 show the results for the front surface and the back surface. The spikes in the curves below 200 µs are due to elastic unloading and reloading. In reality, there are many more spikes in the solution, but these are not seen because the results plotted are based on computer output saved at every 50th time step. After 200 µs, the stresses are observed to rise monotonically. Stresses remaining at the completion of the event will be the sum of the residual stresses brought about by plastic deformation, and the stresses that are in equilibrium with the pressure load on the upstream side of the disc.

10A.4.7 DISTRIBUTION OF STRAINS IN THE CONTACT REGION

The distribution of effective strain ($\bar{\varepsilon}$) at times of 300, 700, and 1150 µs is shown in figures 10A-41 through 10A-43. As observed in subsection 10A.4.5, strains in the contact zone of the body clearly do not rise as fast as in the contact zone of the disc. The diagrams are also instructive in showing that large strains in the body are confined to the immediate vicinity of the body seat. Furthermore, they show that the largest strains occur at some distances below the contact surface, a phenomenon not uncommon to contact problems.

At solution termination time, the distributions of strains ε_x, ε_y, ε_z, and ε_{xy} are as presented in figures 10A-44 through 10A-47. It will be noted that at the high-strain locations, the sum of ε_x,

ε_y, and ε_z is approximately zero. This is a consequence of the constant volume condition associated with plastic deformation.

10A.4.8 DISTRIBUTION OF STRAINS IN THE CENTRAL DISC REGION

Figures 10A-48 through 10A-50 provide insight into the distribution of the effective strain $\bar{\varepsilon}$ at times of 300, 700, and 1150 μs. Similar results, but limited to the time of 1150 μs, are shown in figures 10A-51 through 10A-54 for ε_x, ε_y, ε_z, ε_{xy}.

Along the centerline of the disc, ε_x, ε_y, and ε_z are distributed as shown in figure 10A-55. The extrapolated values at the front surface are -17, 8.5, and 8.5 percent, respectively. At the back surface they are 14.4, -7.2, and -7.2 percent. The sum of the strains is zero in each case, which is in accordance with the constant volume condition for plastic strain, elastic strains being small compared to the plastic strains at the two locations considered.

10A.4.9 DISTRIBUTION OF STRESSES IN THE CENTRAL DISC REGION

Distributions of $\bar{\sigma}$, σ_x, σ_y, σ_z, and τ_{xy} radial plane of the disc are presented in figures 10A-56 and 10A-60. The values shown are in ksi (1 ksi = 1000 psi). The diagram for $\bar{\sigma}$ is particularly useful in that it reveals the extent of plastic deformation, as yielding occurs when $\bar{\sigma}$ exceeds 25 ksi. The results are for time t = 1150 μs.

10A.4.10 STRAIN RATES

A tabulation of strain rates at several key locations is presented in tables 10A-5 and 10A-6. Table 10A-5 gives strain rates at various times for the highest strained zones in the body and disc, namely for zones 9, 17 and 13, 27. Strain rates as high as 500 s^{-1} are noted for the body, and as high as 800 s^{-1} for the disc.

Table 10A-6 gives strain rates for zones 12, 2 and 19, 2, which are located at the front surface and back surface of the disc. Strain rates as high as 300 s^{-1} and 200 s^{-1} are noted for these locations. The peak values are reached at time t = ~ 600 μs. This observation agrees with the observation of maximum slopes in the strain time plots (figures 10A-31 through 10A-38).

10A.5 <u>EVALUATION</u>

The impact event associated with valve closure under faulted conditions constitutes an energy dissipation problem. Thus, valve components will deform progressively until the kinetic energy accumulated in the disc, disc post, and disc arm during closure has been dissipated through plastic-strain energy absorption. In the analysis described in this report, it has been assumed, conservatively, that all the kinetic energy is absorbed by the body and disc.

Because the structure must absorb kinetic energy through plastic deformation, meaningful acceptance criteria by which to judge the structural adequacy of the valve should consist of limits placed on geometric distortion (to ensure proper functioning of the valve) and on strain (to preclude fracture).

10A.5.1 DEFORMATION CONSIDERATIONS

The obvious criterion for limiting deformation is that geometric distortion caused by the impact shall not prevent the proper closure of the valve. Application of this criterion requires a qualitative appraisal of the results of the PISCES solution.

Consideration of the deformed shape presented in figure 10A-24 shows that, in spite of considerable geometric distortion, closure is unimpaired. In fact, as evident from the distorted grid plots in figures 10A-21 through 10A-23, the contact surface on the disc has moved radially outward rather than inward, while the radius of the body seat opening has decreased slightly.

Figures 10A-23 and 10A-24 show that the body seat corner has indented the disc below the stellite overlay. This condition is likely to cause higher strains than the PISCES solution is capable of showing. However, such a condition can be circumvented by deepening of the fillet in the disc by 0.1 in. This modification has been incorporated into the disc design. Since it is a minor geometry change, the results of the PISCES solution will remain valid.

With reference to subsection 10A.4.2, the maximum deflection at the center of the disc is 1.84 in. Since any axial displacement of the shaft about which the disc rotates can be assumed to be negligible, the large deflection of the disc could cause binding of the disc post in the collar of the disc arm in the configuration analyzed. However, this concern has been eliminated by the redesign of the disc arm mentioned earlier.

10A.5.2 EVALUATION AGAINST STRAIN CRITERIA

The strain criteria presented below are intended to prevent fracture initiation caused by large local strains in the contact region of body and disc, and excessive bending distortion in the central portion of the disc. Each of the criteria is expressed in terms of the uniform elongation ε_{ut} and the fracture strain ε_f. Section 10A.3 furnishes the following values of these ductility parameters:

A. Disc (type 304 stainless steel) - ε_{ut} = 30%, $\varepsilon_f/3$ = 35%.

B. Body (type A-216 grade WCB steel) - ε_{ut} = 11%, $\varepsilon_f/3$ = 29%.

10A.5.2.1 Local Strain Limits for Contact Region

The strain criteria adopted for limiting local strain are as follows:

A. Rule 1

If the hydrostatic stress component $(\sigma_x + \sigma_y + \sigma_z)/3$ at the location of maximum effective strain is tensile, $\bar{\varepsilon}$ shall be limited to the smaller of ε_{ut} and $\varepsilon_f/3$.

B. Rule 2

If the hydrostatic stress component $(\sigma_x + \sigma_y + \sigma_z)/3$ at the location of maximum effective strain is compressive, $\bar{\varepsilon}$ shall be limited to the larger of ε_{ut} and $\varepsilon_f/3$.

The first rule is justified on the basis that it would have been effective in preventing fracture in burst experiments on clamped discs which had a circumferential structural discontinuity near the clamped edge. The results of the burst tests conducted on special disc specimens were reported in reference 8 and analyzed in reference 9.[a] In the tests, the specimens were rigidly clamped along the rim and subjected to pressure on one face. Three materials with different degrees of ductility were used, one of which was type 304 stainless steel. Depending on the material and the disc dimensions, the discs failed in tension either at the rim fillet or in the center. The rim failures resulted from strain concentration, the center failures resulted from strain instability. By applying rule 1 to the maximum equivalent strain in the rim fillet, it was ascertained that no rim failures would have occurred in the tests had they been interrupted when the true strain reached the lesser of ε_u and $\varepsilon_f/3$ of the materials involved.

Because fracture initiation is unlikely when the hydrostatic stress component is compressive, the second rule must be viewed as conservative from a fracture prevention point of view. However, the rule also serves as a useful limit for preventing excessive local distortion of the structure.

It is noted that for both the body and the disc, ε_{ut} is smaller than $\varepsilon_f/3$. For the body, ε_{ut} = 11 percent, and $\varepsilon_f/3$ = 29-percent true absolute strain; for the disc, ε_{ut} = 30 percent, and $\varepsilon_f/3$ = 35-percent true absolute strain.

Considering the body first, inspection of the strain distribution in figure 10A-43 shows that ε_{ut} is exceeded only in three locations. At zone 9, 17, $\bar{\varepsilon}$ = 15 percent, and at zones 9, 16 and 10, 18, $\bar{e}$ = 12 percent. For each of these locations, the PISCES solution shows that the hydrostatic stress component is compressive, so that an effective strain as high as 29 percent is allowed. Hence, the effective strains at the three locations are well within the limit provided by rule 2. Therefore, the body is judged structurally adequate.

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a. A copy of reference 9 is included in the report as attachment E.

Inspection of figure 10A-43 also shows that $\bar{\varepsilon}$ does not exceed ε_{ut} in the rim region of the disc. That is, the maximum value of $\bar{\varepsilon}$ is 17 percent, whereas $\bar{\varepsilon}_{ut}$ = 30 percent. Consequently, since the disc meets the limit provided by rule 1, examination of the hydrostatic stress component is unnecessary.

10A.5.2.2 Strain Limit for Central Region of Disc

The criterion adopted for qualifying the central portion of the disc is the following:

A. Rule 3

The value of $\bar{\varepsilon}$ along the surfaces of the disc shall not exceed 60 percent of ε_{ut}; i.e., $\bar{\varepsilon} \leq 0.6\ \varepsilon_{ut}$.

Basis for this criterion is the observation gleaned from reference 10 that in an internally-pressurized thin-walled sphere, the uniform circumferential strain at maximum pressure will not be less than 0.3 ε_{ut}, for materials whose strain-hardening exponent (n) is less than 0.3. (The precise formula given in reference 10 states that the ratio of the circumferential strain at maximum pressure and the uniform elongation = $(2/3)^n$). By neglecting elastic strains as being very small, it follows that $\bar{\varepsilon}$ is equal to twice the circumferential strain for such a sphere. Since n is less than 0.3 for most steels, limiting $\bar{\varepsilon}$ to 0.6 ε_{ut} would ensure that the maximum pressure in the sphere is not reached. Unstable progressive distortion is thereby prevented.

Invoking rule 3 for the disc evaluation is a conservative procedure because pressure loading of the thin-walled sphere produces membrane loading only, while the loading mode of the disc is primarily bending. However, a conservative rule on $\bar{\varepsilon}$ is desirable from the viewpoint that it places an indirect limit on gross geometric distortion.

The maximum value of $\bar{\varepsilon}$ is found at the center of the front surface, where it is 17 percent. This is less than 0.6 ε_{ut} (18 percent), so that the central portion of the disc is also structurally adequate.

REFERENCES

1. Southern Company Services, Inc., for Alabama Power Company, "Special Conditions Main Steam Isolation Valves - Joseph M. Farley Nuclear Plant, Unit No. 1,"Inquiry No. SS-1102-32, Addendum 8," November 9, 1973.

2. Steichen, J. M., "High Strain Rate Mechanical Properties of Types 304 and 316 Stainless Steel," Technical Document HEDL-TMF 71-164, Hanford Engineering Development Laboratory, November 1971.

3. "Liquid Metal Fast Breeder Reactor Materials Handbook," Technical Document HEDL-TMR 71-32, Hanford Engineering Development Laboratory, Current.

4. "General Description of Finite-Difference Equations," Version 3, Revision 3, PISCES 2DL, Manual A, Physics International Company, 1972.

5. "Input Manual," Version 3, Revision 2, PISCES 2DL, Manual B, Physics International Company, 1973.

6. "Non-Standard Options," Version 3, Revision 3, PISCES 2DL, Manual C, Physics International Company, 1972.

7. "High Strain Rate Tensile Properties of SA-216, GR WCB Steel Casting and SA-182, GR. F304 Stainless Steel Forging Materials," Technical Report No. TR-1901, May 30, 1975.

8. Cooper, W. E., Kottcamp, E. H., and Spiering, G. A., "Experimental Effort on Bursting of Constrained Discs as Related to the Effective Utilization of Yield Strength," ASME 71-PVP-49, American Society of Mechanical Engineers, May 1971.

9. Riccardella, P. C., "Elastic-Plastic Analysis of Constrained Disc Burst Tests," ASME 72-PVP-12, American Society of Mechanical Engineers, June 1972.

10. Cooper, W. E., "The Significance of the Tensile Test of Pressure Vessel Design," Welding Journal, Research Supplement, pp 49-s - 56-s, January 1957.

TABLE 10A-1 (SHEET 1 OF 2)

NOMENCLATURE

Word	Abbreviation or Letter Symbol
time (from initial impact)	t
temperature	T
axial coordinate	x
radial coordinate	y
hoop coordinate	z
velocities	$\dot{x}, \dot{y}$
displacements	U_x , U_y
effective stress (defined as follows)	$\bar{\sigma}$
effective strain (defined as follows)	$\bar{\varepsilon}$
stresses	σ_x, σ_y, σ_z, τ_{xy}
strains	ε_x, ε_y, ε_z, ε_{xy}
strain rates	$\dot{\varepsilon}_x$, $\dot{\varepsilon}_y$, $\dot{\varepsilon}_z$, $\dot{\varepsilon}_{xy}$
Young's modulus	E
shear modulus	G
bulk modulus	K
Poisson's ratio	ν
relative density	D
pressure	P
kinetic energy	KE
Teledyne Materials Research	TMR
Atwood and Morrill Company	A & M

TABLE 10A-1 (SHEET 2 OF 2)

Definitions

$$\bar{\sigma} = \left(1/\sqrt{2}\right)\left[\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + \left(\sigma_z - \sigma_x\right)^2 + 6\tau_{xy}{}^2\right]^{1/2}$$

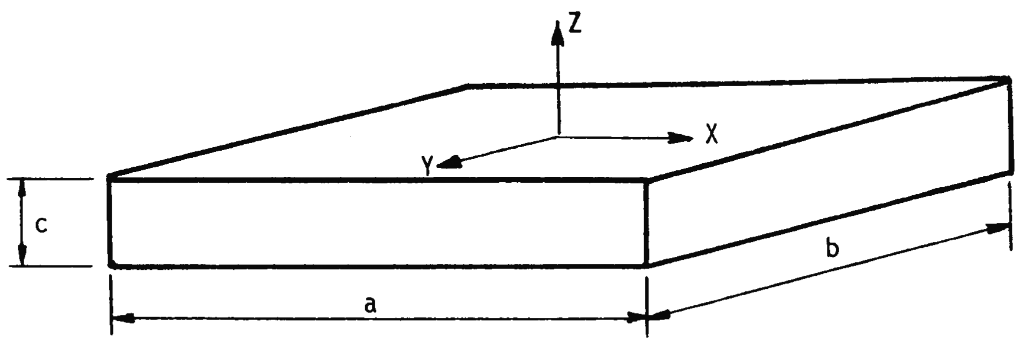
$$\bar{\varepsilon} = \left(\sqrt{2}/3\right)\left[\left(\varepsilon_x - \varepsilon_y\right)^2 + \left(\varepsilon_y - \varepsilon_z\right)^2 + \left(\varepsilon_z - \varepsilon_x\right)^2 + 6\varepsilon_{xy}{}^2\right]^{1/2}$$

TABLE 10A-2 (SHEET 1 OF 2)

TENSION TEST RESULTS

Test blank dimensions:
a = 14 in.
b = 14 in.
c = 2 in.

Test temperature = 600°F



Specification Number	Loading Direction	$\dot{\varepsilon}$ S^{-1}	ε_u %	ε_{ut} %	RA %	ε_f %
2	X	0.092	13.5	12.7	54.0	78
5	X	0.90	12.0	11.3	57.4	85
4	X	6.0	14.0	13.1	59.9	91
6	X	13.0	15.0	14.0	62.0	97
11	Y	0.097	11.0	10.4	51.7	73
13	Y	0.96	12.0	11.3	56.6	83
14	Y	6.0	9.0	8.6	59.2	90
9	Y	13.0	14.0	13.1	62.0	97
19	Z	0.11	8.5	8.2	58.9	89
20	Z	1.1	10.5	10.0	61.5	95

TABLE 10A-2 (SHEET 2 OF 2)

Specification Number	Loading Direction	$\dot{\varepsilon}$ s^{-1}	ε_u %	ε_{ut} %	RA %	ε_f %
15	Z	9.8	10.5	10.0	60.9	94
Average Values:		-	11.8	11.2	58.6	88

Legend

$\dot{\varepsilon}$ = nominal strain rate (based on ram velocity of testing machine)

ε_u = uniform elongation (engineering strain at maximum load)

ε_{ut} = $\ln(1 + \varepsilon_u)$ = true uniform elongation

RA = reduction of area at fracture

ε_f = $\ln[1/(1 - RA)]$ = true fracture strain

TABLE 10A-3

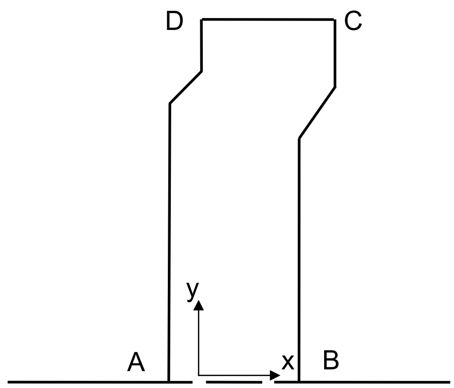
KINETIC ENERGY IN MODEL VERSUS TIME

Time ($t/\mu s$)	Kinetic Energy (KE(t), eu)[(a)]	Kinetic Energy (KE(T), 10 in.^{6}/lb)	KE(t)/KE(0) (%)
0	3.404	3.009	1.000
36	3.119	2.757	0.916
74	2.828	2.500	0.831
151	2.318	2.049	0.681
228	1.994	1.763	0.586
304	1.759	1.555	0.517
381	1.574	1.391	0.462
458	1.372	1.213	0.403
534	1.167	1.032	0.343
611	0.993	0.878	0.292
688	0.809	0.715	0.238
765	0.613	0.542	0.180
841	0.451	0.399	0.132
918	0.332	0.293	0.098
995	0.230	0.203	0.068
1072	0.155	0.137	0.046
1148	0.097	0.086	0.028

a. 1 energy unit (eu) = 1 x 10^{12} dyn/cm = 8.84 x 10^5 in/lb.

TABLE 10A-4

DISC LOCATIONS VERSUS TIME



Time (t/μs)	X_A (cm)	X_B (cm)	X_C (cm)	X_D (cm)	Y_C (cm)	Y_D (cm)
0	-2.86	6.67	9.53	0.00	34.93	34.92
36	-3.02	6.51	9.38	-0.02	34.92	35.04
74	-3.20	6.33	9.26	-0.05	34.89	35.14
151	-3.56	5.96	9.13	-0.09	34.82	35.24
228	-3.95	5.57	9.12	-0.12	34.69	35.28
304	-4.35	5.16	9.12	-0.13	34.57	35.29
381	-4.75	4.74	9.14	-0.13	34.46	35.29
534	-5.53	3.94	9.16	-0.14	34.26	35.27
688	-6.22	3.22	9.16	-0.15	34.12	35.26
841	-6.75	2.65	9.15	-0.16	34.06	35.26
995	-7.09	2.27	9.14	-0.17	33.92	35.24
1148	-7.27	2.08	9.11	-0.20	33.89	35.24
change(cm)	-4.41	-4.59	-0.42	-0.20	-1.04	0.32
change(in.)	-1.74	-1.81	-0.17	-0.08	-0.41	0.13

TABLE 10A-5

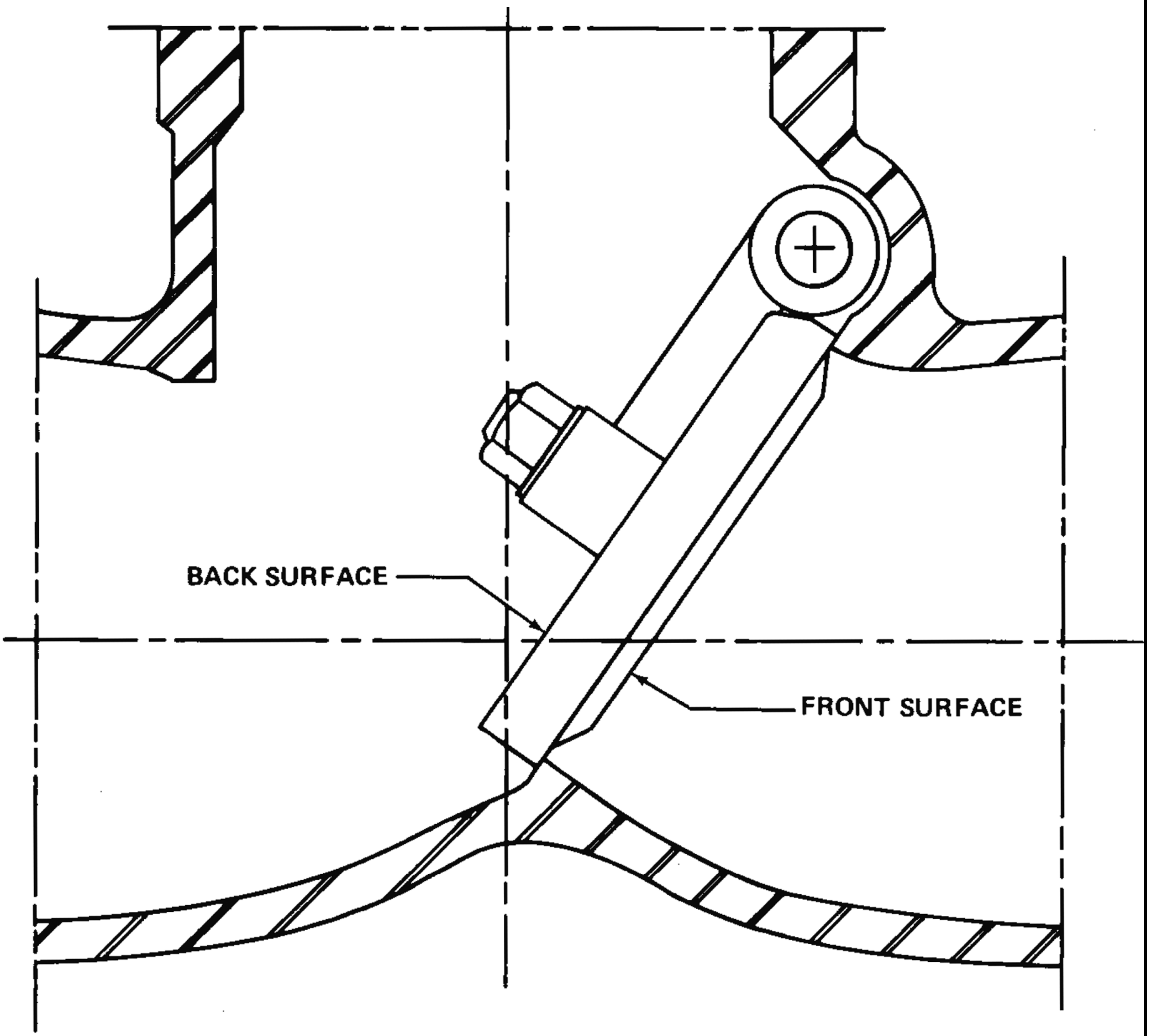
STRAIN RATES AT HIGHEST-STRAINED ZONES OF BODY AND DISC

Time (μs)	Zone I, J	$\dot{\varepsilon}_x$ (s^{-1})	$\dot{\varepsilon}_y$ (s^{-1})	$\dot{\varepsilon}_z$ (s^{-1})	$\dot{\varepsilon}_{xy}$ (s^{-1})
37	9, 17	-373	488	-21	123
74		-238	280	-13	79
151		-124	124	-2	52
228		-104	104	-2	53
304		-162	175	-5	128
381		-130	122	-5	117
534		-43	46	0	51
841		-43	46	-4	46
1148		-2	-3	1	-4
37	13, 27	-793	785	25	509
74		-765	746	17	602
51		-107	94	19	159
228		-19	11	5	42
304		-11	4	3	31
381		-4	-3	-1	12
534		-3	0	-3	0
841		-7	8	-2	33
1148		-2	0	0	-4

TABLE 10A-6

STRAIN RATES AT CENTERLINE OF DISC

Time (μs)	Zone I, J	$\dot{\varepsilon}_x$ (s^{-1})	$\dot{\varepsilon}_y$ (s^{-1})	$\dot{\varepsilon}_z$ (s^{-1})
37	12, 2	0	-2	-2
74		31	-96	-96
151		-76	46	44
228		-43	23	26
304		-44	13	12
381		-101	58	58
534		-232	119	117
688		-272	138	137
841		-181	92	91
1148		-55	28	28
37	19, 2	-4	5	5
74		36	-94	-93
151		133	-76	-77
228		-50	-82	-75
304		-24	-20	-18
381		88	-59	-57
534		207	-106	-105
688		187	-96	-95
841		106	-56	-53
1148		15	-12	-7



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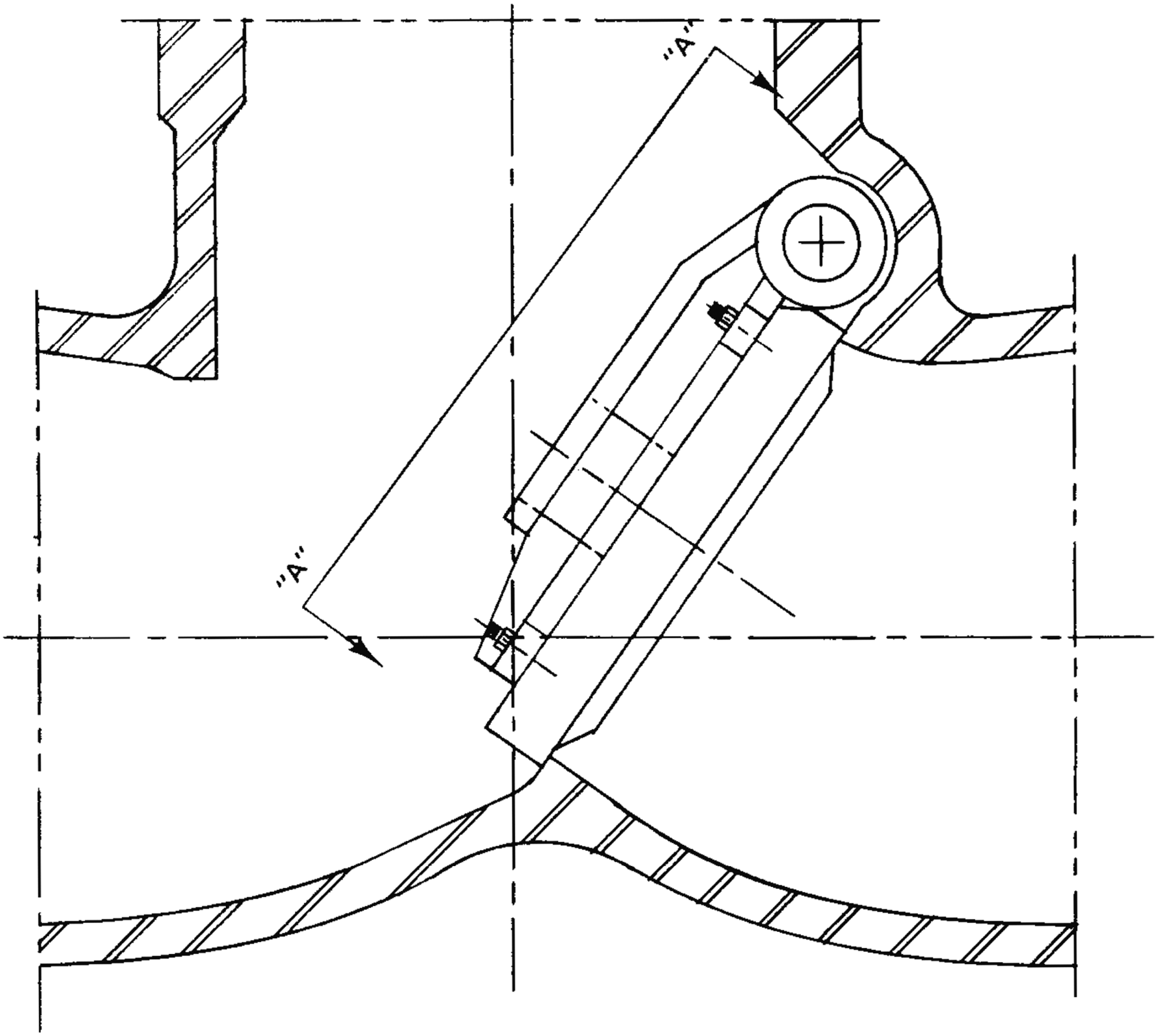
UNIT 1 AND UNIT 2

ISOLATION VALVE
IN CLOSED POSITION

FIGURE 10A-1



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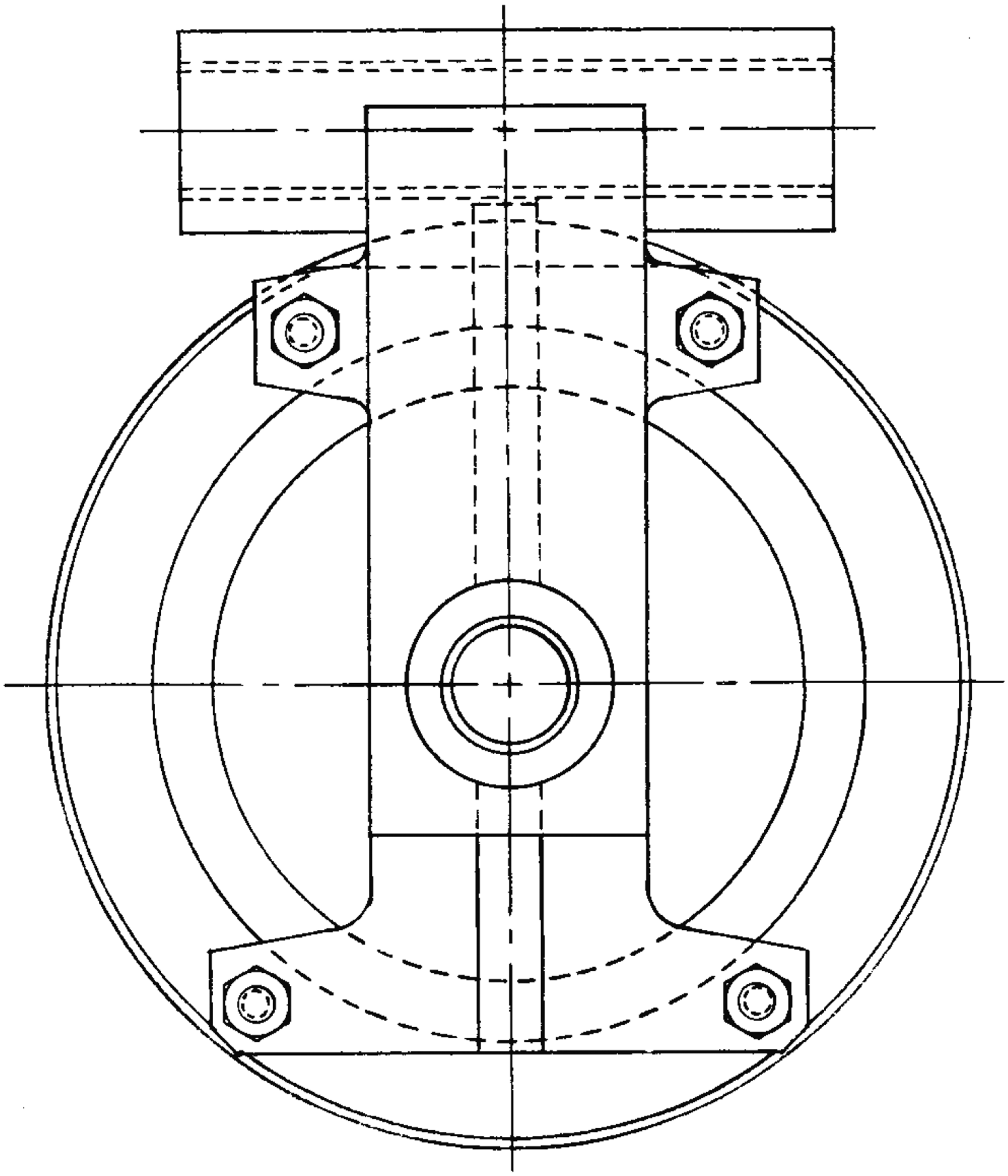
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	ISOLATION VALVE WITH MODIFIED DISC ARM
		FIGURE 10A-2



NOTE: SEE SHEET 2 OF THIS FIGURE FOR THE FINAL AS-BUILT CONFIGURATION SHOWING DETAILS OF LOCKING DEVICES USED ON THE DISC ARM STUDS AND NUTS.

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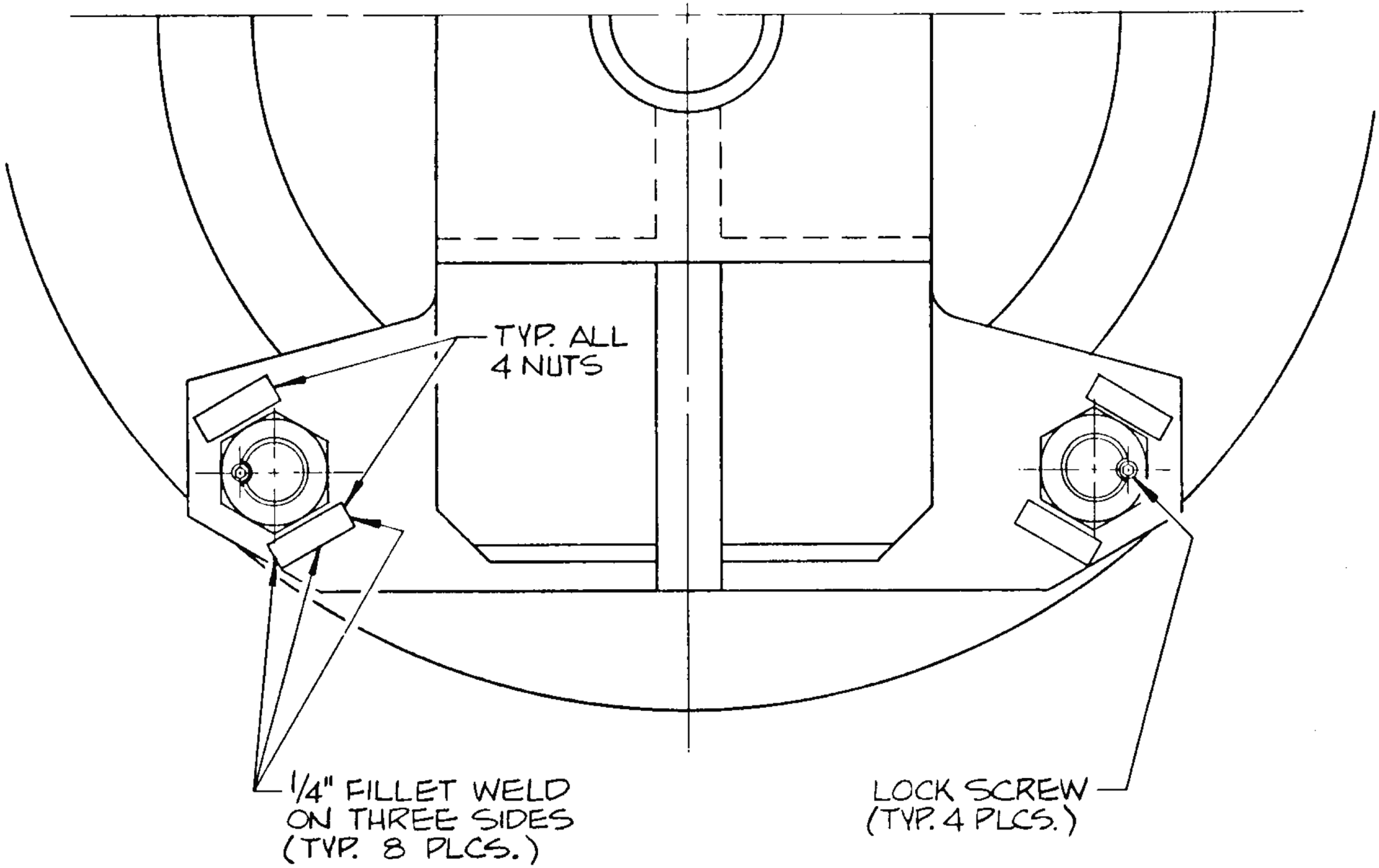
SECTION “A-A” FROM FIGURE 10A-2
TOP VIE W OF MODIFIED
DISC ARM ASSEMBLY

FIGURE 10A-3 (SHEET 1 OF 2)



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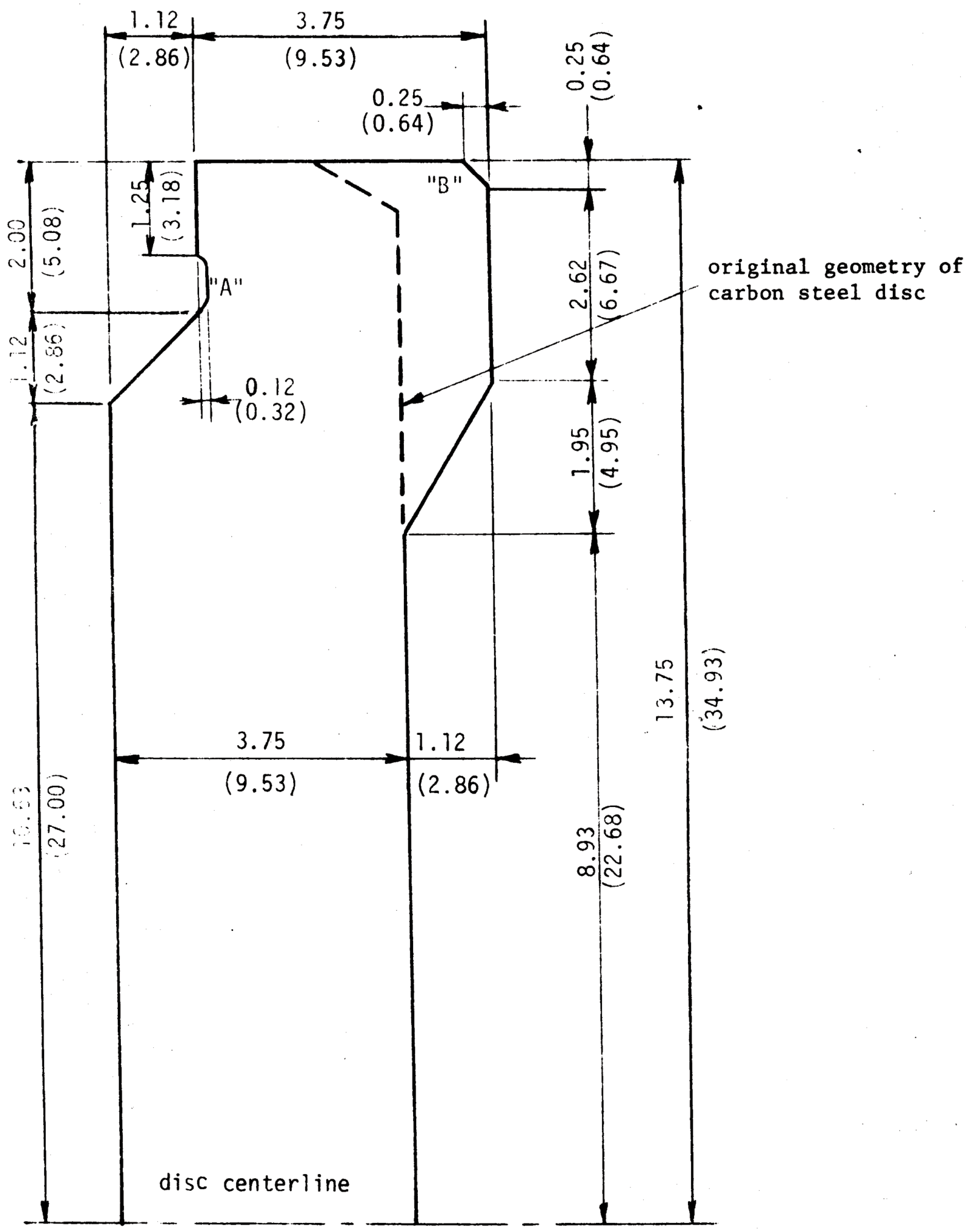
DETAIL OF MODIFIED DISC ARM ASSEMBLY SHOWING LOCKING DEVICES USED ON STUDS AND NUTS

FIGURE 10A-3 (SHEET 2 OF 2)



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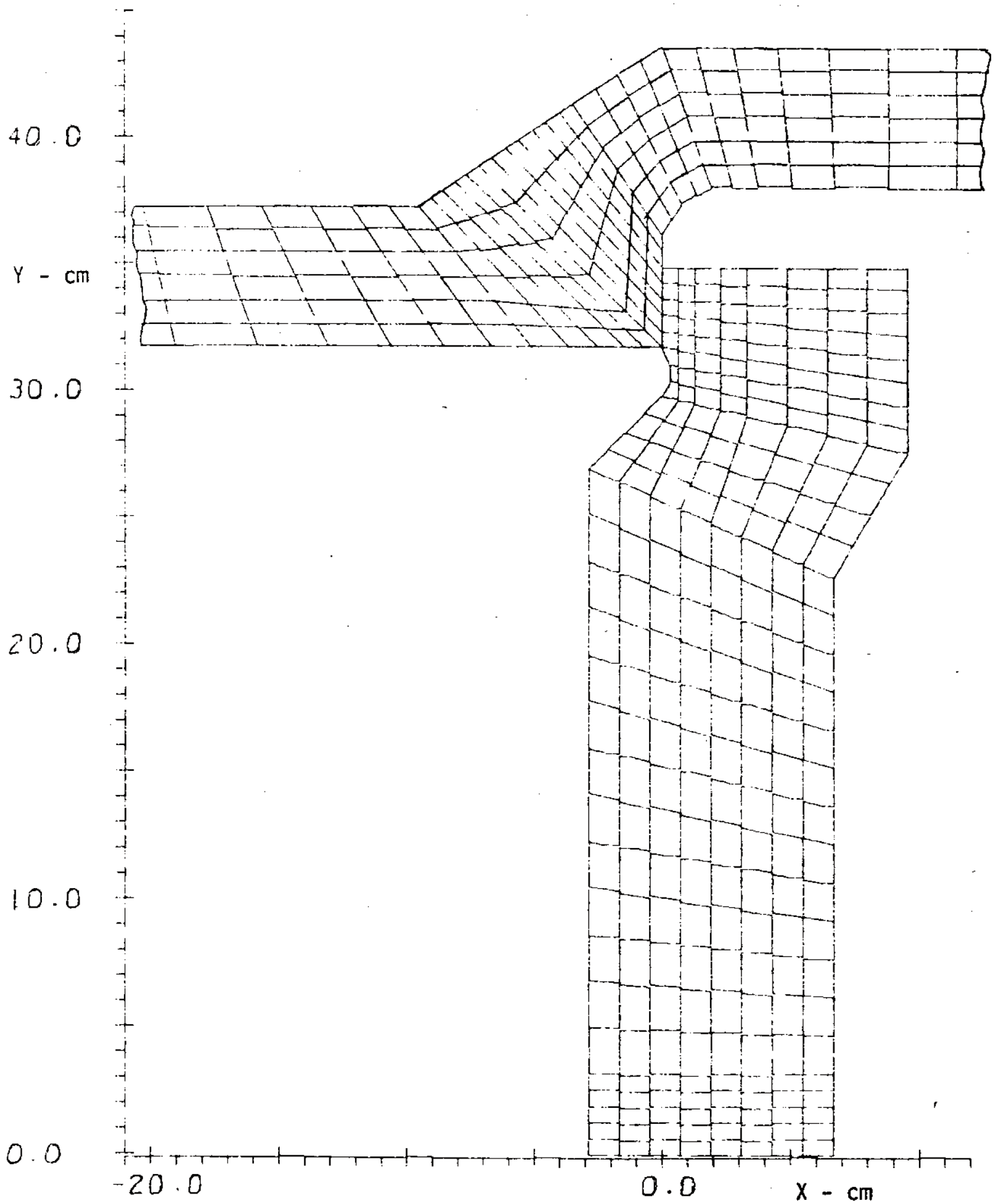
SOUTHERN COMPANY Energy to Serve Your World®	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	BASIC DISC DIMENSIONS IN INCHES AND IN CENTIMETERS
		FIGURE 10A-4



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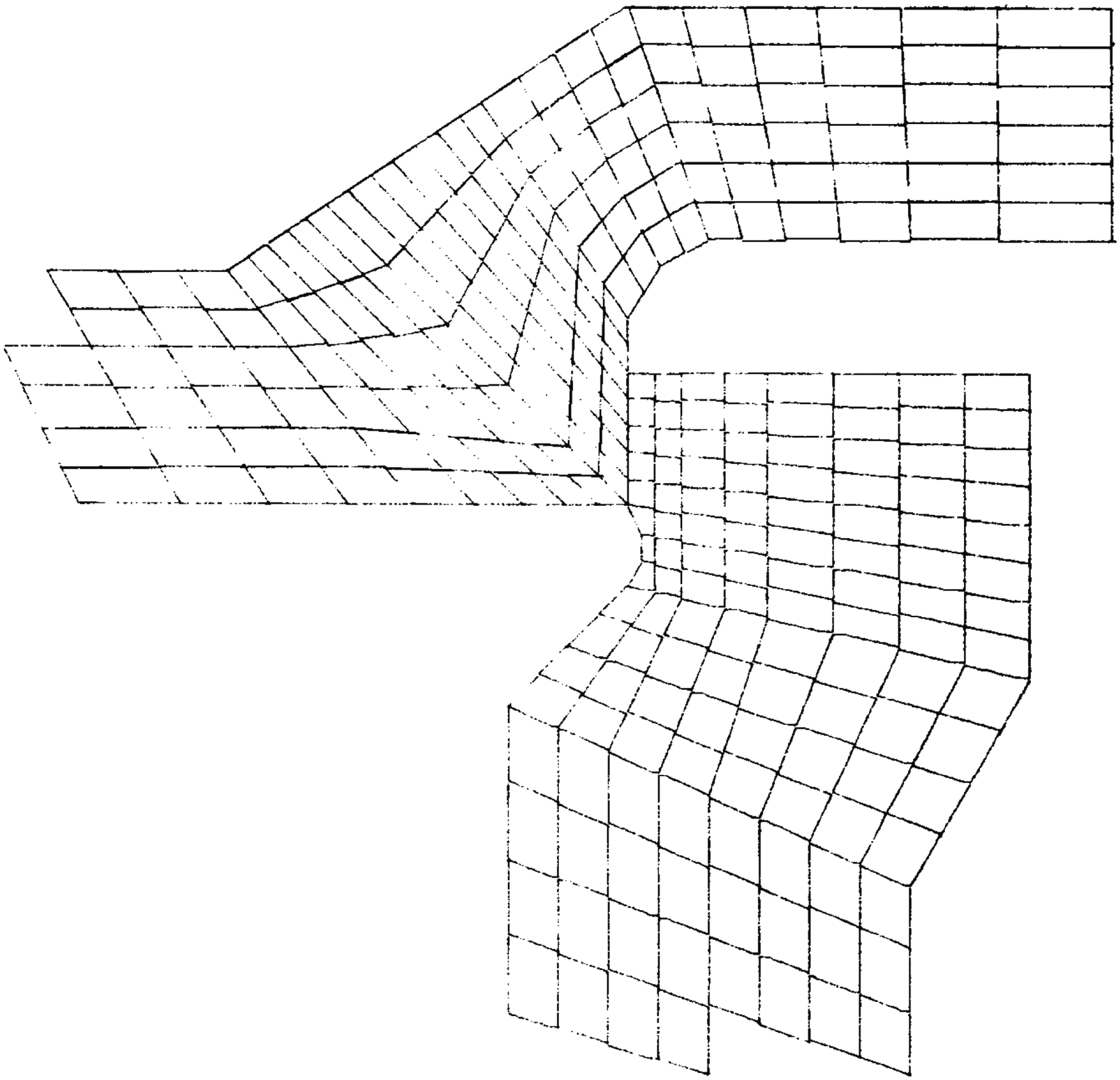
FIRST PISCES MODEL
(BODY SHOWN IN PART)

