TABLE OF CONTENTS

CHAPTER 6.0

ENGINEERED SAFETY FEATURES

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

CHAPTER 6.0

ENGINEERED SAFETY FEATURES

Engineered safety features (ESF) are those safety-related systems and components designed to directly mitigate the consequences of a design basis accident by:

a. Protecting the fuel cladding

b. Ensuring the containment integrity

c. Limiting fission product releases to the environment within the guideline values of 10 CFR, Part 100

The limiting design basis accidents which are discussed and analyzed in Chapter 15.0 and Section 6.3 are:

a. Loss-of-coolant accident (LOCA)

b. Main steam line break (MSLB)

c. Steam generator tube rupture

d. Fuel handling accident

The engineered safety features consist of the following systems:

a. Containment (Section 6.2.1)

b. Containment heat removal (Section 6.2.2)

c. Containment isolation (Sections 6.2.4 and 6.2.6)

d. Containment combustible gas control (Section 6.2.5)

e. Emergency core cooling (Section 6.3)

f. Fission product removal and control systems (Section 6.5)

g. Emergency HVAC and filtration (Section 9.4)

h. Control room habitability (Section 6.4)

i. Auxiliary feedwater (Section 10.4.9)

The containment is provided to contain radioactivity following a LOCA.

The containment spray system, in conjunction with the containment fan coolers and the emergency core cooling system, is designed to remove sufficient heat from the containment atmosphere following a LOCA or main steam line break inside the containment to rapidly reduce the containment pressure and temperature and maintain them at acceptably low levels.

The containment spray system is also designed to minimize the iodine and particulate fission product inventories in the containment atmosphere resulting from a postulated LOCA.

Containment isolation is provided to minimize leakage from the containment. Steam line and feedwater line isolation is provided to minimize the heat removal from the reactor coolant system and prevent excessive blowdown of a steam generator following a postulated main steam line rupture. Steam line isolation will also prevent excessive radioactivity release following a steam generator tube rupture. The containment purge isolation capability is provided to reduce the radioiodine released following a fuel handling accident inside the containment.

Hydrogen recombiners prevent the accumulation of combustible mixtures of hydrogen and oxygen following a LOCA.

The emergency core cooling system (ECCS), consisting of accumulator tanks, safety injection pumps, RHR pumps, and ECCS centrifugal charging pumps, is provided for emergency core cooling to limit fuel damage following a LOCA or main steam line break.

An emergency exhaust system is provided to reduce the radioiodine released following a fuel handling accident outside the containment and to filter ECCS leakage outside the containment following a LOCA.

The auxiliary feedwater system provides an adequate amount of feedwater into the steam generators to prevent a pressure transient which could cause a loss of reactor coolant through the pressurizer relief valves and a possible uncovering of the reactor core following a main steam line break or loss of the main feedwater system.

Other safety-related systems are identified in Section 3.2. Because of the importance of safety-related systems to the health and safety of the general public, special precautions are taken to ensure high quality in the components and in the system design and to ensure reliable and dependable operation.

6.1 ENGINEERED SAFETY FEATURE MATERIALS

This section provides a discussion of the materials used in the fabrication of engineered safety feature components and of the material interactions that could potentially impair the operation of the ESF.

6.1.1 METALLIC MATERIALS

6.1.1.1 Materials Selection and Fabrication

Information on the selection and fabrication of the materials in the engineered safety features of the plant, such as the emergency core cooling systems, the containment heat removal systems, the containment combustible gas control system, and the containment spray system, is provided below. Materials for use in the ESF are selected for their compatibility with the reactor coolant system and containment spray solutions, as required by Section III of the ASME Boiler and Pressure Vessel Code, Articles NC-2160 and NC-3120.

6.1.1.1.1 Specifications for Principal Pressure-Retaining Materials

All pressure-retaining material in the engineered safety feature systems' components complies with the corresponding material specification permitted by ASME Section III, Division 1.

The material specifications for pressure-retaining material in each component of the engineered safety feature systems will meet the requirements of Article NC-2000 of ASME Section III, Class 2, for quality group B and Article ND-2000 of ASME Section III, Class 3, for quality group C components. Containment penetration materials will meet the requirements of Article NE-2300 of ASME Section III, Division I. Table 6.1-1 includes the specifications for the principal pressure-retaining components.

6.1.1.1.2 Engineered Safety Feature Materials of Construction

The engineered safety feature materials that would be exposed to the emergency core cooling water and containment sprays following a LOCA are indicated in Table 6.1-1. These materials are chosen to be compatible with the core cooling and spray solutions. Additional information concerning metallic materials' compatibility with post-LOCA conditions is provided in Reference 1.

In order to keep materials within the containment that are subject to corrosion to a minimum, the following restrictions are placed on the use of zinc, aluminum, and mercury in the containment:

a. Aluminum is severely attacked by the alkaline containment spray solution. This reaction may result in the loss of structural integrity and the generation of gaseous hydrogen. The use of aluminum in the containment is minimized.

b. Boric acid reacts with zinc, oxidizing it and liberating hydrogen gas. The use of zinc (galvanized materials and paint) in the containment is minimized to reduce the generation of hydrogen.

c. The use of mercury and mercuric compounds is minimized inside the containment because of its corrosive effects on stainless steel, NiCrFe alloy 600, and alloys containing copper. The amount of mercury associated with plant lighting and control switches, etc., is negligible.

Figure 6.2.5-2 shows the maximum allowable quantities of zinc and aluminum inside the containment building. Corrosion rates for zinc and aluminum are given in Table 6.2.5-4. Use of aluminum and zinc inside containment is minimized to the extent practicable.

For other materials which could come in contact with containment sprays, tests have been performed and are detailed in Reference 2. These tests have shown that no significant amount of corrosion products will be produced from these materials.

Many coatings which are in common industrial use may deteriorate in the post-accident environment and contribute substantial quantities of foreign solids and residue to the containment sump. Consequently, protective coatings used inside the containment in significant quantities are demonstrated to withstand the design basis accident conditions and are designed to meet the criteria given in ANSI N101.2 (1972), "Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities," and are in compliance with Regulatory Guide 1.54, "Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants," as indicated in Table 6.1-2. Some small items may be painted or coated using common industrial practice but the paint/coating will not be in sufficient quantity to cause any clogging problems for the sump strainer. Any precipitation of appreciable size that occurs either settles out prior to reaching the sump strainer or is trapped by the sump filter strainer. The strainer opening size (0.045 inch) is smaller than the line piping, the RHR heat exchanger tubes, the spray nozzles, and clearances in the reactor core. Therefore, particles which could potentially cause blockage are filtered out. Refer to Section 6.2.2.1 for a discussion of the sump design and consideration given to strainer clogging. For each containment component, a complete list of the surface coatings, the dry film thickness, and the surface area covered is presented in Table 6.1-3.

6.1.1.1.3 Integrity of Safety-Related Components

The following information is provided to demonstrate that the integrity of the safety-related components is maintained during all stages of component manufacturing:

a. Regulatory Guide 1.44, Control of the Use of Sensitized Stainless Steel, is complied with to the extent specified in Table 6.1-4 for the purpose of avoiding significant sensitization and stress corrosion cracking in austenitic stainless steel components of the engineered safety features.

b. Cleaning and contamination protection of austenitic stainless steel components of the engineered safety features complies with Regulatory Guide 1.44, Control of the Use of Sensitized Stainless Steel, as described in Table 6.1-4. Regulatory Guide 1.37, Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants, is complied with to the extent specified in Table 6.1-5.

c. Cold worked austenitic stainless steel material with 0.2-percent offset yield strengths greater than 90,000 psi are not used in components that are part of the engineered safety features.

d. The selection, procurement, testing, storage, and installation of all nonmetallic thermal insulation assure that the leachable concentrations of chloride, fluoride, sodium, and silicate are in accordance with Regulatory Guide 1.36, Nonmetallic Thermal Insulation for Austenitic Stainless Steel, with clarifications as discussed in Table 6.1-6.

e. With regard to the preheat temperature used for welding low alloy steels, the recommendations of Regulatory Guide 1.50, Control of Preheat Temperatures for Welding of Low Alloy Steel, were followed, as discussed in Table 6.1-7.

f. The recommendations of Regulatory Guide 1.71, Welder Qualification for Areas of Limited Accessibility, are followed as discussed in Table 6.1-8.

g. In order to determine the RT NDT for the steam and feedwater system materials, the guidelines in NRC Branch Technical Position MTEB 5-2 Section 1.1, Article 4 were followed.

The applied test methods and acceptance criteria for all materials used in the steam and feedwater systems, with the exception of the steam generators, comply completely with ASME Code Section III, Article NC-2310 of the Winter 1974 Addenda for fracture toughness of ferritic materials used in Class 2 components. The applied test methods and acceptance criteria for all Class 2 steam generator materials comply with the requirements of ASME Code Section III 1971 Edition through Summer 1973 Addenda.

6.1.1.1.4 Control of Stainless Steel Welding

Regulatory Guide 1.31, Control of Stainless Steel Welding, as supplemented by Branch Technical Position MTEB 5-1, is complied with to the extent specified in Table 6.1-9 for the purpose of avoiding fissuring in austenitic stainless steel welds that are part of the engineered safety features.

6.1.1.2 Composition, Compatibility, and Stability of Containment and Core Spray Coolants

The information given below is provided on the composition, compatibility, and stability of the core cooling water and the containment sprays on the engineered safety features.

6.1.1.2.1 Control of pH During a Loss-of-Coolant Accident

A description of the method of establishing containment spray and recirculation sump pH following a LOCA is included in Sections 6.2.2 and 6.5. The resultant basic equilibrium pH, which is greater than or equal to 7.1, is not conducive to stress-corrosion cracking in austenitic stainless steels. Hydrogen evolution is discussed in Section 6.2.5, Combustible Gas Control in Containment.

6.1.1.2.2 Engineered Safety Feature Coolant Storage

The borated water supply for the containment sprays and emergency core cooling system is drawn from the refueling water storage tank. As described in Section 6.3, the refueling water storage tank is fabricated of stainless steel and is not subject to significant corrosive attack by the tank's contents.

The accumulator tanks which store borated water for the accumulator safety injection system are made of carbon steel and are clad with stainless steel to ensure that they are resistant to corrosion.

6.1.2 ORGANIC MATERIALS

Use of organic material inside the containment is kept to a minimum.

The amounts of lubricants inside the containment that are subject to being released to the containment are listed in Table 6.1-10. As noted in Table 6.1-10, some lubricants are totally enclosed and not open to the containment atmosphere.

Table 6.1-3 is a coating schedule for the containment which indicates the type of paint and compliance with Regulatory Guide 1.54.

All protective coatings covered by Regulatory Guide 1.54 which are applied to surfaces within the containment have been tested to demonstrate that they will remain intact during postulated LOCA conditions. The tests are performed by an independent laboratory and show that no significant decomposition, radiolytic or pyrolytic failures will occur during a DBA.

Where the surface area and application type do not dictate special coatings, the coatings are evaluated by generic-type and formulation information. Paint chip formation is controlled by limiting the thickness of nonqualified coatings to a point where there is insufficient tensile strength in a removed film to form a chip.

6.1.3 POST-ACCIDENT CHEMISTRY

Following a main steam line break or design basis LOCA, trisodium phosphate and boric acid solutions will be present in the containment sumps. Table 6.5-5 indicates the quantities of trisodium phosphate and boric acid that will be present in the containment after an accident. The pH control reduces the probability of chloride stress corrosion cracking on stainless steel and attack on aluminum fittings. The long term, equilibrium pH of the sump fluid will be greater than or equal to 7.1 following complete dissolution of the stored trisodium phosphate.

6.1.4 REFERENCES

1. Whyte, D. D. and Picone, L. F., "Behavior of Austenitic Stainless Steel in Post Hypothetical Loss-of-Coolant Environment," WCAP-7798-L (Proprietary), November 1971 and WCAP-7803 (Non-Proprietary), December 1971.

2. Picone, L. F., "Evaluation of Protective Coatings for use in Reactor Containment," WCAP-7198-L (Proprietary), April 1968 and WCAP-7825 (Non-Proprietary), December 1971.

3. Caplan, J. S., "The Application of Preheat Temperatures after Welding Pressure Vessel Steels," WCAP-8577 (Non-Proprietary), September 1975.

TABLE 6.1-1 ESF MATERIALS OF CONSTRUCTION

Item	Applicable Section	Externally Exposed to Containment Environment	Internally Exposed to Containment DBA Environment	Design Code	Specification	Protective Coating
Safety Injection Systems-Includes Residual Heat Removal and CVCS Systems						
Refueling water storage tank	6.3	No	No	III-2	SA 240, Type 304; SA 312, Type 304; SA 182, F 304; SA 479, Type 304	N/A
Accumulator	6.3	Yes	No	III-2	SA 537 with SA 240, Type 304 Clad	Chemically cured epoxy or modified phenolic epoxy
Intermediate head safety injection pump	6.3	No	Yes	III-2		
Casing					SA 351, Grade CF8 or CF8M, SA 182, F 304 or F 316	N/A
Impeller					A 296 CA40	N/A
Shaft					A 276 410	N/A
Residual heat removal pump	5.4.7/6.3	No	Yes	III-2		
Casing					SA 182, F 304	N/A
Impeller					A 296 CA 40	N/A
Shaft					A 276 410	N/A
Residual heat removal heat exchanger	5.4.7/6.3	No	Yes	III-2		
Shell					SA 240 and SA 312, Type 304	N/A
Tubes					SA 213, Type 304; SA 249, Type 304	N/A
Tube Sheets					SA 182, F 304; SA 246, Type 304; SA 516, Grade 70 with SS Cladding	N/A

TABLE 6.1-1 (Sheet 2)

Item	Applicable Section	Externally Exposed to Containment Environment	Internally Exposed to Containment DBA Environment	Design Code	Specification	Protective Coating
Recirculation valve encapsulation	6.3	No	No	III-2	SA 240, Type 304; SA 312, Type 304; SA 182, F 304; SA 285, Grade C	Carbozinc 11 for carbon steel skirt
High head ECCS centrifugal charging pump	9.3.4	No	Yes	III-1	SA 182, F 304	N/A
Containment Spray System						
Containment spray pump	6.2.2	No	Yes	III-2		
Casing					SA 182, F 304	N/A
Impeller					A 487, CB 6MM	N/A
Shaft					A 276, Type 410, Condition T	N/A
Containment spray pump eductor	6.2.2	No	Yes	III-2		
Body					SA 182, Type 304 (Body)	N/A
Insert					SA 564, Type 630 (Insert)	N/A
Trisodium phosphate baskets	6.2.2	Yes	Yes	AISC	Type 304/316	N/A
Containment spray header and nozzles	6.2.2	Yes	Yes	III-2		
Header					SA 312, Type 304 or SA 376, Type 304	N/A
Nozzles					SA 351 Type 304	N/A
Containment recirculation sump strainer	6.2.2	Yes	Yes	N/A	Type 304 or 316 SS	N/A
Recirculation valve encapsulation	6.2.2	No	No	III-2	SA 240, Type 304; SA 312, Type 304, SA 182, F 304; SA 285, Grade C	Carbozinc 11 for carbon steel skirt
Auxiliary Feedwater System						
Motor-driven auxiliary feedwater pump	10.4.9	No	No	III-3		
Casing					SA 217, WC9	Mfrs. Std.

TABLE 6.1-1 (Sheet 3)

Item	Applicable Section	Externally Exposed to Containment Environment	Internally Exposed to Containment DBA Environment	Design Code	Specification	Protective Coating
Impeller					A 296, CA6NM	N/A
Shaft					A 276, Type 410, Condition T	N/A
Turbine-driven auxiliary feedwater pump	10.4.9	No	No	III-3		
Casing					SA 217, WC9	Mfrs. Std.
Impeller					A 297, CA6NM	N/A
Shaft					A 276, Type 410, Condition T	N/A
Auxiliary feedwater pump turbine	10.4.9	No	No	MS		
Casing					A 216, WCB	Mfrs. Std.
Rotor					AISI 4140	N/A
Main Feedwater System						
Portion of system piping and instrumentation	10.4.7	Yes	No	III-2	SA 333, Grade 6	Carbozinc 11
Isolation valve	10.4.7	No	No	III-2	SA 216, WCB	N/A
Main Steam System						
Portion of system piping and instrumentation	10.3	Yes	No	III-2	SA 155, KCF-70	Carbozinc 11
Isolation valve	10.3	No	No	III-2	SA 216, WCB	N/A
Containment and Piping Penetrations						
Containment piping penetration	6.2.4	Yes	Yes/No	III-2	SA 155, KCF-70 CL SA 333, Grade 6	Carbozinc 11
Containment penetration isolation valves	6.2.4	Yes	Yes/No	III-2	See ASME III Class 2 Valves	N/A
Containment penetration piping between isolation valves	6.2.4	Yes	Yes/No	III-2	See ASME III Class 2 Piping	Carbozinc 11 or N/A
Containment liner	6.2.4	Yes	N/A	III, Div 2 (Prop) Sec. 3,000	SA 285, Grade A	Carbozinc 11

TABLE 6.1-1 (Sheet 4)

Item	Applicable Section	Externally Exposed to Containment Environment	Internally Exposed to Containment DBA Environment	Design Code	Specification	Protective Coating
Containment Cooling System						
Containment cooler fan	6.2.2/9.4	Yes	Yes	N/A	A 283	Modified phenolic epoxy
Housing, cone and bell						
Containment cooler coils	6.2.2/9.4	Yes	No	III-3	SB 111, Alloy 706; B 152, Alloy 110; SB 466, Alloy 706; A 526	N/A
Containment cooler housing	6.2.2/9.4	Yes	Yes	N/A	A 500 B, A 570, Grade D	Modified phenolic epoxy
Containment cooler fan motor	6.2.2/9.4	Yes	No	NEMA	Carbon steel, copper	Modified phenolic epoxy
Hydrogen mixing fan	6.2.2/9.4	Yes	Yes	N/A	Carbon steel	Modified phenolic epoxy
Hydrogen mixing fan motor	6.2.2/9.4	Yes	No	NEMA	Carbon steel, copper	Mfrs. Std.
Containment Hydrogen Control System						
Electric recombiner	6.2.5	Yes	Yes	NEMA	A 240, Type 304	N/A
Hydrogen analyzer	6.2.5	No	Yes	N/A		
Tubing (including coolers)					SA 213, Type 304 or 316	N/A
Fittings					SA 479, Type 316, SA 182, Type 316	N/A
Piping and Valves						
ASME III Class 1	3.9.3			III-1		
Piping		Yes	Yes		SA 312, Type 304, seamless	N/A
Valves		Yes	Yes		SA 182, F 316 SA 351, Grade CP8 or CF8M	N/A

TABLE 6.1-1 (Sheet 5)

Item	Applicable Section	Externally Exposed to Containment Environment	Internally Exposed to Containment DBA Environment	Design Code	Specification	Protective Coating
ASME III Class 2	3.9.3			III-2		
Piping		Yes	Yes		SA 312, Type 304, seamless or welded	N/A
					SA 155, KC-70, Cl.1, welded	Carbozinc 11
					SA 155, KCP-70	
					SA 106, Grades B and C, seamless	Carbozinc 11
					SA 333, Grade 6, seamless or welded	Carbozinc 11
Valves		Yes	Yes		SA 182, F 316	N/A
					SA 351, Grade CP8 or CF8M	N/A
					SA 216, WCB	
ASME III Class 3	3.9.3			III-3		
Piping		Yes	Yes		SA 312, Type 304, seamless or welded	N/A
					SA 155, KC-70, C1.1, welded	Carbozinc 11
					SA 106, Grade B, seamless	Carbozinc 11
Valves		Yes	Yes		SA 182, F316	N/A
					SA 351, Grade CF8 or CF8M	
					SA 216, WCB	Carbozinc 11

TABLE 6.1-2 DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.54 REVISION 0, DATED JUNE 1973, TITLED "QUALITY ASSURANCE REQUIREMENTS FOR PROTECTIVE COATINGS APPLIED TO WATER-COOLED NUCLEAR POWER PLANTS"

Regulatory Guide 1.54 Position	Position on Non-NSSS Components	Position on NSSS Components
1. ANSI N101.4-1972 should be used in conjunction with ANSI N45.2-1971, "Quality Assurance Program Requirements for Nuclear Power Plants."	1. Complies.	1, 2, 3 and 4. NSSS equipment located in the containment building is separated into four categories to identify the applicability of this regulatory guide to various types of equipment. These categories of equipment are as follows:
2. Subdivision 2.7 of ANSI N101-4-1972 states that when references are made to other standards, these references shall imply the most recent or current editions of the referenced standards. The specific applicability or acceptability of referenced standards will be covered separately in other regulatory guides, where appropriate.	2. Complies.	a. Category 1 - Large equipment b. Category 2 - Intermediate equipment c. Category 3 - Small equipment d. Category 4 - Insulated/stainless steel equipment A discussion of each equipment category follows:
3. Subdivision 1.1.2 of ANSI N101.4-1972 states that quality assurance, as covered by this standard, comprises all those planned and systematic actions necessary to provide specified documentation and adequate confidence that shop or field coating work for nuclear facilities will perform satisfactorily in service. This statement should not be interpreted as implying that the end product of quality assurance actions is the production of specified documentation. The term "quality assurance," as used in ANSI N101.4-1972, should be considered to comprise all those planned and systematic actions necessary to provide adequate confidence that shop or field coating work for nuclear facilities will perform satisfactorily in service. In this connection, it is emphasized that records and documents listed in Subdivisions 7.4 through 7.8, and included in the standard, are suggested forms only. Alternate documentation consistent with the requirements of Appendix B to 10 CFR Part 50 is also considered acceptable.	3. Complies, except that for certain applications within the containment, where the coating is not necessary for the protection of the component, a quality assurance program is not applied. In those applications, the coating is reviewed to assure that there are no long-term detrimental effects.	a. Category 1 - Large Equipment The Category 1 equipment consists of the following: (1) Reactor coolant system supports (2) Reactor coolant pumps (motor and motor stand) (3) Accumulator tanks (4) Refueling machine Since this equipment has a large surface area and is procured from only a few vendors, it is possible to implement tight controls over these items. Stringent requirements are specified for protective coatings on this equipment through the use of a painting specification in the procurement documents. This specification defines requirements for: (1) Preparation of vendor procedures (2) Use of specific coatings systems which are qualified to ANSI N101.2 (3) Surface preparation (4) Application of the coating systems in accordance with the paint manufacturer's instructions (5) Inspections and nondestructive examinations (6) Exclusive of certain materials

TABLE 6.1-2 (Sheet 2)

Regulatory Guide 1.54 Position	Position on Non-NSSS Components	Position on NSSS Components
4. Sections 3 and 4 of ANSI N101.4-1972 delineate quality assurance requirements for coating materials and surface preparation of substrates. Cleaning materials used with stainless steel would not be compounded from or treated with chemical compounds containing elements that could contribute to corrosion, intergranular cracking, or stress corrosion cracking. Examples of such chemical compounds are those containing chlorides, fluorides, lead, zinc, copper, sulfur, or mercury where such elements are leachable or where they could be released by breakdown of the chemical compounds under expected environmental conditions (e.g., by radiation). This limitation is not intended to prohibit the use of trichlorotrifluoroethane which Military Specification MIL-C-81302b for cleaning or degreasing of austenitic stainless steel provided adequate removal is assured.	4. Complies	(7) Identification of all nonconformances (8) Certifications of compliance The vendor's procedures are subject to review by engineering personnel, and the vendor's implementation of the specification requirements is monitored during quality assurance surveillance activities. This system of controls provides assurance that the protective coatings will properly adhere to the base metal during prolonged exposure to a post-accident environment present within the containment building. b. Category 2 - Intermediate Equipment The Category 2 equipment consists of the following: (1) Seismic platform and tie rods (2) Reactor internals lifting rig (3) Head lifting rig (4) Electrical cabinets Since these items are procured from a large number of vendors, and individually have very small surface areas, it is not practical to enforce the complete set of stringent requirements which are applied to Category 1 items. Another painting specification is used in these procurement documents. This specification defines to the vendors the requirements for: (1) Use of specific coating systems which are qualified to ANSI N101.2 (2) Surface preparation (3) Application of the coating systems in accordance with the paint manufacturer's instructions

TABLE 6.1-2 (Sheet 3)

Regulatory Guide 1.54 Position	Position on Non-NSSS Components	Position on NSSS Components
		The vendor's compliance with the requirements is also checked during quality assurance surveillance activities in the vendor's plant. These measures of control provide a high degree of assurance that the protective coatings will adhere properly to the base metal and withstand the postulated accident environment within the containment building. c. Category 3 - Small Equipment Category 3 equipment consists of the following: (1) Transmitters (2) Alarm horns (3) Small instruments (4) Valves (5) Heat exchanger supports These items are procured from several different vendors and are painted by the vendor in accordance with conventional industry practices. Because the total exposed surface area is very small, Westinghouse does not specify further requirements. d. Category 4 - Insulated or Stainless Steel Equipment Category 4 equipment consists of the following: (1) Steam generators - covered with metallic reflective insulation (2) Pressurizer - covered with wrapped insulation (3) Reactor pressure vessel covered with rigid reflective insulation (4) Reactor cooling piping -stainless steel (5) Reactor coolant pump casings -stainless steel Since Category 4 equipment is insulated or is stainless steel, no painted surface areas are exposed within the containment. Therefore, this regulatory guide is not applicable for Category 4 equipment.

TABLE 6.1-3 CONTAINMENT COMPONENTS - COATING SCHEDULE

Category	Item/Type/ Description	R.G 1.54 Q Coating	Mfrs. Std. Coat	Uncoated: Stainless	Uncoated: Galvanized	Uncoated: Insulation	Generic Type (1)	Estimated Total Film Thickness (mils)	Shop Applied	Field Applied	Estimated Area (Square Feet)
Carbon steel liner	Containment - dome	X					Inorganic zinc	2-4	X	Touch-up	31,000
plate	Containment - walls	X					Inorganic zinc	2-4	X	Touch-up	59,000
Structural steel	Heavy support steel	X					Inorganic zinc	2-4	X	Touch-up	179, 657
	Miscellaneous steel	X					Inorganic zinc	2-4	X	Touch-up	16,500
	Gratings				X						43,700
Elevator	Metal siding				X						8,500
Tanks and pools	Accumulator tanks	X					Epoxy	4-5	X	Touch-up	5,200
	Refueling pool			X							N/A
	Reactor coolant drain tank			X							N/A
Carbon steel pipe,	Pipe			X		X					N/A
hangers, valves, and supports	Pipe	X					Inorganic zinc	2-4	X	Touch-up	9,100
	Pipe supports	X					Inorganic zinc	2-4	X	Touch-up	25,500
	Valves and valve actuators		X				Alkyd/red oxide	2.5-4	X	Touch-up	3,500
Mechanical	Polar crane	X					Inorganic zinc	4-7	X		36,700
equipment	Pumps (RCPs)	X					Epoxy	2-4	X	Touch-up	3,000
(including	Fans and fan housings	X					Epoxy	7.5-11	X		813
driver)	(carbon steel)		X				Epoxy	7.5-11	X		400
	CRDM coil stack housings	X					Zinc Metalizing	2-5	X		558
	HVAC ducting				X						9,226 (2)
	HVAC ducting			X							N/A
	Steam generators					X					15,200
	Hydrogen recombiners			X							N/A
	Containment coolers	X					Epoxy	6-10	X		5,400
	Containment coolers				X						1,100
	Heat exchangers	X					Epoxy	2-4	X	Touch-up	300
Electrical	Motor control centers		X				Alkyd/red oxide	1-2.5	X		500
	Terminal boxes				X						600
	Control panels		X				Epoxy	1.75-3	X		1,000

TABLE 6.1-3 (Sheet 2)

Category	Item/Type/ Description	R.G 1.54 Q Coating	Mfrs. Std. Coat	Uncoated: Stainless	Uncoated: Galvanized	Uncoated: Insulation	Generic Type (1)	Estimated Total Film Thickness (mils)	Shop Applied	Field Applied	Estimated Area (Square Feet)
	Raceways, conduit, cable trays, and supports				X						38,482 (2)
Concrete and masonry	Floor, cove, and wainscot	X					Epoxy (3)	12		X	12,900 (4)

NOTES:

(1) Generic coating systems acceptable for containment use are selected from suppliers who are prequalified to Bechtel standards and test criteria. Other coating systems may be shown to be acceptable based on individual analyses.

(2) Estimated area includes a limited amount of unqualified touch-up coating.

(3) Concrete, if painted, will be painted with epoxy surfacer or epoxy coating system.

(4) The wainscot extends 12 inches above the floor and is painted the same as described in Note 2, then top coated with 8 to 10 mils of epoxy-based paint.

(5) Deleted

(6) Deleted

TABLE 6.1-4 DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.44, REVISION 0, DATED MAY 1973, TITILED “CONTROL OF THE USE OF SENSITIZED STAINLESS STEEL”

Regulatory Guide 1.44 Position	Position on Non-NSSS Components	Position on NSSS Components
Unstabilized, austenitic stainless steel of the AISI Type 3XX series used for components that are part of (1) the reactor coolant pressure boundary, (2) systems required for reactor shutdown, (3) systems required for emergency core cooling, and (4) reactor vessel internals that are relied upon to permit adequate core cooling for any mode of normal operation or under credible postulated accident conditions should meet the following:		
1. Material should be suitably protected against contaminants capable of causing stress corrosion cracking during fabrication, shipment, storage, construction, testing, and operation of components and systems.	1. Complies	1. Complies, as discussed in Sections 5.2.3.4.1 and 5.2.3.4.4.
2. Material from which components and systems are to be fabricated should be solution heat treated to produce a nonsensitized condition in the material.	2. Complies.	2. Complies, as discussed in Section 5.2.3.4.2.
3. Nonsensitization of the material should be verified using ASTM A 262-70, "Recommended Practices for Detecting Attack in Stainless Steel," Practices A or E, or another method that can be demonstrated to show nonsensitization in austenitic stainless steel. Test specimens should be selected from material subject to each different heat treatment practice and from each heat.	3. All austenitic stainless steels are furnished in the solution annealed and water-quenched condition. Since susceptibility to stress corrosion cracking in this condition is minimal, testing is not performed.	3. Complies, as discussed in Section 5.2.3.4.3.
4. Material subjected to sensitizing temperature in the range of 800 to 1500°F, subsequent to solution heat treating in accordance with Subparagraph C.2. above and testing in accordance with Subparagraph C.3. above, should be L Grade material; that is, it should not have a carbon content greater than 0.03 percent. Exceptions are: a. Material exposed to reactor coolant which has a controlled concentration of less than 0.10 ppm dissolved oxygen at all temperatures above 200°F during normal operation, or	4. During fabrication and installation, austenitic stainless steels are not permitted to be exposed to temperatures in the range of 800-1500°F, except for welding. Welding practices are controlled to minimize sensitization, as discussed in Position 5 below.	4. Complies, as discussed in Section 5.2.3.4.4.

TABLE 6.1-4 (Sheet 2)

Regulatory Guide 1.44 Position	Position on Non-NSSS Components	Position on NSSS Components
b. Material in the form of castings or weld metal with a ferrite content of at least 5 percent; or		
c. Piping in the solution annealed condition whose exposure to temperatures in the range of 800 to 1500°F has been limited to welding operations, provided it is of sufficiently small diameter so that in the event of a credible postulated failure of the piping during normal reactor operation, the reactor can be shut down and cooled down in an orderly manner, assuming makeup is provided by the reactor coolant makeup system only.		
5. Material subjected to sensitizing temperatures in the range of 800 to 1500°F during heat treating or processing other than welding, subsequent to solution heat treating in accordance with Subparagraph C.2. above, and testing in accordance with Subparagraph accordance with Subparagraph C.3. above, should be retested in accordance with Subparagraph C.3 above, to demonstrate that it is not susceptible to intergranular attack, except that retest is not required for:	5. Heat treatment of austenitic stainless steel in the temperature range 800 to 1,500°F is not permitted. Hot bending of austenitic stainless steel piping is performed at the solution annealing temperature, followed by an immediate water quenching. If hot bending is performed at some temperature other than the solution annealing temperature, the pipes are re-solution annealed and water quenched. Since sensitization is avoided, testing to determine susceptibility to intergranular attack is not performed.	5. Complies, as discussed in Section 5.2.3.4.5.
a. Cast metal or weld metal with a ferrite content of 5 percent or more: or		
b. Material with a carbon content of 0.03 percent or less that is subjected to temperatures in the range of 800 to 1500°F for less than 1 hour or		
c. Material exposed to special processing, provided the processing is properly controlled to develop a uniform product and provided that adequate documentation exists of service experience and/or test data to demonstrate that the processing will not result in increased susceptibility to intergranular stress corrosion.		

TABLE 6.1-4 (Sheet 3)

Regulatory Guide 1.44 Position	Position on Non-NSSS Components	Position on NSSS Components
Specimens for the above retest should be taken from each heat of material and should be subjected to a thermal treatment that is representative of the anticipated thermal conditions that the production material will undergo.		
6. Welding practices and, if necessary, material composition should be controlled to avoid excessive sensitization of base metal heat-affected zones of weldments. An intergranular corrosion test, such as specified in Subparagraph C.3 above, should be performed for each welding procedure to be used for 0.03 percent.	6. Welding practices are controlled to minimize sensitization in the heat-affected zone of unstabilized austenitic stainless steels, as described below. a. Weld Heat Input Heat input during welding is controlled by limiting the size of electrodes for the shielded metal arc and gas tungsten arc processes and the bead thickness for submerged arc welding. Other welding processes are not permitted. b. Interpass Temperatures Interpass temperatures during welding are controlled so as not to exceed 350°F. c. Ferrite Content Stainless steel welding materials are furnished with a ferrite content in the range of 8 to 25 percent for type 308 and 308L welding materials and 5 to 15 percent for type 316, 316L, 309, and 309L welding materials. Additional discussion regarding compliance to Regulatory Guide 1.31 is provided in Table 6.1-9.	6. Complies, as discussed in Sections 5.2.3.1, 5.2.3.2.2, 5.2.3.3.2 and 5.2.3.4.

TABLE 6.1-4 (Sheet 4)

Regulatory Guide 1.44 Position	Position on Non-NSSS Components	Position on NSSS Components
	d. Postweld Heat Treatment Postweld heat treatment at temperatures in excess of 350 F are not permitted unless a full-solution anneal and water quench are performed. The above welding practices are sufficient to ensure that unacceptable sensitization of the base metal heat affected does not occur; therefore, the intergranular corrosion testing is not performed	

TABLE 6.1-5 DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.37, REVISION 0, DATED MARCH 1973, TITLED “QUALITY ASSURANCE REQUIREMENTS FOR CLEANING OF FLUID SYSTEMS AND ASSOCIATED COMPONENTS OF WATER-COOLED NUCLEAR POWER PLANTS”

Regulatory Guide 1.37 Position	Union Electric Position
The requirements and recommendations for onsite cleaning of materials and components, cleanness control, and preoperational cleaning and layup of water-cooled nuclear power plant fluid systems that are included in ANSI N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants," are generally acceptable and provide an adequate basis for complying with the pertinent quality assurance requirements of Appendix B to 10 CFR Part 50, subject to the following:	
1. Subdivision 1.5 of ANSI N45.2.1, 1973 states that other documents required to be included as a part of the standard are either identified at the point of reference or described in Section 10 of the standard. The specific applicability or acceptability of these listed documents has been or will be covered separately in other regulatory guides or in Commission regulations, where appropriate.	1. Complies.
2. Although subdivision 1.2 of ANSI N45.2.1-1973 states that the requirements promulgated apply during the construction phase of a nuclear power plant, many of the requirements and recommendations contained in the standard are also appropriate to cleaning of fluid systems and associated components during the operation phase of a nuclear power plant and they should be used when applicable. In this regard, however, it should be particularly noted that decontamination and cleanup of radioactively contaminated systems and components are not addressed by ANSI N45.2.1-1973. These operations will be considered separately in future regulatory guides.	2. Complies

TABLE 6.1-5 (Sheet 2)

Regulatory Guide 1.37 Position	Union Electric Position
3. Subdivision 3.2 of ANSI N45.2.1-1973 states that the selection of the water quality for a specific application shall be made by the organization responsible for the cleaning operations unless otherwise specified in the purchase document. The water quality for final flushes of fluid systems and associated components should be at least equivalent to the quality of the operating system water.	3. Complies. Refer to OQAM Appendix A for clarifications
4. Section 5 of ANSI N45.2.1-1973 states, in part, that low sulfur, low fluorine, and/or low chlorine compounds may be used on austenitic stainless steels and that low sulfur and low lead compounds may be used on nickel-base alloys. Chemical compounds that could contribute to inter-granular cracking or stress-corrosion cracking should not be used with austenitic stainless steel and nickel-base alloys. Examples of such chemical compounds are those containing chlorides, fluorides, lead, zinc, copper, sulfur, or mercury where such elements are leachable or where they could be released by breakdown of the compounds under expected environmental conditions (e.g., by radiation). This limitation is not intended to prohibit the use of trichlorotrifluoroethane which meets the requirements of Military Specification Mil-C-81302b for cleaning or degreasing of austenitic stainless steel provided the precautions of subdivision 7.3(4) of ANSI N45.2.1-1973 are observed.	4. Complies. Refer to OQAM Appendix A for clarifications.
5. Section 5 of ANSI N45.2.1-1973 states, in part, that operations such as grinding and welding which generate particulate matter should be controlled. Adequate control of tools used in abrasive work operations such as grinding, sanding, chipping, or wire brushing should be provided. Specifically, tools which contain materials that could contribute to intergranular cracking or stress-corrosion cracking or which, because of previous usage may have become contaminated with such materials, should not be used on surfaces of corrosion-resistant alloys. Examples of such materials are listed in Regulatory Position 4.	5. Complies. Refer to OQAM Appendix A for clarifications.

TABLE 6.1-5 (Sheet 3)

Regulatory Guide 1.37 Position	Union Electric Position
6. Subdivision 1.4 of ANSI N45.2.1-1973 suggests the use of ASTM A 262-68 or ASTM A 393-63 for detection of intergranular precipitation of chromium carbides in corrosion-resistant alloys. ASTM A 393-63 has been withdrawn by ASTM and is no longer considered a valid test.	6. Complies.

TABLE 6.1-6 DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.36, REVISION 0, DATED FEBRUARY 1973, TITLED "NONMETALLIC THERMAL INSULATION FOR AUSTENITIC STAINLESS STEEL"

Regulatory Guide 1.36 Position	Union Electric Position
The levels of leachable contaminants in nonmetallic insulation materials that come into contact with austenitic stainless steels of the American Iron & Steel Institute (AISI) Type 3XX series used in fluid systems important to safety should be carefully controlled so that stress-corrosion cracking is not promoted. In particular, the leachable chlorides and fluorides should be held to the lowest practicable levels. Insulation for the above application should meet the following conditions:	
1. All insulating materials should be manufactured, processed, packaged, shipped, stored, and installed in a manner that will limit, to the maximum extent practical, chloride and fluoride contamination from external sources.	1. Complies.
2. Qualification Test: Each type of insulating material should be qualified by the manufacturer or supplier for use by:	2. Complies, except that the 1977 version of ASTM C 692 may be used.
a. An appropriate test to reasonably assure that the insulation formulation does not induce stress corrosion. Two acceptable tests are:	
(1) ASTM C 692-71, Standard Method for Evaluating Stress Corrosion Effect of Wicking-Type Thermal Insulations on Stainless Steel" (Dana Test). The material should be rejected if more than one of five specimens crack; and	
(2) RDT M12-1T, "Test Requirements for Thermal Insulating Materials for Use on Austenitic Stainless Steel," Section 5 (Knolls Atomic Power Laboratory (KAPL) Test). The material should be rejected if more than one of four specimens crack.	

TABLE 6.1-6 (Sheet 2)

Regulatory Guide 1.36 Position	Union Electric Position
b. Chemical analysis to determine the ion concentrations of leachable chloride, fluoride, sodium, and silicate. Insulating material that is not demonstrated by the analysis to be within the acceptable region of figure 1 of this guide would be rejected. This analysis should also be used as a comparison basis for the production test specified in C.3 below.	
3. Production Test: A representative sample from each production lot of insulation material to be used adjacent to, or in contact with, austenitic stainless steels used in fluid systems important to safety should be chemically analyzed to determine leachable chloride, fluoride, sodium, and silicate ion concentrations as in C.2.a above. The lot should be accepted only if: a. The analysis shows the material to be within the acceptable region of Figure 1; and b. Neither the sum of chloride plus fluoride ion concentrations nor the sum of sodium plus silicate ion concentrations determined by this analysis deviates by more than 50 percent from the values determined on the sample used to qualify the insulation in C.2 above.	3. Complies, except for the following clarification regarding C.3.b: The sum of chloride plus fluoride ion concentrations determined by this analysis does not deviate by more than 50% greater than the value determined on the sample used to qualify the insulation in C.2.above. The sum of sodium plus silicate ion concentrations determined by this analysis does not deviate by more than 50% less than the value determined on the sample used to qualify the insulation in C.2 above.
4. Requalification: When a change is made in the type, nature, or quality of the ingredients, the formulation, or the manufacturing process, the insulation material should be requalified by repeating the tests described in C.2 above.	4. Complies.

TABLE 6.1-7 DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.50 REVISION 0, DATED MAY 1973, TITLED, "CONTROL OF PREHEAT TEMPERATURES FOR WELDING OF LOW-ALLOY STEEL"

Regulatory Guide 1.50 Position	Position on Non-NSSS Components	Position on NSSS Components
Weld fabrication for low-alloy steel components should comply with the fabrication requirements specified in Section III and Section IX of the ASME B&PV Code supplemented by the following:		Westinghouse considers this Regulatory Guide applicable only to ASME III, Class 1 components.
1. The procedure qualification should require that: a. A minimum preheat and a maximum interpass temperature be specified.	1. Paragraph 1.a is complied with when impact testing, in accordance with ASME Boiler and Pressure Vessel Code, Section III, Subarticle 2300, is required. When impact testing is not required, specification of a maximum interpass temperature in the welding procedures is not necessary in order to assure that the other required mechanical properties of the weld are met.	1.a. Complies, for Class components.
b. The welding procedures be qualified at the minimum preheat temperature.	1.b. Complies.	1.b. For Class 1 components, welding procedures are qualified within the preheat temperature ranges required by Section IX of the ASME Boiler and Pressure Vessel Code.
2. For production welds, the preheat temperature should be maintained until a postweld heat treatment has been performed.	2. Complies for pressure vessels with nominal thicknesses greater than 1 inch. Maintenance of preheat beyond completion of welding until postweld heat treatment (PWHT) is not required for thinner sections, since experience has indicated that delayed cracking in the weld or heat affected zone (HAZ) is not a problem.	2. Compliance is discussed in Section 6.1.4, Reference 3.
3. Production welding should be monitored to verify that the limits on preheat and interpass temperatures are maintained.	3. Current usage of low alloy steel in piping, pumps, and valves is minimal and is normally limited to Class 3 construction. When low alloy steel piping, pumps, and valves are used, preheat is maintained until welding is complete, but not until postweld heat treatment (PWHT) is performed, since the conditions which cause delayed cracking in the weld or heat affected zone (HAZ) are not present.	3. Complies, for Class 1 components.

TABLE 6.1-7 (Sheet 2)

Regulatory Guide 1.50 Position	Position on Non-NSSS Components	Position on NSSS Components
4. In the event that regulatory positions C.1, C.2, and C.3, above, are not met, the weld is subject to rejection. However, the soundness of the weld may be verified by an acceptable examination procedure.	4. Complies.	4. Complies, for Class 1 components.

TABLE 6.1-8 DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.71 REVISION 0, DATED DECEMBER 1973, TITLED, "WELDER QUALIFICATION FOR AREAS OF LIMITED ACCESSIBILITY"

Regulatory Guide <u>1.71 Position</u>	Position on Non-NSSS <u>Components</u>	Position on <u>NSSS Components</u>
Weld fabrication and repair for wrought low-alloy or other materials such as static and centrifugal castings and bimetallic joints should comply with the fabrication requirements specified in Section III and Section IX supplemented by the following:		
1. The performance qualification should require testing of the welder under simulated access conditions when physical conditions restrict the welder's access to a production weld to less than 30 to 35 cm (12 to 14 inches) in any direction from the joint.	1. Performance qualifications for personnel who weld under conditions of limited access are maintained in accordance with the applicable requirements of ASME Sections III and IX. Additionally, responsible site supervisors are required to assign only the most highly skilled welders to limited-access welding. Of course, welding conducted in areas of limited access is subjected to the required nondestrucive testing, and no waiver or relaxation of examination methods or acceptance criteria because of the limited access is permitted.	1. Performance qualification (or requalification) of welder for areas of limited accessibility is not required. Experience shows that current shop practices produce high quality welds. In addition, the performance of nondestructive examinations provides further assurance of acceptable weld quality. Limited accessibility qualification (or requalification) in excess of ASME Code, Section III or IX requirements is an unduly restrictive requirement for component fabrication, where the welder's physical position relative to the welds is controlled.
2. Requalification is required: a. When significantly different restricted accessibility conditions occur, or b. When any of the essential welding variables listed in Section IX are changed.	2. Requalification is required: when any of the essential variables of ASME Section IX are changed, or when any authorized inspector questions the ability of the welder to perform satisfactorily the requirements of ASME Section III or IX.	2. See response to 1 above.
3. Production welding should be monitored and adherence to welding qualification requirements should be certified.	3. Production welding is monitored and welding qualifications are certified in accordance with (1) and (2) above.	3. See response to 1 above.

TABLE 6.1-9 DESIGN COMPARISON TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.31, REVISION 3, DATED APRIL 1978, TITLED, "CONTROL OF FERRITE CONTENT ON STAINLESS STEEL WELD METAL"

Requirements of this regulatory guide are applied to production welds (full penetration pressure boundary welds) which could be subject to microfissures due to low delta ferrite content of the deposited weld metal, in austenitic stainless steel ASME Section III, Class 1 and 2 components, and core support structures.

Regulatory Guide 1.31 Position	Position on Non-NSSS Components	Position on NSSS Components
1. Verification of Delta Ferrite Content of Filler Materials Prior to production usage, the delta ferrite content of test weld deposits from each lot and each heat of weld filler metal procured for the welding of austenitic stainless steel core support structures and Class 1 and 2 components should be verified for each process to be used in production. It is not necessary to make delta ferrite determination for SFA-5.4 type 16-8-2 weld metal or for filler metal used for weld metal cladding. Delta ferrite determinations for consumable inserts, electrodes, rod or wire filler metal used with the gas tungsten arc welding process, and deposits made with the plasma arc welding process may be predicted from their chemical composition using an applicable constitutional diagram to demonstrate compliance. Delta ferrite verification should be made for all other processes by tests using magnetic measuring devices on undiluted weld deposits. For submerged arc welding processes, the verification tests for each wire and flux combination may be made on a production weld or simulated production weld. All other delta ferrite weld filler verification tests should be made on weld pads that contain undiluted layers of weld metal.	1. Portions of the non-NSSS components conform to the requirements of Revision 3 of this regulatory guide. The remainder of the non-NSSS components, fabricated prior to the implementation of Revision 3 of this regulatory guide, conform to the requirements specified in the PSAR position on the NRC interim position on Revision 1 of this regulatory guide. The requirements of the PSAR include magnetic testing of randomly selected production welds made from wire whose delta ferrite content was determined from constitution diagrams. Revision 3 requirements include the requirement to determine the delta ferrite content of the weld wire by magnetic tests on undiluted test pads. Production weld testing is not required by Revision 3 of this regulatory guide.	1. Field welding of NSSS components is done in accordance with Revision 3 of this regulatory guide. Section 5.2.3.4.6 describes the extent of compliance to the NRC interim position on Revision 1 of this regulatory guide of the NSSS supplied and fabricated components.
2. Ferrite Measurement Appendix A to this guide contains extracts from a future edition of the American Welding Society's AWS A5.4, "Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes," which describes a procedure for pad preparation and ferrite measurement. The NRC staff considers this procedure acceptable for use with covered electrodes.	2. Complies where magnetic testing is performed to verify the weld filler material as described in 1. above.	2. See Section 5.2.3.4.6

TABLE 6.1-9 (Sheet 2)

Regulatory Guide 1.31 Position	Position on Non-NSSS Components	Position on NSSS Components
3. Instrumentation The weld pad should be examined for ferrite content by a magnetic measuring instrument which has been calibrated against a Magnegage in accordance with American Welding Society Specification AWS A4.2-74, "Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal." The Magnegage should have been previously calibrated in accordance with AWS A4.2-74 using primary standards as defined therein.	3. Complies where magnetic testing is performed to verify the weld filler material as described in 1. above. When production weld testing is performed to support chemical composition similar instrumentation requirements will be met.	3. See Section 5.2.3.4.6
4. Acceptability of Test Results Weld pad test results showing an average Ferrite Number from 5 to 20 indicate that the filler metal is acceptable for production welding of Class 1 and 2 austenitic stainless steel components and core support structures. The upper limit of 20 may be waived for (a) welds that do not receive postweld stress relief heat treatment or welds for which such postweld stress relief treatment is conducted at temperatures less than 900°F, (b) welds that are given a solution annealing heat treatment, and (c) welds that employ consumable inserts.	4. Complies.	4. See Section 5.2.3.4.6
5. Quality Assurance The applicable provisions of 10 CFR Part 50, Appendix B, should be used in verifying compliance with requirements for delta ferrite as described herein.	5. Complies.	5. See Section 5.2.3.4.6

TABLE 6.1-10 TABLE OF LUBRICANTS INSIDE CONTAINMENT

Equipment	Lubricant Type	Quantity[1]
Reactor coolant pumps[2]	Oil	265 gal
Polar crane[3]	Wire rope lube Gear lube	24 lb 10 lb
Miscellaneous hoists and cranes[3]	Wire rope lube	1 lb
Miscellaneous fans[4]	Oil/grease	Neg
Miscellaneous pumps[4]	Oil/grease	Neg
Steam generator mechanical snubbers[4]	Grease	Neg

NOTES:

(1) Quantity subject to be released into the containment.

(2) Assumes lube oil from one RC pump spills into sump.

(3) Assumes 10 percent will be washed off by containment spray.

(4) Motors, bearings, and snubbers are enclosed.

6.2 CONTAINMENT SYSTEMS

The containment systems include the containment, the containment heat removal systems, the containment isolation system, and the containment combustible gas control system.

The design basis accident (DBA) is defined as the most severe of a spectrum of hypothetical loss-of-coolant accidents (LOCA). The ability of the containment systems to mitigate the consequences of a DBA depends upon the high reliability of these systems. This section provides the design criteria and evaluations to demonstrate that these systems function within the specified limits throughout the unit operating lifetime.

6.2.1 CONTAINMENT FUNCTIONAL DESIGN

A physical description of the containment and the design criteria relating to construction techniques, static loads, and seismic loads is provided in Section 3.8. This section pertains to those aspects of containment design, testing, and evaluation that relate to the accident mitigation function.

6.2.1.1 Containment Structure

6.2.1.1.1 Design Bases

The safety design basis for the containment is that the containment must withstand the pressures and temperatures of the DBA without exceeding the design leakage rate, as required by 10 CFR 50, Appendix A, General Design Criterion 50, and that, in conjunction with the other containment systems and the other engineered safety features, the release of radioactive material subsequent to a DBA does not result in doses in excess of the guideline values specified in 10 CFR 100. The radiological consequences of the DBA are presented in Section 15.6.

a. Assumed Accident Conditions

   For the purpose of determining the design pressure requirements for the containment structure and the containment internal structures, the following simultaneous occurrences are assumed:

   1. The postulated reactor coolant system pipe rupture, as listed in Table 6.2.1-1, is assumed to be concurrent with the loss of offsite power and the worst single active failure. No two pipe breaks are assumed to occur simultaneously or consecutively. For design loadings on the systems used to mitigate the consequences of a postulated reactor coolant system pipe rupture, a safe shutdown earthquake is assumed.

2. The postulated secondary system pipe rupture, as identified in Section 6.2.1.4, is assumed concurrent with the loss of offsite power and the worst single active failure. No two pipe breaks are assumed to occur simultaneously or consecutively.

3. The postulated inadvertent operation of a containment heat removal system is considered a low probability event and is not considered to be concurrent with any other event.

The calculated maximum containment structure internal and external pressures are listed in Table 6.2.1-2. These calculated pressures are based on the conservative analyses described in Section 6.2.1.1.3 and demonstrate that margin exists (approximately 20 percent on internal pressure and approximately 0.7 percent on external pressure) between the calculated maximum pressure and the design pressures.

The calculated maximum pressures on the containment internal structures (e.g. primary and secondary shield walls) are listed in Table 6.2.1-2. These pressures are based on the conservative analyses described in Section 6.2.1.2. The loads on the internal structures are calculated using the differentials between the maximum calculated subcompartment pressures and 14.7 psia, the pressure of the containment atmosphere at the time of peak subcompartment pressure.

b. Sources and Amounts of Mass and Energy Released

The sources and amounts of mass and energy released for the postulated reactor coolant system pipe ruptures and secondary system pipe ruptures are discussed in Sections 6.2.1.3 and 6.2.1.4, respectively.

c. Effects of the ESFs as Heat Removal Systems

The effects of the ECCS as an energy removal system are discussed in the determination of the mass and energy release data provided in Section 6.2.1.3. The only additional effect of this system considered is the long-term heat removal capability of the residual heat removal heat exchangers. In performing the containment design evaluation in Section 6.2.1.1.3, single failures of the ECCS are assumed to be consistent with the mass and energy release data assumptions for the break analyzed.

The effects of the containment heat removal systems, as active energy removal systems, have been considered in the containment design evaluation in Section 6.2.1.1.3. The most stringent single active failure of these systems is assumed to be consistent with the mass and energy release data assumptions for each break analyzed. The total heat removed by each of the containment heat removal systems up to the time of the calculated peak containment pressure is listed in Table 6.2.1-8. The design bases of the containment heat removal systems are discussed in Section 6.2.2.

The functional performance of the containment and the ECCS also rely upon the operation of the containment isolation system, as described in Section 6.2.4. Required isolation operations are assumed for purposes of the containment design evaluation in Section 6.2.1.1.3.

d. Parameters Affecting Capability for Post-Accident Pressure Reduction

The principal parameters which affect post-accident pressure reduction are 1) the heat absorbed by the heat sinks inside the containment, 2) the heat removed by the containment air coolers, and 3) the heat transferred to the containment sump by the containment spray system.

A conservative amount of heat sink material has been calculated, and its heat absorption capability has been considered in the containment design evaluation in Section 6.2.1.1.3. The parameters describing the heat sinks credited with heat absorption are provided in Table 6.2.1-4.

The pressure reduction capability of the containment air coolers and the containment spray system consider the parameters provided in Table 6.2.1-3. The assumed start time of these active heat removal systems considers a diesel start time of 12 seconds, load sequencing times, and the maximum startup time of the systems.

In support of large break LOCA with a 12-second diesel generator start an evaluation of the assumptions used in the LOCA and MSLB containment pressurization calculations, with respect to the full functioning times of the containment spray system and the containment air coolers, was performed. The evaluation shows that the containment pressurization calculations for both LOCA and MSLB provided sufficient margin so that a 12-second diesel generator start time does not change the assumed full functioning times of the containment spray and the containment air coolers.

e. Parameters Affecting Heat Removal from the Containment

Heat is transferred from the containment to the outside environment via the fan coolers and residual heat removal heat exchangers through the component cooling water and essential service water systems and released to the ultimate heat sink. A small amount of heat is also transferred through the containment wall and dome to the outside atmosphere.

The component cooling water system is described in Section 9.2.2, the essential service water system is described in Section 9.2.1, and the ultimate heat sink is described in Section 9.2.5.

Single failures in systems which remove energy from the containment are considered to be consistent with the single failures assumed in the development of the mass and energy release data. The energy removal capability of the containment air coolers, the containment spray system, and the residual heat removal system consider the parameters provided in Table 6.2.1-3.

f. Bases for Containment Depressurization Rate

To meet the containment safety design basis of limiting the release of radioactive material subsequent to a DBA so that the doses are within the guideline values specified in 10 CFR 100, the containment pressure is reduced to less than 50 percent of the containment design pressure within 24 hours after an accident. Chapter 15.0 contains the assumptions used in the analysis of the offsite radiological consequences of the accident.

g. Bases for Minimum Containment Pressure Used in ECCS Performance Studies

The minimum containment pressure transient used in the analysis of the emergency core cooling system's capability is based on the conservative overestimated heat removal capability and pressure reduction capability of the containment structures and the containment systems and on the conservative reactor coolant system thermal analysis provided in Section 15.6. The determination and evaluation of the minimum containment pressure transient are provided in Section 6.2.1.5.

6.2.1.1.2 Design Features

The principal containment and containment subcompartment design parameters are provided in Table 6.2.1-2. General arrangement drawings for the reactor containment are provided in Figures 1.2-9 through 1.2-18. Simplified arrangement drawings illustrating the nodalization model used for the containment subcompartment analyses are provided in Figures 6.2.1-43 through 6.2.1-46, 6.2.1-51 through 6.2.1-55, and 6.2.1-76.

a. Missile and Pipe Whip Protection

Missile shield considerations are described in Section 3.5. The structural design of the containment and the containment subcompartments is discussed in Section 3.8. The designed structural strength considers the effects of pipe whip and jet forces, as discussed in Section 3.6.

b. Codes and Standards

The codes, standards, and guides applied in the design of the containment structure and the containment internal structures are identified in Section 3.8.

c. Inadvertent Operation of the Containment Spray System

The design external pressure load on the reactor containment is provided in Table 6.2.1-2. The lowest calculated internal pressure is also provided in Table 6.2.1-2, and is the result of an assumed inadvertent actuation of the containment spray system. The analysis performed to determine the lowest calculated internal pressure following an inadvertent actuation of the containment spray system is provided in Section 6.2.1.1.3. Approximately 0.7-percent margin exists between the lowest calculated internal pressure and the design external pressure load.

d. Entrapment of Recirculation Water

Locations within the reactor containment which may entrap spray water and subtract from the water inventory considered to be available in the containment sump are identified in Section 6.2.2.1. The effect of this potential water loss is considered in determining the net positive suction head available to the RHR and containment spray pumps. Any special provisions which reduce the amount of the entrapped water are discussed in Section 6.2.2.1.

e. Normal Operation of Systems Which Control the Containment Environment

The functional capability and frequency of operation of the systems provided to maintain the containment and subcompartment atmospheres within prescribed pressure, temperature, and humidity limits during normal operation are discussed in Sections 6.2.2.2 and 9.4.6.

6.2.1.1.3 Design Evaluation

a. Analysis of Postulated Ruptures

In the event of a LOCA in the containment, much of the released reactor coolant will flash to steam. This release of mass and energy raises the temperature and pressure of the atmosphere within the containment. The severity of the temperature and pressure peaks depends upon the nature, size, and location of the postulated rupture.

In order to identify the worst case, the spectrum of hypothetical accidents listed in Table 6.2.1-1 has been analyzed. The analytical model and computer code designed to predict containment pressure and temperature responses following the accidents are described in item b. of this section.

A summary of the results of the containment pressure and temperature analysis for this spectrum of postulated accidents is provided in Table 6.2.1-8. The peak containment pressure calculated resulted from the assumed (DEHLG) break.

The calculated containment pressure and temperature responses as a function of time for the spectrum of postulated accidents are illustrated in Figures 6.2.1-1 through 6.2.1-6.

b. Computer Codes for LOCA Analyses

The spectrum of hypothetical accidents has been analyzed by the GOTHIC computer code, which is designed to predict the pressure and temperature transients in the containment following a rupture. The mass and energy release data used by GOTHIC are developed and described in Section 6.2.1.3. The analytical model is described in Reference 13:

c. Initial Conditions

Initial conditions used for the containment analysis are listed inTable 6.2.1-5.

The initial containment conditions were selected based on the range of the normal expected conditions within the containment with consideration given to maximizing the calculated peak containment pressure. Parametric studies have been performed to determine the effects of varying these initial containment conditions (Ref. 1). The results of these studies showed that varying the initial containment conditions over a wide range of values changes the calculated peak pressure by less than 1 percent. Therefore, the initial containment conditions are relatively unimportant parameters with respect to the containment pressure temperature analysis.

The conservatisms in the assumptions made with respect to the containment heat removal systems and the emergency core cooling system operability are discussed in Sections 6.2.2 and 6.3, respectively.

d. Results of the Failure Mode and Effects Analysis

Single active failures have been considered in the emergency core cooling system and in the containment heat removal systems with respect to maximizing energy release to the containment and minimizing the heat removal from the containment. The criteria used to determine the worst single active failure was the calculated peak containment pressure.

Therefore, single active failures in the containment heat removal systems were considered consistent with the mass and energy release data determined by the corresponding common mode failure in the emergency core cooling system.

The worst calculated peak containment pressure was the result of a double-ended hot leg guillotine break. The peak pressure occurs near the end of the blowdown phase, before the pumped ECCS or containment heat removal systems are activated.

e. Containment Design Parameters

The principal containment design parameters are provided in Table 6.2.1-2.

f. Engineered Safety Features Design Parameters

The engineered safety features design parameters used in the containment analysis are listed in Table 6.2.1-3. The parameters identified as full capacity were used when no failure was assumed to affect the operation of that system, and the parameters identified of minimum capacity were used when a single failure was assumed to affect the operation of that system. The containment air cooler duty curve per air cooler used in the analysis is given in Figure 6.2.1-15.

g. Results of Postulated Accidents Analyzed

A summary of the results of the containment pressure temperature analyses for the spectrum of postulated accidents is tabulated in Table 6.2.1-8.

h. Secondary System Pipe Rupture Containment Analysis

A complete discussion of secondary system pipe ruptures inside the containment with respect to the containment pressure and temperature responses is provided in Section 6.2.1.4.

i. Containment Passive Heat Sinks

With respect to the modeling of the containment passive heat sinks for the heat transfer calculations used in the containment pressure temperature analysis, Reference 1, Section 3.2.7, provides the justification for the steel-concrete interface resistance used for the steel-lined concrete heat sinks. Reference 13 provides justification for the heat transfer correlations used in the heat transfer calculations.

The specific passive heat sinks considered in the containment pressure temperature analysis and their parameters are listed in Table 6.2.1-4. Figures 6.2.1-13 and 6.2.1-14 show the condensing heat transfer coefficient as a function of time for the DEPSG with minimum safeguards and DEPSG with maximum safeguards cases, respectively.

Zero heat transfer is specified at the outside surface of the containment exposed to the earth, and between the containment sump liquid and the containment atmosphere within the containment.

j. Analysis of Inadvertent Operation of a Containment Heat Removal System

Inadvertent actuation of the containment spray system results in the lowest calculated containment internal pressure.

As discussed in Section 6.2.2.1, the containment spray system can only be actuated in two ways, either automatically upon receipt of two-out-of-four containment high pressure signals or manually from the control room.

Section 7.3.8 discusses the engineered safety features actuation system and demonstrates that the system design precludes a single active or passive failure from inadvertently actuating the containment spray system. Manual actuation of the containment spray system can only be accomplished by the reactor operator deliberately switching on two switches on the main control board. The main control board is designed with physical separation of these switches to prevent accidental actuation of the spray system. Thus, inadvertent actuation of the sprays is precluded by design, and only a deliberate actuation of the containment spray system could result in the reactor building being sprayed.

Although precluded by design, inadvertent actuation of the containment spray system has been assumed, and the resultant reduction in the containment pressure has been calculated. The postulated inadvertent actuation of the containment spray system is assumed, concurrent with the following conservative containment and environmental conditions:

	Summer	Winter
Initial containment temperature,°F	120	100
Initial containment pressure, psia	14.4	14.4
Initial containment relative humidity, %	100	100
Containment spray flow rate, gpm (per train)	3,900*	3,900*
RWST water temperature,°F	60	37

* Runout flow rates for the containment spray system.

Actuation of the containment spray system could be postulated under any set of containment and environmental conditions. However, no consistent set of realistic conditions can categorically be selected as the worst case initial condition to be used in the containment pressure analysis. These assumed initial conditions are defined as limiting in that these conditions 1) represent the largest differences in the containment ambient temperature and the RWST temperature and 2) the 100-percent humidity case maximizes the amount of mass transferred out of the containment atmosphere.

Using Henry's law of partial pressures and the Ideal Gas Law and assuming that the inadvertent operation of the containment spray system will reduce the containment vapor temperature to coincide with that of the RWST water being sprayed, the maximum reduction in the containment pressure is provided in Table 6.2.1-2.

The containment design external pressure load is provided in Table 6.2.1-2, and shows approximately 0.7-percent margin above the maximum reduction in the containment pressure calculated by the above-described method. Thus, corrective action by the operator is not required to ensure that containment integrity is maintained.

The control room operator will be notified that the containment spray system is operating through the following means:

1. The containment spray actuation annunciator light will be on, and an audible alert alarm will be sounded.

2. The running status light of the containment spray pumps will be on.

3. The open status lights of the containment spray system isolation valves will be on.

4. The containment normal sump and the incore instrumentation tunnel level indicators and level alarms will be actuated.

5. The flow indicators for the discharge of the containment spray pumps will indicate flow in the containment spray pumps.

6. The balance-of-plant computer will audibly alert and visually inform the operator that the containment spray system is actuated.

k. Accident Chronology

The chronology of events occurring after a DEPSG break with minimum safeguards is given in Table 6.2.1-6. The chronology of events after a DEPSG break with maximum safeguards is given in Table 6.2.1-7. The chronology of events occurring after a DEHLG break is given in Table 6.2.1-43.

l. Mass and Energy Balances

A mass and energy balance for the reactor coolant system, steam generators, and the safety injection system is provided in Section 6.2.1.3.2 and shows the distribution of energy prior to the accident, at the end of the blowdown phase, at the end of the core reflood phase, and at the end of the post-reflood phase.

A mass and energy balance for the reactor and containment systems for the DEPSG break with minimum safeguards and DEPSG break with maximum safeguards are provided in Tables 6.2.1-35 and 6.2.1-36, 6.2.1-41, and 6.2.1-42. These tables provide the distribution of energy at the following times:

1. Prior to the accident
2. End of blowdown
3. End of reflood
4. End of SG energy release

m. Long-Term Cooling Following a LOCA

The long-term system behavior during various LOCAs has been evaluated to verify the ability of the ECCS and the containment heat removal systems to keep the reactor vessel flooded and maintain the containment below design conditions for all times following a LOCA. This evaluation is based on the conservative predictions of the performance of these engineered safety features consistent with the single failures assumed for each accident analyzed. The heat generation rate from shutdown fissions, heavy isotope decay, and fission product decay is provided in Figure 6.2.1-16.

The containment pressure and temperature transients for the DEPSG break with minimum safeguards up to 10^6 seconds are shown in Figures 6.2.1-1 and 6.2.1-4, respectively. These figures demonstrate the containment systems' capability of rapidly reducing the containment pressure and temperature and maintaining those parameters to acceptably low values. The containment pressure and temperature transients for the DEPSG break with maximum safeguards up to 10^6 seconds are shown in Figures 6.2.1-2 and 6.2.1-5, respectively. The DEHLG blowdown pressure and temperature transients are shown in .Figures 6.2.1-3 and Figures 6.2.1-6.

The sump temperature transients for the DEPSG break with minimum safeguards and the DEPSG break with maximum safeguards are provided in Figures 6.2.1-7 and 6.2.1-8, respectively.

For the DBA at the time of the calculated peak containment pressure, the vapor energy is 298 x 10^6 Btu, the energy deposited in the sump is 17.1 x 10^6 Btu, and the containment passive heat sinks have absorbed 19.0 x 10^6 Btu. No energy has been removed by the containment fan coolers, sprays, or the RHR system.

n. Accumulator Nitrogen Release

Table 6.2.1-11 provides the nitrogen release rate from the accumulators following the discharge of their liquid volumes. The added mass and associated energy of this nitrogen release are accounted for in the LOCA analysis.

o. Normal Containment Ventilation System Evaluation

The functional capability of the normal containment ventilation systems to maintain the temperature, pressure, and humidity in the containment and containment subcompartments is discussed in Sections 6.2.2.2 and 9.4.6.

p. Post-Accident Monitoring

Instrumentation for post-accident monitoring is discussed in Section 7.5.

6.2.1.2 Containment Subcompartments

6.2.1.2.1 Design Basis

Subcompartments within the containment, principally the reactor cavity, the steam generator loop compartments, and the pressurizer compartment, are designed to withstand the transient differential pressures and jet impingement forces of a postulated pipe break. Venting of these chambers maintains the differential pressures within the structural limits. In addition, restraints on the reactor coolant pipes, reactor vessel, steam generators, etc., are designed so that neither pipe whip nor vessel upset forces threaten the integrity of the subcompartments or of the containment structure.

Analysis of the pressure transients in the steam generator compartment and pressurizer compartment has been performed to verify the adequacy of the structural design of these structures under accident conditions. The following is a synopsis of the pipe breaks analyzed:

a. For the steam generator loop compartments, the design basis break is a steam generator inlet elbow longitudinal split with a break flow area of 763 square inches, a double-ended steam generator outlet nozzle break restrained to a break flow area of 436 square inches, and a double-ended reactor coolant pump outlet nozzle break restrained to a break flow area of 236 square inches.

b. The pressurizer compartment is divided into two compartments: 1) the pressurizer vault and 2) the pressurizer surge line compartment.

   The design basis break for these subcompartments is the double-ended pressurizer surge line break. In addition to this break, the pressurizer spray line break and the three break cases from the steam generator loop compartment analysis were considered in the selection of the design analysis break. In all cases, the pressures in the pressurizer compartment were substantially lower than those resulting from the pressurizer surge line break.

   In accordance with NRC approval of WCAP-10691-P, WCAP-16019-P, and WCAP-16020-P, postulated pipe breaks in the RCS primary loops, 12-inch RHR hot leg suction lines, and 10-inch accumulator injection lines are excluded from the structural design basis for Callaway Plant. Postulated pipe breaks in the 14-inch pressurizer surge line and in piping less than 10-inches in diameter remain as part of the structural design basis.

6.2.1.2.2 Design Features

All design features provided for alleviating pressure buildup within the subcompartments are discussed in the subcompartment design evaluation in Section 6.2.1.2.3. Reference 2 describes the design features which limit the movement of the pipe after the postulated break.

6.2.1.2.3 Design Evaluation

a. Mass and Energy Release Rate Transient Model

   The computer programs used to develop the mass and energy release transients for subcompartment pressurization analyses are described in Reference 3. Tables 6.2.1-13 through 6.2.1-16 provide tabulations of the mass and energy release rates versus time for the spectrum of breaks analyzed.

b. Subcompartment Pressure Analyses Model

The COPDA computer code (Ref. 4) employs a finite difference technique to solve the time dependent equations for the conservation of mass, energy, and momentum to perform the subcompartment analyses. This code and the assumptions inherent to it are described fully in Reference 5.

1. Reactor Cavity Rupture Analysis

On May 31, and October 26, 1984, Union Electric submitted Westinghouse topical reports (WCAP's -10500, -10501, -10690 and 10691) to the NRC in order to demonstrate compliance with the revised GDC-4, which provides for the application of "leak-before-break" technology to eliminate protective devices against dynamic loads resulting from postulated ruptures of primary coolant loops. By letter dated October 28, 1986, the NRC confirmed its finding that, based on the UE submittals, Callaway is in compliance with the revised GDC-4. Based upon the revised GDC-4, the water bags were deleted from the design. A permanent reactor cavity seal/neutron shield, as described in Section 3.8.3.1.4, has been installed.

2. Steam Generator Loop Compartments

The steam generator loop compartment is subjected to double-ended breaks of the pump suction line, the cold leg, the hot leg, a longitudinal split of the hot leg, and double-ended branch line breaks. All double-ended breaks are mechanically restrained so that the largest breaks in the hot leg, cold leg, and pump suction are 763 in.^{2}, 236 in.^{2}, and 436 in.^{2}, respectively. These three breaks envelope all postulated breaks within the steam generator loop compartment. These breaks were analyzed, using the same 59-node model, to determine the maximum pressures on the walls of the compartment and on the enclosed equipment, i.e., the steam generator, the reactor coolant pump, and the pressurizer. The blowdown data for the three breaks are given in Tables 6.2.1-13 through 6.2.1-15. The nodalization model for the analyses is given in Figures 6.2.1-43 through 6.2.1-46 and 6.2.1-51 through 6.2.1-55. Only breaks in loop 4 were analyzed, since this loop has the smallest vent area directly to the remainder of the containment due to the presence of the pressurizer, and thus results in the highest pressures.

To ensure conservative design of the loop compartment walls and the equipment supports, the loads calculated for loop 4 were applied to the other three steam generator loop compartments by appropriate translation and rotation of the force vector axes. The ‘C’ loop steam generator cubicle secondary shield wall in the area of the access opening has been analyzed with compartment pressure loads specific to that area. The volumes of the subcompartments, as well as the initial conditions prior to the transient, are given in Table 6.2.1-22.

As with the reactor cavity analysis, the node boundaries were selected wherever significant restrictions to flow occurred. A sensitivity study was performed in which the number of nodes in the steam generator compartment was varied. The resulting forces on the compartment walls and on the equipment in all cases were less than the forces calculated with the 59-node model. Therefore, it was assumed that the nodalization employed in the original model was both adequate and conservative. All major obstructions, such as columns, pumps, tanks, grating, and the steam generators, were considered in the calculation of the subcompartment volumes and vent areas. In addition, the values for volume were reduced by 5 percent to allow for minor obstructions, such as cable trays, supports, and various piping. The principal obstructions within the steam generator loop compartments were the reactor coolant pumps and the steam generators. Flow through the reactor cavity was neglected. The flow coefficients associated with the flow paths were calculated in the same manner as for the reactor cavity. The head loss coefficients used in the calculation of the flow coefficients, as well as the vent areas and l/a's for each flowpath, are listed in Table 6.2.1-23.

The fluid flow from one subcompartment to another was calculated, using the homogeneous frozen flow option in the analysis. The peak pressures for each subcompartment are listed in Table 6.2.1-22. The complete pressure histories for those subcompartments near the break for each of the three break cases analyzed are shown in Figures 6.2.1-56, 6.2.1-57, 6.2.1-61, and 6.2.1-69. When the subcompartment pressures were applied to their projected areas on the steam generator and the reactor coolant pump, the forces were determined on these pieces of equipment. The forces on the reactor coolant pump and the steam generator are shown in Figures 6.2.1-58, 6.2.1-59, 6.2.1-62 through 6.2.1-67, and 6.2.1-70 through 6.2.1-74. The coefficients used to calculate the forces are given in Tables 6.2.1-24 and 6.2.1-25.

The component and resultant forces on the steam generator and reactor coolant pump for the three breaks analyzed are illustrated in Figures 6.2.1-60, 6.2.1-68, and 6.2.1-75.