FIGURE 10A-5



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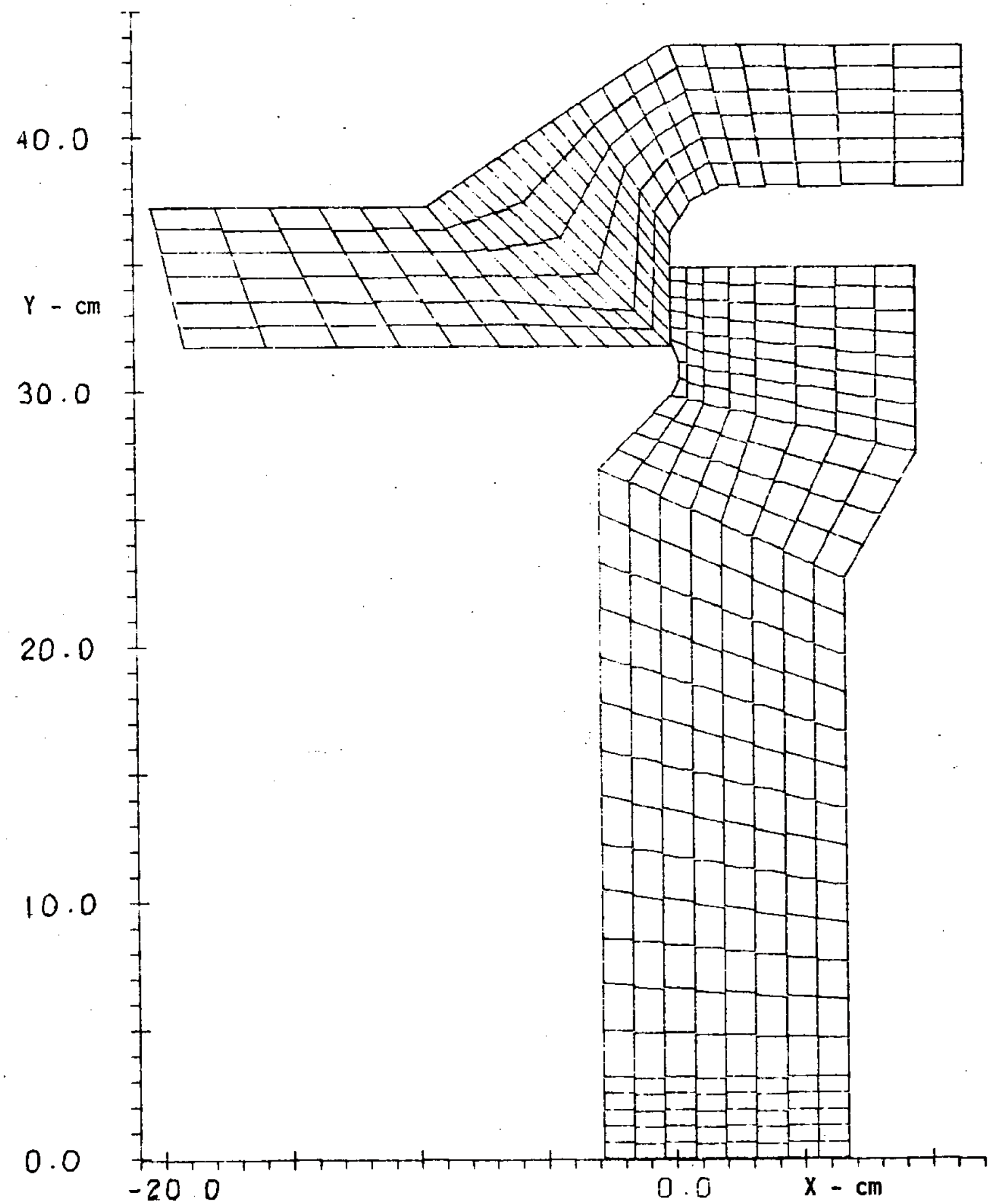
FIRST PISCES MODEL
(CLOSEUP OF CONTACT REGION)

FIGURE 10A-6



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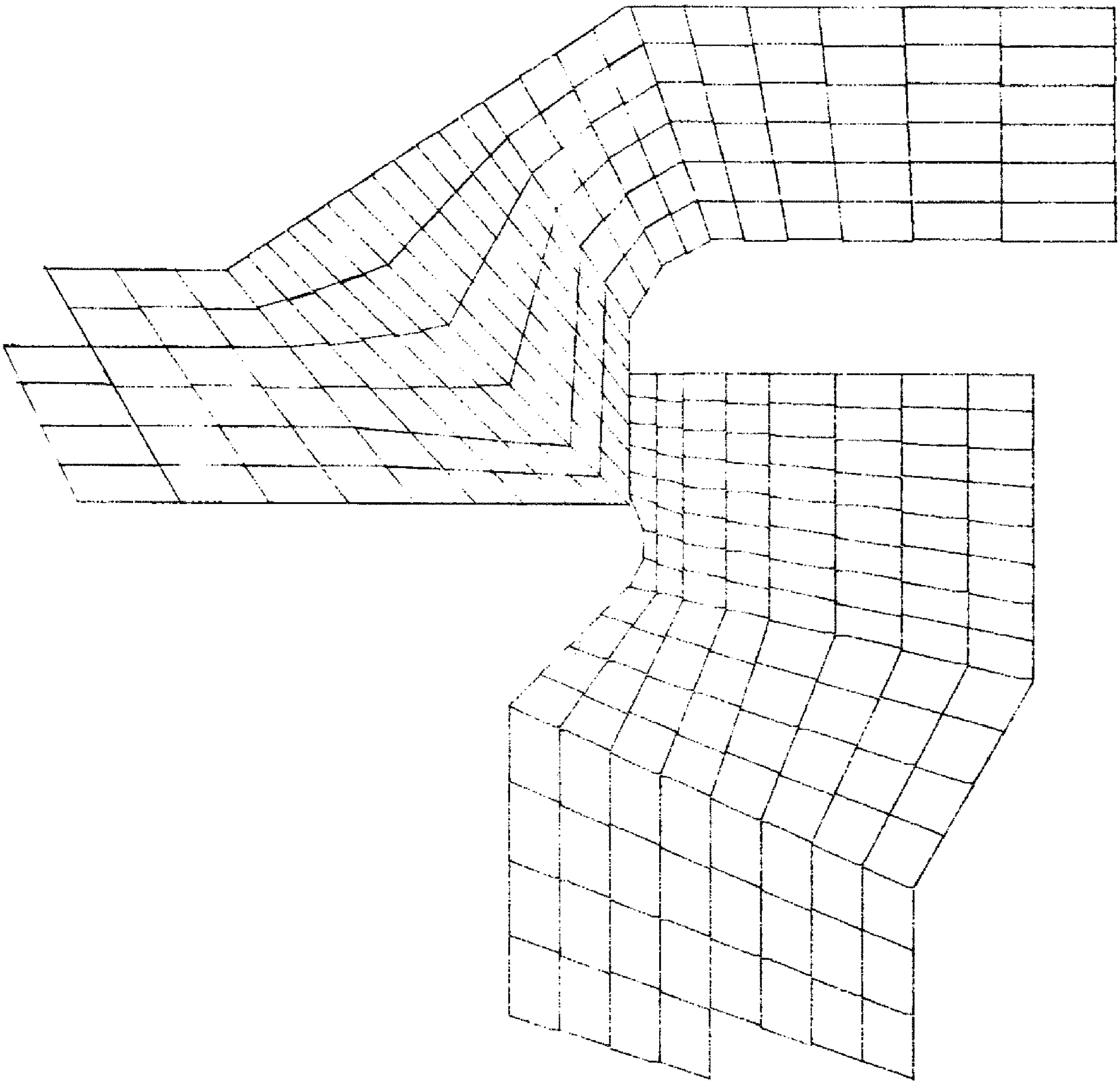
SECOND PISCES MODEL
(BODY SHOWN IN PART)

FIGURE 10A-7



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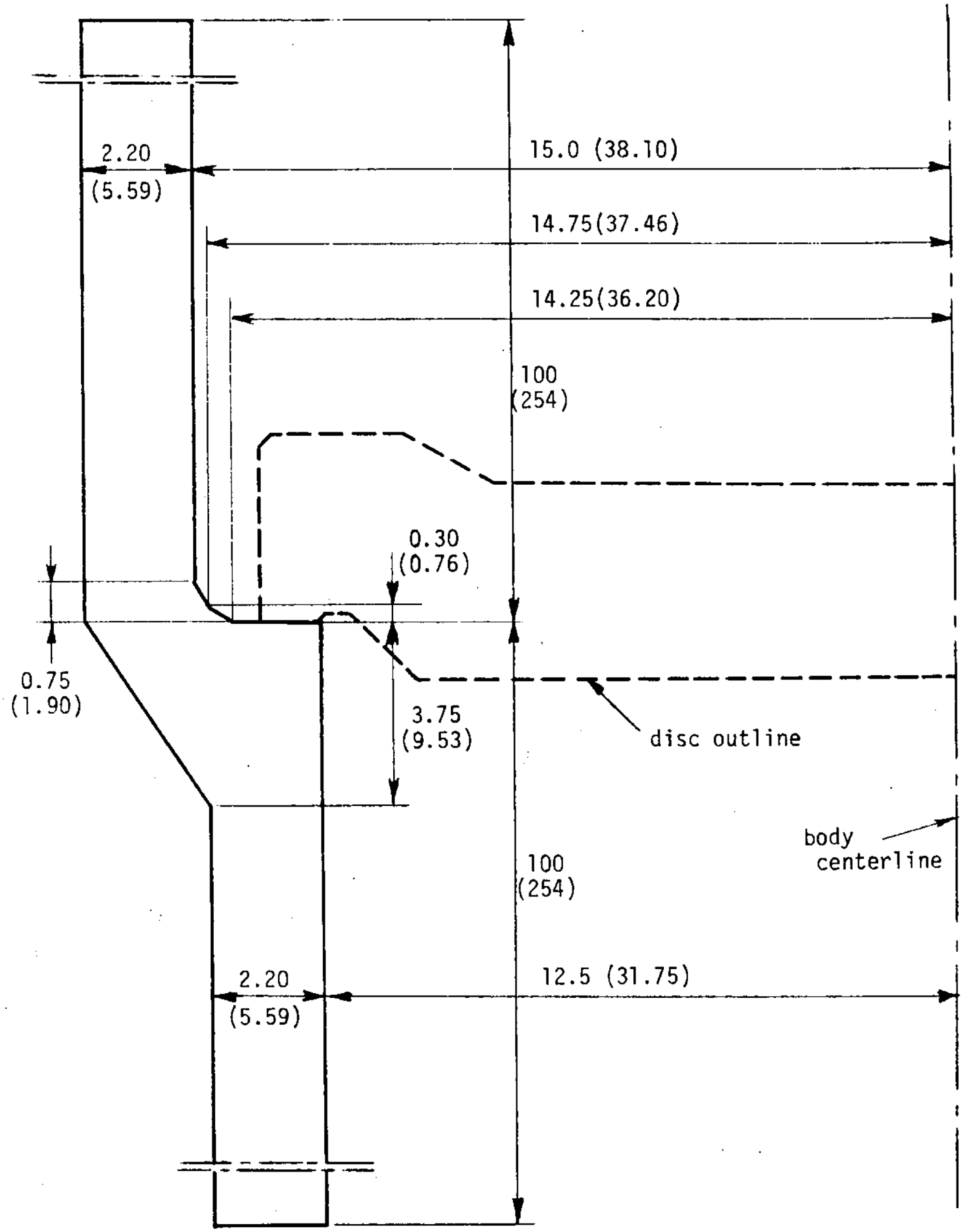
UNIT 1 AND UNIT 2

SECOND PISCES MODEL
(CLOSEUP OF CONTACT REGION)

FIGURE 10A-8



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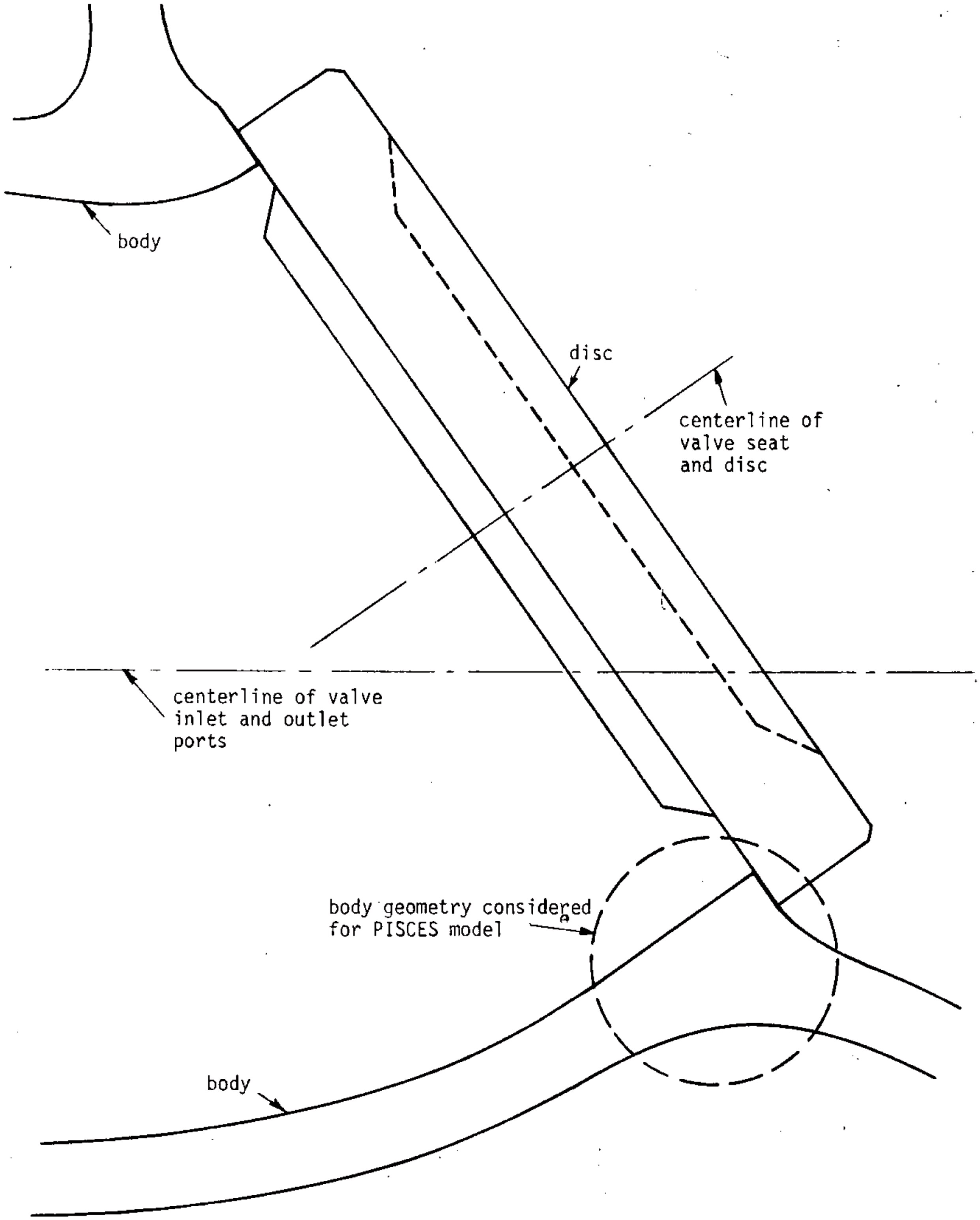
BODY DIMENSIONS ASSUMED FOR PISCES MODEL (IN INCHES AND IN CENTIMETERS)

FIGURE 10A-9



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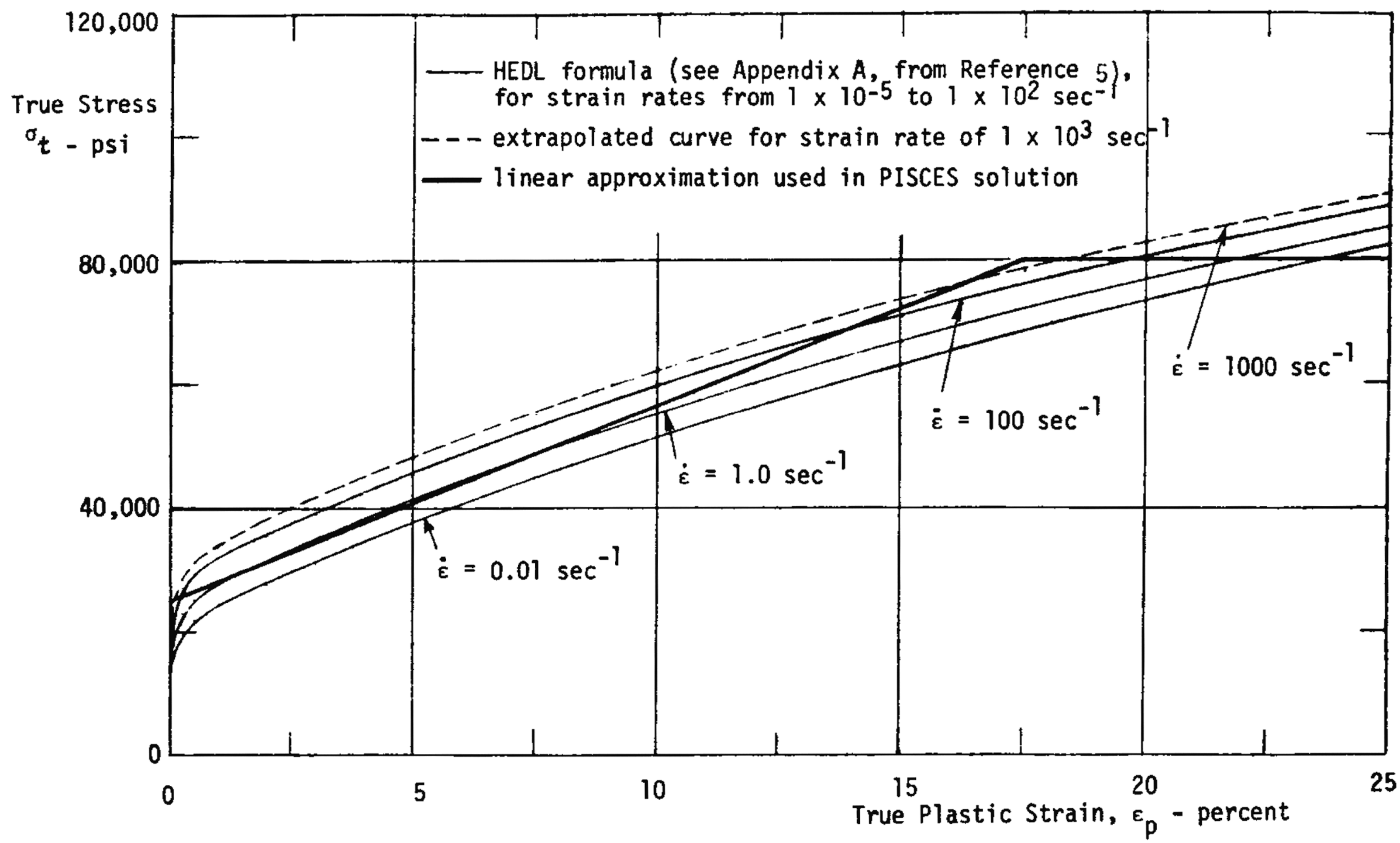
UNIT 1 AND UNIT 2

VALVE SEAT REGION OF
ISOLATION VALVE

FIGURE 10A-10



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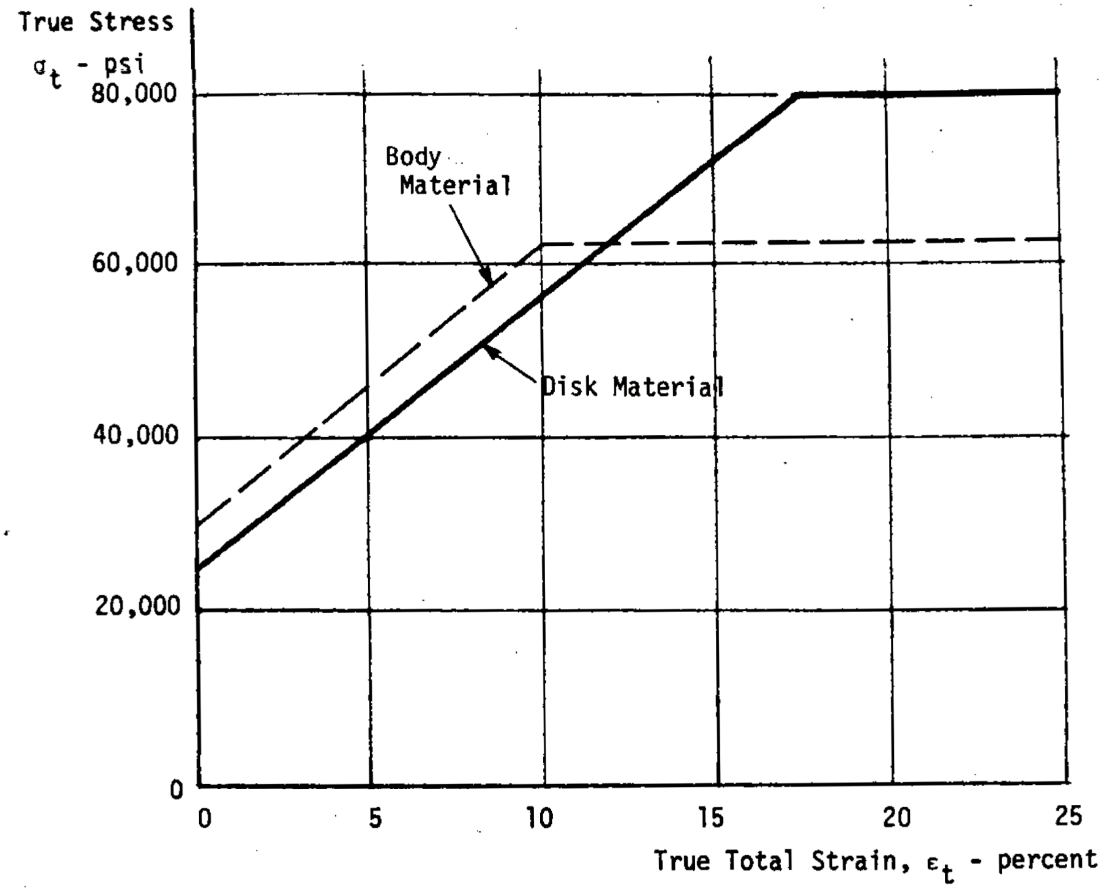
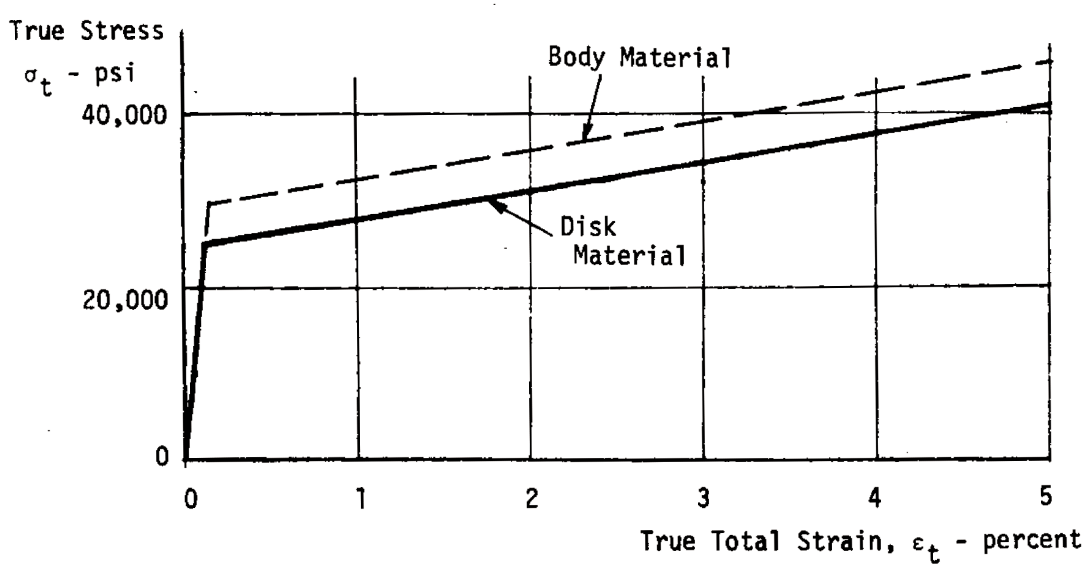
TYPICAL STRESS – TRUE STRAIN DIAGRAMS FOR AISI 304 STAINLESS STEEL

FIGURE 10A-11





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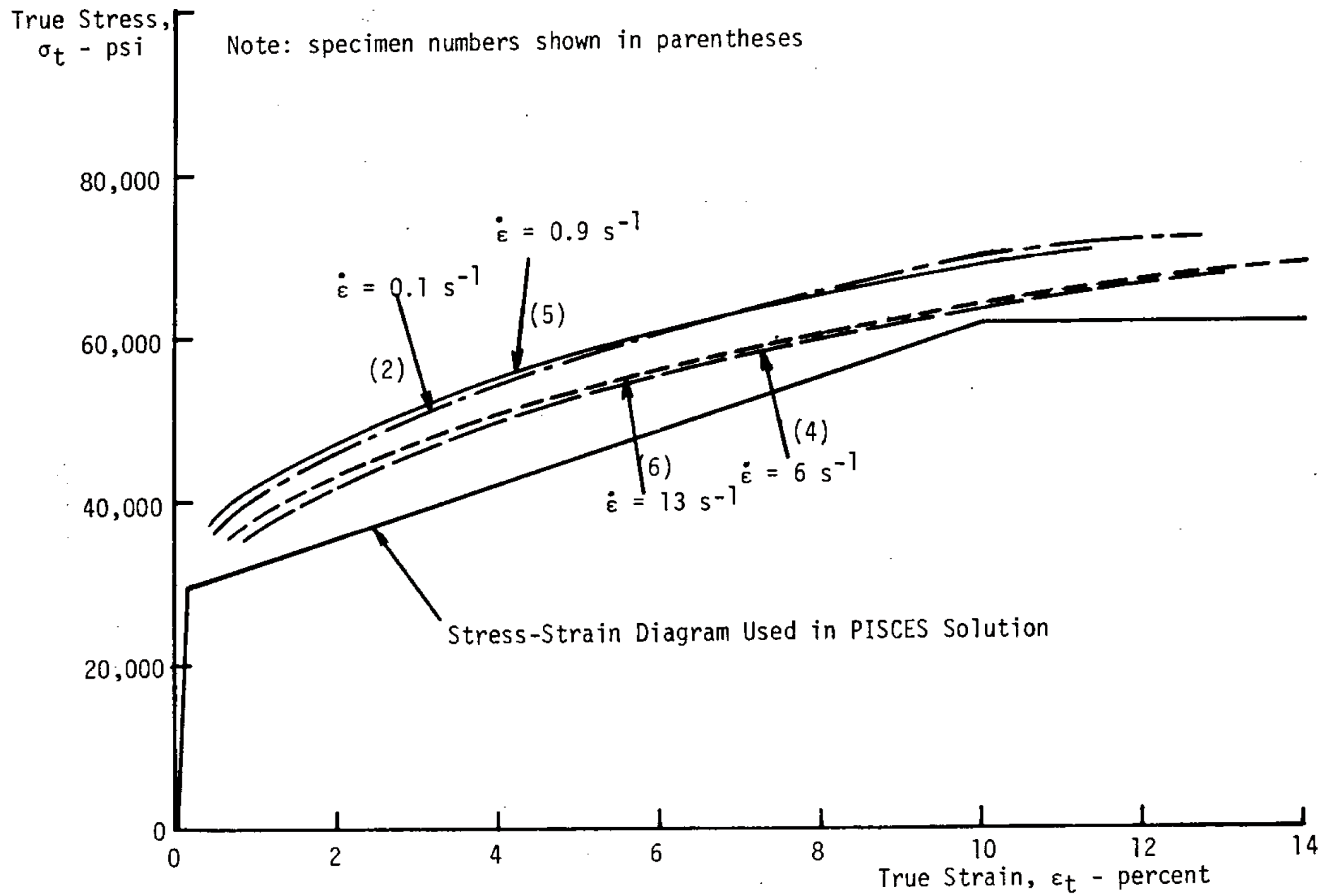
STRESS-STRAIN DIAGRAMS USED
IN PISCES SOLUTION

FIGURE 10A-12



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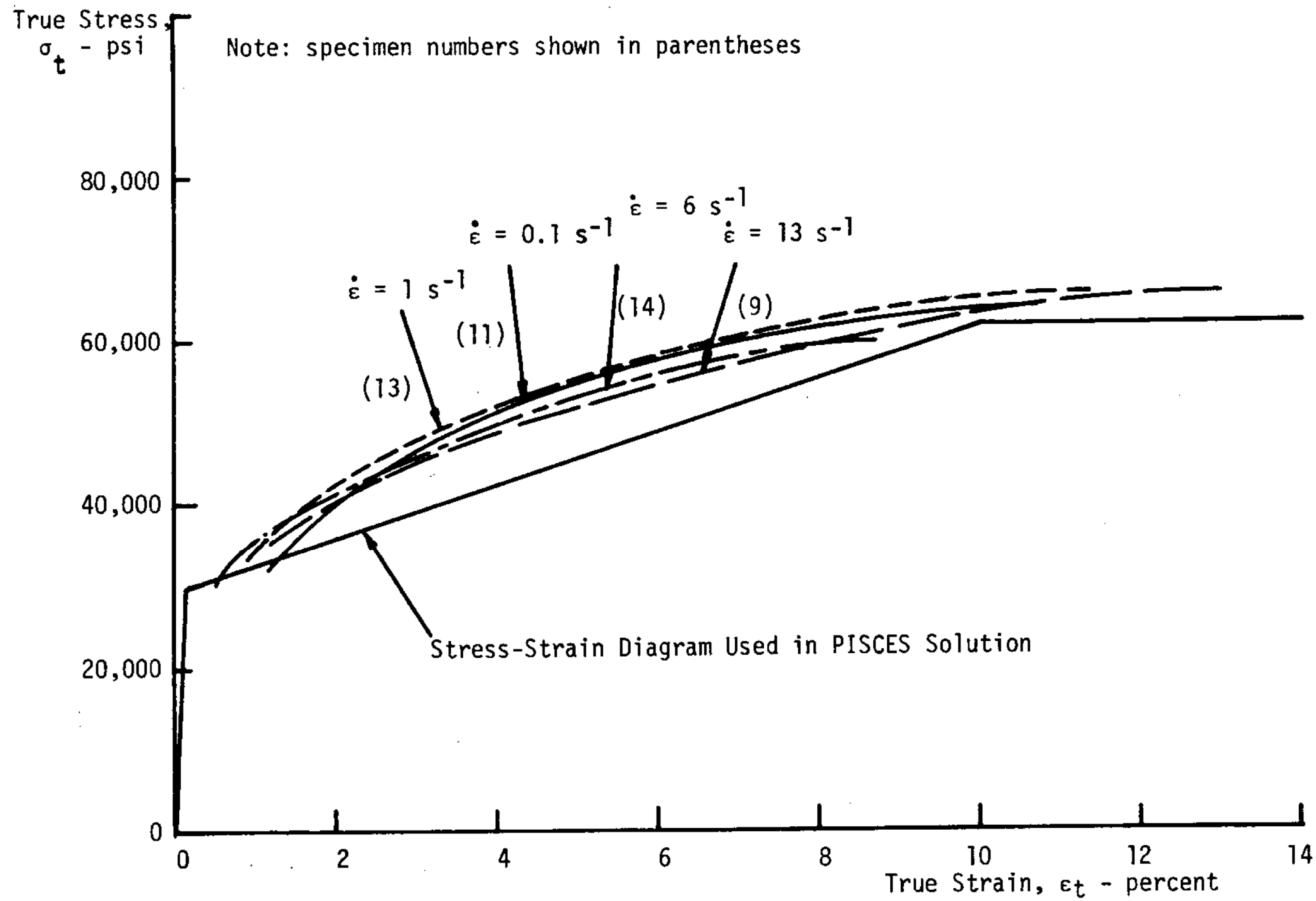
JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2

TYPICAL STRESS-STRAIN DIAGRAMS FOR A-216 GRADE WCB STEEL (X-DIRECTION, SEE TABLE 10A-2)

FIGURE 10A-13



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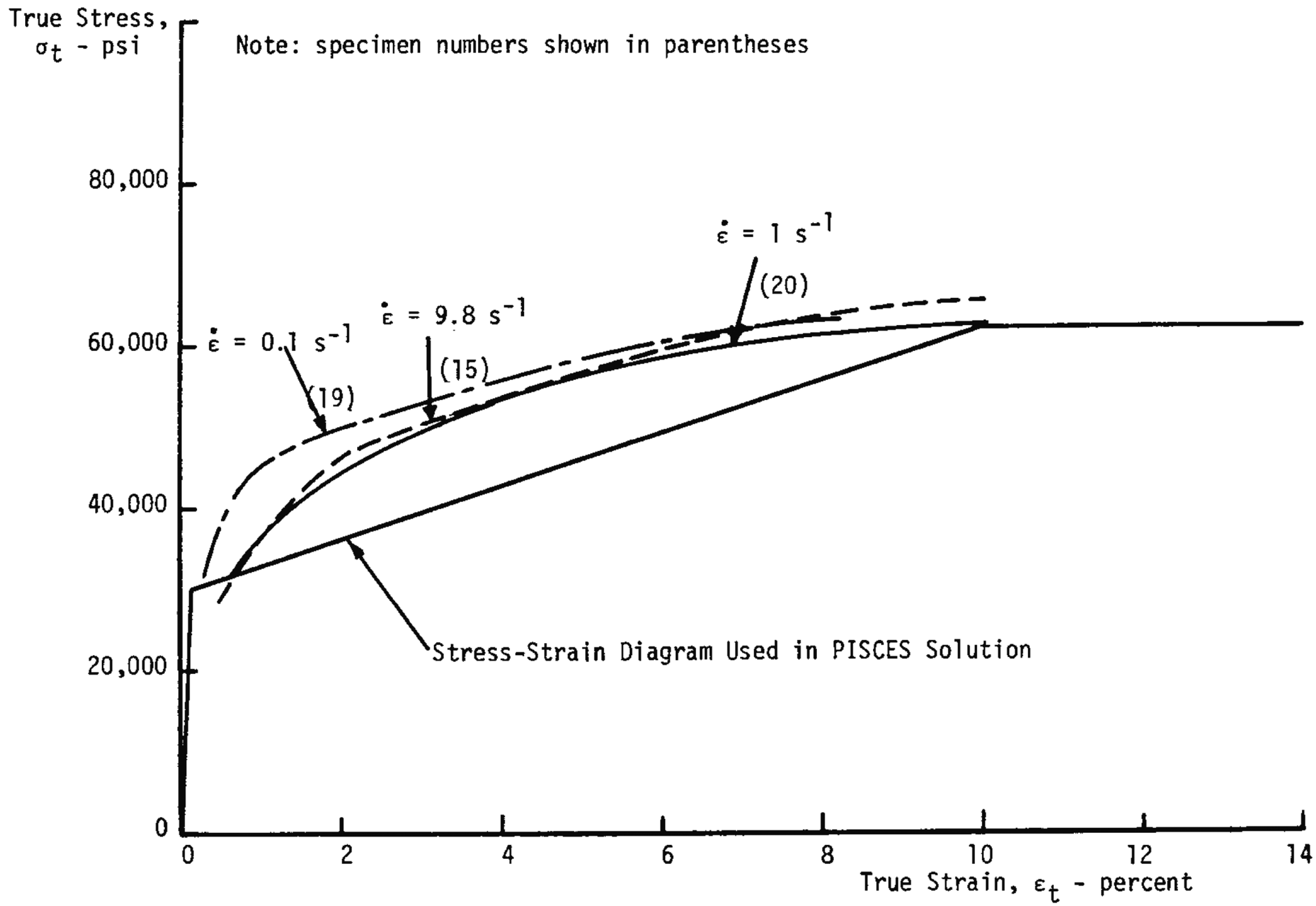
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	TYPICAL STRESS-STRAIN DIAGRAMS FOR A-216 GRADE WCB STEEL (Y-DIRECTION, SEE TABLE 10A-2)
		FIGURE 10A-14



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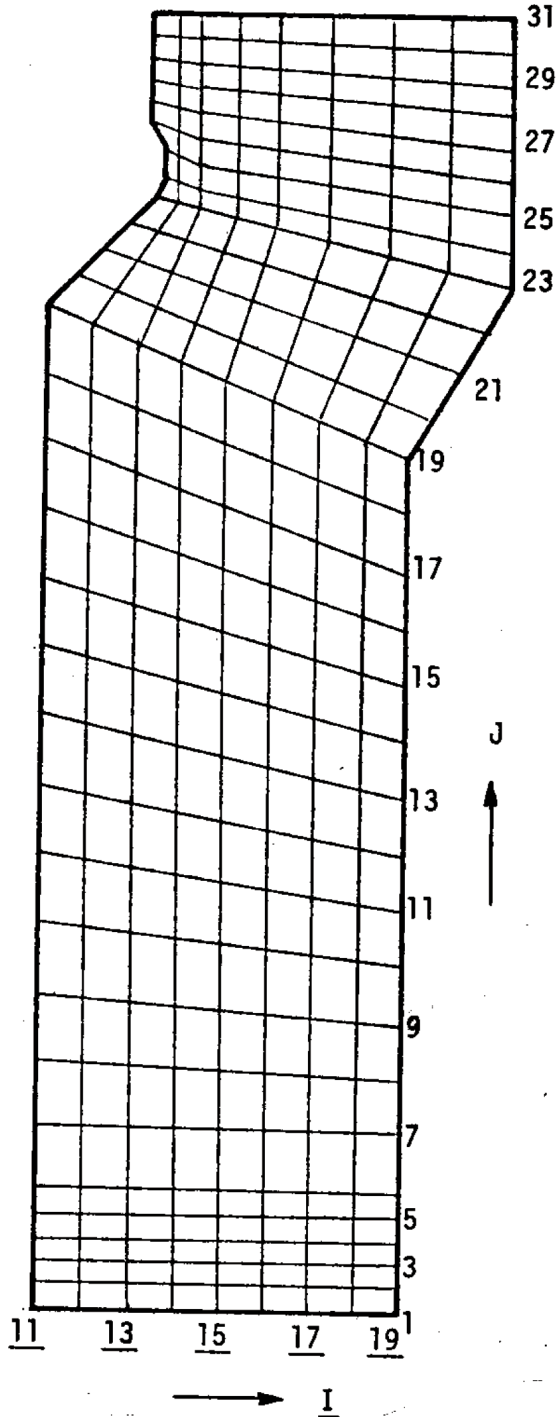
UNIT 1 AND UNIT 2

TYPICAL STRESS-STRAIN DIAGRAMS FOR
A-216 GRADE WCB STEEL
(Z-DIRECTION, SEE TABLE 10A-2)

FIGURE 10A-15

I = Column Number
J = Row Number



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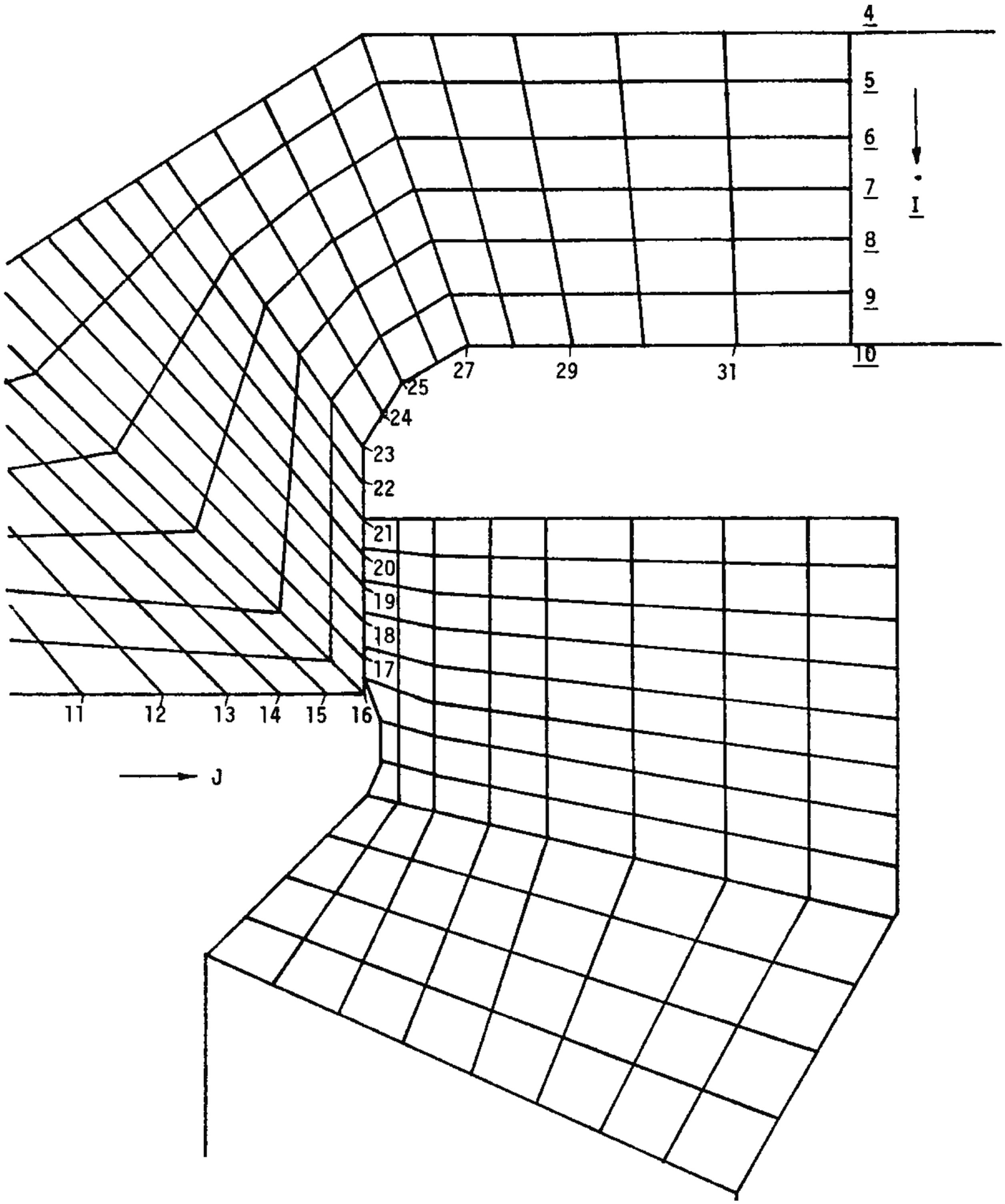
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

COLUMN AND ROW NUMBERS
OF DISC REGION

FIGURE 10A-16



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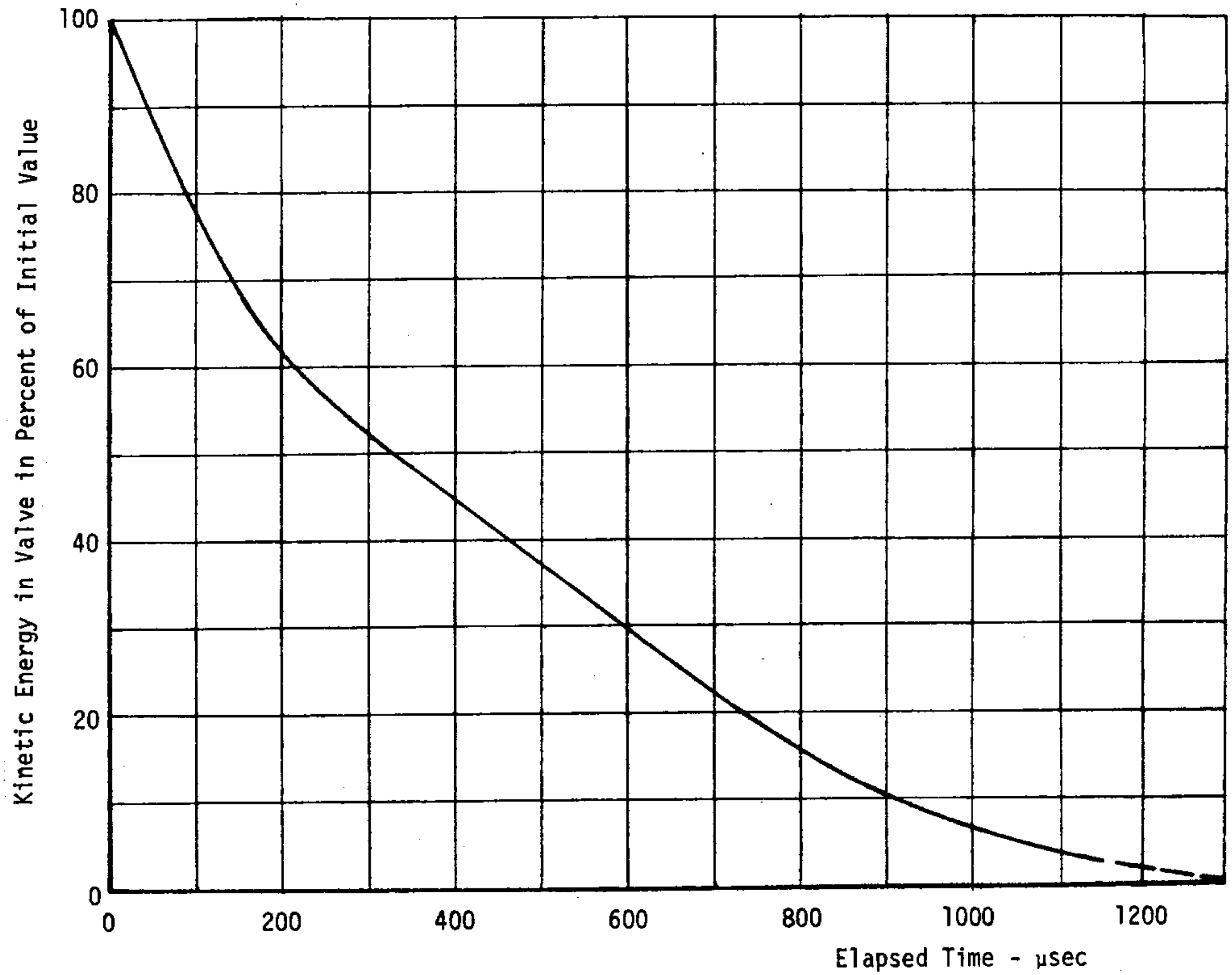
UNIT 1 AND UNIT 2

COLUMN AND ROW NUMBERS
OF BODY REGION

FIGURE 10A-17



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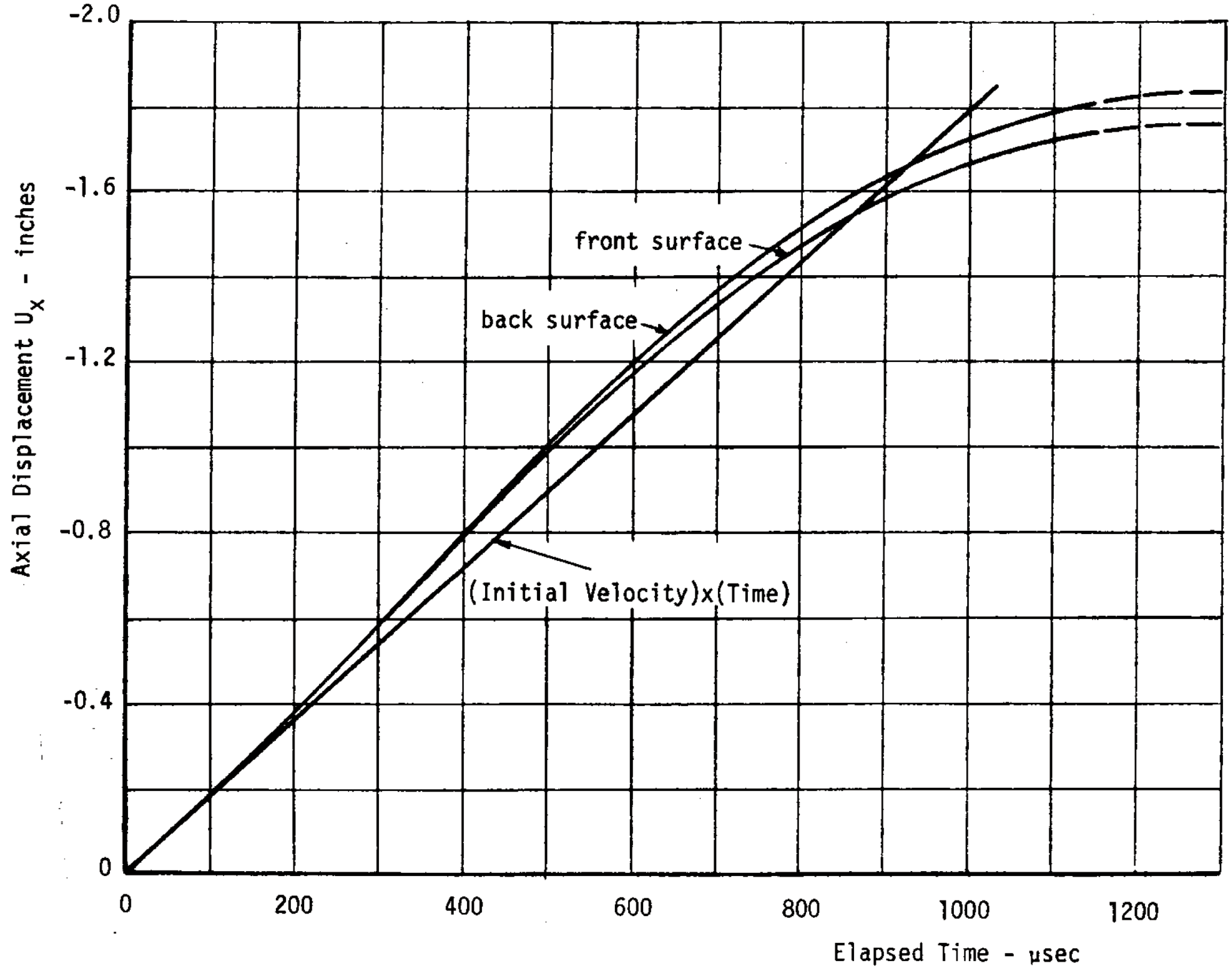
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

KINETIC ENERGY IN VALVE
VERSUS TIME SINCE IMPACT

FIGURE 10A-18



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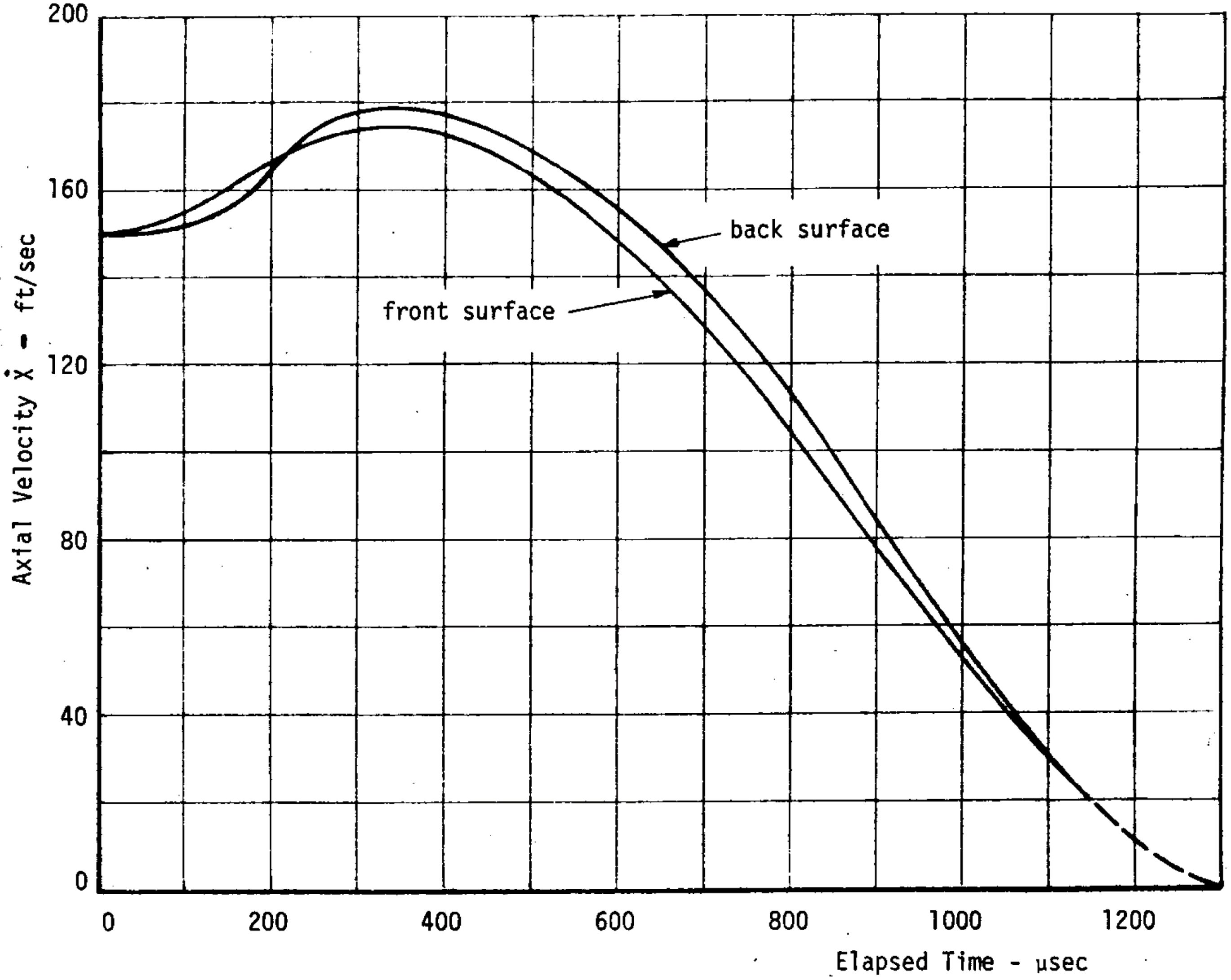
NUCLEAR PLANT
UNIT 1 AND UNIT 2

AXIAL DISPLACEMENTS AT
CENTERLINE OF DISC VERSUS TIME
SINCE IMPACT

FIGURE 10A-19



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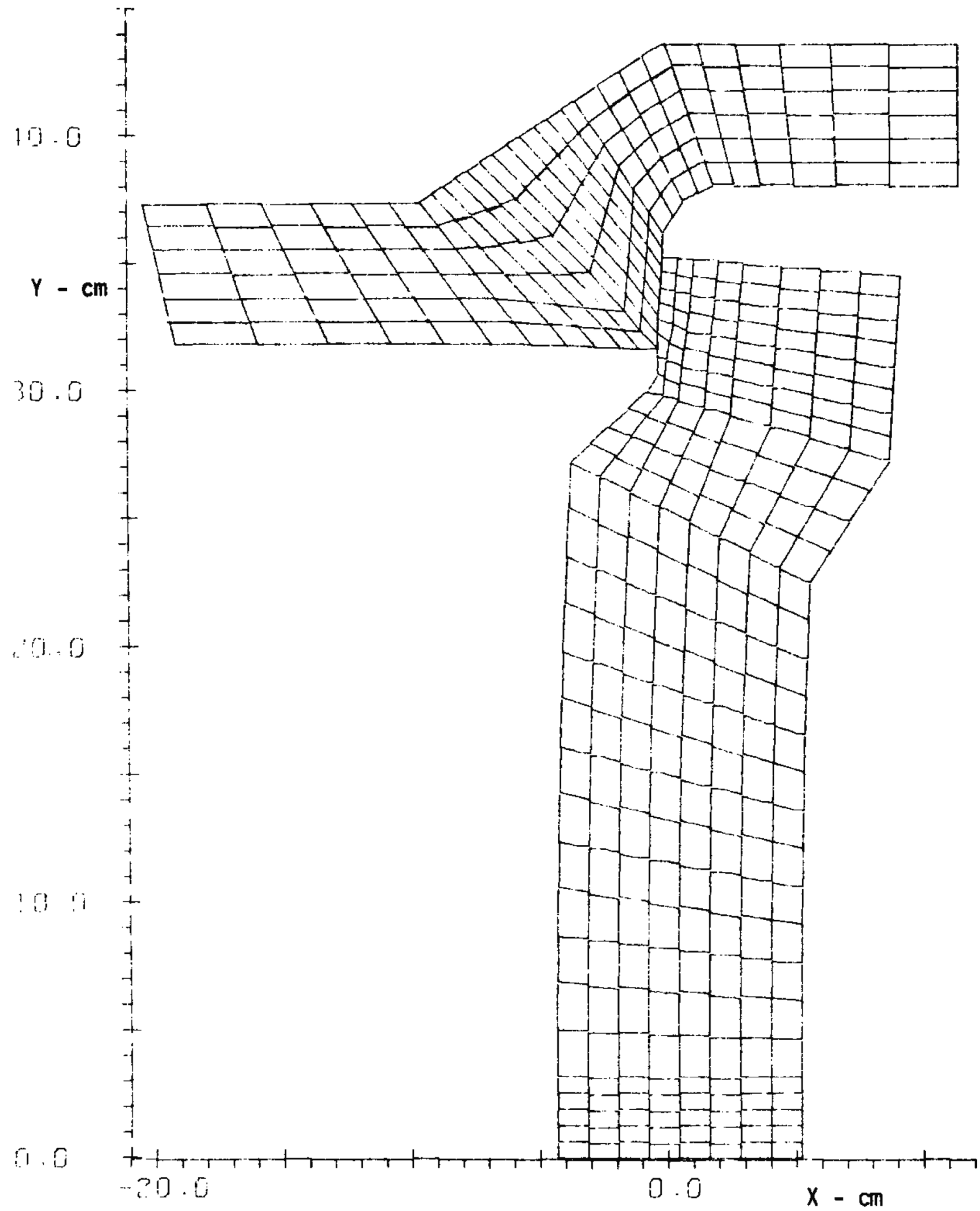
JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2

AXIAL VELOCITY AT CENTERLINE OF DISC VERSUS TIME SINCE IMPACT

FIGURE 10A-20



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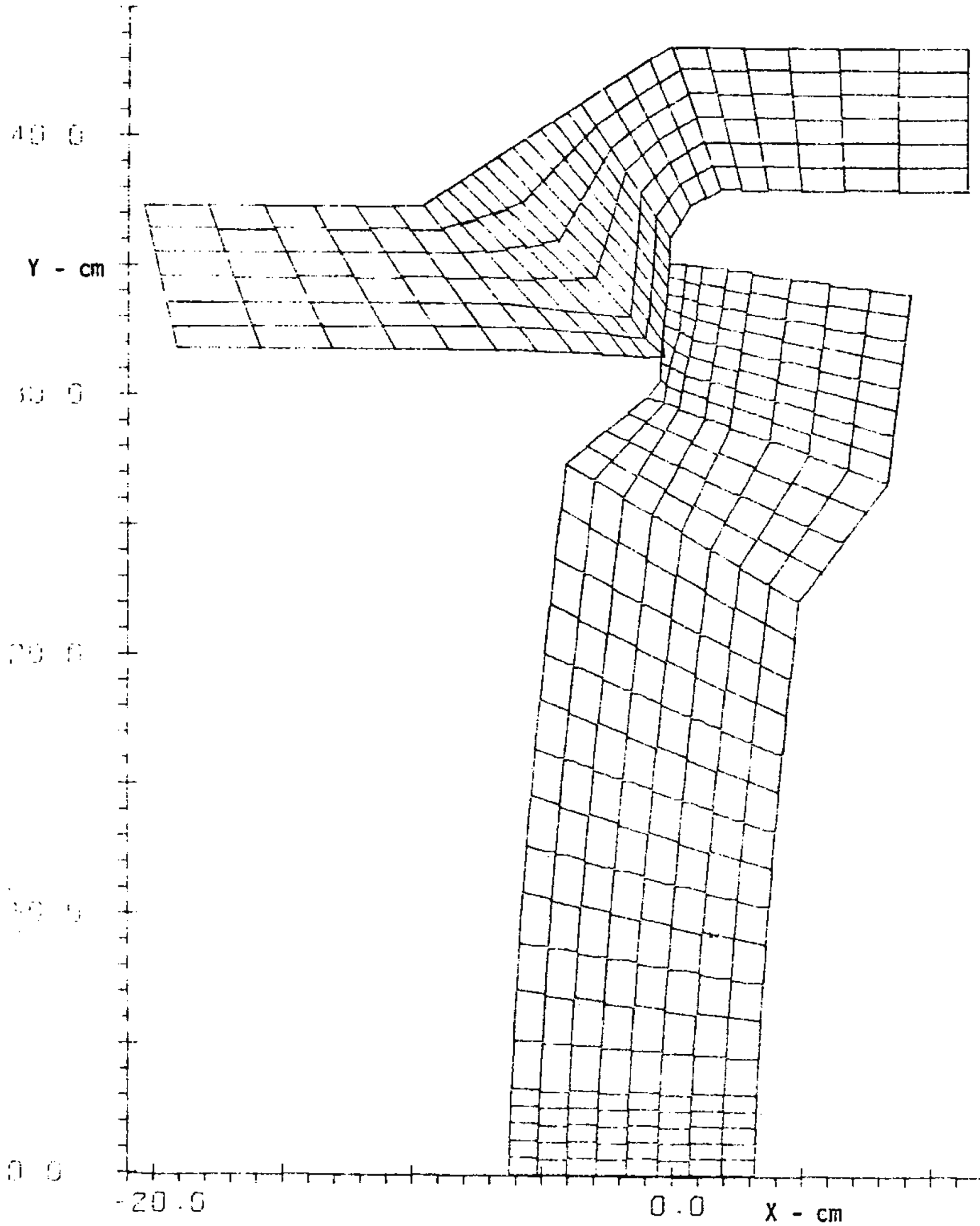
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTORTED GEOMETRY AT TIME
t = 300 μS

FIGURE 10A-21



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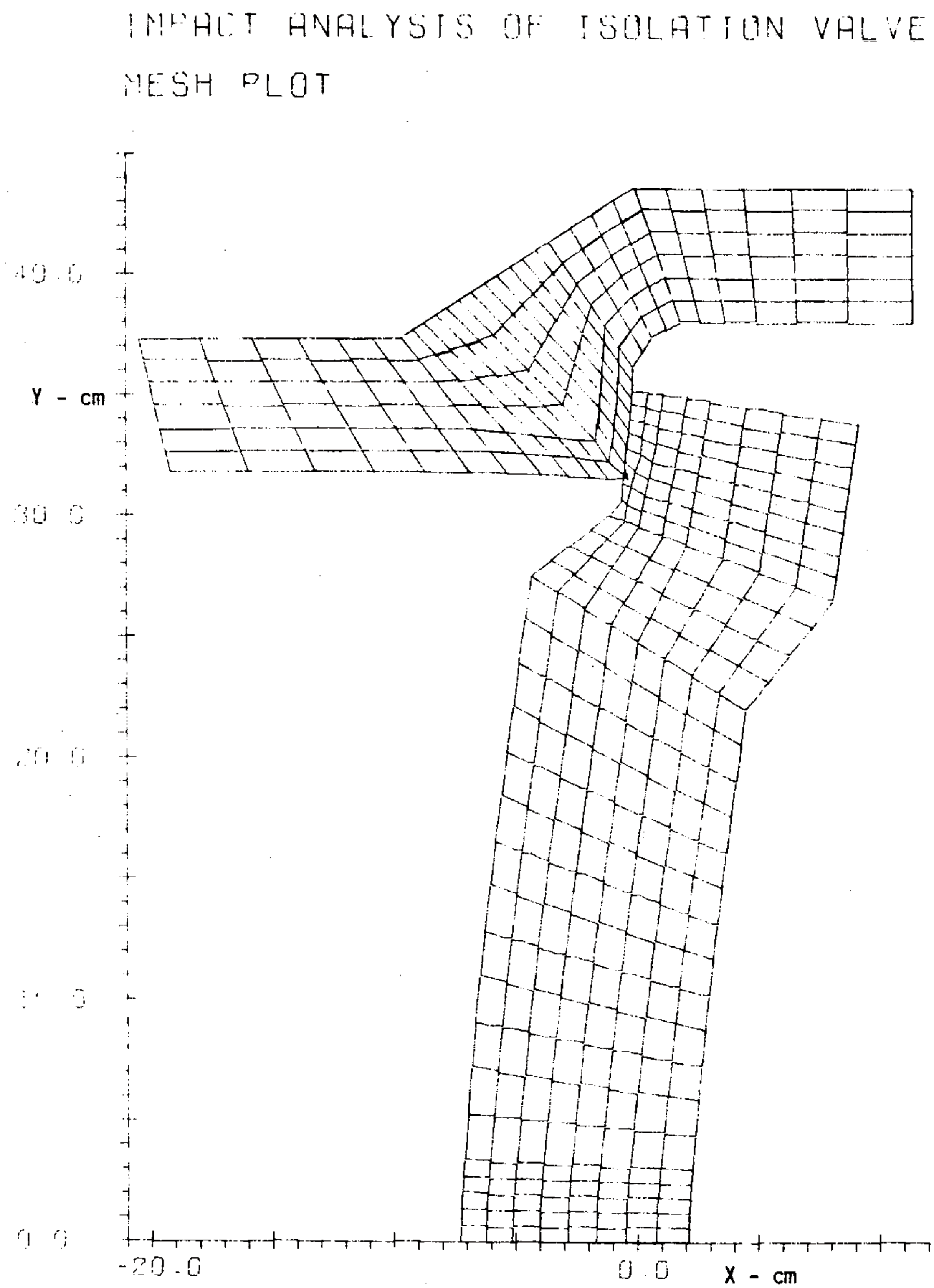
JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2

DISTORTED GEOMETRY AT TIME
t = 700 µS

FIGURE 10A-22



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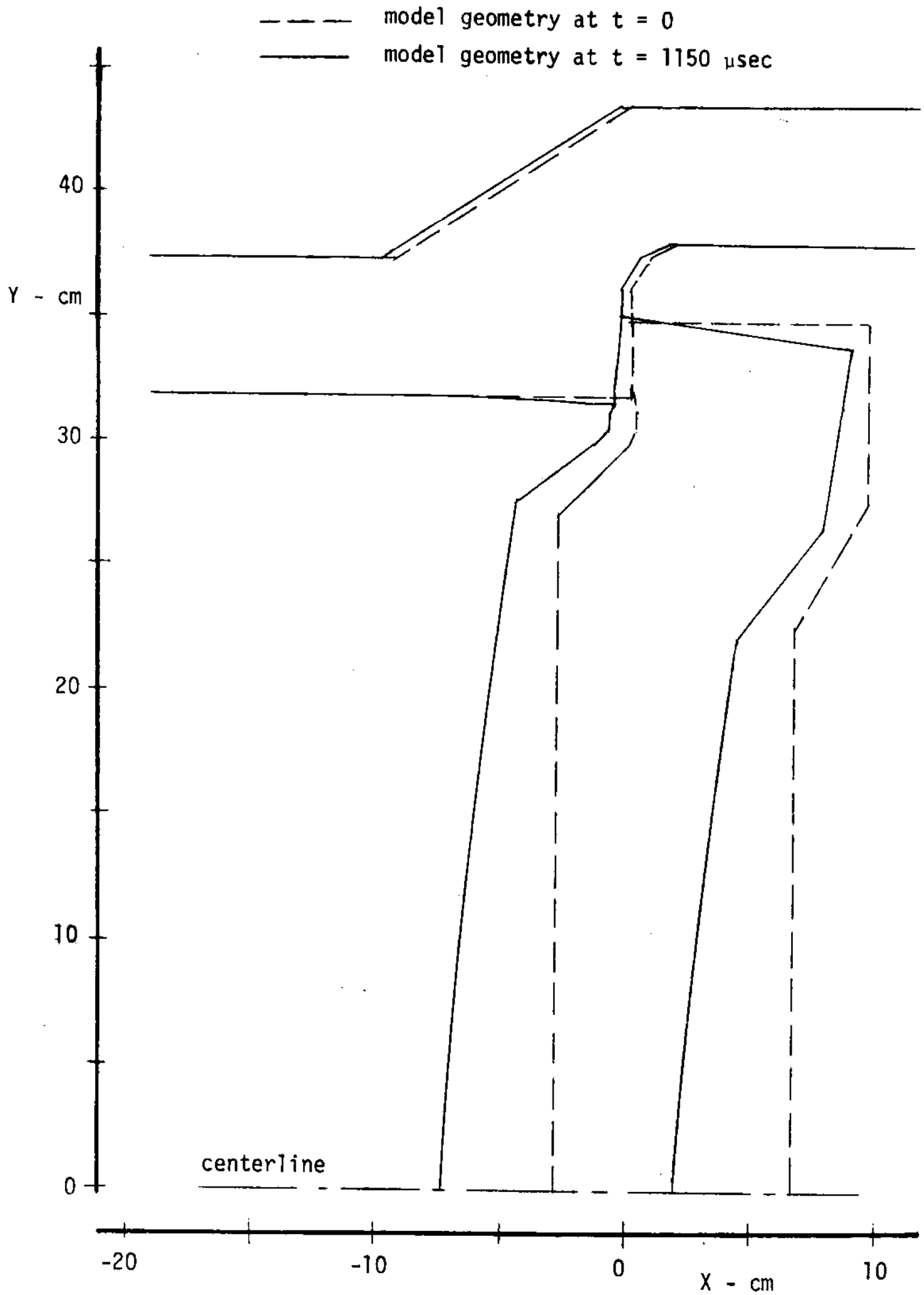
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTORTED GEOMETRY AT TIME
t = 1150 μS

FIGURE 10A-23



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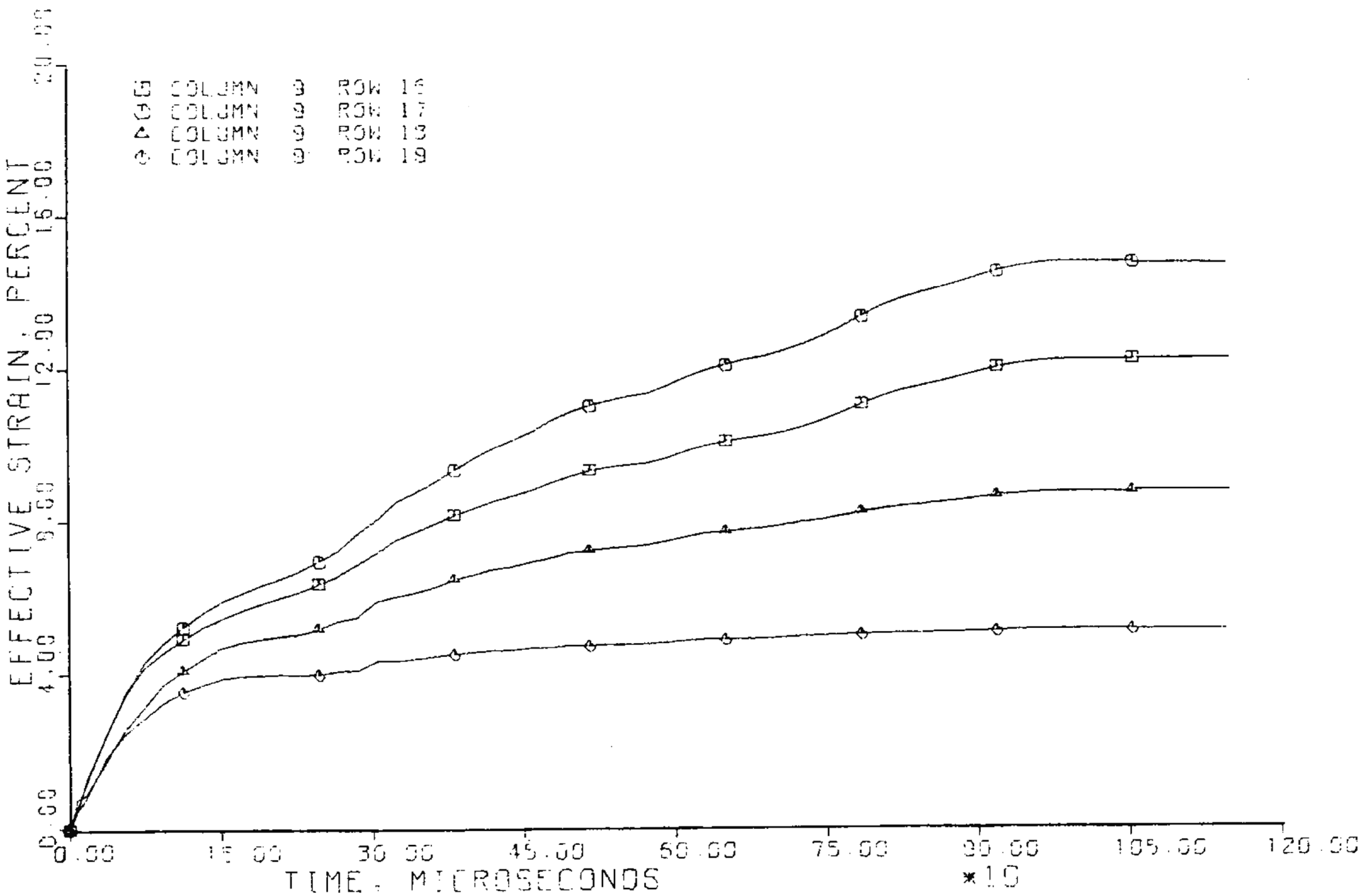
SHAPE OF MODEL BEFORE
AND AFTER IMPACT

FIGURE 10A-24



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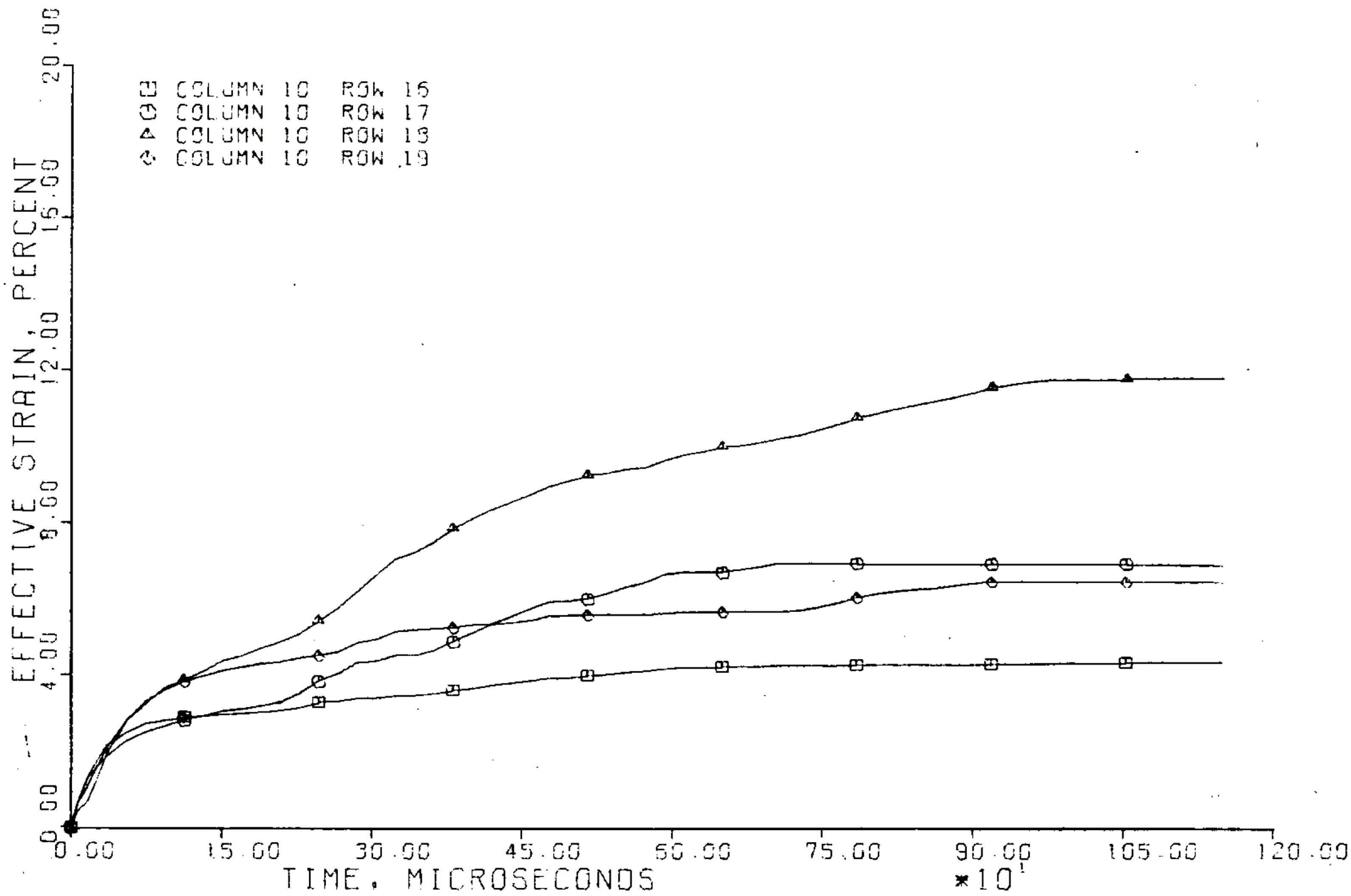
**JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2**

EFFECTIVE STRAINS IN BODY VERSUS TIME SINCE IMPACT

FIGURE 10A-25



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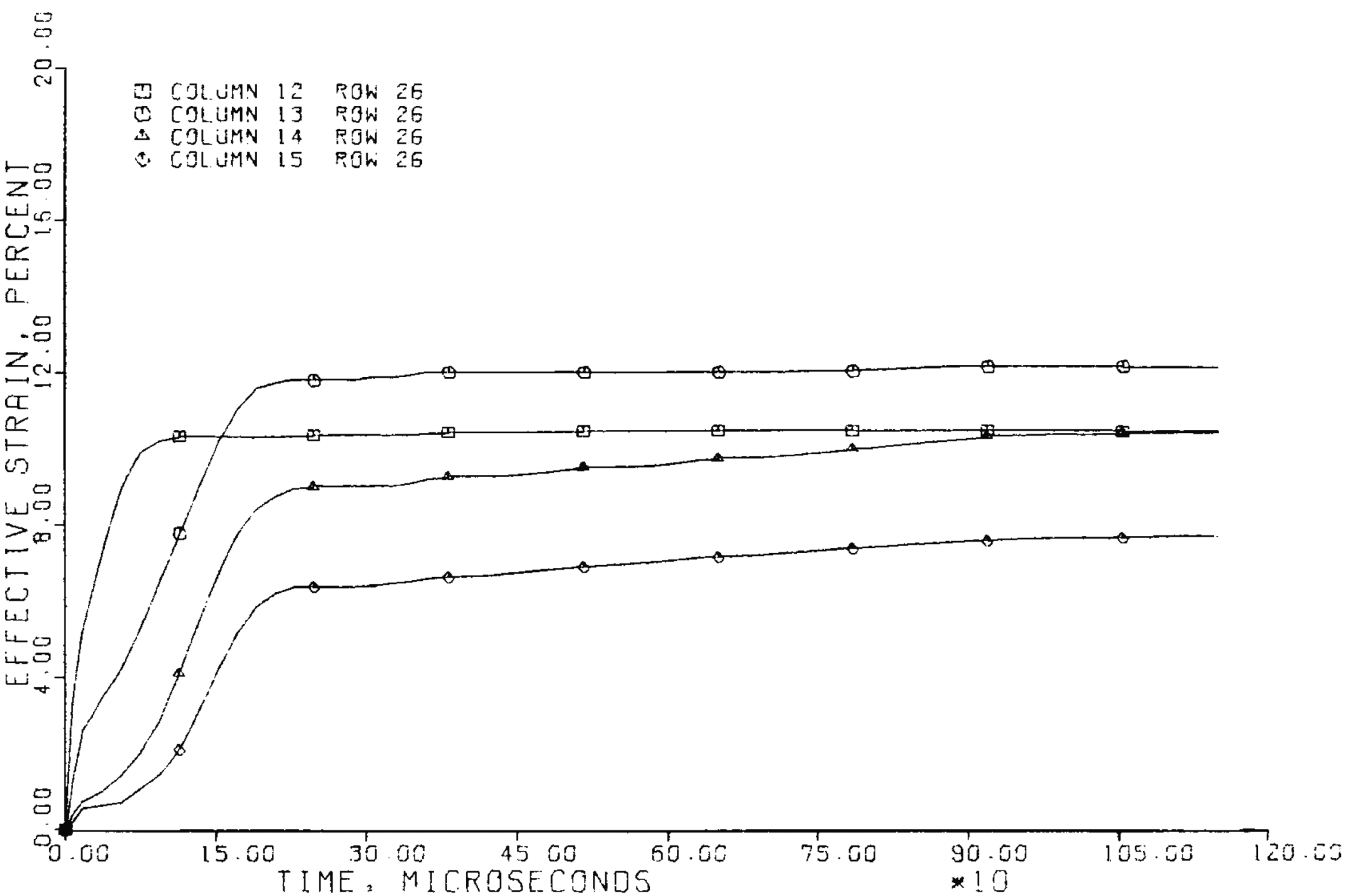
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECTIVE STRAINS IN BODY VERSUS TIME SINCE IMPACT

FIGURE 10A-26



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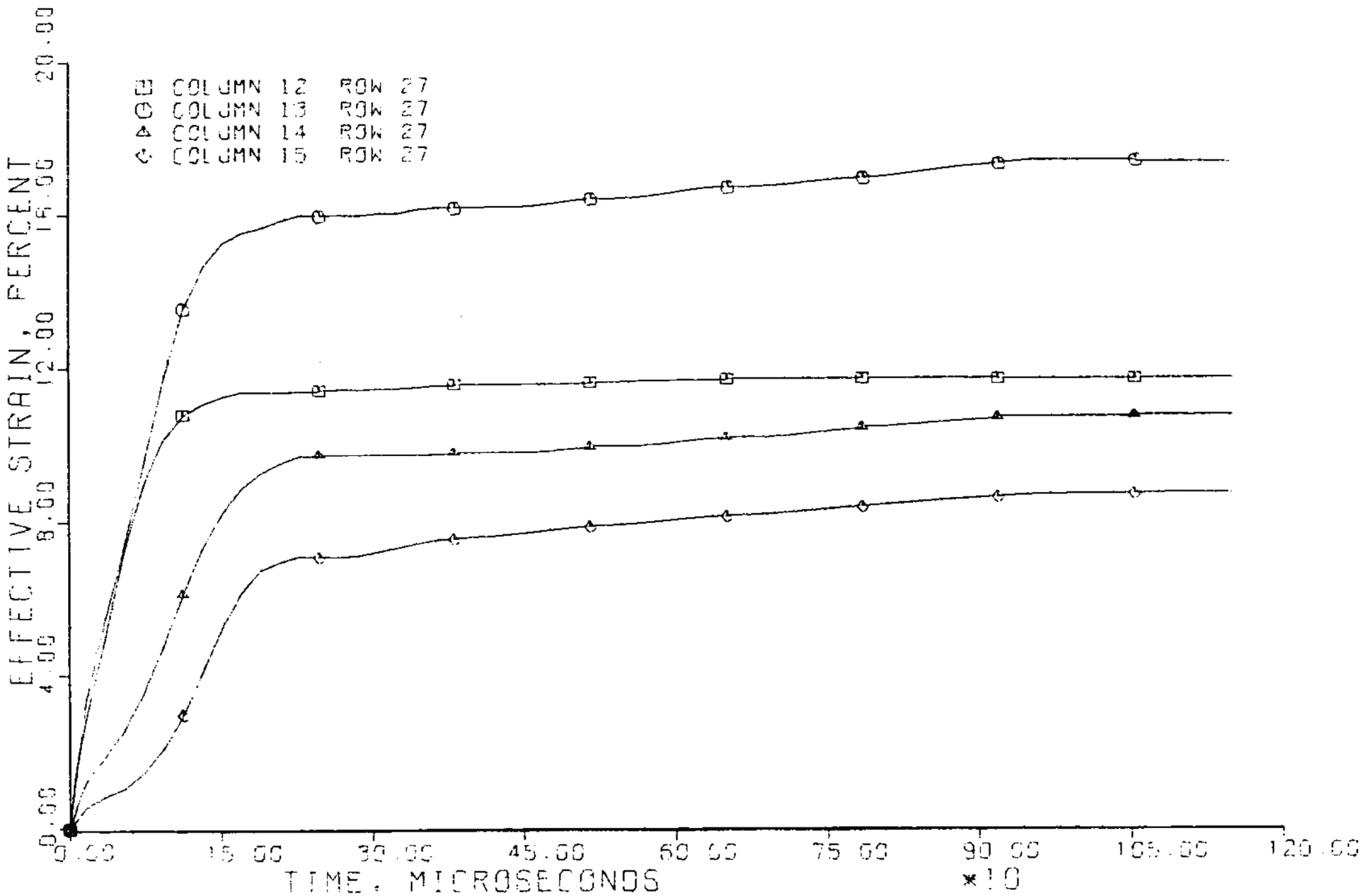
SOUTHERN COMPANY *Energy to Serve Your World®*	**JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2**	EFFECTIVE STRAINS IN DISC VERSUS TIME SINCE IMPACT
		FIGURE 10A-27



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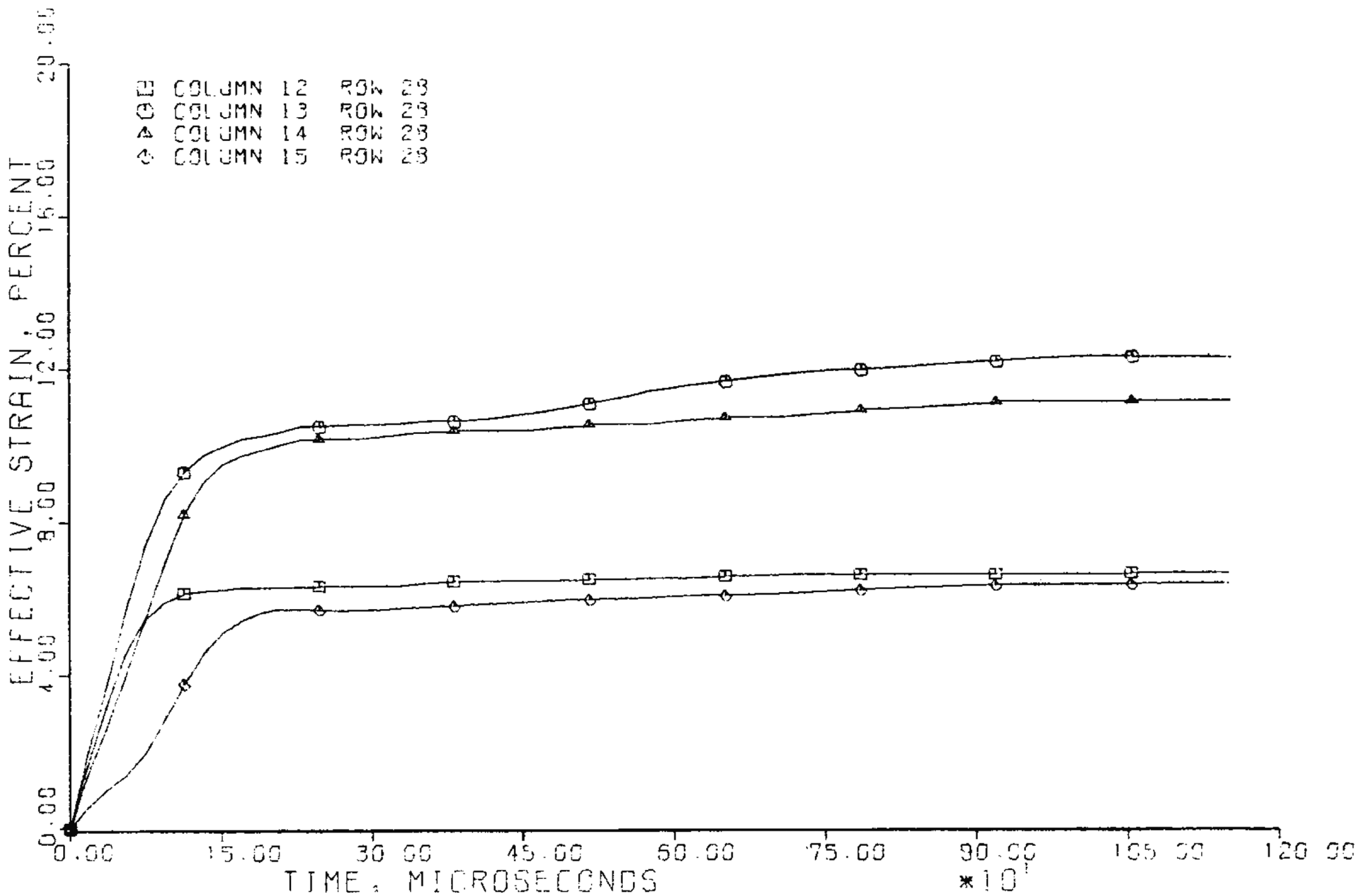
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECTIVE STRAINS IN DISC VERSUS TIME SINCE IMPACT

FIGURE 10A-28



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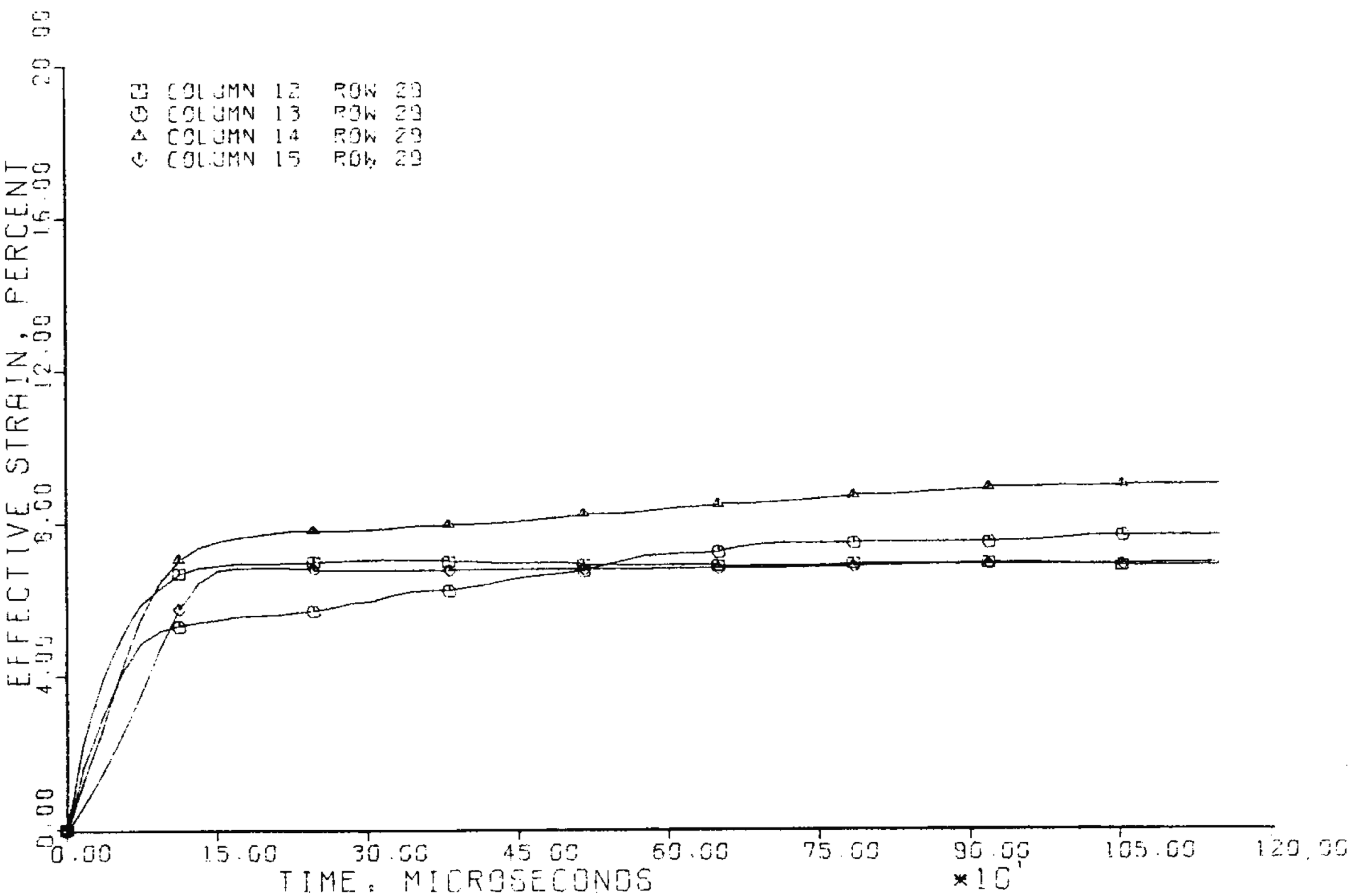
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECTIVE STRAINS IN DISC VERSUS TIME SINCE IMPACT