3. Pressurizer Vault

The pressurizer vault is subjected to a pressurizer spray line break, a pressurizer surge line break, and a reactor coolant loop break. The pressurizer surge line compartment located directly below the pressurizer vault is subject to a pressurizer surge line break and reactor coolant pipe break within the steam generator compartment adjacent to the pressurizer vault. Analyses showed that the worst postulated break for both the pressurizer vault and the surge line compartment was the double-ended pressurizer surge line break. The mass and energy release data for this case are given in Table 6.2.1-16.

In the model, the pressure is relieved through large vents in the top of the pressurizer vault, and through the surge line compartment, out into the steam generator loop compartment and then up to the remainder of the containment. Figure 6.2.1-76 provides a simplified elevation view of the pressurizer vault, and Figure 6.2.1-77 shows a schematic diagram of the flow model.

The subcompartment volumes along with the peak calculated pressures and the design pressures in the pressurizer vault and the surge line compartment are given in Table 6.2.1-26. The pressure histories of those subcompartments directly below the pressurizer are given in Figure 6.2.1-78. Table 6.2.1-27 summarizes the head loss coefficients used to calculate the flow coefficients and the vent areas and l/a's for all of the flow paths.

c. Nodalization Model Adequacy

The determination of nodalization models used for the SNUPPS subcompartment analysis is adequate and based on the following criteria:

a. The models are physically representative of the geometry investigated.

b. The models are of adequate detail to consider all significant obstructions and flow losses.

c. The selection of nodal boundaries and volumes reflect the conservative theoretical thermo and fluid dynamic application.

A determination that these criteria are met is based on previously performed developmental SNUPPS subcompartment analysis, Bechtel experience in the performance of other PWR subcompartment analyses, and comparisons with information in the public domain (such as NUREG/CR-1199, and NUREG-0609).

6.2.1.2.4 Replacement Steam Generator, Uprate, and T-average Band Increase

The short-term LOCA-related mass and energy releases discussed above have been reviewed to assess the effects associated with the replacement steam generator program and a wider T-average operating band for Callaway Plant. The blowdown mass and energy (M&E) release rates are affected by the initial RCS temperature conditions. Since short-term releases are linked directly to the critical mass flux, which increases with decreasing temperatures, the short-term LOCA releases would be expected to increase due to any reductions in RCS coolant temperature conditions. Short-term blowdown transients are characterized by a peak mass and energy release rate that occurs during a sub-cooled condition, thus the Zaloudek correlation, which models this condition, is currently used in the short term LOCA mass and energy release analyses with the SATAN computer program (Reference 3). For this evaluation, an RCS pressure of 2300 psia, and a vessel/core inlet temperature of 535.2°F and a hot leg temperature of 600.2°F were considered for the steam generator replacement program. These temperatures reflect a reduction based on temperature measurement uncertainty.

Callaway is approved for Leak-Before-Break (LBB) in the primary reactor coolant loop piping. Therefore, the decrease in mass and energy releases associated with assuming the smaller RCS branch line breaks, as compared to the larger RCS pipe breaks, more than offsets the increased releases associated with the Callaway replacement steam generator conditions. As a result, the current licensing basis subcompartment analyses that consider breaks in the RCS loop piping (i.e., steam generator loop compartment) remain bounding.

Since Callaway is not approved for Leak-Before-Break (LBB) on the pressurizer surge line, an evaluation was performed to demonstrate that the current short-term LOCA mass and energy releases in the pressurizer vault continue to remain bounding with the replacement steam generator conditions. This evaluation, documented in Reference 17, showed this to be the case.

6.2.1.3 Mass and Energy Release Analyses for Postulated Loss-of-Coolant Accidents

The uncontrolled release of pressurized high temperature reactor coolant, termed a Loss-of-Coolant Accident (LOCA), will result in release of steam and water into the containment. This, in turn, will result in increases in the local subcompartment pressures, and an increase in the global containment pressure and temperature. Therefore, there are both long and short-term issues reviewed relative to a postulated LOCA that must be considered for the steam generator replacement program for the Callaway Plant.

The long-term LOCA mass and energy releases are analyzed to approximately 10^7 seconds and are utilized as input to the containment integrity analysis, which demonstrates the acceptability of the containment safeguards systems to mitigate the consequences of a hypothetical large break LOCA. The containment safeguards systems must be capable of limiting the peak containment pressure to less than the design pressure and to limit the temperature excursion to less than the Environmental Qualification (EQ) acceptance limits. For this program, Westinghouse generated the mass and energy releases using the March 1979 model, described in Reference 12. The NRC review and approval letter is included with Reference 12. Even though this is a first time application of this methodology for Callaway Plant, it has also been utilized and approved on many plant specific dockets. Section 6.2.1.3.1 discusses the long term LOCA mass and energy releases generated for this program. The results of this analysis were provided for use in the Callaway containment integrity analysis.

6.2.1.3.1 Long-Term LOCA Mass and Energy Releases

The mass and energy release rates described in this section are the long term LOCA mass and energy releases for the hypothetical double-ended pump suction (DEPS) rupture and double-ended hot leg (DEHL) rupture break cases for Callaway Plant with the replacement steam generators.

6.2.1.3.2 Input Parameters and Assumptions

The mass and energy release analysis is sensitive to the assumed characteristics of various plant systems, in addition to other key modeling assumptions. Where appropriate, bounding inputs are utilized and instrumentation uncertainties are included. For example, the RCS operating temperatures are chosen to bound the highest average coolant temperature range of all operating cases, and a temperature uncertainty allowance of (+4.3ºF) is then added. Nominal parameters are used in certain instances. For example, the reactor coolant system (RCS) pressure in this analysis is based on a nominal value of 2250 psia plus an uncertainty allowance (+30 psi). All input parameters are chosen consistent with accepted analysis methodology.

Some of the most critical items are the RCS initial conditions, core decay heat, safety injection flow, and primary and secondary metal mass and steam generator heat release modeling. Specific assumptions concerning each of these items are next discussed. Tables 6.2.1-51 through 6.2.1-53 present key data assumed in the analysis.

The core rated power of 3565 MWt adjusted for calorimetric error (+2 percent of power) was used in the analysis. As previously noted, the use of RCS operating temperatures to bound the highest average coolant temperature range were used as bounding analysis conditions. The use of higher temperatures is conservative because the initial fluid energy is based on coolant temperatures, which are at the maximum levels attained in steady state operation. Additionally, an allowance to account for instrument error and deadband is reflected in the initial RCS temperatures. As previously discussed, the initial reactor coolant system (RCS) pressure in this analysis is based on a nominal value of 2250 psia plus an allowance which accounts for the measurement uncertainty on pressurizer pressure. The selection of 2280 psia as the limiting pressure is considered to affect the blowdown phase results only, since this represents the initial pressure of the RCS. The RCS rapidly depressurizes from this value until the point at which it equilibrates with containment pressure.

The rate at which the RCS blows down is initially more severe at the higher RCS pressure. Additionally the RCS has a higher fluid density at the higher pressure (assuming a constant temperature) and subsequently has a higher RCS mass available for releases. Thus, 2250 psia plus uncertainty was selected for the initial pressure as the limiting case for the long term mass and energy release calculations.

The selection of the fuel design features for the long term mass and energy release calculation is based on the need to conservatively maximize the energy stored in the fuel at the beginning of the postulated accident (i.e., to maximize the core stored energy). The margin in core-stored energy is a statistical value that is dependent upon fuel type, power level, and burnup. Thus, the analysis very conservatively accounts for the stored energy in the core.

Margin in RCS volume of 3% (which is composed of 1.6% allowance for thermal expansion and 1.4% for uncertainty) is modeled.

A uniform steam generator (SG) tube plugging level of 0% is modeled. This assumption maximizes the reactor coolant volume and fluid release by virtue of consideration of the RCS fluid in all SG tubes. During the post-blowdown period the steam generators are active heat sources since significant energy remains in the secondary metal and secondary mass that has the potential to be transferred to the primary side. The 0% tube plugging assumption maximizes heat transfer area and therefore the transfer of secondary heat across the SG tubes. Additionally, this assumption reduces the reactor coolant loop resistance, which reduces the Δp upstream of the break for the pump suction breaks and increases break flow. Thus, the analysis very conservatively accounts for the level of steam generator tube plugging.

Regarding safety injection flow, the mass and energy release calculation considered configurations/ failures to conservatively bound respective alignments. The cases include (a) a Minimum Safeguards Case (1 CH/SI, 1 HHSI, and 1 RHR Pumps); and (b) Maximum Safeguards, (2 CH/SI, 2 HHSI, and 2 RHR Pumps).

The following assumptions were employed to ensure that the mass and energy releases are conservatively calculated, thereby maximizing energy release to containment:

1. Maximum expected operating temperature of the reactor coolant system (100% full power conditions)

2. Allowance for RCS temperature uncertainty (+4.3ºF)

3. Margin in RCS volume of 3% (which is composed of 1.6% allowance for thermal expansion, and 1.4% for uncertainty)

4. Core rated power of 3565 MWt

5. Allowance for calorimetric error (+2 percent of power)

6. Conservative heat transfer coefficient (i.e., steam generator primary/secondary heat transfer and reactor coolant system metal heat transfer)

7. Allowance in core stored energy for effect of fuel densification

8. A margin in core-stored energy that is a statistical value that is dependent upon fuel type, power level, and burnup

9. An allowance for RCS initial pressure uncertainty (+30 psi)

10. A maximum containment backpressure equal to design pressure (60 psig)

11. Minimum RCS loop flow (93,600 gpm/loop)

12. Steam generator tube plugging leveling (0% uniform)

    - Maximizes reactor coolant volume and fluid release

    - Maximizes heat transfer area across the SG tubes

    - Reduces coolant loop resistance, which reduces the Δp upstream of the break for the pump suction breaks and increases break flow.

13. Feedwater addition: Main feedwater addition will add mass and energy to the SG secondary side that must be removed in the long term. Thus main feedwater addition was modeled in the Double Ended Pump Suction (DEPS) break. Main feedwater coastdown was modeled starting from the SI signal, plus instrument delay and a 15 second valve stroke time. Main feedwater addition was not modeled for the Double Ended Hot Leg (DEHL) break because the addition of main feedwater post reactor/turbine trip would cool down the SG secondary side during blowdown. While additional energy has been added to the SG, this is energy that is released much later after blowdown. Since the DEHL break is only analyzed through blowdown, the effect of main feedwater in cooling the SG secondary side would increase primary to secondary heat transfer and thus be a benefit.

Thus, based on the previously discussed conditions and assumptions, a bounding analysis of Callaway Plant was made for the release of mass and energy from the RCS in the event of a LOCA at 3565 MWt.

6.2.1.3.3 Description of Analyses

The evaluation model used for the long term LOCA mass and energy release calculations is the March 1979 model described in Reference 12. This evaluation model has been reviewed and approved generically by the NRC. The approval letter is included with Reference 12. Even though this is a first time application for Callaway Plant, it has also been utilized and approved on the plant specific dockets for other Westinghouse PWRs. NRC approved the use of Reference 12 for Callaway in Section 3.6.3.1.2 of their Safety Evaluation for Reference 18.

This report section presents the long term LOCA mass and energy releases generated in support of the Callaway Plant replacement steam generator program. These mass and energy releases are then subsequently used in the containment integrity analysis.

6.2.1.3.3.1 LOCA M&E Release Phases

The containment system receives mass and energy releases following a postulated rupture in the RCS. These releases continue over a time period, which, for the LOCA mass and energy analysis, is typically divided into four phases:

1. Blowdown - the period of time from accident initiation (when the reactor is at steady state operation) to the time that the RCS and containment reach an equilibrium state.

2. Refill - the period of time when the lower plenum is being filled by accumulator and ECCS water. At the end of blowdown, a large amount of water remains in the cold legs, downcomer, and lower plenum. To conservatively consider the refill period for the purpose of containment mass and energy releases, it is assumed that this water is instantaneously transferred to the lower plenum along with sufficient accumulator water to completely fill the lower plenum. This allows an uninterrupted release of mass and energy to containment. Thus, the refill period is conservatively neglected in the mass and energy release calculation.

3. Reflood - begins when the water from the lower plenum enters the core and ends when the core is completely quenched.

4. Post-reflood (Froth) - describes the period following the reflood phase. For the pump suction break, a two-phase mixture exits the core, passes through the hot legs, and is superheated in the steam generators prior to exiting the break as steam. After the broken loop steam generator cools, the break flow becomes two phase.

6.2.1.3.3.2 Computer Codes

The Reference 12 mass and energy release evaluation model is comprised of mass and energy release versions of the following codes: SATAN VI, WREFLOOD, FROTH, and

EPITOME. These codes were used to calculate the long term LOCA mass and energy releases for Callaway Plant.

SATAN VI calculates blowdown, the first portion of the thermal-hydraulic transient following break initiation, including pressure, enthalpy, density, mass and energy flowrates, and energy transfer between primary and secondary systems as a function of time.

The WREFLOOD code addresses the portion of the LOCA transient where the core reflooding phase occurs after the primary coolant system has depressurized (blowdown) due to the loss of water through the break and when water supplied by the Emergency Core Cooling System refills the reactor vessel and provides cooling to the core. The most important feature of WREFLOOD is the steam/water mixing model (see subsection 6.2.1.3.7.2).

FROTH models the post-reflood portion of the transient. The FROTH code is used for the steam generator heat addition calculation from the broken and intact loop steam generators.

EPITOME continues the FROTH post-reflood portion of the transient from the time at which the secondary equilibrates to containment design pressure to the end of the transient. It also compiles a summary of data on the entire transient, including formal instantaneous mass and energy release tables and mass and energy balance tables with data at critical times.

6.2.1.3.4 Break Size and Location

Generic studies have been performed with respect to the effect of postulated break size on the LOCA mass and energy releases. The double ended guillotine break has been found to be limiting due to larger mass flow rates during the blowdown phase of the transient. During the reflood and froth phases, the break size has little effect on the releases:

Three distinct locations in the reactor coolant system loop can be postulated for pipe rupture for any release purposes:

1. Hot leg (between vessel and steam generator)

2. Cold leg (between pump and vessel)

3. Pump suction (between steam generator and pump).

The break locations analyzed for this program are the double-ended pump suction (DEPS) rupture (10.46 ft^2), and the double-ended hot leg (DEHL) rupture (9.20 ft^2). Break mass and energy releases have been calculated for the blowdown, reflood, and post-reflood phases of the LOCA for the DEPS cases. For the DEHL case, the releases were calculated only for the blowdown. The following information provides a discussion on each break location.

The DEHL rupture has been shown in previous studies to result in the highest blowdown mass and energy release rates. Although the core flooding rate would be the highest for this break location, the amount of energy released from the steam generator secondary is minimal because the majority of the fluid, which exits the core, vents directly to containment bypassing the steam generators. As a result, the reflood mass and energy releases are reduced significantly as compared to either the pump suction or cold leg break locations where the core exit mixture must pass through the steam generators before venting through the break. For the hot leg break, generic studies have confirmed that there is no reflood peak (i.e., from the end of the blowdown period the containment pressure would continually decrease). Therefore only the mass and energy releases for the hot leg break blowdown phase are calculated and presented in this section of the report.

The cold leg break location has also been found in previous studies to be much less limiting in terms of the overall containment energy releases. The cold leg blowdown is faster than that of the pump suction break, and more mass is released into the containment. However, the core heat transfer is greatly reduced, and this results in a considerably lower energy release into containment. Studies have determined that the blowdown transient for the cold leg is, in general, less limiting than that for the pump suction break. During reflood, the flooding rate is greatly reduced and the energy release rate into the containment is reduced. Therefore, the cold leg break is bounded by other breaks and no further evaluation is necessary.

The pump suction break combines the effects of the relatively high core flooding rate, as in the hot leg break, and the addition of the stored energy in the steam generators. As a result, the pump suction break yields the highest energy flow rates during the post-blowdown period by including all of the available energy of the Reactor Coolant System in calculating the releases to containment.

6.2.1.3.5 Application of Single Failure Criterion

An analysis of the effects of the single failure criterion has been performed on the mass and energy release rates for each break analyzed. An inherent assumption in the generation of the mass and energy release is that offsite power is lost. This results in the actuation of the emergency diesel generators, required to power the safety injection system. This is not an issue for the blowdown period which is limited by the DEHL break.

Two cases have been analyzed to assess the effects of a single failure. The first case assumes minimum safeguards SI flow based on the postulated single failure of an emergency diesel generator. This results in the loss of one train of safeguards equipment. The other case assumes maximum safeguards SI flow based on no postulated failures that would impact the amount of ECCS flow. The analysis of the cases described provides confidence that the effect of credible single failures is bounded.

6.2.1.3.6 Acceptance Criteria for Analyses

A large break loss of coolant accident is classified as an ANS Condition IV event, an infrequent fault. To satisfy the Nuclear Regulatory Commission acceptance criteria presented in the Standard Review Plan Section 6.2.1.3, the relevant requirements are as follows:

a. 10 CFR 50, Appendix A

b. 10 CFR 50, Appendix K, paragraph I.A.

In order to meet these requirements, the following must be addressed:

1. Sources of Energy

2. Break Size and Location

3. Calculation of Each Phase of the Accident.

6.2.1.3.7 Mass and Energy Release Data

6.2.1.3.7.1 Blowdown Mass and Energy Release Data

The SATAN-VI code is used for computing the blowdown transient. The code utilizes the control volume (element) approach with the capability for modeling a large variety of thermal fluid system configurations. The fluid properties are considered uniform and thermodynamic equilibrium is assumed in each element. A point kinetics model is used with weighted feedback effects. The major feedback effects include moderator density, moderator temperature, and Doppler broadening. A critical flow calculation for subcooled (modified Zaloudek), two-phase (Moody), or superheated break flow is incorporated into the analysis. The methodology for the use of this model is described in Reference 12.

Table 6.2.1-28 presents the calculated mass and energy release for the blowdown phase of the DEHL break. For the hot leg break mass and energy release tables, break path 1 refers to the mass and energy exiting from the reactor vessel side of the break; break path 2 refers to the mass and energy exiting from the steam generator side of the break.

Table 6.2.1-31 presents the calculated mass and energy releases for the blowdown phase of the DEPS break with minimum ECCS flows. Table 6.2.1-37 presents the calculated mass and energy releases for the blowdown phase of the DEPS break with maximum ECCS flows. For the pump suction breaks, break path 1 in the mass and energy release tables refers to the mass and energy exiting from the steam generator side of the break; break path 2 refers to the mass and energy exiting from the pump side of the break.

6.2.1.3.7.2 Reflood Mass and Energy Release Data

The WREFLOOD code is used for computing the reflood transient. The WREFLOOD code consists of two basic hydraulic models - one for the contents of the reactor vessel, and one for the coolant loops. The two models are coupled through the interchange of the boundary conditions applied at the vessel outlet nozzles and at the top of the downcomer. Additional transient phenomena such as pumped safety injection and accumulators, reactor coolant pump performance, and steam generator release are included as auxiliary equations which interact with the basic models as required. The WREFLOOD code permits the capability to calculate variations during the core reflooding transient of basic parameters such as core flooding rate, core and downcomer water levels, fluid thermodynamic conditions (pressure, enthalpy, density) throughout the primary system, and mass flow rates through the primary system. The code permits hydraulic modeling of the two flow paths available for discharging steam and entrained water from the core to the break; i.e., the path through the broken loop and the path through the unbroken loops.

A complete thermal equilibrium mixing condition for the steam and ECCS injection water during the reflood phase has been assumed for each loop receiving ECCS water. This is consistent with the usage and application of the Reference 12 mass and energy release evaluation model in recent analyses, e.g., D. C. Cook docket (Reference 14). Even though the Reference 12 model credits steam/water mixing only in the intact loop and not in the broken loop; the justification, applicability, and NRC approval for using the mixing model in the broken loop has been documented (Reference 14). Moreover, this assumption is supported by test data and is further discussed below.

The model assumes a complete mixing condition (i.e., thermal equilibrium) for the steam/water interaction. The complete mixing process, however, is made up of two distinct physical processes. The first is a two phase interaction with condensation of steam by cold ECCS water. The second is a single phase mixing of condensate and ECCS water. Since the steam release is the most important influence to the containment pressure transient, the steam condensation part of the mixing process is the only part that need be considered. (Any spillage directly heats only the sump.)

The most applicable steam/water mixing test data has been reviewed for validation of the containment integrity reflood steam/water mixing model. This data was generated in 1/3 scale tests (Reference 15), which are the largest scale data available and thus most clearly simulates the flow regimes and gravitational effects that would occur in a PWR. These tests were designed specifically to study the steam/water interaction for PWR reflood conditions.

A group of 1/3 scale tests corresponds directly to containment integrity reflood conditions. The injection flowrates for this group cover all phases and mixing conditions calculated during the reflood transient. The data from these tests were reviewed and discussed in detail in Reference 12. For all of these tests, the data clearly indicates the occurrence of very effective mixing with rapid steam condensation. The mixing model used in the containment integrity reflood calculation is therefore wholly supported by the 1/3 scale steam/water mixing data.

Additionally, the following justification is also noted. The post-blowdown limiting break for the containment integrity peak pressure analysis is the pump suction double ended rupture break. For this break, there are two flowpaths available in the RCS by which mass and energy may be released to containment. One is through the outlet of the steam generator, the other via reverse flow through the reactor coolant pump. Steam which is not condensed by ECCS injection in the intact RCS loops passes around the downcomer and through the broken loop cold leg and pump in venting to containment. This steam also encounters ECCS injection water as it passes through the broken loop cold leg, complete mixing occurs and a portion of it is condensed. It is this portion of steam which is condensed that is taken credit for in this analysis. This assumption is justified based upon the postulated break location, and the actual physical presence of the ECCS injection nozzle. A description of the test and test results are contained in References 12 and 15.

Tables 6.2.1-32 and 6.2.1-38 present the calculated mass and energy releases for the reflood phase of the pump suction double ended rupture, minimum safeguards, and maximum safeguards cases, respectively.

The transient response of the principal parameters during reflood are given in Tables 6.2.1-33 and 6.2.1-39 for the DEPS cases.

6.2.1.3.7.3 Post-Reflood Mass and Energy Release Data

The FROTH code (Reference 3) is used for computing the post-reflood transient. The FROTH code calculates the heat release rates resulting from a two-phase mixture present in the steam generator tubes. The mass and energy releases that occur during this phase are typically superheated due to the depressurization and equilibration of the broken loop and intact loop steam generators. During this phase of the transient, the RCS has equilibrated with the containment pressure, but the steam generators contain a secondary inventory at an enthalpy that is much higher than the primary side. Therefore, there is a significant amount of reverse heat transfer that occurs. Steam is produced in the core due to core decay heat. For a pump suction break, a two phase fluid exits the core, flows through the hot legs and becomes superheated as it passes through the steam generator. Once the broken loop cools, the break flow becomes two phase. During the FROTH calculation ECCS injection is addressed for both the injection phase and the recirculation phase. The FROTH code calculation stops when the secondary side equilibrates to the saturation temperature (Tsat) at the containment design pressure, after this point the EPITOME code completes the SG depressurization (see subsection 6.2.1.3.7.5 for additional information).

The methodology for the use of this model is described in Reference 12. The mass and energy release rates are calculated by FROTH and EPITOME until the time of containment depressurization. After containment depressurization (14.7 psia), the mass and energy release available to containment is generated directly from core boiloff/decay heat.

Tables 6.2.1-34 and 6.2.1-40 present the two phase post-reflood mass and energy release data for the pump suction double ended cases, minimum and maximum ECCS assumptions.

6.2.1.3.7.4 Decay Heat Model

On November 2, 1978, the Nuclear Power Plant Standards Committee (NUPPSCO) of the American Nuclear Society approved ANS Standard 5.1 (Reference 16) for the determination of decay heat. This standard was used in the M&E release. Table 6.2.1-46 lists the decay heat curve used in the M&E release analysis, post blowdown, for the Callaway Plant replacement steam generator program.

Significant assumptions in the generation of the decay heat curve for use in the LOCA M&E releases analysis include the following:

1. Decay heat sources considered are fission product decay and heavy element decay of U 239 and Np-239.

2. Decay heat power from fissioning isotopes other than U 235 is assumed to be identical to that of U-235.

3. Fission rate is constant over the operating history of maximum power level.

4. The factor accounting for neutron capture in fission products has been taken from Equation 11 of Reference 16, up to 10,000 seconds and from Table 10 of Reference 16, beyond 10,000 seconds.

5. The fuel has been assumed to be at full power for 10^8 seconds.

6. The number of atoms of U-239 produced per second has been assumed to be equal to 70 percent of the fission rate.

7. The total recoverable energy associated with one fission has been assumed to be 200 MeV/fission.

8. Two-sigma uncertainty (two times the standard deviation) has been applied to the fission product decay.

Based upon NRC staff review, Safety Evaluation Report (SER) of the March 1979 evaluation model (Reference 12), use of the ANS Standard-5.1, November 1979 decay heat model was approved for the calculation of M&E releases to the containment following a LOCA.

6.2.1.3.7.5 Steam Generator Equilibration and Depressurization

Steam generator equilibration and depressurization is the process by which secondary side energy is removed from the steam generators in stages. The FROTH computer code calculates the heat removal from the secondary mass until the secondary temperature is the saturation temperature (T_{sat}) at the containment design pressure. After the FROTH calculations, the EPITOME code continues the FROTH calculation for SG cooldown removing steam generator secondary energy at different rates (i.e., first and second stage rates). The first stage rate is applied until the steam generator reaches T_{sat} at the user specified intermediate equilibration pressure, when the secondary pressure is assumed to reach the actual containment pressure. Then the second stage rate is used until the final depressurization, when the secondary reaches the reference temperature of T_{sat} at 14.7 psia, or 212ºF. The heat removal of the broken loop and intact loop steam generators are calculated separately.

During the FROTH calculations, steam generator heat removal rates are calculated using the secondary side temperature, primary side temperature and a secondary side heat transfer coefficient determined using a modified McAdam's correlation. Steam generator energy is removed during the FROTH transient until the secondary side temperature reaches saturation temperature at the containment design pressure. The constant heat removal rate used during the first heat removal stage is based on the final heat removal rate calculated by FROTH. The SG energy available to be released during the first stage interval is determined by calculating the difference in secondary energy available at the containment design pressure and that at the (lower) user specified intermediate equilibration pressure, assuming saturated conditions. This energy is then divided by the first stage energy removal rate, resulting in an intermediate equilibration time. At this time, the rate of energy release drops substantially to the second stage rate. The second stage rate is determined as the fraction of the difference in secondary energy available between the intermediate equilibration and final depressurization at 212ºF, and the time difference from the time of the intermediate equilibration to the user specified time of the final depressurization at 212ºF. With current methodology, all of the secondary energy remaining after the intermediate equilibration is conservatively assumed to be released by imposing a mandatory cooldown and subsequent depressurization down to atmospheric pressure at 3600 seconds, i.e., 14.7 psia and 212ºF.

6.2.1.3.7.6 Sources of Mass and Energy

The sources of mass considered in the LOCA mass and energy release analysis are given in Tables 6.2.1-29, 6.2.1-35, and 6.2.1-41. These sources are the reactor coolant system, accumulators, and pumped safety injection.

The energy inventories considered in the LOCA mass and energy release analysis are given in Tables 6.2.1-30, 6.2.1-36, and 6.2.1-42. The energy sources include:

1. Reactor Coolant System Water
2. Accumulator Water (all four inject)
3. Pumped Safety Injection Water
4. Decay Heat
5. Core Stored Energy
6. Reactor Coolant System Metal (includes SG tubes)
7. Steam Generator Metal (includes transition cone, shell, wrapper, and other internals)
8. Steam Generator Secondary Energy (includes fluid mass and steam mass)
9. Secondary Transfer of Energy (feedwater into and steam out of the steam generator secondary).

Energy Reference Points:

1. Available Energy: 212ºF; 14.7 psia
2. Total Energy Content: 32ºF; 14.7 psia.

The mass and energy inventories are presented at the following times, as appropriate:

1. Time zero (initial conditions)
2. End of blowdown time
3. End of refill time
4. End of reflood time
5. Time of broken loop steam generator equilibration to pressure setpoint
6. Time of intact loop steam generator equilibration to pressure setpoint
7. Time of full depressurization (3600 seconds).

In the mass and energy release data presented, no Zirc-water reaction heat was considered because the clad temperature is assumed not to rise high enough for the rate of the Zirc-water reaction heat to be of any significance.

The sequence of events for the LOCA transients are shown in Tables 6.2.1-6, 6.2.1-7, and 6.2.1-43.

6.2.1.3.8 Conclusions

The consideration of the various energy sources in the long term mass and energy release analysis provides assurance that all available sources of energy have been included in this analysis. Thus, the review guidelines presented in Standard Review Plan Section 6.2.1.3 have been satisfied.

6.2.1.4 Mass and Energy Release Analysis for Postulated Secondary Pipe Ruptures Inside Containment

Steam line ruptures occurring inside a reactor containment structure may result in significant releases of high energy fluid to the containment environment, possibly resulting in high containment temperatures and pressures. The quantitative nature of the releases following a steam line rupture is dependent upon the many possible configurations of the plant steam system and containment designs as well as the plant operating conditions and the size of the rupture. These variations make a reasonable determination of the single absolute "worst case" for both containment pressure and temperature evaluations following a steambreak difficult. This section describes the methods used in determining the containment responses to a variety of postulated pipe breaks encompassing wide variations in plant operation, safety system performance, and break size.

Table 6.2.1-56 lists the 24 cases that were analyzed to determine the worst case containment pressures and temperatures following a main steam line break. Each of these 24 cases has been analyzed at the conditions associated with the Framatome-design Model 73/19T replacement steam generators. The nominal power assumed in the steam line break analysis is the uprated 3579 Mwt NSSS power. Other assumptions regarding important plant conditions and features are discussed in the following paragraphs.

6.2.1.4.1 Significant Parameters Affecting Steam Line Break Mass and Energy Releases

There are four major factors that influence the release of mass and energy following a steam line break: steam generator fluid inventory, primary to secondary heat transfer, protective system operation, and the state of the secondary fluid blowdown. The following is a list of those plant variables which determine the influence of each of these factors:

a. Plant power level

b. Main feedwater system design

c. Auxiliary feedwater system design

d. Postulated break type, size, and location

e. Availability of offsite power

f. Safety system failures

g. SG reverse heat transfer and reactor coolant system metal heat capacity

The following is a discussion of each of these variables.

6.2.1.4.1.1 Plant Power Level

Steam line breaks can be postulated to occur with the plant in any operating condition ranging from hot standby to full power. Since steam generator water mass decreases with increasing power level, breaks occurring at lower power will generally result in a greater total mass release to the plant containment. However, because of increased energy storage in the primary plant, increased heat transfer in the steam generators, and the additional energy generation in the nuclear fuel, the energy release to the containment from breaks postulated to occur during power operation may be greater than for breaks occurring with the plant in a hot standby condition. Additionally, steam pressure and the dynamic conditions in the steam generators change with increasing power and have significant influence on both the rate of blowdown and the amount of moisture entrained in the fluid leaving the break following a steambreak event.

Because of the opposing effects of changing power level on steam line break releases, no single power level can be singled out as a worst case initial condition for a steam line break event. Therefore, several different power levels spanning the operating range as well as the hot standby condition have been analyzed.

During startup or shutdown evolutions when safety injection on low pressurizer pressure or low steamline pressure is blocked and steamline isolation on low steamline pressure is blocked below P-11 (pressurizer pressure less than 1970 psig), the high negative steamline pressure rate (HNPR) signal is enabled by P-11 to provide steamline isolation. A series of steamline break sensitivities in Mode 3 conditions has been performed using the LOFTRAN code (Ref. 1) to investigate the response of the HNPR function below P-11. Specifically, a spectrum of break sizes over a wide range of Mode 3 temperatures has been considered. The results of this study demonstrate that automatic steamline isolation is provided by the HNPR function for all but the smallest breaks for RCS temperatures from approximately the middle to the high end of the Mode 3 range. As the RCS temperature is decreased below these values, the smaller break sizes are no longer automatically protected by the HNPR function. Finally, as the RCS temperature is automatically protected by the HNPR function. Finally, as the RCS temperature is reduced further, the HNPR function does not provide protection for any break size. This is consistent with the expected response of the protection function since, as the assumed RCS temperature is decreased, the initial steam generator pressure decreases as well, making it less likely that the HNPR setpoint would be reached. It should be noted that steamline isolation can also be provided by a containment pressure High-2 signal for breaks inside containment or by manual actions performed in accordance with established procedures. Mass and energy releases inside containment for steamline breaks during the shutdown modes not accompanied by an automatic steamline isolation signal will result in less severe containment pressurization rates due to there being less thermal energy discharged from the main steam system if the accident occurs with the initial RCS T_{avg} less than 400°F. The limiting cases presented in Section 6.2.1.4.3.3 rely on containment pressure signals to provide feedwater and steamline isolation. The containment pressure High-1 and High-2 signals are not blocked below P-11.

6.2.1.4.1.2 Main Feedwater System Design

The rapid depressurization which occurs following a rupture may result in large amounts of water being added to the steam generators through the main feedwater system. Rapid closing isolation valves are provided in the main feedwater lines to limit this effect. Also, the piping layout downstream of the isolation valves affects the volume in the feedwater lines that cannot be isolated from the steam generators. As the steam generator pressure decreases, some of the fluid in this volume will flash into the steam generator, providing additional secondary fluid which may exit out the rupture.

The feedwater addition which occurs prior to closing of the feedwater line isolation valves influences the steam generator blowdown in two ways. First, because the water entering the steam generator is subcooled, it lowers the steam pressure, thereby reducing the flow rate out of the break. Secondly, the increased flow rate causes an increase in the heat transfer rate from the primary to secondary system, resulting in greater energy being released out the break. Determination of total steam generator inventory is based on conservatively large feedwater additions, as explained in Section 6.2.1.4.3.2.

The unisolated feedwater line volumes between the steam generator and the isolation valves serve as a source for additional high energy fluid to be discharged through the pipe break. This volume is accounted for in the mass and energy release data presented in Section 6.2.1.4.3.2.

6.2.1.4.1.3 Auxiliary Feedwater System Design

Within the first minute following a steam line break, the auxiliary feed system is initiated on any one of several protection system signals. Addition of auxiliary feedwater to the steam generators increases the secondary mass available for release to the containment, as well as increases the heat transferred to the secondary fluid. The auxiliary feedwater flow to the faulted and intact steam generators has been assumed to be a function of the backpressure on the auxiliary feed pumps as a result of the depressurizing steam generator. Auxiliary feedwater flow to the faulted-loop steam generator has been assumed up until the time of manual operator action at 10 minutes after event initiation to isolate the flow to the steam generator near the break location.

6.2.1.4.1.4 Postulated Break Type, Size, and Location

a. Postulated Break Type

Two types of postulated pipe ruptures are considered in evaluating steam line breaks.

First is a split rupture in which a hole opens at some point on the side of the steam pipe or steam header but does not result in a complete severance of the pipe. A single, distinct break area is fed uniformly by all steam generators until steam line isolation occurs. The blowdown flow rates from the individual steam generators are interdependent, since fluid coupling exists among all steam lines. Because flow limiting orifices are provided in each steam generator, the largest possible split rupture can have an effective area prior to isolation that is no greater than the throat area of the flow restrictor times the number of plant primary coolant loops. Following isolation, the effective break area for the steam generator with the broken line can be no greater than the flow restrictor throat area.

The second break type is the double-ended guillotine rupture in which the steam pipe is completely severed and the ends of the break displace from each other. Guillotine ruptures are characterized by two distinct break locations, each of equal area but being fed by different steam generators. The largest possible guillotine rupture can have an effective area per steam generator no greater than the throat area of one steamline flow restrictor.

The type of break influences the mass and energy releases to containment by altering both the nature of the steam blowdown from the piping in the steam plant and the effective break area fed by each steam generator prior to steam line isolation. For example, a double-ended rupture in a pipe having a cross-sectional area of 3.565 square feet would appear as a 1.39-square-foot rupture to a single steam generator feeding one end of the break, but would appear as a 0.725-square-foot rupture to each of the steam generators feeding the other end of the break.

b. Postulated size

The break area is important when evaluating steam line breaks because it controls the rate of releases to the containment as well as influences the steam pressure decay. The data presented in this section include releases for two break areas at each of four initial power levels, as follows:

1. A full double-ended pipe rupture downstream of the steam line flow restrictor. For this case, the actual break area equals the cross-sectional area of the steam line, but the blowdown from the steam generator with the broken line is controlled by the flow restrictor throat area (1.39 square feet). The reverse flow from the intact steam generators is controlled by the smaller of the pipe cross section, the steam stop valve seat area, or the total flow restrictor throat area in the intact loops. The reverse flow has been conservatively assumed to be controlled by the pipe cross section. Actually, the combined flow from the three steam generators must pass through an 18-inch (1.42 square feet) line, which would greatly restrict the flow.

2. A split break that represents the largest break that will neither generate a steam line isolation signal from the primary protection equipment nor result in moisture entrainment. Steam and feedwater line isolation signals will be generated by high containment pressure signals for these cases. Being a split rupture, the effective area seen by the faulted steam generator will increase by a factor of 4, following steam line isolation. Conceivably, moisture entrainment could occur at that time. However, since steam line isolation for these breaks will generally not occur before 20-60 seconds, it is conservatively assumed that the pressure has decreased sufficiently in the affected steam generator to preclude any moisture carryover.

c. Postulated Break Location

Break location affects steam line blowdowns by virtue of the pressure losses which would occur in the length of piping between the steam generator and the break. The effect of the pressure loss is to reduce the effective break area seen by the steam generator. Although this would reduce the rate of blowdown, it would not significantly change the total release of energy to the containment. Therefore, piping loss effects have been conservatively ignored in all blowdown results.

6.2.1.4.1.5 Availability of Offsite Power

The effects of the assumption of the availability of offsite power have been enveloped in the analysis. Loss of offsite power has been assumed where it delays the actuation of the containment heat removal systems (i.e., containment sprays and containment air coolers) due to the time required to start the emergency diesel generators. Offsite power has been assumed to be available where it maximizes the mass and energy released from the break due to 1) the continued operation of the reactor coolant pumps which maximizes the energy transferred from the reactor coolant system to the steam generators and 2) continued operation of the feedwater pumps and actuation of the auxiliary feedwater system which maximizes the steam generator inventories available for release.

6.2.1.4.1.6 Safety System Failures

In addition to assuming a loss of offsite power, the following single active failures were considered:

a. Loss of one emergency diesel

b. Failure of one main steam isolation valve

c. Failure of one main feedwater isolation valve

The loss of one emergency diesel results in the loss of one train of each of the containment heat removal systems. As discussed in Section 6.2.1.4.3.3, this is the most severe single active failure in terms of peak containment pressure.

The effect of a main steam isolation valve failure is to provide additional fluid which may be released to the containment via the break. This results from the blowdown of all the steam piping between the break location and the isolation valves in the intact loops.

The failure of a main feedwater isolation valve will result in additional fluid being released to the containment following a main steam line break. The additional fluid to be released will be the volume between the isolation valve and the feedwater regulating valve. The latter also receives an automatic closure signal.

The incorporation of digital controls into the feedwater control system has no significant impact on the mass and energy releases resulting from a steam line break.

6.2.1.4.1.7 Steam Generator Reverse Heat Transfer and Reactor Coolant System Metal Heat Capacity

Once steam line isolation is complete, those steam generators in the intact steam loops become sources of energy which can be transferred to the steam generator with the broken line. This energy transfer occurs via the primary coolant. As the primary plant cools, the temperature of the primary coolant flowing in the steam generator tubes drops below the temperature of the secondary fluid in the intact units, resulting in energy being returned to the primary coolant. This energy is then available to be transferred to the steam generator with the broken steamline.

Similarly, the heat stored in the metal of the reactor coolant piping, the reactor vessel, and the reactor coolant pumps will be transferred to the primary coolant as the plant cooldown progresses. This energy also is available to be transferred to the steam generator with the broken line.

The effects of both the reactor coolant system metal and the reverse steam generator heat transfer are included in the results presented in this document.

6.2.1.4.2 Description of the Blowdown Model

The blowdown model used for the steam line break mass and energy releases inside containment is documented in WCAP 8822 and its supplements (Reference 6). However, the computer code used to represent the blowdown model is RETRAN 02, which has been approved for use in the analysis of the steam line break mass and energy releases inside containment (Reference 7). Blowdown mass and energy releases determined using RETRAN include the effects of core power generation, main and auxiliary feedwater additions, engineered safeguards systems, reactor coolant system thick-metal heat storage including steam generator thick-metal mass and tubing, and reverse steam generator heat transfer. As noted in Reference 7, no entrainment is assumed in the break effluent. The assumption of saturated steam being released from the break location is a conservative assumption that maximizes the energy release into containment.

The plant initial conditions are assumed to be at the nominal value corresponding to the initial power for that case, with appropriate uncertainties included. Table 6.2.1 57A identifies the values assumed for NSSS power, RCS vessel average temperature, RCS flow, RCS pressure, pressurizer water volume, feedwater enthalpy, steam generator pressure, and steam generator water level corresponding to each power level analyzed. Uncertainties on the initial conditions assumed in the steam line break analysis have been applied only to the power fraction at full power (2 percent), the RCS average temperature (4.3ºF), and the steam generator water level (6.2 percent narrow-range span). Uncertainty conditions are only applied to those parameters that could increase the amount of mass or energy discharged into containment.

The plant-specific assumptions related to the main feedwater system and the auxiliary feedwater system as discussed in Sections 6.2.1.4.1.2 and 6.2.1.4.1.3, as well as the main steam system, are presented in Table 6.2.1 57B.

The protection systems available to mitigate the effects of the steam line break inside containment include reactor trip, safety injection, feedwater isolation, and steam line isolation. The plant-specific protection system actuation signals and associated setpoints credited in the steam line break analysis are identified in Table 6.2.1 57C.

Conservative core reactivity coefficients corresponding to end of cycle conditions are used to maximize the reactivity feedback effects resulting from the steam line break. Use of maximum reactivity feedback results in higher power generation if the reactor returns to criticality, thus maximizing heat transfer to the secondary side of the steam generators. For all steam line breaks, the control rod located at the most reactive location is assumed to be stuck out of the core. Core decay heat generation assumed in calculating the steamline break mass and energy releases is based on the 1979 ANS Decay Heat + 2σ model.

6.2.1.4.3 Containment Response Analysis

The GOTHIC computer code (Ref. 13), which is discussed in Section 6.2.1.1.3, was used to determine the containment responses following the postulated main steam line breaks. The following assumptions were made to obtain these responses.

6.2.1.4.3.1 Initial Conditions

The initial containment conditions are the same as those used in the containment response analysis for the postulated reactor coolant system pipe ruptures (see Table 6.2.1-5).

6.2.1.4.3.2 Mass and Energy Release Data

Tables of mass and energy release data are generated by RETRAN and are electronically read into GOTHIC for use in determining the containment pressure temperature responses for the spectrum of breaks analyzed. The basis for the tabulated mass and energy release data is provided in References 6 and 7. The specific plant design input that was assumed is provided for the spectrum of breaks in Tables 6.2.1-57A, 6.2.1-57B, and 6.2.1-57C. Tables 6.2.1-57D and 6.2.1-57E provide the mass and energy release data for the cases that resulted in the highest temperature and pressure, respectively.

The rate of auxiliary feedwater addition is a function of the backpressure on the auxiliary feedwater pumps as a result of the depressurizing steam generator in the steam line break analysis. The value given for mass added by feedwater pumping assumes that no reduction in feedwater pump turbine speed occurs following a MSLB and prior to main feedwater isolation. Feedwater isolation for the double-ended ruptures is dependent on signals generated by the primary protection system, which results in isolation times of approximately 17 seconds for these cases. Feedwater isolation for the split breaks is based on the time required to reach the containment High-1 pressure setpoints which generates an SIS, which then results in the feedwater isolation signal. Determination of feedwater flowrates prior to isolation assumed that the feedwater control valve in the broken loop goes wide open while those in the intact loop remain in their pre-break positions.

Containment Pressure-Temperature Results

Figures 6.2.1-79 through 6.2.1-82 provide curves of the resultant containment pressure-temperature transients for the cases producing the highest peak containment pressure and temperature. Table 6.2.1-58 summarizes the results of all the cases analyzed and indicates the times at which dryout occurs and the various containment pressure setpoints are reached. The sequence of events following a postulated main steam line break is listed in Tables 6.2.1-59 and 6.2.1-60 for worst pressure and temperature cases, respectively.

The worst single active failure, in terms of peak containment pressure, is the loss of an emergency diesel. This is evident by comparing the results given in Table 6.2.1-58. As illustrated in Figure 6.2.1-79, case 24, 0.803 ft^2 split break at 2-percent power, results in a peak pressure of 46.2 psig. This case represents the peak calculated containment pressure for the spectrum of breaks analyzed. The condensing heat transfer coefficient versus time for this case is provided in Figure 6.2.1-83.

It is important to note that the peak calculated pressure is coincident with the termination of the auxiliary feedwater flow to the affected steam generator, which was assumed to occur at 600 seconds (10 minutes). Termination of auxiliary feedwater flow to the affected steam generator due to operator action is expected to occur prior to 600 seconds (10 minutes), as discussed in Section 10.4.9. In all cases, the peak calculated containment pressure demonstrates considerable margin below the containment design pressure.

As illustrated in Figure 6.2.1-82, case 1, 1.39 ft^2 double-ended break at 102-percent power, results in a peak vapor temperature of 345.4°F. This case represents the peak calculated containment vapor temperature for the spectrum of breaks analyzed. The condensing heat transfer coefficient versus time for this case is provided in Figure 6.2.1-84.

For the spectrum of breaks analyzed, the calculated containment vapor temperature for some cases exceeds the specified containment design temperature of 320°F for a short period of time. The 320°F containment design temperature is the design temperature for safety-related equipment and instrumentation located within the containment and not the maximum temperature allowed for the containment atmosphere vapor.

Figure 6.2.1-85 provides plots of surface temperature versus time for various representative materials within the containment for the original steam generators (see Table 6.2.1-2). These curves are based on the IEM model discussed in Reference 8, used in conjunction with COPATTA (Reference 1) for the case resulting in the highest material surface temperatures. These figures clearly show that the actual equipment temperatures, following a postulated secondary system break, are well below their design temperatures and are, in fact, approximated more closely by the containment vapor saturation temperature.

Cables located inside the containment are qualified to higher temperatures (340 to 385°F) than their surfaces are expected to experience as shown in Figure 3.11(B)-7A for the original steam generators Table 6.2.1-2. The calculated temperature for each type of cable is below the qualification temperature; however, due to the low mass to surface area ratios for cables, the calculated jacket/cable surface temperatures exceed the containment vapor saturation temperature.

Equipment qualification conclusions based on these surface temperature curves remain valid for the replacement steam generators.

6.2.1.4.4 Results of Postulated Feedwater Line Breaks Inside Containment

The effects of a postulated feedwater line break on the containment is not as severe as the MSLB because the initial break effluent during a feedwater line break is at a lower specific enthalpy.

6.2.1.4.5 Additional Information Required for Confirmatory Analysis

An evaluation has been performed to support the increased closure time associated with the system medium actuated main feedwater and main steam isolation valves. For plant operation conditions below hot standby, an analysis of the steamline break mass and energy releases with increased main feedwater and main steam isolation valve stroke times has been completed using the RETRAN computer code (Reference 7). Tables of mass and energy release data were electronically read into the GOTHIC computer code (Reference 13) for use in determining the containmment pressure and temperature responses for steamline break cases analyzed. The results of the containment response analysis show that the pressure and temperature for the Modes 1 and 2 Replacement Steam Generator analysis bound those determined in the hot standby analysis (See Reference 19).

In addition, it is noted that the incorporation of digital controls into the feedwater control system has no significant impact on the containment pressure and temperature responses following a steam line break.

6.2.1.5 Minimum Containment Pressure Analysis for Performance Capability Studies on Emergency Core Cooling System

The containment backpressure used for the limiting case (C_D = 0.6) double-ended cold leg guillotine break for the ECCS analysis presented in Section 15.6.5 is presented in Figure 6.2.1-86. The containment backpressure is calculated, using the methods and assumptions described in Appendix A of Reference 9. Input parameters, including the containment initial conditions, net free containment volume, passive heat sink materials, thicknesses, and surface areas, and starting time and number of containment cooling systems used in the analysis, are described in the following paragraphs.

6.2.1.5.1 Mass and Energy Release Data

The mass and energy releases to the containment during the blowdown and reflood portions of the limiting break transient are presented in Tables 6.2.1-63 and 6.2.1-64.

The mathematical models which calculate the mass and energy releases to the containment are described in Section 15.6.5 and conform to 10 CFR Part 50, Appendix K, "ECCS Evaluation Models." A break spectrum analysis is performed (see references in Section 15.6.5) that considers various break sizes, break locations, and Moody discharge coefficients for the double-ended cold leg guillotines which affect the mass and energy released to the containment. This effect is considered for each case analyzed. During refill, the mass and energy released to the containment is assumed to be zero, which minimizes the containment pressure. During reflood, the effect of steam water mixing between the safety injection water and the steam flowing through the reactor coolant system intact loops reduces the available energy released to the containment vapor spaces and therefore tends to minimize containment pressure.

6.2.1.5.2 Initial Containment Internal Conditions

The following initial values were used in the analysis:

a. A containment pressure of 14.7 psia.

b. A containment temperature of 90°F.

c. A refueling water storage tank temperature of 37°F.

d. An outside temperature of -30°F.

e. A relative humidity of 99 percent.

These containment initial conditions are representatively low values anticipated during normal full power operation.

6.2.1.5.3 Containment Volume

The volume used in the analysis was 2.7 x 10^6 ft^3, plus an additional amount to account for the effect of containment mini-purge operation, resulting in a total containment volume of 3.03 x 10^6 $ft.^3$.

6.2.1.5.4 Active Heat Sinks

The containment spray system and containment air coolers operate to remove heat from the containment.

Pertinent data for these systems which were used in the analysis are presented in Table 6.2.1-65.

The sump temperature was not used in the analysis because the maximum peak cladding temperature occurs prior to initiation of the recirculation phase for the containment spray system. In addition, heat transfer between the sump water and the containment vapor space was not considered in the analysis.

6.2.1.5.5 Steam-Water Mixing

Water spillage rates from the broken loop accumulator are determined as part of the core reflooding calculation and are included in the containment code (COCO) calculational model.

6.2.1.5.6 Passive Heat Sinks

The passive heat sinks used in the analysis, with their thermophysical properties, are given in Table 6.2.1-66. The passive heat sinks and thermophysical properties were derived in compliance with Branch Technical Position CSB 6-1, "Minimum Containment Pressure Model for PWR ECCS Performance Evaluation."

6.2.1.5.7 Heat Transfer to Passive Heat Sinks

The condensing heat transfer coefficients used for heat transfer to the steel containment structures are given in Figure 6.2.1-87 for the limiting case. The containment pressure transient for the limiting case is shown in Figure 6.2.1-86.

6.2.1.5.8 Effect of Containment Mini-purge Operation

The effect of having containment mini-purge in operation at the onset of the double-ended cold leg guillotine break has been incorporated into the analysis by increasing the containment volume as discussed in Section 6.2.1.5.3.

6.2.1.6 <u>Tests and Inspections</u>

Refer to Sections 6.2.6 and 6.6

6.2.1.7 <u>Instrumentation Requirements</u>

Instrumentation is provided to actuate the engineered safety features and to monitor the containment temperature, pressure, and sump level. Design details and logic of the instrumentation are discussed in Sections 7.1, 7.2, 7.3, and 7.5.

6.2.1.8 REFERENCES

1. Bechtel Power Corporation, "Performance and Sizing of Dry Pressure Containments," Topical Report No. BN-TOP-3, (Rev. 4), October 1977.

2. "Pipe Breaks for the LOCA Analysis of the Westinghouse Primary Coolant Loop," WCAP-8082-P-A (Proprietary) and WCAP-8172-A (Non-Proprietary), January 1975.

3. "Westinghouse Mass and Energy Release Data for Containment Design," WCAP-8264-P-A, Rev. 1, (Proprietary) and WCAP-8312-A, (Non-Proprietary), August 1975.

4. Bechtel Power Corporation "COPDA, Compartment Pressure Design Analysis," (Bechtel Computer Code), 1973.

5. Bechtel Power Corporation, "Subcompartment Pressure and Temperature Transient Analysis," Topical Report No. BN-TOP-4, (Rev. 1), October 1977.

6. Land, R. E., "Mass and Energy Releases Following a Steam Line Rupture," WCAP-8822 (Proprietary) and WCAP-8860 (Nonproprietary), September 1976; Osborne, M. P., and Love, D. S., “Supplement 1 - Calculations of Steam Superheat in Mass/Energy Releases Following a Steam Line Rupture,” WCAP-8822-S1-P-A., (Proprietary) and WCAP-8860-S1-A (Nonproprietary) September 1986; Butler, J. C., and Linn, P. A., “Supplement 2 - Impact of Steam Superheat in Mass/Energy Releases Following a Steam Line Rupture for Dry and Subatmospheric Containment Designs, “WCAP-8822-S2-P-A (Proprietary) and WCAP-8860-S2-A (Nonproprietary) September 1986.

7. Huegel, D. S., et al., “RETRAN-02 Modeling and Qualification for Westinghouse Pressurized Water Reactor Non-LOCA Safety Analysis,” WCAP-14882-P-A (Proprietary) and WCAP-15234-A (Nonproprietary), April 1999 (Proprietary) and May 1999 (Nonproprietary).

8. Letter - Docket 50-368, "Main Steamline Break Accident Environmental Qualifications," John F. Stolz (NRC) to William Cavanaugh III (Arkansas Power and Light Co.), April 14, 1978.

9. Bordelon, F. M., Massie, H. W., Jr., Zordon, T. A., "Westinghouse Emergency Core Cooling System Evaluation Model Summary", WCAP-8339, June 1974.

10. ULNRC-1471 "Callaway Plant Uprating Submittal", March 31, 1987.

11. NUREG/CR-0255, "CONTEMPT-LT/028-A Computer Program For Predicting Containment Pressure - Temperature Response To A Loss-of-Coolant Accident", March 1979.

12. “Westinghouse LOCA Mass and Energy Release Model for Containment Design - March 1979 Version,” WCAP-10325-P-A, May 1983 (Proprietary), WCAP-10326-A (Nonproprietary).

13. Letter SCP-04-74/SCP-RSG-04-31 (Proprietary), “Transmittal of Final Reports for Containment and Radiological Dose RSG Analyses,” P. J. McDonough (Westinghouse) to Keith Mills (AmerenUE), July 19, 2004.

14. Docket No. 50-315, “Amendment No. 126, Facility Operating License No. DPR-58 (TAC No. 7106), for D. C. Cook Nuclear Plant Unit 1,” June 9, 1989.

15. EPRI 294-2, “Mixing of Emergency Core Cooling Water with Steam; 1/3-Scale Test and Summary,” (WCAP-8423), Final Report, June 1975.

16. ANSI/ANS-5.1 1979, “American National Standard for Decay Heat Power in Light Water Reactors,” August 1979.

17. Westinghouse letter SCP-05-50, “Effect of Absence of Surge LIne LBB on RSG LoCA M&E Analyses: Pressurizer Vault and Pressurizer Skirt Pressurization,” June 30, 2005.

18. Callaway Operating License Amendment No. 168 dated September 29, 2005.

19. Westinghouse letter SCP-07-19, “Main Steam Isolation Valve (MSIV) Stroke Time Evaluation Phase 2 Report Revision 0,” February 16, 2007.

6.2.2 CONTAINMENT HEAT REMOVAL SYSTEMS

The functional performance objective of the containment heat removal system, as an engineered safety features system, is to reduce the containment temperature and pressure following a LOCA or main steam line break (MSLB) accident, by removing thermal energy from the containment atmosphere. These cooling systems also serve to limit offsite radiation levels by reducing the pressure differential between the containment atmosphere and the external environment, thereby diminishing the driving force for the leakage of fission products from the containment to the environment. The containment heat removal systems include the residual heat removal system discussed in Sections 5.4.7, 6.2.1, and 6.3, the containment spray system (CSS) discussed in Section 6.2.2.1, and the containment cooling system discussed in Section 6.2.2.2.

6.2.2.1 Containment Spray System

6.2.2.1.1 Design Bases

6.2.2.1.1.1 Safety Design Bases

SAFETY DESIGN BASIS ONE - The CSS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, or external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The CSS is designed to remain functional after a SSE or to perform its intended function following the postulated hazard of a pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power (GDC-38).

SAFETY DESIGN BASIS FOUR - The active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of components at appropriate times specified in the ASME Boiler and Pressure Vessel Code, Section XI (GDC-39 and 40).

SAFETY DESIGN BASIS FIVE - The CSS is designed and fabricated to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - The capability of isolating components or piping is provided so that the CSS safety function will not be compromised. This includes isolation of components to deal with leakage or malfunctions (GDC-38).

SAFETY DESIGN BASIS SEVEN - The containment isolation valves in the system are selected, tested, and located in accordance with the requirements of GDC-54 and 56 and 10 CFR 50, Appendix J, Type A testing.

SAFETY DESIGN BASIS EIGHT - The CSS, in conjunction with the containment fan cooler system and the emergency core cooling system, is designed to be capable of removing sufficient heat and subsequent decay heat from the containment atmosphere following the hypothesized LOCA or MSLB to maintain the containment pressure below the containment design pressure. Section 6.2.1 provides the assumptions as to sources and amounts of energy considered and the analysis of the containment pressure transient following a LOCA or MSLB accident inside the containment (GDC-38).

SAFETY DESIGN BASIS NINE - The CSS remains operable in the accident environment.

SAFETY DESIGN BASIS TEN - The containment spray water does not contain substances which would be unstable in the thermal or radiolytic environment of the LOCA or cause extensive corrosive attack on equipment.

SAFETY DESIGN BASIS ELEVEN - The CSS is designed so that adequate net positive suction head (NPSH) exists at the suction of the containment spray pumps during all operating phases, in accordance with Regulatory Guide 1.1.

SAFETY DESIGN BASIS TWELVE - The CSS is designed to prevent debris which could impair the performance of the containment spray pumps, valves, eductors, or spray nozzles from entering the recirculation piping. Design is in accordance with Regulatory Guide 1.82, as discussed in Table 6.2.2-1.

6.2.2.1.1.2 Power Generation Design Bases

The CSS has no power generation design bases.

6.2.2.1.2 System Design

6.2.2.1.2.1 General Description

The CSS, shown schematically in Figure 6.2.2-1, consists of two separate trains of equal capacity, each independently capable of meeting the design bases. Each train includes a containment spray pump, spray header and nozzles, spray recirculation path, valves, and the necessary piping, instrumentation, flushing connections, and controls.

The refueling water storage tank supplies borated injection water to the containment spray system. Each train takes suction from separate containment recirculation sumps during the recirculation phase.

The CSS provides a spray of cold or subcooled borated water from the upper regions of the containment to reduce the containment pressure and temperature during either a LOCA or MSLB inside the containment.

Each CSS pump discharges into the containment atmosphere through an independent spray header. The spray headers are located in the upper part of the reactor building to allow maximum time for the falling spray droplets to reach thermal equilibrium with the steam-air atmosphere. The condensation of the steam by the falling spray results in a reduction in containment pressure and temperature. Each spray train provides adequate coverage to meet the design requirements with respect to both containment heat removal and iodine removal. Further discussion of the iodine removal function of the CSS is provided in Section 6.5.2.

In the CSS, only the containment recirculation sumps, the trisodium phosphate baskets, the spray headers, nozzles, and associated piping and valves are located within the containment. The remainder of the system is located within the auxiliary building, separated from that portion in the containment by motor-operated isolation valves. During the recirculation phase, leakage outside of the containment will be detected with the auxiliary building radiation indicators and alarms, temperature alarms, and auxiliary building sump alarms. The motor-operated isolation valves in each train assure train isolation capability in the event of leakage during the recirculation phase. Leakage detection within the auxiliary building is discussed in Section 9.3.3.

Following a large break LOCA, the containment spray during the injection phase will be a boric acid solution having a pH of about 4.5. The desired pH level is greater than 7.0 to assure iodine retention in the sumps, to limit corrosion and the associated production of hydrogen, and to limit chloride induced stress-corrosion cracking of austenitic stainless steels. To adjust the sump solution pH into the desired range, a minimum of 9000 pounds of trisodium phosphate dodecahydrate ($NA_3PO_4 \cdot 12H_2O \cdot 1/4\ NaOH$) is stored in two baskets, one adjacent to each containment recirculation sump, at an elevation to assure dissolution after a LOCA. This amount of trisodium phosphate is sufficient to assure that the equilibrium sump solution pH will be greater than or equal to 7.1.

The baskets are stainless steel with mesh sides and bottoms to permit a large surface to be exposed to the solution, thus maximizing the rate of dissolution into the sump. During the recirculation phase, the fluid mass released to the containment is screened through a recirculation sump strainers with a perforated plate having nominal openings of 0.045 inch before entering the recirculation sumps to be pumped back through the spray nozzles. Trisodium phosphate (TSP-C), stored in baskets adjacent to the recirculation sumps at an elevation to assure dissolution post-LOCA, dissolves in the sump solution thereby raising the sump solution pH to enhance materials compatibility and retention of iodine in the sump fluid.

6.2.2.1.2.2 Component Description

Mechanical components of the CSS are described in this section. Component design parameters are given in Table 6.2.2-2.

Each component in the CSS is designed and manufactured to withstand the environmental effects, including radiation, found in Table 3.11(B)-2.

CONTAINMENT SPRAY PUMPS - The two CS pumps are the vertical centrifugal type, driven by electric induction motors. The motors have open drip-proof enclosures and are provided with adequate insulation which will allow continuous operation of a 100-percent-rated load at 50°C ambient. Power for these motors is supplied from the Class 1E 4,160-Volt busses. Power supply availability is discussed in Section 8.3.

The pump motors are specified to have the capability of starting and accelerating the driven equipment, under load, to a design point running speed within 4 seconds, based on 75 percent of the rated motor voltage. The pumps are designed to withstand a thermal transient from 37°F to 300°F occurring in 10 seconds, which exceeds the severity of the transient occurring when pump suction is switched from the RWST to the containment sump.

The shaft seals on the pumps are reliable, easy to maintain, and compatible with the fluids to be circulated. They are designed to operate at a temperature of 300°F, which exceeds the maximum temperature to which they will be exposed following an accident.

The containment spray pumps are designed to handle the runout flow associated with the startup transient, when minimal discharge head is applied.

CONTAINMENT SPRAY HEADER AND NOZZLES - Each containment spray header contains 197 hollow cone nozzles, each capable of the design flow and differential pressure given in Table 6.2.2-2. These nozzles have a 7/16-inch spray orifice. The nozzles produce a drop size distribution, as described in Figure 6.5-2, at system design conditions. Special tests performed on the spray nozzles are discussed in Section 6.5.2.2.2. The spray solution is completely stable and soluble at all temperatures of interest in the containment and, therefore, will not precipitate or otherwise interfere with nozzle performance. The nozzles of each header are oriented to provide greater than 90-percent area coverage at the operating deck of the reactor building. The area coverage at the operating deck (based on the calculated post-LOCA containment saturation temperature) is provided in Table 6.5-2 for various nozzle orientations. The containment spray envelope reduction factor as a function of post-LOCA containment saturation temperature is provided in Figure 6.5-4. The spray header design, nozzle spacing, and orientation are shown in Figure 6.2.2-2. The containment spray header and nozzles are designed to withstand the impulse of a water hammer at the commencement of flow.

CONTAINMENT RECIRCULATION SUMPS - The two containment recirculation sumps are collecting reservoirs from which the containment spray pumps and the residual heat removal pumps separately take suction after the contents of the refueling water storage tank have been expended. The sumps are located as far as feasible from the reactor coolant system piping and components which could become sources of debris. Thermal insulation used inside containment will be a source of debris. The majority of insulation is NUKON which is discussed in Reference 2, although a significant amount of NUKON was replaced with metallic reflective insulation on the replacement steam generators. Limited quantities of other types of insulation are used in widely dispersed locations. A design basis accident will not degrade a sufficient quantity of this insulation to adversely affect the performance of the sump. Containment emergency recirculation sump strainers are installed within each sump and prevent floating debris and high-density particles from entering. The strainer perforated plate has nominal 0.045 inch openings. The strainer support structure is designed to keep debris from bypassing the strainer. The strainer arrangement is shown in Figure 6.2.2-3.

Sources of debris, as indicated above, are physically remote from the recirculation sumps. Debris generated as a result of a LOCA will either be retained in an area such as the reactor cavity or refueling pool or must follow a tortuous path to reach the recirculation sump strainers. Therefore, no appreciable debris will reach the recirculation sump strainers to cause any significant blockage. In addition, as demonstrated in Figure 6.2.2-3, the recirculation sumps are covered with concrete pads supporting the accumulator tanks; thus, debris cannot fall directly upon the strainer structure. However, the strainers have been sized per Regulatory Guide 1.82, as discussed in Section 6.2.2.1.3, Safety Evaluation Twelve. To limit any possible vortexing, vortex breakers are placed in the suction lines from containment sumps to the containment spray pumps. The suction pipe from the sump is horizontal to limit any possible vortexing and has sufficient submergence to ensure continuous intake flow. The suction lines from the containment sumps to the containment spray pumps are sloped to assure switchover capability. These lines, up to and including the isolation valve, are encased in guard piping.

DEBRIS BARRIERS AND BASKETS - The debris barriers and baskets are designed to reduce the quantity of debris at the containment sumps following a high energy line break (HELB) inside the bioshield. The barriers will diminish the amount of debris that can take the shortest path to the containment sumps, thereby increasing the probability that debris will be held up in low flow areas or deposited on components within the post-HELB flood plain. This debris hold-up will decrease the quantity of debris at the containment sumps, thus minimizing blockage and maximizing NPSH available to the Emergency Core Cooling System (ECCS) and Containment Spray (CS) pumps.

REFUELING WATER STORAGE TANK - The refueling water storage tank (RWST) is an austenitic stainless steel tank containing borated water at a concentration of 2,350-2,500 ppm boron. The design parameters are given in Table 6.2.2-2.

The tank is an atmospheric storage tank vented directly to the atmosphere. Thermal insulation and heating are provided to prevent the tank contents from freezing. A manway is provided for tank internal inspection. Tank level indication and high and low level alarms are also provided. Additional information is provided in Section 6.3.

VALVES - CSS motor-operated valves are capable of being operated from the control room. All valve seats are capable of limiting through leakage to less than 2 cubic centimeters per hour per nominal inch of pipe diameter. Gate and globe valves are provided with backseats.

Encapsulation - The containment spray system suction lines from the containment recirculation sumps are each provided with a single remote manual gate isolation valve outside the containment. The piping from the sump up to and including the valve and its motor operator is enclosed in an encapsulation arrangement which is leaktight at the containment design pressure. A seal is provided so that the encapsulation is not connected directly to the containment sump or containment atmosphere. A single passive or active failure in the sump lines or in the encapsulation arrangement will not provide a path for leakage to the environment.

Each encapsulated gate valve is designed with an expansion pipe assembly to preclude the occurrence of thermally induced pressure locking. The expansion pipe assembly provides additional free volume to accommodate thermal expansion of water that may be in the valve bonnet, to prevent a significant increase in bonnet pressure. Each expansion pipe assembly is connected through tubing to the packing leakoff line from the valve bonnet.

PIPING - The piping of each spray header contains a test connection. Air can be introduced into this connection to verify spray nozzle flow. Check valves immediately upstream of each spray ring header prevent system contamination due to pressurization in the containment and provide containment isolation backup protection.

A containment spray pump test line between the pumps' discharges and the RWST is installed for periodic testing.

6.2.2.1.2.3 System Operation

The CSS has two phases of operation, which are initiated sequentially following system actuation; they are the injection phase and the recirculation phase.

INJECTION PHASE - The CSS is actuated either manually from the control room or on the coincidence of two-out-of-four containment Hi-3 pressure signals.

Both containment spray pumps start and the motor-operated spray ring header isolation valves open to begin the injection phase. A summary of the accident chronology for the containment spray system is provided in Table 6.2.2-3 for the injection phase of a LOCA and MSLB inside the containment.

The containment spray pump inlet nozzle, located at El. 1,970, takes suction from the RWST, located at El. 2,000'-6", through locked open valves. More than 95 percent of the pump discharge is directed to the containment spray ring headers. These headers are located at elevations up to 2,201 feet, the highest practical level to maximize iodine removal (discussed in Section 6.5.2). The headers are located outside of and above the internal containment structures which serve as missile barriers and are thereby protected from missiles generated during a LOCA or MSLB. The remaining portion of the containment spray pump discharge is recirculated.

On coincidence of two-out-of-four low level signals from the RWST level transmitters, the emergency core cooling system (ECCS) pumps switch suction to the containment recirculation sump, as described in Section 6.3.2. The low-low-1 level setpoint indicates that 121,464 useable gallons remain in the RWST. Switchover for the spray pumps is manually initiated when the low-low-2 level in the RWST is reached. The low-low-2 level indicates imminent depletion of the RWST. Switchover initiated at the time of the low-low-2 level alarm ensures that adequate NPSH for the spray pumps is maintained. The RWST low-low-2 level alarms and level indicators inform the operator of the need to make this switchover.

Containment spray system piping and components have the potential to develop voids and pockets of entrained gases. Preventing and managing gas intrusion and accumulation in the pump suction and pump discharge piping, however, supports proper operation of the containment spray system and may also prevent water hammer and pump cavitation.

The time length of the containment spray injection phase is given in Table 6.2.2-4. These times are based on the minimum RWST volume and are given for credible combinations of minimum and maximum containment spray and ECCS operation and runout flow rates of these pumps.

RECIRCULATION PHASE - The recirculation phase is initiated by the operator manually shifting containment spray pump suction from the RWST to the containment recirculation sump. The accident chronology for the containment spray system for the recirculation phase of a LOCA is provided in Table 6.2.2-3.

The RWST suction line valves remain open during the switchover to the recirculation phase to preclude the loss of supply to the containment spray pumps in the highly unlikely event that the isolation valve in the recirculation line is delayed in opening. The operator then remote manually closes the motor-operated valves in the RWST suction lines

The suction line from the containment recirculation sump to the spray pump is a sloped line which precludes air from entering the system. The single valve in the containment sump recirculation line for the containment spray pump is encapsulated and located outside the containment. The flow paths from the spray pumps are the same as in the injection phase. Check valves are provided in the recirculation sump suction lines to prevent the establishment of a flow path between the RWST and the containment sump.

Containment spray in the recirculation mode maintains an equilibrium temperature between the containment atmosphere and the recirculation sump water. The length of time that the CSS operates during the recirculation phase is determined by the operator. The spray cannot be terminated until completion of the injection phase.

6.2.2.1.3 Safety Evaluation

Safety evaluations are numbered to correspond to the safety design basis.

SAFETY EVALUATION ONE - The safety-related portions of the CSS are located in the reactor and auxiliary buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the basis for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The safety-related portions of the CSS are designed to remain functional after a SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. Section 3.6 provides the hazards analysis to assure that the system performs its intended function.

SAFETY EVALUATION THREE - There are two spray system trains with complete redundancy of active components. Each train is capable of providing full design flow and cooling. In the event of the failure of a pump, valve, actuation system, or any other component in one train, the other train would be unaffected. To assure that a single failure will neither initiate a spurious containment spray nor prevent the activation of a necessary component, the containment spray pumps and containment header valves are actuated by the independent containment spray actuation signal (CSAS). The refueling water storage tank (RWST) is common to the two trains and is used only during the injection phase following a LOCA. Redundant level indication for this tank is provided. No power-operated valve is installed in the common suction header from the RWST so that it is impossible for an active failure to disable both trains during the injection phase. Single failure analysis for the CSS is given in Table 6.2.2-5.

The emergency power supply pump room cooling and control and instrumentation systems serving one train are independent of comparable supporting systems for the other train. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0. Minimum availability of the CSS is discussed in the Callaway Technical Specifications.

SAFETY EVALUATION FOUR - The CSS was initially tested with the program given in Chapter 14.0. Functional testing is done in accordance with Section 6.2.2.1.4.

Section 6.6 provides the ASME Boiler and Pressure Vessel Code, Section XI requirements that are appropriate for the CSS.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting systems. Section 6.2.2.1.2.2 shows that safety-related components meet the design and fabrication codes given in Section 3.2. All the power supplies and the control functions necessary for the safe function of the CSS are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - Section 6.2.2.1.2.1 describes provisions made to identify and isolate leakage or malfunction and to isolate the nonsafety-related portions of the system.

SAFETY EVALUATION SEVEN - Sections 6.2.4 and 6.2.6 provide the safety evaluation for the system containment isolation arrangement and testability.

SAFETY EVALUATION EIGHT - As shown by the containment analysis and the description of the analytical methods and models given in Section 6.2.1, the containment spray system, in conjunction with the emergency core cooling system and the containment fan coolers, is capable of removing sufficient heat energy and subsequent decay heat from the containment atmosphere following the hypothesized LOCA and MSLB inside the containment to maintain the containment pressure below the design pressure. Curves showing sump temperature, heat generation rates, heat removal rates of the containment heat removal systems, and containment total pressure, vapor pressure, and temperature as a function of time for minimum engineered safety features performance are also given in Section 6.2.1.

During the injection phase, all pressure transient analyses take credit for a spray system capable of delivering borated 100°F spray water at the design flow rate. For the design basis LOCA and MSLB accident, credit is taken for spray flow initiation within 60 seconds.[1]

An assured water volume of 394,000 gallons is available in the RWST to ensure that, after a LOCA, sufficient water is injected for emergency core cooling and for rapidly reducing the containment pressure and temperature. In addition, this volume ensures that sufficient water is available in the containment sump to permit recirculation flow to the core and the containment and to meet the NPSH requirements of the residual heat removal and containment spray pumps and assures that a sufficient water volume is available in the RWST to allow for manual switchover of the containment spray pumps.

For the recirculation phase, while the safety injection system pumps are still operating after a LOCA, containment pressure transient analysis in Section 6.2.1 assumes residual

1 LOCA case-4 spray flow initiation within 70 seconds.

heat removal by heat exchangers, as described in Section 5.4.7. Credit is taken for heat removal from heat exchangers during the recirculation phase based on a tube side inlet temperature equal to the recirculation sump temperature, which is given in Section 6.2.1 as a function of time after the accident.

Each spray header train provides a minimum of 90-percent area coverage at the operating deck, as demonstrated in Figure 6.2.2-4. Area coverage by these spray nozzles varies as a function of saturation temperature. The design basis coverage for the nozzles at various orientations is provided in Table 6.5-2 and is based on the calculated containment saturation temperature. Figure 6.5-4 provides the curve of the containment spray envelope reduction factor to determine the design basis coverage. The minimum of 90-percent area coverage at the operating deck is used as a layout guide for the location of the spray nozzles on the containment spray headers to assure 100-percent volumetric coverage above the operating floor of the containment. Physical obstructions, such as the containment polar crane, are not considered to impede the spray coverage due to the extreme turbulence created by the hydrogen mixing fans, containment air coolers, the spray within the containment, and the blowdown resulting from the postulated rupture. Thus, the header layout coupled with the extreme turbulence assures the validity of a one-region model above the operating deck for accident dose calculations (see Chapter 15.0).

Discussion of the volume of containment covered by the sprays is provided in Section 6.5.2.

SAFETY EVALUATION NINE - That part of the CSS located inside the containment is designed to remain operable in the containment accident environment described in Section 3.11(B). The material compatibility of the containment spray system in contact with the post-accident recirculation fluids is discussed in Section 6.1. That part of the CSS located in the auxiliary building is designed to remain operable in the auxiliary building accident environment described in Section 3.11(B).

SAFETY EVALUATION TEN - The borated spray solution is stable under the anticipated LOCA thermal and radiolytic conditions. The borated solution is chemically compatible with components with which it may come into contact. The use of materials which react to release hydrogen (principally zinc and aluminum) has been minimized in equipment located inside the containment. An analysis of hydrogen generation following a LOCA is given in Section 6.2.5.

SAFETY EVALUATION ELEVEN - System piping size and layout will provide adequate NPSH to the containment spray pump during all anticipated operating conditions, in accordance with Regulatory Guide 1.1. In calculating available NPSH, the conservative assumption has been made that the water in the containment sump after a design basis LOCA is a saturated liquid, and no credit has been taken for anticipated subcooling. That is, although NPSH = elevation head + (containment pressure - liquid vapor pressure) - suction line losses, the (containment pressure - liquid vapor pressure) term has been assumed to be zero. Calculated NPSH exceeds required NPSH by at least 10 percent. The recirculation piping penetrating the containment sumps is nearly horizontal to minimize vortexing. In addition, a vortex breaker is provided in the inlet of the piping from the sump.

In calculating the water level within the reactor building which contributes to the NPSH available to the containment spray pumps at the beginning of its recirculation phase, consideration has been given to the potential mechanisms of water loss within the reactor building. These water loss mechanisms include water present in the vapor phase, water loss to compartments below El. 2,000, water loss above El. 2,000, and water loss due to wetted surfaces. Tables 6.2.2-6 and 6.2.2-6a identify each water source which releases water to the reactor building and its associated mass and each potential water loss mechanism and the volume of water not assumed to contribute to the water level within the containment for a large LOCA and a MSLB, respectively. The static head available to contribute to the NPSH of the pump, suction line losses, and the minimum NPSH available are also given in Table 6.2.2-7. The CSS pump NPSH versus flow is shown in Figure 6.2.2-5. The reduction in water level due to potential water loss mechanisms is considered in the calculated NPSH available.

SAFETY EVALUATION TWELVE - Recirculation sump strainer construction provides straining down to 0.045 inch to prevent entrained particles in excess of that size from entering the containment recirculation sump and containment spray system suction piping.

Since the containment spray pumps are designed to operate with entrained particles up to 1/4 inch in diameter and the minimum constriction size in the spray nozzles is 7/16 inch, the strainers are adequate to assure proper system operability.

Each strainer is designed to ensure sufficient NPSH to the containment spray and ECCS pumps to maintain recirculation capability during the recirculation phase of an event. The strainer arrangement is shown in Figure 6.2.2-3.

The strainer arrangement does not allow flow into the sump below 6 inches above the concrete floor level surrounding the sump. This arrangement leaves ample depth for buildup of high-density debris without affecting sump performance. Additionally, the velocity of recirculated fluids approaching the strainer will be less than 0.08 fps for all modes of operation following a LOCA or MSLB, and thus a low velocity settling region for high-density particles is provided. Table 6.2.2-9 provides the approach flow velocity for a large LOCA and an MSLB.

Any debris which eludes the strainers and settling region passes into the sump through the 0.045 inch perforated plate and will be drawn into the suction piping for the containment spray and residual heat removal systems. Such debris is small enough to pass through any restriction in either system or the reactor vessel channels, and will eventually be pumped back into the containment.

A comparison of the containment recirculation sump design features with each of the positions of Regulatory Guide 1.82, "Sump for Emergency Core Cooling and Containment Spray Systems," is provided in Table 6.2.2-1.

6.2.2.1.4 Tests and Inspections

Testing and inspection of components of the CSS are discussed in this section.

Each containment spray pump has a shop test to generate complete performance curves. The test includes verifying total developed head (TDH), efficiency, and brake horsepower for various flow rates. An NPSH test for various flow rates was performed on one pump. A shop thermal transient analysis, from ambient temperature to 350°F in 10 seconds, has been performed on the CSS pump. Results of that analysis assure that the design is suitable for the switchover from the injection to the recirculation phase.

The strainer configuration on the containment recirculation sumps is shop tested to verify that all design requirements are adequately met.

The spray nozzles' design parameters were verified with prototype tests in the vendor's shop. Results of those test are provided in Section 6.5.2.2.2.

PREOPERATIONAL TESTING - Instruments are calibrated prior to system preoperational testing. Alarm functions are checked for operability and limits during preoperational testing. The flow paths and flow capacities of all components are verified during preoperational tests.

The functional test of the ECCS, described in Section 6.3, demonstrates proper transfer to the emergency diesel generator power source in the event of a loss of power. A test signal simulating the containment spray signal is used to demonstrate the operation of the spray system up to the isolation valves on the pump discharge. The isolation valves are closed for the test. These isolation valves are functionally tested separately.

The spray header nozzle performance is verified during the preoperational testing by blowing air through the nozzles and observing the movement of the telltales.

The objectives of preoperational testing are to:

a. Demonstrate that the system is adequate to meet the design pressure and temperature conditions. Components are tested in conformance with applicable codes.

b. Demonstrate that the spray nozzles in the containment spray header are clear of obstructions by passing air through them, utilizing test connections.

c. Verify that the proper sequencing of valves and pumps occurs on initiation of the CSS and demonstrate the proper operation of remotely operated valves.

d. Verify the operation of the spray pumps. Each spray pump is operated at full flow to verify that it meets the design curve generated during shop testing. Both design point and runout flow rates are utilized to verify that the pump performance is within design. In addition, each spray pump is operated at minimum flow, which is directed back to the refueling water storage tank. A flow orifice is provided to regulate minimum flow to that required for routine testing.

The containment recirculation sump strainers have been evaluated for vortex formation, air ingestion, and void fraction. The results of these evaluations were determined to be acceptable. In addition, scaled head loss testing was performed for the strainers. Data from these tests together with known pressure drops across suction lines and valves (determined using standard engineering calculations) verified that the available net positive suction head is adequate.

Further details of each preoperational test to be performed are discussed in Chapter 14.0.

OPERATIONAL TESTING - The CSS is designed to permit periodic determination of proper system operability, as specified in the Callaway Technical Specifications. The objectives of operational testing are to:

a. Verify that the proper sequencing of valves and pumps occurs on initiation of the containment spray signal and demonstrate the proper operation of remotely operated valves.

b. Verify the operation of the spray pumps. Each pump is run at a minimum flow and the flow is directed back to the RWST. Full flow testing capability is provided by recirculation lines connecting the pump discharge to the pump suction for each train. The recirculation lines contain a globe valve for throttling and a flow orifice that is used to measure the flowrate. The recirculation lines allow the pumps to achieve a discharge flowrate within +/-20% of pump design flow.

To assure the structural and leaktight integrity of components, the operability and performance of the active components, and the operability of the system as a whole, the system is periodically tested up to the last isolation valve before the containment penetration. The testing is accomplished by using a recirculation line (sized to take 10 percent of the design flow) back to the RWST.

All instrumentation will also be periodically checked and calibrated. The CSS actuation is verified as follows:

a. A containment spray actuation signal (CSAS) subchannel is actuated during a plant outage to start the containment spray pump.

b. A separate CSAS slave relay is actuated during normal reactor operation to ensure the opening of the containment header valves. The CSS pump will not be operating.

Gas Management

The containment spray system is operable when it is sufficiently filled with water. The Technical Specifications include Surveillance Requirements for verifying systems are sufficiently full of water. Voiding may occur, however, due to the accumulation of entrained gas, and acceptance criteria are established for the volume of accumulated gas at susceptible locations. If accumulated gas is discovered that exceeds the acceptance criterion for the susceptible location (or if the volume of accumulated gas at one or more susceptible locations exceeds an acceptance criterion for gas volume at the suction or discharge of a pump), the Technical Specification Surveillance Requirement is not met and past operability reviews are initiated. If it is determined by subsequent evaluation that the containment spray system was not rendered inoperable by the accumulated gas (i.e., the system was sufficiently filled with water), the Surveillance Requirement may be declared met. Accumulated gas should be eliminated or brought within the acceptance criteria limits.

Containment spray system locations susceptible to gas accumulation are monitored and, if gas is found, the gas volume is compared to the acceptance criteria for the location. Susceptible locations in the same system flow path that are subject to the same gas intrusion mechanisms may be verified by monitoring a representative subset of susceptible locations. Monitoring may not be practical for locations that are inaccessible due to radiological or environmental conditions, the plant configuration, or personnel safety. For these locations, alternative methods (e.g., operating parameters, remote monitoring) may be used to monitor the susceptible location. Monitoring is not required for susceptible locations where the maximum potential accumulated gas void volume has been evaluated and determined to not challenge system operability. The accuracy of the method used for monitoring the susceptible locations and trending of the results must be sufficient to assure system operability between surveillance performances.

6.2.2.1.5 Instrumentation Requirements

The CSS instrumentation was designed to facilitate automatic operation, remote control, and continuous indication of system parameters.

The containment has redundant analog level channels for sump recirculation with indication and alarms in the control room.

These circuits will aid the operator in determining the presence and rate of increase of the sump water level.

All system motor-operated valves have position indication provided in, and are operable from, the control room. This allows the operator to continuously monitor system status and remotely operate valves, as necessary. Details of the design and logic of the instrumentation are discussed in Chapter 7.0.

6.2.2.1.6 Materials

The CSS is constructed primarily of corrosion-resistant austenitic stainless steel and contains none of the restricted materials discussed in Section 6.1.1.1.2.

Construction materials for components in the CSS are provided in Table 6.2.2-2.

Further discussion of the materials associated with the CSS, including containment spray fluid chemistry, is given in Section 6.5.2.6.

6.2.2.2 <u>Containment Cooling System</u>

The containment cooling system (CtCS), in conjunction with the containment HVAC systems described in Section 9.4.6, functions during normal plant operation to maintain a suitable atmosphere for equipment located within the containment. Subsequent to a DBA within the containment, the containment cooling system provides a means of cooling the containment atmosphere to reduce pressure and thus reduce the potential for containment leakage of airborne and gaseous radioactivity to the environment.

6.2.2.2.1 Design Bases

6.2.2.2.1.1 Safety Design Bases

The CtCS, excluding the system ductwork downstream of the cooler discharge plenum, is safety related and required to function following a DBA to achieve and maintain the plant in a safe shutdown condition.

SAFETY DESIGN BASIS ONE - The CtCS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, or external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The CtCS is designed to remain functional after a safe shutdown earthquake or to perform its intended function following a postulated hazard, such as a fire, internal missile, or pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power (GDC-38).

SAFETY DESIGN BASIS FOUR - Active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of components at appropriate times specified in the ASME Boiler and Pressure Vessel Code, Section XI (GDC-39 and 40).

SAFETY DESIGN BASIS FIVE - The CtCS is designed and fabricated to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - The capability of isolating components, systems, or piping is provided, if required, so that the system's safety function will not be compromised. This includes the bypassing of the nonsafety-related ductwork portions of the system.

SAFETY DESIGN BASIS SEVEN - The CtCS, in conjunction with the CSS, is capable of removing sufficient heat energy and subsequent decay heat from the containment atmosphere following the LOCA or MSLB accident to maintain the containment pressure below design values. Section 6.2.1, Containment Functional Design, provides the assumptions as to sources and amounts of energy considered and the analyses of the containment pressure transient following a LOCA or an MSLB accident inside the containment. Actual containment fan cooler system parameters are such that those used in the analyses are equal to or more conservative than the actual containment fan cooler system capability.

SAFETY DESIGN BASIS EIGHT - The containment coolers, including the fan/motor combination, will remain operable in the accident environment.

6.2.2.2.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS ONE - The containment cooling system, operating in conjunction with the containment heating, ventilating, and air-conditioning system described in Section 9.4.6, is designed to limit the ambient containment air temperature during normal plant operation to 120°F with any three of the four containment coolers operating. During normal plant operations, the hydrogen mixing fans are designed to provide sufficient air flow through the steam generator compartments so that a suitable environment for the equipment in the steam generator compartment can be maintained.

6.2.2.2.2 System Description

6.2.2.2.2.1 General Description

The containment cooling system provides cooling by recirculation of the containment air across air-to-water heat exchangers. The bulk of this cooled air is supplied to the lower regions of the steam generator compartments. The remaining air is supplied to the instrument tunnel and at each level (operating floor and below) of the containment outside the secondary shield wall. The air supplied to each steam generator compartment is drawn upwards through the compartments by the hydrogen mixing fans and discharged into the upper elevations of the containment.

6.2.2.2.2.2 Component Description

Design parameters for the major components of the containment cooling system are provided in Table 6.2.2-2.

CONTAINMENT COOLER FAN - The containment cooler fans are located vertically in the bottom of the cooler housing. Fans are vaneaxial fans with two-speed motors. The fans and motors are designed for high-speed operation during normal plant operations and for low-speed operation under post-LOCA conditions.

CONTAINMENT COOLER HOUSING/DISCHARGE PLENUM - The containment cooler housing and discharge plenums are constructed of structural steel framework and galvanized steel coverings.

The containment cooler housing, including the section of ductwork containing the fusible link plates, is designed to sustain a differential pressure of 2 psi during pressure transients associated with accident conditions. An analysis which was performed to establish the differential pressure across the cooler housing indicates the maximum differential to be less than 0.1 psi (2.8 in. w.g.) under accident conditions. Ductwork was not considered in the analysis since it is designed to separate from the cooler by action of the fusible link plates. The fusible link plates are steel plates which are hinged to the ductwork and held in a closed position by the fusible links (typical detail is shown in Figure 6.2.2-6). The plates will employ a release mechanism so that after fusion of the links the plates will release from the ductwork. The fusible links will be designed to release at a temperature of approximately 160°F. The open area vacated by the plates exceeds the cross-sectional area of the fan, thus providing an unrestricted flow path.

6.2.2.2.2.3 System Operation

NORMAL OPERATION - Normally, each of the four containment coolers are operating to provide containment cooling capabilities. Although only three coolers are required to provide the proper cooling (approximately 10.152×10^6 Btu/hr), four coolers are operated to maintain proper air flow distribution. The fans are normally operating at the higher speed and the cooling water flow to the coils on low (normal) flow. The coil heat removal capabilities were designed, assuming a tube fouling factor of 0.002.

Condensate from the fan cooler coils is collected and measured to detect leaks into the containment atmosphere, as discussed in Section 5.2.5.

PLANT SHUTDOWN/REFUELING - The containment coolers may be operated during shutdown/refueling operations to provide supplemental air distribution within the containment. The containment cooler fans may be operated at low speed to reduce noise levels within the containment during this mode of operation. The coolers may be operated with the service water to provide supplemental cooling or without service water for supplemental heating by utilizing the motor heat load.

CONTAINMENT INTEGRATED LEAK RATE TESTING - The containment coolers are operated during containment integrated leak rate testing (ILRT) to maintain uniform containment temperature. The coolers are operated with service water to provide cooling and without service water to provide heating, by utilizing the motor heat load, during the test procedure. The fans are operated at low speeds during this elevated pressure condition to prevent motor overload.

POSTACCIDENT OPERATION - Following an SIS, the fans are designed to start automatically in slow speed if not already running. If running in high (normal) speed, the fans automatically shift to slow speed. Assuming loss of offsite power, the containment cooler fans are started 47 seconds after generation of the SIS with full ESW flow established after 85 seconds.

To compensate for the reduced air flow over the coils and to maximize heat removal, the cooling water flow through the cooling coils for each unit is automatically re-aligned (upon receipt of a SIS) for supply from the essential service water system (ESW) with a flow rate pre-established by flow balancing performed in accordance with plant procedures and calculations. The fusible link plates open to allow unrestricted flow through the air coolers. Each containment cooler train is capable of removing at least 100×10^6 Btu/hr under design post-LOCA conditions. (A heat removal rate of 100×10^6 Btu/hr per cooling train is assumed in the accident analyses.) The coil heat removal capabilities were designed, assuming a tube fouling factor of 0.002.

The fan can be operated from the control room at any time, but cannot be manually operated at high speed if a containment high pressure signal is in effect in order to prevent motor overload.

The postaccident air distribution system is designed to discharge the air from each unit through the opening left by the fusible link plate. The fusible link plates are steel plates which are hinged to the ductwork and held in a closed position by the fusible links. The plates will employ a release mechanism, using counterbalance weights to ensure that after fusion of the links the plates will release from the ductwork without the aid of the fan head and against the pressure differential established during the pressure transient. The fusible links will be designed to release at a temperature of approximately 160°F. The open area vacated by the plates approximately equals the cross-sectional area of the fan, thus providing an unrestricted flow path.

Under design conditions, it is assumed that the existing ductwork is restricted so that all the air is discharged through this opening. Under these conditions, the throw is approximately 100 feet. Thus, the discharge from the units is well beyond their intake regions, preventing any short circuiting. The air streams drop off toward the end of the throw and tend to settle toward the bottom of the containment due to the slightly lower temperatures and the air flow patterns established by the operation of the hydrogen mixing fans. These expected air flow patterns are shown in Figure 6.2.2-7. The volume of air recirculated in 1 hour by the combined air flows of one train of the containment coolers and one train of the hydrogen mixing fans will be approximately four times the containment free volume. These air flow patterns and recirculation volumes provide adequate circulation and, therefore, sufficient postaccident mixing of the containment atmosphere.

6.2.2.2.3 Safety Evaluation

Safety evaluations are numbered to correspond to the safety design bases in Section 6.2.2.2.1.

SAFETY EVALUATION ONE - The safety-related portions of the containment cooling system are located in the reactor building. This building is designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The safety-related portions of the containment cooling system are designed to remain functional after a SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. Section 3.5, 3.6, and 9.5.1 provide the hazards analyses to assure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

SAFETY EVALUATION THREE - The system description for the containment cooling system shows that complete redundancy is provided and, as indicated by Table 6.2.2-8, no single failure will compromise the system's safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

SAFETY EVALUATION FOUR - The containment cooling system is initially tested with the program given in Chapter 14.0. Periodic inservice functional testing is done in accordance with Section 6.2.2.2.4.

Section 6.6 provides the ASME Boiler and Pressure Vessel Code, Section XI requirements that are appropriate for the containment cooling system.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting system. All the power supplies and control functions necessary for safe function of the containment cooling system are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - Section 6.2.2.2.2.3 describes provisions made to allow the bypassing of the nonsafety-related ductwork portions of the system.

SAFETY EVALUATION SEVEN - As shown by the containment analysis and the description of the analytical methods and models given in Section 6.2.1, the containment cooling system, in conjunction with the containment spray system, is capable of removing sufficient energy and subsequent decay heat from the containment atmosphere following the hypothesized LOCA or MSLB accident inside the containment to maintain the containment below the design pressure. Both analyses assume the single failure which results in the minimum containment cooling capability.

Curves showing sump temperature, heat generation rates, heat removal rates of the containment heat removal systems, and containment total pressure, vapor pressure, and temperature as a function of time for minimum engineered safety features performance are given in Section 6.2.1. The containment cooler heat removal rates as a function of containment temperature and pressure are given in Figure 6.2.1-15. This data has been furnished by American Air Filter and is supported by their topical report (Ref. 1) and calculation (Ref. 3). Essential service water temperatures used in the analysis of the performance of the containment heat removal systems are discussed in Section 9.2.5.

SAFETY EVALUATION EIGHT - The containment cooler fan/motor combination is qualified to operate during the DBA, in accordance with IEEE 334, 1974. Section 6.2.2.2.2.2 provides the basis for the assumption of structural integrity of the cooler housing and discharge plenum during a DBA. American Air Filter (Ref. 1) demonstrates the compatibility of the housing and plenum materials with the DBA environment.

6.2.2.2.4 Tests and Inspections

Preoperational testing is described in Chapter 14.0. One containment cooler fan is tested in accordance with AMCA Standard Test Code 211, "Certified Rating for Air-Moving Devices."

The analytical data used to predict coil performance for both normal and DBA conditions are based upon the tests and data in Reference 1.

Major components are accessible during normal plant operation for inspection, maintenance, and periodic testing.

6.2.2.2.5 Instrumentation Applications

Each containment cooler is monitored for leaving air temperature and fan vibration via the plant computer. In addition, containment air temperature will also be monitored in the area of each containment cooler intake. Direct control room indication is provided for the inlet air temperatures. The leaving air temperature can be displayed in the control room via the plant computer.

Each containment cooler fan is operable from the control room.

6.2.2.3 REFERENCES

1. Topical Report AAF-TR-7101, "Design and Testing of Fan Cooler-Filter Systems for Nuclear Applications"; February 20, 1972; American Air Filter Co., Inc.; Louisville, KY.

2. Topical Report OCF-1, "Nuclear Containment Insulation System," August 1977, Owens-Corning Fiberglas Corporation, Lenexa, KS.

3. American Air Filter Calculation NESE-1081, "Cooling Coil Performance Calculations And Pulldown Curves", March 27, 2000.

6.2.3 SECONDARY CONTAINMENT FUNCTIONAL DESIGN

Based on the fission product removal and control systems discussed in Section 6.5 and the radiological consequences analyzed in Chapter 15.0 following a LOCA, no secondary containment is required for SNUPPS.

6.2.4 CONTAINMENT ISOLATION SYSTEM

The containment isolation system allows the normal or emergency passage of fluids through the containment boundary while preserving the ability of the boundary to minimize the release of fission products following a LOCA or fuel handling accident within the containment.

6.2.4.1 Design Bases

6.2.4.1.1 Safety Design Bases

SAFETY DESIGN BASIS ONE - The containment isolation system is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The containment isolation system is designed to remain functional after a safe shutdown earthquake and to perform its intended function following the postulated hazards of fire, internal missiles, or pipe breaks (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - The containment isolation system is designed and fabricated to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS FOUR - Piping systems penetrating the primary reactor containment are provided with leak detection, isolation, and containment capabilities having redundancy, reliability, and performance capabilities which reflect the importance to safety of isolating these piping systems. Such piping systems are designed with a capability to periodically test the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits (GDC-54).

SAFETY DESIGN BASIS FIVE - Each line that is part of the reactor coolant pressure boundary and that penetrates the primary reactor containment is provided with containment isolation valves as follows:

a. One locked closed isolation valve inside and one locked closed isolation valve outside the containment; or

b. One automatic isolation valve inside and one locked closed isolation valve outside the containment; or

c. One locked closed isolation valve inside and one automatic isolation valve outside the containment. A simple check valve is not used as the automatic isolation valve outside the containment; or

d. One automatic isolation valve inside and one automatic isolation valve outside the containment. A simple check valve is not used as the automatic isolation valve outside the containment; or

e. Some other defined bases that meet the intent of containment isolation as an alternative to a through d above.

Isolation valves outside the containment are located as close to the containment as practical and, upon loss of actuating power, automatic isolation valves are designed to take the position that provides the greater safety (GDC-55).

SAFETY DESIGN BASIS SIX - Each line that connects directly to the containment atmosphere and penetrates the primary reactor containment is provided with containment isolation valves as follows:

a. One locked closed isolation valve inside and one locked closed isolation valve outside the containment; or

b. One automatic isolation valve inside and one locked closed isolation valve outside the containment; or

c. One locked closed isolation valve inside and one automatic isolation valve outside the containment. A simple check valve is not used as the automatic isolation valve outside the containment; or

d. One automatic isolation valve inside and one automatic isolation valve outside the containment. A simple check valve is not used as the automatic isolation valve outside the containment; or

e. Some other defined bases that meet the intent of containment isolation, as an alternative to a through d above.

Isolation valves outside the containment are located as close to the containment as practical and, upon loss of actuating power, automatic isolation valves are designed to take the position that provides greater safety (GDC-56).

SAFETY DESIGN BASIS SEVEN - Each line that penetrates the primary reactor containment and is neither part of the reactor coolant pressure boundary nor connected directly to the containment atmosphere has:

a. At least one containment isolation valve which is either automatic, locked closed, or capable of remote manual operation; or

b. Some other defined bases that meet the intent of containment isolation, as an alternative to a above.

Valves are outside the containment and located as close to the containment as practical. A simple check valve is not used as the automatic isolation valve. For a closed system, the design is commensurate with quality group B (GDC-57).

SAFETY DESIGN BASIS EIGHT - The containment isolation system, in conjunction with other plant features, serves to minimize the release of fission products generated following a LOCA or fuel handling accident within the containment.

6.2.4.1.2 Power Generation Design Basis

The containment isolation system has no power generation design basis.

6.2.4.2 System Description

6.2.4.2.1 General Description

Each piping system which penetrates the containment is provided with containment isolation features which serve to minimize the release of fission products following a LOCA or fuel handling accident. Provisions are made to allow for passage of emergency fluid through the boundary following a postulated accident. Figure 6.2.4-1 provides the arrangement for each piping penetration, along with design information and justification of how the appropriate General Design Criteria are met. NRC SRP 6.2.4 and Regulatory Guide 1.141 provide acceptable alternative arrangements to the explicit arrangements given in GDC-55, 56, and 57. Each penetration is provided with a redundant barrier so that in the event that a single failure is postulated and one barrier does not perform as intended the containment integrity is maintained. Table 6.2.4-1 lists each penetration under the appropriate GDC and provides a reference to the section that describes the system of which the containment penetration is an integral part.

Piping penetration sleeves have been assigned numbers P-1 through P-17 and P-21 through P-104. Numbers P-18, 19, and 20 were not utilized. The fuel transfer tube was assigned to P-17; however, this is not a true piping penetration since it utilizes a blind flange which serves as the containment boundary and is subject to Type B testing. The remainder of the "P" numbers between 1 and 104 not appearing on Figure 6.2.4-1 are maintenance spares primarily used during outages, or spare sleeves to which closure heads have been permanently attached, as shown in Figure 3.8-47. These penetration sleeves include P-31, 33, 35, 37, 38, 42, 46, 47, 60, 61, 70, 72, 77, 81, 90, 94, 96, 100, and 102. The leaktight integrity of the sleeve and closure head is verified during the periodic Type A tests.

For those systems which have automatic isolation valves or for which remote manual isolation is provided, Section 6.2.4.5 describes the vital power supply and associated actuation system.

Two phases of valve actuation are considered in Table 6.2.4-1. The actuation signal which occurs directly as a result of the event initiating containment isolation is designated as the primary actuation signal. The primary valve position is a consequence of the primary actuation signal. If a change in valve position is required at any time following primary actuation, a secondary actuation signal is generated which places the valve in the secondary position.

The closure times for automatic isolation valves are provided in Figure 6.2.4-1. The containment purge system provides a direct path between the containment and outside atmospheres. As described in Section 9.4, the 18-inch 4,000 cfm minipurge lines may be open during normal plant operation and are provided with isolation valves capable of five-second closure. The 36-inch 20,000 cfm purge lines are open only during a shutdown condition and are provided with an isolation valve capable of 10-second closure. An analysis of the radiological consequences and the effect on the containment backpressure due to the release of containment atmosphere are discussed in Sections 15.6.5.4.1.4 and 6.2.1.5, respectively.

In the event of a LOCA, the secondary shield wall prevents any missiles or jet impingement from damaging or degrading the performance capability of containment isolation. Sections 3.5 and 3.6 discuss in detail the missiles and pipe break effects, and Section 3.8 discusses the internal structures, including the secondary shield wall. The operators for all power-operated containment isolation valves inside the containment are located above the maximum water level, following a LOCA. In addition, lines associated with those penetrations which are considered closed systems inside the containment are protected from the effects of a LOCA.

Provisions are made to ensure that closure of the containment isolation valves is not inhibited by entrapped debris in the valve body. For the majority of the systems, the fluid is demineralized water; thus quality will not affect valve operation. For containment purge lines, screens are provided in the lines upstream of the isolation valves. For the containment sump lines, including the emergency sump, a provision is provided to prevent large debris from entering the system.

Some other defined bases for containment isolation are provided in NRCSRP 6.2.4 and Regulatory Guide 1.141. Compliance with Regulatory Guide 1.141 is provided to the extent specified in Table 6.2.4-2. For the ECCS and containment spray system penetrations, the acceptability of the alternative arrangement relies upon provisions for the detection of possible leakage from these lines outside the containment. Section 9.3.3 describes the leak detection provisions that have been made in the plant drainage system. Other provisions, such as containment water level and system flow, temperature, and pressure instrumentation, may be used by the operator.

In addition to containment isolation, Figure 6.2.4-1 also contains systems which are required for post-LOCA mitigation. Since these systems, such as the ECCS, perform additional safety-related functions, they are associated with engineered safety features and are so indicated on Figure 6.2.4-1. Because these systems are required to operate for post-LOCA mitigation and because they are closed systems external to the containment, the length of the piping between the containment and the system outside the isolation valves is not shown.

6.2.4.2.2 Component Description

Codes and standards applicable to the piping and valves associated with containment isolation are listed in Table 3.2-1. Containment penetrations are classified as quality group B and seismic Category I.

Section 3.11 provides the post-LOCA environment that is used to qualify the operability of power-operated isolation valves located inside the containment.

The containment penetrations are designed to meet the stress requirements of NRC BTP MEB 3-1 and the classification and inspection requirements of NRC BTP APCSB 3-1, as described in Section 3.6. Section 3.8 discusses the interface between the piping system and the containment liner.

6.2.4.2.3 System Operation

During normal operation, many penetrations are not isolated. Lines that are not required for the passage of emergency fluids are automatically isolated upon receipt of isolation signals, as discussed in Sections 6.2.4.5 and 7.0. Other open lines to the containment can be isolated subsequent to the LOCA by remote-manual operation when dictated by the emergency system functional requirements. Lines not in use during power operation are normally closed, and remain closed under Technical Specification administrative control during reactor operation; refer to Section 6.2.4.4 for a further discussion.

Upon detection of high radioactivity indicative of a fuel handling accident during refueling, the isolation valves in the containment purge system are closed to minimize any fission product release to the environment.

6.2.4.3 <u>Safety Evaluation</u>

Safety evaluations are numbered to correspond to the safety design bases in Section 6.2.4.1.1.

SAFETY EVALUATION ONE - The piping and valves associated with the containment isolation system are located in the reactor and auxiliary buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The piping and valves associated with the containment isolation system are designed to remain functional after a safe shutdown earthquake. Sections 3.7(B).2, 3.9(B), and 3.9(N) provide the design loading conditions that were considered. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to assure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

SAFETY EVALUATION THREE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting systems. Figure 6.2.4-1 shows that the components meet the design and fabrication codes given in Section 3.2. All the power supplies and control functions necessary for the safe function of the containment isolation system are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION FOUR - Figure 6.2.4-1 shows the arrangement for each line penetrating the containment and provides the design information that demonstrates that GDC-54 is met. Leak detection capabilities are discussed in Section 9.3.3 and in the system descriptions associated with the applicable penetrations. Tests and inspections for piping penetrations are discussed in Sections 6.2.4.4 and 6.2.6.

SAFETY EVALUATION FIVE - Figure 6.2.4-1 shows the arrangement and justifies compliance with the intent of GDC-55 for lines that are part of the reactor coolant pressure boundary and that penetrate the primary reactor containment. A list of penetrations subject to GDC-55 is provided in Table 6.2.4-1.

SAFETY EVALUATION SIX - Figure 6.2.4-1 shows the arrangement and justifies compliance with the intent of GDC-56 for lines that are connected directly to the containment atmosphere and penetrate the primary reactor containment. A list of penetrations subject to GDC-56 is provided in Table 6.2.4-1.

SAFETY EVALUATION SEVEN - As indicated in Table 6.2.4-1, there are no penetrations which are subject to GDC-57. Note that the containment penetrations associated with the steam generators are not subject to GDC-57, since the containment barrier integrity is not breached. The boundary or barrier against fission product leakage to the environment is the inside of the steam generator tubes, the outside of the steam generator shell, and the outside of the lines emanating from the steam generator shell side. Figure 6.2.4-2 shows the arrangement and justifies compliance with containment isolation.

As shown in Section 18.2.11.3, several portions of the main steam lines are considered essential and do not receive an automatic signal to close. These include the power-operated relief valves (PV-01, 02, 03, and 04) which receive no signal and the steam supply line isolation valves (HV-05 and 06) to the AFW pump turbines which open on AFAS.

SAFETY EVALUATION EIGHT - Sections 6.2.2, 6.5, and 9.4 and Chapter 15.0 provide an evaluation that demonstrates that the containment isolation system, in conjunction with other plant features, serves to minimize the release of fission products generated following a LOCA or fuel handling accident inside the containment.

6.2.4.4 Tests and Inspections

Preoperational testing is described in Chapter 14.0. The system associated with each penetration is in continuous use or is periodically in use, which demonstrates the system performance and structural and leaktight integrity of its components.

Testing of the containment isolation valves, including verification that normally closed valves are closed, and the use of administrativve controls to maintain such valves closed or to open them under administrative control when required, are implemented in accordance with the plant Technical Specifications.

The containment isolation system is testable through the operational sequence that is postulated to take place following an accident, including operation of applicable portions of the protection system and the transfer between normal and standby power sources.

The piping and valves associated with the containment penetration are designed and located to permit preservice and inservice inspection in accordance with ASME Section XI, as discussed in Section 6.6.

Each line penetrating the containment is provided with testing features to allow containment leakrate tests in accordance with 10 CFR 50, Appendix J, as discussed in Section 6.2.6.

6.2.4.5 Instrumentation Application

The generation of a CIS-A, SLIS, CIS-B, or CPIS which isolates the appropriate containment isolation valves is described in Section 7.3.

The CPIS serves to isolate the containment purge in the event of a fuel-handling accident or LOCA.

The CIS-A, SLIS, and CIS-B serve to actuate the containment isolation system following a LOCA. A CIS-A signal actuates all power-operated valves which can be immediately closed, since doing so will not increase the potential for damage to the containment equipment, or which are not required to be open for the operation of essential equipment post accident.

SLIS signal actuates appropriate power-operated valves based on system functional requirements, as discussed in the appropriate system description.

As described in Section 9.2.2 and shown on Figure 9.2-3, Sheet 3, CIS-B isolates component cooling water system (CCWS) to the components located within the containment. The CCWS is a seismically designed closed loop system both inside and outside of the containment. A hazards analysis of the system has ensured that the system boundary will remain intact following a LOCA or high energy line break.

Since the CCWS penetrations are classified as essential penetrations (refer to Section 18.2.11.3), isolation of the system is not provided until cooling to the RCPS is no longer warranted. During the short time period following an accident, passive failures are not postulated, and the pressure boundary would remain intact until a CIS-B is received. Also, the radiation monitor on the CCWS surge tank closes the vent valve on high radiation, refer to Section 9.2.2.5, thus preventing release of radioactivity to the auxiliary building. As described in Section 9.3.3, Class 1E level indication is provided in the auxiliary building sumps to help identify any liquid leakage from the CCW system.

Figure 7.2-1, Sheet 8, shows the actuation logic for CIS-B. The pressure transmitters which actuate CIS-B also actuate the containment spray system. Diversity for CIS-B is provided in the logic for manual actuation of containment spray, which, when manually actuated, also automatically actuates CIS-B.

For those valves for which automatic closure is not desired, based on the system safety function, remote-manual operation is available from the control room.

Containment isolation valves equipped with power operators and which are automatically actuated may also be controlled individually by positioning hand switches in the control room. Except as noted below, containment isolation valves cannot be repositioned via hand switches in the control room when the automatic containment isolation signal is present. Reset of the automatic signal is required to permit remote manual control of a containment isolation valve. Containment isolation valves that require repositioning for post-event monitoring or sampling are provided with device level manual overrides which permit valve repositioning when the automatic isolation signal is present. The device manual override is described in Section 7.3.5. Containment isolation valves with power operators are provided with open/closed indication, which is displayed in the control room. The valve mechanism also provides a local, mechanical indication of valve position.

All power supplies and control functions necessary for containment isolation are Class 1E, as described in Chapters 7.0 and 8.0.

6.2.5 COMBUSTIBLE GAS CONTROL IN CONTAINMENT

The hydrogen control system (HCS) is an engineered safety feature which serves to control combustible gas concentrations in the containment. The HCS consists of redundant hydrogen recombiners, a redundant hydrogen mixing system, a redundant hydrogen monitoring subsystem, and a backup hydrogen purge subsystem. The HCS satisfies GDC-41.

Sources of hydrogen gas in containment are as follows:

a. Metal-water reaction involving the zirconium fuel cladding and the reactor coolant

b. Radiolytic decomposition of the post-LOCA emergency cooling solutions (oxygen also evolves in this process)

c. Corrosion of metals and paints by solutions used for emergency core cooling or containment spray

6.2.5.1 Design Bases

6.2.5.1.1 Safety Design Bases

Portions of the HCS are safety related and are required to function following a LOCA.

SAFETY DESIGN BASIS ONE - The HCS is capable of withstanding the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, or external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The HCS is designed to remain functional after a SSE or a pipe break in containment (LOCA, steam line break, etc.) (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Component redundancy is provided so that safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power (GDC-44).

SAFETY DESIGN BASIS FOUR - The HCS is designed and fabricated to codes consistent with the quality group classification assigned by Regulatory Guides 1.7 and 1.26 and the seismic category assigned by Regulatory Guides 1.7 and 1.29. The power supply and control functions are in accordance with Regulatory Guides 1.7 and 1.32.

SAFETY DESIGN BASIS FIVE - The capability of isolating components, systems, or piping is provided, if required, so that the system's safety function will not be compromised. This includes the isolation of components to deal with leakage or malfunctions and to isolate nonsafety-related portions of the system.

SAFETY DESIGN BASIS SIX - The containment isolation valves in the system are selected, tested, and located in accordance with the requirements of 10 CFR 50, Appendix A, General Design Criteria 54 and 56 and 10 CFR 50, Appendix J, Type C testing.

SAFETY DESIGN BASIS SEVEN - The hydrogen mixing subsystem provides mixing of the containment atmosphere in order to eliminate stagnant pockets and prevent stratification of the hydrogen-air mixture.

SAFETY DESIGN BASIS EIGHT - The hydrogen monitoring subsystem is designed to inform the operator of the hydrogen concentration inside the containment and to provide periodic samples of the post-accident containment atmosphere to be analyzed for combustible gases (and other substances if required) resulting from beyond-design-basis accidents.

SAFETY DESIGN BASIS NINE - The HCS is designed with provisions for periodic inspection and testing of all safety-related components (GDC-42 and 43).

6.2.5.1.2 Power Generation Design Bases

POWER GENERATION DESIGN BASIS - The hydrogen mixing subsystem provides continual mixing of the containment air during normal plant operation. The containment penetrations in the hydrogen monitoring subsystem will be closed during normal plant operation. The remainder of the HCS performs no function during normal plant operations.

6.2.5.2 System Design

6.2.5.2.1 General Description

The total system for control of combustible hydrogen concentrations in the containment following a LOCA, shown schematically in Figures 6.2.5-1 and 9.4-6, consists of a hydrogen monitoring subsystem that provides containment atmosphere samples, a hydrogen mixing subsystem that assures a nearly uniform hydrogen concentration in the containment atmosphere, electric (thermal) hydrogen recombiners which provide the primary means of reducing containment hydrogen concentrations, and a hydrogen purge subsystem which is used as a backup system to the recombiners. The hydrogen monitoring, recombiner, and mixing subsystems are designed to meet seismic Category I requirements and the single failure criterion, as defined in Section 3.1. Except for the containment penetration and associated isolation valves, the purge subsystem is not redundant or seismic Category I. Generation of hydrogen is discussed in Section 6.2.5.2.3.

Those portions of the HCS that are exposed to the post-accident environment are located within containment except for portions of the hydrogen monitoring system. Leakage outside the containment will be detected with the auxiliary building radiation indicators and alarms. The solenoid-operated isolation valves in each train ensure train isolation capability in the event of leakage.

Design requirements for the HCS were based, in part, on compliance with 10 CFR 50.44; however, the NRC has eliminated the requirement for a postulated hydrogen release associated with a design-basis LOCA from 10 CFR 50.44, and the hydrogen recombiners and purge system discussed below are no longer required.

6.2.5.2.2 Component Description

Design data for major components of the HCS are presented in Table 6.2.5-1. Codes and standards applicable to this system are listed in Table 3.2-1.

6.2.5.2.2.1 Hydrogen Recombiner Subsystem

Each recombiner subsystem consists of a control panel located in the control building, a control switch located on the main control board, a power supply cabinet located in the control building, and a recombiner located on the operating deck of the containment. There are no moving parts or controls inside the containment. Heating of air within the unit causes air flow by natural convection. The recombiner is a completely passive device.

The power supply cabinet located in the control building contains an isolation transformer, plus a controller, to regulate the power supply to the recombiner. This equipment will not be exposed to the post-LOCA environment. The controls for the power supply are located in the control room and are manually actuated.

Each hydrogen recombiner consists of the following design features:

a. A preheater section, consisting of a shroud placed around the central heaters to take advantage of heat conduction through the central walls, for preheating incoming air

b. An orifice plate to regulate the rate of air flow through the unit

c. A heater section, consisting of four banks of metal-sheathed electric resistance heaters, to heat the air flowing through it to hydrogen-oxygen recombination temperatures

d. An exhaust chamber which mixes and dilutes the hot effluent with containment air to lower the temperature of the discharge stream

e. An outer enclosure to protect the unit from impingement by containment spray

f. No need for external services except electrical power

Containment atmosphere is heated within the recombiner in a vertical duct, causing it to rise by natural convection. As it rises, replacement air is drawn through intake louvers downward through a preheater section which will temper the air and lower its relative humidity. The preheated air then flows through an orifice plate, sized to maintain a 100-scfm flow rate, to the heater section. The air flow is heated to a temperature above 1,150°F, the reaction temperature for the hydrogen-oxygen reaction. Any free hydrogen present reacts with atmospheric oxygen to form water vapor. After passing through the heater section, the flow enters a mixing section which is a louvered chamber where the hot gases are mixed and cooled with containment atmosphere before the gases are discharged directly into the containment. The air-discharge louvers are located on three sides of the recombiner. To avoid short-circuiting of previously processed air, no discharge louvers are located on the intake side of the recombiner.

Tests have verified that the hydrogen-oxygen recombination is not a catalytic surface effect associated with the heaters (see Section 6.2.5.4), but occurs due to the increased temperature of the process gases. As the phenomenon is not a catalytic effect, saturation of the unit cannot occur.

Two recombiners are provided to meet the requirements for redundancy and independence. Each recombiner is powered from a separate Class 1E 480-V load center described in Chapter 8.0 and is provided with a separate power panel and control panel. No interdependency exists between this system and the other safety-related subsystems.

The unit is manufactured of corrosion-resistant, high-temperature material. The electric hydrogen recombiner uses commercial-type electric resistance heaters sheathed with Incoloy-800, which is an excellent corrosion-resistant material for this service. The recombiner heaters operate at significantly lower power densities than similar heaters used in commercial practice.

Operation of the recombiner is performed manually from a switch on the main control board or from a control panel located in the control room. The power panel for the recombiner contains an isolation transformer plus a controller to regulate power into the recombiner. This equipment is not exposed to the post-LOCA environment. For equipment test and periodic checkout, a thermocouple readout instrument is also provided in the control panel for monitoring temperatures in the recombiner.

6.2.5.2.2.2 Hydrogen Mixing Subsystem

The hydrogen mixing subsystem shown in Figure 9.4-6 consists of four mixing fans which maintain a uniformly mixed, containment post-LOCA atmosphere. Air is drawn from the steam generator compartments by the locally mounted mixing fans and is discharged toward the upper regions of the containment. This complements the air patterns established by the containment air coolers, which take suction from the operating floor level and discharge to the lower regions of the containment, and the containment sprays which cool the air and cause it to drop to lower elevations. The containment design is such that potentially stagnant areas where hydrogen pockets could develop are eliminated. Two-speed, hydrogen mixing fans are provided. The design flow rate of the hydrogen mixing fans (high-speed operation) is based on air distribution requirements during normal operation when a containment air cooler is taken out of service. The design flow rate of the hydrogen mixing fans (low-speed operation) is based on the air distribution requirements to eliminate stagnant hydrogen pockets. Plan and elevation drawings showing the air flow patterns are provided in Figure 6.2.2-7. Further information is contained in Section 6.2.2.2.

6.2.5.2.2.3 Hydrogen Monitoring Subsystem

Each redundant hydrogen monitoring train in the hydrogen monitoring subsystem consists of a hydrogen analyzer and two associated sample lines with isolation valves inside and outside the containment. These sampling lines are designed to be free of water traps (runs where liquid could accumulate), and are equipped with sufficient heat tracing to prevent condensation of the sample being supplied to the analyzers.

After the sample has been analyzed, it is returned to the containment. The analyzers are located in accessible areas outside of the containment. The hydrogen monitoring subsystem pressure boundary outside the containment is in accordance with the criteria of Regulatory Guide 1.26, quality group B. Solenoid-operated isolation valves are provided to obtain samples from two locations within the containment for each train. One sampling point is above the main operating level near the intake of the containment air coolers, and the other is near the post-LOCA water level in the containment recirculation sumps. The operator may select either of these sampling points from the main control room.

The operation of the hydrogen gas analyzer is based on the measurement of thermal conductivity of the gaseous containment atmosphere sample. The thermal conductivity of the gas mixture changes proportionally to the changes in the concentration of the individual gas constituents of the mixture. The thermal conductivity of hydrogen is far greater (approximately seven times the thermal conductivity of air) than any other gases or vapors expected to be present. The operation of the hydrogen monitoring subsystem is not limited due to radiation, moisture, or temperature expected at the equipment location. The equipment qualification testing, including radiation exposure, aging and vibration, satisfies IEEE Standards 323-1974 and 344-1975.

6.2.5.2.2.4 Hydrogen Purge Subsystem

As originally designed, the hydrogen purge subsystem serves as a backup to the hydrogen recombiners and is capable of venting and purging the containment atmosphere in order to maintain the hydrogen concentration below 4.0 volume percent following a LOCA. With the purge system operating, the doses at the exclusion area boundary and the low population zone outer boundary will not exceed the guideline values of 10 CFR 100. However, the NRC has eliminated the requirement for a postulated hydrogen release associated with a design-basis LOCA from 10 CFR 50.44, and the purge system discussed below is no longer required.

The hydrogen purge subsystem utilizes the fuel/auxiliary building emergency exhaust system to perform its functions. The emergency exhaust system is described in Section 9.4.3. The isolation valve is the only moving part located inside the containment. The hydrogen purge subsystem is designed to vent containment atmosphere at a rate of 100 scfm.

The hydrogen purge subsystem has one penetration through which the containment air is purged and filtered. This purge line is located in a missile-protected area, and draws air from well-ventilated areas of the containment in a manner which prevents either spray or sump water from entering the pipe. As indicated in Section 6.2.5.3, purging would not be initiated before approximately 5.1 days after a LOCA, therefore, no separate air supply line will be needed. Makeup air will be available through the instrument air penetration; and, if this penetration is unavailable by the time purging would be necessary, an air bottle can be connected to a number of available penetrations. Should it be necessary to use this backup system, operational considerations and site meteorology would determine the timing and duration of the purges. In any case, sufficient purging would be performed to maintain the hydrogen concentration in the containment atmosphere below 4 volume percent.

6.2.5.2.3 Hydrogen Generation

Hydrogen is generated within the containment by various mechanisms, as described below.

a. Radiolytic Hydrogen Generation

Water is decomposed into hydrogen and oxygen by the absorption of energy emitted by nuclides contained in the fuel and those intimately mixed with the LOCA water. The quantity of hydrogen that is produced by radiolysis is a function of both the energy of ionizing radiation absorbed by the LOCA water and the net hydrogen radiolysis yield, $G(H_2)$, pertaining to the particular physical-chemical state of the irradiated water.

Evidence indicates that the net hydrogen yield from the radiolysis of pure water is 0.44-0.45 molecule per 100 eV of absorbed energy when the gaseous radiolysis products are continuously purged from the water. In the presence of reactive solutes and water in the absence of gas purging of the solution, significant recombination of the products of radiolysis can occur, thereby reducing the net hydrogen yield. However, in accordance with Regulatory Guide 1.7 Revision 2, a value of 0.5 molecule/100 eV has been assumed for the net yield of hydrogen from radiolysis of all LOCA water.

The assumptions given in Regulatory Guide 1.7 Revision 2 were used to determine the fission product distribution after the accident. This distribution is assumed to be instantaneous after the accident, and hydrogen production is assumed to begin immediately. Fifty percent of the halogens and 1 percent of the solids are assumed to be released from the fuel and intimately mixed with the water in the sump. All noble gas activity is released from the fuel and is present in the containment atmosphere. The decay energy of the solids was determined from Shure (Ref. 1), conservatively assuming a 600-day reactor operating time for fission product buildup. Halogen and noble gas inventories were determined from Reference 2. Table 6.2.5-2 gives a summary of the remaining assumptions made in the analysis.

b. Corrosion of Metals and Paints in the Containment

Hydrogen is formed by corrosion of metals in the containment. The significant portion of this source of hydrogen is from the corrosion of zinc and aluminum. Figure 6.2.5-2 shows the maximum allowable quantities of zinc and aluminum inside the containment. Any combination of aluminum and zinc along the curve shown on Figure 6.2.5-2 will yield a maximum hydrogen concentration of 3.0% if the purge is initiated at the time the concentration reaches 3.0%. A worst case combination, namely that combination which causes the hydrogen concentration in containment to reach 3 volume percent the fastest and which results in the highest peak hydrogen concentration when the recombiner is initiated at one day after a LOCA, is selected as a bounding case. This worst case combination is used to generate Figures 6.2.5-3 through 6.2.5-7. Table 6.2.5-4 gives the temperature dependent corrosion rates used in the calculation for aluminum and zinc.

Zinc metal in the containment is in primarily two forms: zinc base paint and in galvanized steel. For the hydrogen generation calculation, the corrosion rates for zinc base paint are conservatively assumed to be the same as the corrosion rates for galvanized steel. This is conservative because, as can be seen in Table 6.2.5-4, the corrosion rates for galvanized steel are greater than those for zinc base paint. The containment, during the injection phase, is sprayed with a borated solution having a pH as low as 4.0. During the recirculation phase, the equilibrium pH of the spray is calculated to be greater than or equal to 7.1. The corrosion rates for zinc and aluminum used in the hydrogen generation calculation are temperature-dependent with the assumption of a constant recirculation sump pH of 9.5. With the replacement of the spray additive system with trisodium phosphate baskets adjacent to the containment recirculation sumps, an assessment was performed to evaluate the impact on the post-LOCA hydrogen generation calculation. The generation of hydrogen due to the corrosion of aluminum for a minimum equilibrium sump pH of 7.1

would be less than that previously calculated for a sump pH of 9.5. The generation of hydrogen due to the corrosion of zinc for the lower sump pH would also be less than that previously calculated for a sump pH of 9.5 above a temperature of 170°F. The generation of hydrogen due to the corrosion of zinc below a temperature of 170°F would be greater at the lower sump pH; however, this effect would be compensated for by the decrease in the aluminum corrosion rates. Since aluminum is the dominant source of hydrogen from corrosion at Callaway, the use of trisodium phosphate baskets in replacing the spray additive system will not adversely impact the results of the post-LOCA hydrogen generation calculation.

The corrosion rates used in the hydrogen generation calculation, as given in Table 6.2.5-4, have been adjusted upward for higher temperatures which occur early in the accident, as requested in Regulatory Guide 1.7, Revision 2.

The surface areas for the corrosion of metals and paints are assumed constant throughout the analysis.

The aluminum is assumed to be of such a thickness that, given the corrosion rate and the LOCA temperature profile, all of the aluminum is calculated to corrode in approximately sixty days.

c. Insignificant Sources of Hydrogen

During normal operation of the plant, hydrogen is dissolved in the primary system water. The concentration of hydrogen in primary coolant ranges from 25 to 50 cc(STP)/kg of coolant. The total amount of hydrogen in the primary system has been calculated to be insignificant.

After a LOCA, hydrogen is also generated by noble gas radiolysis. Calculations show that this total amount of hydrogen is insignificant when compared with the sources discussed in a and b above.

6.2.5.2.4 System Operation

6.2.5.2.4.1 Normal Operation

Except for testing and the normal use of the hydrogen mixing subsystem, as discussed in Section 9.4.6, the system is generally not normally operated. A portion of the hydrogen monitoring system, however, is used routinely to obtain grab samples of the containment atmosphere. This system is normally closed to the containment atmosphere, but the containment isolation valves are periodically opened for the routine sampling and for testing.

The solenoid-operated containment isolation valves located in the hydrogen monitoring system sample supply and return lines for each analyzer are designed to automatically close in response to a CIS-A signal in the event of a LOCA. However, the control circuits for these valves (within each subsystem or loop) are not redundant, so administrative controls are used to ensure that anytime the valves are opened for testing or sampling during plant operation, they are also closed when the activity is completed. These controls (in accordance with the plant Technical Specifications) include procedural requirements that direct electrical power to be removed from the control circuits for these valves when not in use. Maintaining the valves normally closed and deactivated enables the valves to serve as a passive containment barrier and ensures that in the event of an accident the valves' containment isolation function will not be compromised due to a single failure in the control circuit.

6.2.5.2.4.2 Accident Operation

The HCS is normally on standby and is initiated manually from the control room following a LOCA. At one day after a LOCA, sufficient emergency power is available to handle the load required to operate the electric (thermal) hydrogen recombiners. Hence, the electric recombiners are turned on (even though they are not required at this early point in time) in order to keep the hydrogen concentration as low as practicable.

The electric hydrogen recombiner subsystem is to be started one day after a LOCA. However, inadvertent actuation immediately after a LOCA will not damage the recombiners in any manner, nor will their capability to perform their function be impaired. Figure 6.2.5-3 shows the hydrogen volume concentration versus time within the containment as a result of one recombiner starting 1 day following a LOCA. The electric (thermal) recombiners are completely passive devices. The recombiners heat the containment hydrogen-air atmosphere that is introduced into the recombiner to a temperature of approximately 1,150°F, causing the recombination of H_2 and O_2 to occur. Hence, the hydrogen volume percent is reduced. The air is then passed to a mixing chamber, in the top of the recombiner, where the hot air is mixed with the cooler containment air to discharge it back into the containment at a temperature of approximately 50°F above ambient.

Only the recombiners are located in the containment. All auxiliary equipment associated with the recombiners is located outside the containment. The recombiners are designed to withstand exposure to the design temperature and pressure transient in the containment and are resistant to the chemical and radiation environment of the post-LOCA containment environment. The auxiliary equipment located in the control building is designed to withstand the exposure to the post-LOCA control building environment.

The hydrogen generation rate and hydrogen accumulation within the containment, as a function of time, are given in Figures 6.2.5-4 and 6.2.5-5, respectively. The hydrogen concentration in the containment is given in Figure 6.2.5-6, assuming that no preventative action is taken.

The recombiners are located in the containment so that they process a flow of containment air containing hydrogen at a concentration which is generally typical of the average concentration throughout the containment.

The recombiners are located away from the high velocity air streams, such as could emanate from the fan cooler exhaust ports.

In the event that a beyond-design-basis LOCA occurs and the redundant recombiners fail to function properly, a purge subsystem may be utilized to control the hydrogen concentration inside the containment.

Since the purging of any amount of containment atmosphere is undesirable, the operation of the purge system would be initiated only when it has been determined that the recombiners are not functional and only if samples taken from the containment atmosphere indicate that a hydrogen content of 3.0 volume percent has been attained.

The concept of purging allows considerable operational flexibility and, in practice, the specific mode of operation would be determined by the actual hydrogen generation rate and hydrogen concentration in the containment atmosphere, the amount of airborne activity in the containment, and the prevailing meteorological conditions.

Calculations, assuming no operation of the recombiners, show that the hydrogen concentration will reach 3 percent at approximately 5.1 days. A 100-cfm purge initiated at that time would reduce the hydrogen concentration below the 3-percent level. The effect of the purge on the hydrogen volume concentration is shown in Figure 6.2.5-7.

The purge subsystem will be used only for severe accident management in the highly unlikely event that redundant recombiners fail to function properly. Exclusion area boudary and low population zone outer boundary doses would be calculated prior to operation of the purge subsystem.

Doses for a 100 cfm purge, assuming a beyond-design-basis accident, for the exclusion area boundary and low population zone outer boundary would be maintained well below 10 CFR 100 guidelines.

Following indication of an accident condition, each hydrogen mixing fan will be automatically started or switched from high speed to low speed by a SIS. The hydrogen mixing fans are designed to withstand the pressure transients associated with a design basis LOCA and remain functional. The containment coolers provide supplemental mixing of the containment post-LOCA atmosphere in conjunction with the hydrogen mixing fans. Operation of the containment coolers is described in Section 6.2.2.2.

Operation of the hydrogen monitoring system is manually initiated following a LOCA. The operator can manually open the normally-closed containment isolation valves via control switches provided in the main control room. The valve control circuits include a provision for remote manual bypass as described in Section 7.3.5. Containment atmosphere samples, maintained in the vapor phase, are brought to the analyzer, which measures the concentration of hydrogen. From the analyzer, the sample is returned to the containment atmosphere. The hydrogen analyzer system is designed with the capability to obtain an accurate sample 30 minutes after initiation of safety injection.

6.2.5.3 Safety Evaluations

Safety evaluations are numbered to correspond to safety design bases.

SAFETY EVALUATION ONE - The safety-related portions of the HCS are located in the reactor, auxiliary, and control buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The safety-related portions of the HCS are designed to remain functional after a SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. Section 3.6 provides a hazards analysis which assures protection of the HCS and piping following a postulated LOCA or MSLB.

SAFETY EVALUATION THREE - Section 6.2.5.2 demonstrates that the required redundancy is provided and, as indicated by Table 6.2.5-5, no single failure will compromise the system's safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

SAFETY EVALUATION FOUR - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting systems. Table 6.2.5-1 shows that the components meet the design and fabrication codes given in Section 3.2. All the power supplies and control functions necessary for safe functioning of the HCS are Class 1E, as described in Chapters 7.0 and 8.0. Comparison of the design to Regulatory Guide 1.7 positions is provided in Table 6.2.5-6.

SAFETY EVALUATION FIVE - Section 6.2.5.2.1 describes the provisions made to identify and isolate leakage or malfunction and to isolate the nonsafety-related portions of the system.

SAFETY EVALUATION SIX - Sections 6.2.4 and 6.2.6 provide the safety evaluation for the system containment isolation arrangement and testability.

SAFETY EVALUATION SEVEN - The hydrogen mixing subsystem is designed so that two out of four mixing fans are capable of providing a nearly uniform distribution of hydrogen throughout the containment by drawing air from the steam generator loop compartments where hydrogen may accumulate and exhausting it into the upper containment airspace where rapid mixing occurs in the turbulence created by the suction of the containment fan coolers. Each pair of hydrogen mixing fans is completely redundant, full capacity, and powered from independent Class 1E power sources. Further discussion of the mixing fans is provided in Section 9.4.6.

SAFETY EVALUATION EIGHT - The hydrogen monitoring subsystem is designed to take air samples from a total of four locations (two for each redundant train) inside the containment. These samples are analyzed, and the results are indicated in the control room.

The hydrogen monitor and associated sample lines, located outside the containment, are considered to be an extension of the containment pressure boundary, and, therefore, are designed to withstand the pressure, temperature, and humidity transients associated with the design basis LOCA.

SAFETY EVALUATION NINE - The HCS is initially tested with the program given in Chapter 14.0. Periodic inservice functional testing and inspection are done in accordance with Section 6.2.5.4.

6.2.5.4 Testing and Inspections

The performance of the hydrogen gas analyzer will be periodically verified by comparing the response of the thermal conductivity instrument to a known sample of reference gas.

Nondestructive examination is performed on the components of the hydrogen monitoring subsystem and the hydrogen purge subsystem. Periodic inservice testing of all fans, valves, and instrumentation is performed.

6.2.5.5 Instrumentation Requirements

6.2.5.5.1 Hydrogen Recombiner Subsystem

Controls for operation of the hydrogen recombiners are provided in the control room. A manual control station is provided for each train to regulate power to the heaters in the associated recombiner. The controller maintains the correct power input to bring the recombiner above the threshold temperature for the recombination process. The controller setting is adjusted to accommodate variations in the containment temperature, pressure, and hydrogen concentration in the post-LOCA environment. The system is designed to conform to the applicable portions of IEEE 279, 323, 344, and 383 and is powered from a Class 1E source.

Proper recombiner operation is assured by measuring the power input to the heaters from a station outside the containment. The proper air flow through the recombiners is achieved through the use of an orifice plate built into each unit.

For convenience in testing and conducting periodic checkout of the recombiners, temperature indicators are provided. The temperature indicators are not required to assure proper operation of the recombiner during post-LOCA conditions.

6.2.5.5.2 Hydrogen Mixing Subsystem

Operation of the hydrogen mixing subsystem is actuated automatically upon receipt of a safety injection signal. Control switches and indicator lights for the four hydrogen mixing fans are located in the control room. The system is designed to conform to the applicable portions of IEEE 279 and 334 and is powered from a Class 1E source.

6.2.5.5.3 Hydrogen Purge Subsystem

Operation of the hydrogen purge subsystem is manually initiated from the control room. Instrumentation requirements of the hydrogen purge subsystem are described in more detail in Section 9.4.3.

The line penetrating the primary reactor containment is provided with power-operated isolation valves with position indicators and controls in the control room to allow operator control during post-LOCA operation. A complete discussion of the isolation valve provisions is presented in Section 6.2.4.

6.2.5.5.4 Hydrogen Monitoring Subsystem

Hydrogen analyzers are provided for periodic sampling of the containment atmosphere following a design basis event. The hydrogen analyzers have a readout scale of 0 to 10 percent with an accuracy of 4.0 percent of the scale. The output signals of the analyzers are indicated at the analyzer mounting location and recorded and alarmed in the main control room. In addition to the high hydrogen alarm, each analyzer provides malfunction alarms, including low sample flow, low temperature, and loss of power. The displays provided are described further in Section 7.5.

6.2.5.6 REFERENCES

1. WAPD-PT 24, "Fission Product Decay Energy" (December 1961).

2. TID 14844, "Calculation of Distance Factors for Power and Test Reactor Sites," J. J. DiNunno, F. D. Anderson, R. E. Baker, R. L. Waterfield; March 23, 1962; Division of Licensing and Regulation, USAEC, Washington, D. C.

6.2.6 CONTAINMENT LEAKAGE TESTING

The reactor containment, containment penetrations, and containment isolation barriers are designed to permit periodic leakage rate testing as required by 10 CFR 50, Appendix A, General Design Criteria 52, 53, and 54. 10 CFR 50, Appendix J, outlines the containment leakage test requirements and establishes the acceptance criteria for such tests. The objective of the leakrate testing is to ensure that the leakage from the containment is within the limits set by Chapter 16.0.

Compliance with 10 CFR 50 Appendix J, Types A, B, and C, testing is discussed in Sections 6.2.6.1, 6.2.6.2, and 6.2.6.3.

6.2.6.1 Containment Integrated Leakage Rate Test (Type A Test)

The design leakage rate for the containment is 0.2 percent free volume per day for the first 24 hours. The actual leakage rate will be determined by using the methods and requirements of Appendix J Option B and the Callaway Plant Containment Leakage Rate Testing Program.

6.2.6.1.1 ILRT Pretest Requirements

A general inspection of the accessible interior and exterior surfaces of the containment structures and components for any evidence of structural deterioration which may affect either the containment structural integrity or leaktightness will be made. These examinations should be conducted prior to initiating a Type A test, and during two other refueling outages before the next Type A test if the interval for the Type A test has been extended to 10 years. Any evidence of structural deterioration will be corrected before the Type A test is performed.

The steam generator tubes and shell and the associated piping systems passing through the containment liner are considered to be an extension of the containment. Therefore, the secondary side of the steam generator and connecting systems are not vented to the containment atmosphere. After the containment stabilization period of the Type A test, the secondary side of the steam generators will be vented outside of the containment to ensure the most conservative test configuration. The systems associated with the secondary side of the steam generator are identified in Figure 6.2.4-1.

Pressurized gas and water systems are vented downstream of the outside isolation valve for the system and vented outside of the containment. This is done to preclude inleakage into the containment and to expose the outside isolation valve to a conservatively low back pressure to obtain leakage characteristics.

The reactor coolant drain tank, pressurizer relief tank, and accumulator tanks are vented to the containment atmosphere. This is done to protect the tanks from the external pressure of the test and to preclude leakage to or from the tanks which would detract from the accuracy of the test results.

During preoperational testing, a structural integrity test (SIT) was performed in conjunction with the first ILRT. The SIT is a pressure test that was conducted to verify that the containment structural response due to the induced load is consistent with the predicted behavior. Section 3.8.1.7 describes the SIT deflection measurements and concrete crack inspections.

Following the preoperational SIT, an ILRT was performed.

6.2.6.1.2 ILRT Test Method

Type A test requirements and guidelines are described in the Callaway Plant Containment Leakage Rate Testing Program. Figure 6.2.6-1 shows the test arrangement for a Type A test. The ILRT pressurization line may also be used for post-test venting (to outside atmosphere) provided sampling is performed as described in Section 16.11.2. For penetrations which are exempt from Type B or C tests, as noted in Figure 6.2.4-1, the leakage testing requirement of Appendix J is accomplished by the Type A test.

6.2.6.2 Containment Penetration Leakage Rate Tests (Type B Tests)

Each of the following containment penetrations is tested with a Type B test.

a. Personnel access hatches (refer to Section 3.8.2)

b. Equipment hatch (refer to Section 3.8.2)

c. Fuel transfer tube (refer to Section 3.8.2)

d. Electrical penetrations (refer to Section 8.3)

e. Penetration 34, containment pressurization line

f. Penetration 51, ILRT pressurization pressure sensing line

g. Penetration 36, 50 and 68, maintenance spare air and electrical access penetrations

These penetrations are provided with double seal closures and connections to allow for pressurization between the seals. Each penetration is designed to withstand the calculated peak containment pressure while maintaining its seal. Equipment and personnel hatches have provisions for test clamps to ensure seating of the internal seal during testing. In addition, Penetrations 34 and 51, containment pressurization line and pressure sensing lines for the ILRT pressurization system, are also Type B tests.

The test pressure for Type B tests is the calculated peak pressure for the containment, Pa. The combined leakage rate for all Type B and C tests must be less than 0.6 L_a

(maximum allowable leakage rate). The individual leakage rates and testing performed on the Type B penetration are described in Chapter 16.0.

The test equipment utilized to perform the Type B tests is the same equipment used for Type C tests. The test equipment is described in Section 6.2.6.3. The test procedure will be the same as the one used for Type C tests.

Type B tests are performed in accordance with Appendix J to 10 CFR 50, with the following addition:

a. An additional test method may be used. This method measures the air flow rate to maintain the test volume at a constant pressure.

b. Deleted

6.2.6.3 <u>Containment Isolation Valve Leakage Rate Tests (Type C tests)</u>

Figure 6.2.4-1 lists all valves which are associated with the penetrating piping systems. Figure 6.2.4-1 also indicates the containment isolation valves which are to be subjected to a Type C test. The following criteria were used to determine which containment isolation valves will be local leak tested.

a. The penetrating system provides a direct connection between the inside and outside atmospheres of the containment under normal operation.

b. The system is isolated by containment isolation valves which close automatically to effect containment isolation in response to a CIS signal.

c. The system is not an engineered safety feature system consisting of a closed piping system outside of the containment.

The lines serving engineered safety feature systems which consist of closed piping systems outside the containment have isolation valves which will not be leak tested. All of these lines will initially open or will be opened during some phase following a LOCA. Valves which are closed initially or closed at some time following a LOCA are positioned to effect proper system operation and not to effect a barrier against release of containment atmosphere. Should the valves leak slightly when closed, the fluid seal within the pipe and the closed piping system outside the containment would preclude release of containment atmosphere to the environs. Engineered safety features in this classification penetrate the containment at penetrations numbered P-13, 14, 15, 16, 21, 27, 48, 49, 52, 66, 79, 82, 87, 88 and 89. The containment pressure transmitters are designed to meet the requirements of Regulatory Guide 1.11 and are described in Section 7.3.8.1.1. These lines have no isolation valves and rely on closed systems both inside and outside of the containment to preclude the release of the containment atmosphere. The RVLIS lines are similarly designed as discussed in Table 6.2.4-2, Figure 6.2.4-1, and Section 18.2.13. These lines penetrate the containment at penetrations P-59, P-91, P-103, P-104, and E-256 (see sheets 47, 72, 80, 81, and 84 of Figure 6.2.4-1). The integrity of these closed systems will be verified during the periodic Type A tests.

As noted in Section 6.2.4.3, the valves associated with the piping systems connected to the secondary side of the steam generators isolate the steam generators and are not considered containment isolation valves and are, therefore, not leak tested. All portions of the secondary side of the steam generators are considered an extension of the containment. These systems penetrate the containment shell at penetrations P-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 83, 84, 85, and 86. As shown on Figure 6.2.4-2 the water level in all steam generators will be maintained above the tubes following a LOCA to preclude the entrance of containment atmosphere into the secondary side of the steam generators. This requirement will be included in the Emergency Operating Instructions.

The test equipment to be used during the Type C tests will consist of a connection to an air supply source, a holding vessel, a pressure regulator, a gage indicating gage pressure, a flow indicator, and associated valving.

Isolation valves will be positioned to their post-accident position by the normal method with no accompanying adjustments. Fluid systems are properly drained and vented with the valves aligned to provide a test volume and atmospheric air back pressure on the isolation valve(s) being tested.

The test volume and holding vessel are pressurized to the test pressure Pa, as specified in Chapter 16.0. The pressure regulator(s) maintain the test volume at a minimum of Pa. The air flow rate into the test volume is recorded, as is the pressure reading, at the intervals specified on the data form. These records are utilized to determine the leakage rate in cubic centimeters per minute.

For larger test volumes, a pressure decay method may be utilized to determine the leakage rate.

The total leakage rate for Type B and C tests must be less than 0.6 L_a.

The criteria for determining the direction in which the test pressure is applied to the isolation valves are as follows:

Gate Valves

Parallel disc	a.	Test in the DBA direction.
	b.	Testing can be performed between the discs if a test connection or drain is provided in the valve design.
Flexible Wedge	a.	Test in the DBA direction.

	b.	Testing can be performed between the wedge sections if a test connection or drain is provided in the valve design.
Solid Wedge	a.	Test in the DBA direction.
Globe Valves		If the DBA flow direction is over the disc (flow to close), the valve may be tested in the reverse direction. However, if the DBA flow direction is under the disc (flow to open), then the valve must be tested in this direction.
Butterfly Valves		Test in either direction.
Flanges		Test in either direction.

Testing of the isolation valves in the nonaccident pressure direction, as allowed above, is as conservative or more conservative than testing them in the accident pressure direction.

6.2.6.4 Scheduling and Reporting of Periodic Tests

Type A, B, and C tests are conducted at the intervals specified in the Containment Leak Rate Test Program. These intervals are in accordance with Appendix J to 10 CFR 50, with the exception of the testing of the hatches, as described in Section 6.2.6.2.

The preoperational test report contained a schematic of the leak measuring system, instrumentation used, supplemental test method, test program, and analysis and interpretation of the leakage test data for the Type A test.

6.2.6.5 Special Testing Requirements

The Callaway Plant does not have a subatmospheric containment or a secondary containment; hence, there are no special testing requirements beyond those delineated in Sections 6.2.6.1 through 6.2.6.4.

TABLE 6.2.1-1 SPECTRUM OF POSTULATED LOSS-OF-COOLANT ACCIDENTS

1. Double-ended pump suction guillotine (DEPSG) break, with minimum safety injection.

2. DEPSG with maximum safety injection.

3. Double-ended hot leg guillotine break.

TABLE 6.2.1-2 PRINCIPAL CONTAINMENT DESIGN PARAMETERS

Containment design internal pressure	60 psig
Containment peak calculated internal pressure	
LOCA	47.8 psig**
MSLB	48.1 psig* (47.1)**
Containment design external pressure load	3.0 psid
Containment calculated external pressure	2.98 psid
Containment design temperature	320°F
Containment peak calculated vapor temperature	
LOCA	308.6°F* (271.7°F)**
MSLB	384.9°F* (345.4°F)**
Peak calculated equipment temperature-MSLB	See Figure 6.2.1-85
Internal dimensions	
Cylindrical wall diameter	140 ft
Cylindrical wall height	135 ft
Curved dome height above spring line	70 ft
Volume	
Minimum net free internal volume	2.50×10^6 ft^3
Containment design leak rate	
First 24 hrs	0.20 percent free vol/day
After 1 day	0.10 percent free vol/day
Containment Internal Compartments:	
Steam generator loop compartment	See Table 6.2.1-22
Steam generator loop compartment calculated pressure	See Table 6.2.1-22
Pressurizer vault design pressure	See Table 6.2.1-26
Pressurizer vault calculated pressure w/surge line break	See Table 6.2.1-26
Pressurizer surge line compartment design pressure	See Table 6.2.1-26
Pressurizer surge line compartment calculated pressure w/surge line break	See Table 6.2.1-26

* These peak temperature and pressure values represent Callaway's original steam generator (OSG) results. The analyses for the replacement steam generators demonstrated that these values remain bounding. These values are maintained to provide operating margins.

** RSG values.

TABLE 6.2.1-3 ENGINEERED SAFETY FEATURES DESIGN PARAMETERS FOR CONTAINMENT ANALYSIS

	Full Capacity	Minimum Capacity
ECCS		
Passive safety injection system		
Number of accumulators	4	4
Pressure setpoint, psig	600-650	600-650
Liquid volume, ft^3	850/accumulator	850/accumulator
Active safety injection systems		
High-pressure system injection		
Number of lines	4	4
Number of ECCS centrifugal charging pumps	2	1
Intermediate pressure safety injection		
Number of lines	4	4
Number of safety injection pumps	2	1
Low-pressure safety injection		
Number of lines	4	4
Number of RHR pumps	2	1
Total injection flow rate, lbm/sec	1,401	586
Total recirculation flow rate, gpm	9,600	4,800
Containment heat removal systems		
Containment spray system		
Number of lines	2	1
Number of pumps	2	1
Number of headers	2	1
Injection flow rate, gpm*	3086/pump	3086/pump
Recirculation flow rate, lbm/sec**	499.4/pump	499.4/pump
Containment air coolers		

TABLE 6.2.1-3 (Sheet 2)

	Full Capacity	Minimum Capacity
Number of units	4	2
Duty per cooler	(See Figure 6.2.1-15)	
Air-side flow rate, cfm	69,400	69,400
RHR Heat Exchangers		
Type	Shell and U-type	
Number	2	1
Primary side flow through RHR heat exchanger, lb/hr	2.3×10^6/unit	2.3×10^6/unit
Secondary side flow through RHR heat exchangers, lb/hr	3.8×10^6/unit	3.8×10^6/unit
Source of cooling water Flow begin, sec, minimum	Component cooling water	
	2,221	3,063
Component cooling Water Heat Exchangers		
Type	Shell and straight tube Number	
	2	1
Primary side flow through CCW heat exchangers, lb/hr	3.8×10^6/unit	3.8×10^6/unit
Secondary side flow through CCW heat exchangers, lb/hr	3.68×10^6/unit	3.68×10^6/unit
Source of cooling water Temperature of cooling water, max, F	Essential Service Water	
	95	95

*A single failure of 1 spray pump was assumed in the max SI case for LOCA. A spray flow rate of 426.4 lbm/sec per pump was used in the MSLB cases.