FIGURE 10A-29



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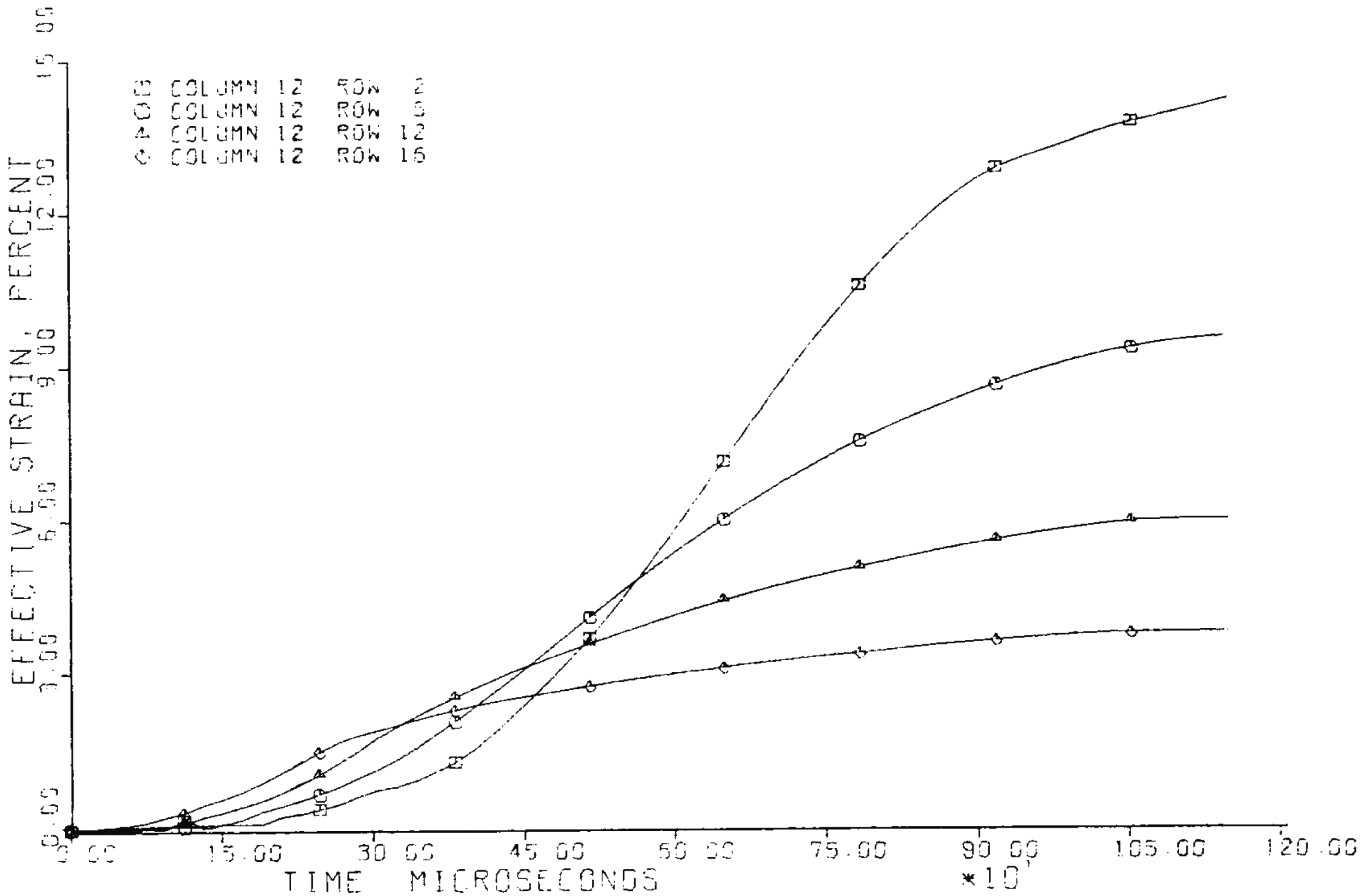
SOUTHERN COMPANY *Energy to Serve Your World®*	**JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2**	EFFECTIVE STRAINS IN DISC VERSUS TIME SINCE IMPACT
		FIGURE 10A-30



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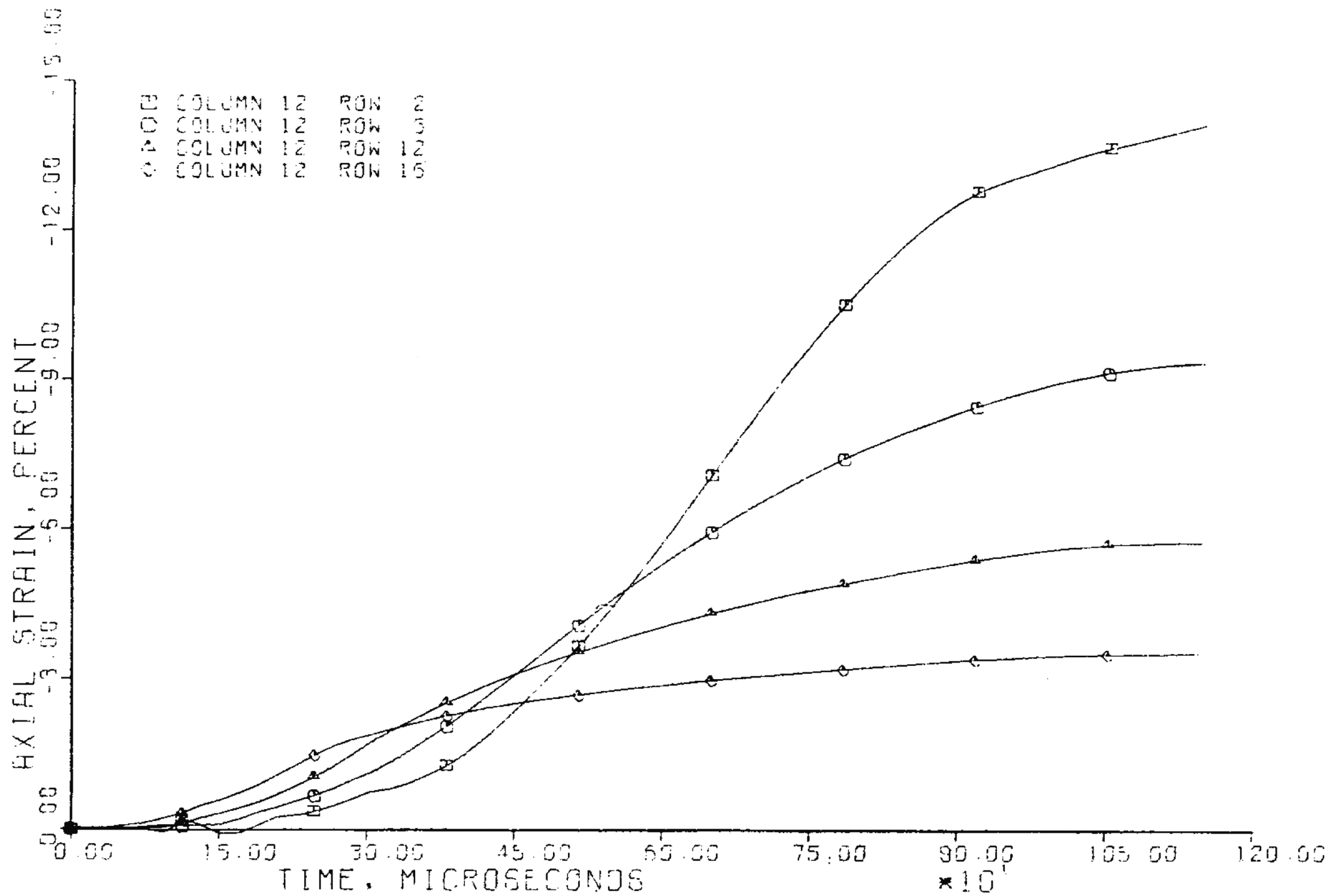
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECTIVE STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-31



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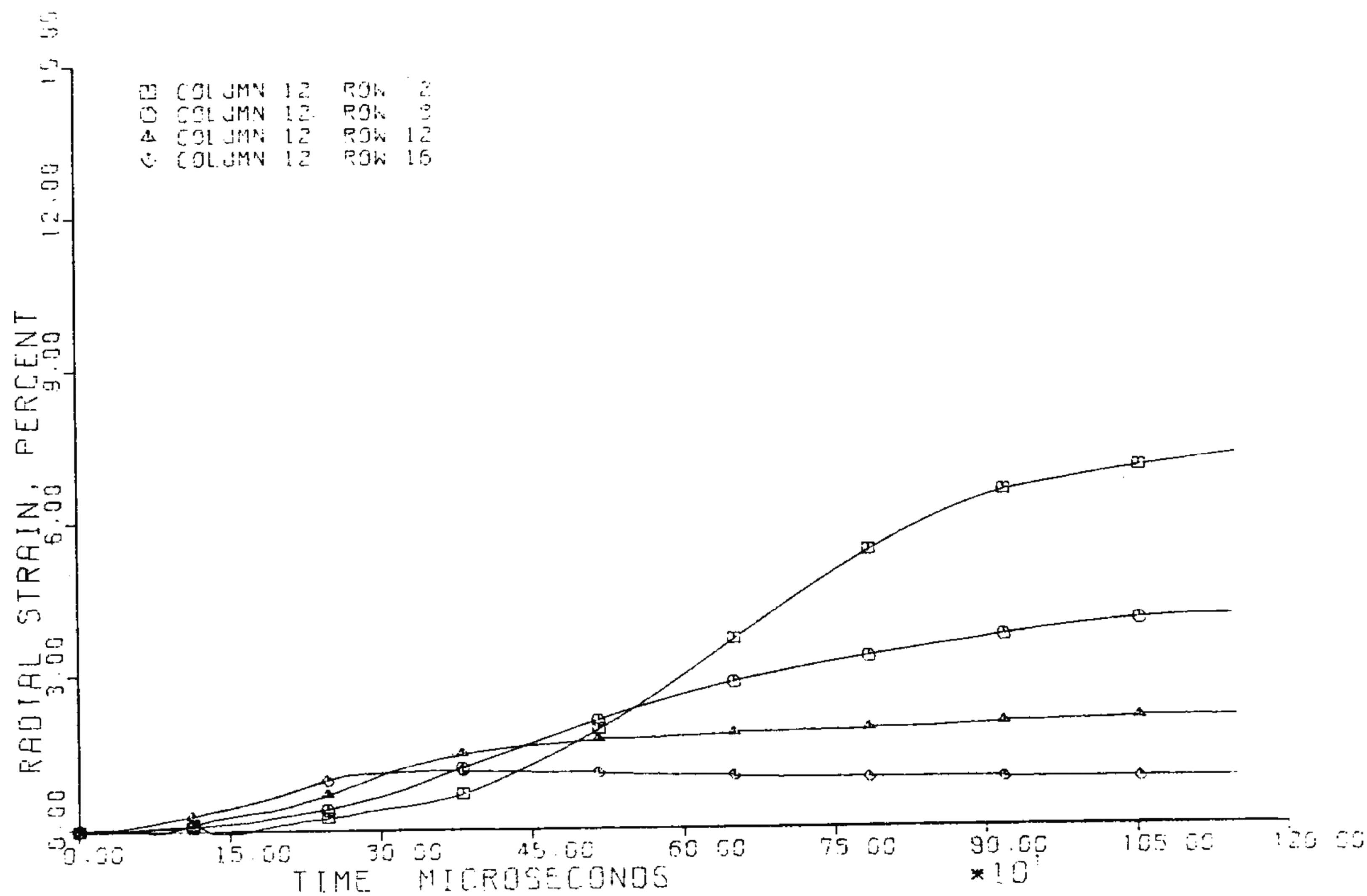
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

AXIAL STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-32



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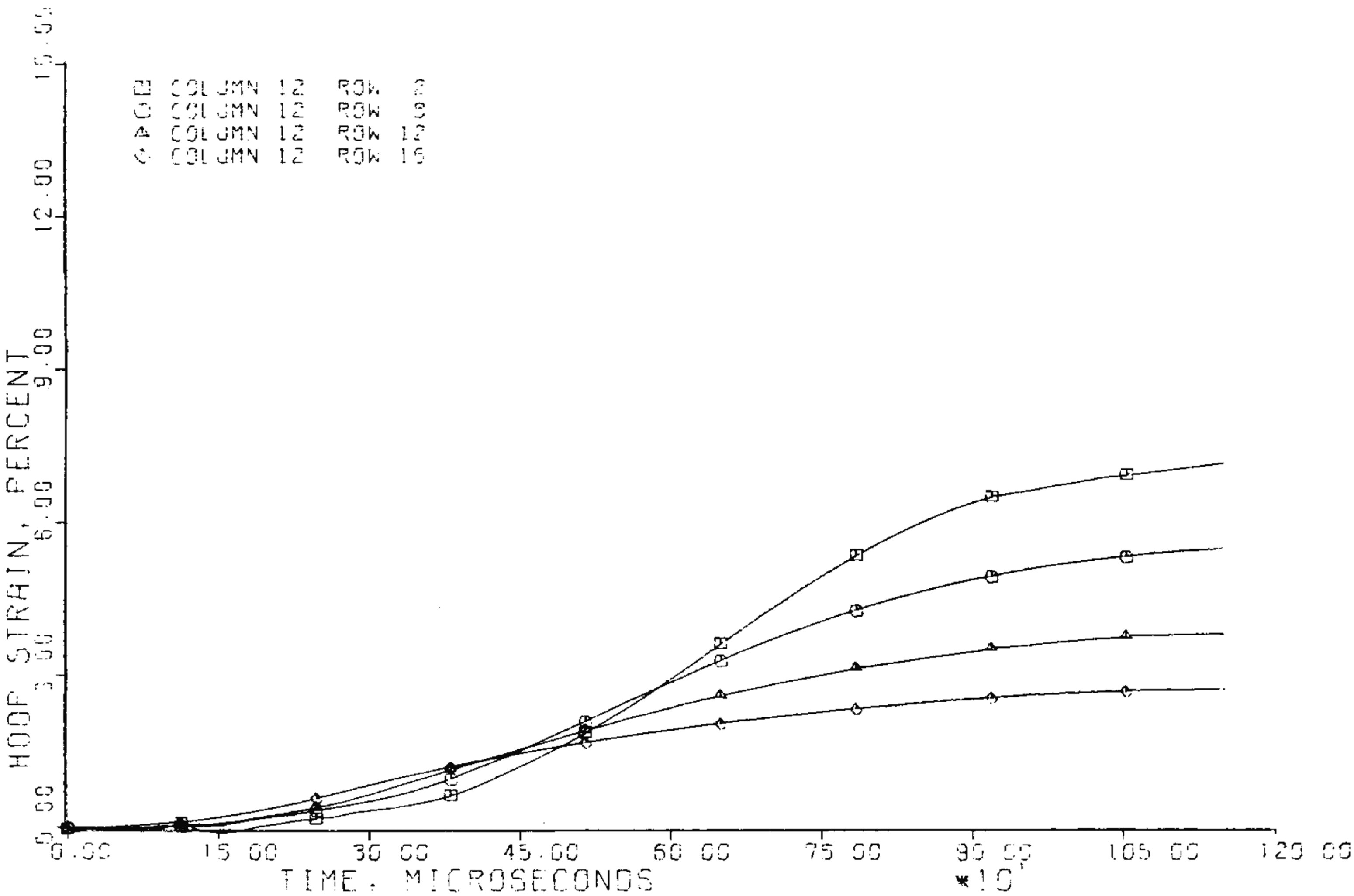
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

RADIAL STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-33



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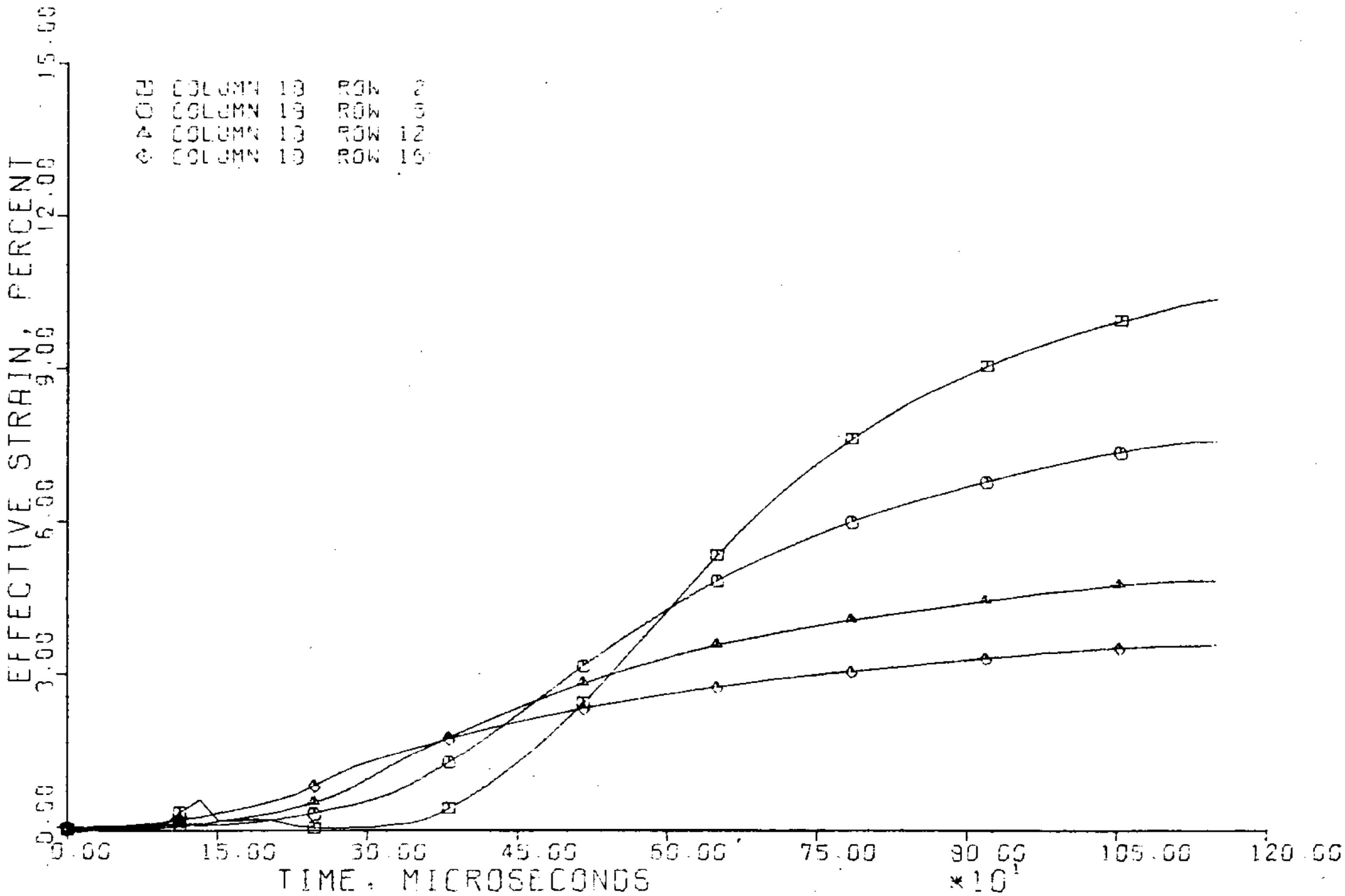
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

HOOP STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-34



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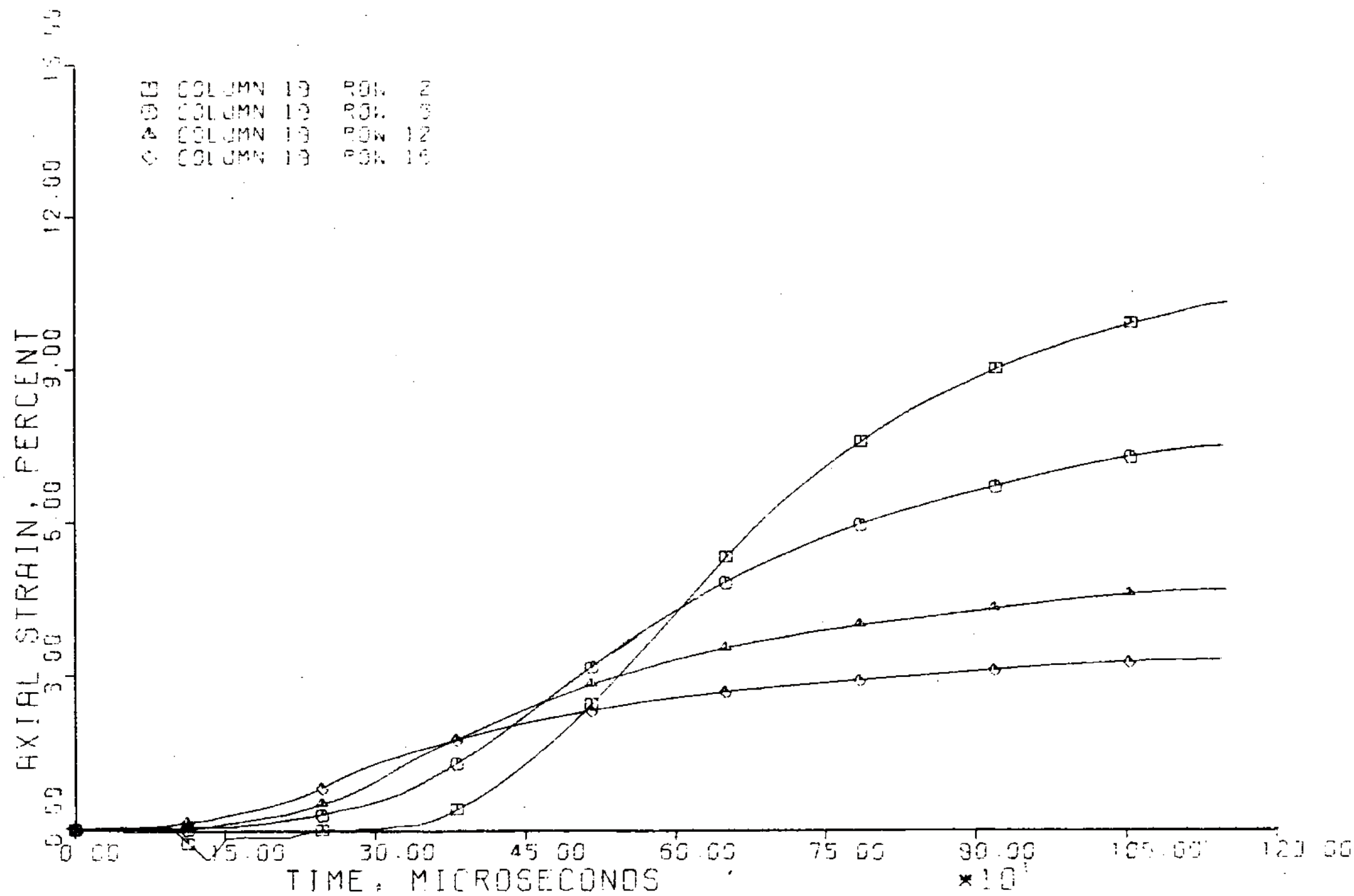
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECTIVE STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-35



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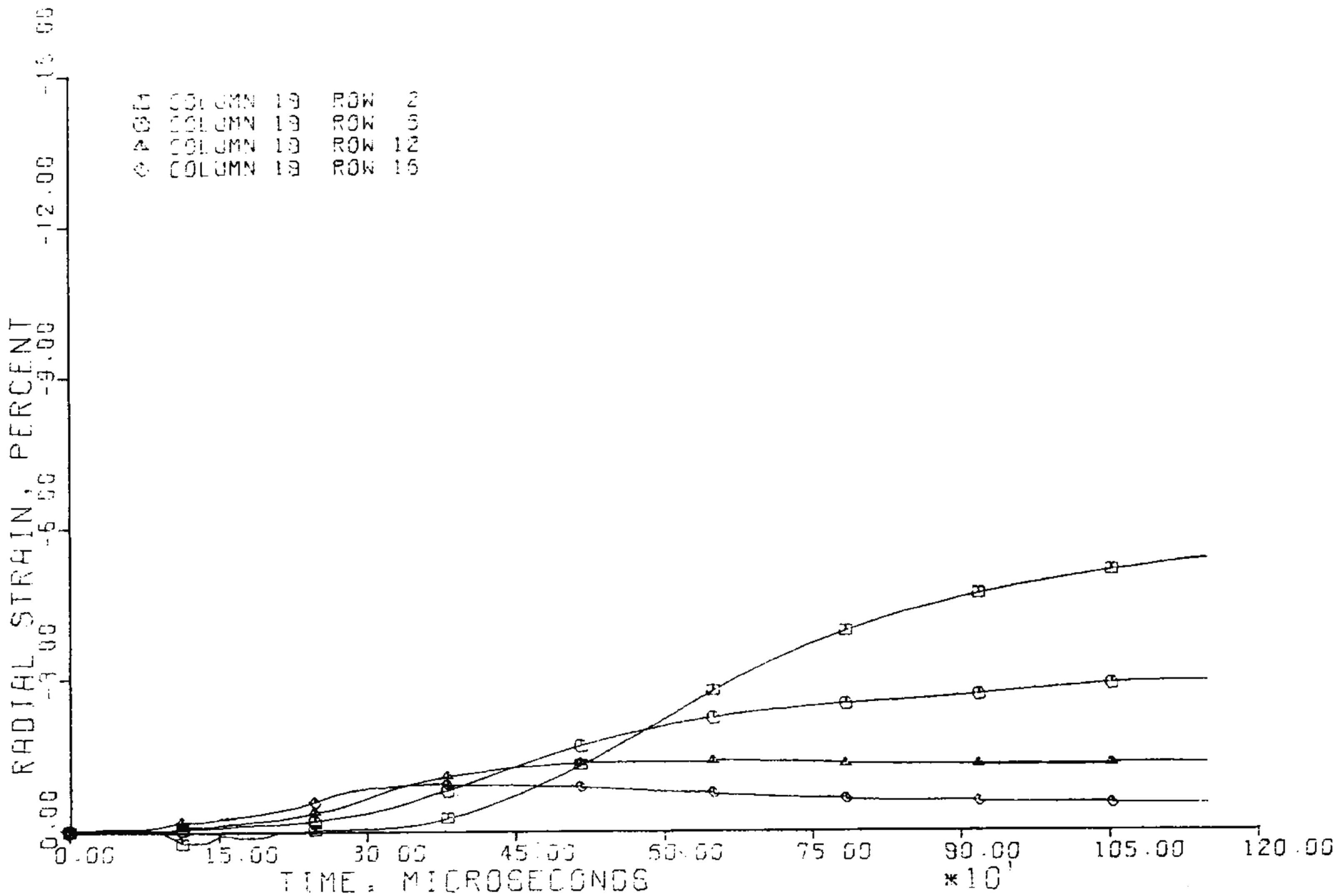
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

AXIAL STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-36



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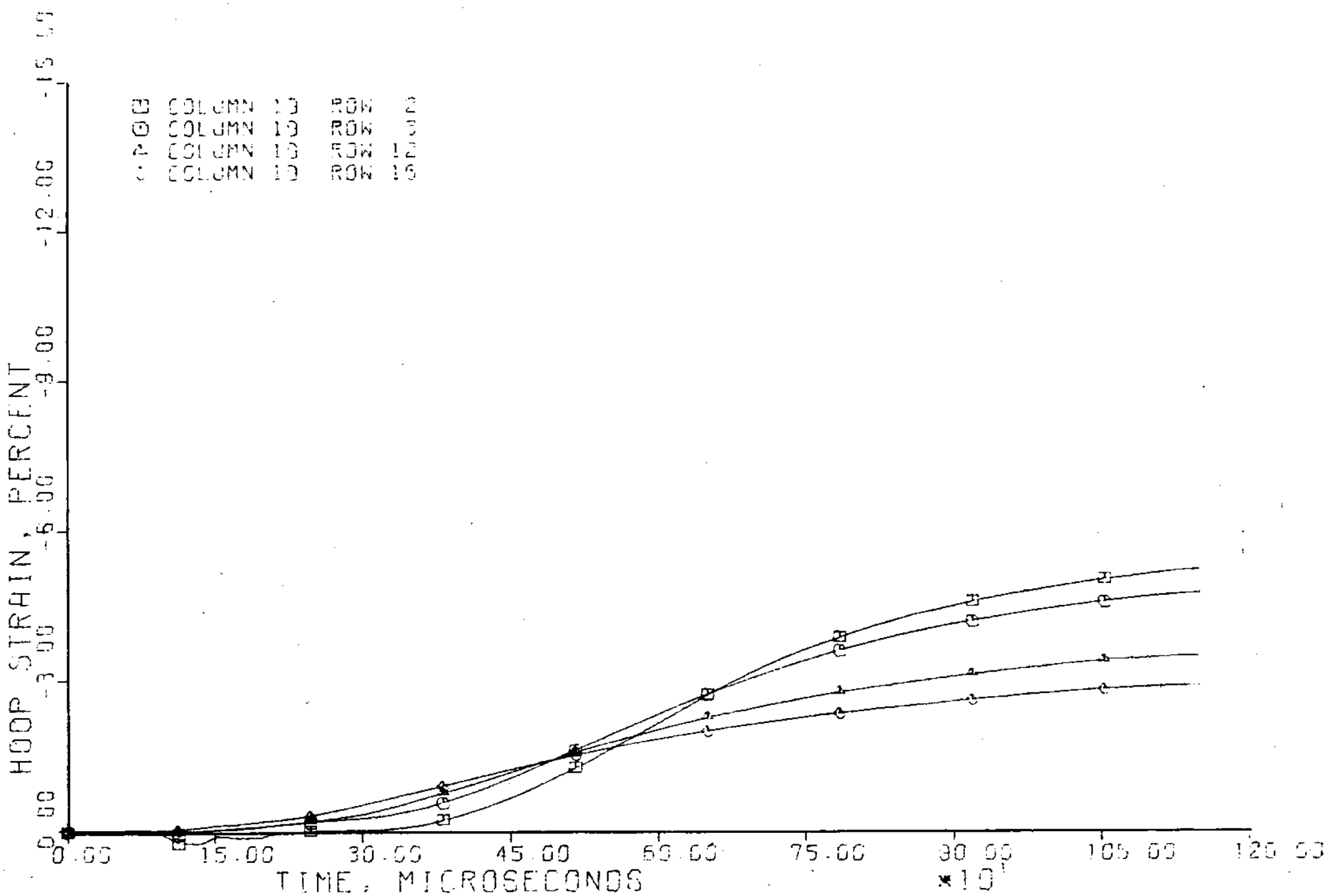
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

RADIAL STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-37



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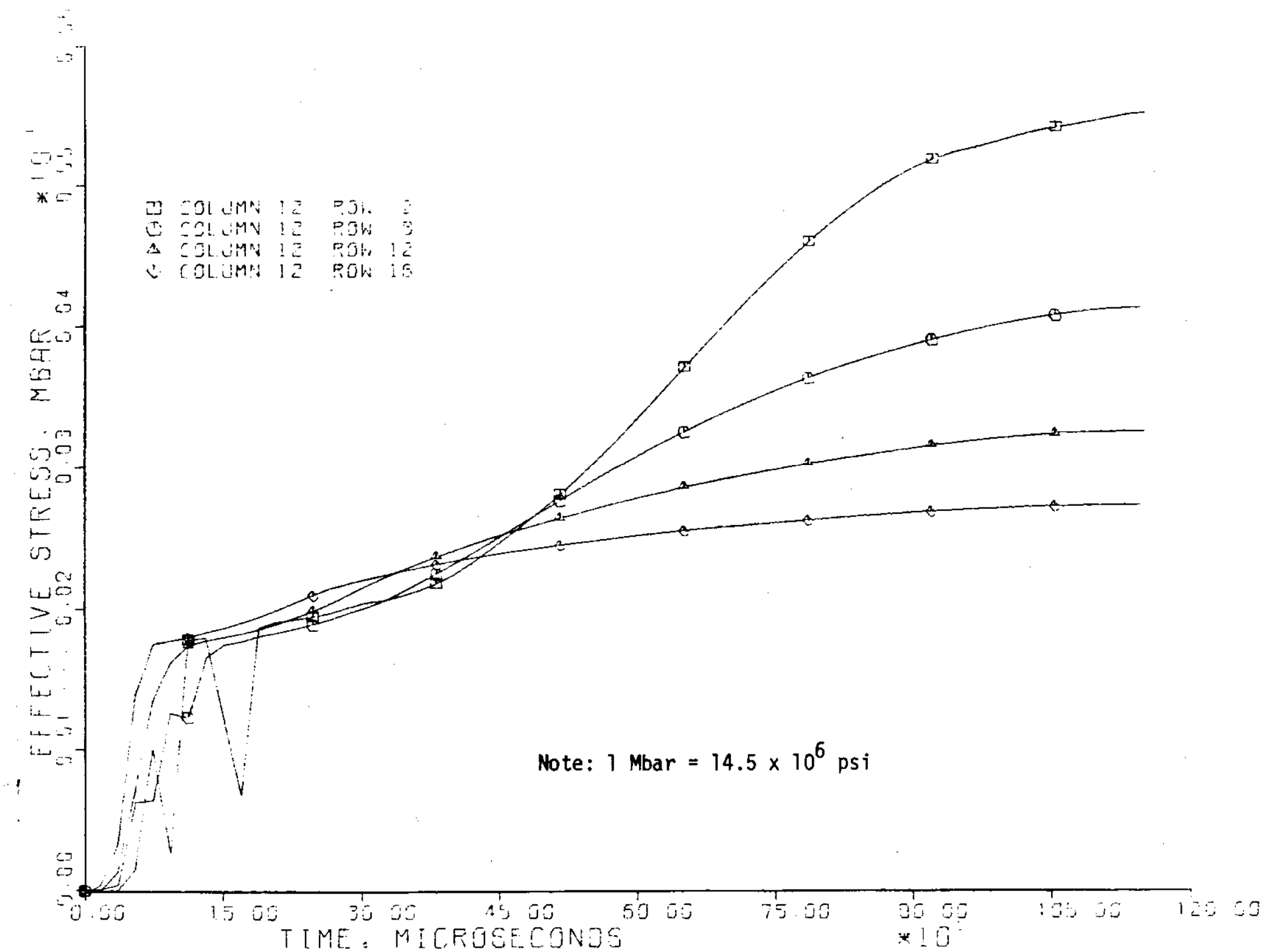
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

HOOP STRAINS IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-38



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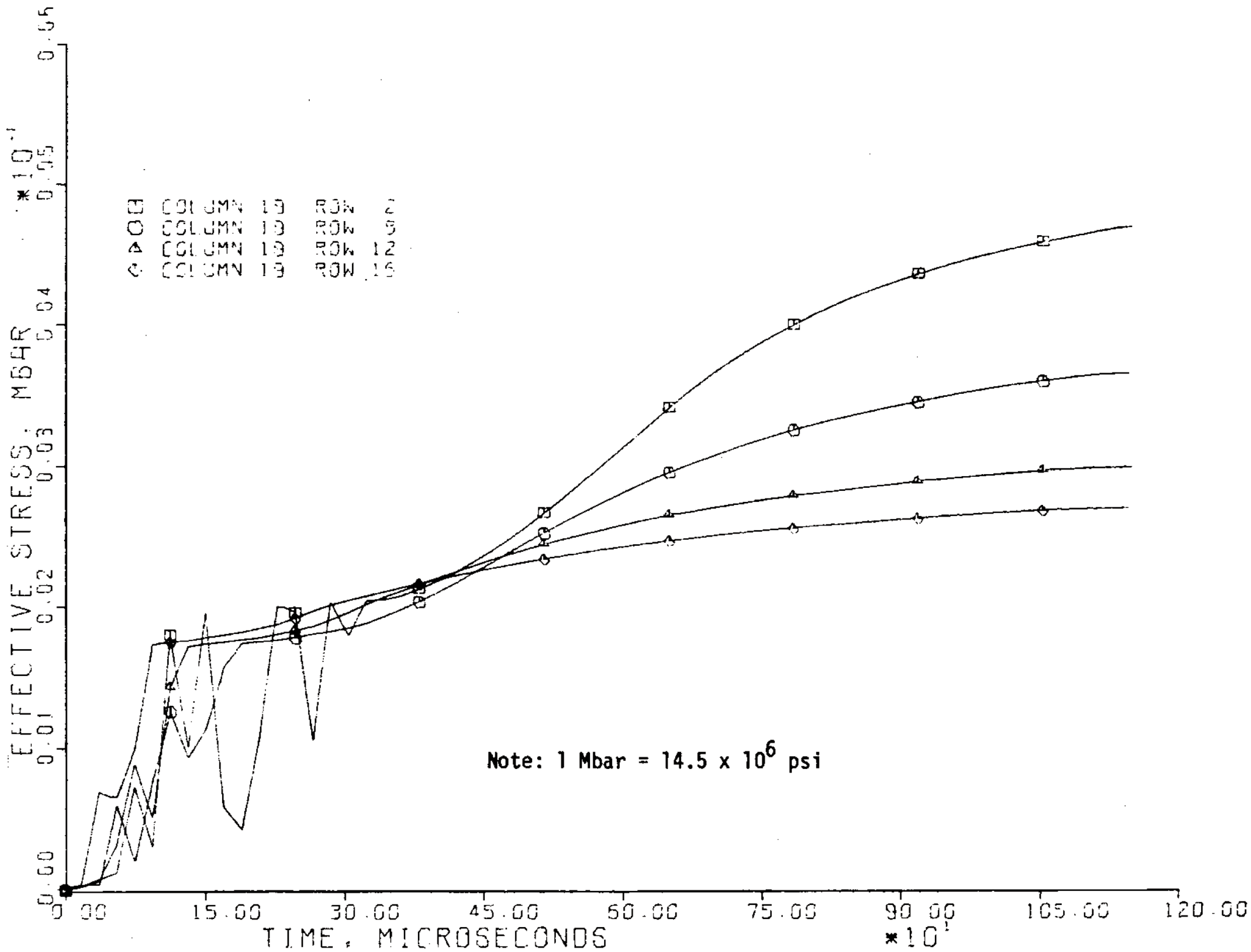
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECTIVE STRESSES IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-39



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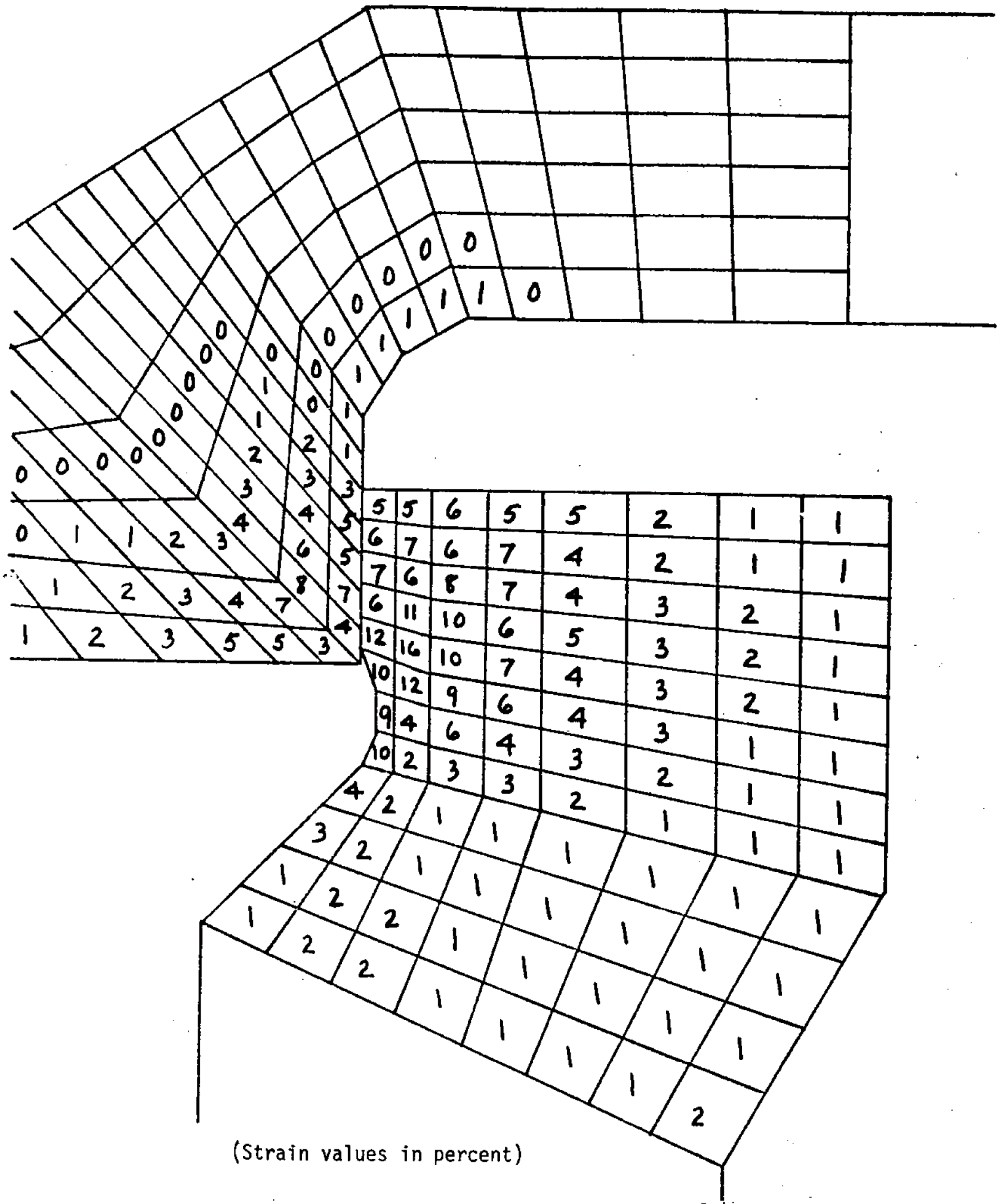
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECTIVE STRESSES IN DISC VERSUS
TIME SINCE IMPACT

FIGURE 10A-40



(Strain values in percent)

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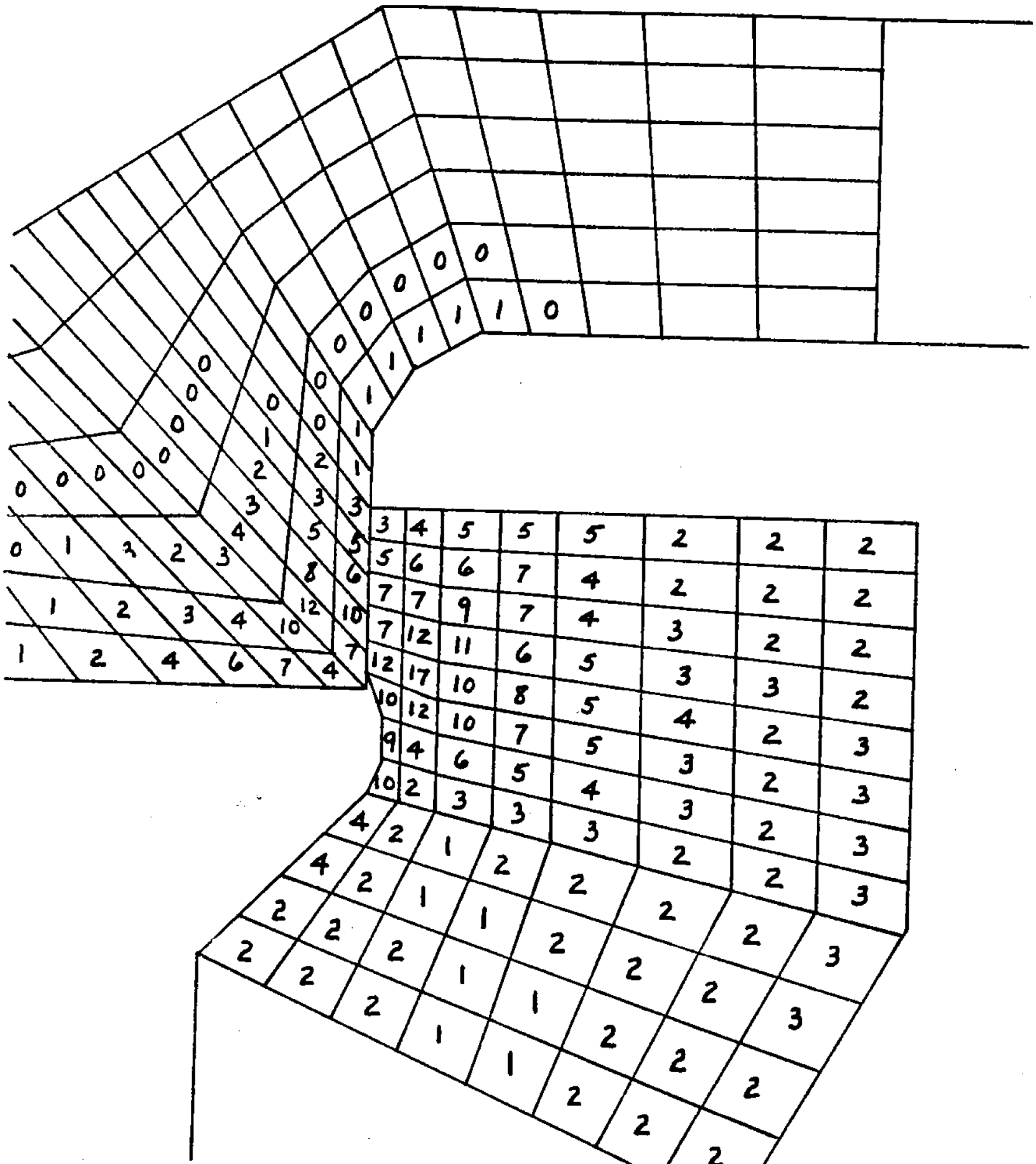
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF EFFECTIVE STRAIN
$\bar{\varepsilon}$ AT TIME t = 300 μS