**The given recirculation flow rate is nominal and not a minimum required value. The nominal value is higher than the flow value calculated using the accident analysis minimum allowable pump performance curve. Higher recirculation flow rates increase

TABLE 6.2.1-3 (Sheet 3)

energy transfer from the containment sump to the containment vapor space, resulting in more limiting, higher, long-term containment temperatures.

TABLE 6.2.1-4 CONTAINMENT PASSIVE HEAT SINK PARAMETERS

Thermophysical Properties

Material	Volumetric Heat Capacity Btu/ft^3 - F	Thermal Conductivity Btu/hr ft F
Epoxy paint	49.9	0.97
Inorganic zinc paint	21.7	0.63
Stainless steel	53.9	8.40
Carbon steel	54.3	28.35
Concrete	30.1	0.80
Zinc coating	40.9	64.8
Air	0.0145	0.0174

Heat Transfer Coefficient	Value
Containment atmosphere to heat sink surfaces	"Diffusion Layer Model"
Containment atmosphere to containment sump water	0
Containment sump water to containment floor	0
Liner gap conductance	20 Btu/hr-ft^2-F
Containment walls to outside atmosphere	2.0 Btu/hr-ft^2-F

Passive Heat Sink Description

Containment walls

Geometry	Slab
Surface area, ft^2	58807
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel	0.02083
Air gap	0.00083
Concrete	4.00000

Boundary conditions - Liner plate exposed to containment atmosphere; outside exposed to the outside atmosphere

TABLE 6.2.1-4 (Sheet 2)

Containment Dome	
Geometry	Slab
Surface area, ft^2	30806
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel	0.02083
Air gap	0.00083
Concrete	3.00000
Boundary conditions - Liner plate exposed to containment atmosphere; outside exposed to the outside atmosphere	
Unlined Concrete	
Geometry	Slab
Surface area, ft^2	65476
Composition, ft	
Concrete	1.72000
Boundary conditions - One side exposed to containment atmosphere; the other side insulated.	
Stainless Steel Lined Concrete	
Geometry	Slab
Surface area, ft^2	7197
Composition, ft	
Stainless steel	0.02083
Air gap	0.00083
Concrete	2.00000
Boundary conditions - One side exposed to containment atmosphere, the other side insulated.	
Carbon Steel Lined Concrete	
Geometry	Slab
Surface area, ft^2	6464
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel	0.02083
Air gap	0.00083

TABLE 6.2.1-4 (Sheet 3)

Concrete	2.00000
Boundary conditions - One side exposed to containment atmosphere, the other side insulated.	
Galvanized Steel Lined Concrete	
Geometry	Slab
Surface area, ft^2	6679
Composition, ft	
Zinc coating	0.00011
Carbon steel	0.00529
Air gap	0.00083
Concrete	1.34300
Boundary Conditions - One side exposed to containment atmosphere, the other side insulated.	
Stainless Steel	
Geometry	Slab
Surface area, ft^2	34819
Composition, ft	
Stainless steel	0.02021
Boundary conditions - One side exposed to containment atmosphere, the other side insulated.	
Galvanized Steel	
Geometry	Slab
Surface area, ft^2	70489
Composition, ft	
Zinc coating	0.00011
Carbon steel	0.00785
Boundary conditions - One side exposed to containment atmosphere, the other side insulated.	
Carbon steel - unpainted	
Geometry Surface area, ft^2	508
Composition, ft	
Carbon steel	0.43553
Boundary Conditions - One side exposed to containment atmosphere, the other side insulated.	
Carbon Steel - Painted	

TABLE 6.2.1-4 (Sheet 4)

Geometry	Slab
Surface area, ft^2	13799
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel (0→0.125 in thick)	0.00693
Surface area, ft^2	88714
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel (0.125→0.25 in. thick)	0.01652
Surface area, ft^2	40173
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel (0.25→0.5 in. thick)	0.02879
Surface area, ft^2	23445
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel (0.5→1.0 in. thick)	0.05916
Surface area, ft^2	11821
Composition, ft	
Epoxy paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel (1.0→2.5 in. thick)	0.11205
Surface area, ft2	7816
Composition, ft	
Epoxy Paint	0.00177
Inorganic zinc paint	0.00033
Carbon steel (>2.5 in. thick)	0.27960

Boundary conditions - One side exposed to containment atmosphere, the other side insulated.

TABLE 6.2.1-5 CONTAINMENT AND REACTOR COOLANT SYSTEM INITIAL CONDITIONS FOR CONTAINMENT ANALYSIS

Reactor coolant system (at overpower of 102-percent licensed core power)	
Reactor core power level, MWT	3636
Average coolant temperature, °F	592.7
Reactor coolant system pressure, psia	2280
Containment	
Free volume, ft^3	2.5×10^6
Pressure, psia	16.2
Atmosphere temperature, °F	120
Outside atmosphere temperature, °F	95
Relative humidity, percent	50
Stored water	
Refueling water temperature, °F	100
Essential service water temperature, °F	95
Accumulators water volume (4), ft^3	3664.8

NOTE: These values are limiting for maximum containment pressure and temperature.

TABLE 6.2.1-6 DOUBLE-ENDED PUMP SUCTION BREAK - MINIMUM SAFEGUARDS - SEQUENCE OF EVENTS

Time (sec)	Event Description
0.0	Break occurs, Reactor Trip and Loss of Offsite Power are assumed
0.635	Reactor trip signal on compensated pressurizer low pressure (1860 psia)
4.3	Low Pressurizer Pressure SI Setpoint - 1715 psia reached in blowdown
17.5	Accumulator injection begins
21.3	Main feedwater isolation
23.7	Peak containment temperature (269°F)
23.8	Peak containment pressure (45.9 psig)
26.2	Primary system blowdown complete
43.9	Containment spray injection begins
48.3	ECCS charging pump injection begins
48.3	Safety injection pump injection begins
48.3	RHR pump injection begins
53.1	Accumulators empty
85.7	Containment fan coolers begin
194.3	Reflood complete
1611	Cold leg ECCS recirculation begins
2615	Containment pressure less than 50% of design
3063	Containment spray recirculation begins
3600	End of steam generator energy release
1.0E+07	Transient modeling terminated (end of analysis)

TABLE 6.2.1-7 DOUBLE-ENDED PUMP SUCTION BREAK - MAXIMUM SAFEGUARDS - SEQUENCE OF EVENTS

Time (sec)	Event Description
0.0	Break occurs, Reactor Trip and Loss of Offsite Power are assumed
0.635	Reactor trip signal on compensated pressurizer low pressure (1860 psia)
4.3	Low Pressurizer Pressure SI Setpoint - 1715 psia reached in blowdown
17.6	Accumulator injection begins
21.3	Main feedwater isolation
23.7	Peak containment temperature (269.0°F)
23.8	Peak containment pressure (45.9 psig)
26.2	Primary system blowdown complete
34.3	ECCS charging pump injection begins
34.3	Safety injection pump injection begins
34.3	RHR pump injection begins
43.9	Containment spray injection begins
54.2	Accumulators empty
85.7	Containment fan coolers begin
182.9	Reflood complete
643	Containment pressure less than 50% of design
889	Cold leg ECCS recirculation begins
1180	Containment spray recirculation begins
3600	End of steam generator energy release
1.0E+07	Transient modeling terminated (end of analysis)

TABLE 6.2.1-8 COMPARATIVE RESULTS: SUMMARY OF RESULTS OF CONTAINMENT PRESSURE AND TEMPERATURE ANALYSIS FOR THE SPECTRUM OF POSTULATED ACCIDENTS

Accident	1	2	3
Break location	Pump suction (PS)	PS	Hot Leg
Break type	Double-ended guillotine (DEG)	DEG	DEG
Break size	10.46 ft^2	10.46 ft^2	9.20 ft^2
Safety injection	min	max	max
Containment sprays	min	min	max
Containment fan coolers	min	max	min
Peak pressure, psig	45.9	45.9	47.8
Time to peak pressure, sec	23.8	23.8	22.5
Peak temperature, °F	269	269	271.8
Time to peak temperature, sec	23.7	23.7	22.4
Energy released to containment at time of peak pressure, 10^6 Btu	396	395.5	401.6
Energy absorbed by passive heat sinks at time of peak pressure, 10^6 Btu	18.5	18.5	18.5
Energy in vapor region at time of peak pressure, 10^6 Btu	290.3	290.3	302.1
Energy in sump water at time to peak pressure, x 10^6 Btu	17.3	16.8	17.0
Energy removed by containment fan coolers up to the time of peak pressure, x 10^6 Btu	0	0	0.0
Energy removed by containment sprays up to time of peak pressure, x 10^6 Btu	0	0	0.0

TABLE 6.2.1-9 DELETED.

TABLE 6.2.1-10 DELETED

TABLE 6.2.1-11 ADDITIONAL MASS AND ENERGY RELEASE-LOCA

Accumulator Nitrogen Release Following Accumulator Empty

Time (sec)	Mass Lbs/sec)	Temp (F)
0	0	0
Accumulator empty -0.1	0	0
Accumulator empty	180	470
Accumulator empty +30	180	470
Accumulator empty +30.1	0	0
10^6	0	0

TABLE 6.2.1-12 DELETED

TABLE 6.2.1-13 HOT LEG LONGITUDINAL SPLIT BREAK 763 SQUARE INCHES
BREAK MASS FLOW AND ENERGY FLOW

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.00000	0.	0.	0.00
.00101	8.1033415E+03	5.2479074E+06	647.62
.00202	1.4891822E+04	9.6436977E+06	647.58
.00300	3.3538763E+04	2.1729309E+07	647.89
.00402	4.3750401E+04	2.8341351E+07	647.80
.00502	4.8666372E+04	3.1512215E+07	647.52
.00601	5.0589146E+04	3.2737434E+07	647.12
.00702	5.1006945E+04	3.2992058E+07	646.82
.00803	5.0895242E+04	3.2914153E+07	646.70
.00902	5.0885216E+04	3.2910703E+07	646.76
.01001	5.1218730E+04	3.3131758E+07	646.87
.01100	5.1876999E+04	3.3560988E+07	646.93
.01202	5.2726932E+04	3.4110885E+07	646.93
.01303	5.3551829E+04	3.4641668E+07	646.88
.01403	5.4244736E+04	3.5085029E+07	646.79
.01503	5.4734699E+04	3.5395489E+07	646.67
.01600	5.4991203E+04	3.5553987E+07	646.54
.01700	5.5031540E+04	3.5572926E+07	646.41
.01802	5.4890352E+04	3.5475352E+07	646.29
.01900	5.4638748E+04	3.5308193E+07	646.21
.02003	5.4323329E+04	3.5101741E+07	646.16
.02101	5.4037895E+04	3.4917074E+07	646.16
.02201	5.3815910E+04	3.4775539E+07	646.19
.02304	5.3696178E+04	3.4701830E+07	646.26
.02400	5.3694077E+04	3.4704850E+07	646.34
.02500	5.3796572E+04	3.4775974E+07	646.43
.02602	5.3990369E+04	3.4906106E+07	646.52
.02702	5.4234465E+04	3.5068321E+07	646.61
.02805	5.4519544E+04	3.5256767E+07	646.68
.02904	5.4803890E+04	3.5444269E+07	646.75
.03003	5.5093564E+04	3.5634737E+07	646.80
.03105	5.5368834E+04	3.5815396E+07	646.85
.03204	5.5628834E+04	3.5985533E+07	646.90
.03301	5.5870866E+04	3.6144992E+07	646.94
.03403	5.6116586E+04	3.6306019E+07	646.97

TABLE 6.2.1-13 (Sheet 2)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.03504	5.6352566E+04	3.6460386E+07	647.00
.03604	5.6574044E+04	3.6605007E+07	647.03
.03705	5.6788352E+04	3.6744693E+07	647.05
.03801	5.6980592E+04	3.6869767E+07	647.06
.03903	5.7166900E+04	3.6990763E+07	647.07
.04002	5.7333293E+04	3.7098501E+07	647.07
.04104	5.7482392E+04	3.7194704E+07	647.06
.04203	5.7606029E+04	3.7274227E+07	647.05
.04304	5.7708024E+04	3.7339466E+07	647.04
.04402	5.7784192E+04	3.7387841E+07	647.03
.04505	5.7840728E+04	3.7423358E+07	647.01
.04602	5.7873443E+04	3.7443488E+07	646.99
.04701	5.7889007E+04	3.7452485E+07	646.97
.04805	5.7888115E+04	3.7450818E+07	646.95
.04902	5.7873180E+04	3.7440175E+07	646.93
.05003	5.7845754E+04	3.7421521E+07	646.92
.05103	5.7807767E+04	3.7396135E+07	646.91
.05201	5.7759239E+04	3.7364084E+07	646.89
.05301	5.7703737E+04	3.7327910E+07	646.89
.05401	5.7642796E+04	3.7288847E+07	646.90
.05501	5.7580205E+04	3.7249159E+07	646.91
.05601	5.7520836E+04	3.7212224E+07	646.93
.05701	5.7470363E+04	3.7182530E+07	646.99
.05800	5.7459013E+04	3.7182770E+07	647.12
.05901	5.7519410E+04	3.7230371E+07	647.27
.06001	5.7665585E+04	3.7335873E+07	647.46
.06101	5.7877470E+04	3.7477569E+07	647.53
.06202	5.8086446E+04	3.7615994E+07	647.59
.06302	5.8243275E+04	3.7719911E+07	647.63
.06401	5.8331248E+04	3.7778611E+07	647.66
.06502	5.8345634E+04	3.7789282E+07	647.68
.06601	5.8292793E+04	3.7756256E+07	647.70
.06702	5.8186575E+04	3.7688681E+07	647.72
.06801	5.8048569E+04	3.7600591E+07	647.74
.06903	5.7887936E+04	3.7498055E+07	647.77
.07004	5.7725913E+04	3.7394812E+07	647.80

TABLE 6.2.1-13 (Sheet 3)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.07105	5.7577918E+04	3.7300713E+07	647.83
.07201	5.7442843E+04	3.7215231E+07	647.87
.07301	5.7328001E+04	3.7143113E+07	647.91
.07403	5.7229128E+04	3.7081251E+07	647.94
.07501	5.7145380E+04	3.7028937E+07	647.98
.07604	5.7061007E+04	3.6976103E+07	648.01
.07700	5.6975294E+04	3.6922210E+07	648.04
.07801	5.6874079E+04	3.6858249E+07	648.07
.07900	5.6755906E+04	3.6782928E+07	648.09
.08001	5.6604661E+04	3.6685846E+07	648.11
.08101	5.6411574E+04	3.6561466E+07	648.12
.08201	5.6177799E+04	3.6410684E+07	648.13
.08302	5.5901391E+04	3.6232262E+07	648.15
.08400	5.5597445E+04	3.6035854E+07	648.16
.08500	5.5257094E+04	3.5815753E+07	648.17
.08601	5.4895819E+04	3.5581993E+07	648.17
.08702	5.4507445E+04	3.5330892E+07	648.18
.08802	5.4119131E+04	3.5079676E+07	648.19
.08902	5.3735948E+04	3.4832294E+07	648.21
.09001	5.3370360E+04	3.4596380E+07	648.23
.09100	5.3026446E+04	3.4374325E+07	648.25
.09203	5.2689097E+04	3.4156435E+07	648.26
.09302	5.2396247E+04	3.3967350E+07	648.28
.09402	5.2128103E+04	3.3794433E+07	648.30
.09502	5.1897012E+04	3.3645411E+07	648.31
.09602	5.1677805E+04	3.3504063E+07	648.33
.09705	5.1491386E+04	3.3384382E+07	648.35
.09802	5.1342918E+04	3.3288972E+07	648.37
.09905	5.1204513E+04	3.3200117E+07	648.38
.10002	5.1098817E+04	3.3132545E+07	648.40
.10506	5.0873716E+04	3.2993792E+07	648.54
.11003	5.1124634E+04	3.3166978E+07	648.75
.11503	5.1599480E+04	3.3486750E+07	648.97
.12004	5.2014096E+04	3.3765100E+07	649.15
.12512	5.2266069E+04	3.3934436E+07	649.26
.13006	5.2387018E+04	3.4016716E+07	649.33

TABLE 6.2.1-13 (Sheet 4)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.13501	5.2404864E+04	3.4031458E+07	649.40
.14008	5.2342945E+04	3.3994574E+07	649.46
.14506	5.2260398E+04	3.3944682E+07	649.53
.15008	5.2157685E+04	3.3881463E+07	649.60
.15513	5.2015304E+04	3.3791729E+07	649.65
.16005	5.1824647E+04	3.3670065E+07	649.69
.16504	5.1575205E+04	3.3510530E+07	649.74
.17013	5.1289450E+04	3.3328672E+07	649.82
.17508	5.1047575E+04	3.3176979E+07	649.92
.18008	5.0890714E+04	3.3082720E+07	650.07
.18507	5.0832171E+04	3.3053862E+07	650.25
.19015	5.0840397E+04	3.3069401E+07	650.46
.19509	5.0862614E+04	3.3094170E+07	650.66
.20005	5.0849271E+04	3.3095949E+07	650.86
.21009	5.0589926E+04	3.2947105E+07	651.26
.22007	5.0165355E+04	3.2684782E+07	651.54
.23008	5.0018470E+04	3.2597158E+07	651.70
.24008	5.0155702E+04	3.2690539E+07	651.78
.25002	5.0235222E+04	3.2744556E+07	651.82
.26002	5.0043009E+04	3.2623793E+07	651.92
.27007	4.9754984E+04	3.2443934E+07	652.07
.28008	4.9607409E+04	3.2356377E+07	652.25
.29011	4.9578057E+04	3.2344552E+07	652.40
.30002	4.9479037E+04	3.2285716E+07	652.51
.31006	4.9217645E+04	3.2120448E+07	652.62
.32005	4.8987294E+04	3.1974617E+07	652.71
.33009	4.8990341E+04	3.1979432E+07	652.77
.34003	4.9108943E+04	3.2058107E+07	652.80
.35006	4.9137581E+04	3.2078127E+07	652.82
.36003	4.9028820E+04	3.2009935E+07	652.88
.37003	4.8894983E+04	3.1926330E+07	652.96
.38013	4.8812191E+04	3.1875826E+07	653.03
.39002	4.8757250E+04	3.1842653E+07	653.09
.40009	4.8677019E+04	3.1792462E+07	653.13
.41012	4.8567941E+04	3.1723202E+07	653.17
.42004	4.8477201E+04	3.1665706E+07	653.21

TABLE 6.2.1-13 (Sheet 5)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.43007	4.8441687E+04	3.1643958E+07	653.24
.44007	4.8444420E+04	3.1646891E+07	653.26
.45003	4.8439546E+04	3.1644850E+07	653.29
.46008	4.8405455E+04	3.1623966E+07	653.31
.47000	4.8347220E+04	3.1587479E+07	653.35
.48004	4.8265944E+04	3.1536071E+07	653.38
.49008	4.8165418E+04	3.1472203E+07	653.42
.50010	4.8064286E+04	3.1407993E+07	653.46
.51011	4.7985748E+04	3.1358441E+07	653.49
.52004	4.7936044E+04	3.1327541E+07	653.53
.53009	4.7906127E+04	3.1309516E+07	653.56
.54006	4.7936807E+04	3.1330817E+07	653.59
.55015	4.8018455E+04	3.1384877E+07	653.60
.56014	4.8060735E+04	3.1413510E+07	653.62
.57009	4.8028295E+04	3.1393693E+07	653.65
.58002	4.7953157E+04	3.1346723E+07	653.69
.59011	4.7879057E+04	3.1300753E+07	653.75
.60001	4.7819109E+04	3.1264058E+07	653.80
.61011	4.7774294E+04	3.1237307E+07	653.85
.62005	4.7749312E+04	3.1223757E+07	653.90
.63010	4.7741022E+04	3.1220407E+07	653.95
.64009	4.7740675E+04	3.1222522E+07	654.00
.65011	4.7737632E+04	3.1222954E+07	654.05
.66005	4.7715946E+04	3.1211437E+07	654.11
.67007	4.7664669E+04	3.1181053E+07	654.18
.68012	4.7594828E+04	3.1138969E+07	654.25
.69012	4.7521882E+04	3.1095090E+07	654.33
.70002	4.7455716E+04	3.1055716E+07	654.41
.71008	4.7398427E+04	3.1022260E+07	654.50
.72007	4.7353041E+04	3.0996566E+07	654.58
.73011	4.7315200E+04	3.0975837E+07	654.67
.74005	4.7281012E+04	3.0957518E+07	654.76
.75013	4.7243509E+04	3.0937209E+07	654.85
.76002	4.7194671E+04	3.0909640E+07	654.94
.77008	4.7128901E+04	3.0871408E+07	655.04
.78009	4.7054137E+04	3.0827582E+07	655.15

TABLE 6.2.1-13 (Sheet 6)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.79009	4.6979598E+04	3.0784111E+07	655.27
.80009	4.6909670E+04	3.0743779E+07	655.38
.81012	4.6846184E+04	3.0707716E+07	655.50
.82004	4.6789900E+04	3.0676296E+07	655.62
.83013	4.6737041E+04	3.0647175E+07	655.74
.84011	4.6684891E+04	3.0618468E+07	655.85
.85009	4.6627681E+04	3.0586542E+07	655.97
.86004	4.6561116E+04	3.0548661E+07	656.10
.87010	4.6484743E+04	3.0504624E+07	656.23
.88003	4.6405813E+04	3.0458971E+07	656.36
.89011	4.6326865E+04	3.0413449E+07	656.50
.90009	4.6251629E+04	3.0370296E+07	656.63
.91010	4.6179916E+04	3.0329443E+07	656.77
.92002	4.6113085E+04	3.0291681E+07	656.90
.93010	4.6047783E+04	3.0254975E+07	657.03
.94007	4.5982134E+04	3.0217963E+07	657.17
.95003	4.5911172E+04	3.0177521E+07	657.30
.96010	4.5831557E+04	3.0131578E+07	657.44
.97003	4.5746802E+04	3.0082265E+07	657.58
.98011	4.5658511E+04	3.0030751E+07	657.73
.99008	4.5572130E+04	2.9980387E+07	657.87
1.00007	4.5488016E+04	2.9931454E+07	658.01
1.05012	4.5093621E+04	2.9702761E+07	658.69
1.10006	4.4639245E+04	2.9435833E+07	659.42
1.15004	4.4211852E+04	2.9186409E+07	660.15
1.20005	4.3751417E+04	2.8917926E+07	660.96
1.25007	4.3329589E+04	2.8672916E+07	661.74
1.30006	4.2799627E+04	2.8364827E+07	662.74
1.35007	4.2388735E+04	2.8129930E+07	663.62
1.40003	4.2008795E+04	2.7912315E+07	664.44
1.45009	4.1662480E+04	2.7710541E+07	665.12
1.50000	4.1333848E+04	2.7514553E+07	665.67
1.55010	4.1022218E+04	2.7324771E+07	666.10
1.60010	4.0719831E+04	2.7135783E+07	666.40
1.65004	4.0437624E+04	2.6953064E+07	666.53
1.70002	4.0164166E+04	2.6772580E+07	666.58

TABLE 6.2.1-13 (Sheet 7)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
1.75006	3.9902789E+04	2.6598232E+07	666.58
1.80007	3.9647963E+04	2.6426705E+07	666.53
1.85005	3.9411803E+04	2.6267045E+07	666.48
1.90008	3.9183080E+04	2.6112873E+07	666.43
1.95010	3.8973644E+04	2.5969514E+07	666.34
2.00012	3.8777963E+04	2.5832984E+07	665.18
2.05001	3.8599076E+04	2.5703956E+07	665.92
2.10013	3.8433525E+04	2.5579363E+07	665.55
2.15013	3.8392287E+04	2.5526412E+07	664.88
2.20005	3.8406062E+04	2.5507508E+07	664.15
2.25003	3.8353069E+04	2.5449311E+07	663.55
2.30012	3.8231713E+04	2.5352190E+07	663.12
2.35007	3.8076095E+04	2.5237305E+07	662.81
2.40017	3.7893101E+04	2.5109325E+07	662.64
2.45012	3.7705570E+04	2.4979815E+07	662.50
2.50026	3.7523172E+04	2.4852799E+07	662.33
2.55018	3.7328598E+04	2.4719165E+07	662.20
2.60005	3.7137102E+04	2.4588828E+07	662.11
2.65002	3.6933419E+04	2.4452387E+07	662.07
2.70024	3.6747504E+04	2.4323077E+07	661.90
2.75032	3.6555254E+04	2.4187540E+07	661.67
2.80009	3.6373800E+04	2.4056056E+07	661.36
2.85014	3.6202085E+04	2.3928924E+07	660.98
2.90010	3.6007079E+04	2.3789049E+07	660.68
2.95007	3.5781539E+04	2.3639916E+07	660.67
3.00011	3.5594393E+04	2.3513164E+07	660.59

TABLE 6.2.1-14 LIMITED AREA CIRCUMFERENTIAL BREAK

PUMP SUCTION
436 SQUARE INCHES
BREAK MASS FLOW AND ENERGY FLOW

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.00000	0.	0.	0.00
.00101	1.0612719E+04	5.9402813E+06	559.73
.00201	1.5477103E+04	8.6430425E+06	556.44
.00300	1.8715158E+04	1.0445304E+07	558.12
.00401	2.0587861E+04	1.1473286E+07	557.28
.00502	2.2870173E+04	1.2745422E+07	557.29
.00602	2.4323128E+04	1.3555706E+07	557.32
.00701	2.5284095E+04	1.4092159E+07	557.35
.00800	2.5934924E+04	1.4455438E+07	557.37
.00902	2.7097377E+04	1.5128925E+07	558.32
.01001	2.8648302E+04	1.5971766E+07	557.51
.01101	2.8321396E+04	1.5785820E+07	557.38
.01202	2.9178242E+04	1.6282400E+07	558.03
.01301	3.0337228E+04	1.6918747E+07	557.69
.01401	3.0532624E+04	1.7021447E+07	557.48
.01500	3.0638207E+04	1.7079211E+07	557.45
.01600	3.0530564E+04	1.7015821E+07	557.34
.01702	3.0637336E+04	1.7082704E+07	557.58
.01804	3.1491107E+04	1.7568886E+07	557.90
.01901	3.2718574E+04	1.8255835E+07	557.97
.02002	3.3697834E+04	1.8796276E+07	557.79
.02102	3.3990467E+04	1.8948289E+07	557.46
.02204	3.3051422E+04	1.8415925E+07	557.19
.02302	3.2317668E+04	1.8010469E+07	557.29
.02401	3.1893177E+04	1.7768510E+07	557.13
.02502	3.1159434E+04	1.7362933E+07	557.23
.02603	3.1058249E+04	1.7306350E+07	557.22
.02701	3.1162295E+04	1.7369362E+07	557.38
.02801	3.1354587E+04	1.7472001E+07	557.24
.02904	3.1163827E+04	1.7364131E+07	557.19
.03001	3.1162137E+04	1.7364544E+07	557.23
.03103	3.0910260E+04	1.7218121E+07	557.04

TABLE 6.2.1-14 (Sheet 2)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.03203	3.0335949E+04	1.6902309E+07	557.17
.03302	3.0473443E+04	1.6979848E+07	557.20
.03401	3.0381381E+04	1.6923743E+07	557.04
.03502	3.0151477E+04	1.6796567E+07	557.07
.03600	3.0013069E+04	1.6718224E+07	557.03
.03702	2.9768551E+04	1.6581642E+07	557.02
.03801	2.9739734E+04	1.6568611E+07	557.12
.03901	2.9792727E+04	1.6596738E+07	557.07
.04001	2.9748776E+04	1.6572473E+07	557.08
.04101	2.9890995E+04	1.6655022E+07	557.19
.04200	3.0148218E+04	1.6796695E+07	557.14
.04300	3.0086983E+04	1.6757676E+07	556.97
.04402	2.9857969E+04	1.6631172E+07	557.01
.04501	2.9813962E+04	1.6607459E+07	557.04
.04602	2.9671708E+04	1.6525465E+07	556.94
.04702	2.9516248E+04	1.6443706E+07	557.11
.04801	3.0768840E+04	1.7173297E+07	558.14
.04901	3.4095683E+04	1.9046548E+07	558.62
.05000	3.6620754E+04	2.0436773E+07	558.07
.05102	3.8088803E+04	2.1256333E+07	558.07
.05202	3.9365211E+04	2.1960727E+07	557.87
.05304	3.9311114E+04	2.1903205E+07	557.18
.05401	3.8337268E+04	2.1356696E+07	557.07
.05503	3.7800104E+04	2.1067346E+07	557.34
.05600	3.7983737E+04	2.1180418E+07	557.62
.05703	3.8878146E+04	2.1692161E+07	557.95
.05802	4.0127890E+04	2.2391612E+07	558.01
.05901	4.0911763E+04	2.2819095E+07	557.76
.06004	4.1054620E+04	2.2890932E+07	557.57
.06102	4.1013622E+04	2.2869661E+07	557.61
.06201	4.1314329E+04	2.3046886E+07	557.84
.06303	4.2199537E+04	2.3552324E+07	558.12
.06405	4.3493146E+04	2.4283572E+07	558.33
.06506	4.4938720E+04	2.5097023E+07	558.47
.06605	4.6276930E+04	2.5844322E+07	558.47
.06703	4.7220224E+04	2.6365572E+07	558.35

TABLE 6.2.1-14 (Sheet 3)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.06806	4.7747552E+04	2.6653684E+07	558.22
.06904	4.7980823E+04	2.6781685E+07	558.17
.07002	4.8179997E+04	2.6893932E+07	558.20
.07103	4.8414892E+04	2.7025673E+07	558.21
.07206	4.8606537E+04	2.7130683E+07	558.17
.07303	4.8666339E+04	2.7161953E+07	558.13
.07406	4.8690461E+04	2.7176006E+07	558.14
.07506	4.8821441E+04	2.7252671E+07	558.21
.07601	4.9112729E+04	2.7419953E+07	558.31
.07706	4.9620229E+04	2.7708124E+07	558.40
.07803	5.0151290E+04	2.8006693E+07	558.44
.07905	5.0618710E+04	2.8266104E+07	558.41
.08003	5.0850883E+04	2.8390601E+07	558.31
.08102	5.0817457E+04	2.8366329E+07	558.20
.08203	5.0612968E+04	2.8248617E+07	558.13
.08307	5.0386212E+04	2.8121516E+07	558.12
.08406	5.0258532E+04	2.8051174E+07	558.14
.08508	5.0203870E+04	2.8020700E+07	558.14
.08601	5.0145171E+04	2.7986129E+07	558.10
.08707	4.9971795E+04	2.7885479E+07	558.02
.08804	4.9707446E+04	2.7734628E+07	557.96
.08906	4.9388985E+04	2.7555369E+07	557.93
.09007	4.9149064E+04	2.7423039E+07	557.96
.09108	4.9102485E+04	2.7401129E+07	558.04
.09204	4.9254670E+04	2.7490224E+07	558.12
.09300	4.9535585E+04	2.7650217E+07	558.19
.09406	4.9890637E+04	2.7850104E+07	558.22
.09500	5.0168142E+04	2.8004932E+07	558.22
.09604	5.0390735E+04	2.8127887E+07	558.20
.09703	5.0494501E+04	2.8184059E+07	558.16
.09810	5.0512250E+04	2.8192052E+07	558.12
.09909	5.0461904E+04	2.8162069E+07	558.09
.10000	5.0365589E+04	2.8106397E+07	558.05
.10510	4.9565693E+04	2.7655238E+07	557.95
.11001	4.9462917E+04	2.7597334E+07	557.94
.11506	4.9112169E+04	2.7395046E+07	557.81

TABLE 6.2.1-14 (Sheet 4)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.12009	4.7947073E+04	2.6739988E+07	557.70
.12514	4.7822210E+04	2.6674141E+07	557.78
.13010	4.8192706E+04	2.6884750E+07	557.86
.13507	4.8521633E+04	2.7071479E+07	557.93
.14015	4.9035115E+04	2.7362858E+07	558.03
.14510	4.9372084E+04	2.7550667E+07	558.02
.15007	4.9301214E+04	2.7510682E+07	558.01
.15520	4.9434402E+04	2.7587019E+07	558.05
.16003	4.9576486E+04	2.7665767E+07	558.04
.16516	4.9299952E+04	2.7508317E+07	557.98
.17018	4.9058771E+04	2.7373159E+07	557.97
.17505	4.8910979E+04	2.7289827E+07	557.95
.18013	4.8626434E+04	2.7129924E+07	557.93
.18513	4.8635917E+04	2.7138547E+07	557.99
.19012	4.9085839E+04	2.7394609E+07	558.10
.19517	4.9648645E+04	2.7712952E+07	558.18
.20016	5.0073564E+04	2.7952642E+07	558.23
.21011	5.0191360E+04	2.8017063E+07	558.20
.22002	4.9667002E+04	2.7721259E+07	558.14
.23008	4.9087501E+04	2.7397055E+07	558.13
.24006	4.9041043E+04	2.7374860E+07	558.20
.25008	4.9219880E+04	2.7478666E+07	558.28
.26011	4.9140217E+04	2.7435036E+07	558.30
.27017	4.8667267E+04	2.7170814E+07	558.30
.28021	4.8455895E+04	2.7056505E+07	558.37
.29004	4.8824196E+04	2.7268675E+07	558.51
.30001	4.9234397E+04	2.7501876E+07	558.59
.31007	4.9184218E+04	2.7474483E+07	558.60
.32005	4.8928510E+04	2.7333010E+07	558.63
.33019	4.8807988E+04	2.7269420E+07	558.71
.34006	4.8837616E+04	2.7290061E+07	558.79
.35008	4.8750832E+04	2.7243868E+07	558.84
.36005	4.8447244E+04	2.7075705E+07	558.87
.37009	4.8267095E+04	2.6979211E+07	558.96
.38017	4.8374968E+04	2.7045550E+07	559.08
.39018	4.8501796E+04	2.7121434E+07	559.18

TABLE 6.2.1-14 (Sheet 5)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.40003	4.8493322E+04	2.7120275E+07	559.26
.41017	4.8447865E+04	2.7098905E+07	559.34
.42010	4.8534561E+04	2.7152719E+07	559.45
.43018	4.8714184E+04	2.7258676E+07	559.56
.44000	4.8704108E+04	2.7256436E+07	559.63
.45002	4.8426303E+04	2.7103518E+07	559.69
.46004	4.8115803E+04	2.6933627E+07	559.77
.47013	4.7988548E+04	2.6868099E+07	559.89
.48007	4.8017445E+04	2.6890163E+07	560.01
.49010	4.8032671E+04	2.6904013E+07	560.12
.50006	4.7944911E+04	2.6859676E+07	560.22
.51004	4.7841510E+04	2.6807167E+07	560.33
.52005	4.7817261E+04	2.6799668E+07	560.46
.53016	4.7837500E+04	2.6816896E+07	560.58
.54004	4.7816839E+04	2.6810540E+07	560.69
.55004	4.7726210E+04	2.6764914E+07	560.80
.56007	4.7592712E+04	2.6695633E+07	560.92
.57008	4.7445915E+04	2.6619144E+07	561.04
.58006	4.7292450E+04	2.6538897E+07	561.17
.59008	4.7155691E+04	2.6468331E+07	561.30
.60008	4.7138608E+04	2.6465977E+07	561.45
.61000	4.7185043E+04	2.6499354E+07	561.60
.62008	4.7217354E+04	2.6524523E+07	561.75
.63020	4.7171530E+04	2.6505072E+07	561.89
.64010	4.7050159E+04	2.6442854E+07	562.01
.65008	4.6943185E+04	2.6389395E+07	562.16
.66015	4.6879717E+04	2.6360798E+07	562.31
.67016	4.6805880E+04	2.6326054E+07	562.45
.68024	4.6671712E+04	2.6257037E+07	562.59
.69021	4.6488324E+04	2.6160386E+07	562.73
.70004	4.6329886E+04	2.6078351E+07	562.88
.71004	4.6240897E+04	2.6035855E+07	563.05
.72006	4.6191780E+04	2.6015591E+07	563.21
.73031	4.6130742E+04	2.5988360E+07	563.36
.74018	4.6038465E+04	2.5943307E+07	563.51
.75006	4.5931516E+04	2.5889976E+07	563.66

TABLE 6.2.1-14 (Sheet 6)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.76006	4.5823546E+04	2.5836135E+07	563.82
.77004	4.5710748E+04	2.5779538E+07	563.97
.78009	4.5623139E+04	2.5737669E+07	564.14
.79010	4.5560045E+04	2.5709858E+07	564.31
.80022	4.5489725E+04	2.5677850E+07	564.48
.81002	4.5413072E+04	2.5642185E+07	564.64
.82010	4.5327081E+04	2.5601209E+07	564.81
.83004	4.5260966E+04	2.5571549E+07	564.98
.84011	4.5209732E+04	2.5550368E+07	565.15
.85006	4.5159309E+04	2.5529469E+07	565.32
.86015	4.5089401E+04	2.5497327E+07	565.48
.87012	4.4994500E+04	2.5450746E+07	565.64
.88013	4.4886321E+04	2.5397036E+07	565.81
.89013	4.4780254E+04	2.5344589E+07	565.98
.90015	4.4682893E+04	2.5297033E+07	566.15
.91020	4.4589254E+04	2.5251457E+07	566.31
.92011	4.4494474E+04	2.5205284E+07	566.48
.93015	4.4403112E+04	2.5161086E+07	566.65
.94019	4.4318967E+04	2.5120874E+07	566.82
.95011	4.4241866E+04	2.5084499E+07	566.99
.96008	4.4166304E+04	2.5048726E+07	567.15
.97014	4.4081519E+04	2.5007956E+07	567.31
.98014	4.3990876E+04	2.4963692E+07	567.47
.99009	4.3895397E+04	2.4916558E+07	567.63
1.00004	4.3796575E+04	2.4867540E+07	567.80
1.05019	4.3461808E+04	2.4713931E+07	568.64
1.10027	4.3133378E+04	2.4561816E+07	569.44
1.15009	4.2739703E+04	2.4370168E+07	570.20
1.20010	4.2323008E+04	2.4161890E+07	570.89
1.25010	4.1895920E+04	2.3945093E+07	571.54
1.30004	4.1641428E+04	2.3825574E+07	572.16
1.35001	4.1275019E+04	2.3639530E+07	572.73
1.40013	4.0900745E+04	2.3446529E+07	573.25
1.45005	4.0510783E+04	2.3242466E+07	573.74
1.50012	4.0209646E+04	2.3088304E+07	574.20
1.55007	3.9977551E+04	2.2973632E+07	574.66

TABLE 6.2.1-14 (Sheet 7)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
1.60020	3.9686581E+04	2.2823239E+07	575.09
1.65011	3.9367441E+04	2.2655369E+07	575.48
1.70009	3.9019099E+04	2.2468653E+07	575.84
1.75005	3.8650194E+04	2.2268489E+07	576.15
1.80004	3.8459410E+04	2.2171721E+07	576.50
1.85006	3.8205780E+04	2.2037365E+07	576.81
1.90018	3.7913564E+04	2.1879585E+07	577.09
1.95012	3.7624174E+04	2.1723045E+07	577.37
2.00011	3.7317209E+04	2.1555841E+07	577.64
2.05010	3.7002820E+04	2.1384087E+07	577.90
2.10009	3.6833263E+04	2.1297559E+07	578.22
2.15009	3.6549989E+04	2.1144677E+07	578.51
2.20015	3.6227378E+04	2.0967794E+07	578.78
2.25024	3.5847987E+04	2.0756612E+07	579.02
2.30012	3.5473524E+04	2.0547327E+07	579.23
2.35014	3.5068678E+04	2.0318710E+07	579.40
2.40004	3.4845902E+04	2.0196771E+07	579.60
2.45001	3.4721634E+04	2.0133621E+07	579.86
2.50010	3.4519313E+04	2.0024657E+07	580.10
2.55021	3.4334784E+04	1.9925016E+07	580.33
2.60007	3.3939978E+04	1.9701369E+07	580.48
2.65009	3.3620292E+04	1.9520341E+07	580.61
2.70001	3.3325382E+04	1.9353676E+07	580.75
2.75018	3.3013720E+04	1.9176809E+07	580.87
2.80023	3.2709340E+04	1.9003776E+07	580.99
2.85022	3.2406780E+04	1.8830564E+07	581.07
2.90021	3.2076055E+04	1.8641111E+07	581.15
2.95021	3.1762886E+04	1.8460860E+07	581.21
3.00000	3.1438030E+04	1.8272828E+07	581.23

TABLE 6.2.1-15 LIMITED AREA CIRCUMFERENTIAL BREAK-COLD LEG

236 SQUARE INCHES
BREAK MASS FLOW AND ENERGY FLOW

Time (sec)	Mass Flow(lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.00000	1.0572100E+04	5.9341197E+06	561.30
.00100	2.1707552E+04	1.2082083E+07	556.58
.00200	2.2095902E+04	1.2332674E+07	558.14
.00301	2.4453587E+04	1.3647396E+07	558.09
.00401	2.4614206E+04	1.3742704E+07	558.32
.00501	2.5073813E+04	1.4000423E+07	558.37
.00600	2.4968001E+04	1.3940432E+07	558.33
.00701	2.4799097E+04	1.3844457E+07	558.26
.00800	2.4521907E+04	1.3687502E+07	558.17
.00900	2.4235127E+04	1.3525275E+07	558.09
.01001	2.3956426E+04	1.3367745E+07	558.00
.01101	2.3712499E+04	1.3229957E+07	557.93
.01201	2.3509080E+04	1.3115107E+07	557.87
.01300	2.3348860E+04	1.3024663E+07	557.83
.01401	2.3224463E+04	1.2954460E+07	557.79
.01501	2.3136405E+04	1.2904766E+07	557.77
.01601	2.3078900E+04	1.2872302E+07	557.75
.01701	2.3045835E+04	1.2853614E+07	557.74
.01801	2.3031261E+04	1.2845346E+07	557.74
.01901	2.3031093E+04	1.2845199E+07	557.73
.02000	2.3042896E+04	1.2851798E+07	557.73
.02101	2.3062478E+04	1.2862774E+07	557.74
.02201	2.3085219E+04	1.2875528E+07	557.74
.02301	2.3112249E+04	1.2890722E+07	557.74
.02401	2.3154911E+04	1.2914784E+07	557.76
.02501	2.3232817E+04	1.2958803E+07	557.78
.02600	2.3363203E+04	1.3032514E+07	557.82
.02701	2.3560296E+04	1.3143944E+07	557.89
.02801	2.3815409E+04	1.3288187E+07	557.97
.02901	2.4108987E+04	1.3454219E+07	558.06
.03002	2.4416539E+04	1.3628203E+07	558.15
.03101	2.4702619E+04	1.3790082E+07	558.24
.03202	2.4956193E+04	1.3933591E+07	558.32

TABLE 6.2.1-15 (Sheet 2)

Time (sec)	Mass Flow(lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.03302	2.5153480E+04	1.4045262E+07	558.38
.03400	2.5295757E+04	1.4125764E+07	558.42
.03503	2.5393058E+04	1.4180785E+07	558.45
.03601	2.5445431E+04	1.4210337E+07	558.46
.03700	2.5469811E+04	1.4224050E+07	558.47
.03801	2.5485016E+04	1.4233333E+07	558.50
.03900	2.5532165E+04	1.4260386E+07	558.53
.04001	2.5579295E+04	1.4286873E+07	558.53
.04100	3.1975101E+04	1.7928469E+07	560.70
.04201	3.8448314E+04	2.1502956E+07	559.27
.04300	3.9352140E+04	2.2033352E+07	559.90
.04401	3.9125641E+04	2.1906483E+07	559.90
.04501	3.9425222E+04	2.2073567E+07	559.88
.04600	3.9569449E+04	2.2156188E+07	559.93
.04701	3.9803243E+04	2.2290123E+07	560.01
.04801	4.0236633E+04	2.2536969E+07	560.11
.04901	4.0627082E+04	2.2759128E+07	560.20
.05002	4.0925012E+04	2.2928780E+07	560.26
.05102	4.1169127E+04	2.3067753E+07	560.32
.05201	4.1385789E+04	2.3191572E+07	560.38
.05300	4.1753771E+04	2.3402932E+07	560.50
.05401	4.2223803E+04	2.3671342E+07	560.62
.05503	4.2137045E+04	2.3618406E+07	560.51
.05603	4.1529382E+04	2.3270169E+07	560.33
.05701	4.1295423E+04	2.3138628E+07	560.32
.05801	4.1411429E+04	2.3204564E+07	560.34
.05901	4.1105545E+04	2.3027420E+07	560.20
.06001	4.0603325E+04	2.2741035E+07	560.08
.06103	4.0521101E+04	2.2695491E+07	560.09
.06201	4.0645395E+04	2.2766492E+07	560.12
.06304	4.0704550E+04	2.2799744E+07	560.13
.06404	4.0705829E+04	2.2800277E+07	560.12
.06507	4.0750515E+04	2.2825982E+07	560.14
.06608	4.0871065E+04	2.2895040E+07	560.18
.06708	4.0998964E+04	2.2967904E+07	560.21
.06803	4.1053073E+04	2.2998295E+07	560.21

TABLE 6.2.1-15 (Sheet 3)

Time (sec)	Mass Flow(lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.06902	4.1019766E+04	2.2978676E+07	560.19
.07001	4.0926484E+04	2.2924851E+07	560.15
.07108	4.0801842E+04	2.2853207E+07	560.10
.07211	4.0692741E+04	2.2790552E+07	560.06
.07309	4.0594318E+04	2.2734095E+07	560.03
.07409	4.0469378E+04	2.2662473E+07	559.99
.07504	4.0337650E+04	2.2586968E+07	559.95
.07608	4.0214347E+04	2.2516653E+07	559.92
.07709	4.0121581E+04	2.2463789E+07	559.89
.07804	4.0053713E+04	2.2425111E+07	559.88
.07908	4.0002239E+04	2.2395892E+07	559.87
.08009	3.9980392E+04	2.2383654E+07	559.87
.08108	3.9983680E+04	2.2385754E+07	559.87
.08208	3.9995601E+04	2.2392735E+07	559.88
.08304	3.9996317E+04	2.2393274E+07	559.88
.08405	3.9966032E+04	2.2376087E+07	559.88
.08504	3.9891651E+04	2.2333703E+07	559.86
.08610	3.9750341E+04	2.2253151E+07	559.82
.08709	3.9568354E+04	2.2149429E+07	559.78
.08801	3.9364804E+04	2.2033483E+07	559.73
.08901	3.9131631E+04	2.1900720E+07	559.67
.09012	3.8871669E+04	2.1752747E+07	559.60
.09103	3.8662831E+04	2.1633870E+07	559.55
.09212	3.8430757E+04	2.1501990E+07	559.50
.09305	3.8228150E+04	2.1386925E+07	559.45
.09405	3.8028085E+04	2.1273173E+07	559.41
.09503	3.7840641E+04	2.1166762E+07	559.37
.09602	3.7653190E+04	2.1060321E+07	559.32
.09707	3.7460086E+04	2.0950587E+07	559.28
.09803	3.7314180E+04	2.0867701E+07	559.24
.09910	3.7157535E+04	2.0778860E+07	559.21
.10009	3.7027859E+04	2.0705323E+07	559.18
.10501	3.6632913E+04	2.0481815E+07	559.11
.11010	3.6501225E+04	2.0408199E+07	559.11
.11509	3.6282348E+04	2.0284419E+07	559.07
.12011	3.5914523E+04	2.0075865E+07	558.99

TABLE 6.2.1-15 (Sheet 4)

Time (sec)	Mass Flow(lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.12508	3.5368349E+04	1.9766474E+07	558.87
.13006	3.4928346E+04	1.9518017E+07	558.80
.13506	3.5003152E+04	1.9561727E+07	558.86
.14011	3.5387174E+04	1.9780616E+07	558.98
.14508	3.5790435E+04	2.0009865E+07	559.08
.15001	3.6094288E+04	2.0182489E+07	559.16
.15512	3.6303763E+04	2.0301364E+07	559.21
.16001	3.6531599E+04	2.0430727E+07	559.26
.16510	3.6764783E+04	2.0562948E+07	559.31
.17002	3.6887528E+04	2.0632243E+07	559.33
.17520	3.6876132E+04	2.0625015E+07	559.31
.18010	3.6792829E+04	2.0577088E+07	559.27
.18513	3.6751757E+04	2.0553520E+07	559.25
.19002	3.6796516E+04	2.0578936E+07	559.26
.19501	3.6827018E+04	2.0596085E+07	559.27
.20018	3.6769437E+04	2.0563047E+07	559.24
.21010	3.6573096E+04	2.0450930E+07	559.18
.22002	3.6391667E+04	2.0347573E+07	559.13
.23009	3.6096589E+04	2.0179782E+07	559.05
.24013	3.5990575E+04	2.0120049E+07	559.04
.25015	3.6081958E+04	2.0172127E+07	559.06
.26009	3.6088556E+04	2.0175920E+07	559.07
.27008	3.6400732E+04	2.0353382E+07	559.15
.28008	3.6757692E+04	2.0555821E+07	559.23
.29008	3.6832638E+04	2.0597661E+07	559.22
.30016	3.6764781E+04	2.0558426E+07	559.19
.31016	3.6608228E+04	2.0469086E+07	559.14
.32006	3.6501532E+04	2.0408435E+07	559.11
.33008	3.6395300E+04	2.0348183E+07	559.09
.34007	3.6267729E+04	2.0275857E+07	559.06
.35002	3.6140651E+04	2.0203992E+07	559.04
.36013	3.6103086E+04	2.0183052E+07	559.04
.37010	3.6185810E+04	2.0230379E+07	559.07
.38005	3.6361709E+04	2.0330496E+07	559.12
.39012	3.6541541E+04	2.0432623E+07	559.16
.40007	3.6641160E+04	2.0489029E+07	559.18

TABLE 6.2.1-15 (Sheet 5)

Time (sec)	Mass Flow(lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.41006	3.6647514E+04	2.0492391E+07	559.18
.42009	3.6545798E+04	2.0434414E+07	559.15
.43001	3.6399205E+04	2.0351154E+07	559.11
.44001	3.6264088E+04	2.0274615E+07	559.08
.45005	3.6168431E+04	2.0220592E+07	559.07
.46013	3.6112827E+04	2.0189330E+07	559.06
.47004	3.6085029E+04	2.0173814E+07	559.06
.48008	3.6105125E+04	2.0185470E+07	559.07
.49008	3.6180307E+04	2.0228345E+07	559.10
.50010	3.6277334E+04	2.0283486E+07	559.12
.51014	3.6337432E+04	2.0317536E+07	559.14
.52006	3.6326079E+04	2.0310925E+07	559.13
.53012	3.6249658E+04	2.0267427E+07	559.11
.54016	3.6141407E+04	2.0205948E+07	559.08
.55012	3.6033220E+04	2.0144621E+07	559.06
.56001	3.5947203E+04	2.0095959E+07	559.04
.57005	3.5896821E+04	2.0067563E+07	559.03
.58009	3.5881727E+04	2.0059175E+07	559.04
.59017	3.5892773E+04	2.0065579E+07	559.04
.60002	3.5918369E+04	2.0080179E+07	559.05
.61005	3.5947401E+04	2.0096682E+07	559.06
.62004	3.5965029E+04	2.0106650E+07	559.06
.63005	3.5953838E+04	2.0100216E+07	559.06
.64001	3.5906058E+04	2.0073003E+07	559.04
.65006	3.5834052E+04	2.0032083E+07	559.02
.66010	3.5760760E+04	1.9990497E+07	559.01
.67009	3.5708143E+04	1.9960697E+07	559.00
.68003	3.5682226E+04	1.9946058E+07	558.99
.69001	3.5682166E+04	1.9946073E+07	558.99
.70001	3.5700880E+04	1.9956700E+07	559.00
.71006	3.5728117E+04	1.9972114E+07	559.00
.72011	3.5752752E+04	1.9986001E+07	559.01
.73006	3.5764762E+04	1.9992684E+07	559.01
.74005	3.5760249E+04	1.9989968E+07	559.00
.75006	3.5740351E+04	1.9978527E+07	558.99
.76001	3.5711821E+04	1.9962206E+07	558.98

TABLE 6.2.1-15 (Sheet 6)

Time (sec)	Mass Flow(lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
.77007	3.5682869E+04	1.9945670E+07	558.97
.78006	3.5666198E+04	1.9936132E+07	558.96
.79009	3.5667682E+04	1.9936906E+07	558.96
.80022	3.5687294E+04	1.9947954E+07	558.97
.81017	3.5718441E+04	1.9965520E+07	558.97
.82002	3.5751430E+04	1.9984084E+07	558.97
.83005	3.5779223E+04	1.9999675E+07	558.97
.84009	3.5796825E+04	2.0009453E+07	558.97
.85001	3.5801848E+04	2.0012090E+07	558.97
.86003	3.5796359E+04	2.0008764E+07	558.96
.87008	3.5786932E+04	2.0003223E+07	558.95
.88010	3.5779140E+04	1.9998615E+07	558.95
.89002	3.5778563E+04	1.9998114E+07	558.94
.90006	3.5788751E+04	2.0003723E+07	558.94
.91005	3.5809204E+04	2.0015144E+07	558.94
.92004	3.5835475E+04	2.0029846E+07	558.94
.93008	3.5861922E+04	2.0044622E+07	558.94
.94016	3.5882985E+04	2.0056325E+07	558.94
.95010	3.5903621E+04	2.0067778E+07	558.93
.96003	3.5921117E+04	2.0077436E+07	558.93
.97010	3.5924585E+04	2.0079130E+07	558.92
.98007	3.5921512E+04	2.0077130E+07	558.92
.99012	3.5918458E+04	2.0075157E+07	558.91
1.00005	3.5916499E+04	2.0073815E+07	558.90
1.05008	3.5969186E+04	2.0102519E+07	558.88
1.10005	3.5926821E+04	2.0077225E+07	558.84
1.15008	3.5938536E+04	2.0082736E+07	558.81
1.20007	3.5856088E+04	2.0034802E+07	558.76
1.25007	3.5768952E+04	1.9984414E+07	558.71
1.30007	3.5693161E+04	1.9940447E+07	558.66
1.35011	3.5622061E+04	1.9899206E+07	558.62
1.40004	3.5575341E+04	1.9871758E+07	558.58
1.45004	3.5527168E+04	1.9843508E+07	558.54
1.50013	3.5501810E+04	1.9828180E+07	558.51
1.55005	3.5461988E+04	1.9804676E+07	558.48
1.60000	3.5424567E+04	1.9782594E+07	558.44

TABLE 6.2.1-15 (Sheet 7)

Time (sec)	Mass Flow(lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
1.65006	3.5369865E+04	1.9750777E+07	558.41
1.70012	3.5331137E+04	1.9728098E+07	558.38
1.75000	3.5307185E+04	1.9713660E+07	558.35
1.80012	3.5233397E+04	1.9671245E+07	558.31
1.85010	3.5205094E+04	1.9654588E+07	558.29
1.90000	3.5093505E+04	1.9590861E+07	558.25
1.95007	3.5000130E+04	1.9537568E+07	558.21
2.00000	3.4879758E+04	1.9469036E+07	558.18
2.05002	3.4793253E+04	1.9419705E+07	558.15
2.10004	3.4689036E+04	1.9360421E+07	558.11
2.15003	3.4615720E+04	1.9318672E+07	558.09
2.20007	3.4538643E+04	1.9274849E+07	558.07
2.25021	3.4464155E+04	1.9232569E+07	558.05
2.30004	3.4381216E+04	1.9185591E+07	558.03
2.35008	3.4363178E+04	1.9175402E+07	558.02
2.40008	3.4252834E+04	1.9113112E+07	558.00
2.45015	3.4152419E+04	1.9056583E+07	557.99
2.50006	3.4056072E+04	1.9002467E+07	557.98
2.55005	3.3960401E+04	1.8948763E+07	557.97
2.60008	3.3798412E+04	1.8857833E+07	557.95
2.65015	3.3704717E+04	1.8805516E+07	557.95
2.70013	3.3560589E+04	1.8724864E+07	557.94
2.75010	3.3442746E+04	1.8659151E+07	557.94
2.80012	3.3327683E+04	1.8595164E+07	557.95
2.85002	3.3216236E+04	1.8533322E+07	557.96
2.90006	3.3172549E+04	1.8510071E+07	557.99
2.95015	3.3058421E+04	1.8447012E+07	558.01
3.00008	3.2942895E+04	1.8383423E+07	558.04

TABLE 6.2.1-16 PRESSURIZER SURGE LINE DOUBLE-ENDED GUILLOTINE BREAK

BREAK MASS FLOW AND ENERGY FLOW

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
0.00000	0.	0.	0.00
0.00251	1.6681148E+04	1.1296008E+07	677.17
0.00501	1.6556361E+04	1.1212058E+07	677.21
0.00752	1.6699069E+04	1.1302997E+07	676.86
0.01002	1.9033506E+04	1.2830006E+07	674.07
0.01250	2.2089365E+04	1.4828262E+07	671.29
0.01501	2.1648161E+04	1.4533929E+07	671.37
0.01754	2.1247911E+04	1.4268193E+07	671.51
0.02002	2.0465838E+04	1.3752132E+07	671.96
0.02250	2.0393611E+04	1.3704347E+07	671.99
0.02505	2.0706044E+04	1.3907231E+07	671.65
0.02752	2.0931729E+04	1.4053966E+07	671.42
0.03001	2.0998600E+04	1.4096217E+07	671.29
0.03259	2.0967919E+04	1.4074876E+07	671.26
0.03507	2.0990414E+04	1.4088700E+07	671.20
0.03750	2.1019840E+04	1.4107187E+07	671.14
0.04009	2.1062241E+04	1.4134287E+07	671.07
0.04259	2.1156624E+04	1.4195514E+07	670.97
0.04512	2.1160405E+04	1.4197306E+07	670.94
0.04761	2.1098863E+04	1.4156324E+07	670.95
0.05009	2.1066994E+04	1.4134990E+07	670.95
0.05264	2.1095761E+04	1.4153509E+07	670.92
0.05505	2.1085426E+04	1.4146331E+07	670.91
0.05751	2.1000054E+04	1.4089897E+07	670.95
0.06008	2.0863697E+04	1.4000108E+07	671.03
0.06255	2.0694171E+04	1.3888722E+07	671.14
0.06512	2.0509657E+04	1.3767663E+07	671.28
0.06750	2.0407265E+04	1.3700589E+07	671.36
0.07002	2.0418448E+04	1.3708034E+07	671.36
0.07250	2.0481072E+04	1.3749121E+07	671.31
0.07507	2.0519777E+04	1.3774417E+07	671.28
0.07754	2.0521037E+04	1.3775092E+07	671.27
0.08003	2.0488129E+04	1.3753315E+07	671.28
0.08255	2.0410939E+04	1.3702503E+07	671.33

TABLE 6.2.1-16 (Sheet 2)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
0.08504	2.0305825E+04	1.3633481E+07	671.41
0.08755	2.0203846E+04	1.3566573E+07	671.48
0.09006	2.0124810E+04	1.3514710E+07	671.54
0.09261	2.0067276E+04	1.3476990E+07	671.59
0.09501	2.0049927E+04	1.3465634E+07	671.61
0.09751	2.0091047E+04	1.3492584E+07	671.57
0.10011	2.0190095E+04	1.3557427E+07	671.49
0.10259	2.0322401E+04	1.3644022E+07	671.38
0.10513	2.0470869E+04	1.3741182E+07	671.26
0.10762	2.0613302E+04	1.3834228E+07	671.13
0.11001	2.0698652E+04	1.3889843E+07	671.05
0.11251	2.0710177E+04	1.3896955E+07	671.02
0.11504	2.0648143E+04	1.3855823E+07	671.04
0.11753	2.0539220E+04	1.3783979E+07	671.11
0.12009	2.0392131E+04	1.3687301E+07	671.21
0.12255	2.0235027E+04	1.3584155E+07	671.32
0.12505	2.0076107E+04	1.3479844E+07	671.44
0.12762	1.9907452E+04	1.3369294E+07	671.57
0.13001	1.9721330E+04	1.3247406E+07	671.73
0.13253	1.9515669E+04	1.3112767E+07	671.91
0.13515	1.9325524E+04	1.2988402E+07	672.09
0.13760	1.9143891E+04	1.2869713E+07	672.26
0.14000	1.8989530E+04	1.2768843E+07	672.41
0.14263	1.8858030E+04	1.2682997E+07	672.55
0.14517	1.8757129E+04	1.2617164E+07	672.66
0.14757	1.8681814E+04	1.2568006E+07	672.74
0.15014	1.8626059E+04	1.2531659E+07	672.80
0.15265	1.8590127E+04	1.2508250E+07	672.84
0.15504	1.8569023E+04	1.2494497E+07	672.87
0.15764	1.8551204E+04	1.2482868E+07	672.89
0.16005	1.8525873E+04	1.2466307E+07	672.91
0.16250	1.8477290E+04	1.2434527E+07	672.96
0.16509	1.8394683E+04	1.2380511E+07	673.05
0.16765	1.8282083E+04	1.2306962E+07	673.17
0.17002	1.8146081E+04	1.2218190E+07	673.32
0.17253	1.7994507E+04	1.2119261E+07	673.50

TABLE 6.2.1-16 (Sheet 3)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
0.17510	1.7851733E+04	1.2026175E+07	673.67
0.17754	1.7718757E+04	1.1939508E+07	673.83
0.18004	1.7607714E+04	1.1867137E+07	673.97
0.18257	1.7516255E+04	1.1807583E+07	674.09
0.18510	1.7440413E+04	1.1758207E+07	674.19
0.18753	1.7384799E+04	1.1721993E+07	674.27
0.19006	1.7331275E+04	1.1687159E+07	674.34
0.19258	1.7283259E+04	1.1655900E+07	674.40
0.19513	1.7239302E+04	1.1627267E+07	674.46
0.19757	1.7196585E+04	1.1599461E+07	674.52
0.20000	1.7153255E+04	1.1571232E+07	674.58
0.20257	1.7114304E+04	1.1545858E+07	674.63
0.20515	1.7075604E+04	1.1520650E+07	674.68
0.20764	1.7047204E+04	1.1502146E+07	674.72
0.21013	1.7030892E+04	1.1491517E+07	674.75
0.21262	1.7026041E+04	1.1488355E+07	674.75
0.21509	1.7031337E+04	1.1491802E+07	674.74
0.21755	1.7044630E+04	1.1500441E+07	674.73
0.22014	1.7064231E+04	1.1513204E+07	674.70
0.22261	1.7085144E+04	1.1526752E+07	674.67
0.22519	1.7104103E+04	1.1539031E+07	674.64
0.22757	1.7120939E+04	1.1549913E+07	674.61
0.23002	1.7133999E+04	1.1558321E+07	674.58
0.23261	1.7139862E+04	1.1562022E+07	674.57
0.23511	1.7135943E+04	1.1559323E+07	674.57
0.23756	1.7121402E+04	1.1549700E+07	674.58
0.24007	1.7091493E+04	1.1530055E+07	674.61
0.24253	1.7044464E+04	1.1499260E+07	674.66
0.24509	1.6981075E+04	1.1457784E+07	674.74
0.24752	1.6909137E+04	1.1410815E+07	674.83
0.25000	1.6816993E+04	1.1350678E+07	674.95
0.25256	1.6725891E+04	1.1291225E+07	675.07
0.25505	1.6633374E+04	1.1230921E+07	675.20
0.25751	1.6542717E+04	1.1171824E+07	675.33
0.26005	1.6466594E+04	1.1122207E+07	675.44
0.26251	1.6403107E+04	1.1080847E+07	675.53

TABLE 6.2.1-16 (Sheet 4)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
0.26504	1.6352876E+04	1.1048104E+07	675.61
0.26751	1.6321725E+04	1.1027787E+07	675.65
0.27009	1.6296620E+04	1.1011400E+07	675.69
0.27265	1.6276846E+04	1.0998473E+07	675.71
0.27509	1.6255893E+04	1.0984763E+07	675.74
0.27751	1.6228524E+04	1.0966874E+07	675.78
0.28003	1.6185426E+04	1.0938740E+07	675.84
0.28253	1.6127011E+04	1.0900616E+07	675.92
0.28512	1.6053276E+04	1.0852567E+07	676.03
0.28755	1.5970294E+04	1.0798521E+07	676.16
0.29001	1.5898962E+04	1.0752073E+07	676.28
0.29256	1.5832910E+04	1.0709102E+07	676.38
0.29509	1.5829868E+04	1.0707076E+07	676.38
0.29751	1.5825312E+04	1.0704075E+07	676.39
0.30009	1.5808551E+04	1.0693108E+07	676.41
0.30265	1.5808165E+04	1.0692807E+07	676.41
0.30517	1.5803688E+04	1.0689818E+07	676.41
0.30753	1.5753769E+04	1.0657243E+07	676.49
0.31006	1.5744724E+04	1.0651197E+07	676.47
0.31256	1.5753012E+04	1.0656385E+07	676.47
0.31501	1.5760820E+04	1.0661304E+07	676.44
0.31761	1.5737615E+04	1.0646068E+07	676.47
0.32014	1.5735895E+04	1.0644859E+07	676.47
0.32273	1.5734566E+04	1.0643956E+07	676.47
0.32509	1.5732595E+04	1.0642618E+07	676.47
0.32753	1.5729905E+04	1.0640794E+07	676.47
0.33024	1.5726744E+04	1.0638378E+07	676.47
0.33251	1.5723019E+04	1.0636121E+07	676.47
0.33526	1.5718891E+04	1.0633317E+07	676.47
0.33752	1.5715349E+04	1.0630912E+07	676.47
0.34003	1.5711537E+04	1.0628319E+07	676.47
0.34271	1.5707870E+04	1.0625820E+07	676.46
0.34506	1.5704632E+04	1.0623609E+07	676.46
0.34770	1.5701190E+04	1.0621254E+07	676.46
0.35025	1.5698641E+04	1.0619896E+07	676.46
0.35261	1.5695247E+04	1.0617177E+07	676.46

TABLE 6.2.1-16 (Sheet 5)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
0.35516	1.5692136E+04	1.0615038E+07	676.46
0.35762	1.5688914E+04	1.0612827E+07	676.45
0.36011	1.5685456E+04	1.0610463E+07	676.45
0.36259	1.5681810E+04	1.0607961E+07	676.45
0.36518	1.5677911E+04	1.0605294E+07	676.45
0.36758	1.5674219E+04	1.0602767E+07	676.45
0.37034	1.5670037E+04	1.0599906E+07	676.44
0.37267	1.5666639E+04	1.0597581E+07	676.44
0.37504	1.5663437E+04	1.0595386E+07	676.44
0.37757	1.5660250E+04	1.0593197E+07	676.44
0.38027	1.5657086E+04	1.0591016E+07	676.44
0.38277	1.5654322E+04	1.0589105E+07	676.43
0.38516	1.5651744E+04	1.0587321E+07	676.43
0.38754	1.5649144E+04	1.0585526E+07	676.43
0.39027	1.5646820E+04	1.0583914E+07	676.43
0.39262	1.5644725E+04	1.0582456E+07	676.42
0.39522	1.5642789E+04	1.0581100E+07	676.42
0.39760	1.5641070E+04	1.0579890E+07	676.42
0.40004	1.5639449E+04	1.0578741E+07	676.41
0.40257	1.5637925E+04	1.0577652E+07	676.41
0.40505	1.5636591E+04	1.0576689E+07	676.41
0.40763	1.5635413E+04	1.0575828E+07	676.40
0.41013	1.5634337E+04	1.0575027E+07	676.40
0.41251	1.5633562E+04	1.0574432E+07	676.39
0.41504	1.5632975E+04	1.0573960E+07	676.39
0.41775	1.5632551E+04	1.0573584E+07	676.38
0.42001	1.5632366E+04	1.0573381E+07	676.38
0.42268	1.5632315E+04	1.0573254E+07	676.37
0.42502	1.5632376E+04	1.0573212E+07	676.37
0.42781	1.5632537E+04	1.0573215E+07	676.36
0.43027	1.5632708E+04	1.0573240E+07	676.35
0.43267	1.5632877E+04	1.0573264E+07	676.35
0.43533	1.5633025E+04	1.0573264E+07	676.34
0.43752	1.5633896E+04	1.0573227E+07	676.34
0.44015	1.5633088E+04	1.0573125E+07	676.33
0.44257	1.5632964E+04	1.0572955E+07	676.32

TABLE 6.2.1-16 (Sheet 6)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
0.44523	1.5632658E+04	1.0572657E+07	676.32
0.44756	1.5632172E+04	1.0572247E+07	676.31
0.45019	1.5631366E+04	1.0571613E+07	676.31
0.45287	1.5630249E+04	1.0570770E+07	676.30
0.45517	1.5629249E+04	1.0569885E+07	676.30
0.45757	1.5627623E+04	1.0568848E+07	676.29
0.46022	1.5635881E+04	1.0567590E+07	676.29
0.46289	1.5623874E+04	1.0566152E+07	676.28
0.46614	1.5622119E+04	1.0564900E+07	676.28
0.46777	1.5619955E+04	1.0563361E+07	676.27
0.47036	1.5617741E+04	1.0561792E+07	676.27
0.47288	1.5615520E+04	1.0560223E+07	676.26
0.47503	1.5613565E+04	1.0558844E+07	676.26
0.47757	1.5611133E+04	1.0557133E+07	676.26
0.48011	1.5608643E+04	1.0555384E+07	676.25
0.48262	1.5606180E+04	1.0553588E+07	676.25
0.48512	1.5603492E+04	1.0551775E+07	676.24
0.48758	1.5600916E+04	1.0549973E+07	676.24
0.49009	1.5598319E+04	1.0548154E+07	676.24
0.49273	1.5595641E+04	1.0546276E+07	676.23
0.49505	1.5593323E+04	1.0544647E+07	676.23
0.49786	1.5590573E+04	1.0542711E+07	676.22
0.50029	1.5588315E+04	1.0541119E+07	676.22
0.51019	1.5579889E+04	1.0535146E+07	676.20
0.52041	1.5571914E+04	1.0529450E+07	676.18
0.53013	1.5564820E+04	1.0524389E+07	676.17
0.54025	1.5557270E+04	1.0518995E+07	676.15
0.55044	1.5550075E+04	1.0513839E+07	676.13
0.56029	1.5544285E+04	1.0509628E+07	676.11
0.57043	1.5539811E+04	1.0506279E+07	676.09
0.58035	1.5537036E+04	1.0504053E+07	676.07
0.59012	1.5535838E+04	1.0502863E+07	676.04
0.60013	1.5535793E+04	1.0502401E+07	676.01
0.61030	1.5536152E+04	1.0502172E+07	675.98
0.62023	1.5535777E+04	1.0501463E+07	675.95
0.63027	1.5533739E+04	1.0499646E+07	675.93

TABLE 6.2.1-16 (Sheet 7)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
0.64028	1.5529494E+04	1.0496323E+07	675.90
0.65009	1.5523642E+04	1.0491943E+07	675.87
0.66010	1.5516674E+04	1.0486820E+07	675.84
0.67006	1.5509627E+04	1.0481657E+07	675.82
0.68002	1.5503246E+04	1.0476939E+07	675.79
0.69043	1.5497613E+04	1.0472703E+07	675.76
0.70003	1.5493333E+04	1.0469413E+07	675.74
0.71008	1.5489729E+04	1.0466564E+07	675.71
0.72062	1.5486462E+04	1.0463919E+07	675.68
0.73047	1.5483628E+04	1.0461579E+07	675.65
0.74006	1.5481145E+04	1.0459476E+07	675.63
0.75058	1.5478712E+04	1.0457353E+07	675.60
0.76039	1.5476578E+04	1.0456447E+07	675.57
0.77046	1.5474438E+04	1.0453521E+07	675.53
0.78003	1.5472213E+04	1.0451554E+07	675.50
0.79034	1.5469339E+04	1.0449119E+07	675.47
0.80022	1.5465740E+04	1.0446217E+07	675.44
0.81004	1.5461251E+04	1.0442584E+07	675.41
0.82013	1.5455070E+04	1.0478084E+07	675.38
0.83054	1.5447988E+04	1.0432852E+07	675.36
0.84013	1.5441170E+04	1.0427849E+07	675.33
0.85057	1.5433935E+04	1.0422535E+07	675.30
0.86010	1.5427803E+04	1.0418005E+07	675.27
0.87064	1.5421686E+04	1.0413445E+07	675.25
0.88049	1.5416519E+04	1.0409555E+07	675.22
0.89029	1.5411736E+04	1.0405923E+07	675.19
0.90062	1.5496860E+04	1.0402204E+07	675.17
0.91043	1.5402219E+04	1.0398661E+07	675.14
0.92014	1.5397541E+04	1.0395092E+07	675.11
0.93032	1.5392543E+04	1.0391286E+07	675.09
0.94013	1.5387606E+04	1.0387534E+07	675.06
0.95020	1.5382356E+04	1.0383562E+07	675.03
0.96044	1.5376745E+04	1.0379341E+07	675.00
0.97022	1.5371025E+04	1.0375073E+07	674.98
0.98023	1.5364719E+04	1.0370408E+07	674.95
0.99000	1.5358118E+04	1.0365561E+07	674.92

TABLE 6.2.1-16 (Sheet 8)

Time (sec)	Mass Flow (lb/sec)	Energy Flow (Btu/sec)	Average Enthalpy (Btu/lb)
1.00924	1.5350854E+04	1.0360257E+07	674.90
1.05009	1.5319038E+04	1.0336848E+07	674.77
1.10020	1.5296400E+04	1.0318842E+07	674.64
1.15027	1.5270563E+04	1.0299964E+07	674.50
1.20066	1.5244981E+04	1.0280607E+07	674.36
1.25022	1.5225611E+04	1.0265425E+07	674.22
1.30001	1.5284826E+04	1.0249226E+07	674.08
1.35009	1.5181682E+04	1.0231482E+07	673.94
1.40043	1.5158958E+04	1.0214058E+07	673.80
1.45008	1.5135654E+04	1.0196263E+07	673.66
1.50052	1.5108628E+04	1.0175997E+07	673.52
1.55021	1.5082453E+04	1.0156373E+07	673.39
1.60001	1.5056220E+04	1.0136713E+07	673.26
1.65041	1.5029192E+04	1.0116506E+07	673.12
1.70053	1.5003251E+04	1.0097044E+07	672.99
1.75042	1.4978791E+04	1.0078568E+07	672.86
1.80000	1.4954574E+04	1.0060259E+07	672.72
1.85004	1.4910174E+04	1.0027829E+07	672.55
1.90038	1.4937494E+04	1.0045448E+07	672.50
1.95060	1.4846071E+04	9.9803806E+06	672.26
2.00032	1.4821804E+04	9.9621501E+06	672.13

TABLE 6.2.1-17 DELETED

TABLE 6.2.1-18 DELETED

TABLE 6.2.1-19 DELETED

TABLE 6.2.1-20 DELETED

TABLE 6.2.1-21 DELETED

TABLE 6.2.1-22 STEAM GENERATOR LOOP COMPARTMENT ANALYSIS

Node[a]	Net Volume (ft^3)	Peak Pressure[c] (psig)	Time to Peak Pressure (sec)	Break Case[b]	Design Pressure[c] (psig)
1	3962.5	8.911	9.800×10^{-2}	1	24.53
2	545.9	9.368	9.550×10^{-2}	1	24.53
3	828.1	9.895	5.550×10^{-2}	1	24.53
4	2452.8	7.522	5.500×10^{-2}	1	24.53
5	1957.1	15.864	3.700×10^{-2}	1	24.53
6	826.8	12.746	8.300×10^{-2}	2	24.53
7	231.7	27.321[d]	5.700×10^{-3}	3	24.53
8	2299.5	17.463	1.800×10^{-2}	1	24.53
9	4075.4	10.903	9.450×10^{-2}	1	24.53/13.03[e]
10	3452.2	13.219	1.600×10^{-2}	1	24.53/13.03
11	3294.4	8.868	4.800×10^{-2}	1	13.03
12	8144.3	8.397	1.000×10^{-1}	1	13.03
13	7912.9	3.475	1.000×10^{-1}	1	13.03
14	17788.0	-	1.000×10^{-1}	1	-[f]
15	23994.0	1.532	1.000×10^{-1}	1	24.53/13.03
16	2.5×10^6	-	1.000×10^{-1}	1	-
17	1677.5	8.667	9.950×10^{-2}	1	24.53
18	295.2	9.407	5.550×10^{-2}	1	24.53
19	184.7	9.058	7.400×10^{-2}	1	24.53
20	78.1	10.385	6.000×10^{-2}	1	24.53
21	734.4	10.754	5.950×10^{-2}	1	24.53
22	278.6	10.231	8.650×10^{-2}	1	24.53
23	639.0	12.078	3.300×10^{-2}	1	24.53
24	1303.4	10.202	3.000×10^{-2}	1	24.53/13.03
25	1165.1	9.984	9.200×10^{-2}	1	24.53/13.03
26	1167.7	8.464	1.000×10^{-1}	1	13.03
27	2976.2	8.282	1.000×10^{-1}	1	13.03
28	1385.1	6.160	8.700×10^{-2}	1	13.03
29	10860.2	1.638	1.000×10^{-1}	1	24.53/13.03

TABLE 6.2.1-22 (Sheet 2)

Node[a]	Net Volume (ft^3)	Peak Pressure[c] (psig)	Time to Peak Pressure (sec)	Break Case[b]	Design Pressure[c] (psig)
30	865.3	8.047	9.600×10^{-2}	1	17.96
31	2208.9	7.218	9.750×10^{-2}	1	17.96
32	679.5	12.049	6.600×10^{-2}	1	17.60
33	3152.0	10.210	8.050×10^{-2}	1	17.60
34	7706.7	9.307	9.300×10^{-2}	1	17.60
35	12006.6	8.987	9.300×10^{-2}	1	11.79
36	4206.6	6.765	9.850×10^{-2}	1	11.79
37	25571.4	1.792	1.000×10^{-1}	1	17.60
38	1578.0	5.610	9.150×10^{-2}	1	14.63
39	1862.0	8.236	9.550×10^{-2}	1	17.60
40	1920.6	8.254	8.500×10^{-2}	1	17.60
41	1920.6	7.723	9.750×10^{-2}	1	17.60
42	1862.0	8.054	9.150×10^{-2}	1	17.60
43	4008.7	1.154	1.000×10^{-1}	1	17.60
44	3824.0	1.150	1.000×10^{-1}	1	17.60
45	1621.8	4.662	8.650×10^{-2}	1	14.63
46	896.9	5.650	8.700×10^{-2}	1	11.79
47	979.4	5.520	8.050×10^{-2}	1	11.79
48	979.4	5.562	8.050×10^{-2}	1	11.79
49	896.9	5.489	8.100×10^{-2}	1	11.79
50	2011.7	0.702	1.000×10^{-1}	1	11.79
51	1904.3	0.705	1.000×10^{-1}	1	11.79
52	4543.7	1.842	9.900×10^{-2}	1	14.63
53	2234.9	-	7.550×10^{-2}	1	-[f]
54	2305.4	-	7.900×10^{-2}	1	-[f]
55	2305.4	-	7.900×10^{-2}	1	-[f]
56	2234.9	-	8.200×10^{-2}	1	-[f]
57	4811.4	-	1.000×10^{-1}	1	-[f]
58	4595.6	-	1.000×10^{-1}	1	-[f]
59	2601.5	9.825	8.750×10^{-2}	1	17.60

TABLE 6.2.1-22 (Sheet 3)

NOTES:

a Initial conditions for all nodes are identical:Temp = 120°F, press. = 16.2 psia, and relative humidity = 50%

b Break cases: 1 = 763 in.^{2} hot leg split
2 = 436 in.^{2} double-ended pump suction line break
3 = 236 in.^{2} double-ended cold leg break

c These are diffential pressures between the compartment and the remainder of the containment (Node 16).

d Structural model considered average pressure load over element (see nodes 3 and 7, Figure 6.2.1-43). Hence, resultant pressure on affected element does not exceed design pressure of 24.53 psig.

e Structural model divided at this node. Design pressure higher on affected half (24.53 psig), lower on non-affected half (13.03 psig).

f The compartments where no peak or design pressure is given are considered to be part of the containment with no walls between them and the containment on which a pressure differential could be exerted.

TABLE 6.2.1-23 STEAM GENERATOR LOOP COMPARTMENT ANALYSIS

Nodes		Vent Area	Head Loss Coefficients			Flow	
From	To	(Ft²)	$K_{contraction}$	$K_{expansion}$	$K_{friction}$	Coefficient	ℓ / a
1	2	205.87	0.32	1.0	0.0158	0.870	0.0447
1	3	80.75	0.40	1.0	0.052	0.830	0.2238
1	16	21.00	0.44	1.0	0.000	0.830	0.3667
I	17	207.00	0.05	1.0	0.0228	0.966	0.0476
2	3	126.23	0.09	1.0	0.01	0.950	0.0454
2	6	105.0	0.12	1.0	0.0142	0.938	0.0819
2	19	17.35	0.32	1.0	0.105	0.838	0.6821
3	4	42.00	0.00	1.0	0.08	0.980	0.500
3	7	65.00	0.20	1.0	0.025	0.903	0.0779
3	18	33.96	0.28	1.0	0.055	0.870	0.3485
4	7	26.30	0.00	1.0	0.103	0.950	0.9290
4	8	18.30	0.44	1.0	0.087	0.809	0.3128
4	15	86.60	0.00	1.0	0.087	0.960	0.2944
5	6	270.70	0.02	1.0	0.010	0.985	0.0516
5	9	177.20	0.02	1.0	0.027	0.980	0.0960
5	23	100.62	0.08	1.0	0.029	0.950	0.094
6	8	224.91	0.10	1.0	0.011	0.950	0.0322
6	22	41.91	0.20	1.0	0.060	0.891	0.2824
7	8	103.60	0.125	1.0	0.024	0.933	0.0736
7	20	6.2	0.35	1.0	0.202	0.800	1.909
8	10	189.0	0.050	1.0	0.025	0.960	0.0792
8	21	91.84	0.22	1.0	0.0352	0.890	0.1289
9	10	382.73	0.02	1.0	0.011	0.985	0.0286
9	11	177.20	0.02	1.0	0.027	0.980	0.1096
9	24	210.00	0.08	1.0	0.019	0.954	0.0455
10	12	190.00	0.05	1.0	0.037	0.960	0.0987
10	25	168.13	0.08	1.0	0.022	0.953	0.0704
11	12	266.50	0.02	1.0	0.019	0.980	0.0492
11	26	182.76	0.04	1.0	0.015	0.974	0.0571
12	13	247.30	0.27	1.0	0.066	0.865	0.056
12	16	102.00	0.38	1.0	0.0243	0.843	0.1862
12	27	477.66	0.05	1.0	0.012	0.970	0.0209
13	14	127.225	0.15	1.0	0.128	0.885	0.3868
13	15	131.00	0.17	1.0	0.066	0.865	0.1764
13	28	46.25	0.41	1.0	0.115	0.810	0.2560
15	16	204.00	0.38	1.0	0.216	0.790	0.1155
15	29	1334.00	0.05	1.0	0.009	0.970	0.009
17	18	31.68	0.40	1.0	0.084	0.820	0.125
17	19	59.85	0.42	1.0	0.041	0.845	0.1118
17	30	187.70	0.03	1.0	0.011	0.980	0.0298
18	19	37.34	0.22	1.0	0.019	0.898	0.1156
18	20	13.00	0.36	1.0	0.0246	0.850	0.1986
18	32	45.67	0.10	1.0	0.047	0.933	0.2976
19	32	17.35	0.32	1.0	0.105	0.838	0.7883
20	21	30.20	0.40	1.0	0.0425	0.833	0.2615
20	59	19.03	0.17	1.0	0.075	0.896	0.7141
21	22	50.88	0.28	1.0	0.021	0.877	0.0822
21	25	82.90	0.03	1.0	0.036	0.969	0.2015
21	59	64.45	0.08	1.0	0.040	0.940	0.2109

TABLE 6.2.1-23 (Sheet 2)

Nodes From	Nodes To	Vent Area (Ft²)	Head Loss Coefficients $K_{contraction}$	$K_{expansion}$	$K_{friction}$	Flow Coefficient	ℓ / a
22	23	72.30	0.15	1.0	0.013	0.927	0.1316
22	59	16.16	0.20	1.0	0.098	0.877	0.8410
22	23	34.34	0.08	1.0	0.111	0.916	0.3957
24	25	150.84	0.03	1.0	0.012	0.979	0.1086
24	26	35.15	0.28	1.0	0.047	0.868	0.2895
24	34	210.00	0.08	1.0	0.019	0.954	0.065
25	27	82.90	0.03	1.0	0.036	0.970	0.2516
25	34	207.55	0.08	1.0	0.022	0.960	0.0655
26	27	70.62	0.15	1.0	0.050	0.913	0.1250
26	35	182.76	0.04	1.0	0.974	0.974	0.0744
27	16	40.20	0.38	1.0	0.843	0.836	0.4747
27	28	99.39	0.27	1.0	0.066	0.865	0.1430
27	35	477.60	0.05	1.0	0.012	0.970	0.0285
28	29	98.94	0.17	1.0	0.066	0.865	0.4061
28	36	216.00	0.00	1.0	0.00	1.0	0.0629
29	16	80.40	0.38	1.0	0.207	0.794	0.2944
29	37	1334.00	0.05	1.0	0.009	0.970	0.0102
30	16	10.5	0.44	1.0	0.00	0.833	0.9606
30	31	147.00	0.10	1.0	0.023	0.944	0.0663
31	16	21.00	0.44	1.0	0.00	0.833	0.3939
31	38	102.00	0.12	1.0	0.0353	0.930	0.1489
32	59	215.30	0.12	1.0	0.043	0.927	0.0456
33	34	248.00	0.27	1.0	0.0224	0.880	0.0366
33	39	147.86	0.14	1.0	0.03	0.925	0.1185
33	59	415.12	0.00	1.0	0.00	1.00	0.0284
34	35	248.00	0.27	1.0	0.0224	0.880	0.064
34	40	149.30	0.08	1.0	0.028	0.950	0.1172
34	41	149.30	0.08	1.0	0.028	0.950	0.1172
35	16	0.00	-	-	-	-	-
35	36	300.30	0.02	1.0	0.0161	0.980	0.075
35	42	147.86	0.37	1.0	0.0379	0.843	0.1185
36	37	300.30	0.02	1.0	0.054	0.965	0.132
37	43	313.60	0.10	1.0	0.0137	0.948	0.0558
37	44	300.60	0.10	1.0	0.023	0.944	0.0582
38	45	102.00	0.00	1.0	0.0266	0.987	0.113
39	40	131.30	0.30	1.0	0.0253	0.869	0.0233
39	46	109.10	0.23	1.0	0.034	0.890	0.1062
40	47	119.00	0.20	1.0	0.0285	0.903	0.0974
41	42	131.30	0.30	1.0	0.0253	0.869	0.2330
41	48	119.00	0.20	1.0	0.0285	0.903	0.0974
42	49	109.10	0.23	1.0	0.034	0.890	0.1062
43	50	244.50	0.20	1.0	0.020	0.905	0.0474
44	51	231.50	0.23	1.0	0.020	0.894	0.0501
45	52	102.00	0.00	1.0	0.0361	0.982	0.1481
46	47	60.00	0.35	1.0	0.050	0.845	0.055
46	53	109.10	0.23	1.0	0.034	0.888	0.1195
47	48	125.90	0.12	1.0	0.0418	0.928	0.1896
47	54	119.00	0.20	1.0	0.0285	0.903	0.1096
48	49	60.00	0.35	1.0	0.050	0.845	0.055

TABLE 6.2.1-23 (Sheet 3)

Nodes From	Nodes To	Vent Area (Ft^2)	Head Loss Coefficients $K_{contraction}$	$K_{expansion}$	$K_{friction}$	Flow Coefficient	ℓ / a
48	55	119.00	0.20	1.0	0.0285	0.903	0.1096
49	56	109.10	0.23	1.0	0.034	0.888	0.1195
50	51	125.90	0.12	1.0	0.0418	0.928	0.1876
50	57	244.50	0.20	1.0	0.0534	0.904	0.0533
51	58	231.45	0.23	1.0	0.023	0.893	0.0563
53	54	160.85	0.30	1.0	0.026	0.868	0.0274
54	55	405.42	0.00	1.0	0.00	1.00	0.0344
55	56	160.85	0.30	1.0	0.026	0.868	0.0274
57	58	405.42	0.00	1.0	0.00	1.00	0.0632
19	22	29.00	0.27	1.0	0.031	0.877	0.2093
23	24	35.15	0.28	1.0	0.047	0.868	0.2895
23	33	100.62	0.08	1.0	0.029	0.950	0.1351
52	16	219.43	0.00	1.0	0.0	1.0	0.0494
53	16	183.56	0.00	1.0	0.0	1.0	0.0474
54	16	173.92	0.00	1.0	0.0	1.0	0.0500
55	16	173.92	0.00	1.0	0.0	1.0	0.0500
56	16	183.56	0.00	1.0	0.0	1.0	0.0474
57	16	372.24	0.00	1.0	0.0	1.0	0.0234
58	16	360.496	0.00	1.0	0.0	1.0	0.0241

TABLE 6.2.1-24 STEAM GENERATOR LOOP COMPARTMENT ANALYSIS

FORCE COEFFICIENTS FOR STEAM GENERATOR

Node	Force in E-W Direction	Force in N-S Direction	Uplift Force
5	-2251.36	-2141.19	3593.4
6	265.60	-1179.78	1283.6
8	2830.43	-1023.38	3454.85
9	-2254.31	2254.31	3712.23
10	1409.97	2090.03	2804.8
21	6905.60	-2496.80	------
22	648.00	-2878.40	------
23	-5492.80	-5224.00	------
24	-5500.00	5500.00	------
25	3440.00	5099.20	------
34	6206.70	-32208.78	------
35	-6206.70	32208.78	------
39	5075.58	-26115.66	5612.84
40	-5075.58	26115.66	4390.24
46	3430.96	-17651.92	------
47	-3430.96	17651.92	------
53	5781.17	-29743.49	-13689.8
54	-578l.17	29743.49	-10707.7

TABLE 6.2.1-25 STEAM GENERATOR LOOP COMPARTMENT ANALYSIS

FORCE COEFFICIENTS ON REACTOR COOLANT PUMP

Node	Force in E-W Direction	Force in N-S Direction	Uplift Force
2	-9311.58	-10347.0	1929.33
3	10404.0	-10404.0	2042.82
6	-10273.7	5519.62	1543.45
7	7356.74	3048.37	1021.41
8	1829.44	12241.12	1663.76
18	4082.04	-4082.04	
19	-3653.86	-4060.16	
20	2886.78	1196.04	
21	717.79	4803.0	
22	-4031.0	2165.90	
32	1311.4	-25029.30	-3949.45
59	-1311.4	25023.27	-4221.82

TABLE 6.2.1-26 PRESSURIZER COMPARTMENT ANALYSIS

Node[a]	Net Volume (ft^3)	Peak Pressure (psig)	Time to Peak Pressure (sec)	Design Pressure (psig)
1	3962	7.3	0.04	24.53
2	1374	5.8	0.04	24.53
3	2453	0.7	0.5	24.53
4	1677	12.0	0.014	24.53
5	480	4.3	0.07	24.53
6	865	12.2	0.014	17.96
7	2209	10.2	0.03	17.96
8	1578	8.1	0.04	14.63
9	1622	7.0	0.06	14.63
10	4544	0.9	0.5	14.63
11	2.6×10^6	-	0.5	-

a Initial conditions for all nodes are identical. Temp = 120°F, press. = 14.7 psia, and relative humidity = 50%.

TABLE 6.2.1-27 PRESSURIZER COMPARTMENT ANALYSIS

Nodes			Head Loss Coefficients				
From	To	Vent Area (Ft^2)	$K_{contraction}$	$K_{expansion}$	$K_{friction}$	Flow Coefficient	ℓ / a
1	2	286.62	0.25	1.0	0.0134	0.89	0.034
1	4	207.00	0.05	1.0	0.0228	0.966	0.0476
2	3	42.00	0.25	1.0	0.080	0.0867	0.500
2	5	51.31	0.27	1.0	0.160	0.838	0.5153
2	11	170.00	0.28	1.0	0.039	0.8707	0.001
3	11	216.50	0.00	1.0	0.00	1.00	0.001
4	5	91.53	0.30	1.0	0.0253	0.869	0.0866
4	6	187.70	0.03	1.0	0.011	0.980	0.0298
5	11	105.02	0.00	1.0	0.00	1.00	0.001
6	7	147.00	0.10	1.0	0.023	0.944	0.0663
6	11	10.5	0.44	1.0	0.00	0.833	0.9606
7	8	102.00	0.12	1.0	0.0353	0.93	0.1489
7	11	21.00	0.44	1.0	0.00	0.833	0.3939
8	9	102.00	0.00	1.0	0.0266	0.987	0.113
9	10	102.00	0.00	1.0	0.0361	0.982	0.1481
10	11	219.43	0.00	1.0	0.00	1.00	0.001

TABLE 6.2.1-28 DOUBLE-ENDED HOT LEG BREAK BLOWDOWN
MASS AND ENERGY RELEASES
CALLAWAY NUCLEAR PLANT
UTILIZING THE REPLACEMENT STEAM GENERATOR

TIME	BREAK PATH NO.1 FLOW*		BREAK PATH NO.2 FLOW**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
0.00	0.00	0.00	0.00	0.00
0.00108	47327.0	30634.1	47325.1	30631.5
0.00209	46756.2	30262.6	46414.6	30034.7
0.101	43590.2	28478.6	28097.5	18148.5
0.202	36676.8	23947.0	24831.3	15940.4
0.302	35441.3	23110.2	22462.6	14261.5
0.401	34451.3	22462.8	21290.5	13338.7
0.502	33857.5	22080.6	20561.7	12713.1
0.601	33786.1	22043.8	20042.6	12247.7
0.702	33464.5	21875.8	19629.9	11870.7
0.801	32822.2	21522.8	19351.8	11599.7
0.901	32180.1	21187.4	19100.1	11361.5
1.00	31690.9	20967.2	18912.1	11175.4
1.10	31443.6	20916.6	18731.9	11007.4
1.20	31116.2	20810.5	18603.0	10876.9
1.30	30655.7	20606.8	18495.9	10767.2
1.40	30067.9	20308.9	18426.8	10684.2
1.50	29501.3	20011.8	18392.1	10625.6
1.60	29066.5	19797.2	18387.1	10587.1
1.70	28728.3	19645.9	18405.9	10565.2
1.80	28333.4	19451.3	18438.0	10553.4
1.90	27790.4	19144.3	18472.6	10545.2
2.00	27185.1	18781.3	18505.8	10538.8
2.10	26648.8	18462.3	18540.3	10535.3
2.20	26243.9	18238.1	18577.8	10535.6
2.30	25868.9	18032.4	18610.9	10535.8
2.40	25419.8	17761.8	18636.2	10533.8
2.50	24942.8	17458.5	18650.5	10527.7
2.60	24514.4	17185.2	18657.7	10519.7
2.70	24138.7	16946.6	18656.9	10508.9
2.80	23790.8	16722.3	18646.6	10494.7
2.90	23468.6	16511.1	18625.1	10475.8
3.00	23161.7	16304.1	18594.0	10453.0
3.10	22860.4	16091.9	18551.7	10425.2
3.20	22591.0	15897.1	18497.9	10392.1
3.30	22361.7	15728.4	18436.2	10355.8
3.40	22143.7	15561.7	18364.9	10315.0
3.50	21945.6	15403.6	18283.8	10269.6
3.60	21779.1	15265.5	18193.1	10219.5
3.70	21625.6	15132.7	18093.4	10165.1

TABLE 6.2.1-28 (Sheet 2)

TIME	BREAK PATH NO.1 FLOW*		BREAK PATH NO.2 FLOW**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
3.80	21484.9	15004.6	17981.5	10104.3
3.90	21369.9	14892.7	17856.1	10036.5
4.00	21267.9	14788.3	17724.2	9965.6
4.20	21103.8	14603.3	17452.5	9820.5
4.40	20990.2	14452.3	17170.6	9670.7
4.60	20939.8	14346.0	16880.8	9517.3
4.80	20912.2	14261.0	16591.1	9364.3
5.00	20880.7	14184.9	16301.3	9211.3
5.20	20885.1	14141.2	16021.8	9064.5
5.40	20894.0	14098.1	15728.5	8909.7
5.60	20971.0	14079.1	15409.0	8739.9
5.80	21106.7	14076.7	15106.2	8580.5
6.00	21306.7	14108.9	14807.7	8424.0
6.20	21548.7	14155.3	14500.8	8262.8
6.40	21874.8	14243.2	14209.1	8110.8
6.60	22320.6	14405.8	13906.4	7952.8
6.80	16838.5	11874.1	13589.7	7786.1
7.00	16975.8	11846.3	13269.9	7618.0
7.20	17162.5	11858.9	12965.3	7458.5
7.40	17291.2	11854.5	12676.3	7307.7
7.60	17434.2	11866.2	12375.1	7149.0
7.80	17620.1	11941.0	12086.9	6997.5
8.00	17785.1	11968.2	11808.3	6850.8
8.20	17919.2	11980.4	11537.2	6707.7
8.40	18026.9	11976.4	11272.0	6567.5
8.60	18163.0	11987.3	11012.9	6429.9
8.80	18298.9	11998.0	10761.9	6296.5
9.00	18114.2	11851.0	10519.5	6167.5
9.20	18328.2	11913.6	10284.3	6042.3
9.40	18604.2	12014.5	10056.9	5921.2
9.60	18941.8	12150.0	9834.3	5803.0
9.80	19512.4	12419.2	9620.2	5689.3
10.0	20402.9	12922.0	9407.8	5576.7
10.2	21071.6	13314.8	9199.3	5466.2
10.4	27590.1	17421.0	8992.9	5357.0
10.6	26092.3	16388.7	8774.9	5241.6
10.8	25433.6	15882.4	8555.4	5126.0
11.0	25114.1	15605.5	8305.9	4993.4
11.2	23758.2	14717.2	8048.0	4858.8
11.4	23365.8	14455.1	7782.6	4722.0
11.6	23164.2	14330.1	7517.0	4588.3
11.8	23012.2	14253.5	7252.9	4457.8

TABLE 6.2.1-28 (Sheet 3)

TIME (sec)	BREAK PATH NO.1 FLOW* (lbm/sec)	BREAK PATH NO.1 FLOW* Thousand (Btu/sec)	BREAK PATH NO.2 FLOW** (lbm/sec)	BREAK PATH NO.2 FLOW** Thousand (Btu/sec)
12.0	22722.6	14081.7	6997.3	4333.9
12.2	22450.0	13903.3	6750.6	4215.9
12.4	22163.6	13725.9	6513.8	4104.0
12.6	21878.8	13554.4	6289.2	3998.6
12.8	21510.7	13346.1	6076.7	3899.3
13.0	21131.0	13141.6	5874.5	3805.1
13.2	14555.1	8923.5	5674.6	3710.4
13.4	10969.2	7503.6	5511.2	3637.1
13.6	10387.3	7181.0	5338.0	3555.8
13.8	10620.9	7282.8	5197.5	3493.6
14.0	10694.2	7321.8	5088.9	3444.5
14.2	10717.1	7356.4	5000.3	3400.6
14.4	10652.2	7355.6	4932.8	3361.8
14.6	10543.9	7343.4	4879.2	3326.2
14.8	10389.9	7309.0	4834.3	3293.2
15.0	10212.6	7262.1	4791.5	3261.3
15.2	10006.9	7194.4	4742.6	3227.1
15.4	9767.9	7104.1	4679.4	3187.3
15.6	9495.4	6990.6	4598.0	3141.2
15.8	9178.3	6848.8	4493.3	3087.1
16.0	8823.6	6685.0	4363.9	3024.7
16.2	8449.5	6511.3	4212.0	2955.0
16.4	8042.4	6224.8	4044.5	2880.4
16.6	7293.1	5839.6	3867.5	2802.5
16.8	6249.1	5537.8	3684.0	2719.5
17.0	5618.9	5270.6	3502.8	2635.6
17.2	5213.8	5006.8	3330.7	2555.9
17.4	4916.3	4759.4	3164.3	2479.5
17.6	4652.1	4538.0	3006.7	2408.8
17.8	4386.7	4326.4	2856.9	2343.5
18.0	4089.2	4104.3	2712.3	2281.7
18.2	3784.2	3855.2	2572.4	2223.7
18.4	3450.3	3608.7	2438.4	2169.2
18.6	3126.3	3375.6	2308.5	2114.7
18.8	2803.3	3143.8	2176.6	2063.9
19.0	2531.8	2933.8	2040.8	2014.7
19.2	2362.9	2795.6	1902.7	1971.0
19.4	2233.0	2659.6	1756.5	1922.0
19.6	2115.6	2525.9	1620.0	1863.3
19.8	1982.4	2375.0	1512.8	1793.9
20.0	1886.9	2269.0	1417.4	1712.6
20.2	1779.1	2136.5	1352.2	1643.7

TABLE 6.2.1-28 (Sheet 4)

TIME	BREAK PATH NO.1 FLOW*		BREAK PATH NO.2 FLOW**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
20.4	1659.3	2002.6	1300.6	1586.3
20.6	1532.6	1861.9	1242.5	1521.5
20.8	1439.1	1755.1	1166.5	1435.9
21.0	1336.5	1634.6	1050.9	1298.5
21.2	1250.4	1537.0	938.1	1162.8
21.4	1173.6	1445.8	839.6	1042.7
21.6	789.1	984.3	718.6	893.7
21.8	496.2	617.8	540.1	672.6
22.0	279.8	345.5	340.4	425.3
22.2	106.9	130.7	267.6	336.9
22.4	.0	.0	144.7	181.9
22.6	.0	.0	166.5	213.6
22.7	.0	.0	.0	.0

* mass and energy exiting from the reactor vessel side of the break.

** mass and energy exiting from the SG side of the break.

TABLE 6.2.1-29 DOUBLE-ENDED HOT LEG BREAK MASS BALANCE CALLAWAY NUCLEAR PLANT UTILIZING THE REPLACEMENT STEAM GENERATOR

Time (Seconds)		.00	22.71	22.71+δ
		Mass (Thousand lbm)		
Initial	In RCS and ACC	807.4	807.4	807.4
Added Mass	Pumped Injection	.00	.00	.00
	Total Added	.00	.00	.00
*** TOTAL AVAILABLE ***		807.4	807.4	807.4
Distribution	Reactor Coolant	580.70	67.99	97.93
	Accumulator	226.70	178.99	149.05
	Total Contents	807.40	246.98	246.98
Effluent	Break Flow	.00	564.00	564.00
	ECCS Spill	.00	.00	.00
	Total Effluent	.00	564.00	564.00
*** TOTAL ACCOUNTABLE ***		807.40	807.38	807.38

TABLE 6.2.1-30 DOUBLE-ENDED HOT LEG BREAK ENERGY BALANCE CALLAWAY NUCLEAR PLANT UTILIZING THE REPLACEMENT STEAM GENERATOR

Time (Seconds)		.00	22.71	22.71+δ
		Energy (Million Btu)		
Initial Energy	In RCS, ACC, S GEN	957.73	957.73	957.73
Added Energy	Pumped Injection	.00	.00	.00
	Decay Heat	.00	8.14	8.14
	Heat From Secondary	.00	-1.67	-1.67
	Total Added	.00	6.47	6.47
*** TOTAL AVAILABLE ***		957.73	964.20	964.20
Distribution	Reactor Coolant	343.94	19.10	21.78
	Accumulator	20.29	16.02	13.34
	Core Stored	24.40	9.52	9.52
	Primary Metal	158.77	148.85	148.85
	Secondary Metal	106.08	103.46	103.46
	Steam Generator	304.25	299.08	299.08
	Total Contents	957.73	596.03	596.03
Effluent	Break Flow	.00	367.57	367.57
	ECCS Spill	.00	.00	.00
	Total Effluent	.00	367.57	367.57
*** TOTAL ACCOUNTABLE ***		957.73	963.60	963.60

TABLE 6.2.1-31 DOUBLE-ENDED PUMP SUCTION BREAK MINIMUM
ECCS FLOWS BLOWDOWN MASS AND ENERGY RELEASES
CALLAWAY NUCLEAR PLANT
UTILIZING THE REPLACEMENT STEAM GENERATOR

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
		Thousand		Thousand
(sec)	(lbm/sec)	(Btu/sec)	(lbm/sec)	(Btu/sec)
.00000	.0	.0	.0	.0
.00108	92747.0	51728.2	42543.9	23666.8
.101	42397.9	23637.4	21839.9	12137.7
.201	47597.6	26658.5	24081.2	13393.7
.302	46883.3	26403.1	24213.0	13478.1
.401	46469.1	26339.0	23444.3	13061.6
.501	46600.6	26611.4	22316.4	12441.3
.602	46049.9	26514.4	21364.4	11915.1
.702	45631.8	26491.1	20533.4	11454.0
.801	45786.2	26786.9	19898.3	11101.7
.901	45606.6	26877.8	19442.4	10851.1
1.00	45030.6	26719.9	19191.4	10713.6
1.10	44174.9	26384.7	19035.9	10628.7
1.20	43316.6	26039.2	18949.3	10581.4
1.30	42508.0	25719.4	18895.2	10551.8
1.40	41759.4	25428.6	18862.0	10533.4
1.50	41030.4	25146.4	18848.9	10526.1
1.60	40309.2	24865.0	18856.6	10530.5
1.70	39575.8	24575.4	18875.0	10540.9
1.80	38815.7	24273.1	18884.7	10546.4
1.90	37987.7	23936.8	18875.1	10540.9
2.00	37079.7	23557.0	18857.4	10531.0
2.10	36087.0	23131.7	18833.1	10517.5
2.20	35017.9	22664.6	18781.4	10488.8
2.30	33912.8	22176.5	18699.7	10443.4
2.40	32709.4	21619.9	18575.6	10374.3
2.50	31519.2	21060.5	18415.8	10285.1
2.60	30313.7	20476.6	17979.6	10040.4
2.70	28949.3	19761.8	17748.3	9912.6
2.80	26126.6	17994.6	17572.7	9815.7
2.90	23995.9	16691.7	17367.2	9701.6
3.00	22657.5	15913.1	17150.9	9581.6
3.10	21304.0	15074.3	16960.4	9476.5
3.20	20176.2	14366.5	16786.1	9380.6

TABLE 6.2.1-31 (Sheet 2)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
3.30	19261.4	13789.2	16607.6	9282.4
3.40	18440.7	13262.5	16445.8	9193.7
3.50	17737.6	12809.1	16298.5	9113.1
3.60	17131.0	12416.9	16155.7	9035.1
3.70	16596.3	12068.8	16013.8	8957.5
3.80	16130.3	11764.4	15887.2	8888.7
3.90	15733.3	11504.6	15769.1	8824.7
4.00	15388.7	11277.2	15652.0	8761.2
4.20	14798.5	10877.7	15425.9	8638.7
4.40	14340.2	10559.0	15225.6	8530.8
4.60	13977.0	10292.4	15019.2	8419.6
4.80	13698.7	10075.8	14823.5	8314.6
5.00	13484.9	9894.8	14626.7	8208.9
5.20	13336.3	9752.7	14279.5	8019.2
5.40	13241.2	9642.1	15977.5	8980.8
5.60	13185.2	9555.0	15809.1	8889.2
5.80	13204.7	9518.6	15527.2	8735.5
6.00	13257.5	9501.6	15442.7	8692.9
6.20	13326.4	9497.7	15270.4	8600.5
6.40	13411.5	9507.3	15109.8	8515.4
6.60	13500.8	9521.4	14961.7	8436.7
6.80	13581.4	9532.5	14789.5	8343.6
7.00	13640.5	9532.8	14601.9	8241.0
7.20	13675.0	9522.5	14447.3	8156.5
7.40	13879.8	9630.8	14382.0	8121.4
7.60	13641.4	9465.7	14424.4	8145.6
7.80	13339.5	9495.8	14202.2	8016.1
8.00	12169.1	9080.6	13990.7	7894.9
8.20	11452.0	8757.4	13891.5	7839.8
8.40	11343.5	8676.1	13722.2	7744.6
8.60	11408.6	8657.5	13547.8	7645.3
8.80	11516.9	8654.5	13372.0	7545.1
9.00	11673.5	8678.5	13195.8	7445.1
9.20	11868.1	8720.4	13032.0	7351.7
9.40	12054.8	8750.5	12852.0	7248.8
9.60	12217.3	8768.2	12684.9	7153.6

TABLE 6.2.1-31 (Sheet 3)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
9.80	12336.2	8762.5	12526.3	7063.0
10.0	12369.2	8708.0	12368.2	6972.4
10.2	12313.4	8607.6	12221.6	6888.5
10.4	12196.0	8479.8	12083.8	6809.5
10.6	12017.7	8323.0	11950.2	6732.7
10.8	11753.2	8120.4	11830.5	6663.9
11.0	11432.3	7895.9	11725.9	6603.5
11.2	11159.1	7716.4	11615.8	6539.8
11.4	10948.8	7582.8	11500.5	6473.3
11.6	10728.0	7442.3	11396.8	6413.9
11.8	10492.8	7296.6	11299.3	6357.9
12.0	10301.6	7183.5	11185.9	6292.7
12.2	10126.7	7076.3	11079.6	6231.9
12.4	9917.3	6943.6	10989.2	6180.3
12.6	9726.4	6827.8	10885.4	6120.5
12.8	9564.7	6731.0	10781.3	6060.9
13.0	9376.8	6614.3	10696.5	6012.4
13.2	9199.6	6508.7	10598.0	5955.8
13.4	9047.5	6420.1	10500.3	5899.7
13.6	8880.6	6318.8	10416.8	5852.1
13.8	8723.6	6225.6	10321.8	5797.7
14.0	8575.8	6138.4	10233.6	5747.5
14.2	8432.1	6053.4	10145.3	5697.3
14.4	8299.6	5975.5	10053.1	5645.1
14.6	8164.0	5893.6	9955.4	5590.2
14.8	8020.8	5806.0	9846.5	5529.4
15.0	7869.9	5713.4	9727.6	5463.7
15.2	7707.6	5611.6	9613.3	5401.3
15.4	7551.4	5510.0	9500.8	5340.1
15.6	7411.2	5412.6	9400.4	5285.6
15.8	7294.8	5325.8	9303.3	5232.7
16.0	7198.5	5250.0	9212.1	5183.3
16.2	7114.0	5183.2	9123.1	5135.9
16.4	7032.8	5121.2	9036.9	5090.7
16.6	6950.8	5062.0	8952.1	5047.2
16.8	6867.0	5005.5	8868.2	5005.0

TABLE 6.2.1-31 (Sheet 4)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
17.0	6780.7	4951.4	8785.5	4964.5
17.2	6691.5	4899.7	8702.9	4925.3
17.4	6598.8	4850.3	8619.4	4886.9
17.6	6504.5	4804.1	8532.4	4847.9
17.8	6406.8	4759.4	8411.6	4784.1
18.0	6304.4	4714.4	8315.9	4717.2
18.2	6200.0	4671.9	8247.0	4647.2
18.4	6091.9	4631.0	8211.7	4580.9
18.6	5976.4	4590.2	8201.4	4518.8
18.8	5853.5	4548.4	8140.9	4427.5
19.0	5724.4	4507.0	8095.9	4348.5
19.2	5588.9	4464.8	7977.8	4237.0
19.4	5455.5	4427.7	7833.4	4125.5
19.6	5363.5	4422.9	7523.9	3957.0
19.8	5271.8	4448.2	7131.5	3754.2
20.0	4981.5	4449.7	6659.4	3494.2
20.2	4449.0	4360.5	6263.2	3286.8
20.4	3897.2	4212.2	5840.2	3090.5
20.6	3415.3	3999.1	5388.1	2882.1
20.8	3067.6	3742.9	4721.4	2445.9
21.0	2767.0	3410.0	4512.2	2174.5
21.2	2539.3	3143.5	4410.1	2003.7
21.4	2343.4	2910.2	4172.6	1813.5
21.6	2155.0	2682.8	4430.0	1852.8
21.8	1953.5	2438.1	5393.8	2207.2
22.0	1775.9	2222.2	4998.9	2027.0
22.2	1641.5	2058.4	3665.2	1476.6
22.4	1530.8	1923.0	3241.9	1303.2
22.6	1425.6	1793.2	2404.5	958.1
22.8	1312.3	1652.8	2005.0	748.1
23.0	1185.5	1495.1	4223.0	1416.6
23.2	1039.5	1313.6	6210.7	2013.0
23.4	916.6	1159.7	5077.4	1632.4
23.6	804.3	1018.6	4276.4	1368.0
23.8	702.3	890.2	3493.1	1110.5
24.0	614.1	779.0	2961.9	933.4

TABLE 6.2.1-31 (Sheet 5)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
24.2	542.9	689.3	2522.9	785.7
24.4	491.7	624.6	2100.0	645.0
24.6	461.3	586.3	1642.4	497.6
24.8	427.9	544.2	1130.1	338.4
25.0	377.0	479.6	564.5	167.8
25.2	322.7	410.7	33.2	9.9
25.4	265.4	338.1	.0	.0
25.6	203.8	259.7	.0	.0
25.8	141.1	180.1	.0	.0
26.0	85.2	109.0	.0	.0
26.2	.0	.0	.0	.0

* Mass and energy exiting the SG side of the break.

** Mass and energy exiting the pump side of the break.

TABLE 6.2.1-32 DOUBLE-ENDED PUMP SUCTION BREAK MINIMUM SAFEGUARDS REFLOOD MASS AND ENERGY RELEASES CALLAWAY NUCLEAR PLANT UTILIZING THE REPLACEMENT STEAM GENERATOR

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
26.2	.0	.0	.0	.0
26.8	.0	.0	.0	.0
26.9	.0	.0	.0	.0
27.0	.0	.0	.0	.0
27.1	.0	.0	.0	.0
27.2	.0	.0	.0	.0
27.2	.0	.0	.0	.0
27.3	91.6	108.3	.0	.0
27.4	40.1	47.4	.0	.0
27.6	28.2	33.3	.0	.0
27.7	32.3	38.2	.0	.0
27.8	40.9	48.4	.0	.0
27.9	47.1	55.7	.0	.0
28.0	54.3	64.1	.0	.0
28.1	59.5	70.4	.0	.0
28.2	64.5	76.3	.0	.0
28.3	69.3	81.8	.0	.0
28.4	73.7	87.1	.0	.0
28.4	74.8	88.4	.0	.0
28.5	78.0	92.2	.0	.0
28.6	82.2	97.1	.0	.0
28.7	86.1	101.8	.0	.0
28.8	90.0	106.3	.0	.0
28.9	93.7	110.7	.0	.0
29.0	97.3	115.0	.0	.0
29.1	100.8	119.1	.0	.0
29.2	104.2	123.1	.0	.0
29.3	107.5	127.1	.0	.0
30.3	136.8	161.7	.0	.0
31.3	161.2	190.6	.0	.0
32.3	377.6	447.7	3293.8	473.0
32.6	460.3	546.4	4134.5	603.3
33.3	508.0	603.6	4536.0	693.6
34.3	502.1	596.6	4484.6	691.9

TABLE 6.2.1-32 (Sheet 2)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
		Thousand		Thousand
(sec)	(lbm/sec)	(Btu/sec)	(lbm/sec)	(Btu/sec)
35.3	493.0	585.6	4405.3	693.7
36.3	483.5	574.2	4321.9	674.7
36.7	479.7	569.7	4288.2	671.0
37.3	474.1	563.0	4237.9	665.4
38.3	464.9	552.0	4154.9	656.0
39.3	455.9	541.3	4073.7	646.7
40.3	447.3	531.0	3994.5	637.7
41.3	439.0	521.1	3917.7	628.8
41.9	434.2	515.3	3872.6	623.6
42.3	431.0	511.5	3843.1	620.2
43.3	423.4	502.4	3770.7	611.8
44.3	416.0	493.5	3700.6	603.6
45.3	408.8	485.0	3632.6	595.7
46.3	402.0	476.9	3566.7	587.9
47.3	395.4	469.0	3502.7	580.4
47.9	391.5	464.4	3465.2	576.0
48.3	389.0	461.4	3440.5	573.1
49.3	418.0	496.0	3744.6	592.0
50.3	412.1	488.9	3688.5	585.2
51.3	406.4	482.1	3633.9	578.6
52.3	400.9	475.6	3580.8	572.2
53.3	335.0	397.1	2840.2	500.4
54.3	326.3	386.7	2808.6	488.1
54.4	325.9	386.2	2804.5	487.6
55.3	439.8	521.7	322.4	234.3
56.3	504.4	599.3	350.3	272.6
57.3	491.2	583.4	344.3	264.8
58.3	474.9	564.0	337.0	255.2
59.3	460.0	546.1	330.3	246.5
60.3	446.0	529.4	324.1	238.3
61.3	432.5	513.2	318.1	230.4
62.3	419.4	497.7	312.4	222.9
63.3	406.9	482.8	306.8	215.7
64.3	394.9	468.4	301.5	208.9
65.3	383.3	454.5	296.4	202.3
66.3	372.1	441.2	291.6	196.0

TABLE 6.2.1-32 (Sheet 3)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
67.3	361.4	428.4	286.9	189.9
67.4	360.3	427.2	286.4	189.3
68.3	351.1	416.1	282.4	184.1
69.3	341.2	404.3	278.1	178.6
70.3	331.7	393.0	274.0	173.4
71.3	322.5	382.2	270.1	168.3
72.3	313.8	371.7	266.4	163.5
73.3	305.4	361.8	262.8	158.9
74.3	297.3	352.2	259.4	154.6
75.3	289.6	343.0	256.1	150.4
76.3	282.2	334.2	253.0	146.4
77.3	275.2	325.8	250.0	142.6
78.3	268.4	317.8	247.2	139.0
79.3	261.9	310.1	244.5	135.6
80.3	255.8	302.8	241.9	132.4
81.3	249.8	295.8	239.4	129.3
82.3	244.2	289.0	237.1	126.3
83.3	238.8	282.7	234.9	123.5
84.3	233.7	276.6	232.8	120.9
85.2	229.3	271.3	231.0	118.6
85.3	228.8	270.8	230.8	118.3
86.3	224.1	265.2	228.9	116.0
87.3	219.7	260.0	227.1	113.7
89.3	211.5	250.2	223.8	109.5
91.3	204.1	241.5	220.8	105.8
93.3	197.4	233.6	218.2	102.5
95.3	191.5	226.5	215.8	99.6
97.3	186.2	220.2	213.8	97.0
99.3	181.5	214.7	211.9	94.7
101.3	177.3	209.7	210.3	92.6
103.3	173.6	205.3	208.9	90.9
105.3	170.4	201.5	207.6	89.3
107.3	167.5	198.1	206.5	87.9
108.8	165.6	195.9	205.8	87.0
109.3	165.0	195.2	205.6	86.7
111.3	162.9	192.7	204.7	85.7

TABLE 6.2.1-32 (Sheet 4)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
113.3	161.1	190.5	204.0	84.8
115.3	159.5	188.6	203.4	84.1
117.3	158.1	187.0	202.9	83.4
119.3	157.0	185.7	202.4	82.9
121.3	156.1	184.6	202.1	82.4
123.3	155.3	183.6	201.8	82.0
125.3	154.7	182.9	201.5	81.7
127.3	154.2	182.3	201.3	81.4
129.3	153.8	181.8	201.1	81.2
131.3	153.5	181.5	201.0	81.0
133.3	153.3	181.3	200.9	80.9
135.3	153.2	181.1	200.8	80.8
136.0	153.2	181.1	200.8	80.8
137.3	153.1	181.1	200.8	80.8
139.3	153.2	181.1	200.7	80.7
141.3	153.2	181.2	200.7	80.7
143.3	153.3	181.3	200.8	80.7
145.3	153.5	181.5	200.8	80.8
147.3	153.7	181.7	200.8	80.8
149.3	153.9	182.0	200.9	80.9
151.3	154.1	182.3	200.9	81.0
153.3	154.4	182.5	201.0	81.0
155.3	154.6	182.8	201.0	81.1
157.3	154.9	183.2	201.1	81.2
159.3	155.2	183.5	201.2	81.3
161.3	155.5	183.9	201.3	81.4
163.3	155.8	184.3	201.4	81.5
164.7	156.1	184.5	201.4	81.6
165.3	156.2	184.7	201.5	81.6
167.3	156.5	185.1	201.6	81.7
169.3	156.8	185.5	201.6	81.9
171.3	157.2	185.9	201.7	82.0
173.3	157.5	186.3	201.8	82.1
175.3	157.9	186.7	202.0	82.2
177.3	158.3	187.1	202.1	82.4
179.3	158.6	187.6	202.2	82.5

TABLE 6.2.1-32 (Sheet 5)

Time	Break Path No.1 Flow*		Break Path No.2 Flow**	
(sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
181.3	159.0	188.0	202.3	82.6
183.3	159.4	188.5	202.4	82.8
185.3	159.7	188.9	202.5	82.9
187.3	160.1	189.3	202.6	83.0
189.3	160.5	189.8	202.7	83.2
191.3	160.9	190.3	202.8	83.3
193.3	161.3	190.7	202.9	83.5
194.3	161.5	191.0	203.0	83.5

* Mass and energy exiting the SG side of the break.

** Mass and energy exiting the pump side of the break.

TABLE 6.2.1-33 DOUBLE-ENDED PUMP SUCTION BREAK – MINIMUM SAFEGUARDS PRINCIPLE PARAMETERS DURING REFLOOD UTILIZING THE REPLACEMENT STEAM GENERATOR

	Flooding						Injection			
Time Seconds	Temp (°F)	Rate (in/sec)	Carryover Fraction (---)	Core Height (Feet)	Downcomer Height (Feet)	Flow Fraction (---)	Total (Pounds Mass Per Second)	Accum	Spill	Enthalpy Btu/Lbm
26.2	180.0	.000	.000	.00	.00	.250	.0	.0	.0	.00
27.0	177.4	21.916	.000	.63	1.55	.000	7657.4	7657.4	.0	89.50
27.2	176.0	24.273	.000	1.01	1.45	.000	7603.2	7603.2	.0	89.50
27.6	175.1	2.960	.132	1.35	2.07	.261	7478.5	7478.5	.0	89.50
27.7	175.1	3.025	.153	1.37	2.38	.263	7452.9	7452.9	.0	89.50
28.4	175.0	2.766	.298	1.50	4.64	.334	7261.8	7261.8	.0	89.50
29.2	175.0	2.695	.405	1.61	7.06	.353	7082.5	7082.5	.0	89.50
32.6	175.4	4.699	.626	2.01	16.07	.588	5957.6	5957.6	.0	89.50
33.3	175.5	4.834	.653	2.11	16.12	.593	5703.3	5703.3	.0	89.50
34.3	175.7	4.625	.676	2.24	16.12	.591	5548.4	5548.4	.0	89.50
36.7	176.4	4.286	.705	2.51	16.12	.585	5240.2	5240.2	.0	89.50
41.9	178.6	3.865	.727	3.00	16.12	.570	4699.2	4699.2	.0	89.50
47.9	181.8	3.555	.735	3.50	16.12	.553	4205.1	4205.1	.0	89.50
48.3	182.1	3.537	.735	3.53	16.12	.552	4175.8	4175.8	.0	89.50
49.3	182.7	3.677	.737	3.61	16.12	.569	4522.3	3993.4	.0	86.99
54.4	185.9	3.152	.736	4.00	16.12	.518	3432.6	2886.7	.0	86.09
55.3	186.5	3.801	.741	4.07	16.03	.602	528.5	.0	.0	68.03
56.3	187.3	4.104	.743	4.15	15.70	.610	510.1	.0	.0	68.03
61.3	191.7	3.573	.742	4.56	14.18	.601	524.0	.0	.0	68.03
67.4	197.7	3.055	.739	5.00	12.82	.589	536.5	.0	.0	68.03
76.3	207.1	2.501	.733	5.54	11.58	.567	548.0	.0	.0	68.03
85.2	216.6	2.129	.729	6.00	10.96	.545	554.5	.0	.0	68.03
97.3	227.9	1.827	.725	6.54	10.73	.519	559.0	.0	.0	68.03

TABLE 6.2.1-33 (Sheet 2)

	Flooding						Injection			
Time	Temp	Rate	Carryover Fraction	Core Height	Downcomer Height	Flow Fraction	Total	Accum	Spill	Enthalpy
Seconds	(°F)	(in/sec)	(---)	(Feet)	(Feet)	(---)	(Pounds Mass Per Second)			Btu/Lbm
108.8	236.6	1.681	.725	7.00	10.89	.502	560.9	.0	.0	68.03
123.3	245.9	1.603	.727	7.54	11.33	.493	561.8	.0	.0	68.03
136.0	253.0	1.580	.730	8.00	11.81	.491	562.0	.0	.0	68.03
149.3	259.5	1.575	.734	8.47	12.34	.492	562.0	.0	.0	68.03
151.3	260.5	1.575	.735	8.54	12.42	.492	562.0	.0	.0	68.03
164.7	266.3	1.578	.739	9.00	12.96	.494	561.8	.0	.0	68.03
181.3	272.6	1.584	.745	9.57	13.62	.498	561.7	.0	.0	68.03
194.3	277.1	1.591	.750	10.00	14.13	.500	561.5	.0	.0	68.03

TABLE 6.2.1-34 DOUBLE-ENDED PUMP SUCTION BREAK MINIMUM SAFEGUARDS POST-REFLOOD MASS AND ENERGY RELEASES UTILIZING THE REPLACEMENT STEAM GENERATOR

TIME	BREAK PATH NO.1 FLOW*		BREAK PATH NO.2 FLOW**	
(Sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
194.3	232.1	290.3	335.1	134.4
199.3	232.0	290.1	335.2	134.2
204.3	232.0	290.2	335.1	134.0
209.3	231.0	288.9	336.2	134.0
214.3	231.0	289.0	336.1	133.8
219.3	230.0	287.6	337.2	133.8
224.3	230.0	287.7	337.2	133.6
229.3	230.0	287.7	337.2	133.3
234.3	228.9	286.3	338.3	133.4
239.3	228.8	286.2	338.3	133.2
244.3	228.8	286.2	338.4	132.9
249.3	227.6	284.7	339.6	133.0
254.3	227.5	284.5	339.7	132.8
259.3	227.4	284.4	339.8	132.6
264.3	226.1	282.8	341.1	132.7
269.3	225.9	282.6	341.2	132.5
274.3	225.7	282.3	341.5	132.3
279.3	225.5	282.0	341.7	132.1
284.3	225.2	281.7	342.0	132.0
289.3	224.9	281.3	342.3	131.8
294.3	223.5	279.5	343.7	131.9
299.3	223.1	279.1	344.1	131.8

TABLE 6.2.1-34 (Sheet 2)

TIME	BREAK PATH NO.1 FLOW*		BREAK PATH NO.2 FLOW**	
(Sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
304.3	222.7	278.5	344.5	131.6
309.3	222.2	278.0	344.9	131.5
314.3	221.7	277.3	345.4	131.4
319.3	221.2	276.7	346.0	131.3
324.3	221.6	277.2	345.6	130.9
329.3	220.9	276.4	346.2	130.9
334.3	220.3	275.5	346.9	130.8
339.3	219.5	274.6	347.7	130.8
344.3	219.7	274.7	347.5	130.5
349.3	218.8	273.7	348.4	130.5
354.3	218.8	273.6	348.4	130.2
359.3	217.8	272.4	349.4	130.2
364.3	217.6	272.2	349.6	130.0
369.3	217.3	271.8	349.9	129.8
374.3	216.1	270.3	351.1	129.9
379.3	215.6	269.7	351.6	129.8
384.3	215.0	269.0	352.1	129.7
389.3	215.2	269.1	352.0	129.4
394.3	214.3	268.1	352.9	129.4
399.3	214.1	267.8	353.1	129.2
404.3	213.1	266.6	354.1	129.2
409.3	212.7	266.1	354.5	129.0
414.3	212.8	266.2	354.3	128.8

TABLE 6.2.1-34 (Sheet 3)

TIME	BREAK PATH NO.1 FLOW*		BREAK PATH NO.2 FLOW**	
(Sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
419.3	212.0	265.1	355.2	128.7
424.3	211.5	264.6	355.6	128.6
429.3	210.8	263.6	356.4	128.6
434.3	210.3	263.1	356.9	128.4
439.3	210.0	262.7	357.1	128.3
444.3	209.8	262.4	357.4	128.1
449.3	208.7	261.1	358.4	128.1
454.3	208.5	260.8	358.6	127.9
459.3	208.1	260.3	359.1	127.8
464.3	207.3	259.3	359.9	127.7
469.3	206.9	258.8	360.3	127.6
474.3	95.3	119.1	471.9	158.3
634.9	95.3	119.1	471.9	158.3
635.0	100.1	124.2	467.0	154.7
639.3	100.0	124.0	467.2	154.5
1441.7	100.0	124.0	467.2	154.5
1441.8	82.5	94.9	484.7	49.6
1611.0	80.3	92.4	486.9	50.0
1611.1	80.3	92.4	566.1	114.8
3590.0	65.8	75.8	580.5	117.4
3590.1	65.8	75.8	580.5	112.2
3600.0	65.8	75.7	580.6	112.3
3600.1	53.5	61.5	592.9	90.1

TABLE 6.2.1-34 (Sheet 4)

TIME	BREAK PATH NO.1 FLOW*		BREAK PATH NO.2 FLOW**	
(Sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
7000.0	43.2	49.7	603.1	91.7
7000.1	42.5	48.9	603.8	82.1
10000.0	38.3	44.0	608.1	82.7
14400.0	34.8	40.0	611.5	83.2
14400.1	34.3	39.5	612.0	74.7
100000.0	20.2	23.2	626.2	76.4
100000.1	19.9	22.9	626.5	66.4
1000000.0	8.5	9.8	637.8	67.6
10000000.0	2.7	3.1	643.7	68.2

* Mass and energy exiting the SG side of the break.

** Mass and energy exiting the pump side of the break.

TABLE 6.2.1-35 DOUBLE-ENDED PUMP SUCTION MASS BALANCE MINIMUM SAFEGUARDS UTILIZING THE REPLACEMENT STEAM GENERATOR

		Mass Balance						
Time (Seconds)		.00	26.20	26.20+δ	194.25	635.01	1441.75	3600
		Mass (Thousand lbm)						
Initial	In RCS and ACC	807.47	807.47	807.47	807.47	807.47	807.47	807.47
Added Mass	Pumped Injection	.00	.00	.00	80.98	330.94	788.50	2170.05
	Total Added	.00	.00	.00	80.98	330.94	788.50	2170.05
TOTAL AVAILABLE		807.47	807.47	807.47	888.45	1138.41	1595.98	2977.52
Distribution	Reactor Coolant	580.70	48.39	78.17	136.06	136.06	136.06	136.06
	Accumulator	226.70	174.27	144.49	.00	.00	.00	.00
	Total Contents	807.47	222.66	222.66	136.06	136.06	136.06	136.06
Effluent	Break Flow	.00	584.79	584.79	740.89	990.85	1448.41	2829.95
	ECCS Spill	.00	.00	.00	.00	.00	.00	.00
	Total Effluent	.00	584.79	584.79	74089	990.85	1448.41	2829.95
TOTAL ACCOUNTABLE		807.47	807.45	807.45	876.94	1126.90	1584.46	2966.01

TABLE 6.2.1-36 DOUBLE-ENDED PUMP SUCTION BREAK ENERGY BALANCE MINIMUM SAFEGUARDS UTILIZING THE REPLACEMENT STEAM GENERATOR

		Energy Balance						
Time (Seconds)		0.0	26.20	26.20+δ	194.25	635.01	1441.75	3600
		Energy (Million Btu)						
Initial Energy	In RCS, ACC, S GEN	957.60	957.60	957.60	957.60	957.60	957.60	957.60
Added Energy	Pumped Injection	.00	.00	.00	5.51	22.51	53.64	265.81
	Decay Heat	.00	8.52	8.52	29.34	70.97	132.65	262.03
	Heat From Secondary	.00	15.70	15.70	15.70	23.25	34.95	34.95
	Total Added	.00	24.22	24.22	50.54	116.73	221.24	562.78
TOTAL AVAILABLE		957.60	981.83	981.83	1008.15	1074.33	1178.85	1520.39
Distribution	Reactor Coolant	343.98	11.65	14.32	37.24	37.24	37.24	37.24
	Accumulator	20.29	15.30	12.93	.00	.00	.00	.00
	Core Stored	24.00	12.10	12.10	5.09	4.91	4.48	3.33
	Primary Metal	161.73	152.99	152.99	127.74	94.21	72.32	53.28
	Secondary Metal	103.35	100.58	100.58	92.80	74.43	53.66	39.38
	Steam Generator	304.25	322.87	322.87	294.33	237.79	180.69	136.79
	Total Contents	957.60	615.80	615.80	557.19	448.58	348.38	270.02
Effluent	Break Flow	.00	365.44	365.44	439.95	614.75	822.61	1244.90
	ECCS Spill	.00	.00	.00	.00	.00	.00	.00
	Total Effluent	.00	365.44	365.44	439.95	614.75	822.61	1244.90
TOTAL ACCOUNTABLE		957.60	981.24	981.24	997.14	1063.32	1170.99	1514.92

TABLE 6.2.1-37 DOUBLE-ENDED PUMP SUCTION BREAK MAXIMUM ECCS FLOWS BLOWDOWN MASS AND ENERGY RELEASES UTILIZING THE REPLACEMENT STEAM GENERATOR

	Break Path No.1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
0.00	0.00	0.00	0.00	0.00
.00108	92747.0	51728.2	42543.9	23666.8
.101	42397.9	23637.4	21839.9	12137.7
.201	47597.6	26658.5	24081.2	13393.7
.302	46883.3	26403.1	24213.0	13478.1
.401	46469.1	26339.0	23444.3	13061.6
.501	46600.6	26611.4	22316.4	12441.3
.602	46049.9	26514.4	21364.4	11915.1
.702	45631.8	26491.1	20533.4	11454.0
.801	45786.2	26786.9	19898.3	11101.7
.901	45606.6	26877.8	19442.4	10851.1
1.00	45030.6	26719.9	19191.4	10713.6
1.10	44174.9	26384.7	19035.9	10628.7
1.20	43316.6	26039.2	18949.3	10581.4
1.30	42508.0	25719.4	18895.2	10551.8
1.40	41759.4	25428.6	18862.0	10533.4
1.50	41030.4	25146.4	18848.9	10526.1
1.60	40309.2	24865.0	18856.6	10530.5
1.70	39575.8	24575.4	18875.0	10540.9
1.80	38815.7	24273.1	18884.7	10546.4
1.90	37987.7	23936.8	18875.1	10540.9
2.00	37079.7	23557.0	18857.4	10531.0
2.10	36087.0	23131.7	18833.1	10517.5
2.20	35017.9	22664.6	18781.4	10488.8
2.30	33912.8	22176.5	18699.7	10443.4
2.40	32709.4	21619.9	18575.6	10374.3
2.50	31519.2	21060.5	18415.8	10285.1
2.60	30313.7	20476.6	17979.6	10040.4
2.70	28949.3	19761.8	17748.3	9912.6
2.80	26126.6	17994.6	17572.7	9815.7

TABLE 6.2.1-37 (Sheet 2)

	Break Path No.1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
2.90	23995.9	16691.7	17367.2	9701.6
3.00	22657.5	15913.1	17150.9	9581.6
3.10	21304.0	15074.3	16960.4	9476.5
3.20	20176.2	14366.5	16786.1	9380.6
3.30	19261.4	13789.2	16607.6	9282.4
3.40	18440.7	13262.5	16445.8	9193.7
3.50	17737.6	12809.1	16298.5	9113.1
3.60	17131.0	12416.9	16155.7	9035.1
3.70	16596.3	12068.8	16013.8	8957.5
3.80	16130.3	11764.4	15887.2	8888.7
3.90	15733.3	11504.6	15769.1	8824.7
4.00	15388.7	11277.2	15652.0	8761.2
4.20	14798.5	10877.7	15425.9	8638.7
4.40	14340.2	10559.0	15225.6	8530.8
4.60	13977.0	10292.4	15019.2	8419.6
4.80	13698.7	10075.8	14823.5	8314.6
5.00	13484.9	9894.8	14626.7	8208.9
5.20	13336.3	9752.7	14279.5	8019.2
5.40	13241.2	9642.1	15977.5	8980.8
5.60	13185.2	9555.0	15809.1	8889.2
5.80	13204.7	9518.6	15527.2	8735.5
6.00	13257.5	9501.6	15442.7	8692.9
6.20	13326.4	9497.7	15270.4	8600.5
6.40	13411.5	9507.3	15109.8	8515.4
6.60	13500.8	9521.4	14961.7	8436.7
6.80	13581.4	9532.5	14789.5	8343.6
7.00	13640.5	9532.8	14601.9	8241.0
7.20	13675.0	9522.5	14447.3	8156.5
7.40	13879.8	9630.8	14382.0	8121.4
7.60	13641.4	9465.7	14424.4	8145.6
7.80	13339.5	9495.8	14202.2	8016.1
8.00	12169.1	9080.6	13990.7	7894.9

TABLE 6.2.1-37 (Sheet 3)

	Break Path No.1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
8.20	11452.0	8757.4	13891.5	7839.8
8.40	11343.5	8676.1	13722.2	7744.6
8.60	11408.6	8657.5	13547.8	7645.3
8.80	11516.9	8654.5	13372.0	7545.1
9.00	11673.5	8678.5	13195.8	7445.1
9.20	11868.1	8720.4	13032.0	7351.7
9.40	12054.8	8750.5	12852.0	7248.8
9.60	12217.3	8768.2	12684.9	7153.6
9.80	12336.2	8762.5	12526.3	7063.0
10.0	12369.2	8708.0	12368.2	6972.4
10.2	12313.4	8607.6	12221.6	6888.5
10.4	12196.0	8479.8	12083.8	6809.5
10.6	12017.7	8323.0	11950.2	6732.7
10.8	11753.2	8120.4	11830.5	6663.9
11.0	11432.3	7895.9	11725.9	6603.5
11.2	11159.1	7716.4	11615.8	6539.8
11.4	10948.8	7582.8	11500.5	6473.3
11.6	10728.0	7442.3	11396.8	6413.9
11.8	10492.8	7296.6	11299.3	6357.9
12.0	10301.6	7183.5	11185.9	6292.7
12.2	10126.7	7076.3	11079.6	6231.9
12.4	9917.3	6943.6	10989.2	6180.3
12.6	9726.4	6827.8	10885.4	6120.5
12.8	9564.7	6731.0	10781.3	6060.9
13.0	9376.8	6614.3	10696.5	6012.4
13.2	9199.6	6508.7	10598.0	5955.8
13.4	9047.5	6420.1	10500.3	5899.7
13.6	8880.6	6318.8	10416.8	5852.1
13.8	8723.6	6225.6	10321.8	5797.7
14.0	8575.8	6138.4	10233.6	5747.5
14.2	8432.1	6053.4	10145.3	5697.3
14.4	8299.6	5975.5	10053.1	5645.1

TABLE 6.2.1-37 (Sheet 4)

	Break Path No.1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
14.6	8164.0	5893.6	9955.4	5590.2
14.8	8020.8	5806.0	9846.5	5529.4
15.0	7869.9	5713.4	9727.6	5463.7
15.2	7707.6	5611.6	9613.3	5401.3
15.4	7551.4	5510.0	9500.8	5340.1
15.6	7411.2	5412.6	9400.4	5285.6
15.8	7294.8	5325.8	9303.3	5232.7
16.0	7198.5	5250.0	9212.1	5183.3
16.2	7114.0	5183.2	9123.1	5135.9
16.4	7032.8	5121.2	9036.9	5090.7
16.6	6950.8	5062.0	8952.1	5047.2
16.8	6867.0	5005.5	8868.2	5005.0
17.0	6780.7	4951.4	8785.5	4964.5
17.2	6691.5	4899.7	8702.9	4925.3
17.4	6598.8	4850.3	8619.4	4886.9
17.6	6504.5	4804.1	8532.4	4847.9
17.8	6406.8	4759.4	8411.6	4784.1
18.0	6304.4	4714.4	8315.9	4717.2
18.2	6200.0	4671.9	8247.0	4647.2
18.4	6091.9	4631.0	8211.7	4580.9
18.6	5976.4	4590.2	8201.4	4518.8
18.8	5853.5	4548.4	8140.9	4427.5
19.0	5724.4	4507.0	8095.9	4348.5
19.2	5588.9	4464.8	7977.8	4237.0
19.4	5455.5	4427.7	7833.4	4125.5
19.6	5363.5	4422.9	7523.9	3957.0
19.8	5271.8	4448.2	7131.5	3754.2
20.0	4981.5	4449.7	6659.4	3494.2
20.2	4449.0	4360.5	6263.2	3286.8
20.4	3897.2	4212.2	5840.2	3090.5
20.6	3415.3	3999.1	5388.1	2882.1
20.8	3067.6	3742.9	4721.4	2445.9

TABLE 6.2.1-37 (Sheet 5)

Time (sec)	Break Path No.1 Flow* (lbm/sec)	Break Path No.1 Flow* Thousand (Btu/sec)	Break Path No. 2 Flow** (lbm/sec)	Break Path No. 2 Flow** Thousand (Btu/sec)
21.0	2767.0	3410.0	4512.2	2174.5
21.2	2539.3	3143.5	4410.1	2003.7
21.4	2343.4	2910.2	4172.6	1813.5
21.6	2155.0	2682.8	4430.0	1852.8
21.8	1953.5	2438.1	5393.8	2207.2
22.0	1775.9	2222.2	4998.9	2027.0
22.2	1641.5	2058.4	3665.2	1476.6
22.4	1530.8	1923.0	3241.9	1303.2
22.6	1425.6	1793.2	2404.5	958.1
22.8	1312.3	1652.8	2005.0	748.1
23.0	1185.5	1495.1	4223.0	1416.6
23.2	1039.5	1313.6	6210.7	2013.0
23.4	916.6	1159.7	5077.4	1632.4
23.6	804.3	1018.6	4276.4	1368.0
23.8	702.3	890.2	3493.1	1110.5
24.0	614.1	779.0	2961.9	933.4
24.2	542.9	689.3	2522.9	785.7
24.4	491.7	624.6	2100.0	645.0
24.6	461.3	586.3	1642.4	497.6
24.8	427.9	544.2	1130.1	338.4
25.0	377.0	479.6	564.5	167.8
25.2	322.7	410.7	33.2	9.9
25.4	265.4	338.1	.0	.0
25.6	203.8	259.7	.0	.0
25.8	141.1	180.1	.0	.0
26.0	85.2	109.0	.0	.0
26.2	.0	.0	.0	.0

* Mass and energy exiting the SG side of the break.
** Mass and energy exiting the pump side of the break.

TABLE 6.2.1-38 DOUBLE-ENDED PUMP SUCTION BREAK MAXIMUM SAFEGUARDS REFLOOD MASS AND ENERGY RELEASES UTILIZING THE REPLACEMENT STEAM GENERATOR

	Break Path No. 1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
26.2	.0	.0	.0	.0
26.8	.0	.0	.0	.0
26.9	.0	.0	.0	.0
27.0	.0	.0	.0	.0
27.1	.0	.0	.0	.0
27.2	.0	.0	.0	.0
27.3	91.6	108.3	.0	.0
27.4	40.1	47.4	.0	.0
27.6	28.2	33.3	.0	.0
27.7	32.3	38.2	.0	.0
27.8	40.9	48.4	.0	.0
27.9	47.1	55.7	.0	.0
28.0	54.3	64.1	.0	.0
28.1	59.5	70.4	.0	.0
28.2	64.5	76.3	.0	.0
28.3	69.3	81.8	.0	.0
28.4	73.7	87.1	.0	.0
28.4	74.8	88.4	.0	.0
28.5	78.0	92.2	.0	.0
28.6	82.2	97.1	.0	.0
28.7	86.1	101.8	.0	.0
28.8	90.0	106.3	.0	.0
28.9	93.7	110.7	.0	.0
29.0	97.3	115.0	.0	.0
29.1	100.8	119.1	.0	.0
29.2	104.2	123.1	.0	.0
29.3	107.5	127.1	.0	.0
30.3	136.8	161.7	.0	.0
31.3	161.2	190.6	.0	.0
32.3	377.6	447.7	3293.8	473.0

TABLE 6.2.1-38 (Sheet 2)

	Break Path No. 1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
32.6	460.3	546.4	4134.5	603.3
33.3	508.0	603.6	4536.0	693.6
34.3	502.1	596.6	4484.6	691.9
35.3	582.7	693.2	5237.1	749.1
36.3	573.8	682.5	5163.7	740.7
36.4	572.9	681.4	5156.2	739.8
37.3	564.8	671.7	5088.5	731.9
38.3	556.0	661.0	5013.4	723.0
39.3	547.3	650.7	4939.5	714.1
40.3	538.9	640.6	4867.1	705.4
41.1	532.4	632.8	4810.5	698.6
41.3	530.8	630.8	4796.5	696.9
42.3	522.9	621.5	4728.0	688.6
43.3	515.4	612.4	4661.3	680.6
44.3	508.1	603.7	4596.7	672.7
45.3	501.0	595.2	4533.9	665.1
46.3	494.2	587.1	4472.9	657.7
47.3	487.7	579.2	4413.7	650.5
48.3	481.3	571.7	4356.2	643.5
49.3	475.2	564.3	4300.3	636.6
50.3	469.2	557.2	4245.9	630.0
51.3	463.5	550.3	4193.0	623.5
52.1	459.0	545.0	4151.7	618.4
52.3	457.9	543.6	4141.5	617.2
53.3	452.5	537.1	4091.4	611.0
54.3	435.4	516.8	3896.3	599.5
55.3	380.1	450.8	3391.3	533.0
56.4	210.9	249.6	954.8	233.1
57.4	209.2	247.6	958.6	232.5
58.4	208.6	246.8	959.9	232.2
59.4	208.0	246.1	961.2	231.9
60.4	207.4	245.4	962.6	231.6

TABLE 6.2.1-38 (Sheet 3)

Time (sec)	Break Path No. 1 Flow* (lbm/sec)	Break Path No. 1 Flow* Thousand (Btu/sec)	Break Path No. 2 Flow** (lbm/sec)	Break Path No. 2 Flow** Thousand (Btu/sec)
61.4	206.8	244.7	964.0	231.3
62.4	206.2	243.9	965.4	231.1
63.4	205.6	243.2	966.8	230.8
64.4	205.0	242.5	968.2	230.5
65.4	204.4	241.8	969.6	230.3
66.4	203.8	241.1	971.0	230.0
67.4	203.2	240.3	972.4	229.7
68.4	202.5	239.6	973.8	229.4
68.5	202.5	239.6	973.9	229.4
69.4	201.9	238.9	975.2	229.2
70.4	201.3	238.2	976.6	228.9
71.4	200.7	237.5	978.0	228.7
72.4	200.1	236.7	979.4	228.4
73.4	199.5	236.0	980.8	228.1
74.4	198.9	235.3	982.2	227.9
75.4	198.3	234.6	983.6	227.6
76.4	197.7	233.8	985.0	227.4
77.4	197.0	233.1	986.4	227.1
78.4	196.4	232.4	987.8	226.8
79.4	195.8	231.7	989.2	226.6
80.4	195.2	230.9	990.6	226.3
81.4	194.6	230.2	992.1	226.1
82.4	194.0	229.4	993.5	225.8
83.4	193.3	228.7	994.9	225.6
84.4	192.7	228.0	996.3	225.3
85.4	192.1	227.2	997.8	225.1
86.4	191.4	226.5	999.2	224.8
87.4	190.8	225.7	1000.7	224.6
87.6	190.7	225.6	1001.0	224.5
89.4	189.5	224.2	1003.6	224.1
91.4	188.2	222.7	1006.5	223.6
93.4	187.0	221.2	1009.4	223.1

TABLE 6.2.1-38 (Sheet 4)

	Break Path No. 1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
95.4	185.7	219.6	1012.4	222.7
97.4	184.4	218.1	1015.4	222.2
99.4	183.0	216.5	1018.3	221.7
101.4	181.7	214.9	1021.3	221.3
103.4	180.4	213.3	1024.3	220.8
105.4	179.0	211.7	1027.3	220.3
107.4	177.6	210.1	1030.3	219.9
108.4	176.9	209.3	1031.8	219.6
109.4	176.3	208.5	1033.3	219.4
111.4	174.9	206.8	1036.2	218.9
113.4	173.5	205.2	1039.2	218.5
115.4	172.1	203.5	1042.2	218.0
117.4	171.2	202.4	1045.1	217.9
119.4	170.5	201.7	1046.6	217.7
121.4	169.9	201.0	1048.2	217.5
123.4	169.3	200.2	1049.7	217.2
125.4	168.7	199.5	1051.2	217.0
127.4	168.1	198.8	1052.7	216.8
129.4	167.4	198.0	1054.1	216.5
131.2	166.9	197.4	1055.5	216.3
131.4	166.8	197.3	1055.6	216.3
133.4	166.2	196.6	1057.1	216.0
135.4	165.6	195.9	1058.5	215.7
137.4	165.0	195.2	1060.0	215.5
139.4	164.4	194.5	1061.4	215.2
141.4	163.8	193.8	1062.8	214.9
143.4	163.2	193.1	1064.3	214.6
145.4	162.7	192.4	1065.7	214.3
147.4	162.1	191.7	1067.1	214.0
149.4	161.5	191.0	1068.5	213.7
151.4	160.9	190.3	1069.8	213.4
153.4	160.3	189.6	1071.2	213.1

TABLE 6.2.1-38 (Sheet 5)

	Break Path No. 1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
155.4	159.8	188.9	1072.6	212.8
155.9	159.6	188.8	1072.9	212.7
157.4	159.2	188.3	1074.0	212.5
159.4	158.6	187.6	1075.3	212.2
161.4	158.1	186.9	1076.7	211.8
163.4	157.5	186.3	1078.0	211.5
165.4	156.9	185.6	1079.3	211.2
167.4	156.4	184.9	1080.7	210.8
169.4	155.8	184.3	1082.0	210.5
171.4	155.3	183.6	1083.3	210.1
173.4	154.7	183.0	1084.6	209.8
175.4	154.2	182.4	1085.9	209.4
177.4	153.7	181.7	1087.2	209.0
179.4	153.1	181.1	1088.4	208.7
181.4	152.6	180.5	1089.7	208.3
183.0	152.2	180.0	1090.7	208.0

* mass and energy exiting the SG side of the break.