FIGURE 10A-41



(Strain values in percent)

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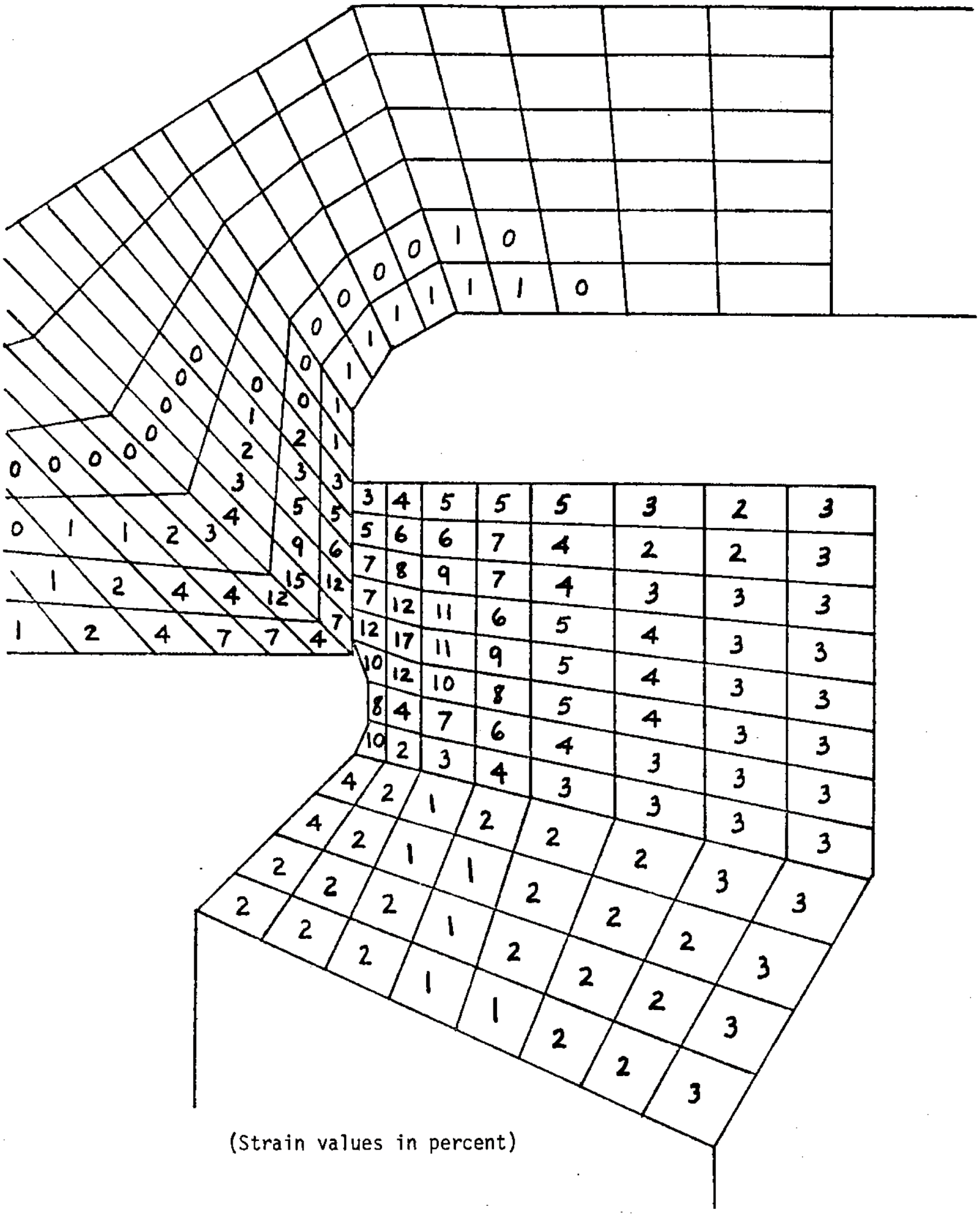
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF EFFECTIVE STRAIN
$\bar{\varepsilon}$ AT TIME t = 700 μS

FIGURE 10A-42



(Strain values in percent)

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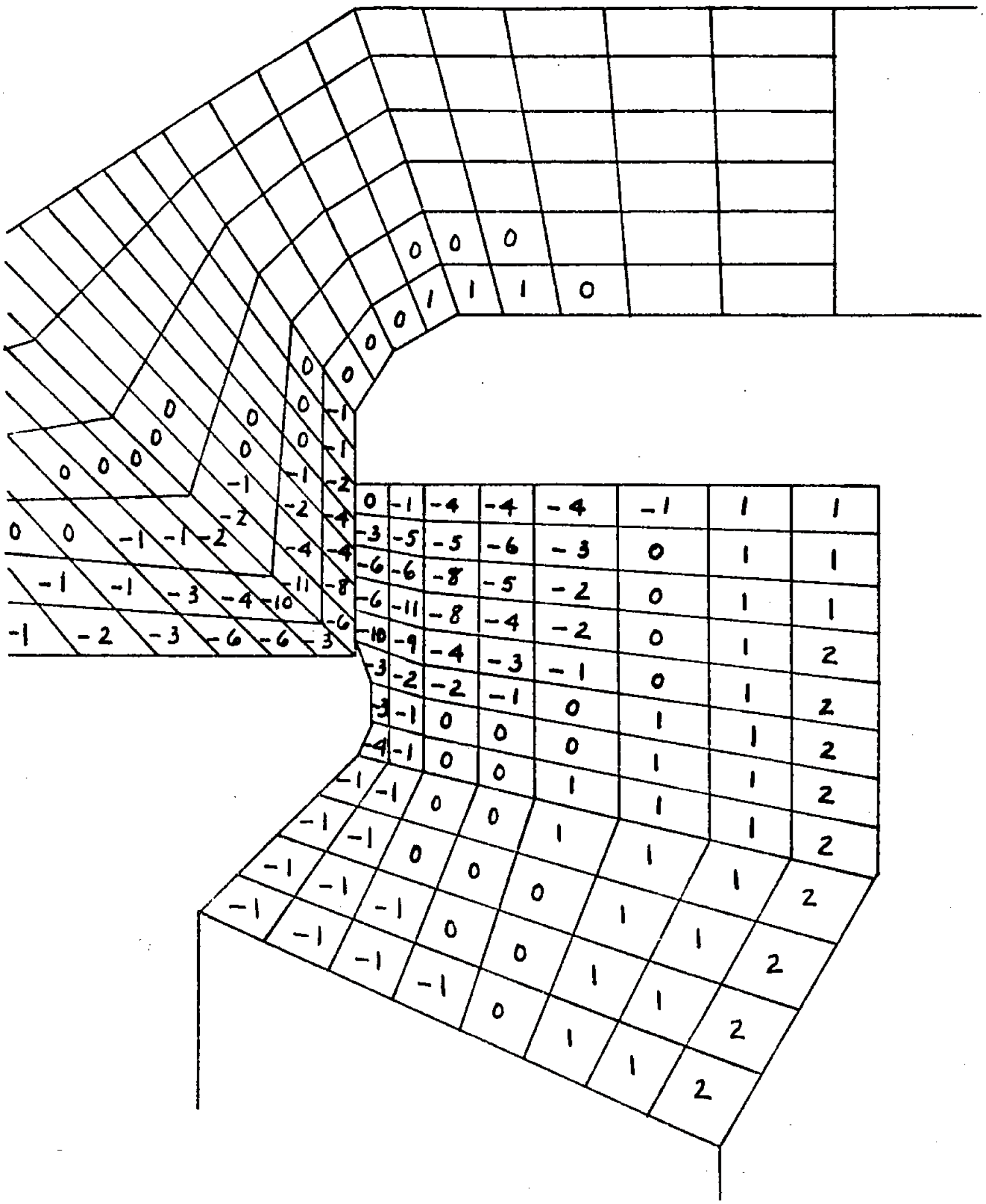
DISTRIBUTION OF EFFECTIVE STRAIN
$\bar{\varepsilon}$ AT TIME t = 1150 μS

FIGURE 10A-43



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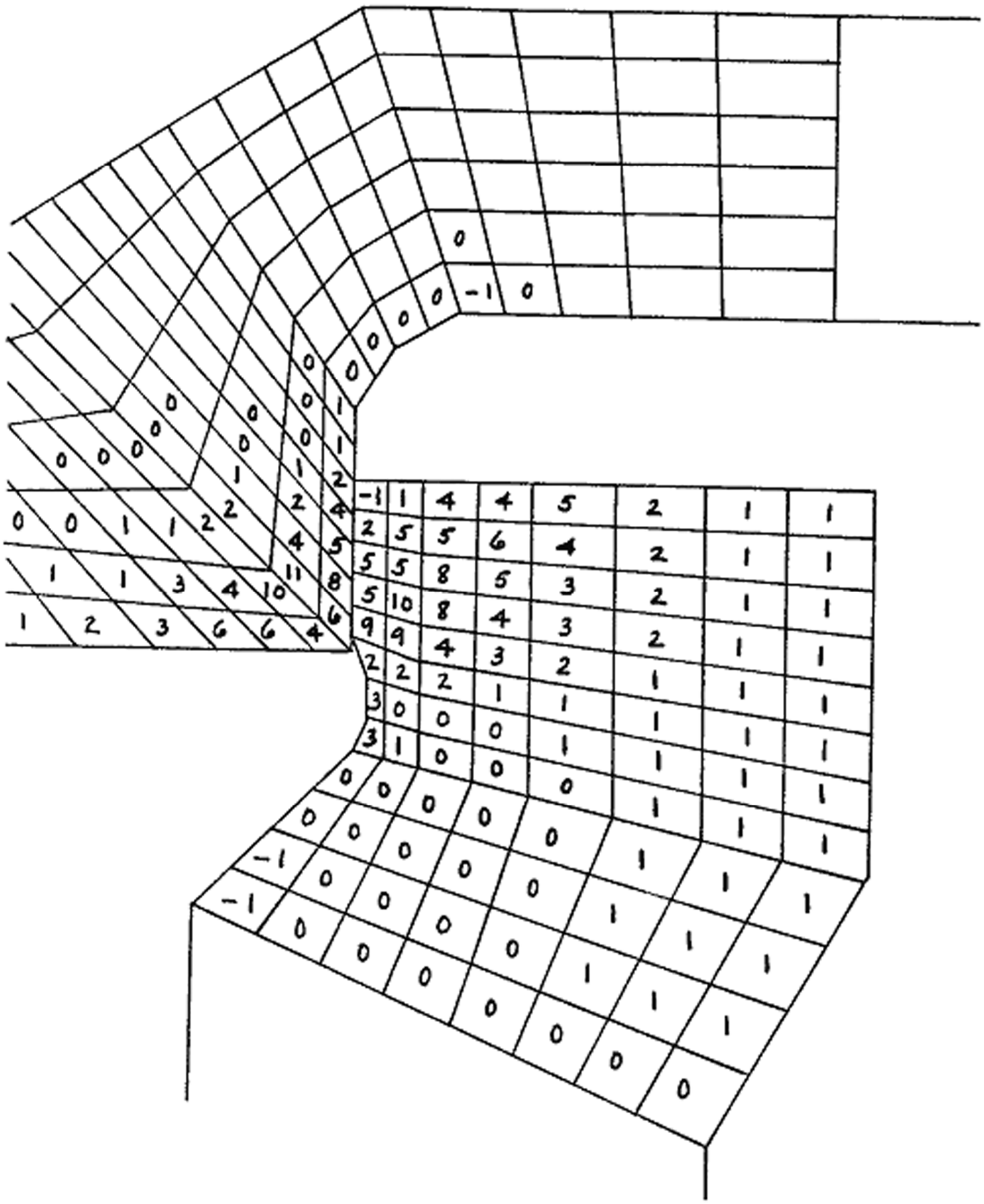
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF AXIAL STRAIN ε_X
$\overline{\varepsilon}$ AT TIME t = 1150 μS

FIGURE 10A-44



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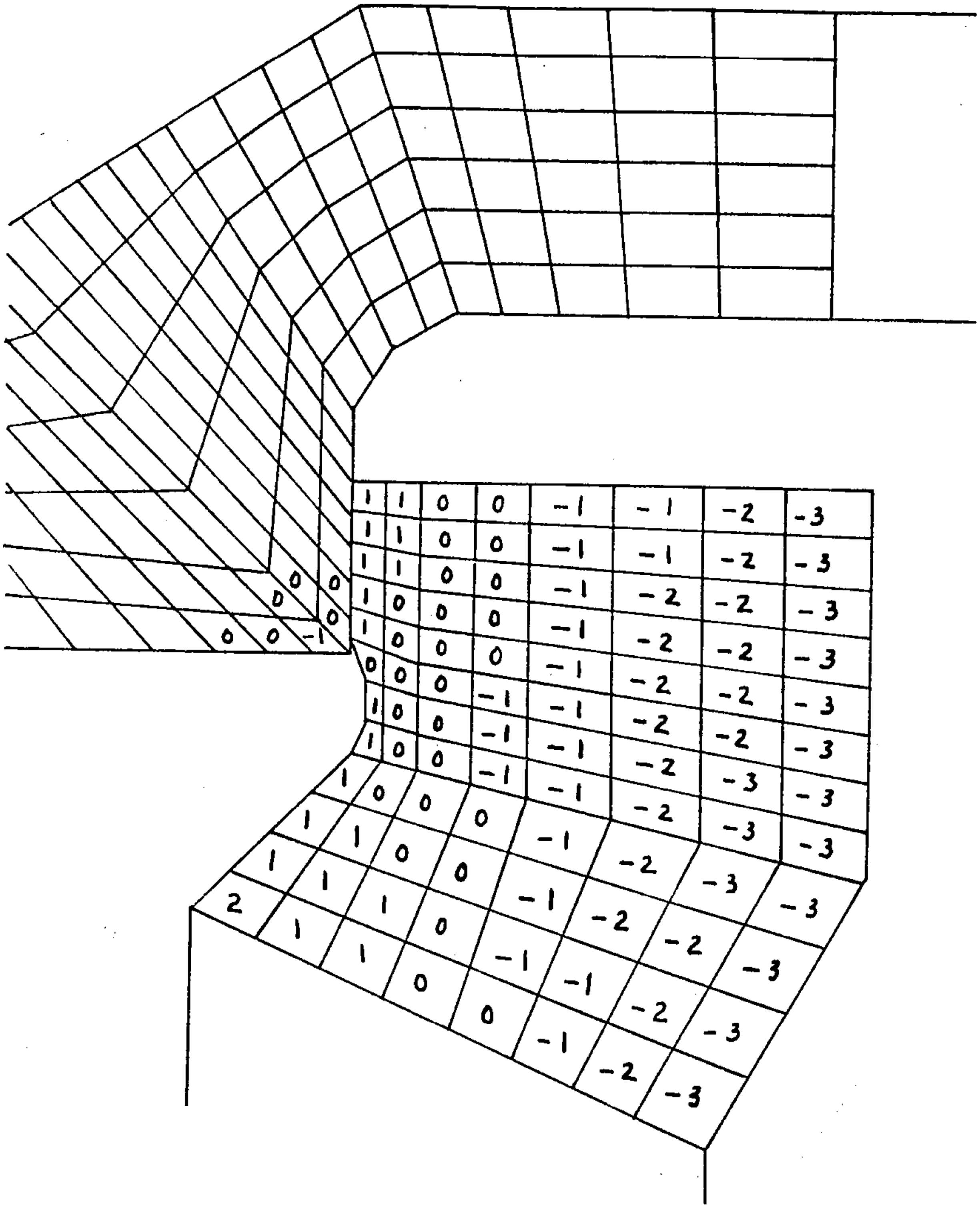
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF RADIAL STRAIN
ε_y AT TIME t = 1150 μS

FIGURE 10A-45



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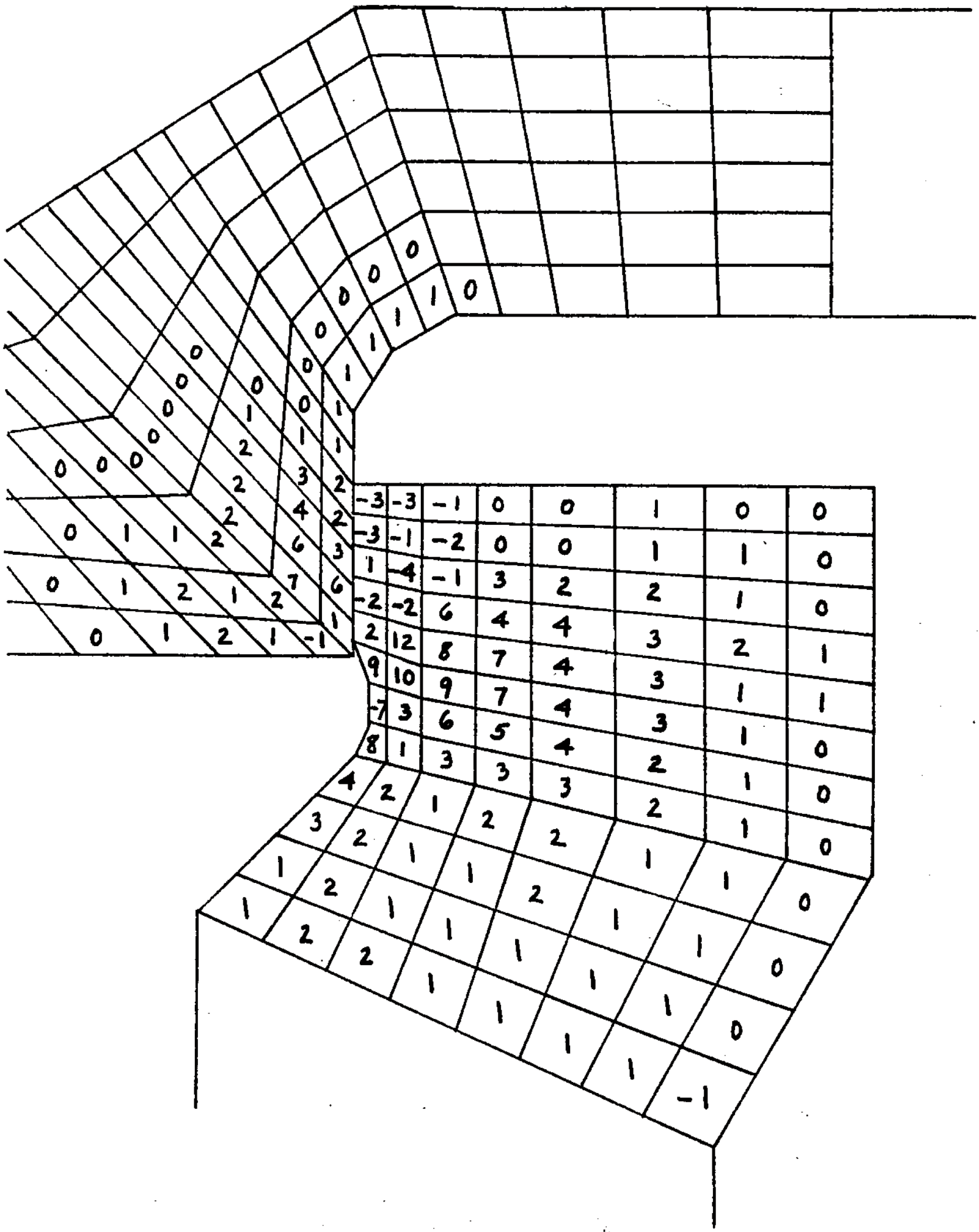
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF HOOP STRAIN
ε_z AT TIME t = 1150 μS

FIGURE 10A-46



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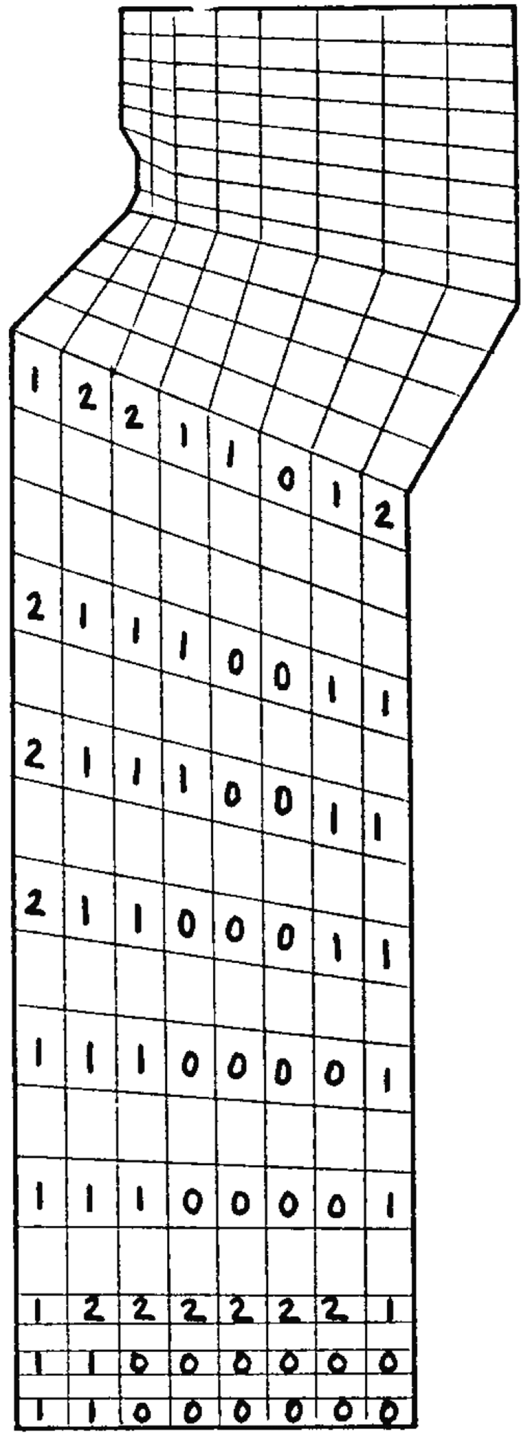
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF SHEAR STRAIN
ε_{XY} AT TIME t = 1150 μS

FIGURE 10A-47



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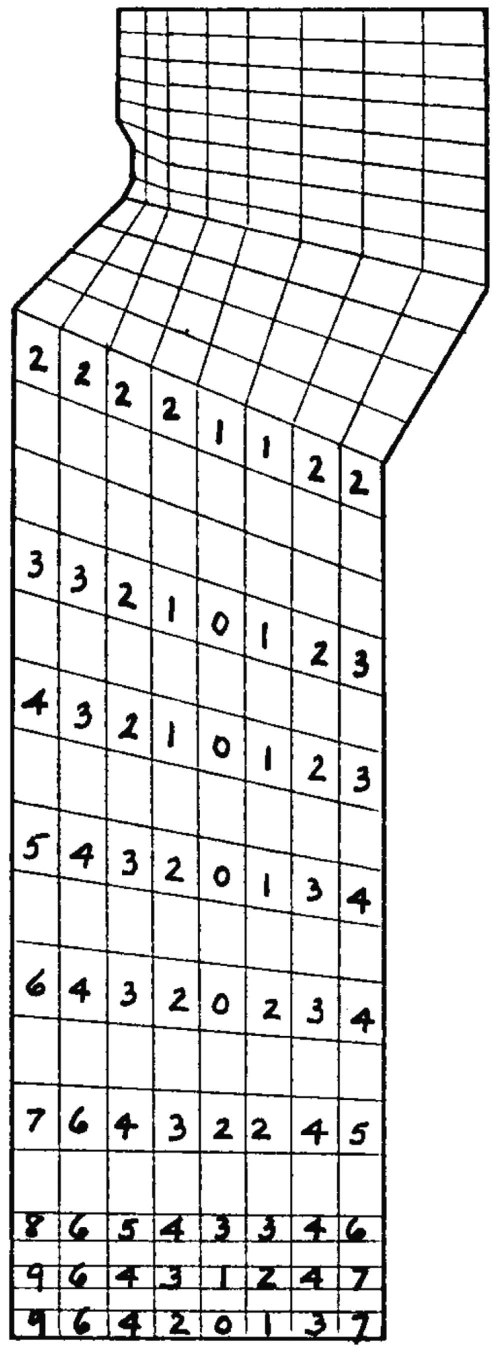
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF EFFECTIVE STRAIN
$\bar{\varepsilon}$ AT TIME t = 300 μS

FIGURE 10A-48



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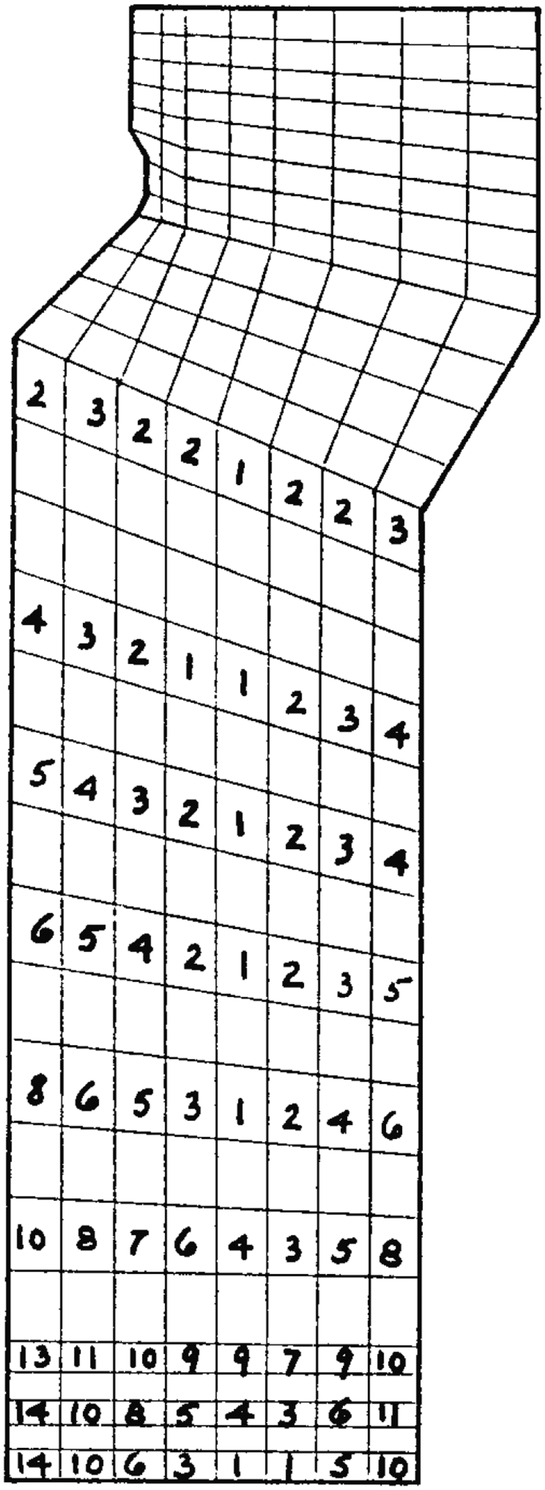
Energy to Serve Your World®

JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF EFFECTIVE STRAIN
$\bar{\varepsilon}$ AT TIME t = 700 μS

FIGURE 10A-49



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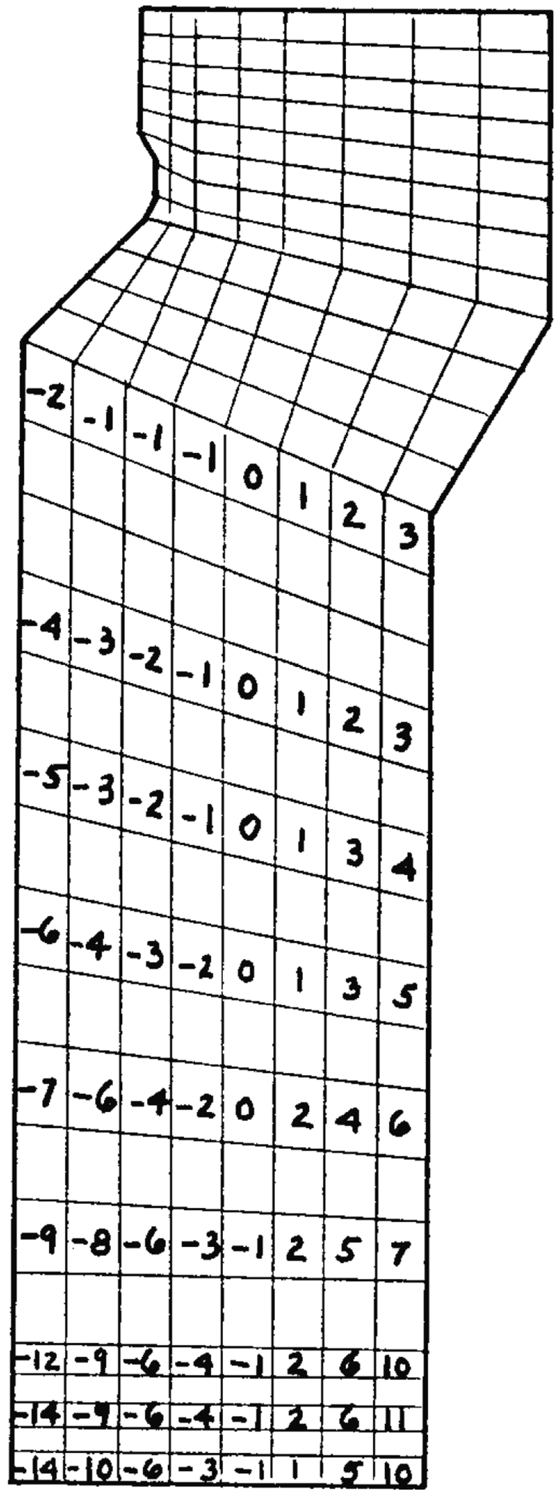
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF EFFECTIVE STRAIN
$\bar{\varepsilon}$ AT TIME t = 1150 μS

FIGURE 10A-50



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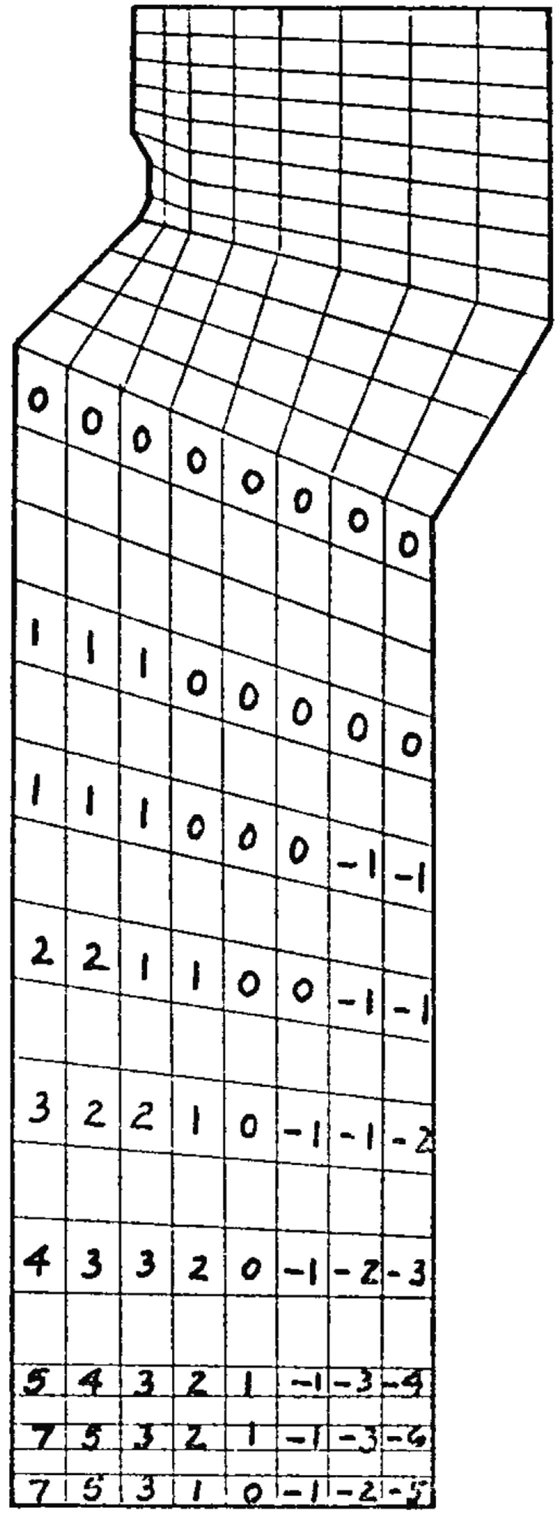
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	DISTRIBUTION OF AXIAL STRAIN ε_x AT TIME t = 1150 μS FIGURE 10A-51



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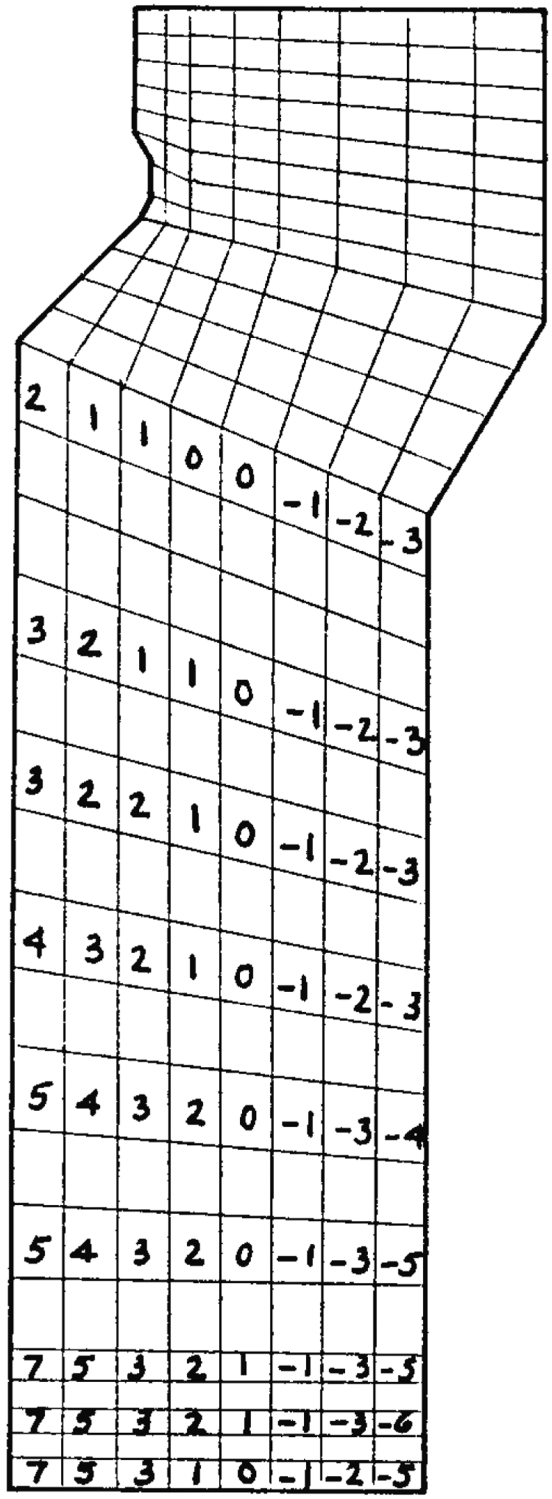
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF RADIAL STRAIN
ε_y AT TIME t = 1150 µS

FIGURE 10A-52



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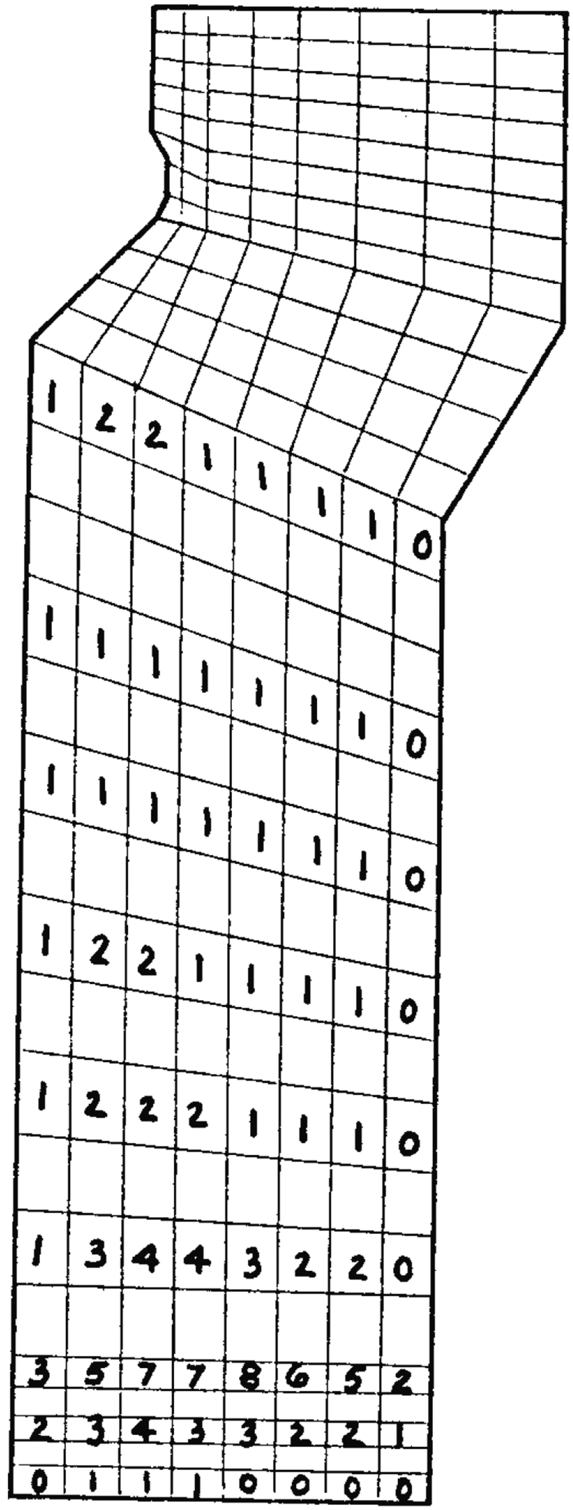
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF HOOP STRAIN
ε_z AT TIME t = 1150 μS

FIGURE 10A-53



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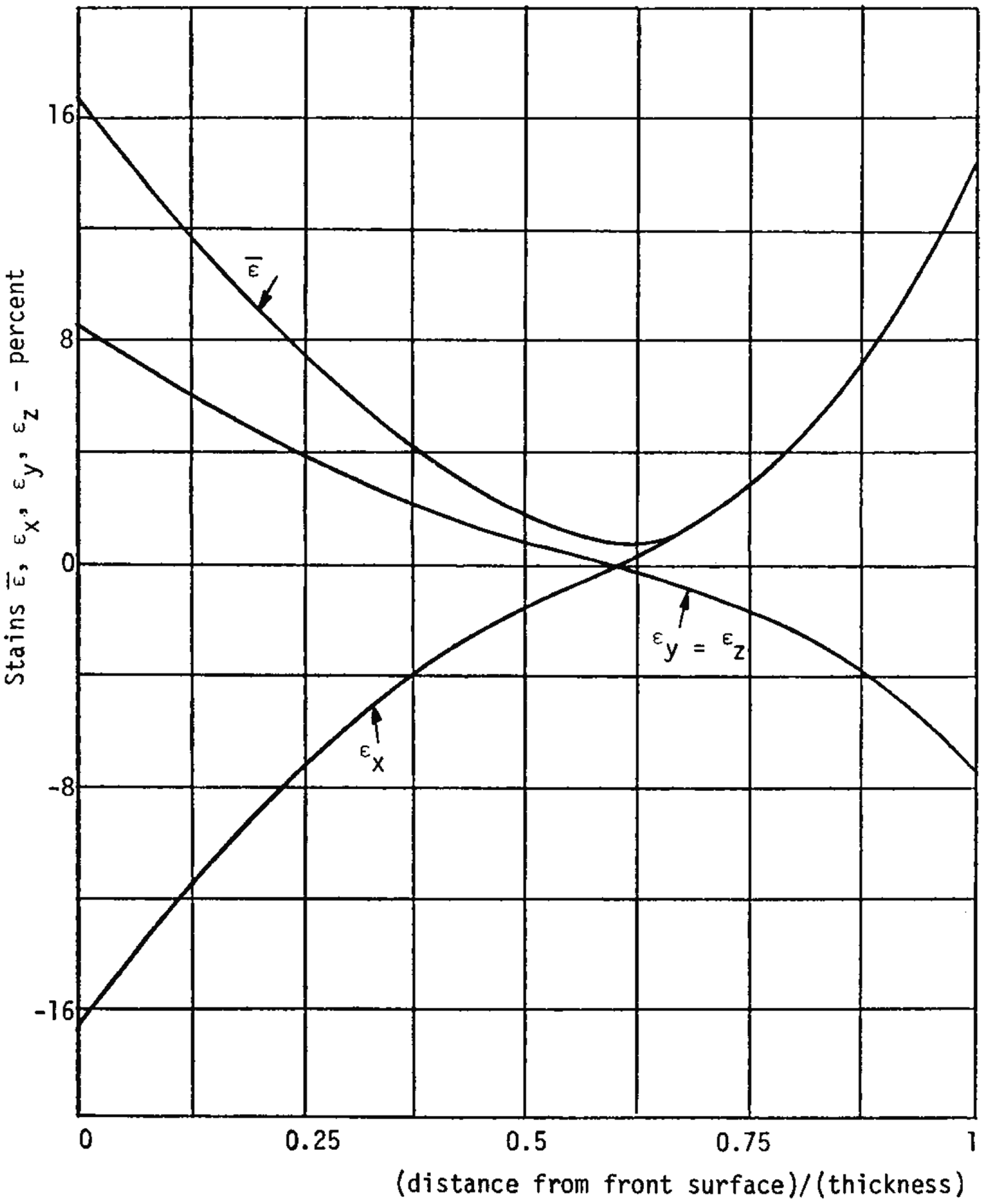
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF SHEAR STRAIN
ε_{XY} AT TIME t = 1150 μS

FIGURE 10A-54



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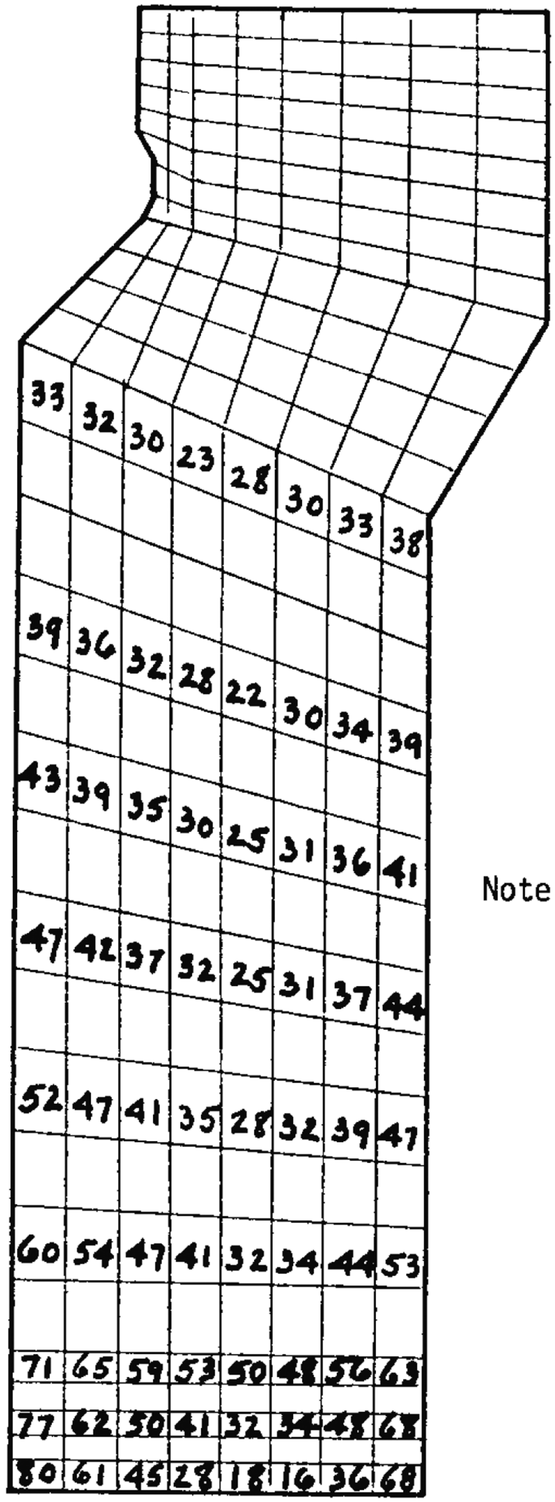
SOUTHERN COMPANY *Energy to Serve Your World®*	JOSEPH M. FARLEY NUCLEAR PLANT UNIT 1 AND UNIT 2	DISTRIBUTION OF STRAINS ALONG CENTERLINE OF DISC FIGURE 10A-55



Note: stresses in ksi

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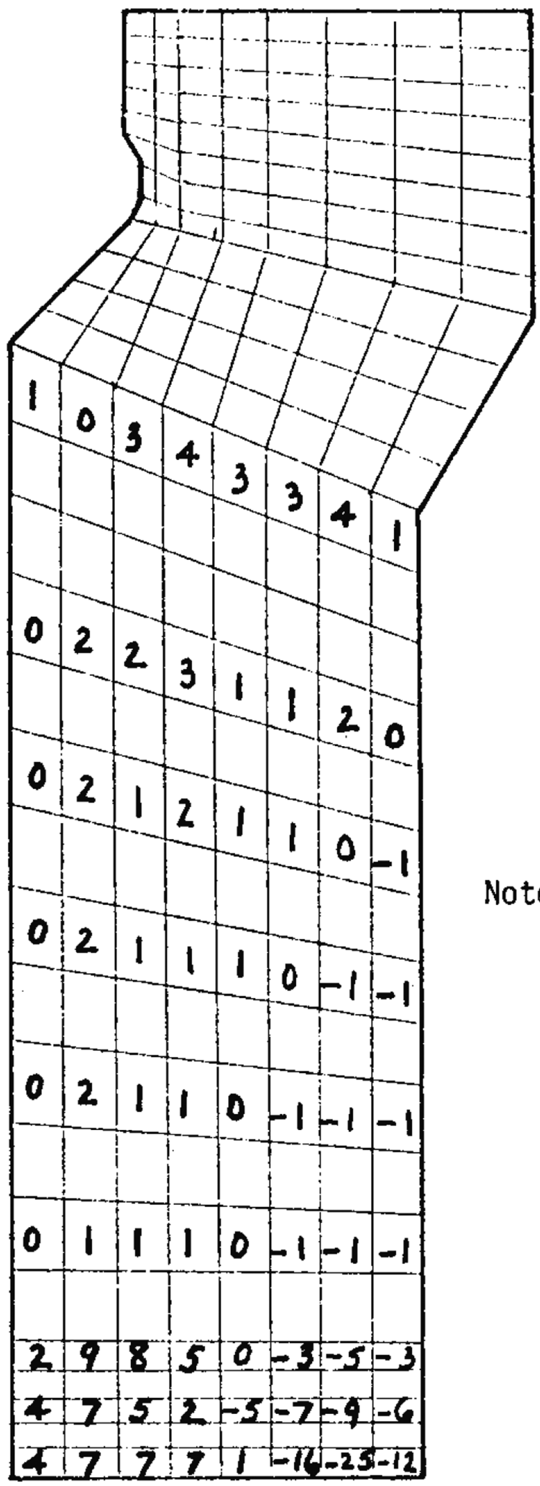
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF EFFECTIVE STRESS $\bar{\sigma}$
AT TIME t = 1150 μS