** mass and energy exiting the pump side of the break.

TABLE 6.2.1-39 DOUBLE-ENDED PUMP SUCTION BREAK - MAXIMUM SAFEGUARDS
PRINCIPLE PARAMETERS DURING REFLOOD UTILIZING THE REPLACEMENT STEAM GENERATOR

Time Seconds	Flooding Temp °F	Flooding Rate in/sec	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Frac	Total (Pounds Mass per Second)	Injection Accum (Pounds Mass per Second)	Spill (Pounds Mass per Second)	Enthalpy Btu/lbm
26.2	180.0	.000	.000	.00	.00	.250	.0	.0	.0	.00
27.0	177.4	21.916	.000	.63	1.55	.000	7657.4	7657.4	.0	89.50
27.2	176.0	24.273	.000	1.01	1.45	.000	7603.2	7603.2	.0	89.50
27.6	175.1	2.960	.132	1.35	2.07	.261	7478.5	7478.5	.0	89.50
27.7	175.1	3.025	.153	1.37	2.38	.263	7452.9	7452.9	.0	89.50
28.4	175.0	2.766	.298	1.50	4.64	.334	7261.8	7261.8	.0	89.50
29.2	175.0	2.695	.405	1.61	7.06	.353	7082.5	7082.5	.0	89.50
32.6	175.4	4.699	.626	2.01	16.07	.588	5957.6	5957.6	.0	89.50
33.3	175.5	4.834	.653	2.11	16.12	.593	5703.3	5703.3	.0	89.50
34.3	175.7	4.625	.676	2.24	16.12	.591	5548.4	5548.4	.0	89.50‘
35.3	175.9	5.003	.694	2.37	16.12	.618	6397.7	5156.4	.0	85.33
36.4	176.3	4.849	.706	2.50	16.12	.617	6266.2	5020.6	.0	85.23
41.1	178.1	4.425	.729	3.01	16.12	.609	5793.4	4529.6	.0	84.82
46.3	180.7	4.128	.737	3.50	16.12	.599	5373.4	4093.0	.0	84.38
52.1	184.0	3.879	.741	4.00	16.12	.589	4986.1	3691.0	.0	83.92
56.4	186.6	2.504	.729	4.34	16.12	.425	1377.9	.0	.0	68.03
59.4	188.3	2.478	.730	4.51	16.12	.425	1378.1	.0	.0	68.03
68.5	195.0	2.411	.731	5.00	16.12	.424	1378.4	.0	.0	68.03
78.4	203.9	2.339	.733	5.53	16.12	.423	1378.8	.0	.0	68.03
87.6	213.0	2.272	.735	6.00	16.12	.422	1379.1	.0	.0	68.03
99.4	225.0	2.183	.737	6.58	16.12	.420	1379.6	.0	.0	68.03
108.4	233.3	2.115	.739	7.00	16.12	.418	1380.0	.0	.0	68.03
121.4	243.6	2.028	.742	7.58	16.12	.417	1380.3	.0	.0	68.03
131.2	250.3	1.976	.744	8.00	16.12	.419	1380.3	.0	.0	68.03
143.4	257.6	1.912	.747	8.51	16.12	.422	1380.2	.0	.0	68.03
155.9	264.1	1.849	.749	9.00	16.12	.426	1380.1	.0	.0	68.03
169.4	270.1	1.782	.752	9.51	16.12	.430	1380.0	.0	.0	68.03

TABLE 6.2.1-39 (Sheet 2)

Time Seconds	Flooding Temp °F	Flooding Rate in/sec	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Frac	Total (Pounds Mass per Second)	Injection Accum (Pounds Mass per Second)	Spill (Pounds Mass per Second)	Enthalpy Btu/lbm
183.0	275.3	1.717	.754	10.00	16.12	.434	1379.9	.0	.0	68.03

TABLE 6.2.1-40 DOUBLE-ENDED PUMP SUCTION BREAK MAXIMUM SAFEGUARDS POST-REFLOOD MASS AND ENERGY RELEASES UTILIZING THE REPLACEMENT STEAM GENERATOR

	Break Path No. 1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
183.0	168.3	211.1	1217.8	208.3
188.0	168.8	211.6	1217.3	208.0
193.0	168.0	210.6	1218.1	207.9
198.0	168.4	211.2	1217.7	207.5
203.0	167.8	210.4	1218.3	207.4
208.0	168.5	211.3	1217.6	207.0
213.0	168.0	210.7	1218.1	206.9
218.0	167.5	210.0	1218.6	206.8
223.0	168.2	210.9	1217.9	206.3
228.0	167.7	210.3	1218.4	206.2
233.0	167.1	209.6	1218.9	206.1
238.0	167.8	210.5	1218.2	205.7
243.0	167.3	209.8	1218.8	205.6
248.0	168.0	210.7	1218.1	205.1
253.0	167.4	210.0	1218.6	205.0
258.0	166.9	209.3	1219.2	204.9
263.0	167.5	210.1	1218.5	204.5
268.0	167.0	209.4	1219.1	204.4
273.0	166.4	208.7	1219.6	204.3
278.0	167.1	209.5	1219.0	203.8
283.0	166.5	208.8	1219.6	203.7
288.0	167.1	209.6	1218.9	203.3
293.0	166.6	208.9	1219.5	203.2
298.0	167.2	209.6	1218.9	202.8
303.0	166.6	208.9	1219.5	202.7
308.0	166.0	208.2	1220.1	202.6
313.0	166.6	208.9	1219.5	202.1
318.0	166.0	208.1	1220.1	202.0
323.0	166.5	208.8	1219.6	201.6
328.0	165.9	208.1	1220.2	201.5

TABLE 6.2.1-40 (Sheet 2)

	Break Path No. 1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
333.0	166.4	208.7	1219.6	201.1
338.0	165.8	208.0	1220.2	201.0
343.0	166.3	208.6	1219.7	200.6
348.0	165.7	207.8	1220.4	200.5
353.0	166.2	208.4	1219.9	200.1
358.0	165.6	207.6	1220.5	200.0
363.0	166.0	208.2	1220.1	199.6
368.0	165.4	207.4	1220.7	199.6
373.0	165.8	207.9	1220.3	199.2
378.0	165.1	207.1	1220.9	199.1
383.0	165.6	207.6	1220.5	198.7
388.0	164.9	206.8	1221.2	198.6
393.0	165.3	207.3	1220.8	198.2
398.0	164.6	206.4	1221.5	198.1
403.0	165.0	207.0	1221.0	197.8
408.0	164.5	206.3	1221.6	197.6
413.0	165.0	206.9	1221.1	197.2
418.0	164.4	206.2	1221.7	197.1
423.0	164.9	206.8	1221.2	196.7
428.0	164.3	206.0	1221.8	196.6
433.0	164.7	206.6	1221.4	196.2
438.0	164.1	205.8	1222.0	196.1
443.0	164.5	206.3	1221.5	195.8
448.0	163.9	205.5	1222.2	195.7
453.0	164.3	206.0	1221.8	200.9
458.0	164.6	206.5	1221.4	200.6
463.0	164.0	205.6	1222.1	200.4
468.0	164.3	206.0	1221.8	200.1
473.0	163.6	205.2	1222.5	200.0
478.0	163.9	205.5	1222.2	199.6
483.0	164.2	205.9	1221.9	199.2
488.0	163.4	205.0	1222.6	199.1

TABLE 6.2.1-40 (Sheet 3)

Time (sec)	Break Path No. 1 Flow* (lbm/sec)	Break Path No. 1 Flow* Thousand (Btu/sec)	Break Path No. 2 Flow** (lbm/sec)	Break Path No. 2 Flow** Thousand (Btu/sec)
493.0	163.7	205.2	1222.4	198.8
498.0	163.9	205.5	1222.2	198.4
503.0	164.0	205.7	1222.0	198.1
508.0	163.2	204.7	1222.8	198.0
513.0	163.4	204.9	1222.7	197.6
518.0	163.5	205.0	1222.6	197.3
523.0	163.5	205.1	1222.5	197.0
528.0	163.6	205.1	1222.5	196.7
533.0	163.6	205.1	1222.5	196.4
538.0	163.5	205.1	1222.5	196.1
543.0	163.5	205.0	1222.6	195.8
548.0	163.4	204.9	1222.7	195.5
553.0	163.2	204.7	1222.8	195.2
558.0	163.1	204.5	1223.0	195.0
563.0	162.8	204.2	1223.2	194.7
568.0	163.4	204.9	1222.7	194.3
573.0	163.1	204.5	1223.0	194.0
578.0	162.7	204.0	1223.4	193.8
583.0	163.1	204.5	1223.0	193.4
588.0	162.6	203.9	1223.5	193.2
593.0	162.8	204.1	1223.3	192.9
598.0	162.9	204.3	1223.2	192.5
603.0	163.0	204.4	1223.1	192.2
608.0	162.9	204.4	1223.1	191.9
613.0	162.8	204.2	1223.3	191.6
618.0	162.6	203.9	1223.5	191.4
623.0	162.2	203.4	1223.9	191.2
628.0	162.4	203.6	1223.7	190.8
633.0	162.3	203.6	1223.8	190.5
638.0	162.1	203.3	1224.0	195.5
643.0	162.2	203.4	1223.9	195.1
648.0	162.0	203.2	1224.0	194.8

TABLE 6.2.1-40 (Sheet 4)

	Break Path No. 1 Flow*		Break Path No. 2 Flow**	
Time (sec)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
653.0	162.1	203.3	1224.0	194.4
658.0	.162.2	203.5	1223.8	194.0
663.0	162.3	203.5	1223.8	193.7
668.0	88.5	110.9	1297.6	213.8
888.0	82.8	103.8	1303.3	207.5
889.1	82.8	103.8	1209.9	312.2
890.6	82.8	103.8	1209.9	312.2
890.7	94.5	117.3	1198.2	309.9
894.1	94.4	117.2	1198.2	309.6
1371.9	94.4	117.2	1198.2	309.6
1372.0	84.6	97.3	1208.1	208.9
3600.0	66.8	76.9	1225.9	212.1
3600.1	53.6	61.6	1239.1	190.9
10000.0	39.0	44.8	1253.7	193.1
100000.0	20.8	24.0	1271.8	195.9
1000000.0	8.9	10.3	1283.7	197.7
10000000.0	2.8	3.2	1289.9	198.7

* mass and energy exiting the SG side of the break

** mass and energy exiting the pump side of the break

TABLE 6.2.1-41 DOUBLE-ENDED PUMP SUCTION BREAK MASS BALANCE MAXIMUM SAFEGUARDS UTILIZING THE REPLACEMENT STEAM GENERATOR

		Mass Balance						
Time (Seconds)		.00	26.20	26.20+δ	182.95	890.65	1371.86	3600.00
		Mass (Thousand lbm)						
Initial	In RCS and ACC	807.47	807.47	807.47	807.47	807.47	807.47	807.47
Added Mass	Pumped Injection	.00	.00	.00	202.79	1183.50	1805.54	4685.77
	Total Added	.00	.00	.00	202.79	1183.50	1805.54	4685.77
TOTAL AVAILABLE		807.47	807.47	807.47	1010.26	1990.97	2613.01	5493.24
Distribution	Reactor Coolant	580.78	48.39	78.17	140.46	140.46	140.46	140.46
	Accumulator	226.70	174.27	144.49	.00	.00	.00	.00
	Total Contents	807.47	222.66	222.66	140.46	140.46	140.46	140.46
Effluent	Break Flow	.00	584.79	584.79	858.28	1839.00	2460.99	5341.21
	ECCS Spill	.00	.00	.00	.00	.00	.00	.00
	Total Effluent	.00	584.79	584.79	858.28	1839.00	2460.99	5341.21
TOTAL ACCOUNTABLE		807.47	807.45	807.45	998.75	1979.46	2601.45	5481.68

TABLE 6.2.1-42 **DOUBLE-ENDED PUMP SUCTION BREAK ENERGY BALANCE MAXIMUM SAFEGUARDS UTILIZING THE REPLACEMENT STEAM GENERATOR**

		Energy Balance						
Time (Seconds)		.00	26.20	26.20+δ	182.95	890.65	1371.86	3600.00
		Energy (Million Btu)						
Initial Energy	In RCS, ACC, S GEN	957.60	957.60	957.60	957.60	957.60	957.60	957.60
Added Energy	Pumped Injection	.00	.00	.00	13.80	80.69	176.50	620.15
	Decay Heat	.00	8.52	8.52	28.11	91.89	127.75	261.98
	Heat From Secondary	.00	15.70	15.70	15.70	27.82	34.00	34.00
	Total Added	.00	24.22	24.22	57.61	200.40	388.25	916.13
TOTAL AVAILABLE		957.60	981.83	981.83	1015.21	1158.00	1295.85	1873.73
Distribution	Reactor Coolant	343.98	11.65	14.32	38.34	38.34	38.34	38.34
	Accumulator	20.29	15.60	12.93	.00	.00	.00	.00
	Core Stored	24.00	12.10	12.10	5.09	4.91	4.63	3.33
	Primary Metal	161.73	152.99	152.99	126.21	86.95	73.47	53.32
	Secondary Metal	103.35	100.58	100.58	92.28	66.84	54.12	39.42
	Steam Generator	304.25	322.87	322.87	292.11	215.86	181.05	135.91
	Total Contents	957.60	615.80	615.80	554.01	412.89	351.60	270.32
Effluent	Break Flow	.00	365.44	365.44	450.21	734.13	923.30	1586.44
	ECCS Spill	.00	.00	.00	.00	.00	.00	.00
	Total Effluent	.00	365.44	365.44	450.21	734.13	923.30	1586.44
TOTAL ACCOUNTABLE		957.60	981.24	981.24	1004.23	1147.02	1274.90	1856.75

TABLE 6.2.1-43 DOUBLE-ENDED HOT LEG BREAK - SEQUENCE OF EVENTS

Time (sec)	Event Description
0.0	Break Occurs, Reactor Trip and Loss of Offsite Power are assumed
0.482	Reactor Trip Signal on Compensated Pressurizer Low Pressure (1860 psia)
3.9	Low Pressurizer Pressure SI Setpoint - 1715 psia reached in blowdown
14.5	Accumulator Injection Begins
22.4	Peak containment Temperature (271.8º F)
22.5	Peak containment pressure (47.8 psig)
22.7	End of Blowdown Phase (end of analysis)

TABLE 6.2.1-44 DELETED

TABLE 6.2.1-45 DELETED

TABLE 6.2.1-46 LOCA MASS AND ENERGY RELEASE ANALYSIS - CORE DECAY HEAT FRACTION

Time (sec)	Decay Heat Generation Rate (Btu/Btu)
1.00E+01	0.053876
1.50E+01	0.050401
2.00E+01	0.048018
4.00E+01	0.042401
6.00E+01	0.039244
8.00E+01	0.037065
1.00E+02	0.035466
1.50E+02	0.032724
2.00E+02	0.030936
4.00E+02	0.027078
6.00E+02	0.024931
8.00E+02	0.023389
1.00E+03	0.022156
1.50E+03	0.019921
2.00E+03	0.018315
4.00E+03	0.014781
6.00E+03	0.013040
8.00E+03	0.012000
1.00E+04	0.011262
1.50E+04	0.010097
2.00E+04	0.009350
4.00E+04	0.007778
6.00E+04	0.006958
8.00E+04	0.006424
1.00E+05	0.006021
1.50E+05	0.005323
4.00E+05	0.003770
6.00E+05	0.003201
8.00E+05	0.002834
1.00E+06	0.002580

TABLE 6.2.1-47 DELETED

TABLE 6.2.1-48 DELETED

TABLE 6.2.1-49 DELETED

TABLE 6.2.1-50 DELETED

TABLE 6.2.1-51 SYSTEM PARAMETERS - INITIAL CONDITIONS

Parameters	Value Replacement Steam Generator
Core Thermal Power (MWt)	3636.3
Reactor Coolant System Total Flowrate (lbm/sec)	38,511.8
Vessel Outlet Temperature (ºF)	624.3
Core Inlet Temperature (ºF)	561.1
Vessel Average Temperature (ºF)	592.7
Initial Steam Generator Steam Pressure (psia)	1033
Steam Generator Tube Plugging (%)	0
Initial Steam Generator Secondary Side Mass (lbm)	132,944
Assumed Maximum Containment Backpressure (psia)	74.7
Accumulator	
Water Volume (ft^3) per accumulator	916.2
N2 Cover Gas Pressure (psia)	663
Temperature (ºF)	120
Safety Injection Delay, total (sec) (from beginning of event)	
(Minimum ECCS case)	48.3
(Maximum ECCS case)	34.3

Note: Core Thermal Power, RCS Total Flowrate, RCS Coolant Temperatures, and Steam Generator Secondary Side Mass include appropriate uncertainty and/or allowance.

TABLE 6.2.1-52 SAFETY INJECTION FLOW - MINIMUM SAFEGUARDS

RCS Pressure (psia)	Total Flow (gpm)
INJECTION MODE (REFLOOD PHASE)	
14.7	4973.0
114.7	3527.4
214.7	933.60
1014.7	633.0
INJECTION MODE (POST-REFLOOD PHASE)	
74.7	4105.2
COLD LEG RECIRCULATION MODE	
74.7	4800

TABLE 6.2.1-53 SAFETY INJECTION FLOW - MAXIMUM SAFEGUARDS

RCS Pressure (psia)	Total Flow (gpm)
INJECTION MODE (REFLOOD PHASE)	
14.7	11727.9
114.7	8904.8
214.7	3474.39
1014.7	1225.3
INJECTION MODE (POST-REFLOOD PHASE)	
74.7	10032.4
COLD LEG RECIRCULATION MODE	
74.7	9600.

TABLE 6.2.1-54 DELETED

TABLE 6.2.1-55 DELETED

TABLE 6.2.1-56 SPECTRUM OF SECONDARY SYSTEM PIPE RUPTURES ANALYZED

DER Cases

Case 1	Full double-ended (1.390 ft^2) rupture at 102 percent power - MSIV failure
Case 2	Full double-ended (1.390 ft^2) rupture at 102 percent power - MFIV failure
Case 3	Full double-ended (1.390 ft^2) rupture at 102 percent power - diesel failure
Case 4	Full double-ended (1.390 ft^2) rupture at 70 percent power - MSIV failure
Case 5	Full double-ended (1.390 ft^2) rupture at 70 percent power - MFIV failure
Case 6	Full double-ended (1.390 ft^2) rupture at 70 percent power - diesel failure
Case 7	Full double-ended (1.390 ft^2) rupture at 30 percent power - MSIV failure
Case 8	Full double-ended (1.390 ft^2) rupture at 30 percent power - MFIV failure
Case 9	Full double-ended (1.390 ft^2) rupture at 30 percent power - diesel failure
Case 10	Full double-ended (1.390 ft^2) rupture at 2 percent power - MSIV failure
Case 11	Full double-ended (1.390 ft^2) rupture at 2 percent power - MFIV failure
Case 12	Full double-ended (1.390 ft^2) rupture at 2 percent power - diesel failure

Split-Break Cases

Case 13	0.750 ft^2 split rupture at 102 percent power - MSIV failure
Case 14	0.750 ft^2 split rupture at 102 percent power - MFIV failure

TABLE 6.2.1-56 (Sheet 2)

Case 15	0.750 ft^2 split rupture at 102 percent power - diesel failure
Case 16	0.852 ft^2 split rupture at 70 percent power - MSIV failure
Case 17	0.852 ft^2 split rupture at 70 percent power - MFIV failure
Case 18	0.852 ft^2 split rupture at 70 percent power - diesel failure
Case 19	0.905 ft^2 split rupture at 30 percent power - MSIV failure
Case 20	0.905 ft^2 split rupture at 30 percent power - MFIV failure
Case 21	0.905 ft^2 split rupture at 30 percent power - diesel failure
Case 22	0.803 ft^2 split rupture at 2 percent power - MSIV failure
Case 23	0.803 ft^2 split rupture at 2 percent power - MFIV failure
Case 24	0.803 ft^2 split rupture at 2 percent power - diesel failure

TABLE 6.2.1-57 DELETED

TABLE 6.2.1-57A MSLB MASS AND ENERGY RELEASES INSIDE CONTAINMENT - INITIAL CONDITIONS ASSUMPTIONS

NSSS Power, Mwt		3579		
Initial Conditions	Power Level (%)			
Parameter	102	70	30	2
RCS Average Temperature (°F)	592.7	583.2	570.7	558.2
RCS Flowrate (gpm) (Thermal Design Flow)	374,400	374,400	374,400	374,400
RCS Pressure (psia)	2250	2250	2250	2250
Pressurizer Water Volume (% span)	60.0	46.3	31.6	26.0
Feedwater Enthalpy (Btu/lbm)	426.2	381.4	307.6	70.7
SG Pressure (psia)	1072	1087	1111	1097
SG Water Level (% NRS)	58.4	58.4	58.4	58.4

TABLE 6.2.1-57B MSLB MASS AND ENERGY RELEASES INSIDE CONTAINMENT - BALANCE OF PLANT ASSUMPTIONS

<u>Main Feedwater System</u>	
Flowrate – DERs @ all powers (until main feedwater isolation)	Feedwater flow based on system performance.
Flowrate – split ruptures @ all powers (until main feedwater isolation)	Feedwater flow matches steam flow.
Unisolable volume from SG nozzle to MFIV (faulted loop)	130 ft^3
Unisolable volume from SG nozzle to FRV assuming a single failure of the MFIV (faulted loop)	152 ft^3
Total response time for feedwater isolation (instrument response, signal processing, and MFIV closure)*	17.0 seconds
<u>Auxiliary Feedwater System</u>	
Flowrate to all steam generators	Maximum flow to the SG in the faulted loop; minimum flow to each of the other 3 SGs. The actual data used is a function of SG pressure.
Temperature (maximum value)	120°F
Actuation delay time	0 seconds
Assumed time of manual termination	10 minutes
<u>Main Steam System</u>	
Total piping volume	5,130 ft^3
Volume between the break and the nearest MSIV	
No failure of the faulted-loop MSIV	787 ft^3
Failure of the faulted-loop MSIV	4,343 ft^3
Total response time for steamline isolation (instrument response, signal processing, and MSIV closure)*	17.0 seconds

* Note: 17 seconds is the total response time for the bounding case as discussed in Section 6.2.1.4.5.

TABLE 6.2.1-57C MSLB MASS AND ENERGY RELEASES INSIDE CONTAINMENT - PROTECTION SYSTEM ASSUMPTIONS

<u>Reactor Trip Setpoints</u>	
Safety injection signal via low steamline pressure in any loop	559 psia
dynamic compensation lead	50 seconds
lag	5 seconds
Safety injection signal via High-1 containment pressure	6 psig
<u>Isolation Setpoints</u>	
For all double-ended ruptures,	
Feedwater isolation from a safety injection signal via low pressurizer pressure	1715 psia
Feedwater isolation from a safety injection signal via low steamline pressure in any loop	559 psia
dynamic compensation lead	50 seconds
lag	5 seconds
Steamline isolation from low steamline pressure in any loop	559 psia
dynamic compensation lead	50 seconds
lag	5 seconds
Steamline isolation from high negative steam pressure rate in any loop	-140 psi
dynamic compensation rate-lag	50 seconds
<u>Isolation Setpoints</u>	
For all split ruptures,	
Feedwater isolation from a safety injection signal via High-1 containment pressure	6 psig
Steamline isolation from High-2 containment pressure	20 psig

TABLE 6.2.1-57D MASS AND ENERGY RELEASE DATA FOR CASE 1 - PEAK CALCULATED CONTAINMENT TEMPERATURE FOR MSLB

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
0.0000	0.0	1195.59	2.9000	7190.7	1205.83	6.1000	6770.9	1205.97
0.0050	10977.0	1195.59	3.0000	7173.4	1205.76	6.2000	6754.7	1205.96
0.0100	10847.0	1194.59	3.1000	7159.6	1205.74	6.3000	6737.8	1205.93
0.0600	9918.1	1188.68	3.2000	7144.2	1205.75	6.4000	6720.4	1205.89
0.1000	9416.2	1185.56	3.3000	7134.3	1205.77	6.5000	6701.6	1205.84
0.2000	8723.4	1183.44	3.4000	7121.9	1205.80	6.6000	6685.2	1205.80
0.3000	8356.1	1184.04	3.5000	7109.7	1205.83	6.7000	6667.5	1205.75
0.4000	8095.1	1185.21	3.6000	7097.9	1205.85	6.8000	6656.6	1205.71
0.5000	7896.4	1186.81	3.7000	7084.1	1205.87	6.9000	6646.7	1205.68
0.6000	7789.1	1188.01	3.8000	7074.3	1205.87	7.0000	6635.9	1205.64
0.7000	7695.0	1189.28	3.9000	7063.0	1205.86	7.1000	6627.4	1205.62
0.8000	7620.5	1190.38	4.0000	7053.6	1205.86	7.2000	6619.1	1205.59
0.9000	7556.6	1191.32	4.1000	7042.3	1205.86	7.3000	6611.1	1205.56
1.0000	7498.3	1192.12	4.2000	7033.3	1205.87	7.4000	6603.3	1205.53
1.1000	7440.6	1192.85	4.3000	7023.4	1205.89	7.5000	6595.6	1205.51
1.2000	7390.6	1193.45	4.4000	7013.5	1205.90	7.6000	6584.8	1205.49
1.3000	7339.2	1194.04	4.5000	7003.1	1205.93	7.7000	6575.3	1205.48
1.4000	7288.7	1194.60	4.6000	6990.3	1205.95	7.8000	6567.0	1205.46
1.5000	7238.6	1195.13	4.7000	6977.7	1205.95	7.9000	6559.0	1205.44
1.6000	7189.0	1195.64	4.8000	6964.5	1205.96	8.0000	6551.0	1205.42
1.7000	7139.6	1196.14	4.9000	6947.8	1205.96	8.1000	6542.8	1205.41
1.8000	7090.6	1196.63	5.0000	6931.7	1205.96	8.2000	6534.6	1205.39
1.9000	7035.0	1197.16	5.1000	6914.2	1205.97	8.3000	6526.4	1205.37
2.0000	6992.7	1197.57	5.2000	6901.5	1205.97	8.4000	6517.6	1205.35
2.1000	6975.4	1198.20	5.3000	6886.4	1205.97	8.5000	6511.9	1205.34
2.2000	7031.6	1199.97	5.4000	6873.8	1205.97	8.6000	6506.8	1205.31
2.3000	7110.9	1202.10	5.5000	6859.2	1205.97	8.7000	6503.8	1205.29
2.4000	7179.9	1203.92	5.6000	6844.9	1205.98	8.8000	6500.8	1205.27
2.5000	7220.1	1205.13	5.7000	6831.5	1205.98	8.9000	6498.6	1205.24
2.6000	7233.4	1205.75	5.8000	6816.9	1205.98	9.0000	6497.1	1205.22
2.7000	7229.2	1205.95	5.9000	6802.0	1205.99	9.1000	6495.0	1205.20
2.8000	7214.1	1205.93	6.0000	6783.6	1205.98	9.2000	6493.0	1205.17

TABLE 6.2.1-57D (Sheet 2)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
9.3000	6490.5	1205.13	12.6000	6212.9	1204.70	15.9000	5783.0	1204.79
9.4000	6487.3	1205.10	12.7000	6200.6	1204.69	16.0000	5769.4	1204.80
9.5000	6483.3	1205.07	12.8000	6188.2	1204.69	16.1000	5758.7	1204.82
9.6000	6479.0	1205.04	12.9000	6175.7	1204.68	16.2000	5744.9	1204.83
9.7000	6474.0	1205.01	13.0000	6163.1	1204.68	16.3000	5731.0	1204.85
9.8000	6470.3	1204.98	13.1000	6150.6	1204.67	16.4000	5720.3	1204.86
9.9000	6465.5	1204.96	13.2000	6137.9	1204.67	16.5000	5705.6	1204.88
10.0000	6461.0	1204.93	13.3000	6125.2	1204.67	16.6000	5696.0	1204.90
10.1000	6456.3	1204.91	13.4000	6112.3	1204.67	16.7000	5682.9	1204.91
10.2000	6450.8	1204.89	13.5000	6099.4	1204.66	16.8000	5669.6	1204.93
10.3000	6444.6	1204.86	13.6000	6086.3	1204.66	16.9000	5656.5	1204.95
10.4000	6437.7	1204.84	13.7000	6073.2	1204.66	17.0000	5626.1	1204.63
10.5000	6430.2	1204.81	13.8000	6060.0	1204.66	17.1000	5507.2	1202.84
10.6000	6422.4	1204.79	13.9000	6046.8	1204.65	17.2000	5356.5	1200.25
10.7000	6414.1	1204.77	14.0000	6034.0	1204.66	17.3000	5180.6	1196.44
10.8000	6405.4	1204.76	14.1000	6021.1	1204.66	17.4000	5025.2	1193.75
10.9000	6396.3	1204.74	14.2000	6008.2	1204.66	17.5000	4844.1	1191.41
11.0000	6386.1	1204.73	14.3000	5995.1	1204.66	17.6000	4695.6	1188.52
11.1000	6377.1	1204.72	14.4000	5981.8	1204.66	17.7000	4557.7	1186.90
11.2000	6367.4	1204.72	14.5000	5968.5	1204.66	17.8000	4415.0	1184.69
11.3000	6357.5	1204.72	14.6000	5955.1	1204.67	17.9000	4277.1	1182.60
11.4000	6347.8	1204.72	14.7000	5941.7	1204.67	18.0000	4147.9	1180.70
11.5000	6337.9	1204.73	14.8000	5928.4	1204.67	18.1000	4023.9	1178.92
11.6000	6327.9	1204.74	14.9000	5915.2	1204.68	18.2000	3885.8	1177.01
11.7000	6317.4	1204.74	15.0000	5902.0	1204.69	18.3000	3792.2	1175.75
11.8000	6306.4	1204.73	15.1000	5888.9	1204.70	18.4000	3684.5	1174.36
11.9000	6295.1	1204.72	15.2000	5875.8	1204.71	18.5000	3581.7	1173.08
12.0000	6283.6	1204.72	15.3000	5862.8	1204.71	18.6000	3471.9	1171.34
12.1000	6271.9	1204.71	15.4000	5849.9	1204.72	18.7000	3389.4	1170.91
12.2000	6260.3	1204.70	15.5000	5837.0	1204.73	18.8000	3183.7	1172.38
12.3000	6248.6	1204.70	15.6000	5824.1	1204.74	18.9000	3056.1	1173.16
12.4000	6236.9	1204.70	15.7000	5811.3	1204.76	19.0000	2965.8	1173.49
12.5000	6225.0	1204.70	15.8000	5798.4	1204.77	19.1000	2909.1	1172.93

TABLE 6.2.1-57D (Sheet 3)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
19.2000	2886.8	1171.37	131.2500	753.4	1218.71	389.0620	192.6	1217.13
19.3000	2889.4	1168.90	139.0630	744.8	1218.56	396.8750	192.6	1216.90
19.4000	2884.1	1166.34	146.8750	735.7	1218.41	404.6870	192.6	1216.69
19.5000	2843.1	1164.81	154.6880	723.8	1218.19	412.5000	192.6	1216.51
19.6000	2775.9	1164.55	162.5000	706.3	1217.87	420.3120	192.6	1216.28
19.7000	2702.8	1165.02	170.3130	659.5	1216.93	428.1250	192.6	1216.11
19.8000	2632.8	1165.75	178.1250	518.3	1213.39	435.9370	192.6	1215.93
19.9000	2568.0	1166.52	185.9370	440.7	1211.70	443.7500	192.6	1215.76
20.0000	2508.2	1167.26	193.7500	328.1	1206.95	451.5620	192.6	1215.54
23.9063	1431.9	1222.87	201.5630	281.2	1215.55	459.3750	192.6	1215.38
27.8125	1312.0	1222.89	209.3750	263.7	1218.10	467.1870	192.6	1215.19
31.7187	1199.0	1222.69	217.1880	235.7	1218.49	475.0000	192.6	1214.98
35.6250	1133.2	1222.44	225.0000	215.6	1219.37	482.8120	192.6	1214.79
39.5313	1066.1	1222.09	232.8130	209.5	1220.51	490.6250	192.6	1214.61
43.4375	1020.6	1221.78	240.6250	206.0	1220.88	498.4370	192.6	1214.40
47.3438	984.4	1221.51	248.4380	200.2	1220.69	506.2500	192.6	1214.20
51.2500	954.0	1221.24	256.2500	196.5	1220.76	514.0620	192.6	1214.00
55.1563	928.4	1221.00	264.0630	195.9	1220.91	521.8750	192.6	1213.77
59.0625	906.9	1220.78	271.8750	195.3	1220.80	529.6870	192.6	1213.58
62.9688	888.6	1220.58	279.6880	193.9	1220.55	537.5000	192.6	1213.37
66.8750	872.9	1220.40	287.5000	193.2	1220.37	545.3120	192.6	1213.12
70.7813	858.4	1220.23	295.3130	193.3	1220.22	553.1250	192.6	1212.90
74.6875	843.8	1220.04	303.1250	193.1	1219.95	560.9380	192.6	1212.68
78.5938	833.8	1219.90	310.9380	192.7	1219.68	568.7500	192.6	1212.41
82.5000	824.4	1219.78	318.7500	192.7	1219.42	576.5630	192.6	1212.18
86.4063	816.1	1219.67	326.5630	192.7	1219.12	584.3750	192.6	1211.92
90.3125	808.6	1219.56	334.3750	192.7	1218.84	592.1880	192.6	1211.67
94.2188	801.0	1219.45	342.1870	192.6	1218.60	600.0000	192.6	1211.40
98.1250	784.3	1219.20	350.0000	192.6	1218.32	607.8130	205.5	1197.19
100.0000	768.8	1218.96	357.8120	192.6	1218.05	615.6250	114.3	1185.00
107.8120	770.4	1218.98	365.6250	192.6	1217.81	631.2500	34.3	1159.34
115.6250	760.4	1218.82	373.4370	192.6	1217.58	639.0630	0.0	1159.34
123.4370	761.4	1218.84	381.2500	192.6	1217.35	700.0000	0.0	1159.34

TABLE 6.2.1-57E MASS AND ENERGY RELEASE DATA FOR CASE 24 - PEAK CALCULATED CONTAINMENT PRESSURE FOR MSLB

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
0.0000	0.00	1189.2	2.8999	1789.93	1187.7	6.1001	1745.94	1187.0
0.0098	646.51	1189.6	3.0000	1788.10	1187.7	6.2002	1744.34	1186.9
0.0098	1445.35	1190.7	3.1001	1786.55	1187.6	6.2998	1742.73	1186.9
0.0601	1838.95	1187.7	3.2002	1785.23	1187.6	6.3999	1741.07	1186.9
0.1001	1828.96	1187.2	3.2998	1784.09	1187.6	6.5000	1739.31	1186.8
0.2002	1826.48	1187.0	3.3999	1782.99	1187.6	6.6001	1737.47	1186.8
0.2998	1834.28	1187.5	3.5000	1781.76	1187.6	6.7002	1735.57	1186.7
0.3999	1843.76	1188.2	3.6001	1780.28	1187.5	6.7998	1733.65	1186.7
0.5000	1852.03	1188.8	3.7002	1778.61	1187.5	6.8999	1731.75	1186.6
0.6001	1856.44	1189.3	3.7998	1776.94	1187.5	7.0000	1729.87	1186.6
0.7002	1855.32	1189.4	3.8999	1775.37	1187.4	7.1001	1727.95	1186.5
0.7998	1849.04	1189.3	4.0000	1774.07	1187.4	7.2002	1725.98	1186.5
0.8999	1839.84	1188.9	4.1001	1772.98	1187.4	7.2998	1723.96	1186.4
1.0000	1830.74	1188.5	4.2002	1771.96	1187.4	7.3999	1721.92	1186.3
1.1001	1824.11	1188.2	4.2998	1770.92	1187.4	7.5000	1719.88	1186.3
1.2002	1820.68	1188.1	4.3999	1769.79	1187.4	7.6001	1717.86	1186.2
1.2998	1819.78	1188.2	4.5000	1768.57	1187.3	7.7002	1715.86	1186.2
1.3999	1820.17	1188.3	4.6001	1767.29	1187.3	7.7998	1713.89	1186.1
1.5000	1820.38	1188.4	4.7002	1765.96	1187.3	7.8999	1711.93	1186.1
1.6001	1819.37	1188.4	4.7998	1764.63	1187.3	8.0000	1710.03	1186.0
1.7002	1816.74	1188.4	4.8999	1763.33	1187.3	8.1001	1708.33	1186.0
1.7998	1812.78	1188.3	5.0000	1762.09	1187.3	8.2002	1706.99	1186.0
1.8999	1808.27	1188.1	5.1001	1760.87	1187.2	8.2998	1706.21	1186.0
2.0000	1804.12	1187.9	5.2002	1759.61	1187.2	8.3999	1705.77	1186.0
2.1001	1801.02	1187.8	5.2998	1758.28	1187.2	8.5000	1705.30	1186.0
2.2002	1799.20	1187.8	5.3999	1756.88	1187.2	8.6001	1704.57	1186.1
2.2998	1798.35	1187.8	5.5000	1755.40	1187.2	8.7002	1703.56	1186.1
2.3999	1797.85	1187.8	5.6001	1753.87	1187.1	8.7998	1702.40	1186.1
2.5000	1797.12	1187.9	5.7002	1752.32	1187.1	8.8999	1701.21	1186.1
2.6001	1795.84	1187.9	5.7998	1750.74	1187.1	9.0000	1700.09	1186.1
2.7002	1794.04	1187.8	5.8999	1749.15	1187.0	9.1001	1699.08	1186.1
2.7998	1791.97	1187.8	6.0000	1747.55	1187.0	9.2002	1698.15	1186.1

TABLE 6.2.1-57E (Sheet 2)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
9.2998	1697.24	1186.1	12.6001	1658.40	1186.4	15.8999	1618.15	1187.0
9.3999	1696.27	1186.1	12.7002	1657.23	1186.4	16.0000	1616.87	1187.0
9.5000	1695.21	1186.2	12.7998	1656.05	1186.4	16.1001	1615.58	1187.0
9.6001	1694.03	1186.2	12.8999	1654.88	1186.4	16.2002	1614.29	1187.1
9.7002	1692.77	1186.2	13.0000	1653.70	1186.4	16.2998	1613.00	1187.1
9.7998	1691.48	1186.2	13.1001	1652.53	1186.4	16.3999	1611.70	1187.1
9.8999	1690.20	1186.2	13.2002	1651.35	1186.5	16.5000	1610.40	1187.1
10.0000	1688.97	1186.2	13.2998	1650.17	1186.5	16.6001	1609.09	1187.1
10.1001	1687.79	1186.2	13.3999	1648.98	1186.5	16.7002	1607.79	1187.2
10.2002	1686.64	1186.2	13.5000	1647.79	1186.5	16.7998	1606.48	1187.2
10.2998	1685.49	1186.2	13.6001	1646.59	1186.5	16.8999	1605.16	1187.2
10.3999	1684.34	1186.2	13.7002	1645.39	1186.6	17.0000	1603.85	1187.2
10.5000	1683.16	1186.2	13.7998	1644.19	1186.6	17.1001	1602.53	1187.2
10.6001	1681.95	1186.2	13.8999	1642.99	1186.6	17.2002	1601.21	1187.3
10.7002	1680.72	1186.2	14.0000	1641.79	1186.6	17.2998	1599.88	1187.3
10.7998	1679.50	1186.2	14.1001	1640.58	1186.6	17.3999	1598.47	1187.3
10.8999	1678.29	1186.2	14.2002	1639.37	1186.6	17.5000	1597.07	1187.3
11.0000	1677.11	1186.2	14.2998	1638.15	1186.7	17.6001	1595.69	1187.3
11.1001	1675.94	1186.2	14.3999	1636.93	1186.7	17.7002	1594.34	1187.3
11.2002	1674.78	1186.2	14.5000	1635.71	1186.7	17.7998	1593.01	1187.3
11.2998	1673.62	1186.2	14.6001	1634.48	1186.7	17.8999	1591.70	1187.3
11.3999	1672.45	1186.2	14.7002	1633.25	1186.7	18.0000	1590.38	1187.4
11.5000	1671.28	1186.2	14.7998	1632.01	1186.8	18.1001	1589.54	1187.4
11.6001	1670.10	1186.3	14.8999	1630.78	1186.8	18.2002	1588.58	1187.4
11.7002	1668.92	1186.3	15.0000	1629.53	1186.8	18.2998	1587.21	1187.4
11.7998	1667.74	1186.3	15.1001	1628.29	1186.8	18.3999	1585.55	1187.4
11.8999	1666.56	1186.3	15.2002	1627.03	1186.8	18.5000	1583.84	1187.4
12.0000	1665.39	1186.3	15.2998	1625.78	1186.9	18.6001	1582.26	1187.4
12.1001	1664.23	1186.3	15.3999	1624.52	1186.9	18.7002	1580.93	1187.4
12.2002	1663.07	1186.3	15.5000	1623.25	1186.9	18.7998	1579.82	1187.4
12.2998	1661.91	1186.3	15.6001	1621.98	1186.9	18.8999	1578.83	1187.5
12.3999	1660.74	1186.3	15.7002	1620.71	1186.9	19.0000	1577.84	1187.5
12.5000	1659.57	1186.3	15.7998	1619.43	1187.0	19.1001	1576.73	1187.5

TABLE 6.2.1-57E (Sheet 3)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
19.2002	1575.46	1187.5	22.5000	1533.95	1187.8	25.7998	1498.91	1188.3
19.2998	1574.02	1187.5	22.6001	1532.80	1187.8	25.8999	1497.92	1188.3
19.3999	1572.51	1187.5	22.7002	1531.65	1187.8	26.0000	1496.92	1188.3
19.5000	1571.04	1187.5	22.7998	1530.51	1187.8	26.1001	1495.93	1188.3
19.6001	1569.69	1187.5	22.8999	1529.37	1187.8	26.2002	1494.93	1188.4
19.7002	1568.45	1187.5	23.0000	1528.23	1187.8	26.2998	1493.94	1188.4
19.7998	1567.29	1187.6	23.1001	1527.11	1187.8	26.3999	1492.95	1188.4
19.8999	1566.15	1187.6	23.2002	1525.98	1187.8	26.5000	1491.96	1188.4
20.0000	1564.97	1187.6	23.2998	1524.87	1187.9	26.6001	1490.96	1188.4
20.1001	1563.71	1187.6	23.3999	1523.76	1187.9	26.7002	1489.97	1188.5
20.2002	1562.39	1187.6	23.5000	1522.67	1187.9	26.7998	1488.98	1188.5
20.2998	1561.03	1187.6	23.6001	1521.58	1187.9	26.8999	1487.99	1188.5
20.3999	1559.67	1187.6	23.7002	1520.50	1187.9	27.0000	1487.00	1188.5
20.5000	1558.35	1187.6	23.7998	1519.43	1187.9	27.1001	1486.01	1188.6
20.6001	1557.07	1187.6	23.8999	1518.36	1187.9	27.2002	1485.02	1188.6
20.7002	1555.84	1187.6	24.0000	1517.29	1187.9	27.2998	1484.03	1188.6
20.7998	1554.64	1187.6	24.1001	1516.23	1188.0	27.3999	1483.04	1188.6
20.8999	1553.43	1187.7	24.2002	1515.18	1188.0	27.5000	1482.05	1188.7
21.0000	1552.21	1187.7	24.2998	1514.13	1188.0	27.6001	1481.06	1188.7
21.1001	1550.96	1187.7	24.3999	1513.09	1188.0	27.7002	1480.07	1188.7
21.2002	1549.69	1187.7	24.5000	1512.06	1188.0	27.7998	1479.08	1188.7
21.2998	1548.42	1187.7	24.6001	1511.03	1188.1	27.8999	1478.09	1188.7
21.3999	1547.16	1187.7	24.7002	1510.00	1188.1	28.0000	1477.09	1188.8
21.5000	1545.92	1187.7	24.7998	1508.98	1188.1	28.1001	1476.11	1188.8
21.6001	1544.69	1187.7	24.8999	1507.96	1188.1	28.2002	1475.12	1188.8
21.7002	1543.49	1187.7	25.0000	1506.94	1188.1	28.2998	1474.13	1188.8
21.7998	1542.30	1187.7	25.1001	1505.93	1188.1	28.3999	1473.14	1188.9
21.8999	1541.10	1187.7	25.2002	1504.92	1188.2	28.5000	1472.15	1188.9
22.0000	1539.91	1187.7	25.2998	1503.91	1188.2	28.6001	1471.16	1188.9
22.1001	1538.70	1187.7	25.3999	1502.91	1188.2	28.7002	1470.17	1188.9
22.2002	1537.50	1187.8	25.5000	1501.91	1188.2	28.7998	1469.20	1188.9
22.2998	1536.31	1187.8	25.6001	1500.91	1188.2	28.8999	1468.28	1189.0
22.3999	1535.12	1187.8	25.7002	1499.91	1188.3	29.0000	1467.41	1189.0

TABLE 6.2.1-57E (Sheet 4)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
29.1001	1466.55	1189.0	32.3999	1438.87	1190.0	35.7002	1410.39	1190.8
29.2002	1465.65	1189.1	32.5000	1438.04	1190.1	35.7998	1409.66	1190.8
29.2998	1464.69	1189.1	32.6001	1437.21	1190.1	35.8999	1408.92	1190.9
29.3999	1463.67	1189.1	32.7002	1436.38	1190.1	36.0000	1408.20	1190.9
29.5000	1462.63	1189.1	32.7998	1435.55	1190.2	36.1001	1407.48	1190.9
29.6001	1461.61	1189.1	32.8999	1434.72	1190.2	36.2002	1406.76	1191.0
29.7002	1460.65	1189.1	33.0000	1433.88	1190.2	36.2998	1406.03	1191.0
29.7998	1459.75	1189.2	33.1001	1433.01	1190.2	36.3999	1405.30	1191.1
29.8999	1458.93	1189.2	33.2002	1432.04	1190.3	36.5000	1404.55	1191.1
30.0000	1458.24	1189.2	33.2998	1430.90	1190.3	36.6001	1403.79	1191.1
30.1001	1457.62	1189.3	33.3999	1429.63	1190.3	36.7002	1403.03	1191.2
30.2002	1456.99	1189.3	33.5000	1428.36	1190.3	36.7998	1402.27	1191.2
30.2998	1456.31	1189.4	33.6001	1427.17	1190.3	36.8999	1401.52	1191.2
30.3999	1455.58	1189.4	33.7002	1426.07	1190.3	37.0000	1400.77	1191.3
30.5000	1454.81	1189.4	33.7998	1425.03	1190.3	37.1001	1400.02	1191.3
30.6001	1454.01	1189.5	33.8999	1424.04	1190.3	37.2002	1399.28	1191.3
30.7002	1453.20	1189.5	34.0000	1423.10	1190.3	37.2998	1398.54	1191.4
30.7998	1452.39	1189.6	34.1001	1422.18	1190.3	37.3999	1397.79	1191.4
30.8999	1451.59	1189.6	34.2002	1421.30	1190.3	37.5000	1397.05	1191.4
31.0000	1450.79	1189.6	34.2998	1420.44	1190.3	37.6001	1396.30	1191.5
31.1001	1449.97	1189.7	34.3999	1419.61	1190.3	37.7002	1395.56	1191.5
31.2002	1449.14	1189.7	34.5000	1418.80	1190.4	37.7998	1394.82	1191.5
31.2998	1448.29	1189.7	34.6001	1418.01	1190.4	37.8999	1394.08	1191.6
31.3999	1447.43	1189.8	34.7002	1417.23	1190.4	38.0000	1393.35	1191.6
31.5000	1446.56	1189.8	34.7998	1416.45	1190.4	38.1001	1392.62	1191.6
31.6001	1445.72	1189.8	34.8999	1415.68	1190.5	38.2002	1391.89	1191.7
31.7002	1444.88	1189.8	35.0000	1414.92	1190.5	38.2998	1391.16	1191.7
31.7998	1444.03	1189.9	35.1001	1414.22	1190.5	38.3999	1390.43	1191.7
31.8999	1443.18	1189.9	35.2002	1413.60	1190.6	38.5000	1389.71	1191.7
32.0000	1442.31	1189.9	35.2998	1413.03	1190.6	38.6001	1388.98	1191.8
32.1001	1441.44	1190.0	35.3999	1412.44	1190.7	38.7002	1388.26	1191.8
32.2002	1440.57	1190.0	35.5000	1411.80	1190.7	38.7998	1387.54	1191.8
32.2998	1439.71	1190.0	35.6001	1411.12	1190.8	38.8999	1386.82	1191.9

TABLE 6.2.1-57E (Sheet 5)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
39.0000	1386.10	1191.9	42.2998	1363.09	1192.8	45.6001	1341.15	1193.6
39.1001	1385.38	1191.9	42.3999	1362.41	1192.8	45.7002	1340.50	1193.6
39.2002	1384.67	1192.0	42.5000	1361.75	1192.9	45.7998	1339.85	1193.7
39.2998	1383.96	1192.0	42.6001	1361.09	1192.9	45.8999	1339.20	1193.7
39.3999	1383.24	1192.0	42.7002	1360.43	1192.9	46.0000	1338.54	1193.7
39.5000	1382.54	1192.1	42.7998	1359.78	1193.0	46.1001	1337.89	1193.7
39.6001	1381.83	1192.1	42.8999	1359.11	1193.0	46.2002	1337.24	1193.7
39.7002	1381.12	1192.1	43.0000	1358.43	1193.0	46.2998	1336.59	1193.8
39.7998	1380.42	1192.1	43.1001	1357.74	1193.0	46.3999	1335.94	1193.8
39.8999	1379.71	1192.2	43.2002	1357.05	1193.1	46.5000	1335.29	1193.8
40.0000	1379.01	1192.2	43.2998	1356.36	1193.1	46.6001	1334.65	1193.8
40.1001	1378.31	1192.2	43.3999	1355.68	1193.1	46.7002	1334.00	1193.8
40.2002	1377.61	1192.3	43.5000	1355.01	1193.1	46.7998	1333.36	1193.9
40.2998	1376.91	1192.3	43.6001	1354.34	1193.2	46.8999	1332.72	1193.9
40.3999	1376.21	1192.3	43.7002	1353.68	1193.2	47.0000	1332.08	1193.9
40.5000	1375.51	1192.3	43.7998	1353.03	1193.2	47.1001	1331.44	1193.9
40.6001	1374.82	1192.4	43.8999	1352.37	1193.2	47.2002	1330.80	1193.9
40.7002	1374.12	1192.4	44.0000	1351.72	1193.3	47.2998	1330.16	1194.0
40.7998	1373.43	1192.4	44.1001	1351.06	1193.3	47.3999	1329.52	1194.0
40.8999	1372.74	1192.4	44.2002	1350.40	1193.3	47.5000	1328.89	1194.0
41.0000	1372.04	1192.5	44.2998	1349.74	1193.3	47.6001	1328.25	1194.0
41.1001	1371.35	1192.5	44.3999	1349.08	1193.3	47.7002	1327.61	1194.1
41.2002	1370.66	1192.5	44.5000	1348.41	1193.4	47.7998	1326.98	1194.1
41.2998	1369.97	1192.6	44.6001	1347.74	1193.4	47.8999	1326.37	1194.1
41.3999	1369.28	1192.6	44.7002	1347.07	1193.4	48.0000	1325.79	1194.1
41.5000	1368.60	1192.6	44.7998	1346.40	1193.4	48.1001	1325.24	1194.1
41.6001	1367.91	1192.7	44.8999	1345.74	1193.5	48.2002	1324.71	1194.2
41.7002	1367.23	1192.7	45.0000	1345.07	1193.5	48.2998	1324.17	1194.2
41.7998	1366.54	1192.7	45.1001	1344.41	1193.5	48.3999	1323.62	1194.2
41.8999	1365.85	1192.7	45.2002	1343.76	1193.5	48.5000	1323.05	1194.2
42.0000	1365.16	1192.8	45.2998	1343.11	1193.6	48.6001	1322.47	1194.3
42.1001	1364.46	1192.8	45.3999	1342.45	1193.6	48.7002	1321.87	1194.3
42.2002	1363.78	1192.8	45.5000	1341.80	1193.6	48.7998	1321.28	1194.3

TABLE 6.2.1-57E (Sheet 6)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
48.8999	1320.69	1194.3	52.2002	1301.15	1195.0	55.5000	1281.86	1195.5
49.0000	1320.11	1194.4	52.2998	1300.56	1195.0	55.6001	1281.28	1195.5
49.1001	1319.53	1194.4	52.3999	1299.97	1195.0	55.7002	1280.70	1195.5
49.2002	1318.95	1194.4	52.5000	1299.38	1195.0	55.7998	1280.12	1195.5
49.2998	1318.37	1194.4	52.6001	1298.79	1195.1	55.8999	1279.53	1195.6
49.3999	1317.78	1194.4	52.7002	1298.21	1195.1	56.0000	1278.95	1195.6
49.5000	1317.18	1194.5	52.7998	1297.62	1195.1	56.1001	1278.36	1195.6
49.6001	1316.58	1194.5	52.8999	1297.03	1195.1	56.2002	1277.78	1195.6
49.7002	1315.98	1194.5	53.0000	1296.45	1195.1	56.2998	1277.20	1195.6
49.7998	1315.39	1194.5	53.1001	1295.86	1195.1	56.3999	1276.62	1195.6
49.8999	1314.79	1194.6	53.2002	1295.28	1195.2	56.5000	1276.04	1195.6
50.0000	1314.20	1194.6	53.2998	1294.69	1195.2	56.6001	1275.46	1195.7
50.1001	1313.61	1194.6	53.3999	1294.11	1195.2	56.7002	1274.87	1195.7
50.2002	1313.01	1194.6	53.5000	1293.52	1195.2	56.7998	1274.29	1195.7
50.2998	1312.42	1194.6	53.6001	1292.94	1195.2	56.8999	1273.70	1195.7
50.3999	1311.82	1194.7	53.7002	1292.35	1195.2	57.0000	1273.12	1195.7
50.5000	1311.23	1194.7	53.7998	1291.77	1195.2	57.1001	1272.53	1195.7
50.6001	1310.63	1194.7	53.8999	1291.19	1195.3	57.2002	1271.94	1195.7
50.7002	1310.04	1194.7	54.0000	1290.60	1195.3	57.2998	1271.35	1195.7
50.7998	1309.44	1194.7	54.1001	1290.02	1195.3	57.3999	1270.77	1195.8
50.8999	1308.85	1194.8	54.2002	1289.44	1195.3	57.5000	1270.19	1195.8
51.0000	1308.26	1194.8	54.2998	1288.85	1195.3	57.6001	1269.60	1195.8
51.1001	1307.67	1194.8	54.3999	1288.27	1195.3	57.7002	1269.02	1195.8
51.2002	1307.07	1194.8	54.5000	1287.69	1195.3	57.7998	1268.44	1195.8
51.2998	1306.48	1194.8	54.6001	1287.10	1195.4	57.8999	1267.85	1195.8
51.3999	1305.88	1194.8	54.7002	1286.52	1195.4	58.0000	1267.27	1195.8
51.5000	1305.29	1194.9	54.7998	1285.94	1195.4	58.1001	1266.69	1195.8
51.6001	1304.69	1194.9	54.8999	1285.36	1195.4	58.2002	1266.11	1195.8
51.7002	1304.10	1194.9	55.0000	1284.78	1195.4	58.2998	1265.53	1195.9
51.7998	1303.51	1194.9	55.1001	1284.19	1195.4	58.3999	1264.94	1195.9
51.8999	1302.92	1194.9	55.2002	1283.61	1195.5	58.5000	1264.36	1195.9
52.0000	1302.33	1194.9	55.2998	1283.03	1195.5	58.6001	1263.78	1195.9
52.1001	1301.74	1195.0	55.3999	1282.44	1195.5	58.7002	1263.20	1195.9

TABLE 6.2.1-57E (Sheet 7)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
58.7998	1262.62	1195.9	62.1001	1243.44	1196.3	65.3999	1224.64	1196.6
58.8999	1262.04	1195.9	62.2002	1242.86	1196.3	65.5000	1224.08	1196.6
59.0000	1261.46	1195.9	62.2998	1242.28	1196.3	65.6001	1223.52	1196.6
59.1001	1260.87	1195.9	62.3999	1241.71	1196.3	65.7002	1222.96	1196.6
59.2002	1260.29	1196.0	62.5000	1241.13	1196.3	65.7998	1222.40	1196.6
59.2998	1259.71	1196.0	62.6001	1240.56	1196.3	65.8999	1221.84	1196.6
59.3999	1259.13	1196.0	62.7002	1239.98	1196.3	66.0000	1221.28	1196.6
59.5000	1258.54	1196.0	62.7998	1239.41	1196.3	66.1001	1220.73	1196.7
59.6001	1257.96	1196.0	62.8999	1238.83	1196.3	66.2002	1220.17	1196.7
59.7002	1257.38	1196.0	63.0000	1238.26	1196.3	66.2998	1219.61	1196.7
59.7998	1256.79	1196.0	63.1001	1237.69	1196.4	66.3999	1219.05	1196.7
59.8999	1256.21	1196.0	63.2002	1237.12	1196.4	66.5000	1218.50	1196.7
60.0000	1255.63	1196.1	63.2998	1236.54	1196.4	66.6001	1217.94	1196.7
60.1001	1255.05	1196.1	63.3999	1235.97	1196.4	66.7002	1217.38	1196.7
60.2002	1254.46	1196.1	63.5000	1235.40	1196.4	66.7998	1216.83	1196.7
60.2998	1253.88	1196.1	63.6001	1234.83	1196.4	66.8999	1216.27	1196.7
60.3999	1253.30	1196.1	63.7002	1234.26	1196.4	67.0000	1215.72	1196.7
60.5000	1252.72	1196.1	63.7998	1233.69	1196.4	67.1001	1215.17	1196.8
60.6001	1252.14	1196.1	63.8999	1233.12	1196.4	67.2002	1214.61	1196.8
60.7002	1251.55	1196.1	64.0000	1232.55	1196.4	67.2998	1214.05	1196.8
60.7998	1250.97	1196.1	64.1001	1231.98	1196.5	67.3999	1213.49	1196.8
60.8999	1250.39	1196.1	64.2002	1231.42	1196.5	67.5000	1212.93	1196.8
61.0000	1249.81	1196.2	64.2998	1230.85	1196.5	67.6001	1212.37	1196.8
61.1001	1249.23	1196.2	64.3999	1230.28	1196.5	67.7002	1211.81	1196.8
61.2002	1248.65	1196.2	64.5000	1229.72	1196.5	67.7998	1211.25	1196.8
61.2998	1248.07	1196.2	64.6001	1229.15	1196.5	67.8999	1210.69	1196.8
61.3999	1247.49	1196.2	64.7002	1228.59	1196.5	68.0000	1210.14	1196.8
61.5000	1246.91	1196.2	64.7998	1228.02	1196.5	68.1001	1209.58	1196.8
61.6001	1246.33	1196.2	64.8999	1227.46	1196.5	68.2002	1209.02	1196.8
61.7002	1245.75	1196.2	65.0000	1226.89	1196.5	68.2998	1208.46	1196.9
61.7998	1245.17	1196.2	65.1001	1226.33	1196.6	68.3999	1207.89	1196.9
61.8999	1244.59	1196.2	65.2002	1225.77	1196.6	68.5000	1207.33	1196.9
62.0000	1244.02	1196.3	65.2998	1225.21	1196.6	68.6001	1206.76	1196.9

TABLE 6.2.1-57E (Sheet 8)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
68.7002	1206.20	1196.9	72.0000	1187.72	1197.2	75.2998	1169.63	1197.4
68.7998	1205.63	1196.9	72.1001	1187.17	1197.2	75.3999	1169.09	1197.4
68.8999	1205.07	1196.9	72.2002	1186.61	1197.2	75.5000	1168.55	1197.5
69.0000	1204.51	1196.9	72.2998	1186.06	1197.2	75.6001	1168.01	1197.5
69.1001	1203.94	1196.9	72.3999	1185.50	1197.2	75.7002	1167.46	1197.5
69.2002	1203.38	1196.9	72.5000	1184.95	1197.2	75.7998	1166.92	1197.5
69.2998	1202.82	1196.9	72.6001	1184.40	1197.2	75.8999	1166.38	1197.5
69.3999	1202.25	1197.0	72.7002	1183.84	1197.2	76.0000	1165.84	1197.5
69.5000	1201.68	1197.0	72.7998	1183.29	1197.3	76.1001	1165.30	1197.5
69.6001	1201.11	1197.0	72.8999	1182.74	1197.3	76.2002	1164.76	1197.5
69.7002	1200.54	1197.0	73.0000	1182.19	1197.3	76.2998	1164.22	1197.5
69.7998	1199.99	1197.0	73.1001	1181.64	1197.3	76.3999	1163.68	1197.5
69.8999	1199.44	1197.0	73.2002	1181.09	1197.3	76.5000	1163.14	1197.5
70.0000	1198.89	1197.0	73.2998	1180.55	1197.3	76.6001	1162.60	1197.6
70.1001	1198.34	1197.0	73.3999	1180.01	1197.3	76.7002	1162.06	1197.6
70.2002	1197.77	1197.0	73.5000	1179.46	1197.3	76.7998	1161.52	1197.6
70.2998	1197.19	1197.0	73.6001	1178.90	1197.3	76.8999	1160.98	1197.6
70.3999	1196.61	1197.1	73.7002	1178.35	1197.3	77.0000	1160.45	1197.6
70.5000	1196.04	1197.1	73.7998	1177.79	1197.3	77.1001	1159.91	1197.6
70.6001	1195.48	1197.1	73.8999	1177.24	1197.3	77.2002	1159.37	1197.6
70.7002	1194.92	1197.1	74.0000	1176.69	1197.3	77.2998	1158.83	1197.6
70.7998	1194.37	1197.1	74.1001	1176.15	1197.3	77.3999	1158.30	1197.6
70.8999	1193.83	1197.1	74.2002	1175.61	1197.4	77.5000	1157.76	1197.6
71.0000	1193.27	1197.1	74.2998	1175.07	1197.4	77.6001	1157.22	1197.6
71.1001	1192.72	1197.1	74.3999	1174.52	1197.4	77.7002	1156.69	1197.6
71.2002	1192.16	1197.1	74.5000	1173.98	1197.4	77.7998	1156.15	1197.6
71.2998	1191.60	1197.1	74.6001	1173.43	1197.4	77.8999	1155.61	1197.7
71.3999	1191.04	1197.1	74.7002	1172.89	1197.4	78.0000	1155.08	1197.7
71.5000	1190.49	1197.1	74.7998	1172.34	1197.4	78.1001	1154.55	1197.7
71.6001	1189.93	1197.2	74.8999	1171.80	1197.4	78.2002	1154.01	1197.7
71.7002	1189.38	1197.2	75.0000	1171.26	1197.4	78.2998	1153.48	1197.7
71.7998	1188.83	1197.2	75.1001	1170.72	1197.4	78.3999	1152.96	1197.7
71.8999	1188.28	1197.2	75.2002	1170.17	1197.4	78.5000	1152.43	1197.7

TABLE 6.2.1-57E (Sheet 9)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
78.6001	1151.90	1197.7	81.8999	1133.08	1197.8	85.2002	1115.24	1198.0
78.7002	1151.38	1197.7	82.0000	1132.51	1197.8	85.2998	1114.73	1198.0
78.7998	1150.85	1197.7	82.1001	1131.94	1197.8	85.3999	1114.22	1198.0
78.8999	1150.32	1197.7	82.2002	1131.38	1197.8	85.5000	1113.71	1198.0
79.0000	1149.78	1197.7	82.2998	1130.81	1197.8	85.6001	1113.20	1198.0
79.1001	1149.24	1197.8	82.3999	1130.25	1197.8	85.7002	1112.69	1198.1
79.2002	1148.70	1197.8	82.5000	1129.68	1197.8	85.7998	1112.18	1198.1
79.2998	1148.15	1197.8	82.6001	1129.12	1197.8	85.8999	1111.67	1198.1
79.3999	1147.60	1197.8	82.7002	1128.56	1197.8	86.0000	1111.16	1198.1
79.5000	1147.03	1197.8	82.7998	1128.01	1197.8	86.1001	1110.65	1198.1
79.6001	1146.47	1197.8	82.8999	1127.46	1197.8	86.2002	1110.15	1198.1
79.7002	1145.89	1197.8	83.0000	1126.91	1197.8	86.2998	1109.64	1198.1
79.7998	1145.31	1197.8	83.1001	1126.36	1197.9	86.3999	1109.14	1198.1
79.8999	1144.73	1197.8	83.2002	1125.82	1197.9	86.5000	1108.64	1198.1
80.0000	1144.15	1197.8	83.2998	1125.27	1197.9	86.6001	1108.13	1198.1
80.1001	1143.56	1197.8	83.3999	1124.73	1197.9	86.7002	1107.63	1198.1
80.2002	1142.97	1197.8	83.5000	1124.19	1197.9	86.7998	1107.13	1198.2
80.2998	1142.37	1197.8	83.6001	1123.65	1197.9	86.8999	1106.63	1198.2
80.3999	1141.78	1197.8	83.7002	1123.12	1197.9	87.0000	1106.12	1198.2
80.5000	1141.19	1197.8	83.7998	1122.58	1197.9	87.1001	1105.62	1198.2
80.6001	1140.60	1197.8	83.8999	1122.05	1197.9	87.2002	1105.11	1198.2
80.7002	1140.01	1197.8	84.0000	1121.51	1197.9	87.2998	1104.61	1198.2
80.7998	1139.42	1197.8	84.1001	1120.98	1197.9	87.3999	1104.10	1198.2
80.8999	1138.84	1197.8	84.2002	1120.45	1197.9	87.5000	1103.59	1198.2
81.0000	1138.26	1197.8	84.2998	1119.92	1197.9	87.6001	1103.08	1198.2
81.1001	1137.68	1197.8	84.3999	1119.40	1197.9	87.7002	1102.57	1198.2
81.2002	1137.10	1197.8	84.5000	1118.87	1197.9	87.7998	1102.07	1198.2
81.2998	1136.53	1197.8	84.6001	1118.35	1197.9	87.8999	1101.57	1198.2
81.3999	1135.95	1197.8	84.7002	1117.83	1198.0	88.0000	1074.97	1197.1
81.5000	1135.37	1197.8	84.7998	1117.31	1198.0	88.1001	1032.10	1193.2
81.6001	1134.79	1197.8	84.8999	1116.79	1198.0	88.2002	1045.09	1194.8
81.7002	1134.22	1197.8	85.0000	1116.27	1198.0	88.2998	1081.43	1200.8
81.7998	1133.65	1197.8	85.1001	1115.76	1198.0	88.3999	1101.67	1203.9

TABLE 6.2.1-57E (Sheet 10)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
88.5000	1088.62	1203.8	91.7998	978.27	1207.2	95.1001	914.09	1208.4
88.6001	1061.10	1201.8	91.8999	976.20	1207.3	95.2002	912.46	1208.4
88.7002	1042.66	1200.6	92.0000	974.03	1207.3	95.2998	910.84	1208.4
88.7998	1043.33	1201.2	92.1001	971.75	1207.4	95.3999	909.21	1208.5
88.8999	1054.50	1202.9	92.2002	969.47	1207.4	95.5000	907.55	1208.5
89.0000	1061.98	1204.6	92.2998	967.30	1207.4	95.6001	905.87	1208.5
89.1001	1056.96	1204.9	92.3999	965.23	1207.5	95.7002	904.20	1208.5
89.2002	1044.58	1204.2	92.5000	963.18	1207.5	95.7998	902.54	1208.5
89.2998	1035.95	1203.7	92.6001	961.07	1207.6	95.8999	900.91	1208.5
89.3999	1033.98	1203.9	92.7002	958.92	1207.6	96.0000	899.26	1208.6
89.5000	1036.49	1204.7	92.7998	956.82	1207.6	96.1001	897.60	1208.6
89.6001	1037.30	1205.4	92.8999	954.77	1207.7	96.2002	895.93	1208.6
89.7002	1033.11	1205.5	93.0000	952.75	1207.7	96.2998	894.26	1208.6
89.7998	1026.71	1205.3	93.1001	950.72	1207.8	96.3999	892.62	1208.6
89.8999	1022.07	1205.2	93.2002	948.69	1207.8	96.5000	890.98	1208.6
90.0000	1020.25	1205.4	93.2998	946.67	1207.8	96.6001	889.34	1208.6
90.1001	1019.37	1205.7	93.3999	944.68	1207.8	96.7002	887.70	1208.6
90.2002	1017.36	1206.0	93.5000	942.72	1207.9	96.7998	886.07	1208.7
90.2998	1013.92	1206.0	93.6001	940.78	1207.9	96.8999	884.44	1208.7
90.3999	1010.35	1206.0	93.7002	938.85	1207.9	97.0000	882.83	1208.7
90.5000	1007.76	1206.1	93.7998	936.93	1208.0	97.1001	881.23	1208.7
90.6001	1006.09	1206.3	93.8999	935.04	1208.0	97.2002	879.65	1208.7
90.7002	1004.44	1206.5	94.0000	933.17	1208.0	97.2998	878.06	1208.7
90.7998	1002.11	1206.6	94.1001	931.33	1208.1	97.3999	876.39	1208.7
90.8999	999.21	1206.6	94.2002	929.52	1208.1	97.5000	874.64	1208.7
91.0000	996.34	1206.7	94.2998	927.73	1208.1	97.6001	872.97	1208.7
91.1001	993.93	1206.7	94.3999	925.96	1208.2	97.7002	871.43	1208.7
91.2002	991.94	1206.8	94.5000	924.20	1208.2	97.7998	869.96	1208.8
91.2998	989.97	1206.9	94.6001	922.47	1208.2	97.8999	868.48	1208.8
91.3999	987.74	1207.0	94.7002	920.76	1208.3	98.0000	866.97	1208.8
91.5000	985.24	1207.1	94.7998	919.07	1208.3	98.1001	865.47	1208.8
91.6001	982.72	1207.1	94.8999	917.40	1208.3	98.2002	864.04	1208.8
91.7002	980.39	1207.1	95.0000	915.74	1208.3	98.2998	862.64	1208.9

TABLE 6.2.1-57E (Sheet 11)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
98.3999	861.24	1208.9	105.3101	779.73	1209.6	115.6201	700.34	1210.0
98.5000	859.91	1208.9	105.6201	776.70	1209.7	115.9399	698.61	1210.0
98.6001	858.76	1209.0	105.9399	773.70	1209.7	116.2500	696.90	1210.1
98.7002	857.76	1209.0	106.2500	770.74	1209.7	116.5601	695.21	1210.1
98.7998	856.72	1209.1	106.5601	767.82	1209.7	116.8701	693.54	1210.1
98.8999	855.53	1209.1	106.8701	764.93	1209.7	117.1899	691.90	1210.1
99.0000	854.21	1209.1	107.1899	762.07	1209.7	117.5000	690.29	1210.1
99.1001	852.89	1209.1	107.5000	759.23	1209.7	117.8101	688.69	1210.1
99.2002	851.63	1209.1	107.8101	756.43	1209.7	118.1201	687.12	1210.1
99.2998	850.41	1209.2	108.1201	753.65	1209.8	118.4399	685.58	1210.1
99.3999	849.17	1209.2	108.4399	750.91	1209.8	118.7500	684.06	1210.1
99.5000	847.87	1209.2	108.7500	748.21	1209.8	119.0601	682.57	1210.1
99.6001	846.55	1209.2	109.0601	745.55	1209.8	119.3701	681.10	1210.1
99.7002	845.23	1209.2	109.3701	742.92	1209.8	119.6899	679.65	1210.1
99.7998	843.93	1209.2	109.6899	740.34	1209.8	120.0000	678.24	1210.1
99.8999	842.63	1209.2	110.0000	737.80	1209.8	120.3101	676.86	1210.1
100.0000	841.30	1209.2	110.3101	735.31	1209.8	120.6201	675.51	1210.1
100.3101	837.09	1209.2	110.6201	732.88	1209.8	120.9399	674.19	1210.1
100.6201	832.91	1209.2	110.9399	730.49	1209.8	121.2500	672.89	1210.1
100.9399	828.75	1209.2	111.2500	728.16	1209.9	121.5601	671.61	1210.1
101.2500	824.66	1209.2	111.5601	725.88	1209.9	121.8701	670.35	1210.1
101.5601	820.67	1209.3	111.8701	723.66	1209.9	122.1899	669.12	1210.1
101.8701	816.78	1209.3	112.1899	721.49	1209.9	122.5000	667.91	1210.1
102.1899	813.00	1209.3	112.5000	719.37	1209.9	122.8101	666.72	1210.1
102.5000	809.32	1209.3	112.8101	717.30	1209.9	123.1201	665.56	1210.1
102.8101	805.74	1209.4	113.1201	715.27	1209.9	123.4399	664.41	1210.2
103.1201	802.25	1209.4	113.4399	713.28	1210.0	123.7500	663.29	1210.2
103.4399	798.84	1209.5	113.7500	711.33	1210.0	124.0601	662.18	1210.2
103.7500	795.51	1209.5	114.0601	709.42	1210.0	124.3701	661.10	1210.2
104.0601	792.25	1209.5	114.3701	707.54	1210.0	124.6899	660.03	1210.2
104.3701	789.04	1209.6	114.6899	705.70	1210.0	125.0000	658.98	1210.2
104.6899	785.90	1209.6	115.0000	703.89	1210.0	125.3101	657.94	1210.2
105.0000	782.79	1209.6	115.3101	702.10	1210.0	125.6201	656.91	1210.2

TABLE 6.2.1-57E (Sheet 12)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
125.9399	655.91	1210.2	136.2500	630.35	1210.2	146.5601	612.39	1210.1
126.2500	654.91	1210.2	136.5601	629.74	1210.2	146.8701	611.86	1210.1
126.5601	653.94	1210.2	136.8701	629.14	1210.2	147.1899	611.33	1210.1
126.8701	652.98	1210.2	137.1899	628.55	1210.2	147.5000	610.82	1210.1
127.1899	652.03	1210.2	137.5000	627.98	1210.2	147.8101	610.30	1210.1
127.5000	651.10	1210.2	137.8101	627.41	1210.2	148.1201	609.79	1210.1
127.8101	650.18	1210.2	138.1201	626.86	1210.2	148.4399	609.28	1210.1
128.1201	649.28	1210.2	138.4399	626.32	1210.2	148.7500	608.78	1210.1
128.4399	648.39	1210.2	138.7500	625.78	1210.2	149.0601	608.28	1210.1
128.7500	647.52	1210.2	139.0601	625.26	1210.2	149.3701	607.78	1210.1
129.0601	646.67	1210.2	139.3701	624.74	1210.2	149.6899	607.29	1210.1
129.3701	645.83	1210.2	139.6899	624.22	1210.2	150.0000	606.80	1210.0
129.6899	645.00	1210.2	140.0000	623.71	1210.2	150.3101	606.32	1210.0
130.0000	644.19	1210.2	140.3101	623.20	1210.2	150.6201	605.85	1210.0
130.3101	643.40	1210.2	140.6201	622.68	1210.2	150.9399	605.38	1210.0
130.6201	642.62	1210.2	140.9399	622.16	1210.2	151.2500	604.92	1210.0
130.9399	641.85	1210.2	141.2500	621.63	1210.2	151.5601	604.46	1210.0
131.2500	641.09	1210.2	141.5601	621.10	1210.2	151.8701	604.02	1210.0
131.5601	640.35	1210.2	141.8701	620.57	1210.2	152.1899	603.58	1210.0
131.8701	639.62	1210.2	142.1899	620.02	1210.1	152.5000	603.15	1210.0
132.1899	638.90	1210.2	142.5000	619.47	1210.1	152.8101	602.73	1210.0
132.5000	638.19	1210.2	142.8101	618.92	1210.1	153.1201	602.32	1210.0
132.8101	637.49	1210.2	143.1201	618.38	1210.1	153.4399	601.92	1210.0
133.1201	636.80	1210.2	143.4399	617.84	1210.1	153.7500	601.53	1210.0
133.4399	636.13	1210.2	143.7500	617.29	1210.1	154.0601	601.15	1210.0
133.7500	635.46	1210.2	144.0601	616.75	1210.1	154.3701	600.78	1210.0
134.0601	634.80	1210.2	144.3701	616.20	1210.1	154.6899	600.41	1210.0
134.3701	634.15	1210.2	144.6899	615.65	1210.1	155.0000	600.06	1210.0
134.6899	633.51	1210.2	145.0000	615.10	1210.1	155.3101	599.71	1210.0
135.0000	632.87	1210.2	145.3101	614.55	1210.1	155.6201	599.36	1210.0
135.3101	632.23	1210.2	145.6201	614.00	1210.1	155.9399	599.03	1210.0
135.6201	631.60	1210.2	145.9399	613.46	1210.1	156.2500	598.70	1210.0
135.9399	630.97	1210.2	146.2500	612.92	1210.1	156.5601	598.37	1210.0

TABLE 6.2.1-57E (Sheet 13)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
156.8701	598.06	1210.0	167.1899	587.88	1209.9	177.5000	580.59	1209.9
157.1899	597.74	1210.0	167.5000	587.58	1209.9	177.8101	580.40	1209.9
157.5000	597.44	1210.0	167.8101	587.29	1209.9	178.1201	580.22	1209.9
157.8101	597.14	1210.0	168.1201	587.01	1209.9	178.4399	580.05	1209.9
158.1201	596.84	1210.0	168.4399	586.74	1209.9	178.7500	579.88	1209.9
158.4399	596.55	1210.0	168.7500	586.48	1209.9	179.0601	579.72	1209.9
158.7500	596.27	1210.0	169.0601	586.23	1209.9	179.3701	579.57	1209.9
159.0601	595.99	1210.0	169.3701	585.99	1210.0	179.6899	579.42	1209.9
159.3701	595.71	1210.0	169.6899	585.76	1210.0	180.0000	579.28	1209.9
159.6899	595.43	1210.0	170.0000	585.54	1210.0	180.3101	579.14	1209.9
160.0000	595.15	1210.0	170.3101	585.33	1210.0	180.6201	579.00	1209.9
160.3101	594.87	1210.0	170.6201	585.12	1210.0	180.9399	578.86	1209.9
160.6201	594.58	1210.0	170.9399	584.91	1210.0	181.2500	578.73	1209.9
160.9399	594.29	1210.0	171.2500	584.72	1210.0	181.5601	578.59	1209.9
161.2500	594.00	1210.0	171.5601	584.52	1210.0	181.8701	578.46	1209.9
161.5601	593.70	1210.0	171.8701	584.32	1210.0	182.1899	578.33	1209.9
161.8701	593.39	1210.0	172.1899	584.13	1210.0	182.5000	578.19	1209.9
162.1899	593.08	1210.0	172.5000	583.93	1210.0	182.8101	578.05	1209.9
162.5000	592.76	1210.0	172.8101	583.73	1210.0	183.1201	577.92	1209.9
162.8101	592.45	1210.0	173.1201	583.52	1210.0	183.4399	577.78	1209.9
163.1201	592.12	1210.0	173.4399	583.32	1210.0	183.7500	577.64	1209.9
163.4399	591.80	1210.0	173.7500	583.11	1209.9	184.0601	577.49	1209.9
163.7500	591.47	1210.0	174.0601	582.90	1209.9	184.3701	577.35	1209.9
164.0601	591.14	1210.0	174.3701	582.68	1209.9	184.6899	577.21	1209.9
164.3701	590.80	1210.0	174.6899	582.47	1209.9	185.0000	577.07	1209.9
164.6899	590.47	1210.0	175.0000	582.25	1209.9	185.3101	576.93	1209.9
165.0000	590.14	1210.0	175.3101	582.03	1209.9	185.6201	576.79	1209.9
165.3101	589.80	1210.0	175.6201	581.82	1209.9	185.9399	576.65	1209.9
165.6201	589.47	1210.0	175.9399	581.60	1209.9	186.2500	576.52	1209.9
165.9399	589.14	1209.9	176.2500	581.39	1209.9	186.5601	576.39	1209.9
166.2500	588.82	1209.9	176.5601	581.18	1209.9	186.8701	576.26	1209.9
166.5601	588.50	1209.9	176.8701	580.98	1209.9	187.1899	576.14	1209.9
166.8701	588.18	1209.9	177.1899	580.78	1209.9	187.5000	576.02	1209.9

TABLE 6.2.1-57E (Sheet 14)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
187.8101	575.90	1209.9	198.1201	572.93	1209.9	410.9399	588.87	1210.1
188.1201	575.79	1209.9	198.4399	572.85	1209.9	418.7500	586.13	1210.0
188.4399	575.67	1209.9	198.7500	572.78	1209.9	426.5601	581.79	1209.9
188.7500	575.57	1209.9	199.0601	572.71	1209.9	434.3799	573.62	1209.7
189.0601	575.46	1209.9	199.3701	572.63	1209.9	442.1899	547.28	1208.7
189.3701	575.36	1209.9	199.6899	572.56	1209.9	450.0000	447.00	1205.2
189.6899	575.26	1209.9	200.0000	572.49	1209.9	457.8101	337.34	1210.2
190.0000	575.16	1209.9	207.8101	571.10	1209.9	465.6201	269.62	1229.4
190.3101	575.07	1209.9	215.6299	570.12	1209.9	473.4399	234.97	1238.3
190.6201	574.97	1209.9	223.4399	569.42	1209.9	481.2500	210.45	1248.9
190.9399	574.88	1209.9	231.2500	569.00	1209.9	489.0601	205.60	1253.6
191.2500	574.78	1209.9	239.0601	568.63	1209.9	496.8701	204.11	1254.4
191.5601	574.69	1209.9	246.8799	568.45	1209.9	504.6899	203.09	1254.7
191.8701	574.60	1209.9	254.6899	568.41	1209.9	512.5000	202.62	1254.8
192.1899	574.51	1209.9	262.5000	568.48	1209.9	520.3101	202.41	1254.7
192.5000	574.42	1209.9	270.3101	568.67	1209.9	528.1299	202.32	1254.5
192.8101	574.33	1209.9	278.1299	568.98	1209.9	535.9399	202.28	1254.2
193.1201	574.24	1209.9	285.9399	569.41	1209.9	543.7500	202.26	1253.9
193.4399	574.16	1209.9	293.7500	569.99	1209.9	551.5601	202.26	1253.6
193.7500	574.07	1209.9	301.5601	570.74	1209.9	559.3799	202.26	1253.3
194.0601	573.98	1209.9	309.3799	571.68	1209.9	567.1899	202.26	1253.0
194.3701	573.90	1209.9	317.1899	573.07	1210.0	575.0000	202.26	1252.7
194.6899	573.81	1209.9	325.0000	574.90	1210.0	582.8101	202.27	1252.3
195.0000	573.73	1209.9	332.8101	577.12	1210.0	590.6201	202.28	1252.1
195.3101	573.64	1209.9	340.6299	576.23	1209.9	598.4399	202.28	1251.8
195.6201	573.56	1209.9	348.4399	573.06	1209.9	606.2500	206.54	1247.2
195.9399	573.48	1209.9	356.2500	578.82	1210.1	614.0601	111.19	1209.8
196.2500	573.40	1209.9	364.0601	583.88	1210.2	621.8701	51.74	1161.7
196.5601	573.32	1209.9	371.8799	588.01	1210.2	637.5000	3.33	1172.1
196.8701	573.24	1209.9	379.6899	591.40	1210.2	645.3101	1.40	1186.6
197.1899	573.16	1209.9	387.5000	595.62	1210.5	653.1201	0.75	1195.7
197.5000	573.08	1209.9	395.3101	592.66	1210.1	660.9399	0.29	1200.6
197.8101	573.00	1209.9	403.1299	590.73	1210.1	668.7500	0.19	1203.5

TABLE 6.2.1-57E (Sheet 15)

Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)	Time (sec)	Flow Rate (lbm/sec)	Enthalpy (Btu/lbm)
676.5601	0.14	1205.5	692.1899	0.09	1208.6	700.0298	0.00	1209.8
684.3701	0.11	1207.2	700.0000	0.08	1209.8			

TABLE 6.2.1-58 SUMMARY OF RESULTS FOR MSLB CONTAINMENT PRESSURE-TEMPERATURE ANALYSIS

Case	Power Level (%)	Break Size ft^2	Single Failure	Max Press (psig)	Time of peak (sec)	Max Vapor Temp @ Time (F @ sec)	Time of peak (sec)	Dryout Time (sec)	6 psig @ Time (sec)	20 psig @ Time (sec)	30 psig @ Time (sec)
DER Cases											
1	102	1.39	MSIV	38.2	189.8	345.4	18.7	639	2.4	10.9	19.9
2	102	1.39	MFIV	37.5	197.5	343	17.2	663	2.4	10.9	27.3
3	102	1.39	EDG	41.0	611.3	343.1	17.2	647	2.4	10.9	27.2
4	70	1.39	MSIV	39.2	226.0	341.3	18.7	647	2.3	11.1	22.8
5	70	1.39	MFIV	38.6	235.4	338.9	17.2	655	2.3	11.1	34.3
6	70	1.39	EDG	42.5	611.1	338.9	17.2	694	2.3	11	34.3
7	30	1.39	MSIV	41.1	300.6	336.9	18.7	655	2.2	11.2	29.2
8	30	1.39	MFIV	40.7	320.0	334.7	17.2	647	2.2	11.2	44.8
9	30	1.39	EDG	45.5	610.4	334.7	17.2	663	2.2	11.2	44.7
10	2	1.39	MSIV	39.2	252.5	339.8	19.8	655	2.2	11.1	35.7
11	2	1.39	MFIV	38.5	252.6	336.3	17.4	678	2.2	11.1	60.5
12	2	1.39	EDG	42.1	608.5	332.7	17.4	647	2.1	11.2	63.9
Split Break Cases											
13	102	0.75	MSIV	36.4	338.8	298.4	96.4	700	11.4	55.2	127.1
14	102	0.75	MFIV	36.2	338.9	298.6	96.4	700	11.4	55.2	131.7
15	102	0.75	EDG	40.2	608.7	298.7	96.4	700	11.4	55.2	129.1
16	70	0.852	MSIV	37.8	356.5	301.1	94.8	700	9.9	50.1	113.7
17	70	0.852	MFIV	37.6	363.8	301.3	94.8	700	9.9	50.1	117.6
18	70	0.852	EDG	42.1	610.9	301.3	94.8	700	9.9	50.1	116.0
19	30	0.905	MSIV	39.4	372.2	299.4	94.1	800	9.2	49.4	120.5
20	30	0.905	MFIV	39.2	373.2	299.6	94.1	795	9.2	49.4	125.1
21	30	0.905	EDG	43.9	638.8	299.6	94.1	800	9.2	49.4	122.8
22	2	0.803	MSIV	42.3	455.6	293.0	199.2	700	10.5	61.7	163.5
23	2	0.803	MFIV	42.3	459.0	293.1	202.6	692	10.5	61.7	166.9
24	2	0.803	EDG	47.1	607.8	293.6	198.3	692	10.5	61.7	162.5

TABLE 6.2.1-59 SEQUENCE OF EVENTS FOR CASE 24

PEAK CALCULATED CONTAINMENT PRESSURE CASE FOR MSLB

Time (sec)	Event
0.0	Break occurs, blowdown starts from all steam generators
10.5	High-1 containment pressure setpoint (6 psig) for safety injection, reactor trip, isolation of main feedwater lines, actuation of the air coolers reached
18.0	Reactor trip assumed
33.0	Main feedwater isolation valves closed
61.7	High-2 containment pressure setpoint (20 psig) for isolation of main steamlines reached
88.0	Main steamline isolation valves closed, blowdown from faulted-loop steam generator and unisolated steam piping only
95.5	Air coolers start
162.5	High-3 containment pressure setpoint (30 psig) for actuation of containment sprays reached
198.3	Peak containment vapor temperature of 293.6^{o}F reached
207.5	Containment sprays start
600.0	Auxiliary feedwater addition is terminated
607.8	Peak containment pressure of 47.1 psig reached
692.0	Dryout occurs in the faulted-loop steam generator

NOTE: The mass and energy releases assume a longer delay to the containment pressure set points.

TABLE 6.2.1-60 SEQUENCE OF EVENTS FOR CASE 1

PEAK CALCULATED CONTAINMENT TEMPERATURE FOR MSLB

Time (sec)	Event
0.0	Break occurs, blowdown starts from all steam generators
0.003	Low steamline pressure setpoint for safety injection, reactor trip, isolation of main feedwater lines, isolation of main steamines reached
2.4	High-1 containment pressure setpoint (6 psig) for actuation of the air coolers reached
17.0	Main feedwater isolation valves closed
17.0	Main steamline isolation valves closed, blowdown from faulted-loop steam generator and unisolated steam piping only
18.7	Peak containment vapor temperature 345.4^{o}F reached
19.9	High-3 containment pressure setpoint (30 psig) for actuation of containment sprays reached
54.9	Containment sprays start
87.4	Air coolers start
189.8	Peak containment pressure 38.2 psig reached
600.0	Auxiliary feedwater addition is terminated
639.0	Dryout occurs in the faulted-loop steam generator

TABLE 6.2.1-61 DELETED

TABLE 6.2.1-62 DELETED

TABLE 6.2.1-63 MASS AND ENERGY RELEASE DURING BLOWDOWN FOR MINIMUM POST-LOCA CONTAINMENT PRESSURE

TIME (SEC)	MASS FLOW RATE (LB/SEC)	ENERGY RELEASE RATE (BTU/SEC)
.0	62732	34775927
1.0	62732	34775927
2.0	54001	30264661
3.0	43521	24674659
4.0	37655	21664945
5.0	32242	19165932
6.0	29996	18165129
7.0	28524	17470424
8.0	26934	16732411
9.0	24931	15831474
10.0	22152	14562956
11.0	19553	13204805
12.0	18026	12231241
13.0	17027	11491254
14.0	15799	10770187
15.0	14672	10193920
16.0	13282	9529639
17.0	11739	8741666
18.0	10056	7814354
19.0	8578	6967435
20.0	7356	6095752
21.0	5548	4974869
22.0	5293	4094805
23.0	6537	3905250
24.0	7077	3639770
25.0	6836	3134650
26.0	5903	2486308
27.0	4817	1849800
28.0	4395	1641529
29.0	3738	1312000
30.0	2993	989608
31.0	2602	804846
32.0	2243	643085
33.0	758	217984
33.81	95	2297

TABLE 6.2.1-64 MASS AND ENERGY RELEASE DURING REFLOOD FOR MINIMUM POST-LOCA CONTAINMENT PRESSURE

TIME (Sec)	Mass Flow Rate (lbm/sec)	Energy Release Rate (BTU/sec)
47.3	7	4838
57.3	57	62744
67.3	102	116369
77.3	107	127255
87.3	100	119531
97.3	99	117096
127.3	128	155026
147.3	181	179373
167.3	308	223393
187.3	360	242659
207.3	365	245654
227.3	361	251878
247.3	356	249437

TABLE 6.2.1-65 ACTIVE HEAT SINK DATA FOR MINIMUM POST-LOCA CONTAINMENT PRESSURE

Containment Spray System Parameters	
Number of pumps operating	2
Runout flow rate (total), gpm	7754
Temperature of spray, °F	37
Actuation time (full flow), sec	15
Containment Air Cooler Parameters	
Number of fan coolers operating	4
Actuation time, sec	35

TABLE 6.2.1-66 STRUCTURAL HEAT SINKS

	Wall Thickness (ft)	Material	Surface Area ft^2
1.	0.021	Carbon Steel	61,968
	4.0	Concrete	
2.	0.021	Carbon Steel	32,578
	3.0	Concrete	
3.	1.5	Concrete	13,280
	0.021	Carbon Steel	
	10.0	Concrete	
4.	1.0	Concrete	8, 201
5.	2.0	Concrete	42,669
6.	2.5	Concrete	16, 880*
7.	0.021	Carbon Steel	7,466
	2.0	Concrete	
8.	0.021	Stainless Steel	8,312
	2.0	Concrete	
9.	0.0001083	Zinc Coating	7,714
	0.005	Carbon Steel	
	2.0	Concrete	
10.	0.0001083	Zinc Coating	175,290
	0.0104	Carbon Steel	
11.	0.0001083	Zinc Coating	23
	0.0417	Carbon Steel	
12.	0.0104	Carbon Steel (Painted)	18,281
13.	0.0208	Carbon Steel (Painted)	108,251
14.	0.0417	Carbon Steel (Painted)	44,371
15.	0.0833	Carbon Steel (Painted)	28,429
16.	0.1667	Carbon Steel (Painted)	5,230
17.	0.3333	Carbon Steel (Painted)	7,525

TABLE 6.2.1-66 (Sheet 2)

	Wall Thickness (ft)	Material	Surface Area ft^2
18.	0.6667	Carbon Steel (Painted)	159
19.	0.0833	Carbon Steel (Painted)	180
20.	0.0104	Carbon Steel (Unpainted)	8
21.	0.0208	Carbon Steel (Unpainted)	373
22.	0.0833	Carbon Steel (Unpainted)	-455
23.	0.1667	Carbon Steel (Unpainted)	759
24.	0.3333	Carbon Steel (Unpainted)	708
25.	0.6667	Carbon Steel (Unpainted)	248
26.	0.0104	Stainless Steel	16,855
27.	0.0208	Stainless Steel	5,415
28.	0.0417	Stainless Steel	7,212
29.	0.0833	Stainless Steel	1,172
30.	0.1667	Stainless Steel	18

* 148 sq. ft. of concrete 3' thick was removed during the removal of the original missile shield. Because there was not a line item for 3' thick concrete, it is assumed that the missile shield is included in this line item.

Material	Thermal Conductivity (BTU/hr-ft-°F)	Heat Capacity (BTU/ft^3-°F)
Stainless Steel	10	60
Carbon Steel	30	54
Concrete	1.2	30
Zinc Coating	65	41

TABLE 6.2.2-1 COMPARISON OF THE RECIRCULATION SUMP DESIGN WITH EACH OF THE POSITIONS OF REGULATORY GUIDE 1.82

	Regulatory Guide 1.82 Position	Recirculation Sump Design
1.	A minimum of two sumps should be provided, each with sufficient capacity to serve one of the redundant halves of the ECCS and CS systems.	Two sumps are provided, and each has sufficient capacity to serve one of the redundant halves of the ECCS and CS systems.
2.	The redundant sumps should be physically separated from each other and from high energy piping systems by structural barriers, to the extent practical, to preclude damage to the sump intake filters by whipping pipes or high-velocity jets of water or steam.	The redundant sumps are physically separated from each other and from high energy piping.
3.	The sumps should be located on the lowest floor elevation in the containment exclusive of the reactor vessel cavity. As a minimum, the sump intake should be protected by two screens: (1) an outer trash rack and (2) a fine inner screen. The sump screens should not be depressed below the floor elevation.	The sumps are located in El. +2,000, which is the lowest floor elevation in the reactor building, exclusive of the reactor cavity. The containment recirculation strainers are fabricated from stainless steel perforated plate with stainless reinforcement. The perforated plate is more structurally rigid than screens and precludes the use of trash racks. The strainers are installed in the recirculation sump pit and extend approximately one foot above the 2000’ elevation of the Reactor Building. The intent is met.
4.	The floor level in the vicinity of the coolant sump location should slope gradually down away from the sump.	The floor is level in the vicinity of the sump.. However, a 6-inch concrete curb is provided which prevents high density particles from entering the sump.
5.	All drains from the upper regions of the reactor building should terminate in such a manner that direct streams of water, which may contain entrained debris, will not impinge on the filter assemblies.	All drains in the upper regions of the reactor building are terminated in such a manner that direct streams of water which may contain entrained debris will not impinge on the filter assemblies.

TABLE 6.2.2-1 (Sheet 2)

	Regulatory Guide 1.82 Position	Recirculation Sump Design
6.	A vertically mounted outer trash rack should be provided to prevent large debris from reaching the fine inner screen. The strength of the trash rack should be considered in protecting the inner screen from missiles and large debris.	The containment recirculation sump strainers are fabricated from stainless steel perforated plate, including structural reinforcement, and are sufficiently rigid to preclude the use of a trash rack. The structural evaluation for the strainers concludes that the strainers meet the acceptance criteria for all applicable loadings during the recirculation phase of an event. The sumps and strainers are outside the secondary shield wall which provides protection from missiles and large debris. The intent is met.
7.	A vertically mounted fine inner screen should be provided. The design coolant velocity at the inner screen should be approximately 6 cm/sec (0.2 ft/sec). The available surface area used in determining the design coolant velocity should be based on one-half of the free surface area of the fine inner screen to conservatively account for partial blockage. Only the vertical screens should be considered in determining available surface area.	The containment sump strainers are composed of stainless steel perforated plate with 0.045-inch diameter holes. The approach velocity of the recirculation coolant flow at the sump strainer face is less than 0.2 ft/sec. The intent is met.
8.	A solid top deck is preferable, and the top deck should be designed to be fully submerged after a LOCA and completion of the safety injection.	A concrete slab over the containment sump strainers is provided. The containment recirculation sump strainers will be fully submerged following a large break LOCA.
9.	The trash rack and screens should be designed to withstand the vibratory motion of seismic events without loss of structural integrity.	The containment recirculation sump strainers are designed as seismic Category I and have been evaluated acceptably for all applicable loadings.

TABLE 6.2.2-1 (Sheet 3)

Regulatory Guide 1.82 Position	Recirculation Sump Design
10. The size of openings in the fine screen should be based on the minimum restrictions found in systems served by the sump. The minimum restriction should take into account the overall operability of the system served.	The containment recirculation strainers have a nominal 0.045-inch hole size, which precludes particles larger than 0.045 inches from passing through the strainers. The containment spray pump is designed to pass particles less than 1/4 inch in size, and the minimum restriction in the spray system is the 7/16-inch orifice in the spray nozzle.
11. Pump intake locations in the sump should be carefully considered to prevent degrading effects, such as vortexing on the pump performance.	The pump intake location in the sump is horizontal to limit any degrading effects due to vortexing.
12. Materials for trash racks and screens should be selected to avoid degradation during periods of inactivity and operation and should have a low sensitivity to adverse effects, such as stress-assisted corrosion, that may be induced by the chemically reactive spray during LOCA conditions.	The containment recirculation strainers are fabricated from stainless steel. Stainless steel has a low sensitivity to corrosion during power operation and after an event.
13. The trash rack and screen structure should include access openings to facilitate inspection of the structure and pump suction intake.	The containment recirculation sump strainers are provided with provisions to allow inspection of the strainer structure and areas downstream of the strainer.
14. Inservice inspection requirements for coolant sump components (trash racks, screens, and pump suction inlets) should include the following:	Inservice inspection requirements consist of visual examination during every scheduled refueling downtime.

TABLE 6.2.2-1 (Sheet 4)

Regulatory Guide 1.82 Position	Recirculation Sump Design
a. Coolant sump components should be inspected during every refueling period downtime, and	Inservice inspection requirements consist of visual examination during every scheduled refueling downtime.
b. The inspection should be a visual examination of the components for evidence of structural distress or corrosion.	

TABLE 6.2.2-2 CONTAINMENT HEAT REMOVAL SYSTEMS COMPONENT DESIGN PARAMETERS

Containment Spray Pumps	
Type	Vertical centrifugal
Quantity	2
Design pressure, psig	450
Design temperature, °F	300
Motor, hp	500
Service factor	1.15
Start time, sec	4
Design flow rate, gpm (injection/recirculation)	3,165/3,750
Design head, ft (injection/recirculation)	464/400
NPSH available, ft	See Table 6.2.2-7
Material in contact with fluid	Stainless steel
Design codes	
Pump	ASME Section III,Class 2
Motor	NEMA, IEEE 323, 334, 344
Seismic design	Category I
Containment Spray Nozzles	
Type	Whirljet, hollow cone spray nozzles
Design flow per nozzle at 40 psi ΔP	15.2 gpm
Number of nozzles	197/header
Material	Stainless steel
Design code	ASME Section III,Class 2
Seismic design	Category I

TABLE 6.2.2-2 (Sheet 2)

Refueling Water Storage Tank	
Quantity	1
Type	Vertical
Assured Water Volume, gal	394,000
Design temperature, °F	120
Design pressure, psig	Atmospheric
Material	Stainless steel
Design code	ASME Section III,Class 2
Seismic design	Category I
Containment Spray System Piping	
Material	Stainless steel
Design code	ASME Section III, Class 2
Seismic design	Category I
Containment Air Coolers	
Quantity	4
Type	Draw-through
Duty Btu/hr each	
Normal	3.384×10^6
Post LOCA	Figure 6.2.1-15
Post steam line break	Figure 6.2.1-15
Air flow (normal/accident), cfm each	140,000/69,400
Static pressure (normal/accident),in. w.g.	3.76/2.38
Water flow (normal/accident), gpm each	1,100/2,000 to 1,000 (min.)
Inlet water temp (normal/accident), °F	95/95
Leaving water temp (normal/accident), °F	100/206
Inlet air temp (normal/accident), °F	120/312

TABLE 6.2.2-2 (Sheet 3)

Leaving air temp (normal/accident), °F	97/260
Type of fan	Vaneaxial
Arrangement	4
Motor horsepower (normal/accident), hp	150/75
Motor rpm (normal/accident)	1,200/600
Fouling factor	0.002
Material (tube)	Cu-Ni
Material (header)	Stainless Steel
Design Code	ASME Section III, Class 3
Seismic Design	Category I

Containment Spray System Isolation Valve Encapsulation Tank

Manufacturer	Richmond Eng.
Quantity	2
Height ft-in.	10 - 9
Diameter, ft-in.	4 - 0
Design pressure, psig	75
Design temperature, °F	400
Material	Austenitic SS
Codes and standards	ASME Section III, Class 2
Seismic Category	I

TABLE 6.2.2-3 SUMMARY OF ACCIDENT CHRONOLOGY FOR CONTAINMENT SPRAY SYSTEM FOR LOSS-OF-COOLANT ACCIDENT

Injection Phase

Time (Sec)	Action
0.0	Event, SIS signal, and start diesel generators.
3.0	Containment pressure reaches Hi1 containment pressure setpoint (6 psig), assuming worst case LOCA or MSLB inside the containment. Time includes instrument lag time.
10.0	Diesel generators attain rated speed and voltage, including actuation instrument lag time. Hi3 containment pressure setpoint (30 psig) attained.
12.0	Sequencer energizes motor control centers to open motor-operated spray header isolation valves. Maximum valve opening time is 15 seconds.
25.0	Sequencer applies power to containment spray pumps.
27.0	Slowest spray header motor-operated isolation valves reach full open position.
29.0	Containment spray pumps attain operating speed and design flow.
±60.0	Flow is delivered to the containment.
	When containment pressure drops below 30 psig, reset containment spray actuation signal (CSAS).

NOTES: The worst case LOCA inside the containment is assumed to occur at time zero.

Using conservative analyses, spray flow will be delivered to all spray nozzles within 25 seconds after the spray pump starts; however, 35 seconds is assumed for conservatism.

TABLE 6.2.2-3 (Sheet 2)

Recirculation Phase

Time (Min)	Action
0.0	Reach lo-lo-2 level in RWST.
0.5	Manually initiate opening the containment sump recirculation valves (opening time max 30 sec).
1.0	Verify sump recirculation valves are open.
1.5	Manually initiate closing of RWST isolation valves.

The time that lo-lo-2 level in the RWST is reached following the event depends on whether full or partial ECCS and containment spray flow is attained, and is ≥ 20.8 minutes.

TABLE 6.2.2-3 (Sheet 3)

SUMMARY OF ACCIDENT CHRONOLOGY FOR CONTAINMENT SPRAY FOR MAIN STEAM LINE BREAK WITH OFFSITE POWER AVAILABLE

(CASE 6 AND CASE 12) [(1)]

Time (Sec) Case 6	Time (Sec) Case 12	Action
0	0	Break occurs, blowdown from all steam generators.
14.4	17.5[(2)]	Containment pressure HI-1 setpoint reached. Initiates SI, CIS-A, feedline isolation, etc. Since offsite power is available, the load sequencer starts and provides power to the CSS containment isolation valve immediately and 15 seconds later power is supplied to the containment spray pump. (The CSS components do not actuate until CSMS is generated by a containment HI-3 pressure signal).
103.3	160	Containment pressure HI-3 setpoint reached. CSAS generated which simultaneously opens the containment isolation valves and starts the spray pumps.
107.3	164	Containment spray pumps reach operating speed. The flow rate has rapidly increased toward runout conditions as flow fills pipe. The resistance of the partially open containment isolation valve rapidly decreases as the circular wedge arises.
118.3	175	Containment isolation valve reaches the first open position. Runout flow rates are conservatively assumed as flow continues to fill the spray headers which offer little flow resistance.
133.3	190	All air is vented from the last spray nozzle as the headers become water solid. The system flow rate rapidly reduces from runout conditions to the design flow rate as the nozzles impose the design pressure drop shown on Figure 6.5-1.

TABLE 6.2.2-3 (Sheet 4)

Time (Sec)		Action
1800	1800	MASS and ENERGY addition to the containment ends, containment pressure reduces. Containment spray may be terminated.

(1) Table 6.2.1-58 provides information on 16 steam breaks analyzed for containment pressure and temperature and analyses and includes the times at which HI-1 and HI-3 containment pressures are reached for each case.

(2) As described in Section 15.1.5, low steam line pressure could initiate safety injection sooner than HI-1; however, the use of HI-1 is conservative.

TABLE 6.2.2-4 SPRAY INJECTION PHASE DURATION

Case	Flow Condition	Single Failure	Operator Action for Spray Switchover	Time Length of Injection (min.)	Remarks
1	Two trains ECCS Two trains spray	None	30 seconds after receipt of the lo-lo-2 alarm	25.3	Refer to Table 6.3-11 and 6.3-11(a) .
2	Two trains ECCS Two trains spray	RHR/RWST valve fails to close	30 seconds after the end of step 6 of ECCS switchover	23.8	Refer to Table 6.3-12. RWST Lo-Lo-2 alarm received during ECCS switchover. CS switchover is assumed to commence following completion of ECCS switchover.
3	Two trains ECCS One train spray	One spray train fails	30 seconds after receipt of the lo-lo-2 alarm	38.2	
4	Two trains spray One train ECCS	One train of ECCS pumps assumed to fail	30 seconds after receipt of the lo-lo-2 alarm	30.2	ECCS one-train flow rates are as follows: RHR 5500 gpm SI 675 gpm CC 550 gpm
5	Two trains spray Two trains ECCS	Ctmt spray sump valve fails to open	30 seconds after receipt of the lo-lo-2 alarm	25.3	Operator shuts down one spray train to protect the pump.

TABLE 6.2.2-5 CONTAINMENT SPRAY SYSTEM SINGLE-FAILURE ANALYSIS

Component	Malfunction	Comments
Containment spray pump	Fails to start	Two pumps provided; operation of one required.
Containment spray pump discharge isolation valve*	Fails to open	Two pumps provided, each with a separate discharge isolation pump valve; operation of one required.
Containment sump recirculation isolation valve	Fails to open	Two line in parallel, one each spray pump; operation of one required.

* Opens on coincidence of two-out-of-four Hi-3 containment pressure signals.

TABLE 6.2.2-6 WATER SOURCES AND WATER LOSSES WHICH CONTRIBUTE TO THE WATER LEVEL WITHIN THE REACTOR BUILDING FOLLOWING A LARGE LOCA

	Min.	Max.
Water Sources		
Reactor coolant inventory, lbm	551,068	580,700
Accumulator tanks inventory, lbm	199,997	226,700
Initial atmosphere water vapor, lbm	732	12,245
RWST, lbm at:		
Initiation of ECCS switchover	1,882,667	2,176,501
Containment spray switchover	2,688,945	3,154,823
Long-term recirculation	2,688,945	3,154,823
Total at:		
Initiation of ECCS switchover, ft^3	44,789	51,186
Containment spray switchover, ft^3	58,610	67,701
Long-term recirculation, ft^3	56,042	65,384
Water Losses		
Below El 2,000 ft, ft^3	16,298	16,298
Water remaining in RCS, ft^3	1,943	13,988
Trenches below El 2,000 ft, ft^3	176	176
Trenches below El 2,001 ft-4, ft^3	120	120
Miscellaneous wetted surfaces, ft^3	1,164	1,164
Upending pit and crossover pits, ft^3	232	232
ECCS Piping, ft^3	245	578
HVAC duct and piping, ft^3	20	25
Water in transit, ft^3	0	322
Refueling pool and head storage area, ft^3	108	351
Miscellaneous holdup, ft^3	0	250
Water in RCS, ft^3	1,937	13,988
Water vapor, ft^3 at:		
Initiation of ECCS switchover	614	4,126
Containment spray switchover	1,110	3,653
Long-term recirculation	321	715

TABLE 6.2.2-6 (Sheet 2)

	Min.	Max.
Total at:		
Initiation of ECCS switchover, ft^3	20,920	28,708
Containment spray switchover, ft^3	22,002	37,157
Long-term recirculation, ft^3	20,949	33,685
Accumulation Volume Available for Buildup		
From El 2,000 ft to El 2001 ft-4 in., ft^3	9,647	9,691
From El 2,001 ft-4 in. to El 2,001 ft-10 in., ft^3	5,851	5,926
From El 2,001 ft-10 in to 2,005 ft-4 in, ft^3/ft	12,043	12,353
Results		
Elevation of water at:		
Initiation of ECCS switchover	2,001'-10"	2003'-1"
Containment spray switchover	2,002'-4"	2004'-5"
Long-term recirculation	2,002'-4"	2004'-3"

TABLE 6.2.2-6A WATER SOURCES AND WATER LOSSES WHICH CONTRIBUTE TO THE WATER LEVEL WITHIN THE REACTOR BUILDING FOLLOWING A MAIN STEAM LINE BREAK

	Min.	Max.
Water Sources		
Blowdown mass including auxiliary feedwater, lbm	339,100	383,200
Initial atmosphere water vapor, lbm	732	12,245
RWST, lbm at:		
Initiation of ECCS switchover	1,882,667	2,176,501
Containment spray switchover	2,688,945	3,154,823
Long-term recirculation	2,688,945	3,154,823
Total at:		
Initiation of ECCS switchover, ft^3	38,045	43,767
Containment spray switchover, ft^3	51,744	60,188
Long-term recirculation, ft^3	49,826	58,405
Water Losses		
a. Primary side loss due to shrinkage, ft^3 at:		
Initiation of ECCS switchover	0	4,146
Containment spray switchover	0	4,137
Long-term recirculation	0	3,984
b. Other losses, ft^3:		
Below El 2,000 ft	16,298	16,298
Trenches below El 2,000 ft	176	176
Trenches below El 2,001 ft-4 in.	120	120
Miscellaneous wetted surfaces	1,164	1,164
Upending pit and crossover pits	232	232
ECCS Piping, ft^3	245	578
HVAC duct and piping, ft^3	20	25
Water in transit, ft^3	0	322
Refueling pool and head storage area, ft^3	108	351
Miscellaneous holdup, ft^3	0	250
Water vapor at:		
Initiation of ECCS switchover	614	3,014
Containment spray switchover	1,110	3,008
Long-term recirculation	321	715

TABLE 6.2.2-6A (Sheet 2)

	Min.	Max.
Total, ft^3 at:		
Initiation of ECCS switchover	18,977	26,676
Containment spray switchover	20,065	26,661
Long-term recirculation	19,078	23,681
Accumulation Volume Available for Buildup		
From El 2,000 ft to El 2,001 ft-4 in., ft^3	9,647	9,691
From El 2,001 ft-4 in. to El 2,001 ft-10 in., ft^3	5,851	5,926
From El 2,001 ft-10 in to 2,005 ft-4 in, ft^3/ft	12,043	12,353
Results		
Elevation of water at:		
Initiation of ECCS switchover	2001'-5"	2002'-8"
Containment spray switchover	2002'-7"	2003'-11"
Long-term recirculation	2003'-0"	2003'-10"

TABLE 6.2.2-7 INPUT AND RESULTS OF NPSH ANALYSIS

Containment Spray Pumps

Static head available (LOCA)	31 ft - 3-1/4 in.
Pump elevation (discharge centerline)	1971 ft - 0-3/4 in.
Suction line losses @ 3,950 gpm	9.2 ft
Available NPSH @ 3,950 gpm	22.0 ft
Required NPSH @ 3,950 gpm (from Figure 6.2.2-5)	16.5 ft

Residual Heat Removal Pumps

Pump elevation (discharge centerline)	1971 ft - 9-1/2 in.
Static head available (LOCA)(1)	30 ft - 0-1/2 in.
Suction line losses @ 4,800 gpm	4.3 ft
Available NPSH @ 4,800 gpm	25.7 ft
Required NPSH @ 4,800 gpm (from Figure 6.3-3)	21.7 ft

(1) Large LOCA conditions are provided for the RHR pumps since the flow rates, line losses, and NPSH required are greater than those associated with an MSLB wherein the RCS pressure remains above the RHR shutoff head at switchover to recirculation.

TABLE 6.2.2-8 CONTAINMENT AIR COOLING SYSTEM

Component	Malfunction	Comments
Containment cooler housing	Housing failure, air bypasses coils	One unit out of service. Three units are functional.*
Cooling coils	Loss of one train of essential service water	Two units out of of service. Redundant train (two coolers) is functional.
	Loss of one emergency diesel	Two units out of service. Redundant train (two coolers) is functional.
Fan	Fails to start at half speed	One unit out of service. Three units are functional.*
Fusible link plates	Fails to open, partial to complete loss of one cooler, depending upon degree of restriction in ductwork system	One unit out of service. Three units are functional.*

---

* Consists of the redundant train (two coolers) and the remaining functional cooler associated with the malfunctioning unit.

TABLE 6.2.2-9 SUMP STRAINER AND APPROACH VELOCITY FOR LOCA AND MSLB CONDITIONS

OPERATIONAL PHASE/MODE	FLOOD DEPTHS[1] Min	FLOOD DEPTHS[1] Max	FLOW RATE, gpm	FLOW VELOCITY - NOMINAL[2] FPS Maximum Approach to Sump Strainers
LARGE LOCA				
o At ECCS Switchover	2001-10	2003-1	4800	<0.08
o At Ctmt. Spray Switchover	2002-4	2004-5	8750	<0.08
o During Long-Term Cooling	2002-4	2004-3	4800	<0.08
MSLB				
o At ECCS Switchover	2001-5	2002-8	1200	<0.08
o At Ctmt. Spray Switchover	2002-7	2003-11	5150	<0.08
o During Long-Term Cooling[3]	2003-0	2003-10	1200	<0.08

NOTES:

(1) Flood depths (minimum and maximum) for each operational mode or phase are taken from Tables 6.2.2-6 and 6.2.2-6a.

(2) Original sump screens were replaced with strainers. The maximum velocity at the sump strainer face is approximately 0.01 fps, which is less than the original maximum approach velocity of 0.08 fps.

(3) The flowrates for long-term cooling following an MSLB assume that containment spray system operation is terminated and the RCS pressure is at 400 psig, which is above the shutoff head of the RHR pumps. As noted on Table 6.2.2-6a, isolation of auxiliary feedwater to the broken loop occurs at 10 minutes which terminates blowdown to the containment. Long-term recovery from an MSLB will be through cooldown using the normal RHR suction from the primary loop hot legs. Once flow is established from the primary loop, suction from the sump will not be required.

TABLE 6.2.4-1 LISTING OF CONTAINMENT PIPING PENETRATIONS

Penetration Number	Service	Section Number
Listing of Penetrations Under Category GDC-55		
P-21	RHR hot leg injection	5.4.7/6.3
P-22	RCP-B seal water supply	5.4
P-23	CVCS letdown	9.3.4
P-24	RCP seal water return	5.4
P-27	RHR cold leg injection loops 3 and 4	5.4.7/6.3
P-39	RCPC, seal water supply	5.4
P-40	RCPD, seal water supply	5.4
P-41	RCP-A, seal water supply	5.4
P-48	SI pump - B, discharge to hot legs 1 and 4	6.3
P-49	SI pumps crosstie to cold legs 1, 2, 3, and 4	6.3
P-52	RHR pump suction from hot leg loop 4	5.4.7/6.3
P-59	Reactor vessel level indication system	18.1.13.2
P-64	Nuclear sampling system	9.3.2
P-69	Pressurizer vapor sample	9.3.2
P-79	RHR pump suction from hot leg loop 1	5.4.7/6.3
P-80	CVCS charging	9.3.4
P-82	RHR pump discharge to hot leg loops 1 and 2	5.4.7/6.3
P-87	SI pump A discharge to hot leg loops 2 & 3	6.3
P-88	Boron injection supply to cold leg loops 1, 2, 3, and 4	6.3
P-91	Reactor vessel level indication system	18.2.13.2
P-93	RC loop and pressurizer liquid sample	9.3.2
P-95	Accumulator liquid sample	9.3.2

TABLE 6.2.4-1 (Sheet 2)

Penetration Number	Service	Section Number
Listing of Penetrations Under Category GDC-56		
P-13	Containment recirculation sump to containment spray pump	6.2.2
P-14	Containment recirculation sump to RHR pump suction	5.4.7/6.3
P-15	Containment recirculation sump to RHR pump suction	5.4.7/6.3
P-16	Containment recirculation sump to containment spray pump	6.2.2
P-25	Reactor make-up water supply	9.2.7
P-26	Reactor coolant drain tank discharge	11.2
P-28	ESW supply to containment air coolers	6.2.2
P-29	ESW return from containment air coolers	6.2.2
P-30	Instrument air	9.3.1
P-32	Containment sump pump discharge	9.3.3
P-34	Containment ILRT test line	6.2.6
P-43	Auxiliary steam-decontamination	12.3
P-44	Reactor coolant drain tank vent	11.2
P-45	Accumulator nitrogen supply	6.3
P-51	ILRT pressure test line	6.2.6
P-53	FPC and clean-up, refueling pool supply	9.1.3
P-54	FPC and clean-up, refueling pool suction	9.1.3
P-55	FPC and clean-up, refueling pool skimmer	9.1.3
P-56	Post-LOCA hydrogen analyzer return	6.2.5
P-56	Containment atmosphere monitor GT-RE-31 return	9.4.6
P-57	Post-accident sampling return to RCDT	18.2.3

TABLE 6.2.4-1 (Sheet 3)

Penetration Number	Service	Section Number
P-58	Accumulator fill line from SI pumps	6.3
P-62	Pressurizer relief tank nitrogen supply	5.4
P-63	Service air supply	9.3.1
P-65	Hydrogen purge	6.2.5
P-66	Containment spray supply from pump B	6.2.2
P-67	Fire protection	9.5.1
P-71	ESW supply to containment coolers	6.2.2
P-73	ESW return from containment coolers	6.2.2
P-74	CCW supply	9.2.2
P-75	CCW return	9.2.2
P-76	Cooling water thermal barrier return	9.2.2
P-78	Drain line from steam generator	10.4.8
P-89	Containment spray supply from pump A	6.2.2
P-92	ECCS test line return	6.3
P-97	Post-LOCA hydrogen analyzer return	6.2.5
P-97	Containment atmosphere monitor GT-RE-32 return	9.4.6
P-98	Breathing air supply	6.2
P-99	Post-LOCA hydrogen analyzer supply	6.2
P-99	Containment atmosphere monitor GT-RE-31 supply	9.4.6
P-101	Post-LOCA hydrogen analyzer supply	6.2
P-101	Containment atmosphere monitor GT-RE-32 supply	9.4.6
P-103	Containment pressure sensing monitor	6.3/9.4
P-104	Containment pressure sensing monitor	6.3/9.4
E-256	Containment pressure sensing monitor	6.3/9.4

TABLE 6.2.4-1 (Sheet 4)

Penetration Number	Service	Section Number
V-160	Containment purge	9.4
V-161	Containment purge	9.4
P-36	Temporary Access	6.2
P-50	Temporary Access	6.2
P-68	Temporary Access	6.2

TABLE 6.2.4-2 DESIGN COMPARISON TO REGULATORY GUIDE 1.141 REVISION 0, DATED APRIL 1978, TITLED CONTAINMENT ISOLATION PROVISIONS FOR FLUID SYSTEMS

Regulatory Guide 1.141 Positions	Union Electric
C. REGULATORY POSITION	
The requirements and recommendations for containment isolation of fluid systems that penetrate the primary containment of light-water-cooled reactors as specified to ANSI N271-1976, "Containment NRC Isolation Provisions for Fluid Systems," are generally acceptable and provide an adequate basis for complying with the pertinent containment isolation requirements of Appendix A to 10 CFR Part 50, subject to the following:	Figure 6.2.4-1 shows the arrangement and justifies compliance with the intent of GDC-55, 56, and 57. Guidelines provided by Regulatory Guide 1.11, ANSI N271-1976, SRPs 6.2.4 and 6.2.6, and this guide are the bases for compliance.
1. Section 3.64 of ANSI N271-1976 states: "The closed system shall be leak tested in accordance with 5.3 of this standard unless it can be shown by inspection that system integrity is being maintained for those systems operating at a pressure equal to or above the containment design pressure." This exception to system leak testing is also applicable to closed systems inside the containment.	1. All containment penetrations are covered by either GDC-55 or GDC-56. Callaway has no penetrations subject to GDC-57.
2. Section 4.2.3 of ANSI N271-1976 states: "Sealed closed isolation valves are under administrative controls and do not require position indication in the control room for valve status." Since the containment isolation valves are components of the containment isolation system, which is an engineered-safety-feature system, all power-operated valves should have position indication in the control room.	2. Complies as described in Section 6.2.4.5.

TABLE 6.2.4-2 (Sheet 2)

Regulatory Guide 1.141 Positions	Union Electric
3. Section 4.2.5 of ANSI N271-1976 states: "Diversity in means of actuation of automatic isolation valves in should be considered to preclude common mode failure." The NRC staff's position is that there should be diversity in the parameters sensed (i.e., types of isolation signals) for the initiation of containment isolation.	3. Complies as described in Section 7.3.
4. Section 4.4.8 of ANSI N271-1976 gives general design requirements for closed systems. In addition, all branch lines and their isolation valves in closed systems both inside and outside the containment should meet the design criteria of Section 3.5 or Section 3.6.7 if the branch lines constitute one of the containment isolation barriers.	4. Complies.
5. In Section 4.6.3 of ANSI N271-1976, reference is made to Regulatory Guide 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident," for guidance in determining radiation exposures for a loss-of-coolant accident. More appropriate guidance is given in Regulatory Guide 1.89, "Qualification of Class 1E Equipment for Nuclear Power Plants."	5. Complies as described in Section 3.11.
6. Section 4.14 of ANSI N271-1976 states: "The piping between isolation barriers or piping which forms part of isolation barriers shall meet the requirements of 3.7 and applicable requirements for isolation barriers." Piping between isolation barriers should meet the applicable requirements of Section 3.5 or Section 3.7.	6. Complies.

TABLE 6.2.5-1 DESIGN DATA FOR CONTAINMENT HYDROGEN CONTROL SYSTEM COMPONENTS

Hydrogen Recombiners	
Quantity	2 per unit
Power (each), max/min, kW	75/50
Capacity (each), minimum, scfm	100
Heaters (per recombiner)	
Number	4 banks
Maximum heat flux, Btu/hr-ft^2	2,850
Maximum sheath temperature, °F	1,550
Gas temperatures	
Inlet, °F	80-155
Outlet of heater section, °F	1,150 to 1,450
Exhaust	Approx 50°F above ambient
Materials	
Outer structure	Type 300 series SS
Inner structure	Incoloy 800
Heater element sheath	Incoloy 800
Base skid	Type 300 series SS
Weight, lbs	4,500
Codes and standards	ASME Sect. IX, UL, NEMA, NFPA, IEEE 279, 308, 323, 344, and 383, ANS Safety Class 2
Hydrogen Analyzer	
Quantity	2 per unit
Type	Thermal conductivity
Range	0-10 volume percent
Accuracy	± 4.0 percent of full scale
Valves (isolation)	
Quantity	10
Type	Solenoid-operated gate valve
Tubing material	Stainless steel
Codes and standards	IEEE 279, 323, 344, 383, NEMA, ANS Safety Class 2
Hydrogen Mixing Fans	
Quantity	4
Type	Vaneaxial
Arrangement/AMCA class	4/II

TABLE 6.2.5-1 (Sheet 2)

Air flow (normal/accident), cfm each	85,000/42,500
Static pressure (normal/accident), in. w.g. each	0.91/0.50
Motor horsepower (normal/accident), hp each	50/25
Motor rpm (normal/accident)	900/450
Codes and standards	(Motor) IEEE Std 334 (Motor) NEMA (Fan) AMCA ANS Safety Class 2

TABLE 6.2.5-2 SUMMARY OF ASSUMPTIONS USED FOR HYDROGEN GENERATION FROM RADIOLYSIS

a. The average fuel exposure is 600 full power days at 3,636 MWt.

b. An insignificant quantity of hydrogen is generated due to the radiolysis from the noble gas isotopes.

c. The guidelines set forth in Regulatory Guide 1.7, Revision 2 were followed:

1. 100 percent of the noble gases is released to the atmosphere.

2. 50 percent of the halogens and 1 percent of the solids present in the core are intimately mixed with the coolant water.

3. $G(H_2)$ is 0.5 molecule/100 eV.

4. $G(O_2)$ is 0.25 molecule/100 eV.

5. The following percentage of fission product radiation energy is absorbed by the coolant:

Percentage	Radiation Type	Location of Source
0%	Beta	Fuel rods
100%	Beta	Coolant
10%	Gamma	Fuel rods
100%	Gamma	Coolant

TABLE 6.2.5-3 PARAMETERS USED TO DETERMINE HYDROGEN GENERATION

Plant power level, MWt	3,636 MWt
Containment free volume, ft^3	2.5×10^6
Containment temperature at accident, °F	120°F
Corrodible metals	Aluminum, zinc

TABLE 6.2.5-4 POST-ACCIDENT CONTAINMENT TEMPERATURE TRANSIENT AND CORROSION RATES USED IN THE HYDROGEN GENERATION ANALYSIS

Aluminum

Temp (F)	Corrosion rate (mils/yr)
400	11,000
275	11,000
240	4,000
202	1,250
170	390
140	200
110	200

Zinc

Temp (F)	Corrosion rate (mils/yr)
400	154.56
200	154.56
170	11.58
140	.62
138	2.35
110	2.35

Zinc paint

Temp (F)	Corrosion rate (mils/yr)
400	72.62
200	72.62
170	6.86
140	1.64
138	1.12
110	1.12

TABLE 6.2.5-4 (Sheet 2)

TIME-DEPENDENT TEMPERATURE PROFILE (FROM FIGURE 6.2.1-7)

Time (sec)	Temp (F)
0	120
1	162
10	251
60	308
200	275
1.0E3	262
1.0E4	187
1.0E5	137
1.0E6	120
1.0E7	120

TABLE 6.2.5-5 SINGLE FAILURE ANALYSIS CONTAINMENT HYDROGEN CONTROL SYSTEM

Component	Malfunction	Consequences
Hydrogen recombiner subsystem	Recombiner fails to operate properly	Redundant recombiner available
Hydrogen analyzer subsystem	Analyzer fails to operate and/or an isolation valve fails to open	Redundant analyzer with separate sampling lines available
Hydrogen mixing subsystem	With loss of one train of power, two fans fail to operate	Two redundant, full capacity mixing fans available, powered from an independent Class 1E bus

TABLE 6.2.5-6 COMPARISON OF THE DESIGN TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.7, REVISION 3, DATED MARCH, 2007, TITLED “CONTROL OF COMBUSTIBLE GAS CONCENTRATIONS IN CONTAINMENT”

Regulatory Guide 1.7 Position	Union Electric Position
1. The following design guidance is applicable to combustible gas control systems installed to mitigate the risk associated with combustible gas generation attributed to beyond-design-basis accidents. Structures, systems, and components (SSCs) installed to mitigate the hazard from the generation of combustible gas in containment should be designed to provide reasonable assurance that they will operate in the severe accident environment for which they are intended and over the time span for which they are needed. The staff considers that the combustible gas control systems are installed and approved by the NRC as of October 16, 2003 are acceptabe without modification.	1. Complies.
2. The equipment for monitoring hydrogen must be functional, reliable, and capable of continuously measuring the concentration of hydrogen in the containment atmosphere following a beyond-design-basis accident for accident management, including emergency planning. Safety-related hydrogen monitoring systems installed and approved by the NRC prior to October 16, 2003, are sufficient to meet these criteria.	2. Complies.

TABLE 6.2.5-6 (Sheet 2)

Regulatory Guide 1.7 Position	Union Electric Position
3. Section 50.44 requires that all containments have a capability for ensuring a mixed atmosphere. The capability may be provided by an active, passive, or combination system. Active systems may consist of a fan, a fan cooler, or containment spray. For passive or combination systems that use convective mixing to mix the combustible gases, the containment internal structures should have design features that promote the free circulation of the atmosphere. All containment types should have an analysis of the effectiveness of the method used for providing a mixed atmosphere. This analysis should demonstrate that combustible gases will not accumulate within a compartment or cubicle to form a combustible or detonable mixture that could cause a loss of containment integrity. Atmosphere mixing systems prevent local accumulation of combustible or detonable gases that could threaten containment integrity or equipment operating in a local compartment. Active systems installed to mitigate this threat should be reliable, redundant, single-failure-proof, able to be tested and inspected, and remain operable with a loss of onsite or offsite power. The NRC staff considers atmosphere mixing systems installed and approved by the NRC as of October 16, 2003, to be acceptable without modification.	3. Complies.
4. Materials within the containment that would yield hydrogen gas by corrosion from the emergency cooling or containment spray solutions should be identified, and their use should be limited as much as practicable.	4. Complies. Table 6.2.5-3 and Figure 6.2.5-2 provide the maximum source inventories.

TABLE 6.2.5-6 (Sheet 3)

Regulatory Guide 1.7 Position	Union Electric Position
5. Section 50.44 requires that containment structural integrity be demonstrated by use of an analytical technique that is accepted by the NRC staff. This demonstration must include sufficient supporting justification to show that the technique describes the containment response to the structural loads involved. The following criteria of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code provide an acceptable method for demonstrating that the requirements are met: (1) Steel containments meet the requirements of the ASME Boiler and Pressure Vessel Code (edition and addenda as incorporated by reference in 10 CFR 50.55a(b)(1)), section III, Division 1, Subsubarticle NE-3220, Service Level C Limits, considering pressure and dead load alone (evaluation of instability is not required). (2) Concrete containments meet the requirements of the ASME boiler and Pressure Vessel Code, Section III, Division 2, Subsubarticle CC-3720, Factored Load Category, considering pressure and dead load alone. As a minimum, the specific code requirements set forth for each type of containment should be met for a combination of dead load and internal pressure of 45 psig. The staff will consider modest deviations from these criteria, if the applicant shows good cause. These criteria, which no longer are contained in Section 50.44, remain acceptable to the NRC staff for meeting the current regulations. The acceptability of licensee analyses using the ASME Code criteria remains unaffected by this rulemaking.	5. Complies.

6.3 EMERGENCY CORE COOLING SYSTEM

The emergency core cooling system (ECCS) is designed to cool the reactor core and provide shutdown capability following initiation of the following accident conditions:

a. Loss-of-coolant accident (LOCA), including a pipe break or a spurious relief or safety valve opening in the reactor coolant system (RCS) which would result in a discharge larger than that which could be made up by the normal makeup system.

b. Rupture of a control rod drive mechanism, causing a rod cluster control assembly ejection accident.

c. Steam or feedwater system break accident, including a pipe break or a spurious relief or safety valve opening in the secondary steam system which would result in an uncontrolled steam release or a loss of feedwater.

d. A steam generator tube failure.

The primary function of the ECCS is to provide emergency core cooling (ECC) in the event of a LOCA resulting from a break in the primary reactor coolant system (RCS) or to provide emergency boration in the event of a steam/or feedwater break accident resulting from a break in the secondary steam system.

6.3.1 DESIGN BASES

6.3.1.1 Safety Design Basis

The ECCS is safety related and is required to function following a DBA and to achieve and maintain the plant in a safe shutdown condition.

SAFETY DESIGN BASIS ONE - Except for the refueling water storage tank (RWST), the ECCS is protected from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC-2). The RWST is designed to seismic Category I requirements only.

SAFETY DESIGN BASIS TWO - The ECCS is designed to remain functional after an SSE and to perform its intended function following the postulated hazards of fire, internal missiles, or pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Safety functions can be performed, assuming a single active component failure coincident with the loss of offsite power (GDC-35).

SAFETY DESIGN BASIS FOUR - The active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of components at appropriate times specified in the ASME Boiler and Pressure Vessel Code, Section XI (GDC-36 and 37).

SAFETY DESIGN BASIS FIVE - The ECCS is designed and fabricated to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - The capability to isolate components or piping is provided so that the ECCS safety function will not be compromised. This includes isolation of components to deal with leakage or malfunctions and to isolate nonsafety-related portions of the system (GDC-35).

SAFETY DESIGN BASIS SEVEN - The containment isolation valves in the system are selected, tested, and located in accordance with the requirements of GDC-54 and 55 and 10 CFR 50, Appendix J, Type A testing.

SAFETY DESIGN BASIS EIGHT - ECCS equipment design ensures acceptable performance for all environments anticipated under normal, testing, and design basis accident conditions.

SAFETY DESIGN BASIS NINE - The functional requirements of the ECCS are derived from Appendix K limits for fuel cladding temperature, etc., following any of the above accidents, as delineated in 10 CFR 50.46. The subsystem functional parameters are integrated so that the Appendix K requirements are met over the range of anticipated accidents and single failure assumptions.

6.3.1.2 Power Generation Design Basis

There are no power generation design bases for the ECCS function. Portions of the ECCS are also portions of the residual heat removal system (RHRS) and chemical and volume control system (CVCS) and are used during normal power operation. Power generation design bases for these portions of the ECCS are discussed in Sections 5.4.7 and 9.3.4, respectively.

6.3.2 SYSTEM DESCRIPTION

6.3.2.1 General Description

The ECCS components are designed so that a minimum of three accumulators, one ECCS centrifugal charging pump, one safety injection pump, and one residual heat removal pump, together with their associated valves and piping, ensure adequate core cooling in the event of a design basis LOCA or to provide boration in the event of a steam/or feedwater break accident. The term “centrifugal charging pump” or “CCP” refers to the safety-related ECCS pumps only (PBG05A and PBG05B). The normal charging pump or NCP (PBG04) does not serve an ECCS function (the NCP is tripped by a safety injection signal).The redundant onsite emergency diesels assure adequate emergency power to at least one train of electrically operated components in the event that a loss of offsite power occurs simultaneously with a LOCA.

The P&IDs for the ECCS are shown in Figures 5.4-7, 6.3-1, and 9.3-8. ECCS flow diagrams are shown in Figure 6.3-2. Pertinent design and operating parameters for the components of the ECCS are given in Table 6.3-1. The design parameters shown represent the values specified in procurement specifications. Operating parameters are typical for the SNUPPS units. However, minor variations in performance characteristics exist between individual components. The accident analyses contain adequate margin to account for these individual component variations.

The component interlocks used in the different modes of system operation are listed below.

a. The SIS initiates the following actions:

   1. Emergency diesel generators start

   2. ECCS centrifugal charging pumps start

   3. RWST suction valves to ECCS charging pumps open

   4. Boron injection suction and discharge parallel isolation valves open

   5. Normal charging path valves close and normal charging pump trips

   6. Deleted

   7. Deleted

   8. Deleted

   9. Safety injection pumps start

   10. Residual heat removal pumps start

   11. Volume control tank outlet isolation valves close after the RWST suction valves to the charging pumps are opened (see Section 7.6.11)

   12. RWST discharge isolation valves to the spent fuel pool cooling and cleanup system close (BNHCV8800A and B).

b. Switchover from injection mode to recirculation involves the following interlocks:

1. The suction valves in the line from the sump to the RHR pumps open when two out of four low level transmitters indicate a low level in the RWST in conjunction with an SIS. The valves from the RWST to the RHR suction will close automatically after the sump suction valves are open. This interlock is also discussed in Section 7.6.5.

2. The safety injection pump and ECCS charging pump recirculation suction isolation valves, EJ-HV-8804A and B, can be opened provided that either the safety injection system miniflow isolation valve, BN-HV-8813, or both safety injection pump miniflow isolation valves, EM-HV-8814A and B, are closed. Additionally, one of the two RHR hot leg suction valves on Loop 1, BB-PV-8702A and EJ-HV-8701A, and on Loop 4, BB-PV-8702B and EJ-HV-8701B, must be closed.

6.3.2.2 Equipment and Component Descriptions

Codes and standards applicable to the ECCS are listed in Tables 3.2-1 and 6.3-1.

The component design and operating conditions are specified as the most severe conditions to which each respective component is exposed, during either normal plant operation or operation of the ECCS. For each component, these conditions are considered in relation to the code to which it is designed. By designing the components in accordance with applicable codes, and with due consideration for the design and operating conditions, the fundamental assurance of structural integrity and operability of the ECCS components is maintained. Components of the ECCS are designed to withstand the appropriate seismic loadings, in accordance with their safety class as given in Table 3.2-1. ECCS piping and components have the potential to develop voids and pockets of entrained gases. Preventing and managing gas intrusion and accumulation in the pump suction and pump discharge piping, however, supports proper operation of the ECCS and may also prevent water hammer, pump cavitation and pumping of noncondensible gas into the reactor vessel.

The elevated temperature of the sump solution during recirculation is well within the design temperature of all ECCS components. In addition, consideration has been given to the potential for corrosion of various types of metals exposed to the fluid conditions prevalent immediately after the accident or during long-term recirculation operations.

The following is a discussion of the major components of the ECCS:

Accumulators

The accumulators are pressure vessels partially filled with borated water and pressurized with nitrogen gas. During normal operation, each accumulator is isolated from the RCS by two check valves in series. Should the RCS pressure fall below the accumulator pressure, the check valves open and borated water is forced into the RCS.

One accumulator is attached to each of the cold legs of the RCS. Mechanical operation of the swing-disc check valves is the only action required to open the injection path from the accumulators to the core via the cold leg.

Connections are provided for adjusting the level and boron concentration of the borated water in each accumulator during normal plant operation, as required. Accumulator water level may be adjusted either by draining to the recycle holdup tank or by pumping borated water from the RWST to the accumulator. Samples of the solution in the accumulators are taken periodically for checks of boron concentration.

Accumulator pressure is provided by a supply of nitrogen gas, and can be adjusted, as required, during normal plant operation. However, the accumulators are normally isolated from this nitrogen supply. Gas relief valves on the accumulators protect them from pressures in excess of design pressure. Accumulator gas pressure is monitored by indicators and alarms. Solenoid-operated vent valves are provided to depressurize the accumulators during emergency cold shutdown conditions.

The accumulators are located within the containment but outside of the secondary shield wall which protects the tanks from missiles generated from a postulated LOCA.

Refueling Water Storage Tank

The borated refueling water storage facility consists of a large outside storage tank (i.e., RWST) with connections for borated demineralized water delivery to and receipt from the fuel pool cooling and cleanup system, the chemical and volume control system, the containment spray system, and the ECCS. In addition to the two safety injection (SI) pumps in their standby lineup, procedural controls ensure that, at most, only one other system is aligned to the RWST return header at any time when the RWST is required to be OPERABLE for ECCS support. In the event of an accident requiring the ECCS for mitigation, these procedural controls ensure proper isloation of non-safety piping aligned to the RWST return header. In particular, whenever the safety injection signal (SIS) is enabled (i.e., when the signal is not manually blocked as allowed when pressurizer pressure is below the P-11 permissive setpoint) and the contents of the RWST are being recirculated via BNHCV8800A and B (valves are automatically isolated after receipt of an SIS) and the fuel pool cooling and cleanup system, no other systems (with the exception of the two SI pumps in their standby lineup) may be aligned to the RWST return header.

The RWST is a passive seismic Category I component and is required only during the short term following a LOCA, MSLB, or any other accident requiring ECCS. Therefore, neither redundancy nor tornado missile protection is required. The safety-related level instrumentation and the temperature monitoring instrumentation associated with the RWST are designed with redundancy.

The RWST is vented directly to the atmosphere. Tank overflow is directed to the waste holdup tank in the liquid radwaste system via the floor and equipment drain system. Sample connections are also provided to allow periodic analysis of the RWST contents.

A heater system is provided to prevent the contents of the RWST from freezing. The RWST heating system is operational when required in accordance with plant cold weather operations or as required in response to low RWST temperature. The heater system consists of steam coils wrapped around the outside of the RWST, insulation on the RWST, electrical heat tracing on the exposed nonessential piping, and a heated enclosure for the essential piping, valves, and instrumentation. These steam coils are serviced by the auxiliary steam system. For freeze protection during colder periods of the year, the RWST is automatically maintained above 50°F by using a temperature control valve to control steam flow to the steam coil heaters. Although the RWST is normally maintained above 50°F the Technical Specifications allow operation of the RWST with a solution temperature as low as 37°F. Redundant temperature instrumentation is provided to inform the operator of any degradation of the heating capability for the RWST.

Water level in the RWST is maintained above the minimum ECCS Technical Specification level consistent with the volumes required for injection, transfer allowances, and instrument error allowances. The RWST levels and volumes shown on Figure 6.3-7 are based on the following considerations.

Injection Mode Allowance

The injection mode of ECCS operation consists of the ECCS pumps (centrifugal charging pumps, safety injection pumps, and residual heat removal pumps) and the containment spray pumps taking suction from the RWST and delivering to the reactor coolant system (RCS) and containment, respectively. The maximum assured RWST volume available for ECCS pump injection mode operation is 235,597 gallons.

Containment and RCS pressures are conservatively assumed to be 0 psig to maximize flow out of the RWST.

Flow out of the RWST during the injection mode includes conservative allowances for two pumps of each type operating at the following flow rates:

Safety injection pump	-	414 gpm per pump
ECCS centrifugal charging pump	-	481 gpm per pump
RHR pump	-	4,867 gpm per pump
Containment spray pump	-	3,806 gpm per pump

Total RWST outflow rate during injection mode operation is 19,136 gpm.

The minimum assured RWST volume available for ECCS pump injection mode operation is 227,163 gallons. Based on this minimum assured RWST volume available for injection mode operation and the maximum total flow rate out of the RWST, the shortest injection mode operation time is approximately 11.8 minutes.

Transfer Allowance - RHR, ECCS Charging, SI

During the injection mode of ECCS operation, the operator monitors the RWST level and containment sump level in anticipation of switchover. Upon receipt of the RHR auto switchover alarm (Lo-Lo-1), the operator is required to initiate the manual operations required to complete switchover in a timely manner.

The ECCS switchover from injection to cold leg recirculation is initiated automatically upon receipt of the RHR auto switchover trip signal and is completed via timely operator action at the main control board. Switchover is initiated via automatic opening of the containment recirculation sump isolation valves (EJHV8811 A/B). This automatic action aligns the suction of the RHR pumps to the containment recirculation sump to ensure continued availability of a suction source. Manual actions 1 through 4 of Table 6.3-8 must be performed following switchover initiation prior to loss of the RWST transfer allowance to ensure that all ECCS pumps are protected with suction flow available from the containment sump. Following the completion of step 4, all ECCS pumps are aligned with suction flow from the containment sump. Completion of steps 5 and 6 only provides redundant isolation of the RWST from the recirculation fluid. The ECCS switchover procedure is carried out in a sequential manner by the operator to provide simultaneous alignment of both trains of the ECCS from injection to recirculation, repositioning functionally similar switches as part of the same procedural steps.

The time available for switchover is dependent on the flow rate out of the RWST as the switchover manual actions are performed. As ECCS valves are repositioned, the flow rate out of the RWST is reduced in magnitude. In order to analyze the time available for switchover, the following conservative bases are established:

1. The minimum RWST transfer allowance available for ECCS pump switchover is 88,851 gallons.

2. Containment and RCS pressures for large break conditions are conservatively assumed to be 0 psig. Thus, no credit is taken for the reduction in RWST outflow that will result with higher containment and RCS pressures following a large break.

Based on the above criteria, the flow rates out of the RWST as a function of switchover manual action are itemized in Table 6.3-11 for large breaks and Table 6.3-12 for a large break with the limiting single failure. The large break with single failure constitutes the condition where RWST outflow is the greatest. The worst single failure is for RWST/RHR isolation valve (8812A or 8812B) not to close. The operators must take additional manual actions as described in Table 6.3-12 to secure the affected RHR pump, manipulate valves, and attempt to restart the RHR pump. The minimum time available for the operator to accomplish the switchover of the ECCS pumps for a large break with the single failure is 8 minutes 20 seconds (note that it is also assumed that the operator secures the affected RHR pump within 2 minutes 55 seconds from receipt of the RWST Lo-Lo-1 alarm). Flow rate data for small breaks are less than for large breaks and are not included in Table 6.3-12.

Transfer Allowance - Containment Spray

The RWST volume between the Lo-Lo-2 setpoint and the empty setpoint is required for containment spray pump switchover from the RWST to the sump. The available volume is 15,757 gallons. With both spray pumps operating, this volume provides a minimum switchover time of 3.0 minutes. This switchover time is consistent with the operator action time of 3.0 minutes provided in Tables 6.3-11(a) and 6.3-12.

The total transfer allowance for ECCS and containment spray pump switchover is 113,034 gallons. In the worst single failure case, the total outflow from the RWST during ECCS pump switchover is 96,774 gallons, leaving 16,260 gallons for containment spray pump switchover. At the completion of switchover step 6 in Table 6.3-12, 7,612 gpm is being drawn from the RWST by two containment spray pumps.

The time required to complete containment spray pump switchover is 3.0 minutes. This will draw another 15,075 gallons from the RWST at the flow rates listed in Table 6.3-12. Since the available transfer allowance is 16,260 gallons, the containment spray pumps can be switched over prior to depletion of the RWST. For a failure of a Sump to CS pump valve to open (ENHV1 or ENHV7), the operator must secure the associated CS pump within 2 minutes of receipt of the RWST Lo-Lo-2 alarm and complete CS switchover of the other pump within 3 minutes.

Setpoints and Instrument Error

The level measurement system for the RWST includes four level transmitters, each of which has five setpoints, High, Low, Lo-Lo-1, Lo-Lo-2, and Empty. One out of four level channels sensing an individual setpoint will initiate the appropriate alarm. Two out of four level channels sensing an individual setpoint will initiate the appropriate automatic action. The RWST volume allows for a 3 percent variation in the level instrument circuits. The normal water level is maintained 3 percent below the overflow and 3 percent above the assured volume. The empty alarm is set 3 percent above the usable volume. These margins allow for the case where multiple level transmitters drift high or low and ensure that all alarms, automatic functions, and injected water quantities occur and are delivered as assumed in the analyses. If any one transmitter drifts high or low at one level, it will drift in the same direction at all other levels except possibly for bistable errors, which could be random in nature.

Inconsistency in bistable error could be ±1 percent. Since there are five bistables associated with each of the four transmitters, the volumes available for each phase have been adjusted for the worst combination of errors (i.e., 2 percent) when appropriate. These combinations are shown on Figure 6.3-7 to occur at the nominal setpoint for Lo-Lo-1, Lo-Lo-2, and Empty. This is conservative, since the amount of injection water for ECCS is based on the assured volume (drifting low) without the corresponding allowances at the other levels.

RWST Sampling and Cleanup

The RWST must be sampled prior to accepting makeup water from the CVCS to ensure the proper final boron concentration in the tank.

Samples are taken periodically from the RWST for analysis to assure that the quality of the contents meets the water chemistry specifications given in Table 9.2-15. If the tank contents require purification, they may be circulated through the fuel pool cooling and cleanup system except during certain plant conditions when RWST alignment to the fuel pool cooling and cleanup system via BNHCV8800A and B is procedurally prohibited, i.e., during MODE 3 with the safety injection signal blocked (the block is enabled when pressurizer pressure is below the P-11 permissive setpoint) and during all of MODE 4. BNHCV8800A and B are automatically closed by an SIS (below the P-11 permissive the SI signals derived from low pressurizer pressure and low steamline pressure may be manually blocked). Section 9.1.3.2.3.2 discusses the use of the fuel pool cleanup system for RWST recirculation and cleanup. To maintain the boron concentration within specification, a strong boric acid solution (7000 to 7700 ppm boron) or reactor makeup water can be added via the chemical and volume control system.