FIGURE 10A-56



Note: stresses in ksi

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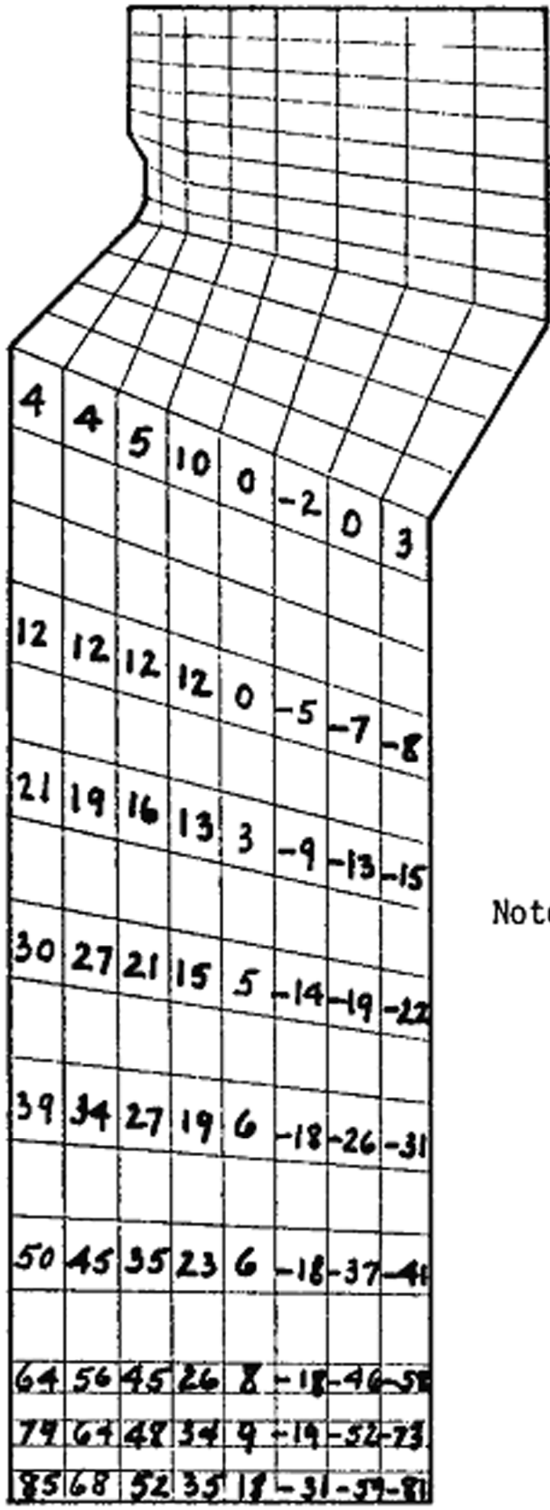
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF AXIAL STRESS
σ_x AT TIME t = 1150 μS

FIGURE 10A-57



Note: stresses in ksi

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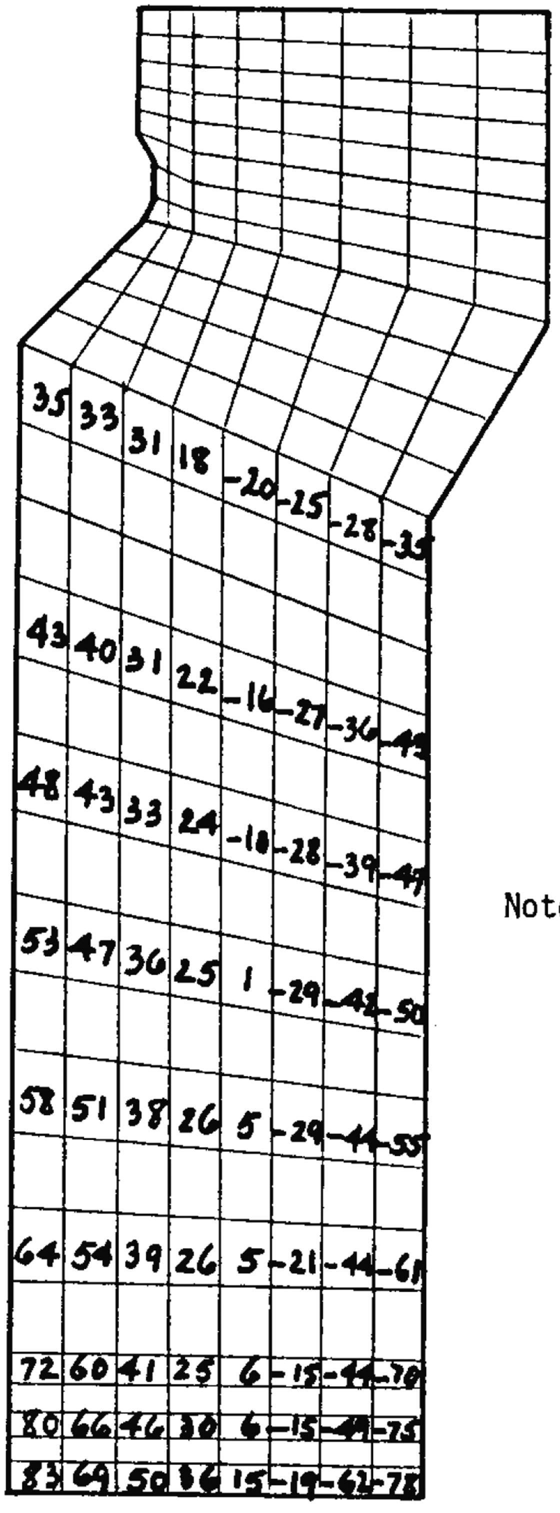
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF RADIAL STRESS
σ_y AT TIME t = 1150 μS

FIGURE 10A-58



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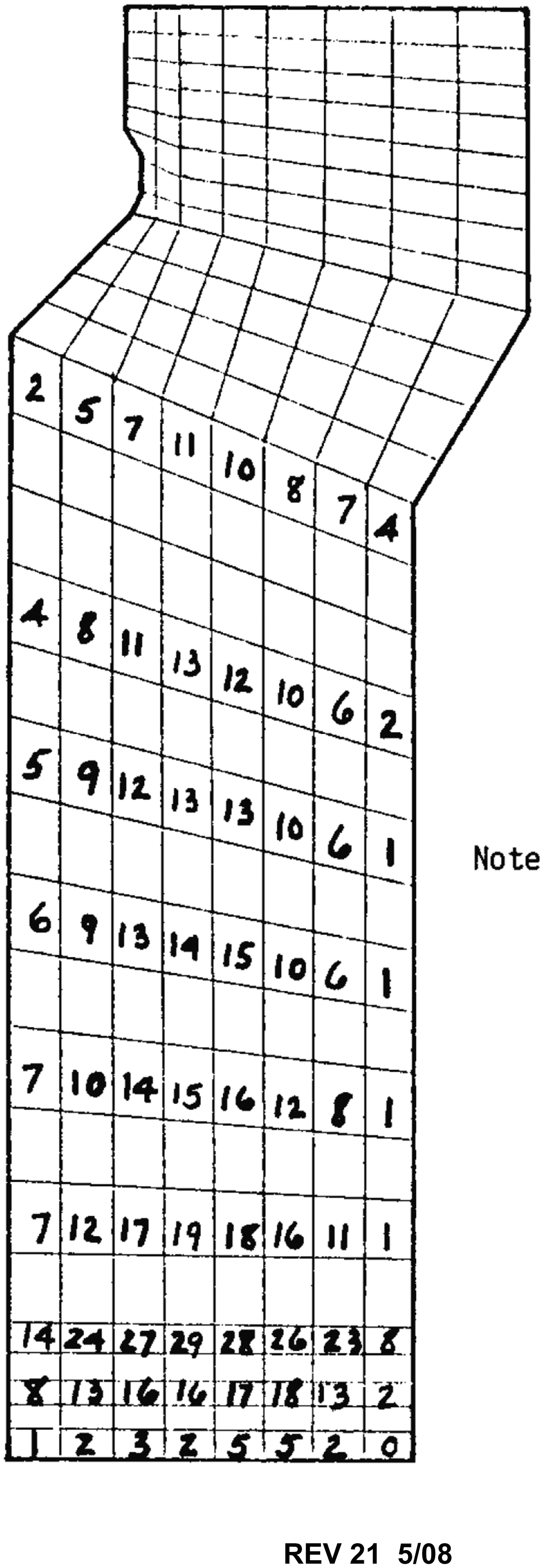
JOSEPH M. FARLEY
NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF HOOP STRESS
σ_z AT TIME t = 1150 μS

FIGURE 10A-59



Note: stresses in ksi

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NUCLEAR PLANT
UNIT 1 AND UNIT 2

DISTRIBUTION OF SHEAR STRESS
τ_{xy} AT TIME t = 1150 μS

FIGURE 10A-60

ATTACHMENT A

EFFECT OF STRAIN RATE ON STRESS-STRAIN BEHAVIOR OF TYPE 304 STAINLESS STEEL[3]

LMFBR	MATERIALS HANDBOOK	Type 304 Stainless Steel*

DATE	1-18-73
SUPERSEDES	New

Effect of Strain Rate on Stress - Strain Behavior

EFFECT OF STRAIN RATE ON AVERAGE TRUE STRESS-TRUE STRAIN BEHAVIOR OF TYPE 304 STAINLESS STEEL*

$$\sigma_T = K_1 \epsilon_p^{\,n_1} + e^{(K_2 + n_2 \epsilon_p)}$$

σ_T = average true stress, ~~ksi~~ psi

ϵ_p = average true plastic strain, in/in

K_1, n_1, K_2, and n_2 = constants

For 600°F	For 800°F	For 1000°F	For 1200°F
$n_1 = 0.473 - 0.023 \log \mathring{\varepsilon}$	$n_1 = 0.508 - 0.013 \log \mathring{\varepsilon}$	$n_1 = 0.490 - 0.005 \log \mathring{\varepsilon}$	$n_1 = 0.475 + 0.006 \log \mathring{\varepsilon}$
$K_1 = 164{,}640 - 2{,}150 \log \mathring{\varepsilon}$	$K_1 = 164{,}220 + 1{,}930 \log \mathring{\varepsilon}$	$K_1 = 155{,}070 + 2{,}070 \log \mathring{\varepsilon}$	$K_1 = 133{,}260 + 5{,}270 \log \mathring{\varepsilon}$
$n_2 = -51.23 - 3.18 \log \mathring{\varepsilon}$	$n_2 = -50.45 - 4.28 \log \mathring{\varepsilon}$	$n_2 = -68.94 - 4.48 \log \mathring{\varepsilon}$	$n_2 = -94.50 + 3.45 \log \mathring{\varepsilon}$
$K_2 = 9.641 + 0.052 \log \mathring{\varepsilon}$	$K_2 = 9.583 + 0.063 \log \mathring{\varepsilon}$	$K_2 = 9.347 + 0.028 \log \mathring{\varepsilon}$	$K_2 = 9.125 + 0.008 \log \mathring{\varepsilon}$

Where: $\mathring{\varepsilon}$ = strain rate, sec^{-1}.

Constants for 600-1000°F valid for nominal strain rates from 1×10^{-5} to 1×10^{2} sec^{-1}.

Constants for 1200°F valid for nominal strain rates from 5×10^{-3} to 1×10^{2} sec^{-1}.

Constants valid for nominal strains up to 25%.

For any level of strain, accuracy of stress is ± 7.5%.

Ref: 71-5
72-4

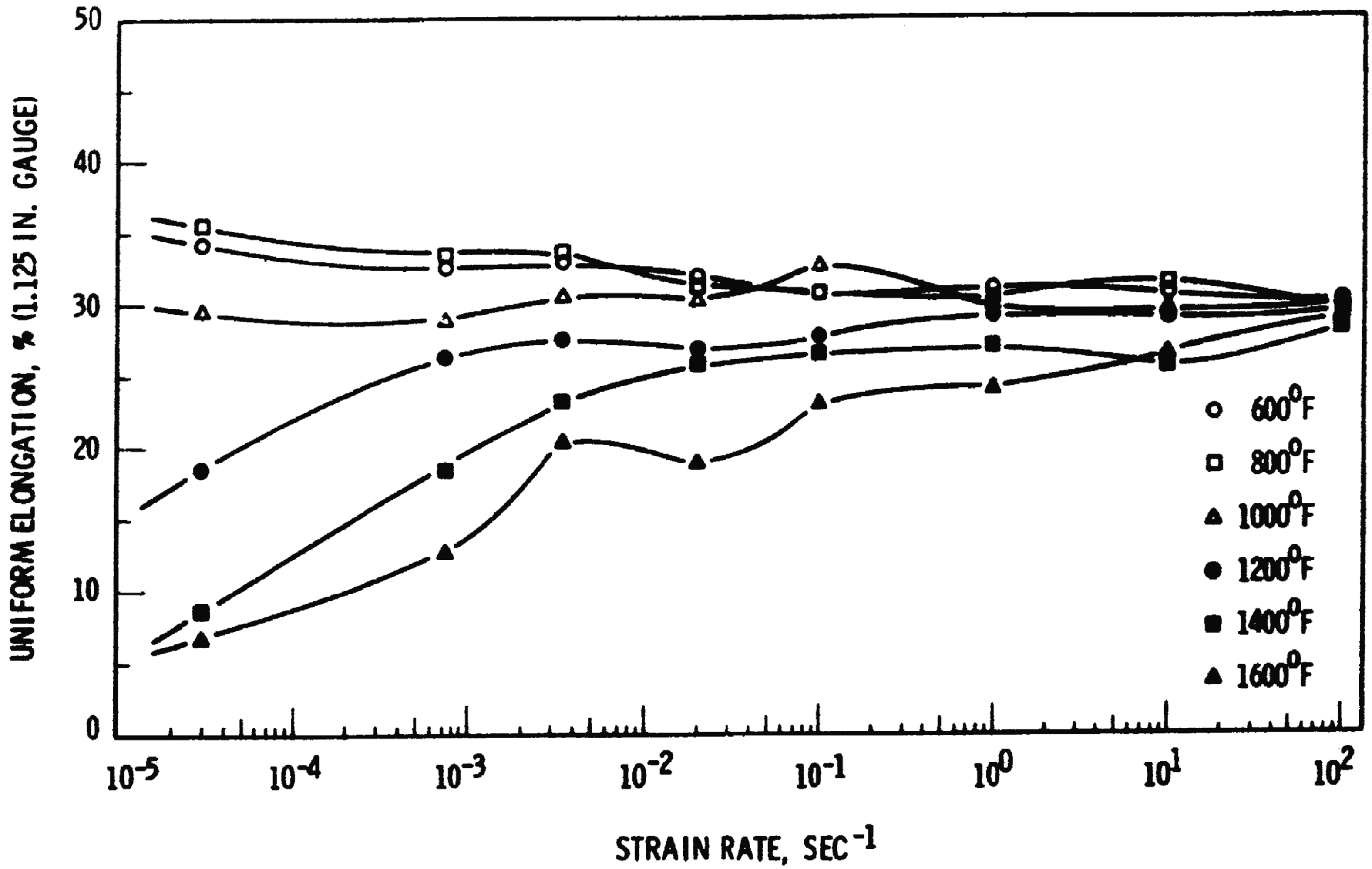
*Bar Only

PREPARED BY JM Steichen — Hanford Engineering Development Laboratory

Approved By: James E. Irvin

ATTACHMENT B

EFFECT OF STRAIN RATE ON UNIFORM ELONGATION AND REDUCTION OF AREA(2)



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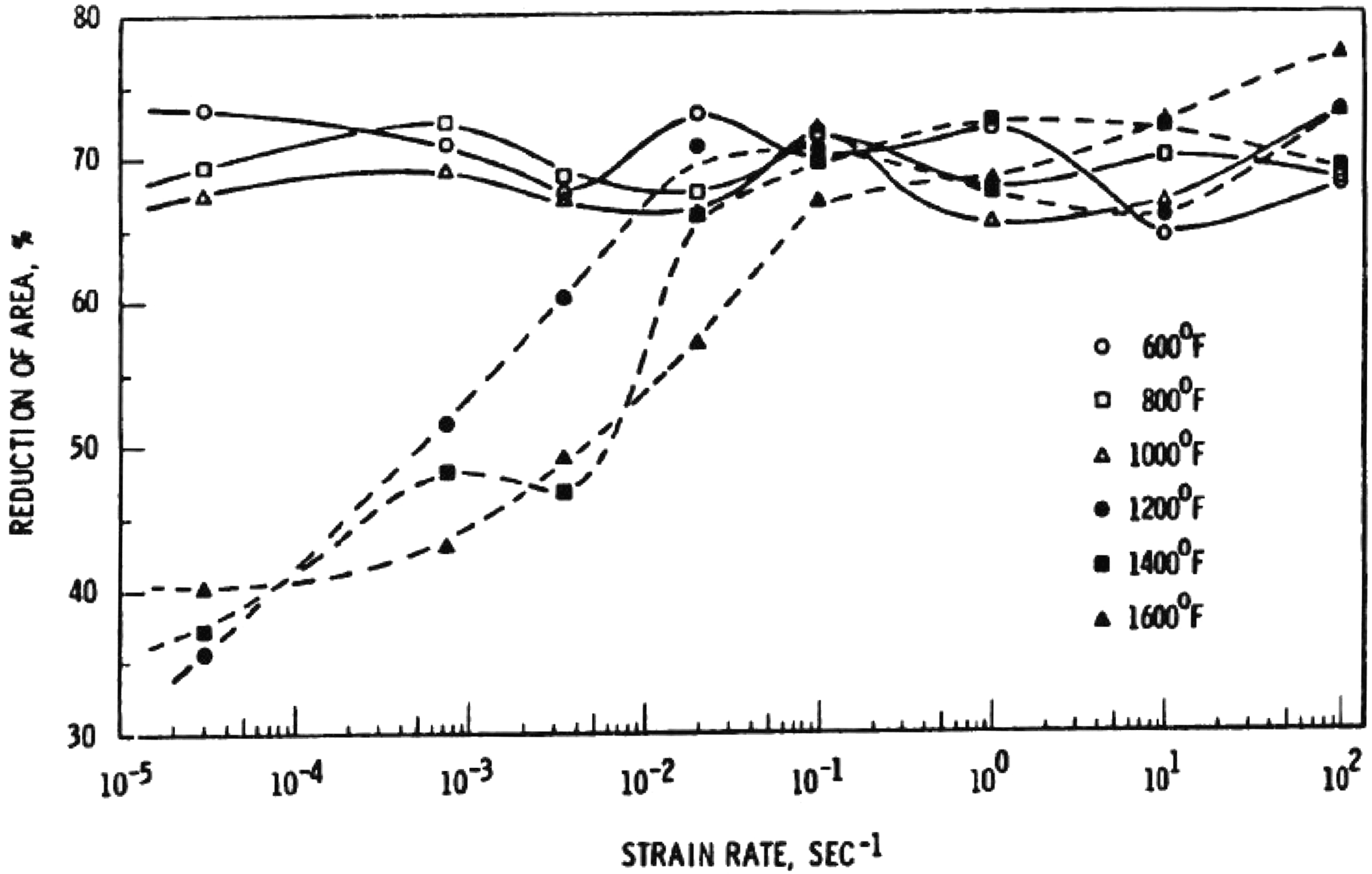
NUCLEAR PLANT
UNIT 1 AND UNIT 2

EFFECT OF STRAIN RATE AND TEMPERATURE
ON THE UNIFORM ELONGATION OF 304 SS

FIGURE B-1



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UNIT 1 AND UNIT 2

EFFECT OF STRAIN RATE AND TEMPERATURE ON THE REDUCTION OF AREA OF 304 SS

FIGURE B-2

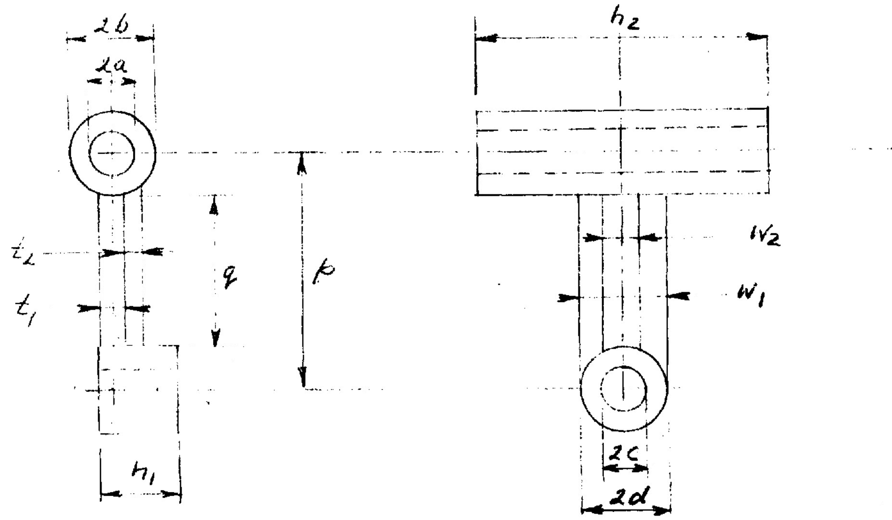
ATTACHMENT C

MASS SIMULATION OF DISC ARM, POST, AND NUT DETERMINATION OF TRANSLATIONAL IMPACT VELOCITY

Mass Simulation Of Disc Arm, Post And Nut

(a) Equivalent Weight Of Disc Arm

Approximated geometry:



dimensions (inches)

$2a = 3.5$	$p = 16.5$	$W_1 = 6.0$
$2b = 6.0$	$q = 10.0$	$W_2 = 2.0$
$2c = 3.28$	$h_1 = 5.5$	$t_1 = 1.5$
$2d = 6.0$	$h_2 = 19.5$	$t_2 = 1.75$

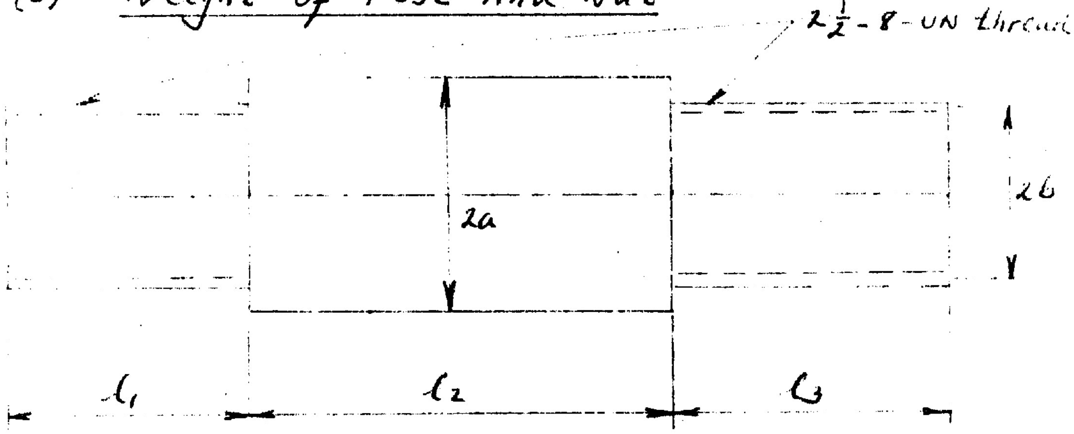
Reference Dwgs (Atwood & Morrill): 30466-405-C, 22751-C

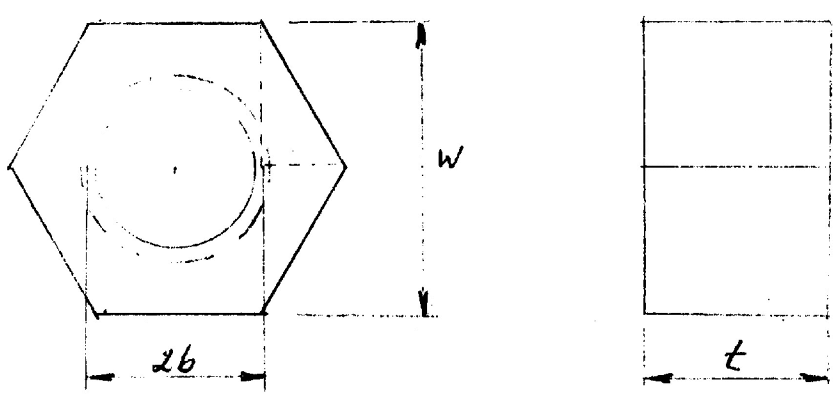
$$M = 152 \times 7.35 \times 10^{-4} = 0.112 \text{ lbm}$$

Let W = weight of equivalent mass

$$\underline{\underline{W}} = Mg = \underline{\underline{43.1}} \text{ lb}$$

(b) Weight of Post And Nut





V_1 = Volume of post, V_2 = Volume of nut

$V_1 = \pi b^2(\ell_1 + \ell_3) + \pi a^2 \ell_2$

$V_2 = (12 \times \frac{1}{2} \times \frac{W}{2} \times \frac{W}{2} \tan 30 - \pi b^2)t$

$= (1.5 W^2 \tan 30 - \pi b^2)t$

dimensions (inches)

$2a = 3.25$	$\ell_1 = 3.44$	$W = 3.88$
$2b = 2.43$	$\ell_2 = 5.81$	$t = 2.55$
	$\ell_3 = 3.75$	

Substitution:

$$\left.\begin{array}{l} V_1 = 81.5 \text{ in}^3 \\ V_2 = 21.4 \text{ in}^3 \end{array}\right\} V = V_1 + V_2 = 102.9 \text{ in}^3$$

$\underline{\underline{W}}$ = Weight of post and nut $= V\rho$

$= 102.9 \times 0.284 = \underline{\underline{29.2}}$ lb

(c) Simulation

Assume central cavity of disc occupied by material having density such that weight matches that of arm, post and nut.

W_t = total weight $= 43.1 + 29.2 = 72.3$ lb

V_c = cavity volume $= \frac{\pi}{4}(2.43)^2 3.75 = 17.4 \text{ in}^3$

Equivalent specific weight $\rho_e' = W_t / V_c = 4.16$ lb/in^3

For steel, $\rho_s' = 0.284$

Conclusion: $\underline{\rho_e'/\rho_s' = \rho_e/\rho_s = 14.6}$

Determination of Translational Impact Velocity

The uniform impact velocity for the disc is determined by matching the kinetic energy for the assumed translational mode (Ke_t) to the kinetic energy computed for the actual rotational mode (Ke_r).

Let, R_c = distance from pivot point to disc center of gravity

ω = angular velocity of disc

$V_c = \omega R_c$ = velocity at center of gravity

I = mass moment of inertia of disc about pivot point

M = mass of disc

V_t = impact velocity

Then, $KE_r = I\omega^2/2$

$KE_t = Mv_t^2/2$

Equating KE_t to KE_r gives $V_t/V_c = (1/R_c)\sqrt{I/M}$

Velocity V_t can be determined with sufficient accuracy by simplifying the disc to one with flat surfaces, 3.75 in. apart, and by assuming the center of gravity to be located on the disc centerline. Denoting the outside diameter, inside diameter and thickness of the disc by D, d and t, respectively, one has

$$I = I_p + Mr_c^2$$

where

$$I_p = \left[\pi t/64\right]\left[D^4\rho_s + d^4\left(\rho_e - \rho_s\right)\right]$$

$$M = \left[\pi t/4\right]\left[D^2\rho_s + d^2\left(\rho_e - \rho_s\right)\right]$$

Therefore,

$$\left(V_t/V_c\right)^2 = 1 + \left[D^4 + \mu d^4\right]\Big/\left[16R_c^2\left(D^2 + \mu d^2\right)\right]$$

where $\mu = \rho_e/\rho_s - 1$

Substitution of D = 27.5 in., d = 2.432 in., ρ_e/ρ_s = 14.6, and V_c = 117.0 ft/sec. (Attachment D), gives the result

$$V_t = 1.081\,V_c = 126.4 \text{ ft/sec.} = 3.853 \times 10^{-3} \text{ cm}/\mu\text{sec.}$$

For conservatism, a V_t of 150 ft/sec will be assumed.

ATTACHMENT D

FLUID DYNAMICS ANALYSIS

D. Fluid Dynamics

Impact Analysis of Main Steam Swing Disk Trip Value

The main steam swing disk trip valve, located in the main steam line outside containment, prevents total blowdown of the steam generator following a downstream pipe rupture.

In operation, the swing disk assembly, consisting of the disk, disk post, and disk arm, is held in an open position some 65° from its seat. Valve positioning is accomplished by means of a pneumatically actuated air cylinder. One hundred (100)-psig air applied to the air cylinder displaces a piston upward, and this motion is transmitted by linkage to the trip valve shaft as rotary motion, raising the disk to its open position. In this position the disk is clear of the main stream of flow through the valve. In displacing the air cylinder upward, the pressurizing air also compresses a return spring located beneath the air cylinder, which is coupled axially to the displaced piston.

Upon rupture of the downstream steam line, a signal is transmitted to the air cylinder dump solenoid valves which are actuated, thereby initiating depressurization of the air cylinder. Elapsed time from break to dump valve operation is 0.500 s. Prior to disk motion, the 100-psig air cylinder pressure must decay to approximately 35 psig at which pressure the disk assembly is just maintained in its open position (65°). As choked flow conditions exist at the dump valve exhaust to ambient, outflow is limited, and the pressure decay occurs over approximately 1.0 s. Thus onset of disk motion occurs some 1.5 s following pipe rupture.

During downward motion of the disk, the disk is initially under the influence of only gravity and spring tension. After traversing an arc of 17.5°, it enters the edge of the main steam flow and induces an ever-increasing ΔP as it swings across the final 47.5° of arc toward closure at the valve seat.

Flow Conditions to be Analyzed

Two steam generator hot standby conditions will be evaluated for disk impact. The flow characteristics for each are summarized as follows:

Case	P_0,PSIA	P_{THROAT},PSIA	Quality,%	Flow, $\frac{LBM}{SEC}$	Stm. Hammer PSI
1	1020	995	Dry & Sat.	2300	300
2	1020	995	4%	7800	150

Upon rupture of the main steam line, choke flow occurs at the break and, concurrently, a pressure rarefaction wave travels upstream, at the local speed of sound, acceleration the initially-stagnant steam toward the break. Initial steam outflow is that which occurs from a 32-in. O.D. pipe at identical initial conditions.

As the rarefaction wave ($C_0 \approx 1771$ ft/s) reaches the 14-in. ∅ flow restrictor, choked flow is established at its throat, limiting steam generator outflow to those flow rates noted above. Because the transition time to choking at the flow restrictor, ≈ 0.12 s, is considerably less than the 1.5-s delay until onset of disk motion, the closing disk will be exposed to only those choked flow rates noted, and not to the initial flow rate in the 32-in. pipe.

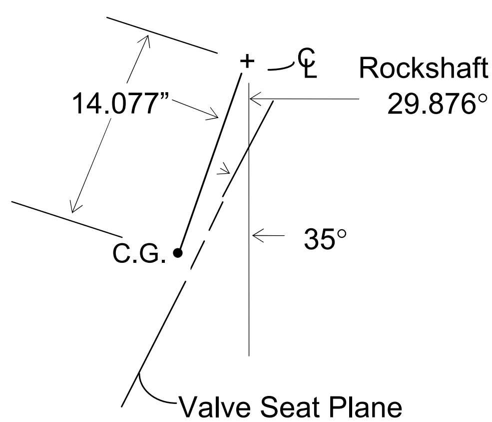
D.1 Swing Disk Trip Valve Characteristics

The following data describe the trip valve:

Weight: Combined weight of the disk, disk post, nut, and disk arm (excluding cyl. segment about rock shaft) is 969 LBM (per A. & M.)

Radius of Gyration, K:

The C.G. of the disk assembly is 16.0 in. from the rockshaft ℄, at an angle of 29.876° to the vertical (per A. & M.)



Moment of Inertia:

$$I = MK^2 \qquad (8)$$

$$I = (969 \text{ LBM})(14.077 \text{ IN})^2 = \underline{\underline{192,019}} \text{ LBM-IN}^2$$

D.2 Relations for Dynamic Analysis During Disk Swing

D.2.1 Disk Equations of Motion

Angular Acceleration:

The angular acceleration of the disk at a given angular displacement is given:

$$\propto = \frac{\Sigma T_{OPCN \bullet \theta}}{I} \tag{1}$$

Angular Velocity:

The angular velocity of the disk at time interval $(t+\Delta t)$ is:

$$W_{t+\Delta t} = W_0 + \propto \Delta t \tag{2}$$

Angular Position:

The angular position of the disk at time t is given:

$$\Delta\theta = W_t \Delta t + \frac{\propto_t \left(\Delta t^2\right)}{2} \tag{3}$$

The disk impact analysis will consider the following disk displacement intervals:

1.	65°	→	47.5°	
2.	47.5°	→	35°	
3.	35°	→	24.5°	(CHOKE $\not<$)
4.	24.5°	→	10°	CHOKED FLOW
5.	10°	→	IMPACT	CHOKED FLOW

For these intervals, average valves of θ, T_{SPRING}, K_θ, & T_{FR} will be used.

D.2.2 Torques Acting on Swing Disk

During angular rotation from its open position (65°) to impact on its seat, the disk is exposed to:

1) Gravitational Torque tending to accelerate the disk to its closed position.

2) Fluid Torque due to the ΔP of steam flowing past the inclining disk.

3) Closing-spring Torque due to compressive load on returning spring.

4) Frictional Torque due to rock shaft rotation within the graphite/asbestos gland packing.

The net torque for various disk angular positions is written:

$65° < \theta < 47.5°$ (4)

$$T_{NET} = I_{\propto} = \left[(M,LBM)(L,IN)\right]\frac{g}{g_o}\ \sin\left(\theta + 29.876\right) + T_{SPRING} - T_{fr}$$

Where:

g = accel of gravity 32 $\frac{FT}{SEC}$

g_o = gravitational constant, 32.2 $\frac{LBM\ FT}{LBF\ SEC^2}$

L = moment arm to C.G., 16. IN

T_{SPRING} = spring load, LBF

T_{fr} = frictional torque, 47.70 in LBF

$47.5° > \theta > 0'$

$$T_{NET} = I_{\propto} = \left[(M,LBM)(L,IN)\right]\frac{g}{g_o}\ \sin\left(\theta + 29.876\right) + T_{SPRING} + \Delta P \bullet A \bullet L - T_{fr} \qquad (5)$$

Where

ΔP = pressure drop across disk

A = surface area of disk MSD normal to ℄

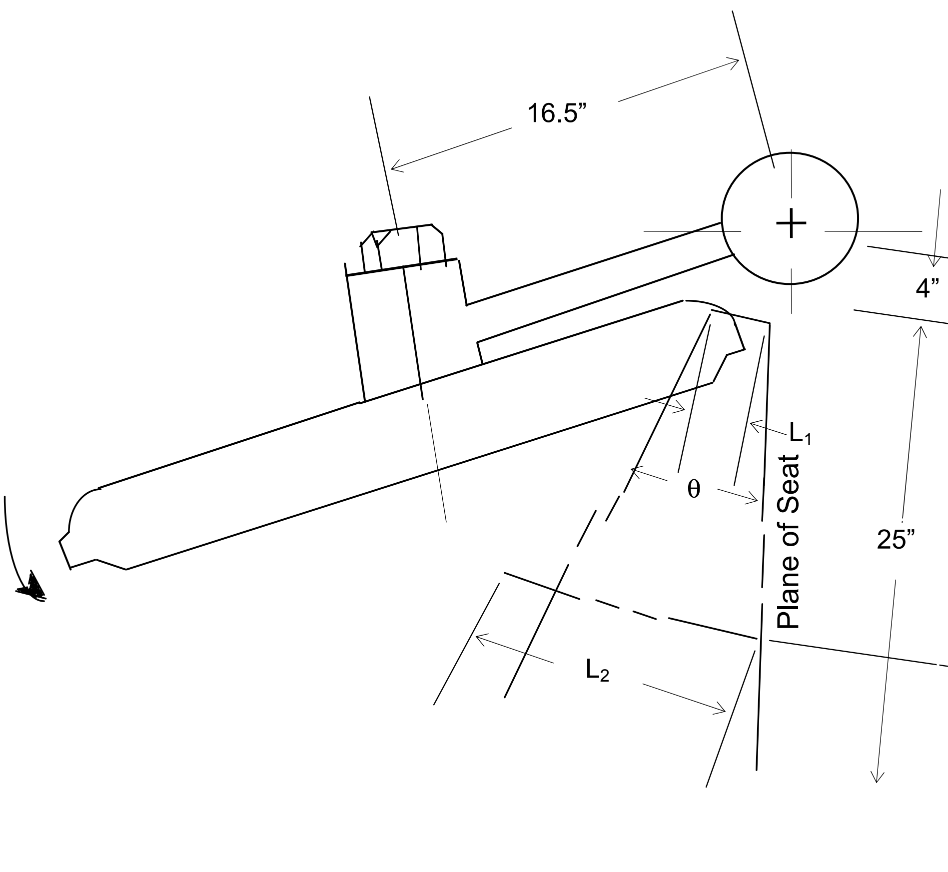
Figure D-1 illustrates the variation of the closing-spring torque for disk displacement angle from its seat.

Choke Angle

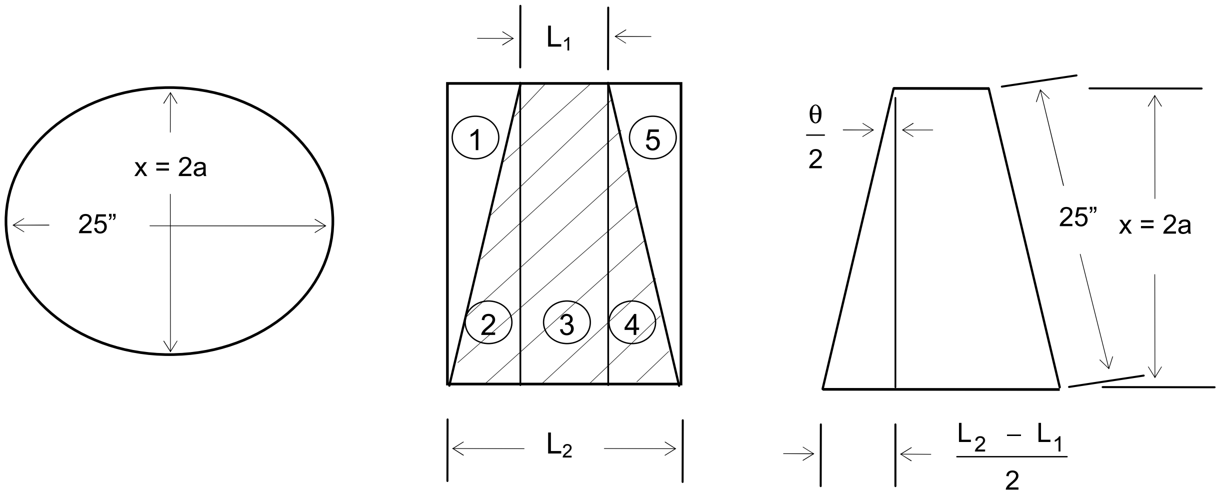
During initial descent of the disk from its open position, choked flow is assumed at the valve seat. At some choke angle, the choke suddenly translates upstream from the valve seat plane to that flow area described between the planes of the disk and seat. Calculations of the choke angle are described in the sheets following.

D.2.3 CALCULATION OF ANGLE FOR ONSET OF CHOKED FLOW DURING CLOSURE OF THE SWING DISK VALVE

An attitude angle for the swing disk trip valve is computed for the onset of choked flow across the closing valve. This condition begins at that instant when the effective orifice area, i.e., that dihedral area between the disk plane and the plane of the valve seat, is exactly equal to the cross-sectional area of flow across the valve seat. As we consider the effective flow area, we must consider the elliptical surface area defined by the intercepting “chords” as shown below.



θ	L_1	L_2
10°	0.697”	5.055”
20°	1.3892”	10.0716”
30°	2.0706”	15.012”



<u>θ = 10° From Seat</u>

$$\cos\frac{\theta}{2} = \frac{x}{25}$$

$$x = 25\cos 5^\circ = 24.905''$$

$$A_T = C \times L_2$$

$$= 2\pi\sqrt{\frac{a^2+6^2}{2}} \times L2 = 2\pi\sqrt{\frac{12.452^2+12.5^2}{2}} \times 5.055$$

$$A_T = (78.391)(5.055) = 396.26 \text{ in.}^2$$

Now: $A_3 = C \times L_1 = (78.391)(0.697) = 54.639 \text{ in.}^2$

$$\therefore A_{1,2,4,5} = \frac{396.26\ \text{IN}^2 - 54.639\ \text{in.}^2}{4} = 85.405\ \text{in.}^2$$

$$\therefore A_{2+3+4} = 54.639 + 2(85.405) = \underline{\underline{225.45}}\ \text{in.}^2$$

<u>20° From Seat</u>

$$\cos\frac{\theta}{2}=\frac{x}{25}$$

$$x = 25 \cos 10° = 24.62''$$

$$A_T = c \times L_2 = 2\pi \sqrt{\frac{12.31^2+12.5^2}{2}}\times 10.072$$

$$A_T = (77.945)(10.072) = 785.06 \text{ in.}^2$$

NOW: $A_3 = (77.945)(1.3892) = 108.28 \text{ in.}^2$

$$A_{1,2,4,5} = \frac{785.06-108.28}{4} = 169.194 \text{ in.}^2$$

$$\therefore A_{2+3+4} = 108.28 + 2(169.194) = \underline{\underline{446.67}} \text{ in.}^2$$

<u>30° From Seat</u>

$$x = 25 \cos 15° = 24.148''$$

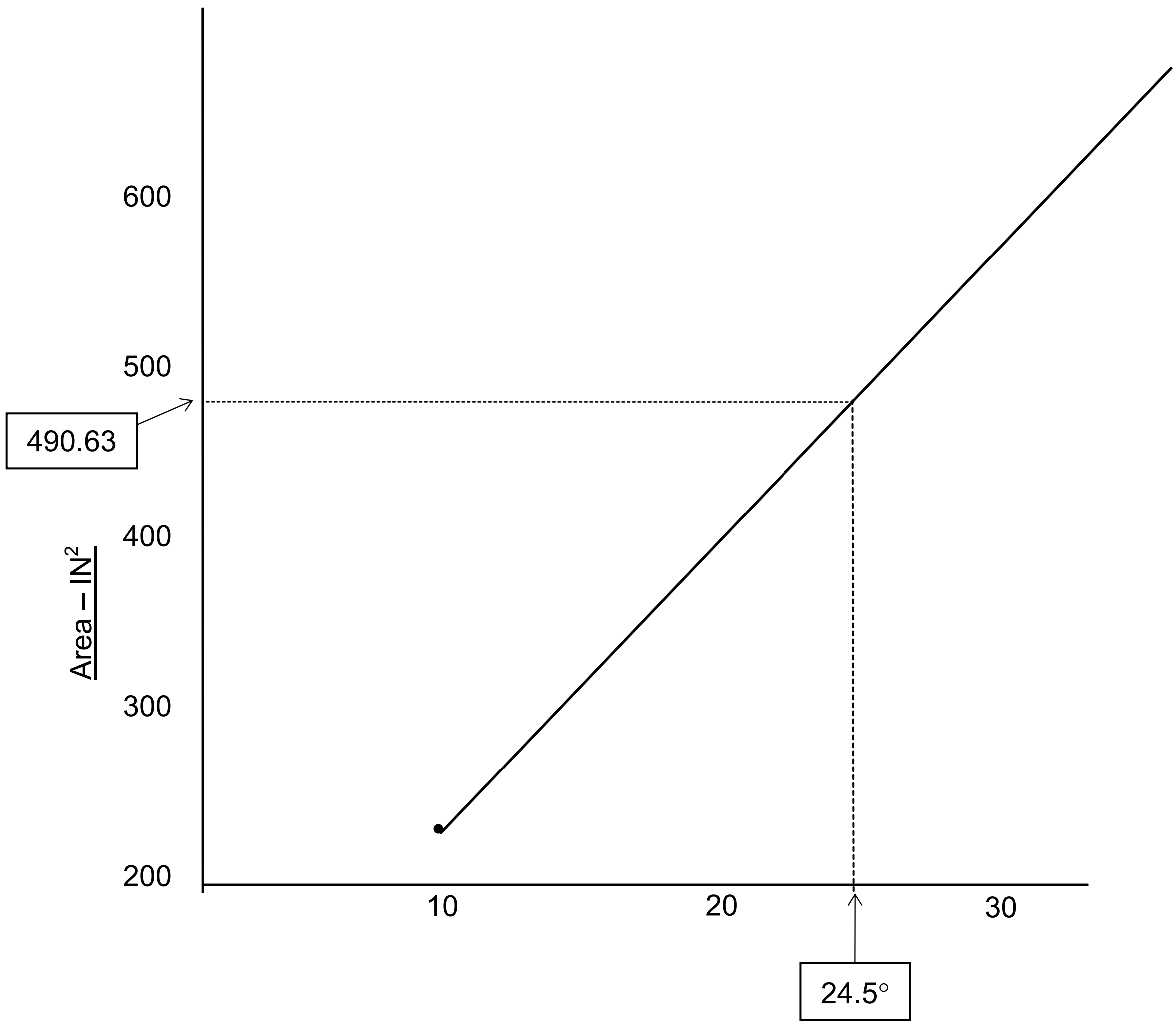
$$A_T = 2\pi \sqrt{\frac{12.074^2+12.5^2}{2}}\times 15.012$$

$$A_T = (77.213)(15.012) = 1159.123 \text{ in.}^2$$

$$A_3 = C \times L_1 = (77.213)(2.0706) = 159.88 \text{ in.}^2$$

$$A_{1,2,4,5} = \frac{1159.123-159.88}{4} = 249.81 \text{ in.}^2$$

$$\therefore A_{2+3+4} = 159.88 + 2(249.81) = \underline{\underline{659.50}} \text{ in.}^2$$



DIHEDRAL ANGLE θ ~ DEGREES

$$A_{seat} = 0.785(25)^2 = 490.63\ in^2$$

From the above we conclude that the choking angle is 24.5°.

D.3 Fluid Flow Equations/Dynamic Analysis

D.3.1 Case 1

Initial condition is Hot Standby, zero flow in the main steam line. Valve disk is held at 65° open-position by 100-psig cylinder air. The steam generator and 32-in. piping upstream of the valve are taken as an infinite reservoir at 1020 psia.

Steam Properties are[1]:

P_o = 1020 PSIA (Dry Saturated Steam)

T_o = 546.95 °F

$$W_o = 0 \ \frac{\text{LBM}}{\text{SEC}}$$

$$h_g = 1191.6 \ \frac{\text{BTU}}{\text{LBM}}$$

$$s_g = 1.3879 \ \frac{\text{BTU}}{\text{LBM}^2}$$

$$\upsilon_g = 0.4361 \ \frac{\text{FT}^3}{\text{LBM}}$$

γ = 1.13[2]

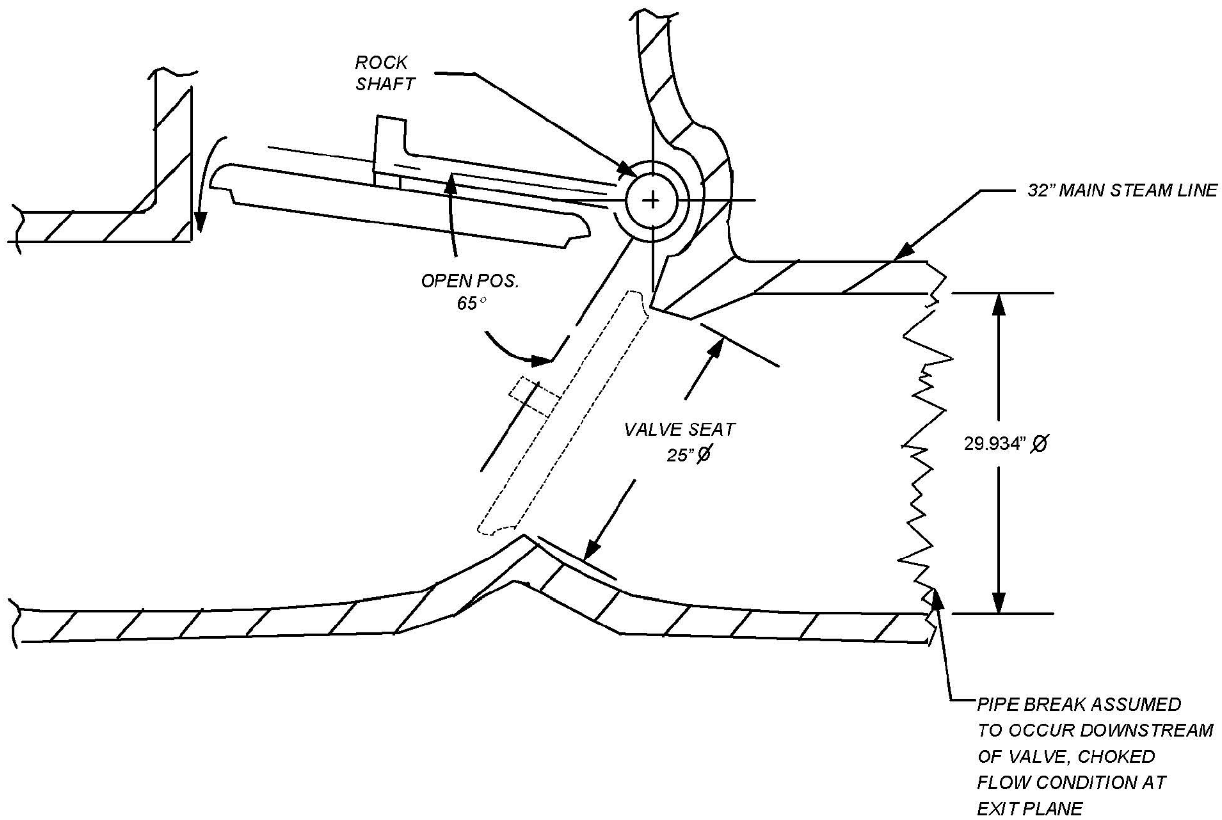
Sonic Velocity:

$$C_o = \sqrt{\text{KRTg}} \qquad (6)$$

$$C_o = \sqrt{(1.13)(85.6)(546.95 + 460)(32.2)} = \underline{\underline{1770.9}} \ \frac{\text{FT}}{\text{SEC}}$$

1. J.Keenan & F.Keyes, Thermodynamic Properties of Steam, John Wiley & Sons, First Edition, 31st Printing, N.Y.

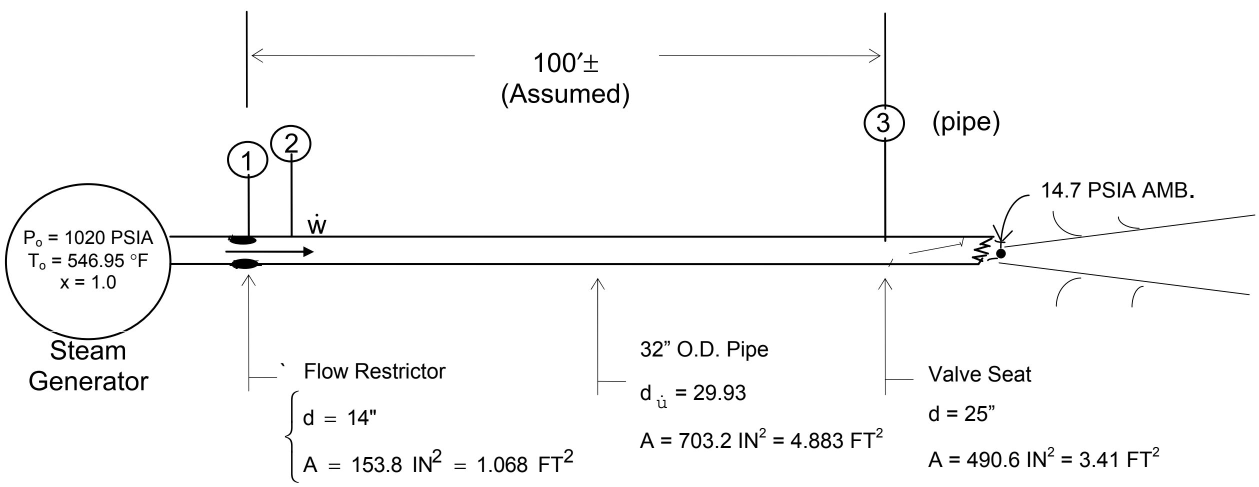
$\therefore$ The velocity of propagation of the pressure rarefaction wave is 1770.9 $\frac{\text{ft}}{\text{sec}}$.



Upon rupture of the pipe, choked flow is established immediately at the break plane. This continues during travel of the pressure rarefaction (at 1771 $\frac{\text{FT}}{\text{SEC}}$) to the flow restrictor which then limits the steam outflow to the break. To determine flow conditions at the valve we must consider the flow path between the flow restrictor and valve such that all flow characteristics are considered. Steady state flow conditions are assumed at onset of disk.

Hall and Orme[3] have investigated the flow of compressible fluid thru sudden enlargements, and the effects of friction upon M (mach no.), P, T, and m. As a first approximation we may consider the nozzle/pipe junction a sudden enlargement, and use the results of this analysis to establish steam flow conditions at the valve.

Consider the following pipe configuration:



To determine flow conditions at each location, ①, ②, and ③, we start at the steam generator, progressing downstream toward the valve.

2. Ichoro Nishiwaki, " On a new theory for Adiabatic Index of Wet Steam," Proc. of 11th Japan National Congress for Appl. Mechs, 1961.

3. W. B. Hall, E. M. Orme, "Flow of a Compressible Fluid Through a Sudden Enlargement in a Pipe," Proc. of Inst. of Mech. Engrs., 1955, Vol. 169, No. 49, pp. 1007-1020.

Mach Numbers, M

As choked flow is established across the nozzle, $M_1 = 1$. Using FIG 7 of ref. 3, and an area ratio, ϕ, where:

$$\frac{A_{nozz}}{A_{pipe}} = \phi = \frac{153.8\ IN^2}{703.2\ IN^2} = 0.219 \tag{7}$$

we obtain $M_2 = 0.2$.

The friction loss between sections ② and ③ along the constant diameter pipe is given:

$$F_f = \frac{f\gamma x}{d_H} \tag{8}$$

Where f = Friction Factor - for turbulent flow conditions in 32" pipe- use 0.01

γ = Ratio specific heats = 1.13

x = Pipe length ≈ 100 FT

d_H = Hydraulic D/A = 29.93" = 2.494′

Solving EQ.(2):

$$F_f = \frac{(0.01)(1.13)(100\ FT.)}{2.494\ FT} = 0.453$$

Entering Fig 8 at $M_2 = 0.2$, with $F_f = 0.453$, we obtain $M_3 = 0.21$.

Pressure Distribution

Using M_1, P_o, and γ and by assuming adiabatic, frictionless flow into the nozzle we compute P_1 (Eq. 12)[3]:

$$\frac{P_o}{P_1} = \left[\frac{\gamma - 1}{2} M_1^{\,2} + 1\right]^{\frac{\gamma}{\gamma - 1}} \tag{9}$$

$$\frac{P_o}{P_1} = \left[\frac{1.13-1}{2}(1)^2 + 2\right]^{\frac{1.13}{1.13-1}} = 1.729$$

$\therefore P_1 = 0.578\ P_o = 590$ PSIA

Using EQ.(9)[3] we now compute P_2:

$$\frac{P_2}{P_1} = \phi \frac{M1}{M2}\sqrt{\frac{(\gamma-1)M_1{}^2 + 2}{(\gamma-1)M_2{}^2 + 2}} \tag{10}$$

Substituting:

$$\frac{P_2}{P_1} = 0.219\frac{1.0}{0.2}\sqrt{\frac{(1.13-1)(1)^2 + 2}{(1.13-1)(0.2)^2 + 2}}$$

$$\frac{P_2}{P_1} = 1.13$$

$\therefore P_2 = (1.13)(.590) = \underline{\underline{665.9}}$ PSIA

Again using EQ.(9)[3] compute P_3 : ($\phi = 1$)

$$\frac{P_3}{P_2} = 1\frac{0.2}{0.21}\sqrt{\frac{(1.13-1)(0.2)^2 + 2}{(1.13-1)(0.21)^2 + 2}}$$

$$\frac{P_3}{P_2} = 0.952$$

$\therefore P_3\ (0.952)(665.9) = \underline{\underline{634}}$ PSIA

For a pipe rupture in close proximity to the valve, the flow chokes at the break, flowing at local sonic velocity. The pressure at the exit plane must correspond to the local sonic conditions.

If, in a limiting case, the break occurs downstream and adjacent to the valve seat, the flow chokes at the valve seat, and M = 1.0, rather than 0.21 as calculated above. In this case EQ. 11 of REF. 3 may be used to solve for the critical pressure at the seat.

Solving:

$$\left(\frac{\gamma-1}{2}\right)M^4 + M^2 - \frac{T\sigma\left(W/A\right)^2 R}{\gamma P^2} = 0 \tag{11}$$

$$\frac{(1.13-1)(1)^4 + 1^2}{2} - \frac{(1007°R)\left(\frac{2300}{3.41}\frac{LBM}{SEC\,FT^2}\right)^2\left(85.6\frac{FT-LBF}{LBM-°R}\right)}{(1.13)\left(P\frac{LBF}{FT^2}\right)^2\left(32.2\frac{LBM\,FT}{LBF\,SEC^2}\right)\left(144^2\frac{IN^4}{FT^4}\right)}$$

$$1.065 - \frac{51974.6}{P^2} = 0$$

P = 220.9 or $\underline{\underline{221}}$ PSIA

From steam tables, at x = 10

$$\nu_g = 2.096\ \frac{FT^3}{LBM}$$

Solving for flow velocity:

$$V = \frac{Q}{A} = \frac{\left(2300\frac{LBM}{SEC}\right)\left(2.096\frac{FT^3}{LBM}\right)}{3.41 FT^2}$$

$$V = \underline{\underline{1414}}\ \frac{FT}{SEC}$$

This velocity is now used in ΔP calculations up thru onset of choking.

Summarizing Flow Conditions

P = 221 PSIA

ν = 2.096 $\frac{FT^3}{LBM}$

x = 1.0

$$W = 2300 \ \frac{LBM}{SEC}$$

$$v = 1414 \ \frac{FT}{SEC}$$

Pressure Drop Across Disk

Pressure drop across the closing disk varies as a function of the included angle between the disk plane and the plane of the valve seat.

For a given θ, pressure drop across the valve is:

$$\Delta P = K_\theta \frac{\int v^2}{2g} \qquad (12)$$

Where K_θ = Empirical value dependent upon θ (per A. & M. data), Fig 3-2

$\int$ = Fluid density, taken as $\frac{1}{v} = \frac{1}{0.7271 \, FT^3 / LBM} = 1.375 \frac{LBM}{FT^3}$

v = Steam velocity upstream of valve seat = 1414 $\frac{FT}{SEC}$

Solving EQ. (6):

$$\Delta P = K_\theta \frac{\left(\frac{1}{2.096}\frac{LBM}{FT^3}\right)\left(1414\frac{FT}{SEC}\right)^2}{(2)\left(32.2\frac{LBM\,FT}{LBF\,SEC^2}\right)\left(144\frac{IN^2}{FT^2}\right)}$$

$$\underline{\underline{\Delta P = 102.9 \, K_\theta}} \qquad (13)$$

Atwood & Morrill data for K_θ are shown in FIG. 3-2.

1. $65° > \theta > 47.5°$ (Free Fall w/Spring Friction)

$$\Delta P = 0$$

T_1, From EQ. (9):

$$T_1 = [(969\ LBM)(14.077\ IN)]\frac{32\ FT}{SEC^2} \times \frac{LBF\ SEC^2}{32\ LBM\ FT} \sin(56.25° + 29.876°)$$

$$+ 10658\ IN.\ LBF - 4770\ IN.\ LBF$$

$$T_1 = 13609 + 10658 - 4770 = 19{,}497\ IN.\ LBF$$

$\propto_1$: $$\propto_1 = \frac{T_1}{I} = \frac{19{,}497\ IN.LBF}{192{,}019\ LBM - IN.^2} \times \frac{32\ LBM - FT}{LBF\ SEC^2} \times \frac{12\ IN.}{FT}$$

$$\propto_1 = 39.2\ \frac{RAD}{SEC^2}$$

t_1: Since disk is accelerated from W = 0_9 by EQ.13:

$$\Delta\theta = \frac{\propto_1 t_1^2}{2}$$

$$t_1 = \sqrt{\frac{2\Delta\theta}{\propto_1}} = \sqrt{\frac{(2)}{39.2}\frac{(17.5)}{57.3}} = 0.125\ SEC$$

W_1: $$W_1 = \propto_1 t_1$$

$$W_1 = \left(39.2\frac{RAD}{SEC^2}\right)(0.125\ SEC) = 4.90\frac{RAD}{SEC}$$

2. $47.5° > \theta > 35°$ ("Caught in Breeze" @ θ = 47.5°)

$$\propto_1 = 39.2\ \frac{RAD}{SEC^2},\ t_1 = 0.125\ SEC,\ W_1 = 4.90\ \frac{RAD}{SEC}$$

ΔP_2: $\Delta P = 102.9\ K_{\bar{\theta}} = (102.9)(1.41) = \underline{\underline{145.1}}$ PSI

T_2: $$T_2 = [(969\ LBM)(14.077\ IN)]\frac{32}{32}\sin(41.25 + 29.876)$$

$$+ \left(145.1\frac{LBF}{IN^2}\right)(490.6\ IN^2)(16.5\ IN) + 9128\ IN.\ LBF$$

$$- 4770\ IN\ LBF$$

T_2 = 12,996 + 1,174,481 + 9128 - 4770 = 1,191,835 IN - LBF

$\propto_2$: $\propto_2 = \frac{T_2}{I} = \frac{1{,}191{,}835 \ \text{IN}-\text{LBF}}{192{,}019 \ \text{LBM}-\text{IN}^2} \times \frac{32 \ \text{LBM FT}}{\text{LBF SEC}^2} \times \frac{12 \ \text{IN}}{\text{FT}}$

$\propto_2 = \underline{\underline{2398}} \ \frac{\text{RAD}}{\text{SEC}^2}$

Δt_2: $\Delta\theta_2 = W_1 \Delta t_2 + \frac{\propto_2 (\Delta t_2)^2}{2}$

$$\frac{12.5}{57.3} = 4.90 \Delta t_2 + \frac{2398 \Delta t_2^{\ 2}}{2}$$

Solving:

$\Delta t_2^2 + 0.00409 \Delta t_2 - 0.00018 = 0$

$$\Delta t_2 = \frac{-0.00409 + \sqrt{(0.00409)^2 + 4(1)(0.00018)}}{2}$$

$\Delta t_2 = \underline{\underline{0.0116}}$ SEC.

$\therefore$ Disk travels thru ARC 47.5° $\rightarrow$ 35° IN. 0.0116 SEC

W: $W_2 = W_1 + \propto_2 \Delta t_2$

$$W_2 = 4.90 \ \frac{\text{RAD}}{\text{SEC}} + \left(2398 \frac{\text{RAD}}{\text{SEC}^2}\right)(0.0112 \ \text{SEC}) = \underline{\underline{32.7}} \ \frac{\text{RAD}}{\text{SEC}}$$

$\sum t$: $\sum t = t_1 + \Delta t_2 = 0.125 + 0.0116 = \underline{\underline{0.1364}}$ SEC.

3. 35° $\rightarrow$ 24.5°

$$\propto_2 = 2398 \ \frac{\text{RAD}}{\text{SEC}^2} W_2 = 32.7 \frac{\text{RAD}}{\text{SEC}} \Sigma t = 0.1364 \ \text{SEC}$$

ΔP_3: $\Delta P_3 = 102.9\ K_{\bar{\theta}} = (102.9)(3.5) = \underline{\underline{360.2}}$ PSI

T_3: $$T_3 = \left[(969\ \text{LBM})(14.077\ \text{IN})\right]\frac{32}{32}\sin(29.75 + 29.876) + \left(360.2\frac{\text{LBF}}{\text{IN}^2}\right)\left(490.6\ \text{IN}^2\right)(16.5\ \text{IN}) + 7955\ \text{IN LBF} - 4770\ \text{IN LBF}$$

$$T_3 = 11{,}813 + 2{,}915{,}378 + 7955 - 4770 = \underline{\underline{2{,}930{,}376}}\ \text{IN -LBF}$$

$\propto_3$: $$\propto_3 = \frac{T_3}{I} = \frac{2{,}930{,}376\ \text{IN} - \text{LBF}}{192{,}019\ \text{LBM} - \text{IN}^2} \times \frac{32\ \text{LBM FT}}{\text{LBF SEC}^2} \times \frac{12\ \text{IN}}{\text{FT}}$$

$$\propto_3 = \underline{\underline{5898}}\ \frac{\text{RAD}}{\text{SEC}^2}$$

Δt_3: $$\Delta\theta_3 = W_2\Delta t_3 + \frac{\propto_3 (\Delta t_3)^2}{2}$$

$$\frac{10.5}{57.3} = 32.7\ \Delta t_3 + \frac{5898 \Delta t_3^{\ 2}}{2}$$

$$\Delta t_3^2 + 0.0111\ \Delta t_3 - 0.000062 = 0$$

$$\Delta t_3 = \frac{-0.0111 + \sqrt{(0.0111)^2 + 4(1)(0.000062)}}{2}$$

$$\Delta t_3 = 0.00409\ \text{SEC.}\ (35° \rightarrow 24.5°)$$

$$\therefore \Sigma t = 0.1364 + 0.00409 = \underline{\underline{0.1405}}\ \text{SEC.}$$

W_3: $$W_3 = W_2 + \propto_3 \Delta t_3$$

$$W_3 = 32.7\ \frac{\text{RAD}}{\text{SEC}} + \left(5898\frac{\text{RAD}}{\text{SEC}^2}\right)(0.00409\ \text{SEC})$$

$$W_3 = \underline{\underline{56.8}}\ \frac{\text{RAD}}{\text{SEC}}$$

4. $24.5° \rightarrow 10°$

Onset of choking (across the Dihedral Angle between the disk and seat) occurs at θ_c = 24.5°. Prior to reaching θ_c, the closing disk has caused considerable pressure regain in the line. Add. 9 to Bechtel Inquiry SS-1102-32 specifies that, for case 1, the static pressure at the valve minimum flow area, with atmospheric pressure downstream, is 995 PSIA. Since choking occurs, we conservatively compute ΔP across the disk.

$$\Delta P_{CHOKE} = P_U - 0.578\ P_U$$

$$\Delta P_{CHOKE} = 995 - 0.578\ (995) = \underline{\underline{419.9}}\ \text{PSID}$$

T_4:

$$T_4 = \left[(969\ \text{LBM})(14.077\ \text{IN})\right]\frac{32}{32}\sin(17.25 + 29.876) + \left(419.9\frac{\text{LBF}}{\text{IN}^2}\right)\left(490.6\ \text{IN}^2\right)(16.5\ \text{IN}) + 6680\ \text{IN LBF} - 4770\ \text{IN LBF}$$

$$T_4 = 9996 + 3{,}399{,}049 + 6680 - 4770 = 3{,}410{,}955\ \text{IN LBF}$$

$\propto_4$:

$$\propto_4 = \frac{T_4}{I} = \frac{3{,}410{,}955\ \text{IN LBF}}{192{,}019\ \text{LBM} - \text{IN}^2} \times \frac{32\ \text{LBM FT}}{\text{LBF SEC}^2} \times \frac{12\ \text{IN}}{\text{FT}}$$

$$\propto_4 = \underline{\underline{6863.9}}\ \frac{\text{RAD}}{\text{SEC}^2}$$

Δt_4:

$$\Delta\theta_4 = W_3 \Delta t_4 + \frac{\propto_4 (\Delta t_4)^2}{2}$$

$$\frac{14.5}{57.3} = 56.8\Delta t_4 + \frac{6863\Delta t_4^{\ 2}}{2}$$

Solving:

$$\Delta t_4^2 + 0.0166\ \Delta t_4 - 0.000074 = 0$$

$$\Delta t_4 = \frac{-0.0166 + \sqrt{(0.0166)^2 + 4(1)(0.0000674)}}{2}$$

$$\Delta t_4 = 0.0036\ \text{SEC} \qquad (24.5° \rightarrow 10°)$$

$\Sigma t = 0.1405 + 0.0036 = \underline{\underline{0.1441}}$ SEC

W_4 $\quad W_4 = W_3 + \propto_4 \Delta t_4$

$W_4 = 59.5 + (7539.6)(0.0035)$

$W_4 = \underline{\underline{81.9}} \dfrac{RAD}{SEC}$

5. $10° \rightarrow$ IMPACT

As noted above, the ΔP across the disk during choke conditions is 419.9 PSID. Addendum #8 also specifies a pressure rise due to steam hammer on the disk of +300 PSI. At the moment of impact, then, the instantaneous pressure on the disk is:

$\Delta P_{IMPACT} = 419.9 + 300 = 719.9$ PSI

The average ΔP during the last 10° of motion is:

$$P_{AVG} = \frac{419.9 + 719.9}{2} = \underline{\underline{569.9}} \text{ PSI}$$

T_5: $\quad T_5 = [(969 \text{ LBM})(14.077 \text{ IN})]\dfrac{32}{32}\sin(5 + 29.876) +$

$$\left(569.9\frac{LBF}{IN^2}\right)\left(490.6 \text{ IN}^2\right)(16.5 \text{ IN}) + 5430 \text{ IN} - \text{LBF} - 4770 \text{ IN LBF}$$

$T_5 = 6203 + 4{,}613{,}284 + 5430 - 4770 = 4{,}621{,}743$ IN LBF

$\propto_5$: $\quad \propto_5 = \dfrac{T_5}{I} = \dfrac{4{,}621{,}743 \text{ IN LBF}}{192{,}019 \text{ LBM} - \text{IN}^2} \times \dfrac{32 \text{ LBM FT}}{\text{LBF SEC}^2} \times 12\dfrac{IN}{FT}$

$\propto_5 = 9{,}300 \dfrac{RAD}{SEC^2}$

Δt_5: $\quad \Delta\theta_5 = W_4 \Delta t_5 + \dfrac{\propto_5 (\Delta t_5)^2}{2}$

$$\frac{10}{57.3} = 81.9\Delta t_5 + \frac{(9{,}300)(\Delta t_5)^2}{2}$$

$\Delta t_5^2 + 0.0176\ \Delta t_5 - 0.0000375 = 0$

$$\Delta t_5 = \frac{-0.0176 + \sqrt{(0.0176)^2 + 4(1)(0.0000375)}}{2}$$

$\Delta t_5 = 0.0019$ SEC.

$\Sigma t = 0.1441 + 0.0019 = \underline{0.1460}$ SEC.

W_5: $W_5 = W_4 + \propto_5 \Delta t_5$

$W_5 = 81.9 + (9{,}300)(0.0019)$

$$W_5 = \underline{\underline{99.8}}\ \frac{\text{RAD}}{\text{SEC}}$$

Summarizing, upon disk impact:

$$\propto_{IMP} = \underline{\underline{9{,}300}}\ \frac{\text{RAD}}{\text{SEC}^2}$$

$$W_{IMP} = \underline{\underline{99.8}}\ \frac{\text{RAD}}{\text{SEC.}}$$

$\Sigma t_{IMP} = 0.1460$ SEC.

$$V_{IMP} = \frac{99.8\ \text{RAD}}{\text{SEC}} \times 14.077\ \text{IN} = \underline{\underline{1404}}\ \frac{\text{IN}}{\text{SEC}} = \underline{\underline{117.0}} = \frac{\text{FT}}{\text{SEC}}$$

D.3.2 Case 2

Case 2 differs from Case 1 in that a 4% steam-water mixture, rather than dry saturated steam, flows at 7800 LBM/SEC. This represents a 2-phase blowdown across the valve. In this case the initial fluid condition is taken as saturated water at 1020 PSIA. During passage of the water through the pipe, the pressure drop results in reduced temperature and enthalpy. The reduction in enthalpy is manifested as latent heat of vaporization of the water, resulting in vapor formation within the liquid. The mixture quality on crossing the valve is 4%.

The critical pressure at the break exit plane is given by Griffith[4] as a function of pipe L/D ratio. Taking L = 100 FT, and D = 29.93 inches, we obtain:

$$\frac{L}{D} = \frac{100\ \text{FT}}{29.93/12\ \text{FT}} = 40$$

Referring to Fig. III - 2 of Ref. 4, we obtain:

$$\frac{P_c}{P_o} = 0.55$$

$\therefore P_c$ = 0.55 (1020 PSIA) = 561 PSIA.

Summarizing flow conditions:

P_c = 561 PSIA

T_c = 479 °F

x = 0.04

$\nu = \nu_f + x\nu_{fg} = 0.020 + (0.04)(0.8250) = 0.053\ \frac{\text{FT}^3}{\text{LBM}}$

$w = 7800\ \frac{\text{LBM}}{\text{SEC}}$ (assumed choked by flow restrictor)

Since the break location is unspecified, we may work upstream to estimate the pressure variation. Assume L = 10; D = 29.93″, f = 0.011; solve for V and ΔP:

$$V = \frac{Q}{A} = \frac{\left(7800\frac{\text{LBM}}{\text{SEC}}\right)\left(0.053\frac{\text{FT}^3}{\text{LBM}}\right)}{4.883\ \text{FT}^2} = 84.7\frac{\text{FT}}{\text{SEC}}$$

$$\Delta P = f\frac{L}{D}\frac{\rho V^2}{2g} \qquad (14)$$

4. P. Griffith, “Choked Two Phase Flow,” Mass. Inst. of Technology, Cambridge, Mass. Unpublished Report.

$$\Delta P = (0.011)\left(\frac{10\ FT}{\frac{29.93}{12}FT}\right)\frac{\left(\frac{LBM}{0.053\ FT^3}\right)\left(84.7\frac{FT}{SEC}\right)^2}{(2)\left(32.2\frac{LBM\ FT}{LBF\ SEC^2}\right)\left(144\frac{IN^2}{FT^2}\right)}$$

ΔP = 0.64 PSI (Does not include density variation)

Therefore for a short length between the break and valve, the pressure may conservatively be taken as P_c of 561 PSIA.

As in Case 1, we again use the valve seat area as the representative valve flow area.

$$\therefore V = \frac{Q}{A} = \frac{\left(7800\frac{LBM}{SEC}\right)\left(0.053\frac{FT^3}{LBM}\right)}{3.41\ FT^2}$$

$$V = \underline{\underline{121.2}}\ \frac{FT}{SEC}$$

For Case 2 we use identical relations for torques, inertia, weight, and equations of motion. EQ. (12) is used to obtain a new ΔP relation:

$$\Delta P = K_\theta \frac{\rho V^2}{2g}$$

$$\Delta P = \frac{K_\theta\left(\frac{LBM}{0.053\ FT^3}\right)\left(121.2\frac{FT}{SEC}\right)^2}{(2)\left(32.2\frac{LBM FT}{LBF\ SEC^2}\right)\left(144\frac{IN^2}{FT^2}\right)}$$

$$\underline{\underline{\therefore \Delta P = 29.9K_\theta}}$$

As earlier, A. & M. data in Fig. 3-2 are used for K_θ.

1. $65^\circ > \theta > 47.5^\circ$ (Free fall w/spring, friction)

$\Delta P = 0$

As all disk mass, spring and friction constants are identical to those used for Case 1, we use those results directly.

$T_1 = 19{,}497 \text{ IN LBF}$

$\propto_1 = 39.2 \dfrac{\text{RAD}}{\text{SEC}^2}$

$t_1 = 0.125 \text{ SEC}$

$W_1 = 4.90 \dfrac{\text{RAD}}{\text{SEC}}$

2. $47.5° > \theta > 35°$ (Caught in "Breeze" at $\theta = 47.5°$)

ΔP_2: $\Delta P_2 = 29.9\, K_{\bar{\theta}} = (29.9)(1.41) = \underline{\underline{42.2}} \text{ PSI}$

T_2:

$$T_2 = \left[(969 \text{ LBM})(14.077 \text{ IN})\right]\frac{32}{32}\sin(41.25 + 29.876) + \left(42.2\frac{\text{LBF}}{\text{IN}^2}\right)\left(490.6 \text{ IN}^2\right)(16.5 \text{ IN}) + 9128 \text{ IN - LBF} - 4770 \text{ IN LBF}$$

$$T_2 = 13{,}239 + 341{,}273 + 9128 - 4770$$

$$T_2 = \underline{\underline{358{,}870}} \text{ IN - LBF}$$

$\propto_2$:

$$\propto_2 = \frac{T_2}{I} = \frac{358{,}850}{192{,}019} \times \frac{32 \text{ LBM FT}}{\text{LBF SEC}^2} \times \frac{12 \text{ IN}}{\text{FT}}$$

$$\propto_2 = \underline{\underline{722.2}} \frac{\text{RAD}}{\text{SEC}^2}$$

Δt_2:

$$\Delta\theta_2 = W_1\, \Delta t_2 + \frac{\propto_2 (\Delta t_2)^2}{2}$$

$$\frac{12.5}{57.3} = 4.90 \Delta t_2 + \frac{722.2(\Delta t_2)^2}{2}$$

Solving

$$\Delta t_2^2 + 0.0136\ \Delta t - 0.00060 = 0$$

$$\Delta t_2 = \frac{-0.0136 + \sqrt{(0.0136)^2 + 4(1)(0.00060)}}{2}$$

$$\Delta t_2 = \underline{\underline{0.0187}}\ \text{SEC}$$

W_2: $$W_2 = W_1 + \propto_2 \Delta t_2$$

$$W_2 = 4.90 + (722.2)(0.0187) = 18.4\ \frac{\text{RAD}}{\text{SEC}}$$

Σt: $$\Sigma t = 0.125 + 0.0187 = \underline{\underline{0.1435}}\ \text{SEC}$$

3. $35^\circ \rightarrow 24.5^\circ$

$$\propto_2 = 722.2\ \frac{\text{RAD}}{\text{SEC}^2} W_2 = 18.4 \frac{\text{RAD}}{\text{SEC}} \Sigma t_2 = 0.1435\ \text{SEC.}$$

ΔP_3: $$\Delta P_3 = 29.9\ K_\theta = (29.9)(3.5) = 104.7\ \text{PSI}$$

T_3: $$T_3 = \left[(969\ \text{LBM})(14.077\ \text{IN})\right]\frac{32}{32}\sin(29.75 + 29.876)$$

$$+ \left(104.7\frac{\text{LBF}}{\text{IN}^2}\right)\left(490.6\ \text{IN}^2\right)(16.5\ \text{IN}) + 7955\ \text{IN LBF} - 4770\ \text{IN LBF}$$

$$T_3 = 12{,}173 + 847{,}131 + 7955 - 4770 = \underline{\underline{862{,}489}}\ \text{IN LBF}$$
-4770 IN LBF

$\propto_3$: $$\propto_3 = \frac{T_3}{I} = \frac{862{,}489\ \text{IN LBF}}{192{,}019\ \text{LBM} - \text{IN}^2} \times 32\frac{\text{LBM FT}}{\text{LBF SEC}^2} \times \frac{12\ \text{IN}}{\text{FT}}$$

$$\propto_3 = \underline{\underline{1736}}\ \frac{\text{RAD}}{\text{SEC}^2}$$

Δt_3: $$\Delta\theta_3 = W_2\ \Delta t_3 + \frac{\propto_3 (\Delta t_3)^2}{2}$$

$$\frac{10.5}{57.3} = 18.9\Delta t_3 + \frac{(1736)\Delta t_3^{\,2}}{2}$$

$$\Delta t_3^{\,2} + 0.02\ \Delta t_3 - 0.000211 = 0$$

$$\Delta t_3 = \frac{-0.02 + \sqrt{(0.02)^2 + 4(1)(0.000211)}}{2}$$

$$\Delta t_3 = \underline{\underline{0.0074}}\ \text{SEC}$$

$$\therefore\ \Sigma t = 0.1435 + 0.0074 = \underline{\underline{0.1509}}\ \text{SEC}$$

W_3: $\quad W_3 = W_2 + \propto_3 \Delta t_3$

$$W_3 = 18.4 + (1736)(0.0074)$$

$$W_3 = \underline{\underline{31.2}}\ \frac{\text{RAD}}{\text{SEC}}$$

4. $24.5° \rightarrow 10°$

As discussed in Case 1, onset of choking across the disk occurs at $\theta = 24.5°$. Addendum 9 states (as for Case 1) that the static pressure at the valve minimum flow area, with atmospheric pressure downstream, is 995 PSIA. Repeating the Case 1 calculation with $\frac{P_c}{P_o} = 0.55$

$$\Delta P_{CHOKE} = P_u - 0.55\ P_u$$

$$\Delta P_{CHOKE} = 995 - 0.55\ (995) = \underline{\underline{448}}\ \text{PSID}$$

$$\propto_3 = 1736\ \frac{\text{RAD}}{\text{SEC}^2} W_3 = 31.2 \frac{\text{RAD}}{\text{SEC}} \Sigma t_3 = 0.1509\ \text{SEC.}$$

T_4

$$T_4 = [(969\ \text{LBM})(14.077\ \text{IN})]\frac{32}{32}\sin(17.25 + 29.876) + 448(490.6\ \text{IN}^2)(16.5\ \text{IN}) + 6680\ \text{IN-LBF} - 4770\ \text{IN LBF}$$

$$T_4 = 9996 + 3{,}626{,}515 + 6680 - 4770$$

$$T_4 = \underline{\underline{3{,}638{,}421}}\ \text{IN LBF}$$

$\propto_4$: $\quad \propto_4 = \frac{T4}{I} = \frac{3{,}638{,}421\ \text{IN LBF}}{192{,}019\ \text{LBM} - \text{IN}^2} \times 32 \frac{\text{LBM FT}}{\text{LBF SEC}^2} \times \frac{12\ \text{IN}}{\text{FT}}$

$$\propto_4 = \underline{\underline{7{,}321}} \frac{\text{RAD}}{\text{SEC}^2}$$

Δt_4: $\quad \Delta\theta_4 = W_3\ \Delta t_4 + \frac{\propto_4 (\Delta t_4)^2}{2}$

$$\frac{14.5}{57.3} = (31.23)\Delta t_4 + \frac{7321(\Delta t_4)^2}{2}$$

$$\Delta t_4^{\ 2} + 0.0085\ \Delta t_4 + 0.000069 = 0$$

$$\Delta t_4 = \frac{-0.0085 + \sqrt{(0.0085)^2 + 4(1)(0.000069)}}{2}$$

$$\Delta t_4 = \underline{\underline{0.0051}}\ \text{SEC}$$

$$\Sigma t_4 = 0.1509 + 0.0051 = \underline{\underline{0.1560}}\ \text{SEC}$$

W_4: $\quad W_4 = W_3 + \propto_4 \Delta t_4 = 31.23 + (7321)(0.0051) = 68.4\ \frac{\text{RAD}}{\text{SEC}}$

5. $10^\circ \rightarrow$ IMPACT

Addendum 9 specifies a fluid hammer at disk impact of 150 PSI. At the moment of impact the total ΔP acting on the disk is:

$$\Delta P_{IMPACT} = 448 + 150 = 598\ \text{PSID}$$

The avg. ΔP during the last 10° of motion is:

$$\Delta P_{AVG} = \frac{448 + 598}{2} = 523\ \text{PSID}$$

T_5: $\quad T_5 = \left[(969\ \text{LBM})(14.077\ \text{IN})\right]\frac{32}{32}\sin(5 + 29.876) +$

$$\left(523\frac{LBF}{IN^2}\right)\left(490.6\ IN^2\right)\left(16.5\ IN\right) + 5430\ IN\text{-}LBF - 4770\ IN\text{-}LBF$$

$T_5 = 7799 + 4{,}233{,}633 + 5430 - 4770$

$T_5 = \underline{\underline{4{,}242{,}092}}\ IN\text{-}LBF$

$\propto_5$:

$$\propto_5 = \frac{T_5}{I} = \frac{4{,}242{,}092\ IN\ LBF}{192{,}019\ LBM - IN^2} \times 32.2\frac{LBM\ FT}{LBM\ SEC^2} \times \frac{12\ IN}{FT}$$

$$\propto_5 = \underline{\underline{8536}}\ \frac{RAD}{SEC^2}$$

Δt_5:

$$\Delta\theta_5 = W_4\ \Delta t_5 + \frac{\propto_5 (\Delta t_5)^2}{2}$$

$$\frac{10}{57.3} = 68.4\Delta t_5 + \frac{8536(\Delta t_5)^2}{2}$$

$\Delta t_5^2 + 0.0160\ \Delta t_5 + 0.000041 = 0$

$$\Delta t_5 = \frac{-0.0160 + \sqrt{(0.0160)^2 + 4(1)(0.000041)}}{2}$$

$\Delta t_5 = \underline{\underline{0.0022}}\ SEC$

$\Sigma t_5 = 0.1560 + 0.0022 = \underline{\underline{0.1582}}\ SEC$

W_5:

$W_5 = W_4 + \propto_5 \Delta t_5$

$W_5 = 68.4 + (8536)(0.0022)$

$$W_5 = \underline{\underline{87.5}}\ \frac{RAD}{SEC}$$

Summarizing, upon disk impact:

$$\propto_{IMP} = 8536\ \frac{RAD}{SEC^2}$$

$$W_{IMP} = 87.5\ \frac{RAD}{SEC}$$

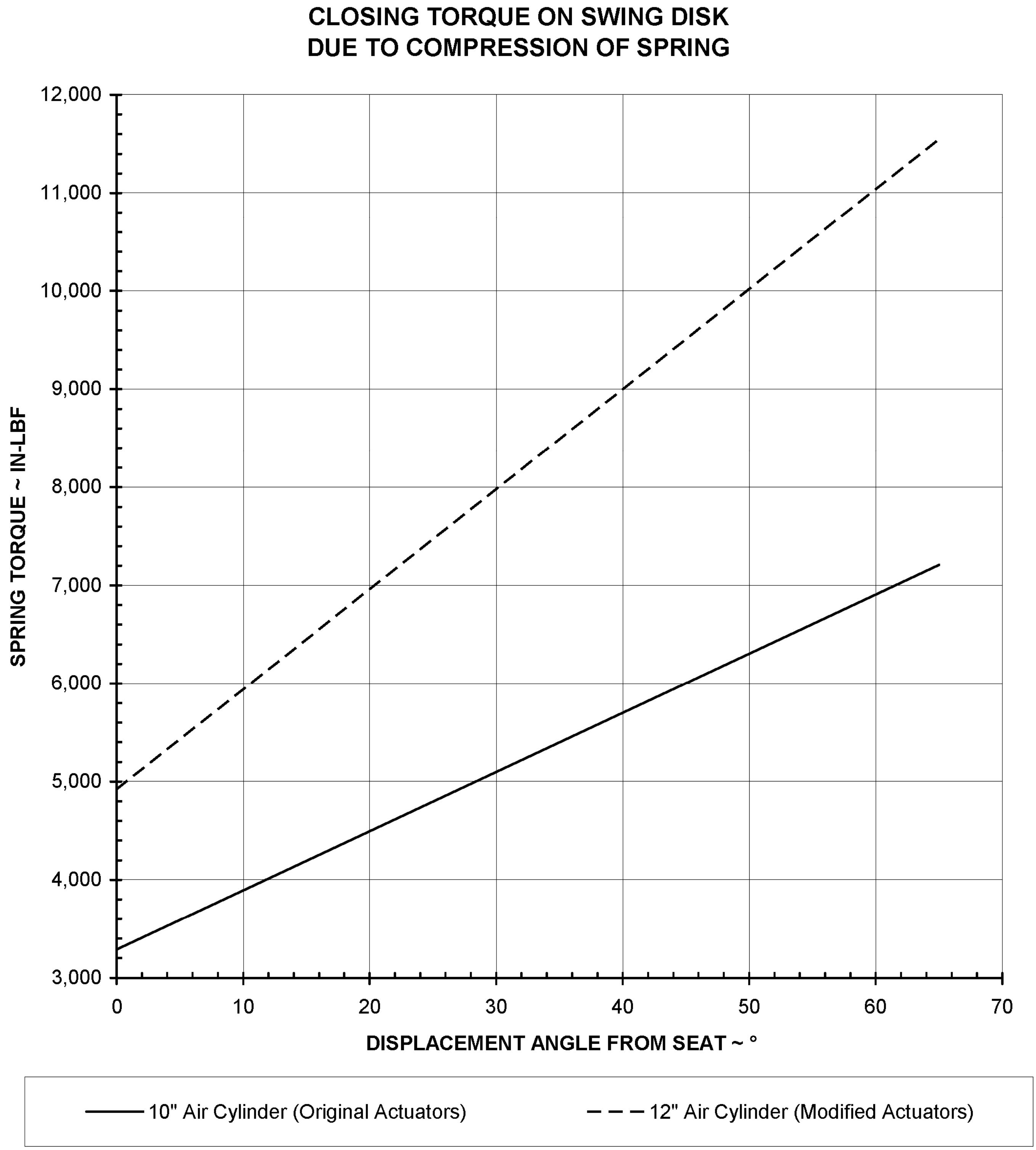
$$\Sigma t_{IMP} = 0.1582\ SEC$$

$$V_{IMP} = 87.5\ \frac{RAD}{SEC} \times 14.077\ IN = \underline{\underline{1232}}\ \frac{IN}{SEC} = \underline{\underline{102.7}}\ \frac{FT}{SEC}$$

D.4 Impact Conditions

The following summarize the disk impact conditions for Cases 1 and 2:

	Case 1	Case 2
Angular acceleration - $\propto, \frac{RAD}{SEC^2}$	9,300	8,536
Angular velocity - W, $\frac{RAD}{SEC}$	99.8	87.5
Closure time ~ SEC	0.146	0.158
Tip velocity - $FT/SEC\ (r = 30.25")$	251.5	220.6
Impact energy E = $\frac{Iw_{MAX}^2}{2}, FT-LBF$	206,254	158,759



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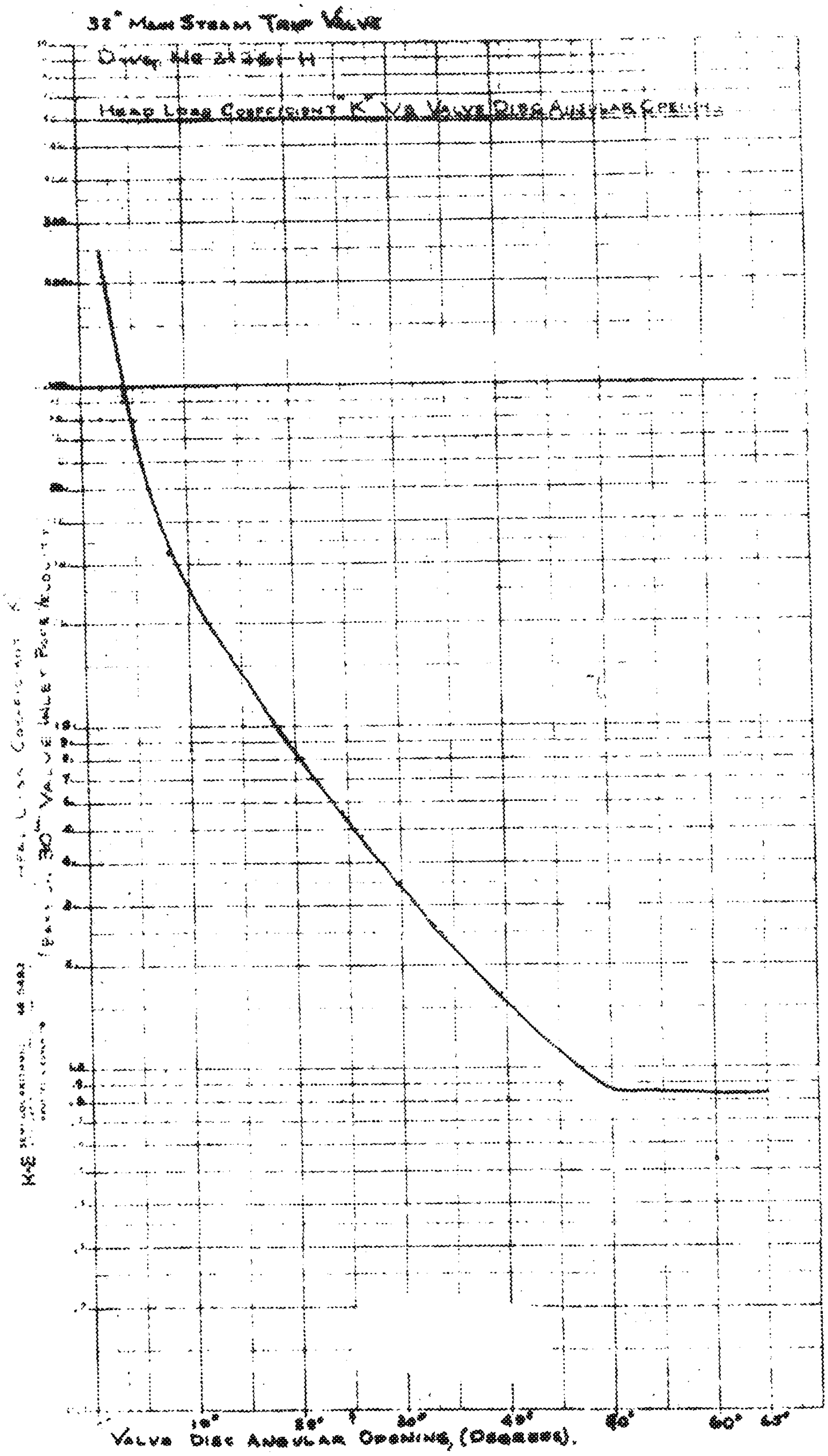
NUCLEAR PLANT
UNIT 1 AND UNIT 2

CLOSING TORQUE ON SWING DISC
DUE TO COMPRESSION OF SPRING

FIGURE D-1



REV 21 5/08

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NUCLEAR PLANT
UNIT 1 AND UNIT 2

HEAD LOSS COEFFICIENT K VERSUS
VALVE DISC ANGULAR OPENINGS

FIGURE D-2

ATTACHMENT E

ASME PAPER NO. 72-PVP-12[9]

P. C. RICCARDELLA
Materials and Stress Analysis,
Westinghouse Nuclear Energy Systems,
Pittsburgh, Pa.

Elasto-Plastic Analysis of Constrained Disk Burst Tests

The PVRC Subcommittee on Effective Utilization of Yield Strength has conducted an extensive series of pressurized burst tests on constrained disk specimens of seven steels. Elasto-plastic analyses have been performed for nine of these tests and the results are presented in this report. Good agreement between the analytical and experimental results all the way to failure pressure is illustrated by a comparison of centerline deflections. Interpretation of the analytical data indicates that both edge type and centerline type of failures are correlated reasonably well by the conventional reduction in area from a uniaxial tensile test once triaxiality is accounted for.

Introduction

THE PVRC Subcommittee on Effective Utilization of Yield Strength has conducted a series of constrained disk burst tests [1][1] using the disk specimen and test setup illustrated in Fig. 1. In order to interpret these tests and their relation to the safety margins which exist in the components of a Westinghouse nuclear steam supply system, elasto-plastic analyses have been performed on three disk geometries with three materials each. The three materials considered were type 304 stainless steel, ASTM A533B low-alloy steel, and ABS-C carbon steel. These materials are representative of reactor core support structures and piping, the reactor pressure vessel, and plant component supports, respectively. A summary of the mechanical properties from uniaxial tensile tests performed on the actual disk materials is given in Table 1.

Extensive data from the disk tests, including burst pressures and experimental pressure versus deflection curves have been reported in references [1] and [2]. Some of the disks failed at the disk centerlines, while others failed along the edge of the disks at the fillet between the thin and thick regions. Table 2 summarizes the failure data for the disks considered in this analysis, which include three centerline failures and six edge failures. The details of the three disk geometries are tabulated in Fig. 1.

[1] Numbers in brackets designate References at end of paper.

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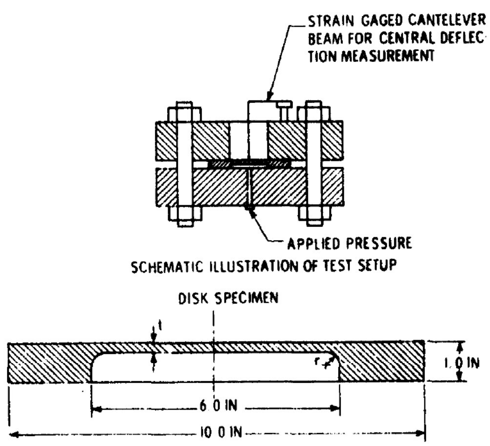

GEOMETRY	THICKNESS (t)	FILLET RADIUS (r)
A	0.25 IN	0.375 IN
B	0.125 IN	0.125 IN
C	0.125 IN	0.375 IN

Fig. 1 PVRC disk test details

Table 1 Material properties

Material	.2% Y.S. (PSI)	$S_{ult.}$ (PSI)	$\epsilon_{ult.}$ (in/in)	Reduction in area	A* (PSI)	n*
Type 304 Stainless Steel	26,000.	84,000.	.64	.74	193,000.	.404
A-533B Low Alloy Steel	74,000.	96,000.	.17	.68.	146,000.	.161
ABS-C Carbon Steel	38,000.	64,000.	.31	..66	115,138.	.242

* Stress-strain curve assumed to be of form $\sigma = A\,\epsilon^{n}$

Table 2 Experimental failure data

Material	Geometry	Burst Pressure (PSI)	Type of Failure
304 S.S.	A	15,000.	Edge
	B	6,800.	Center
	C	7,700.	Center
A-533 B	A	11,000.	Edge
	B	5,300.	Edge
	C	6,700.	Center
ABS-C	A	9,800.	Edge
	B	3,750.	Edge
	C	4,940.	Edge

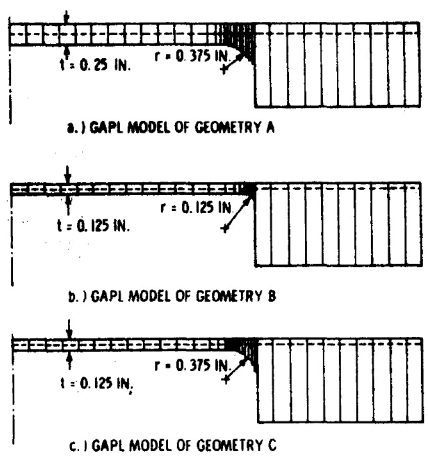

Fig. 2 Computer models of PVRC disks

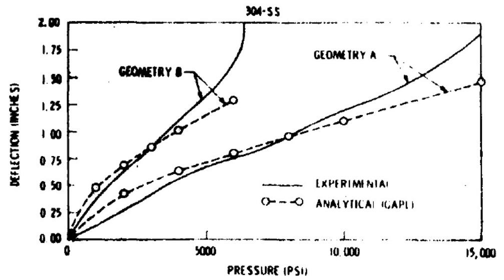

Fig. 3(a) PVRC disk tests—centerline deflection versus pressure (experimental and analytical results for 304 stainless steel disks)

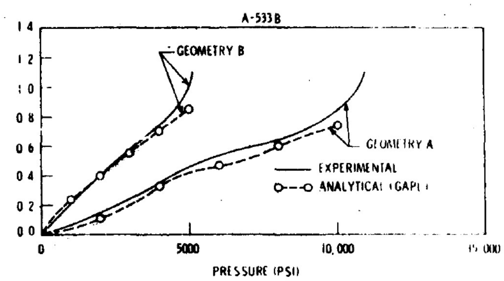

Fig. 3(b) PVRC disk tests—centerline deflection versus pressure (experimental and analytical results for A-533 B low alloy steel disks)

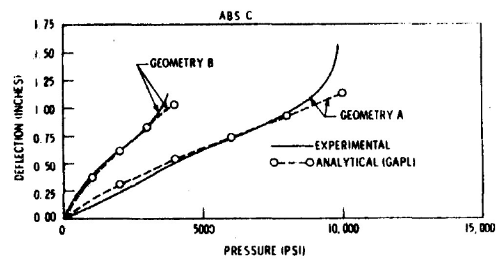

Fig. 3(c) PVRC disk tests—centerline deflection versus pressure (experimental and analytical results for ABS-C carbon steel disks)

Fig. 3

Analysis

The analysis of the disks was performed using the computer program GAPL-3 [3]. This program performs elasto-plastic, large-deformation analysis for stresses, strains, loads, and deflections of thin plates or axially symmetric shells with pressure loading and deflection restraints. The discrete element method employed in GAPL-3 requires fewer elements than conventional finite element techniques to adequately describe structures with high stress gradients because it makes use of a two-layered system of elements: one layer for the strain-displacement field, and a second layer for the stress field. The body is first divided into constant thickness, finite length strain-displacement elements along the axis of the body. The deflections in the elements are represented by a bending type polynomial along the axis and by a linear variation through the thickness. Each element is then further subdivided into constant stress regions in which the stresses are found as a function of the strains in the region. It is the deflection elements, however, which dictate the size of the problem.

The pressure loading is applied in steps and an equilibrium solution is found at each step by iterating for both geometric and material nonlinearities. The choice of incremental or deformation theory of plasticity is made by the user according to the size of the load steps he chooses. Since the program must iterate at each load step, the finer the load steps, the more costly the problem becomes.

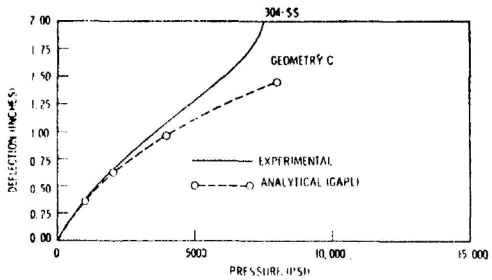

Fig. 4(a) PVRC disk tests—centerline deflection versus pressure (experimental and analytical results for 304 stainless steel disks)

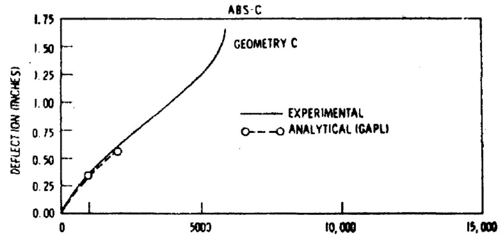

Fig. 4(c) PVRC disk tests—centerline deflection versus pressure (experimental and analytical results for ABS-C carbon steel disks)

Fig. 4

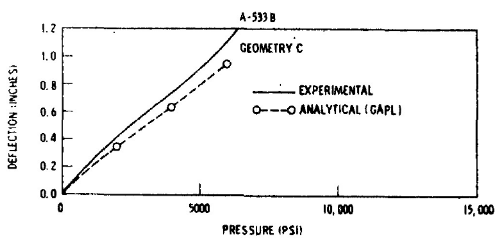

Fig. 4(b) PVRC disk tests—centerline deflection versus pressure (experimental and analytical results for A-533 B low alloy steel disks)

Table 3 Strain concentration factors

Material	Exponent	K_ϵ	GAPL RESULTS					
			Geometry A		Geometry B		Geometry C	
	(n)	(1/n)	K_{GAPL}	K_ϵ/K_{GAPL}	K_{GAPL}	K_ϵ/K_{GAPL}	K_{GAPL}	K_ϵ/K_{GAPL}
A-533 B	.141	7.1	7.2	.98	7.5	.94	8.3	.86
ABS-C	.242	4.1	5.3	.77	6.1	.68	6.6	.62
304-SS	.494	2.0	3.6	.56	4.5	.45	5.2	.38

The three PVRC disk geometries were represented by the discrete strain-displacement element models shown in Fig. 2. In the thin portion of the disks, eight stress regions were specified for each strain-displacement element, while in the fillet regions twelve stress regions per element were used. Material properties for the three steels analyzed were input in terms of a power hardening law, using the constants A and n listed in Table 1. Both fine and crude load steps were tested to evaluate the effect of deformation versus incremental theories of plasticity, and the results were practically identical which indicates that the problem is a proportional loading situation. The production runs were then made using five load steps per case so that a reasonable representation of stresses and displacements as a function of applied pressure could be obtained.

Results

A comparison of the experimental and analytical centerline deflections at various pressures is given for geometries A and B in Fig. 3 and for geometry C in Fig. 4. The agreement is excellent all the way to failure pressure in eight of the nine cases considered. In the ninth case (ABS-C, geometry C) some difficulty was experienced in getting convergence at high pressures, although the experimental-analytical agreement was good at low pressures. In all cases the experimental data shows a tailing up as the pressure approaches burst pressure which the analytical results fail to predict. Since the GAPL program does not account for reduction in thickness, it can not be expected to predict tensile instability which the experimental tailing up represents.

Since the analytical prediction of centerline deflection was so good, it is expected that the stress and strain distributions predicted by GAPL are reasonable estimates of what occurred in the actual test specimens. Some reservation is called for in the fillet region, however, since the thin shell approximations of the GAPL program are not strictly valid there. The GAPL analysis includes plastic hinge type of strain redistribution, but the strain concentration effect due to fillet radius is not accounted for since the predicted strain distribution in the cross section of the fillet is linear there by assumption.

As the pressure increased, the computed stresses at the disk centerlines approached a state of uniform biaxial membrane stress with negligible bending stress. In the fillet, the membrane stresses were lower than at the disk centerline, but the peak stresses on the inside surface of the fillet were the highest in the disk. Figs. 5, 6, and 7 summarize the computed stress and strain data for the fillet and centerline regions of the disks for the 304 SS, the A-533 B, and the ABS-C, respectively. The curves give maximum values of von Mises equivalent stress and strain in the two locations.

Several authors [4, 5, 6] have noted that the strain concentration (or redistribution) in the fillet in tests such as this should increase as the strain hardening exponent (n) decreases. As a first approximation, use of a strain concentration factor (K_ϵ) which is inversely proportional to n has been suggested [7]. In Fig. 8, the maximum radial fillet strains from the GAPL analysis have been cross-plotted against centerline deflections from Figs. 3 and 4 in order to study the effect of hardening exponent upon strain redistribution. The trend of increasing strain concentration with decreasing strain hardening is evident in this figure for all three geometries.

A simple elastic analysis has been performed on the disks in order to test the simple inverse proportion rule mentioned previously. The resulting maximum stresses in the fillet have been divided by Young's modulus and the results are given by the elastic lines in Fig. 8. Strain concentration factors have been computed at three discrete values of centerline deflection (0.6 in., 0.8 in., and 1.0 in.) by dividing the strains from the elasto-plastic GAPL analysis by the elastically computed strains at each deflection. The resulting strain concentration factors were then averaged over the three deflections, and these average values are listed in Table 3. This table shows that while the $(1/n)$ approximation is quite good for the lowest strain hardening exponent ($n = 0.141$), it tends to get worse as n increases. The inverse

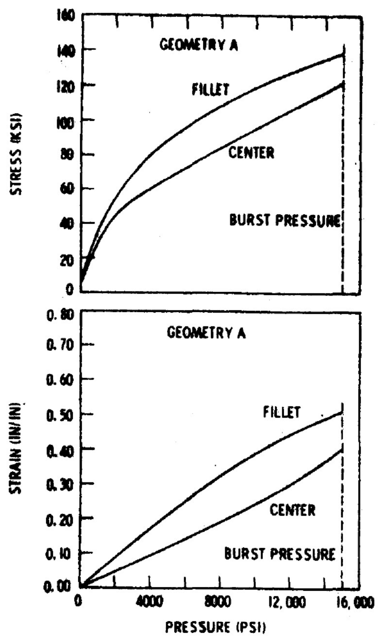

Fig. 5(a) Stress and strain data for 304 stainless steel disks

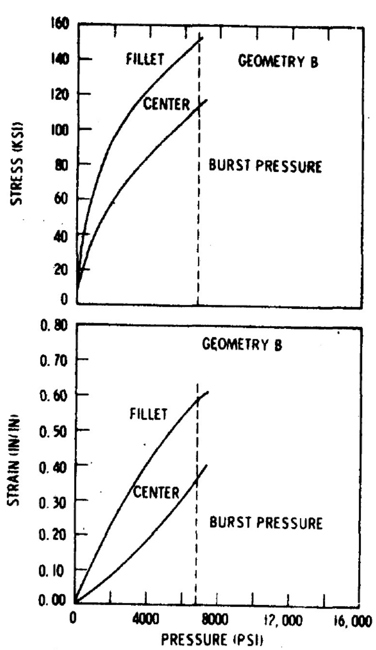

Fig. 5(b) Stress and strain data for 304 stainless steel disks

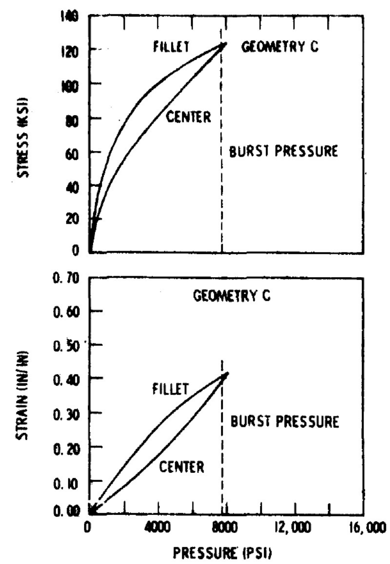

Fig. 5(c) Stress and strain data for 304 stainless steel disks

Fig. 5

proportion rule substantially underestimates the strain concentration for the stainless steel disks (n = 0.494).

Interpretation of Results

An interesting interpretation of this work arises when the equivalent strain levels at failure shown in Figs. 5, 6, and 7 are tabulated. All of the edge failures occurred at approximately the same strain level (~50 percent) and all of the centerline failures occurred at approximately the same strain level (~35 percent). (See Table 4). This seems surprising at first, since the ultimate or uniform strains for the three materials are 54 percent for the stainless steel, 17 percent for the low alloy steel, and 31 percent for the carbon steel as indicated in Table 1. However, the ultimate or uniform strain in a tensile test is somewhat artificial as a material property since it is really a measure of incipient tensile instability, and as such is geometry dependent.

Inspection of the material data in Table 1 indicates that the only tensile property which is approximately constant for all three materials is the reduction in area (R.A.). This suggests that reduction in area might be a good property for correlation* of the test data. Before doing so, however, it is convenient to introduce the concept of triaxiality factor (TF) [8].

$$TF = 3\sigma_{mean}/\sigma_{eq}$$

$$\sigma_{mean} = \frac{(\sigma_1 + \sigma_2 + \sigma_3)}{3} \qquad (1)$$

$$\sigma_{eq} = \frac{1}{\sqrt{2}}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]^{1/2}$$

$\sigma_1, \sigma_2, \sigma_3$ = principal stresses

Note that for uniaxial tension TF = 1, for pure biaxial tension TF = 2, and for pure triaxial tension $TF = \infty$.

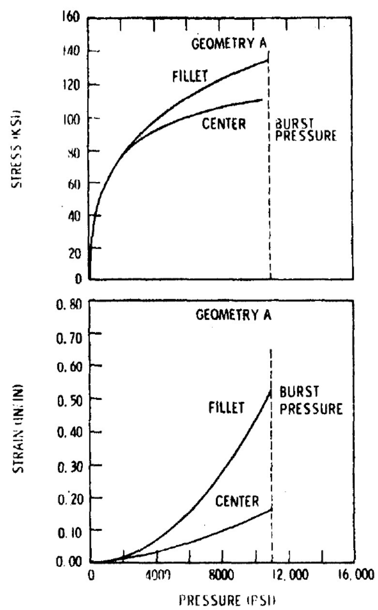

Fig. 6(a) Stress and strain data for A-533 B low alloy steel disks

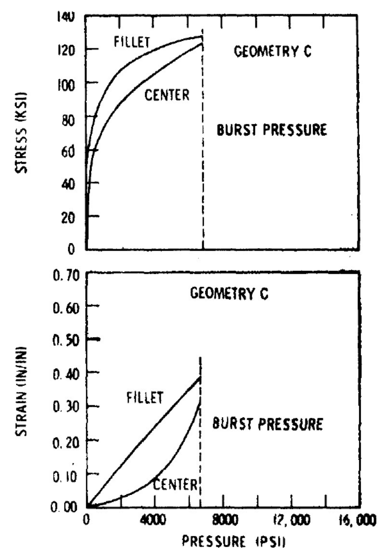

Fig. 6(c) Stress and strain data for A-533 B low alloy steel disks

Fig. 6

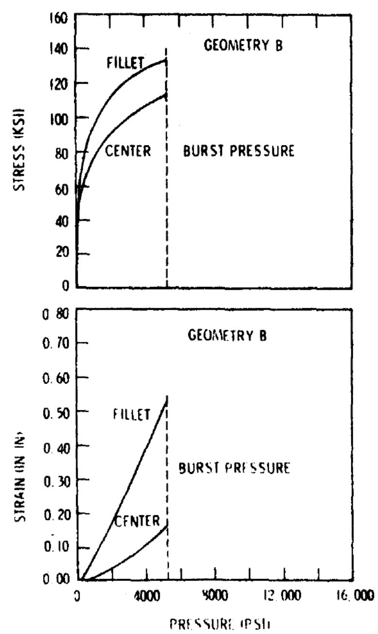

Fig. 6(b) Stress and strain data for A-533 B low alloy steel disks

Generally, the amount of strain that a material can withstand before fracture is expected to decrease with increasing triaxiality of the imposed stress state. Davis and Connelly [8] have suggested that the triaxiality factor as defined previously might be an effective parameter with which to study the reduction in ductility due to multiaxial state of stress. That is:

$$\epsilon_{\substack{crit\\ \text{multiaxial}}} = \epsilon_{\substack{crit\\ \text{uniaxial}}} \times f(TF) \qquad (2)$$

Where $f(TF)$ is a monotonically decreasing function.

Investigation of failure data from several sources [9, 10, 11, 12] indicates that, in the absence of severe anisotropy, the following expression is not a bad first approximation of the influence of triaxiality upon ductility:

$$f(TF) = 1/TF \qquad (3)$$

The triaxiality factors for the disk tests at failure were 2.0 for the centerline region and about 1.65 for the fillet based upon the computed stresses in those regions. The tensile tests used to measure reduction in area can be assumed to have had a triaxiality factor of 1.0. In addition, the tensile tests were performed for both longitudinal and transverse tensile specimens indicating very little anisotropy in the disk materials, so that the approximation of equation [3] should apply. Thus, as a first approximation of multiaxial ductility, the reduction in area values for the three materials have been divided by the appropriate triaxiality factors and listed in Table 4. The final column of Table 4 lists the ratios of equivalent strain in the failure location to the multiaxial ductility at that location. The correlation is always better than 30 percent, and the average error is about 16 percent.

Casting this same information in a slightly different format, the question of how well the foregoing scheme predicts failure pressure can be answered. Using the postulate that failure occurs whenever the value of equivalent strain exceeds the re-

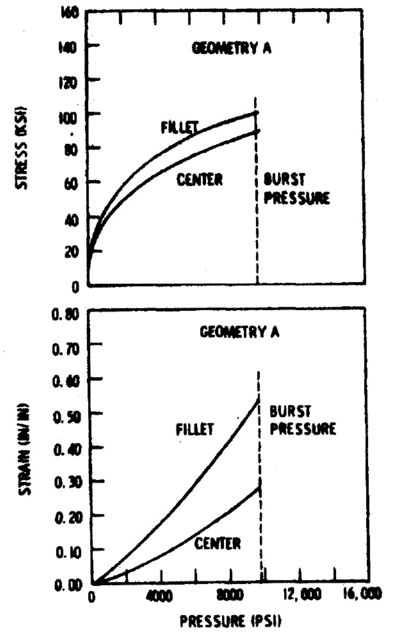

Fig. 7(a) Stress and strain data for ABS-C carbon steel disks

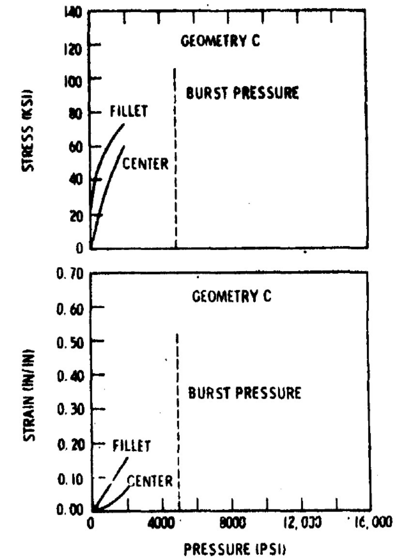

Fig. 7(c) Stress and strain data for ABS-C carbon steel disks

Fig. 7

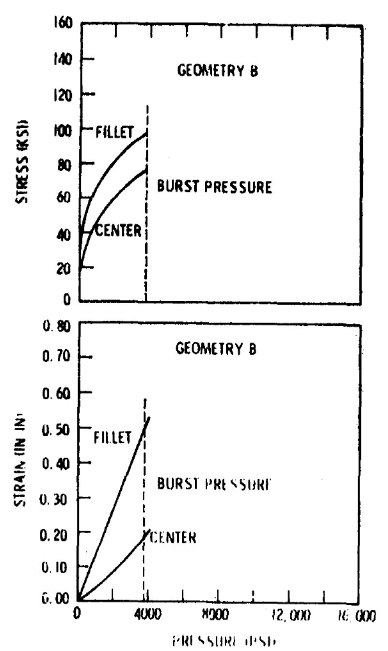

Fig. 7(b) Stress and strain data for ABS-C carbon steel disks

duction in area divided by the triaxiality ratio (multiaxial ductility) at any point in the disk, burst pressures as well as failure locations can be predicted from the analytical strain versus pressure curves of Figs. 5, 6, and 7. Table 5 presents such predictions for the test cases considered here. The predicted burst pressures give reasonably accurate estimates of the actual burst pressures, and the predicted location of failure was correct in all cases but one (304 S.S.—geometry B).

Summary and Conclusions

Results of an elasto-plastic, finite-deformation analysis of selected PVRC disk tests are presented and, in general, there is good agreement between experiment and analysis, which is illustrated by a comparison of the predicted and actual deflections at the disk centerlines as a function of applied pressure. A definite trend of increasing strain concentration in the fillet of the disks as the strain hardening decreases is apparent in the data for all three geometries analyzed. The order of magnitude of this trend supports the assumption of Section 3 of the ASME Boiler and Pressure Vessel Code that plastic strain concentration is inversely proportional to the strain hardening exponent, at least for low values of this exponent.

A scheme for predicting burst pressure from the analytical stress and strain data using the reduction in area from a conventional uniaxial tensile test as a critical strain parameter is suggested. Failure is posited when the computed equivalent strain in the disks exceeds the reduction in area property of the material adjusted by the triaxiality of the stress state. The scheme is shown to be reasonably consistent for the limited number of cases considered.

This analysis demonstrates that it is possible to predict failure loads for material and hardware similar to those used in commercial nuclear power plants, provided that a reasonably accurate

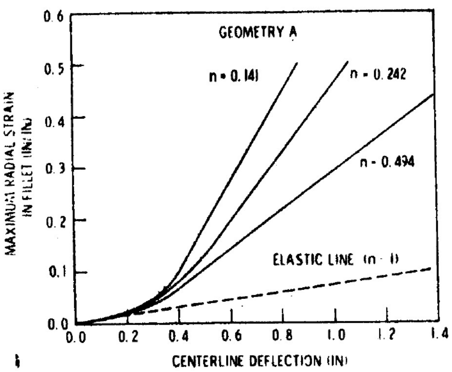

Fig. 8(a) Strain concentration in fillet for various strain hardening exponents

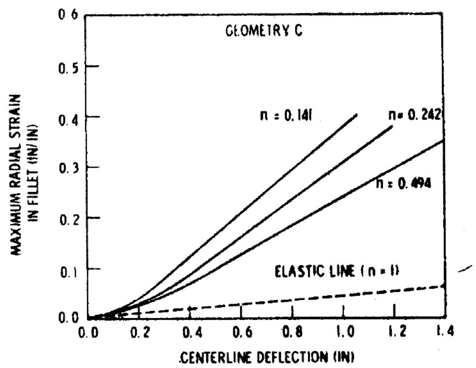

Fig. 8(c) Strain concentration in fillet for various strain hardening exponents

Fig. 8

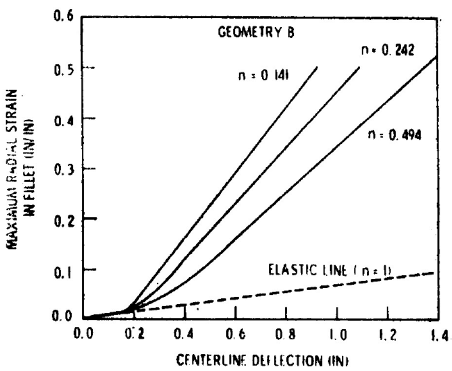

Fig. 8(b) Strain concentration in fillet for various strain hardening exponents

elasto-plastic analysis can be performed. Extension of such an analysis to the more complex loading and geometric conditions which exist in actual plant components will allow accurate evaluations of the margins of safety which exist in these components.

Acknowledgments

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Table 4 Computed strains at failure

Material	Geometry	Type of Failure	CENTERLINE DATA: Strain At Failure	CENTERLINE DATA: Triaxiality Factor (TF)	CENTERLINE DATA: Multiaxial Ductility ($\frac{R.A.}{TF}$)	EDGE DATA: Strain At Failure	EDGE DATA: Triaxiality Factor (TF)	EDGE DATA: Multiaxial Ductility ($\frac{R.A.}{TF}$)	RATIOS: $\frac{\text{Failure Strain}}{\text{Ductility}}$
304 S.S.	A	Edge	.40	2.0	.37	<u>.51</u>	1.66	.45	1.12
	B	Center	<u>.37</u>	2.0	.37	.50	1.65	.45	1.0
	C	Center	<u>.38</u>	2.0	.37	.41	1.69	.45	1.05
A-533 B	A	Edge	.16	2.0	.34	<u>.52</u>	1.67	.41	1.27
	B	Edge	.17	2.0	.34	<u>.52</u>	1.67	.41	1.29
	C	Center	<u>.33</u>	2.0	.34	.38	1.65	.41	.97
ABS-C	A	Edge	.27	2.0	.33	<u>.52</u>	1.64	.40	1.30
	B	Edge	.18	2.0	.33	<u>.50</u>	1.68	.40	1.25
	C	Edge	#	#	.33	#	#	.40	#

Solution did not converge at failure pressure

ATTACHMENT F

JUSTIFICATION OF VELOCITY USED IN VALVE IMPACT ANALYSIS

VELOCITY JUSTIFICATION FOR THE DYNAMIC ANALYSIS OF A SWING-DISK VALVE*

Introduction

The purpose of this section is to justify equating the kinetic energy of translation to the kinetic energy of rotation in an axisymmetric simulation of the rotational motion of the disk during valve closure.

The disk involved is essentially flat and of uniform thickness. It is sufficient for justification purposes to treat the disk as a thin circular plate and to ignore the mass of the support arm. Hence, the problem will be considered as defined in the attached diagram, where the Y-axis is the axis of rotation.

Derivation of Translational Velocity

Rotation: $KE_r = \frac{1}{2} I\omega^2$ Translation: $KE_t = \frac{1}{2} M\, V_t^2$

Let $KE_t = KE_r$, then $V_t^2 = (I/M)\ \omega^2$

$$I = \rho t \left(\pi R^4/4 + \pi R^2\, R_c^2\right) \qquad M = \rho t \left(\pi R^2\right)$$

$$V_t = \omega \sqrt{R^2/4 + R_c^2} = \text{equivalent translational velocity}$$

$$V_c = \omega\ R_c = \text{centerline velocity}$$

$$\text{Ratio } R_1 = V_t/V_c = \sqrt{R^2/4 + R_c^2}\Big/R_c$$

$$R = 13.75 \text{ in.},\ R_c = 16.5 \text{ in.},\ \underline{R_1 = 1.08}$$

* Nomenclature is defined at end of section.

Tip Velocity vs. Translational Velocity

$$V_{max} = \omega\left(R_c + R\right) = \text{tip velocity}$$

$$\text{Ratio } R_2 = V_{max}/V_t = \left(R_c + R\right)\Big/\sqrt{R^2/4 + R_c^2}$$

$$\underline{R_2 = 1.69}$$

Consideration of Kinetic Energy per Unit Volume

Rotation at tip: $q_{max} = \frac{1}{2}\rho\, V_{max}^2$

Translation: $q_t = \frac{1}{2}\rho\, V_t^2$

$$\text{Ratio } R_3 = q_{max}/q_t = \left(V_{max}/V_t\right)^2 = R_2^2$$

$$R_3 = 2.86$$

Radial Distribution of Kinetic Energy

The distribution of the kinetic energy along the X-axis can be obtained with sufficient accuracy by subdividing the disk in 20 regions bounded by equidistant lines parallel to the Y-axis. For a given region, it is first required to obtain the area, moment of inertia, and center-of-gravity location of the two-disk segments bounded by straight edges on the left. Denoting these two sets by A_1, I_1, X_1, and A_2, I_2, X_2, respectively, and denoting the set for the region considered by A_i, I_i, and X_i, the latter can be obtained from the relationships:

$$A_i = A_1 - A_2 \qquad X_i = \left(A_1X_1 - A_2X_2\right) A_i \qquad I_i = \rho t\, A_i\, X_i^2$$

Neglected in this computation of I_i is the moment of inertia of A_i about the line $X = X_i$, but the resulting error is negligible. Summing of I_i for all the regions shows that the total is within 0.05 percent of the exact value obtained with the formula $I = \rho t\left(\pi R^4/4 + \pi R^2 R_c^2\right)$.

The above procedure leads to results given in the diagram. It is noted that the kinetic energy of rotation peaks at $X = R_c + 0.65\ R$. At this location, the ratio of rotational and translational energy is 2.03.

Justification

1. An axisymmetric dynamic plasticity analysis was performed to determine the structural response of the swing-disk valve to impact closure under faulted conditions. At impact, the kinetic energy per unit volume was uniform throughout the disk. The kinetic energy was dissipated in 1.3 milliseconds through plastic strain energy absorption. Energy absorption started in the contact region of the body and disk and ended in the central portion of the disk. This result shows that the impact velocity was low enough to permit redistribution of the dynamic loading.

2. The kinetic energy distributions in the translational mode and the rotational mode, as shown in the diagram, are sufficiently close in view of Item 1 above to permit the assumption that redistribution of nonaxisymmetric to axisymmetric dynamic loading will occur early in the impact event and that the resulting body seat and disk deformation will be essentially axisymmetric at the end of the event. Taken into account in this statement is the fact that the disk is not rigidly connected to the support arm and that the tip velocity is not more than 1.69 times the translational velocity assumed in the analysis.

3. At the location of maximum rotational velocity, the kinetic energy of rotation per unit volume is 2.86 times the translational kinetic energy per unit volume. While the possibility therefore exists that initially locally severe deformation will result, the progression of such preferential deformation will be arrested because it is incompatible with the deformation of the rest of the structure and the seating adjustment provided by the clearance between disk and disk arm. Furthermore, the kinetic energy at the tip is still small compared with the capacity of the material for absorbing energy. A conservative estimate for this capacity, per unit volume, is $\sigma_u \varepsilon_f$. For the body material, $\sigma_u \varepsilon_f$ is approximately 50,000 in.-lb/in.^{3}; for the disk material, $\sigma_u \varepsilon_f$ is approximately 80,000 in.-lb/in.^{3}. The kinetic energy per unit volume at the tip is:

$\frac{1}{2} \rho V_{max}^2 = \frac{1}{2} \left(0.284/386\right)\left(1.69\ V_t\right)^2$. In the analysis, V_t = 150 ft/sec, so that $\frac{1}{2} \rho V_{max}^2$ = 3400 in.-lb/in.^{3}.

Nomenclature

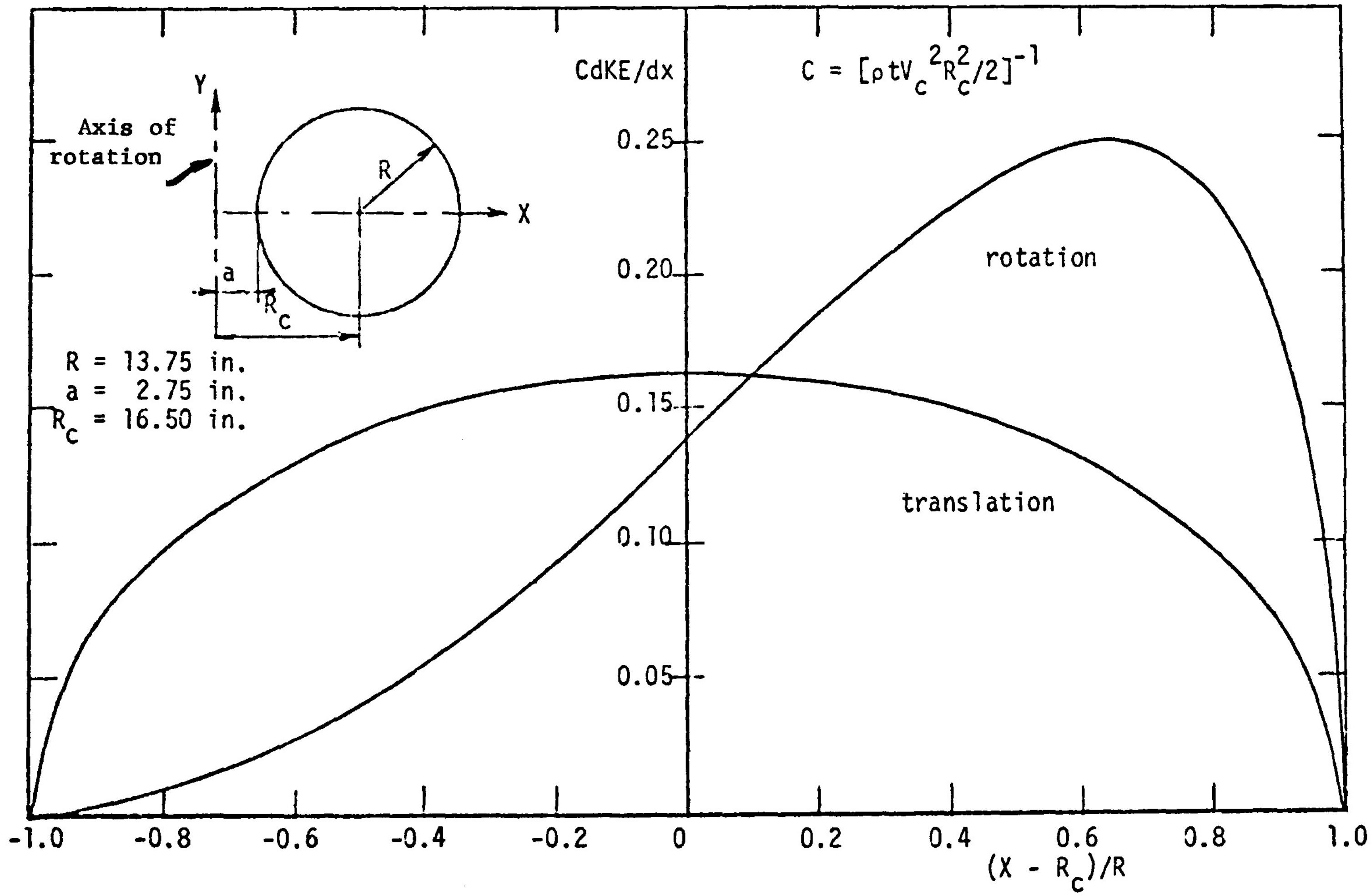
KE_r = kinetic energy of rotation
KE_t = kinetic energy of translation
M = mass of disk
I = moment of inertia of disk about axis of rotation
ω = angular velocity
V_t = translational velocity
V_c = centerline velocity
V_{max} = tip velocity
R = radius of disk
R_c = distance from center of disk to axis of rotation
t = thickness of disk
ρ = mass density of disk
q = kinetic energy per unit volume
σ_u = true ultimate stress
ε_f = true fracture strain

TABLE F-1

DISTRIBUTION OF KINETIC ENERGY

$C = \left[\rho t V_c^2 R_c^2 / 2\right]^{-1}$ X_i = distance to c.g

I	II	III	II/III
$\frac{X_i - R_c}{R}$	$\frac{\text{cdKE/dx}}{\text{Rotation}}$	$\frac{\text{cdKE/dx}}{\text{Translation}}$	Ratio
-0.940	0.0019	0.0479	0.040
-0.847	0.0063	0.0854	0.074
-0.749	0.0130	0.1076	0.121
-0.649	0.0222	0.1237	0.179
-0.549	0.0341	0.1360	0.251
-0.450	0.0485	0.1455	0.333
-0.350	0.0653	0.1526	0.428
-0.250	0.0843	0.1577	0.535
-0.150	0.1051	0.1611	0.652
-0.050	0.1274	0.1627	0.783
0.050	0.1504	0.1627	0.924
0.150	0.1737	0.1611	1.078
0.250	0.1962	0.1577	1.244
0.350	0.2169	0.1526	1.421
0.450	0.2342	0.1455	1.610
0.549	0.2463	0.1360	1.811
0.649	0.2503	0.1237	2.023
0.749	0.2417	0.1076	2.246
0.847	0.2118	0.0854	2.480
0.940	0.1297	0.0479	2.708
	Sum = 2.559	Sum = 2.560	



REV 21 5/08

ROTATIONAL AND TRANSLATIONAL
KINETIC ENERGY DISTRIBUTION IN DISC

FIGURE F-1

ATTACHMENT G

CONVERSION OF TENSION TEST DATA TO TRUE STRESS - STRAIN DATA

CONVERSION OF TENSION TEST DATA TO TRUE STRESS-STRAIN DATA

Nomenclature

A = specimen cross-section

A_o = initial value of A

L = specimen gage length

L_o = initial value of L

P = load

σ = engineering stress

σ_t = true stress

ε = engineering strain

ε_t = true strain

Tension Test Results

Test gives load P vs. elongation $L - L_o$. These results furnish σ and ε via the relations,

$$\sigma = P/A$$

$$\varepsilon = (L-L_o)/L_o$$

Plot of σ vs. ε yields conventional stress-strain curve.

Computation of True Stress

Volume change in specimen is very small in tension test. Neglecting the change gives:

$$AL = A_oL_o$$

Therefore, since $L = L_o(1 + \varepsilon)$,

$$A = A_o/(1 + \varepsilon)$$

Then, σ_t may be computed from σ and ε,

$$\sigma_t = P/A = (P/A_o)(1 + \varepsilon) = \sigma(1 + \varepsilon)$$

Computation of True Strain

True strain is obtained by integration of instantaneous elongation dL,

$$\varepsilon_t = \int_{L_o}^{L} (1/L)\, dL = \ln(L/L_o)$$

Since L/L_o equals $1 + \varepsilon$, ε_t can be computed from ε,

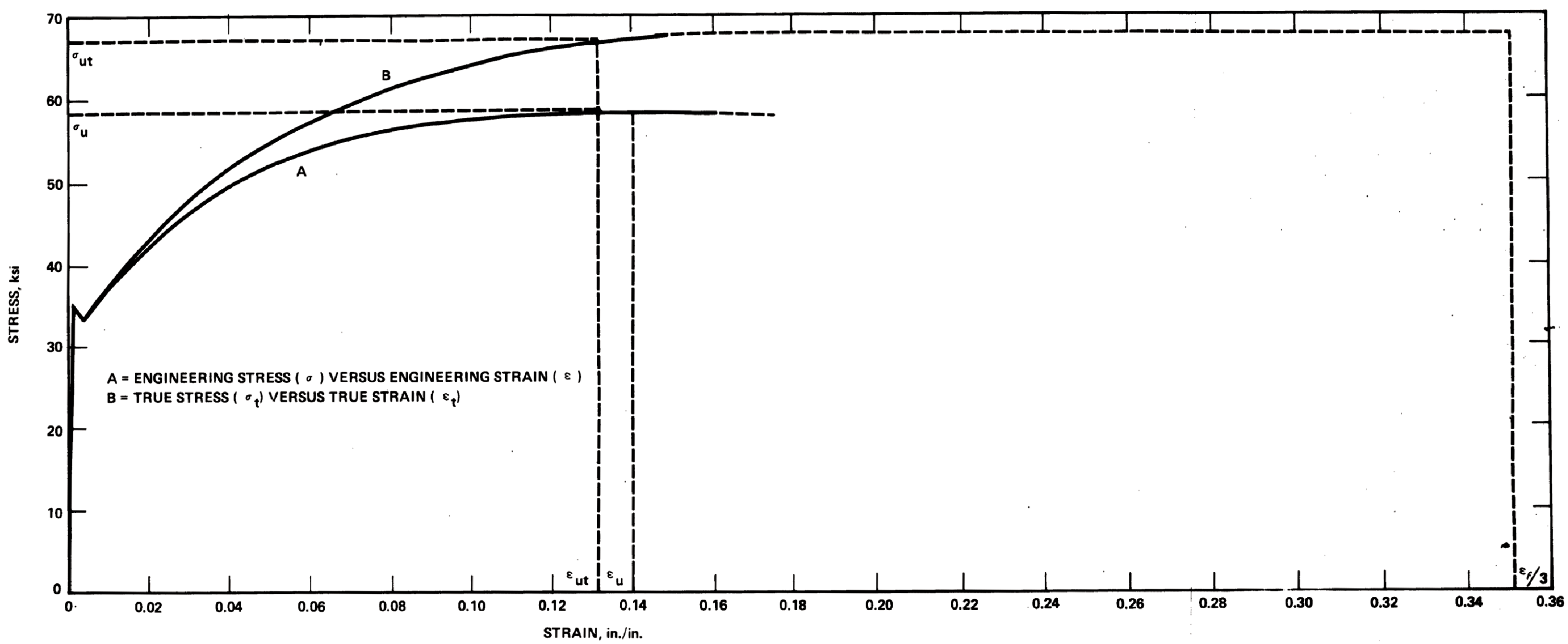
$$\varepsilon_t = \ln(1 + \varepsilon)$$

Reference: A. Nadai, Theory of Flow and Fracture of Solids, McGraw-Hill, 1950 (Chapter 8)

TABLE G-1

Example: A-216, Grade WCB steel at 600°F

ε in/in	σ ksi	ε_t in/in	σ_t ksi
0.01	37.0	0.0100	37.4
0.02	42.3	0.0198	43.1
0.03	46.6	0.0296	48.0
0.04	49.7	0.0392	51.7
0.05	52.0	0.0488	54.6
0.06	54.0	0.0583	57.2
0.07	55.4	0.0677	59.3
0.08	56.5	0.0770	61.0
0.09	57.3	0.0862	62.5
0.10	58.0	0.0953	63.8
0.11	58.3	0.1044	64.7
0.12	58.5	0.1133	65.5
0.13	58.6	0.1222	66.2
0.14	58.7	0.1310	66.9
0.15	58.6	0.1398	67.4
0.16	58.5	0.1484	67.9



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STRESS-STRAIN CURVES FOR
A-216 GRADE WCB STEEL

FIGURE G-1