Residual Heat Removal Pumps

Two residual heat removal (RHR) pumps are provided. Each pump is a single-stage, vertical, centrifugal pump. In the event of a LOCA, the RHR pumps are started automatically on receipt of an SIS. The RHR pumps take suction from the RWST during the injection phase and from the containment sump during the recirculation phase. EJ-HV-8716A and B and EJ-HV-8809A and B are maintained open during operating modes 1-3 in order that either RHR pump is able to inject to all four RCS cold legs.

A minimum flow bypass line is provided for each pump to recirculate and return the pump discharge fluid to the pump suction should these pumps be started with the RCS pressure above their shutoff head. Once flow is established to the RCS, the bypass line is automatically closed. This line prevents deadheading of the pumps and permits pump testing during normal operation.

The RHR pumps are discussed further in Section 5.4.7. A typical pump performance curve is given in Figure 6.3-3.

ECCS Centrifugal Charging Pumps

Two ECCS centrifugal charging pumps are provided. Each pump is a multistage diffuser design, barrel-type casing with vertical suction and discharge nozzles. In the event of an accident, the ECCS centrifugal charging pumps are started automatically on receipt of an SIS and are automatically aligned to take suction from the RWST during the injection phase. These high head pumps deliver flow through the boron injection header to the RCS at the prevailing RCS pressure. During the recirculation phase, suction is provided from the RHR pump discharge.

A minimum flow bypass line is provided on each pump discharge to recirculate flow to the pump suction after cooling, via the seal water heat exchanger, during normal plant operation. The miniflow valves are interlocked to close on an SIS coincident with ECCS charging flow greater than or equal to 258.9 gpm. This interlock is designed to protect the pumps in the event of postulated accidents, such as a feed line break, which are characterized by high RCS pressure.

This SIS also closes the valves to isolate the normal charging line and volume control tank and opens the ECCS charging pump/RWST suction valves to align the high head portion of the ECCS for the injection mode.

The ECCS centrifugal charging pumps may be tested during power operation via the minimum flow bypass line.

The maximum and minimum pump performance curves for the ECCS centrifugal charging pumps are presented in Figure 6.3-4. The required pump performance curve, based upon the accident analysis, lies within these characteristic curves.

Safety Injection Pumps

Two safety injection pumps are provided. Each pump is a multistage, diffuser design, split-case centrifugal pump with side suction and side discharge.

In the event of an accident, the safety injection pumps are started automatically on receipt of an SIS; take suction from the RWST via normally open, motor-operated valves and deliver water to the RCS during the injection phase; and take suction from the containment sump via the RHR pumps during the recirculation phase.

A minimum flow bypass line is provided on each pump discharge to recirculate flow to the RWST in the event that the pumps are started with the RCS pressure above pump shutoff head. This line also permits pump testing during normal plant operation. Two parallel valves in series, with a third valve located in a downstream common header, are provided in this line. These valves are manually closed from the control room as part of the ECCS realignment from the injection to the recirculation mode. The common return header to the RWST is non-safety related, seismically analyzed, ANSI B31.1, moderate energy piping downstream of BNHV8813 (SI pumps common miniflow isolation valve). This non-safety piping returns SI pump flow to the RWST thereby providing pump protection via a miniflow recirculation path for the SI pumps while RCS pressure remains elevated during the ECCS injection phase.

The return header is made up of the main 4-inch nominal diameter line BN-003-HCD-4 and several branch connections with isolation at the non-safety related valves as shown on Figure 6.3-1 (P&ID M-22BN01). The SI miniflow lines have an ASME Code Class change from Class 2 to ANCI B31.1 at BNHV8813, a motor-operated valve downstream of flow orifices that limit the maximum recirculation flow rates from each SI pump. As discussed in Sections 3.1.2 and 3.6.2.1.2.4.c, a passive failure of this non-safety piping (cracks only for moderate energy piping per Section 3.6.2.1) is not postulated to occur during the short term response to a SBLOCA (less that 24 hours). The RWST is credited to deliver borated cooling water in the short term response to an SBLOCA (less than 24 hours) as discussed above. The SI miniflow return line to the RWST is isolated during the switchover to cold leg recirculation prior to the long term (greater than 24 hours) mitigation of a SBLOCA, as discussed in Section 6.3.2.5.

The maximum and minimum pump performance curves for the safety injection pumps are presented in Figure 6.3-5. The required pump performance curve based upon the accident analysis lies within these characteristic curves.

RHR Heat Exchangers

The RHR heat exchangers are conventional shell and U-tube type units. During normal cooldown operation, the RHR pumps recirculate reactor coolant through the tube side while component cooling water flows through the shell side. During the ECCS operation, water from the containment sump flows through the tube side. The tubes are seal welded to the tube sheet.

A further discussion of the RHR heat exchangers is found in Section 5.4.7.

Valves

Design features employed to minimize valve leakage include:

a. Valves which are normally open, except check valves and those which perform a control function, are provided with backseats to limit stem leakage.

b. Normally, closed globe valves are installed with recirculation fluid pressure under the seat to prevent stem leakage of recirculated (radioactive) water.

c. Relief valves are enclosed, i.e., they are provided with a closed bonnet.

Motor-Operated Valves

The seating design of all motor-operated valves is of the Crane flexible wedge design. This design releases the mechanical holding force during the first increment of travel so that the motor operator works only against the frictional component of the hydraulic unbalance on the disc and the packing box friction. The disc is guided throughout the full disc travel to prevent chattering and to provide ease of gate movement. The seating surfaces are hard faced to prevent galling and to reduce wear.

Where a gasket is employed for the body-to-bonnet joint, it is either a fully trapped, controlled compression, spiral wound gasket with provisions for seal welding, or it is of the pressure seal design with provisions for seal welding. The valve stuffing boxes are equipped with either a set of double packing with a lantern ring and leakoff connection or a carbon spacer and 5 rings of packing. The double packed valves contain a minimum of a full set of packing below the lantern ring and a minimum of a half set of packing above the lantern ring. A full set of packing is defined as a depth of packing equal to 1 1/2 times the stem diameter. Figure 6.3-6 illustrates a typical motor-operated valve.

Maximum opening and closing times for the motor-operated valves used in the ECCS operations are given in Table 6.3-1.

The motor operator incorporates a "hammer blow" feature that allows the motor to impact the discs away from the backseat upon opening or closing. This "hammer blow" feature not only impacts the disc but allows the motor to attain its operational speed prior to impact. Valves which must function against system pressure are designed so that they function with a pressure drop equal to full system pressure across the valve disc.

Manual Globes, Gates, and Check Valves

Gate valves employ a wedge design and are straight through. The wedge is either split or solid. All gate valves have backseat and outside screw and yoke.

Globe valves, "T" and "Y" style, are full ported with outside screw and yoke construction.

Check valves are spring loaded, lift piston types for sizes 2 inches and smaller and swing type for sizes 2-1/2 inches and larger. Stainless steel check valves have no penetration welds other than the inlet, outlet, and bonnet. The check hinge is serviced through the bonnet.

The stem packing and gasket of the stainless steel manual globe and gate valves are similar to those described above for motor-operated valves. Carbon steel manual valves are employed to pass nonradioactive fluids only and, therefore, do not contain the double packing and seal weld provisions.

Accumulator Check Valves (Swing-Disc)

The accumulator check valve is designed with a low pressure drop configuration with all operating parts contained within the body.

Design considerations and analyses which assure that leakage across the check valves located in each accumulator injection line will not impair accumulator availability are as follows:

a. During normal operation, the check valves are in the closed position with a nominal differential pressure across the disc of approximately 1,650 psi. Since the valves remain in this position except for testing or when called upon to open following an accident and are, therefore, not subject to the abuse of flowing operation or impact loads caused by sudden flow reversal and seating, they do not experience significant wear of the moving parts, and are expected to function with minimal backleakage. This backleakage can be checked via the test connection, as described in Section 6.3.4.

b. Testing is performed on the check valves in accordance with the Technical Specifications. This testing confirms the seating of the disc and whether or not there has been an increase in the leakage since the last test.

c. The experience derived from the check valves employed in the emergency injection systems indicates that the system is reliable and workable; check valve leakage has not been a problem. This is substantiated by the satisfactory experience obtained from operation of the Robert Emmett Ginna plant and subsequent plants where the usage of check valves is identical to SNUPPS.

d. The accumulators can accept some in-leakage from the RCS without affecting availability. Continuous in-leakage would require, however, that the accumulator water volume and boron concentration be adjusted periodically to meet Technical Specification requirements.

Relief Valves

Relief valves are installed in various sections of the ECCS to protect lines which have a lower design pressure than the RCS. The valve stem and spring adjustment assembly are isolated from the system fluids by a bellows seal between the valve disc and spindle. The closed bonnet provides an additional barrier for enclosure of the relief valves. Table 6.3-2 lists the system's relief valves with their capacities and setpoints.

Butterfly Valves

Each main residual heat removal line has an air-operated butterfly valve which is normally open and is designed to fail in the open position. The actuator is arranged so that air pressure on the diaphragm overcomes the spring force, causing the linkage to move the butterfly to the closed position. Upon loss of air pressure, the spring returns the butterfly to the open position. These valves are left in the full-open position during normal operation to maximize flow from this system to the RCS during the injection mode of the ECCS operation. These valves are used during normal RHR system operation to control cooldown flowrate.

Each RHR heat exchanger bypass line has an air-operated butterfly valve, which is normally closed and is designed to fail closed. Those valves are used during normal cooldown to avoid thermal shock to the residual heat exchanger.

Net Positive Suction Head

Available and required net positive suction head (NPSH) for ECCS pumps are shown in Table 6.3-1. Table 6.2.2-7 provides the assumptions and results of the NPSH analyses for the containment spray and RHR pumps. The safety intent of Regulatory Guide 1.1 is met by the design of the ECCS so that adequate NPSH is provided to system pumps. In addition to considering the static head and suction line pressure drop, the calculation of available NPSH in the recirculation mode assumes that the vapor pressure of the liquid in the sump is equal to the containment ambient pressure. This ensures that the actual available NPSH is always greater than the calculated NPSH. To ensure that the required NPSH is available during the recirculation phase of ECCS operation, restriction orifices are provided in the four discharge lines into the RCS cold legs and in the two discharge lines into the RCS hot legs. The orifices are sized to provide the RHR flow rates specified in the notes to Figure 6.3-2.

Accumulator Motor-Operated Valve

As part of the plant shutdown administrative procedures, the operator is required to close these valves. This prevents a loss of accumulator water inventory to the RCS and is done shortly after the RCS has been depressurized below 1000 psig. The redundant pressure and level alarms on each accumulator would remind the operator to close these valves, if any were inadvertently left open. Power is disconnected at the motor control center after the valves are closed. In the event that the operator is unable to close any of these valves, the accumulator vent valve is opened to depressurize the accumulator and avoid the addition of excess water inventory into the RCS.

During plant startup, the operator is instructed, via procedures, to energize and open these valves before the RCS pressure exceeds 1000 psig. Monitor lights in conjunction with an audible alarm will alert the operator should any of these valves be left inadvertently closed once the RCS pressure increases beyond the safety injection unblock setpoint. After these valves have been opened, power to these valves is disconnected at the motor control center.

The accumulator isolation valves are not required to move during power operation or in a post-accident situation, except for valve testing. For a discussion of limiting conditions for operation and surveillance requirements of these valves, refer to the Callaway Technical Specifications.

For further discussions of the instrumentation associated with these valves, refer to Sections 6.3.5 and 7.6.4.

<u>Motor-Operated Valves and Controls</u>

Remotely operated valves for the injection mode which are under manual control (i.e., valves which normally are in their ready position and do not require an SIS) have their positions indicated on a common portion of the control board. At any time during operation when one of these valves is not in the ready position for injection, an audible alarm is sounded in the control room.

The ECCS delivery lag times are given in Chapter 15.0. The accumulator injection time varies as the size of the assumed break varies, since the RCS pressure drop will vary proportionately to the break size.

Spurious movement of a motor-operated valve due to an electrical fault in the motor actuation circuitry, coincident with a LOCA, has been analyzed (Ref. 1) and found to be an acceptably low probability event. In addition, power lockout in accordance with BTP ICSB-18 is provided for those valves whose spurious movement could result in degraded ECCS performance. Power lockout is provided by providing a control power isolation switch for each of these valves on the main control board.

Table 6.3-3 provides a listing of the motor-operated isolation valves in the ECCS, showing interlocks, automatic features, position indication, and which valves are provided with the power lockout isolation switch.

The supporting auxiliaries which are required to function and support the ECCS are the Class 1E emergency busses, the essential service water system, the component cooling water system, and the engineered safety features ventilation systems. The safeguards electrical busses are required to provide electrical power to the ECCS pumps and motor-operated valves. The essential service water system and the component cooling water system are required to provide cooling for the ECCS pumps and the RHR heat exchanger (during recirculation only). The engineered safety features ventilation system is required to provide cooling for the ECCS pump rooms to maintain the ambient environment within the design of the pump motors.

Periodic visual inspection and operability testing of the motor-operated valves in the ECCS ensures that there is no potential for impairment of valve operability due to boric acid crystallization which could result from valve stem leakage.

In addition, the location of all motor-operated valves within the containment have been examined to identify any motor operators which may be submerged following a postulated LOCA. Based on a maximum post-LOCA flood level at El. 2004'-6", none of the valves require qualification for submerged operation. The submerged valves are either not required for accident mitigation, not closed prior to being flooded, or not required to change position after a LOCA. Failure modes after flooding have been evaluated for potential effects on valve position and operator information. Therefore, the flooding of these motor operators and any resultant postulated failure do not present any problems for either the short- or long-term ECCS operations, containment isolation, or any other safety-related function.

6.3.2.3 Applicable Codes and Construction Standards

The applicable codes and construction standards for the ECCS are identified in Tables 3.2-1 and 6.3-1 and discussed in Section 3.2.

6.3.2.4 Material Specifications and Compatibility

Materials employed for components of the ECCS are given in Table 6.3-4. Materials are selected to meet the applicable material requirements of the codes in Table 3.2-1 and the following additional requirements:

a. All the parts of the components in contact with borated water are fabricated of or clad with austenitic stainless steel or equivalent corrosion-resistant material.

b. All the parts of the components in contact (internal) with the sump solution during recirculation are fabricated of austenitic stainless steel or equivalent corrosion-resistant material.

c. Valve seating surfaces are hard faced with Stellite Number 6, or equivalent, to prevent galling and to reduce wear.

d. Valve stem materials are selected for their corrosion resistance, high tensile properties, and resistance to surface scoring by the packing.

6.3.2.5 System Reliability

Reliability of the ECCS is considered in all aspects of the system, from initial design to periodic testing of the components, during plant operation. The ECCS is a two train, fully redundant, standby emergency safety feature. The system has been designed and proven by analysis to withstand any single credible active failure during injection or active or passive failure during recirculation and maintain the performance objectives desired in Section 6.3.1. Two trains of pumps, heat exchangers, and flow paths are provided for redundancy as only one train is required to satisfy the performance requirements. The initiating signals for the ECCS, as described in Section 7.3, are derived from independent sources as measured from process (e.g., low pressurizer pressure) or environmental variables (e.g., containment pressure).

Redundant, as well as functionally independent variables, are measured to initiate the safety injection signals. Each train is physically separated and protected, where necessary, so that a single event cannot initiate a common failure. Power sources for the ECCS are divided into two independent trains supplied from the Class 1E emergency busses from offsite power. Sufficient diesel generating capacity is maintained onsite to provide required power to each train. The diesel generators and their auxiliary systems are completely independent, and each supplies power to one of the two ECCS trains.

The reliability program extends to the procurement of the ECCS components so that only designs which have been proven by past use in similar applications are acceptable for use. For example, the ECCS pumps (safety injection, centrifugal charging, and residual heat removal pumps) are the same type of pumps that have been used extensively in other operating plants. Their function during recurrent normal power and cooldown operations in such plants as Zion, D.C. Cook, Trojan, and Farley has successfully demonstrated their performance capability. Reliability tests and inspections (see Section 6.3.4.2) further confirm their long-term operability. Nevertheless, design provisions are included that would allow maintenance on ECCS pumps if necessary during long-term operation.

The preoperational testing program assures that the systems, as designed and constructed, will meet the functional requirements calculated in the design.

The ECCS is designed with the ability for on-line testing of most components so the availability and operational status can be readily determined.

In addition to the above, the integrity of the ECCS is assured through examination of critical components during the routine inservice inspection.

A failure modes and effects analysis is provided in Table 6.3-5.

Consideration of an active failure of any Westinghouse nuclear steam supply system (NSSS) check valve is excluded from Tables 6.3-5 and 6.3-6 since the NSSS check valves are not considered to the active (powered) components per the Westinghouse ECCS design, particularly with respect to ECCS failure modes and effects and single active failure analyses. As discussed in Section 3.9(N).3.2.1, NSSS check valves are characteristically simple in design and their operation is not affected by seismic accelerations or the maximum applied nozzle loads. Their design is compact and there are no extended structures or masses whose motion could cause distortions that could restrict operation of the valve. The nozzle loads due to maximum seismic excitation do not affect the functional ability of the valve since the valve disc is typically designed to be isolated from the body wall. The clearance supplied by the design around the disc prevents the disc from becoming bound or restricted due to any body distortions caused by nozzle loads. Therefore, the design of these valves is such that once the structural integrity of the valve is ensured using standard methods, the ability of the valve to operate is ensured by the design features.

Although the design of the NSSS check valves provides assurance of their ability to operate, these NSSS check valves undergo in-shop hydrostatic and seat leakage testing (prior to installation) as well as periodic in-situ valve exercising and inspection to ensure their functional capability. (As discussed in Section 3.1.1.1, the definition of an active component for the purpose of supporting the pump and valve operability program includes NSSS check valves. These check valves, although not powered components, meet the definition of having mechanical motion and are therefore included in Table 3.9(N)-11.)

a. Active Failure Criteria

The ECCS is designed to accept a single failure following an accident without loss of its protective function. The system design will tolerate the failure of any single active component in the ECCS itself or in the necessary associated service systems at any time during the period of required system operations following an accident.

A single active failure analysis is presented in Table 6.3-6, and demonstrates that the ECCS can sustain the failure of any single active component in either the short or long term and still meet the level of performance for core cooling.

Since the operation of the active components of the ECCS following a steam line rupture is identical to that following a LOCA, the same analysis is applicable, and the ECCS can sustain the failure of any single active component and still meet the level of performance for the addition of shutdown reactivity.

b. Passive Failure Criteria

The following philosophy provides for necessary redundancy in the component and system arrangement to meet the intent of the GDC on single failure, as it specifically applies to failure of passive components in the ECCS. Thus, for the long term, the system design is based on accepting either a passive or an active failure.

A single passive failure analysis is presented in Table 6.3-7. It demonstrates that the ECCS can sustain a single passive failure during the long-term phase and still retain an intact flow path to the core to supply sufficient flow to keep the core covered and effect the removal of decay heat. The procedure followed to establish the alternate flow path also isolates the component that failed.

Redundancy of Flow Paths and Components for Long-Term Emergency Core Cooling

The following criteria are utilized in the design of the ECCS:

1. During the long-term cooling period following a postulated loss-of-coolant accident, the emergency core cooling flow paths shall be separable into two subsystems, either of which can provide minimum core cooling functions and return spilled water from the floor of the containment back to the RCS.

2. Either of the two subsystems can be isolated and removed from service in the event of a leak outside the containment.

3. Should one of these two subsystems be isolated in this long-term period, the other subsystem remains operable.

4. Adequate redundancy of the check valves is provided to tolerate failure of a check valve during the long term as a passive component.

5. Provisions are made in the design to detect leakage from components outside the containment, collect this leakage, and provide for maintenance of the affected equipment. For further discussion, see Section 9.3.3 concerning the equipment and floor drainage system.

Thus, for the long-term emergency core cooling function, adequate core cooling capacity exists with one flow path removed from service.

Subsequent Leakage from Components in the ECCS

Leakage from mechanical equipment outside the containment will be detected before it propagates to major proportions by a program for periodic visual inspection and leak detection. A review of the equipment in the system indicates that the largest sudden leak potential would be the sudden failure of a pump shaft seal. Evaluation of leak rate, assuming only the presence of a seal retention ring around the pump shaft, showed flows less than 7.5 gpm would result. Piping leaks, valve packing leaks, or flange gasket leaks have been of a nature to build up slowly with time and are considered less severe than the pump seal failure. The auxiliary building floor and equipment drain system leakage detection capability is discussed in Section 9.3.3.

Larger leaks in the ECCS are prevented by the following:

1. The piping is classified in accordance with ANS Safety Class 2 and receives a quality assurance program in accordance with 10 CFR 50, Appendix B (refer to Section 3.2).

2. The piping, equipment, and supports are designed to ANS Safety Class 2 seismic classification, permitting no loss of function for the SSE (refer to Section 3.2).

3. The system piping is located within a controlled area of the plant.

4. The piping system receives periodic pressure tests, and is accessible for periodic visual inspection.

5. The piping is austenitic stainless steel which, due to its ductility, can withstand severe distortion without failure.

Process Flow Diagram

Figure 6.3-2 is a simplified illustration of the ECCS. The notes provided with Figure 6.3-2 contain information relative to the operation of the ECCS in its various modes. The modes of operation illustrated are full operation of all ECCS components, cold leg recirculation with RHR pump B operating, and hot leg recirculation with RHR pump A operating. These are representative of the operation of the ECCS during accident conditions.

Lag Times

Lag times for initiation and operation of the ECCS are limited by pump startup time and consequential loading sequence of these motors onto the Class 1E busses. Most valves are normally in the required position for the ECCS to fulfill its safety function.

Therefore, valve opening time is not considered for these valves. Power to the valve operators is available anytime the Class 1E busses are energized. If there is no loss of offsite power, all pump motors are still sequenced on the Class 1E busses upon receipt of an SIS. In the case of a loss of offsite power, a 12-second delay is assumed for diesel startup, then pumps are loaded according to the sequencer. For the small and large break LOCAs, the ECCS is assumed to deliver flow to the RCS 29 seconds after generation of an SIS, which includes time required for sensor response (2 seconds), diesel startup (12 seconds), opening the RWST suction isolation valves (BN-LCV-112D and E), and loading of ECCS pumps onto the Class 1E busses (15 seconds). (Note: Although the ECCS is assumed to begin delivering flow to the RCS in 29 seconds, full ECCS flow is not reached until 44 seconds after generation of the SIS. The 44-second interval includes a 15-second duration for the RHR mini-flow valve to close.) For the steamline break accident, an additional 10 second delay (39 seconds total) is assumed which accounts for closing of the VCT outlet isolation valves (BG-LCV-112B and C) to the CCPs. The steamline break transient is the only one analyzed in Chapter 15 which relies on short term boration from the RWST for transient mitigation.

Potential Boron Precipitation

Boron precipitation in the reactor vessel after a postulated LOCA is precluded by a backflush of cooling water through the core to reduce boil-off and resulting concentration of boric acid in the water remaining in the reactor vessel. This is accomplished by switching from cold leg to hot leg recirculation approximately 13 hours following an accident.

Three flow paths are available for the hot leg recirculation of sump water. Each safety injection pump can discharge to two hot legs with suction taken from RHR pump discharge either directly or indirectly via the ECCS charging pump cross connect. One RHR pump will also be aligned to deliver flow to the hot leg injection header.

Loss of one pump or one flow path will not prevent hot leg recirculation since redundant methods are available for use.

6.3.2.6 Protection Provisions

The provisions taken to protect the system from damage that might result from dynamic effects are discussed in Section 3.6. The provisions taken to protect the system from missiles are discussed in Section 3.5. The provisions to protect the system from seismic damage are discussed in Sections 3.7(B) and (N), 3.9(B) and (N), and 3.10(B) and (N). Thermal stresses on the RCS are discussed in Section 5.2.

6.3.2.7 Provisions for Performance Testing

Test lines are provided for performance testing of the ECCS, as well as individual components. These test lines and instrumentation are shown in Figure 6.3-1. All pumps have miniflow lines for use in testing operability. Additional information on testing can be found in Section 6.3.4.2.

6.3.2.8 Manual Actions

No manual actions are required of the operator for proper operation of the ECCS during the injection mode of operation. Only limited manual actions are required by the operator to realign the system for the cold leg recirculation mode of operation, and, after approximately 13 hours, for the hot leg recirculation mode of operation. These actions are delineated in Table 6.3-8. Based on the containment pressure-temperature analyses provided in Section 6.2.1, which assume runout flows of all pumps, including the containment spray pumps, which draw from the RWST, the injection phase will last for a minimum of 11.8 minutes after the accident.

The changeover from the injection mode to recirculation mode is initiated automatically and completed manually by operator action from the main control room. Protection logic is provided to automatically open the two safety injection system recirculation sump isolation valves when two out of four RWST level channels indicate an RWST level less than a low-low-1 level setpoint in conjunction with the initiation of the engineered safety injection signal (SIS). When the containment sump recirculation valves are fully opened, RHR pump suction from the RWST is automatically isolated. This automatic action aligns the two RHR pumps to take suction from the containment sump and to deliver water directly to the RCS. The RHR pumps continue to operate during this changeover from injection mode to recirculation mode.

The two ECCS charging pumps and the two safety injection pumps continue to take suction from the RWST, following the above automatic action, until manual operator action is taken to align these pumps in series with the RHR pumps.

The RWST level protection logic consists of four level channels with each level channel assigned to a separate process control protection set. Four RWST transmitters provide level signals to corresponding normally de-energized level channel bistables. Each level channel bistable would be energized on receipt of an RWST level signal less than the low-low-1 level setpoint.

A two-out-of-four coincident logic is utilized in both protection cabinets, A and B, to ensure a trip signal in the event that two-out-of-four level channel bistables are energized.

This trip signal, in conjunction with the SIS, provides the actuation signal to automatically open the corresponding containment sump isolation valves.

The low-low-1 RWST level signal is also alarmed to inform the operator to initiate the manual action required to realign the ECCS charging and safety injection pumps for the recirculation mode.

The manual switchover sequence that must be performed by the operator is delineated in Table 6.3-8. Following the automatic and manual switchover sequence, the two RHR pumps take suction from the containment sump and deliver borated water directly to the RCS cold legs. A portion of the PEJ01A RHR pump discharge flow is used to supply the two ECCS centrifugal charging pumps, which also deliver water directly to the RCS cold legs. A portion of the discharge flow from the PEJ01B RHR pump is used to provide suction to the two safety injection pumps, which also deliver directly to the RCS cold legs. As part of the manual switchover procedure (see Table 6.3-8, Step 3), the suctions of the safety injection and ECCS centrifugal charging pumps are cross connected so that one RHR pump can deliver flow to the RCS and both safety injection and ECCS centrifugal charging pumps, in the event of the failure of the second RHR pump.

See Section 7.5 for process information available to the operator in the control room following an accident.

The consequences of the operator failing to act altogether will be loss of the intermediate head safety injection pumps and high head ECCS centrifugal charging pumps.

6.3.3 SAFETY EVALUATION

Safety evaluations are numbered to correspond to the safety design bases in Section 6.3.1.1.

SAFETY EVALUATION ONE - Except for the RWST, the ECCS is located in the reactor and auxiliary buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

The events which could result in the loss of function of the RWST (i.e., tornado missile) will not also cause a DBA. For these events, the boric acid transfer system is available to provide a borated source of water to achieve and maintain the plant in a safe shutdown. Therefore, no protection of the RWST is required.

SAFETY EVALUATION TWO - The ECCS is designed to remain functional after an SSE. Sections 3.7(B).2, 3.9(B), and 3.9(N) provide the design loading conditions that were considered. Sections 3.5, 3.6, and 9.5.1 and Appendix 3B provide the hazards analyses to assure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

SAFETY EVALUATION THREE - The ECCS is completely redundant and, as indicated by Tables 6.3-6 and 6.3-7, no single failure will compromise the system's safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

SAFETY EVALUATION FOUR - The ECCS is initially tested with the program given in Chapter 14.0. Periodic inservice functional testing is done in accordance with Section 6.3.4.

Section 6.6 provides the ASME Boiler and Pressure Vessel Code, Section XI requirements that are appropriate for the ECCS.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portion of this system and supporting systems. Table 6.3-1 shows that the components meet the design and fabrication codes given in Section 3.2. All the power supplies and control functions necessary for safe function of the ECCS are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - Section 6.3.2.5 describes provisions made to identify and isolate leakage or malfunction and to isolate the nonsafety-related portions of the system.

SAFETY EVALUATION SEVEN - Sections 6.2.4 and 6.2.6 provide the safety evaluation for the system containment isolation arrangement and testability.

SAFETY EVALUATION EIGHT - As described in Sections 3.11(B) and 3.11(N), all components of the ECCS required to perform a safety function are designed to and environmentally qualified to all environments anticipated under normal, testing, and design basis accident conditions.

SAFETY EVALUATION NINE - Chapter 15.0 accidents that result in ECCS operation.

1. Increase in heat removed by the secondary system
    a. Inadvertent opening of a steam generator relief or safety valve.
    b. Steam system piping failure.
2. Decrease in heat removed by the secondary system.
    a. Feedwater system pipe break.
3. Decrease in reactor coolant system inventory.
    a. Steam generator tube failure
    b. Loss of coolant accident from a spectrum of postulated piping breaks within the system.
    c. Spectrum of rod cluster control assembly (RCCA) ejection accidents.
4. Increase in reactor coolant system inventory
    a. Inadvertent operation of the ECCS during power operation.

Safety injection system actuation results from any of the following:

a. Low pressurizer pressure
b. Low steam line pressure
c. High-1 containment pressure
d. Manual actuation

A safety injection signal will rapidly trip the main turbine, close all feedwater control valves, trip the main feedwater pumps, and close the feedwater isolation valves. The trip of the main feedwater pumps is not part of the primary success path for any accident's mitigation.

Following the actuation signal, the suction of the ECCS centrifugal charging pumps is diverted from the volume control tank to the RWST. Simultaneously, the valves isolating boron injection from the ECCS centrifugal charging pumps and the valves isolating boron injection from the cold leg injection header automatically open. The ECCS centrifugal charging pumps then force the boric acid solution from the RWST into the cold legs of each loop. The safety injection pumps also start automatically but operate at shut off head when the RCS is at normal pressure. The passive accumulator system and the low head RHR system also provide no flow at normal RCS pressure.

INCREASE IN HEAT REMOVED BY THE SECONDARY SYSTEM

Inadvertent Opening of a Steam Generator Relief or Safety Valve

The most severe core conditions resulting from an accidental depressurization of the main steam system are associated with an inadvertent opening of a single steam dump, relief, or safety valve.

The assumed steam release is typical of the capacity of any single steam dump relief or safety valve. The ECCS injection of the boron solution provides sufficient negative reactivity to meet the DNB design basis. The cooldown for this case is more rapid than the actual case of steam release from all steam generators through one steam dump, relief, or safety valve. The transient is quite conservative with respect to cooldown, since no credit is taken for the energy stored in the system metal other than that of the fuel elements or the energy stored in the steam generators. Since the transient occurs over a period of about 5 minutes, the neglected stored energy is likely to have a significant effect in slowing the cooldown. The analysis provided in Section 15.1.4 demonstrates that there will be no consequential damage to the core or reactor coolant system after reactor trip, assuming a stuck rod cluster control assembly, with offsite power available, and assuming a single failure in the engineered safety features. It also concludes that the DNB design limits are not exceeded.

Steam System Pipe Failure

The steam release arising from a rupture of a main steam pipe would result in energy removal from the RCS, causing a reduction of coolant temperature and pressure. In the presence of a negative moderator temperature coefficient, the cooldown results in an insertion of positive reactivity. There is an increased possibility that the core will become critical and return to power.

The core is ultimately shut down by the boric acid injection delivered by the safety injection system. Capability for injection of the boric acid solution is maintained, assuming any single failure in the safety injection system.

For cases where offsite power is assumed to be available, the sequencing of events in the safety injection system is the following. After the generation of the SIS (appropriate delays for instrumentation, logic, and signal transport included), the appropriate valves begin to operate and the ECCS centrifugal charging pumps start. In 27 seconds (2 seconds for SIS generation (sensor) delay, 15 seconds to open RWST suction isolation valves BN-LCV-112D and E, and 10 seconds to close VCT suction isolation valves BG-LCV-112B and C after the RWST valves are fully open), the valves are assumed to be in their final position, and the pumps are assumed to be at full speed. This delay, described above, is included in the calculations.

In cases where offsite power is not available, an additional 12-second delay is assumed to start the diesels and to load the necessary safety injection equipment onto them.

The analysis has shown that even assuming a stuck RCCA with or without offsite power, and assuming a single failure in the engineered safeguards, the core remains in place and intact. Radiation doses will not exceed 10 CFR 100 guidelines.

DECREASE IN HEAT REMOVED BY THE SECONDARY SYSTEM

Feedwater System Pipe Break

A major feedwater line rupture is defined as a break in a feedwater line large enough to prevent the addition of sufficient feedwater to the steam generators to maintain shell side fluid inventory in the steam generators. If the break is postulated in a feedwater line between the check valve and the steam generator, fluid from the steam generator may also be discharged through the break. Further, a break in this location could preclude the subsequent addition of auxiliary feedwater to the affected steam generator. (A break upstream of the feedwater line check valve would affect the NSSS only as a loss of feedwater. This case is covered by the evaluation in Sections 15.2.6 and 15.2.7).

Depending upon the size of the break and the plant operating conditions at the time of the break, the break could cause either an RCS cooldown (by excessive energy discharge through the break) or an RCS heatup. Potential RCS cooldown resulting from a secondary pipe rupture is evaluated in Section 15.1.5. Therefore, only the RCS heatup effects are evaluated for a feedwater line rupture.

A feedwater line rupture reduces the ability to remove heat generated by the core from the RCS for the following reasons:

a. Feedwater flow to the steam generators is reduced. Since feedwater is subcooled, its loss may cause reactor coolant temperatures to increase prior to reactor trip.

b. Fluid in the steam generator may be discharged through the break, and would then not be available for decay heat removal after trip.

c. The break may be large enough to prevent the addition of any main feedwater after trip.

An auxiliary feedwater system functions to ensure the availability of adequate feedwater so that:

a. No substantial overpressurization of the RCS occurs (less than 110 percent of design pressures); and

b. Sufficient liquid in the RCS is maintained so that the core remains inplace and geometrically intact with no loss of core cooling capability.

The engineered safety systems assumed to function are the auxiliary feedwater system and the safety injection system. For the auxiliary feedwater system, the worst case configuration has been used, i.e., only three non-faulted steam generators receive auxiliary feedwater following the break. The flow from the motor-driven auxiliary feedwater (AFW) pump feeding the faulted steam generator was assumed to deliver 158.8 gpm to the associated non-faulted steam generator. A flow controller limits flow to this steam generator. The remainder of the flow from this motor-driven AFW pump was assumed to spill through the break. The turbine-driven (AFW) pump has been assumed to fail. The second motor-driven AFW pump delivers 384.4 gpm equally split to the two remaining intact steam generators (192.2 gpm per steam generator). Total auxiliary feedwater flow was assumed to be 543.2 gpm (See Section 15.2.8).

A safety injection signal from either low steamline pressure or high containment pressure initiates flow of cold borated water into the RCS. The amount of safety injection flow is a function of RCS pressure.

Results of the analyses show that for the postulated feedwater line rupture, the assumed auxiliary feedwater system capacity is adequate to remove decay heat, to prevent overpressurizing the RCS, and to prevent uncovering the reactor core. Radioactivity doses from the postulated feedwater lines rupture are less than those previously presented for the postulated steam line break. All applicable acceptance criteria are therefore met.

DECREASE IN REACTOR COOLANT SYSTEM INVENTORY

Steam Generator Tube Failure

The accident postulated and analyzed is the complete severance of a single steam generator tube, and is assumed to occur at power.

Assuming normal operation of the various plant control systems, the following sequence of events is initiated by a tube failure:

a. Pressurizer low pressure and low level alarms are actuated and ECCS centrifugal charging pump flow increases in an attempt to maintain pressurizer level. On the secondary side, there is a steam flow/feedwater flow mismatch before the trip as feedwater flow to the affected steam generator is reduced due to the additional break flow which is now being supplied to that generator.

b. The steam generator blowdown liquid monitor and/or the condenser air discharge radiation monitor will alarm, indicating a sharp increase in radioactivity in the secondary system, and will automatically terminate steam generator blowdown.

c. Continued loss of reactor coolant inventory leads to a reactor trip on low pressurizer pressure or overtemperature ΔT (low pressurizer pressure provides the trip signal in the Section 15.6.3 analysis). The resultant plant cooldown leads to a continued reduction in pressurizer level and SIS initiation (assumed to occur coincident with reactor trip in Section 15.6.3). The SIS automatically terminates normal feedwater supply and initiates auxiliary feedwater addition. After reactor trip, the break flow reaches equilibrium at the point where incoming safety injection flow is balanced by outgoing break flow. The resultant break flow persists from plant trip until operator action is taken to bring the primary system and affected steam generator secondary system pressures into equilibrium. For the purposes of the analysis presented in Section 15.6.3, the time at which this is assumed to occur is 67.3 minutes after the break.

d. The reactor trip automatically trips the turbine and, if offsite power is available the steam dump valves open, permitting steam dump to the condenser. In the event of a coincident loss of offsite power, the steam dump valves would automatically close to protect the condenser. The steam generator pressure would rapidly increase, resulting in steam discharge to the atmosphere through the steam generator safety and/or power-operated relief valves.

e. Following reactor trip, the continued action of the auxiliary feedwater supply and borated safety injection flow (supplied from the RWST) provide a heat sink which absorbs some of the decay heat. Thus, steam bypass to the condenser or, in the case of loss of offsite power, steam relief to the atmosphere is attenuated during the time in which the recovery procedures leading to break flow termination are being carried out.

A steam generator tube rupture, as demonstrated in the analyses provided in Section 15.6.3, causes no subsequent damage to the RCS or the reactor core. An orderly recovery from the accident can be completed, even assuming simultaneous loss of offsite power.

LOCA From a Spectrum of Postulated Piping Breaks Within the System

Small Break LOCA - Small ruptured pipes, cracks in large pipes, or ejection of a control rod.

A LOCA is defined as a rupture of the RCS piping or of any line connected to the system from which the break flow exceeds the flow capability of the normal makeup/charging system. Ruptures of small cross-sections will cause expulsion of the reactor coolant at a rate which can be accommodated by the ECCS centrifugal charging pumps maintaining an operational water level in the pressurizer, permitting the operator to execute an orderly shutdown.

The maximum break size for which the normal makeup system can maintain the pressurizer level is obtained by comparing the calculated flow from the RCS through the postulated break against the ECCS centrifugal charging pump makeup flow at normal RCS pressure, i.e., 2,250 psia. A makeup flow rate from one ECCS centrifugal charging pump is adequate to sustain pressurizer level at 2,250 psia for a break through a 0.375-inch-diameter hole. This break results in a loss of approximately 17.5 lb/sec (127 gpm at 130°F and 2,250 psia).

The SIS stops normal feedwater flow by closing the main feedwater isolation valves and initiates emergency feedwater flow by starting the auxiliary feedwater pumps.

The small break analyses deal with breaks of up to 1.0 ft^2 in area, where the safety injection pumps play an important role in the initial core recovery because of the slower depressurization of the RCS.

The analysis of this break, as provided in Section 15.6, demonstrates that the high head portion of the ECCS, together with accumulators, provides sufficient core flooding to keep the calculated peak clad temperature below the required limits of 10 CFR 50.46. Hence, adequate protection is afforded by the ECCS in the event of a small break LOCA.

Large Break LOCA

A major LOCA is defined as a 1.0 ft^2 or larger rupture of the RCS piping, including the double-ended rupture of the largest pipe in the RCS or of any line connected to that system. The boundary considered for LOCA, as related to connecting piping, is defined in Section 3.6.

Should a major break occur, depressurization of the RCS results in a pressure decrease in the pressurizer. Reactor trip occurs and the safety injection system is actuated when the pressurizer low pressure trip setpoint is reached. Reactor trip and safety injection system actuation may be provided by a high containment pressure signal, depending on the actual break size. These countermeasures will limit the consequences of the accident in two ways:

a. Reactor trip and borated water injection provide additional negative reactivity insertion to supplement void formation in causing rapid reduction of power to a residual level corresponding to fission produce decay heat.

b. Injection of borated water ensures sufficient flooding of the core to prevent excessive clad temperatures.

When the pressure falls below approximately 600 psi, the accumulators begin to inject borated water. The conservative assumption is made that accumulator water injected bypasses the core and goes out through the break until the expulsion or entrainment mechanisms for bypassing are calculated not to be effective. This conservatism is consistent with the acceptable features of ECCS Evaluation Models, as defined by Appendix K, 10 CFR 50.

The pressure transient in the reactor containment during a LOCA affects ECCS performance in the following ways. The time at which end of blowdown occurs is determined by a zero break flow which is a result of achieving pressure equilibrium between the RCS and the containment. In this way, the amount of accumulator water bypass is also affected by the containment pressure, since the amount of accumulator water discharged during blowdown is dependent on the length of the blowdown phase and RCS pressure at end of blowdown. During the reflood phase of the transient, the density of the steam generated in the core is dependent on the existing containment pressure. The density of this steam affects the amount of steam which can be vented from the core to the break for a given downcomer head, the core reflooding process, and, thus, the ECCS performance. It is through these effects that containment pressure affects ECCS performance.

For breaks up to and including the double-ended severance of a reactor coolant pipe, the ECCS will limit the clad temperature to below 2200°F and ensure that the core will remain in place and substantially intact with its essential heat transfer geometry preserved. See Section 15.6.5 for ECCS sequence of events.

For these breaks, Section 15.6 demonstrates that the ECCS meets the Acceptance Criteria presented in 10 CFR 50.46. That is:

a. The calculated peak fuel element clad temperature is less than 2,200°F.

b. The amount of fuel element cladding that reacts chemically with water or steam does not exceed 1 percent of the total amount of Zircaloy/Zirlo in the reactor.

c. The clad temperature transient is terminated at a time when the core geometry is still amenable to cooling. The cladding oxidation limits of 17 percent are not exceeded during or after quenching.

d. The core temperature is reduced and decay heat is removed for an extended period of time, as required by the long-lived radioactivity remaining in the core.

INCREASE IN REACTOR COOLANT SYSTEM INVENTORY

Inadvertent Operation Of The Emergency Core Cooling System During Power Operation

Spurious emergency core cooling system (ECCS) operation at power could be caused by operator error or a false electrical actuation signal. A spurious signal may originate from any of the safety injection actuation channels, as described in Section 7.3.

A safety injection signal (SIS) normally results in a reactor trip followed by a turbine trip. However, it cannot be assumed that any single fault that actuates the ECCS will also produce a reactor trip. If a reactor trip is generated by the spurious SIS, the operator should determine if the spurious signal was transient or steady state in nature. The operator must also determine if the SIS should be blocked. For a spurious occurrence, the operator would terminate ECCS and maintain the plant in the hot standby condition.

If the reactor protection system does not produce an immediate trip as a result of the spurious SIS, the reactor experiences a negative reactivity excursion due to the injected boron, causing a decrease in reactor power. The power mismatch causes a drop in T_{avg} and consequent coolant shrinkage. The pressurizer pressure and water level decrease. Load will decrease due to the effect of reduced steam pressure on load after the turbine throttle valve is fully open. The transient is eventually terminated by the reactor protection system low pressurizer pressure trip or by manual reactor trip.

Results of the analysis show that spurious ECCS operation without immediate reactor trip presents no hazard to the integrity of the RCS.

If the reactor does not trip immediately, the low pressurizer pressure reactor trip will be actuated. This trips the turbine and prevents excess cooldown, thereby expediting recovery from the transient.

Criteria Used to Judge the Adequacy of the ECCS

(Reference: 10 CFR 50.46)

a. The peak clad temperature calculated shall not exceed 2,200°F.

b. The calculated total oxidation of the clad shall nowhere exceed 0.17 times the total clad thickness before oxidation.

c. The calculated total amount of hydrogen generated from the chemical reaction of the clad with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all of the metal in the clad cylinders surrounding the fuel, excluding the clad around the plenum volume, were to react.

d. Calculated changes in core geometry shall be such that the core remains amenable to cooling.

e. After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptable low value and decay heat shall be removed for the extended period of time required by long lived radioactivity remaining in the core.

In addition to and as an extension of the Final Acceptance Criteria, two accidents have more specific criteria, as shown below.

In the case of the inadvertent opening of a steam generator relief or safety valve, an additional criteria for adequacy of the ECCS is: Assuming a stuck RCCA, offsite power available, and a single failure in the engineered safety features, there will be no return to criticality after reactor trip for a steam release equivalent to the spurious opening with failure to close, of the larger of a single steam dump, relief, or safety valve.

For a steam system piping failure, the added criteria is: Assuming a stuck RCCA with or without offsite power, and assuming a single failure in the engineered safety features, the core remains in place and intact.

Use of Dual Function Components

The ECCS contains components which have no other operating function, as well as components which are shared with other systems. Components in each category are as follows:

a. Components of the ECCS which perform no other function are:

1. One accumulator for each loop which discharges borated water into its respective cold leg of the reactor coolant loop piping.

2. Two safety injection pumps, which supply borated water for core cooling to the RCS. (May be used during check valve testing also.)

3. Deleted

4. Deleted

5. Deleted

6. Associated piping, valves, and instrumentation

b. Components which also have a normal operating function are as follows:

1. RHR pumps and the RHR heat exchangers

These components are normally used during the latter stages of normal reactor cooldown and when the reactor is held at cold shutdown for core decay heat removal or for flooding the refueling cavity. However, during all other plant operating periods they are aligned to perform the low head injection function. EJ-HV-8716A and B and EJ-HV-8809A and B are maintained open during operating modes 1-3 in order that either RHR pump is able to inject to all four RCS cold legs.

2. ECCS centrifugal charging pumps

These pumps are normally aligned for charging service. As a part of the chemical and volume control system, the normal operation of these pumps is discussed in Section 9.3.4.

3. RWST

This tank is used to fill the refueling canal for refueling operations and to provide makeup to the spent fuel pool.

However, during all other plant operating periods it is aligned to the suction of the safety injection pumps and the RHR pumps. The ECCS centrifugal charging pumps are automatically aligned to the suction of the RWST upon receipt of an SIS or a VCT low level alarm. During normal operation, they take suction from the volume control tank.

An evaluation of all components required for operation of the ECCS demonstrates that either:

a. The component is not shared with other systems, or

b. If the component is shared with other systems, it is either aligned during normal plant operation to perform its accident function or, if not aligned to its accident function, two valves in parallel are provided to align the system for injection, and two valves in series are provided to isolate portions of the system not utilized for injection. These valves are automatically actuated by the SIS.

Table 6.3-9 indicates the alignment of components during normal operation and the realignment required to perform the accident function.

In all cases of component operation, safety injection has the priority usage such that an SIS will override all other signals and start or align systems for injection.

Limits on System Parameters

The analyses show that the design basis performance characteristic of the ECCS is adequate to meet the requirements for core cooling following a LOCA with the minimum engineered safety features equipment operating. In order to ensure this capability in the event of the simultaneous failure to operate any single active component, reactor operating limits are established in the Technical Specifications.

Normal operating status of the ECCS components is given in Table 6.3-10.

6.3.4 TESTS AND INSPECTIONS

6.3.4.1 ECCS Performance Tests

6.3.4.1.1 Preoperational Test Program at Ambient Conditions

Preliminary operational testing of the ECCS is conducted with the system cold and aligned for normal power operation with the exception that the BIT (since retired from service) is filled with refueling water instead of concentrated boric acid. An SIS is initiated, and the breakers on the lines supplying offsite power are tripped manually so that operation of the emergency diesels is tested in conjunction with the safety injection system. System testing provides the following verifications of system performance:

a. Satisfactory SIS generation and transmission

b. Proper operation of the emergency diesel generators, including sequential load pickup

c. Valve operating times

d. Pump starting times

e. Pump delivery rates at runout conditions (one point on the operating curve)

Further details of each preoperational test performed are discussed in Chapter 14.0.

6.3.4.1.2 Components

Pumps

Separate flow tests of the pumps in the ECCS are conducted during the preoperational testing (with the reactor vessel head off) to check capability for sustained operation. The ECCS centrifugal charging, safety injection, and RHR pumps discharge into the reactor vessel through the injection lines, the overflow from the reactor vessel passing into the refueling pool. Each pump is tested separately with water drawn from the RWST. Data are taken to determine pump head and flow at this time. Pumps are then run on miniflow circuits and data taken to determine a second point on the head flow characteristic curve.

Section 6.2.2.1.4 discusses the hydraulic model testing used to verify that the available net positive suction head is adequate when the RHR pumps and containment spray pumps take suction from the containment recirculation sumps.

Accumulators

Each accumulator is filled with water from the RWST and pressurized with the motor-operated valve on the discharge line closed. Then the valve is opened and the accumulator allowed to discharge into the reactor vessel with the reactor cold and the vessel head off.

6.3.4.2 Reliability Tests and Inspections

Gas Management

The ECCS is operable when it is sufficiently filled with water. The Technical Specifications include Surveillance Requirements for verifying systems are sufficiently full of water. Voiding may occur, however, due to the accumulation of entrained gas; acceptance criteria are established for the volume of accumulated gas at susceptible locations. If accumulated gas is discovered that exceeds the acceptance criterion for the susceptible location (or if the volume of accumulated gas at one or more susceptible locations exceeds an acceptance criterion for gas volume at the suction or discharge of a pump), the Technical Specification Surveillance Requirement is not met and past operability reviews are initiated. If it is determined by subsequent evaluation that the ECCS was not rendered inoperable by the accumulated gas (i.e., the system was sufficiently filled with water), the Surveillance Requirement may be declared met. Accumulated gas should be eliminated or brought within the acceptance criteria limits.

ECCS locations susceptible to gas accumulation are monitored and, if gas is found, the gas volume is compared to the acceptance criteria for the location. Susceptible locations in the same system flow path that are subject to the same gas intrusion mechanisms may be verified by monitoring a representative subset of susceptible locations. Monitoring may not be practical for locations that are inaccessible due to radiological or environmental conditions, the plant configuration, or personnel safety. For these locations, alternative methods (e.g., Operating parameters, remote monitoring) may be used to monitor the susceptible location. Monitoring is not required for susceptible locations where the maximum potential accumulated gas void volume has been evaluated and determined to not challenge system operability. The accuracy of the method used for monitoring the susceptible locations and trending of the results must be sufficient to assure system operability between surveillance performances.

6.3.4.2.1 Description of Tests Planned

Routine periodic testing of the ECCS components and all necessary support systems at power is planned. Valves which operate after a LOCA are operated through a complete cycle, and pumps are operated individually in this test on their miniflow lines, except the ECCS charging pumps, if they have been tested by their normal charging function. If such testing indicates a need for corrective maintenance, the redundancy of equipment in these systems permits such maintenance to be performed without shutting down or reducing load under certain conditions. These conditions include considerations, such as the period within which the component should be restored to service and the capability of the remaining equipment to provide the minimum required level of performance during such a period.

The operation of the remote stop valve and check valve in each accumulator tank discharge line is tested per the required in-service testing (ASME OM Code).

Where series pairs of check valves form the high pressure to low pressure isolation barrier between the RCS and safety injection system piping outside the reactor containment, periodic testing of these check valves is performed to provide assurance that certain postulated failure modes will not result in a loss-of-coolant from the low pressure system outside the containment with a simultaneous loss of safety injection pumping capacity.

The safety injection system test line subsystem provides the capability for determining the integrity of the pressure boundary formed by series check valves. The tests performed verify that each of the series check valves can independently sustain differential pressure across its disc, and also verify that the valve is in its closed position. The required periodic tests are to be performed after each refueling just prior to plant startup, after the RCS has been pressurized.

Lines in which the series check valves are to be tested are the safety injection pump cold and hot leg injection lines and the RHR pump cold and hot leg injection lines.

Chapter 16.0 and the Technical Specifications provide periodic component testing requirements. During periodic system testing, a visual inspection of pump seals, valve packings, flanged connections, and relief valves is made to detect leakage. Inservice inspection provides further confirmation that no significant deterioration is occurring in the ECCS fluid boundary.

Design measures have been taken to assure that the following testing can be performed:

a. Active components may be tested periodically for operability (e.g., pumps on miniflow, certain valves, etc.).

b. An integrated system actuation test* can be performed when the plant is cooled down and the RHRS is in operation. The ECCS will be aligned so that no flow will be introduced into the RCS for this test.

c. An initial flow test of the full operational sequences can be performed.

The design features which assure this test capability are specifically:

a. Power sources are provided to permit individual actuation of each active component of the ECCS.

b. The safety injection pumps can be tested periodically during plant operation, using the minimum flow recirculation lines provided.

c. The RHR pumps are used every time the RHRS is put into operation. They can also be tested periodically when the plant is at power, using the miniflow recirculation lines.

d. The ECCS centrifugal charging pumps are either normally in use for charging service or can be tested periodically on miniflow.

e. Remote-operated valves can be exercised during routine plant maintenance.

f. Level and pressure instrumentation is provided for each accumulator tank, for continuous monitoring of these parameters during plant operation.

g. Flow from each accumulator tank can be directed through a test line in order to determine valve operability. The test line can be used, when the RCS is pressurized, to ascertain backleakage through the accumulator check valves.

h. A flow indicator is provided in the ECCS centrifugal charging pump, safety injection pump, and RHR pump headers. Pressure instrumentation is also provided in these lines.

i. An integrated system test can be performed when the plant is cooled down and the RHRS is in operation. This test does not introduce flow into the RCS but does demonstrate the operation of the valves, pump circuit breakers, and automatic circuitry, including diesel starting and the

* Details of the testing of the sensors and logic circuits associated with the generation of an SIS, together with the application of this signal to the operation of each active component, are given in Section 7.2.

automatic loading of ECCS components of the diesels (by simultaneously simulating a loss of offsite power to the vital electrical busses).

See Chapter 16.0 and the Technical Specifications for the selection of test frequency, acceptability of testing, and measured parameters. A description of the inservice inspection program is included in Section 6.6. ECCS components and systems are designed to meet the intent of the ASME Code, Section XI for inservice inspection.

6.3.5 INSTRUMENTATION REQUIREMENTS

Instrumentation and associated analog and logic channels employed for initiation of ECCS operation are discussed in Section 7.3.

This section describes the instrumentation employed for monitoring ECCS components during normal plant operation and also ECCS postaccident operation. All alarms are annunciated in the control room.

6.3.5.1 Temperature Indication

RHR Heat Exchanger Temperature

The fluid temperature at both the inlet and the outlet of each RHR heat exchanger is recorded in the control room.

6.3.5.2 Pressure Indication

ECCS Centrifugal Charging Pump Inlet, Discharge Pressure

There is local pressure indication at the suction and discharge of each ECCS centrifugal charging pump.

Safety Injection Pump Suction Pressure

There is a locally mounted pressure indicator at the suction of each safety injection pump.

Safety Injection Header Pressure

Safety injection pump discharge header pressure is indicated in the control room.

Accumulator Pressure

Duplicate pressure channels are installed on each accumulator. Pressure indication in the control room and high and low pressure alarms are provided by each channel.

Test Line Pressure

A local pressure indicator used to check for proper seating of the accumulator check valves between the injection lines and the RCS is installed on the leakage test line.

RHR Pump Suction Pressure

Local pressure indication is provided at the inlet to each RHR pump.

RHR Pump Discharge Pressure

RHR discharge pressure for each pump is indicated in the control room. A high pressure alarm is actuated by each channel.

6.3.5.3 Flow Indication

ECCS Centrifugal Charging Pump Injection Flow

Injection flow to the reactor cold legs is indicated in the control room. Flow instruments also control the ECCS centrifugal charging pump miniflow valves (Section 6.3.2.2) and provide a low flow alarm.

Safety Injection Pump Header Flow

Flow through the safety injection pump header is indicated in the control room.

Safety Injection Pump Minimum Flow

A flow indicator is installed in the safety injection pump minimum flow line.

Test Line Flow

Local indication of the leakage test line flow is provided to check for proper seating of the accumulator check valves between the injection lines and the RCS, and for testing other check valves in the ECCS.

RHR Pump Cold Leg Injection Flow

The flow from each residual heat removal subsystem to the RCS cold legs is recorded in the control room. These instruments also control the RHR bypass valves, maintaining constant return flow to the RCS during normal cooldown.

RHR Pump Minimum Flow

A flowmeter installed in each RHR pump discharge header provides control for the valve located in the pump minimum flow line.

6.3.5.4 Level Indication

RWST Level

Water level indicator channels, which indicate in the control room, are provided for the RWST. Each channel is provided with a high, low, low-low-1, low-low-2, and empty level alarm. The high level alarm is provided to protect against possible overflow of the RWST. The low level alarm is provided to assure that a sufficient volume of water is always available in the RWST. The low-low-1 level alarm, as well as the level indication, alerts the operator to realign the ECCS from the injection to the recirculation mode following an accident and automatically opens the sump isolation valves. The low-low-2 level alarm, as well as the level indication, alerts the operator to realign the containment spray pumps for recirculation. The empty alarm indicates that the usable volume of the RWST has been exhausted.

Accumulator Water Level

Duplicate water level channels are provided for each accumulator. Both channels provide indication in the control room and actuate high and low water level alarms.

6.3.5.5 Valve Position Indication

Motor/Air-Operated Valves

Valve positions are indicated on the control boards by red and green position indication lights associated with the control switch for the valve. In addition, a status monitoring panel is provided which indicates that a valve is in its proper position for safety features system operation by a white light. A potential bypass of automatic operation is indicated by an amber light. See Section 7.5.2.2.1 for additional discussion.

Manual Valves

Control room position indication and alarms are provided for the following ECCS manual valves to ensure correct system alignment.

RWST discharge (V011 on Figure 6.3-1, Sheet 1)
RHR recirculation (8717 on Figure 6.3-1, Sheet 1)

Accumulator Isolation Valve Position Indication

The accumulator motor-operated valves are provided with red (open) and green (closed) position indicating lights located at the control switch for each valve. These lights are powered by valve control power and actuated by valve motor operator limit switches.

A monitor light that is on when the valve is not fully open is provided in an array of monitor lights that are all off when their respective valves are in proper position. This light is energized from a separate monitor light supply and actuated by a valve motor-operator limit switch. Additionally, an ESF status panel bypass indication is provided whenever any of these valves leaves the fully open position.

An alarm annunciator point is activated by both a valve motor operator limit switch and by a valve position limit switch activated by stem travel whenever an accumulator valve is not fully open for any reason with the system at pressure (the pressure at which the safety injection block is unblocked is approximately 1970 psig). A separate annunciator point is used for each accumulator valve.

6.3.6 REFERENCES

1. Hill, R.A., et al., "Evaluation of Mispositioned ECCS Valves," WCAP-9207 (Proprietary) and WCAP-8966 (Non-Proprietary), September 1977

2. Westinghouse Electric Corporation Reference Safety Analysis Report, RESAR-3, Appendix 6A, Pages 6A-1 through 6A-4 dated June 1972.

TABLE 6.3-1 EMERGENCY CORE COOLING SYSTEM COMPONENT PARAMETERS

Accumulators	
Number	4
Design pressure, psig	700
Design temperature, °F	300
Operating temperature, °F	50 to 120
Normal operating pressure, psig	602 to 648
Total volume, ft^3 (each)	1350
Normal operating water volume, ft^3 (each)	850
Volume N_2 gas, ft^3 (each)	500
Boric acid concentration, ppm boron (nominal)	2300-2500
Relief valve setpoint, psig	700
Seismic	Category I
Design code	ASME III, Class 2
Material	Stainless steel
ECCS Centrifugal Charging Pumps	
Number	2
Design pressure, psig	2,800
Design temperature, °F	300
Design flow[(a)], gpm	150
Design head, ft	5,800
Maximum flow, gpm	
Injection phase	550[(b)]
Recirculation phase	567[(b)]
Head at maximum flow, ft	1,400
Discharge head at shutoff, ft	6,200
Required NPSH at maximum flow, ft	33.8
Available NPSH, ft	41.7
Design code	ASME III, Class 2
Seismic design	Category I
Driver:	
Type	Electric motor
Horsepower, hp	600
Rpm	1,800
Power	4,160 V, 60 Hz, 3-phase, Class 1E
Start time	≤5 sec
Design code	NEMA
Seismic design	Category I

(a) Includes miniflow

(b) No miniflow

TABLE 6.3-1 (Sheet 2)

<u>Safety Injection Pumps</u>	
Number	2
Design pressure, psig	1,750
Design temperature, °F	300
Design flow rate, gpm	425
Design head, ft	2,680
Maximum flow rate, gpm	
Injection phase	675[a]
Recirculation phase	691[a]
Head at maximum flow rate, ft	1,650
Discharge head at shutoff, ft	3,645
Required NPSH at max flow, ft	17
Available NPSH, ft	43.8
Design code	ASME III, Class 2
Seismic design	Category I
Driver:	
Type	Electric motor
Horsepower, hp	450
Rpm	3,600
Power	4,160 V, 60 Hz, 3-phase, Class 1E
Start time	≤5 sec
Design code	NEMA
Seismic design	Category I
<u>Residual Heat Removal Pumps</u>	
Number	2
Design pressure, psig	600
Design temperature, °F	400
Design flow, gpm	3,800
Design head, ft	350
NPSH required at 4,800 gpm, ft	21.7
Available NPSH at 4,800 gpm, ft	25.7
Design code	ASME III, Class 2
Seismic design	Category I
Driver:	
Type	Electric motor
Horsepower, hp	500
Rpm	1,800
Power	4,160 V, 60 Hz, 3-phase, Class 1E
Start time	≤5 sec
Design code	NEMA
Seismic design	Category I

(a) Includes miniflow (30 gpm)

TABLE 6.3-1 (Sheet 3)

Residual Heat Exchangers	
(See Section 5.4.7 for design parameters)	
Refueling Water Storage Tank	
Quantity	1
Maximum volume (to overflow), gal	419,434
Normal capacity, gal	406,921
Assured water volume, gal	394,000
Boric acid concentration, ppm boron (nominal)	2,350-2,500
Type	Vertical, field erected
Diameter, ft-in	40-0
Side height, ft-in	46-0
Design pressure, psig	Atmospheric
Design temperature, °F	120/-60
Material	Austenitic stainless steel
Design code	ASME III, Class 2
Seismic design	Category I
Motor-Operated Valves	Maximum Opening Or Closing Time
Up to and including 8 inches, time, sec	15
Over 8 inches, time, sec	$[\text{Valve size (inches)}] \div \left[49\frac{\text{inches}}{\text{min}} \times \frac{1\text{ min}}{60\text{ sec}}\right]$

* Excluding valves EJ-HV-8809A,B; EJ-HV-8716A,B; EJ-HV-8840,and EJ-HV-8811A,B, which have maximum opening/closing times as specified in the Inservice Testing Program.

TABLE 6.3-2 EMERGENCY CORE COOLING SYSTEM RELIEF VALVE DATA

Description	Fluid Discharged	Fluid Inlet Temperature Normal (F)	Set Pressure (psig)	Backpressure Constant (psig)	Maximum Total Backpressure (psig)	Capacity
N_2 supply to accumulators	N_2	120	700	0	0	1,500 scfm
Safety injection pump discharge	Water	120	1,825	0 to 15	50	20 gpm
Residual heat removal pump safety injection line	Water	120	600	0 to 15	50	20 gpm
Safety injection pumps suction header	Water	100	220	0 to 15	50	25 gpm
Accumulator to containment	N_2 gas	120	700	0	0	1,500 scfm

TABLE 6.3-3 MOTOR-OPERATED ISOLATION VALVES IN THE EMERGENCY CORE COOLING SYSTEM

Location	Valve Identification	Interlocks	Automatic Features	Position Indication	Alarms
Accumulator isolation valves	EP-HV-8808 A,B,C,D	Power lockout provided*	Opens on SIS if power on valve and on SIS unblock pressure (P-11absent) if power on valve and control switch in AUTO	MCB	Yes-out of position
Safety injection pump suction from RWST	BN-HV-8806 A&B EM-HV-8923 A&B	None	None	MCB	Yes-out of position
RHR suction from RWST	BN-HV-8812 A&B	Cannot be opened unless sump valve closed	Closes on sump valve fully open	MCB	Yes-out of position
RHR discharge to safety injection/charging pump suction	EJ-HV-8804 A&B	Cannot be opened unless safety injection pump miniflow isolated and RHR suction valve from RCS closed**	None	MCB	Yes-out of position
Safety injection hot leg recirculation	EM-HV-8802 A&B	Power lockout provided	None	MCB	Yes-out of position
RHR hot leg recirculation	EJ-HV-8840	Power lockout provided	None	MCB	Yes-out of position
Containment sump isolation valve	EJ-HV-8811 A&B	Cannot be opened in normal operation unless RHR suction valves from RWST & from RCS closed	Opens on RWST low-low-1 with SIS	MCB	Yes-out of position
CVCS suction from RWST	BN-LCV-112 D&E	SIS	Opens on SIS	MCB	Yes-out of position
CVCS normal suction	BG-LCV-112 B&C	SIS	Closes on SIS if CVCS suction valves from RWST open	MCB	Yes-out of position
MCB - main control board					
Safety injection pump to cold leg	EM-HV-8835	Power lockout provided	None	MCB	Yes-out of position
CVCS normal discharge	BG-HV-8105 BG-HV-8106	SIS	Closes on SIS	MCB	None
Boron injection suction	EM-HV-8803 A&B	SIS	Opens on SIS	MCB	Yes-out of position
Boron injection discharge	EM-HV-8801 A&B	SIS	Opens on SIS	MCB	Yes-out of position
Charging pump/safety injection pump crossover	EM-HV-8807 A&B EM-HV-8924	None Power lockout provided***	None	MCB	Yes-out of position

TABLE 6.3-3 (Sheet 2)

Location	Valve Identification	Interlocks	Automatic Features	Position Indication	Alarms
RHR to RCS cold legs****	EJ-HV-8809 A&B	Power lockout provided	None	MCB	Yes-out of position
Safety injection pump miniflow	EM-HV-8814 A&B BN-HV-8813	Cannot be opened unless RHR discharge to safety injection & to charging pumps closed. Power lock-out on BN-HV-8813 only	None	MCB	Yes-out of position
RHR cross connect****	EJ-HV-8716 A&B	None	None	MCB	Yes-out of position
Safety injection pump cross connect	EM-HV-8821 A&B	None	None	MCB	Yes-out of position
Charging pump miniflow	BG-HV-8110,8111	SIS	Closes on coincident SIS and charging pump flow ≥258.9 gpm.	MCB	Yes-out of position

* Power is disconnected at the MCC.

** EJ-HV-8804A can't be opened unless: EM-HV-8814A and B or BN-HV-8813 is closed and EJ-HV-8701A or BB-PV-8702A is closed. Likewise for EJ-HV-8804B.

*** Breaker locked in the off position and handwheel locked to prevent operation.

**** EJ-HV-8716A and B and EJ-HV-8809A and B are maintained open during operating modes 1-3 in order that either RHR pump is able to inject to all four RCS cold legs.

TABLE 6.3-4 MATERIALS EMPLOYED FOR EMERGENCY CORE COOLING SYSTEM COMPONENTS

Component	Material
Accumulators	Carbon steel clad with austenitic stainless steel
Pumps	
ECCS centrifugal charging	Austenitic stainless steel
Safety injection	Austenitic stainless steel
Residual heat removal	Austenitic stainless steel
RHR heat exchangers	
Shell	Carbon steel
Shell end cap	Carbon steel
Tubes	Austenitic stainless steel
Channel	Austenitic stainless steel
Channel cover	Austenitic stainless steel
Tube sheet	Austenitic stainless steel
Valves	
Motor-operated valves containing radioactive fluids	
Pressure containing parts	Austenitic stainless steel or equivalent
Body-to-bonnet bolting and nuts	Low alloy steel
Seating surfaces	Stellite No. 6 or equivalent
Stems	Austenitic stainless steel or 17-4 PH stainless
Diaphragm valves	Austenitic stainless steel
Accumulator check valves	
Parts contacting borated water	Austenitic stainless steel

TABLE 6.3-4 (Sheet 2)

Component	Material
Clapper arm shaft	17-4 PH stainless
Relief valves	
Stainless steel bodies	Stainless steel
Carbon steel bodies	Carbon steel
All nozzles, discs, spindles, and guides	Austenitic stainless steel
Bonnets for stainless steel valves without a balancing bellows	Stainless steel or plated carbon steel
All other bonnets	Carbon steel
Piping	
All piping in contact with borated water	Austenitic stainless steel

TABLE 6.3-5 FAILURE MODE AND EFFECTS ANALYSIS - EMERGENCY CORE COOLING SYSTEM - ACTIVE COMPONENTS

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
1. Motor-operated gate valve LCV-112B (LCV-112C analogous)	Fails to close on demand	Injection - cold legs of RC loops	Failure reduces redundancy of providing VCT discharge isolation. No effect on safety for system operation; isolation valves LCV-112C and 8440 provide back-up tank discharge isolation.	Valve position indication (open to closed position change) at MCB.	Valve is electrically interlocked with isolation valve LCV-112D. Valve closes on actuation by an SIS provided isolation valve LCV-112D is at a full open position.
2. Motor-operated gate valve LCV-112D (LCV-112E analogous)	Fails to open on demand	Injection - cold legs of RC loops	Failure reduces redundancy of providing fluid flow from RWST to suction of HHSI/CH pumps. No effect on safety for system operation. Alternate isolation valve LCV-112E opens to provide backup flow path to suction of both HHSI/CH pumps.	Valve position indication (closed to open position change) at MCB. (Basis: during injection concern is valve from RWST failing to open- item 22 in this table addresses failure to close during recirculation)	Valve is electrically interlocked with the instrumentation that monitors fluid level of the VCT. Valve opens upon actuation by a "low-low level" VCT signal.
3. Centrifugal charging pump PBG05A (PBG05B analogous)	Fails to deliver working fluid	Injection and recirculation - cold legs of RC loops	Failure reduces redundancy of providing emergency coolant to the RCS via the Boron Injection Header at prevailing incident RCS pressure. Fluid flow from ‘A’ train HHSI/CH pump will be lost. Minimum flow requirements at prevailing high RCS pressures will be met by ‘B’ train HHSI/CH pump delivery via Boron Injection Header.	HHSI/CH pump discharge charge header flow (FI-917A) at MCB. Open pump switchgear circuit breaker indication on MCB. Circuit breaker close position monitor light for group monitoring of components at MCB. Common breaker trip alarm at MCB.	One HHSI/CH pump may be used for normal charging of RCS during plant operation if the normal charging pump has been secured. Pump circuit breaker aligned to close on actuation by an SIS.

* See list at end of table for definition of acronyms and abbreviations used.

** As part of plant operation, periodic tests, surveillance inspections, and instrument calibrations are made to monitor equipment and performance. Failures may be detected during such monitoring of equipment in addition to detection methods noted.

TABLE 6.3-5 (Sheet 2)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
4. Motor-operated globe valve 8110 (8111 analogous)	Fails to close on demand	Injection - cold legs of RC loops	Failure prevents isolation of PBG05A (PBG05B) mini-flow line. No effect on safety for system operation. Alternate isolation valve 8111 for PBG05B (PBG05A) provides miniflow isolation and assures adequate HHSI/CH pump flow.	Same methods of detection as those stated for item 1.	Valve aligned to close upon actuation by a coincident SIS and charging pump flow ≥ 258.9 gpm.
	Fails to open on demand	Injection - cold legs of RC loops	Failure prevents opening of PBG05A (PBG05B) miniflow line. No effect on safety for system operation. Alternate valve 8111 (8110) for PBG05B (PBG05A) provides adequate mini-flow.	Same methods of detection as those stated for item 1.	Valve aligned to open when charging pump flow ≤ 173.5 gpm.
5. Motor-operated gate valve 8105 (8106 analogous)	Fails to close on demand	Injection - cold legs of RC loops	Failure reduces redundancy of providing isolation of HHSI/CH pump discharge to normal charging line of CVCS. No effect on safety for system operation. Alternate isolation valve 8106 provides back-up normal CVCS charging line isolation.	Same methods of detection as those stated for item 1.	Valve aligned to close upon actuation by an SIS.
6. Motor-operated gate valve 8803A (8803B analogous)	Fails to open on demand	Injection - cold legs of RC loops	Failure reduces redundancy of fluid flow paths from HHSI/CH pumps to the RCS via Boron Injection Header. No effect on safety for system operation. Alternate isolation valve 8803B opens to provide back-up flow paths from HHSI/CH pumps to Boron Injection Header.	Same methods of detection as those stated for item 2.	Valve aligned to open upon actuation by an SIS.

*** NSSS check valves are not considered to be active (powered) components in the Westinghouse design with respect to the active components considered in this Emergency Core Cooling System (ECCS) Failure Modes and Effects Analysis (FMEA).

TABLE 6.3-5 (Sheet 3)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
6a. Deleted					
7. Motor-operated gate valve 8801A (8801B analogous)	Fails to open on demand	Injection - cold legs of RC loops	Failure reduces redundancy of fluid flow paths from HHSI/CH pumps to the RCS via Boron Injection Header. No effect on safety for system operation. Alternate isolation valve 8801B opens to provide back-up flow path from HHSI/CH pumps to Boron Injection Header.	Same methods of detection as those stated for item 2.	Valve aligned to open upon actuation by an SIS.
8. Deleted					
9. Deleted					
10. Motor-operated gate valve FCV-610 (FCV-611 analogous)	a. Fails to close on demand	Injection - cold legs of RC loops	Failure reduces working fluid delivered to RCS from RHR pump 1. Minimum flow requirements for LHSI will be met by PEJ01B delivering working fluid to RCS.	Valve position indication (open to closed position change) at MCB. RHR pump return line to cold legs flow indication (FI-618) at MCB.	Valve is regulated by signal from flow transmitter located in pump discharge header. The control valve opens when the RHR pump discharge flow is less than 816 gpm at 300°F (783 gpm at 68°F) and closes when the flow exceeds 1,650 gpm at 300°F (1582 gpm at 68°F).
	b. Fails Closed	Injection - cold legs of RC loops	Failure results in an insufficient fluid flow through PEJ01A for a small LOCA or steam line break resulting in possible pump damage. If pump becomes inoperative minimum flow requirements for LHSI will be met by PEJ01B delivering working fluid to RCS.	Same methods of detection as those stated for item 10.a, except closed to open position change indication at MCB.	

TABLE 6.3-5 (Sheet 4)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
11. RHR pump PEJ01A (PEJ01B analogous)	Fails to deliver working fluid	Injection - cold legs of RC loops	Failure reduces redunancy of providing emergency coolant to the RCS from the RWST at low RCS pressure (195 psig). Fluid flow from PEJ01A will be lost. Minimum flow requirements for LHSI will be met by PEJ01B delivering working fluid.	RHR pump return line to cold legs flow indication (FI-618) and low flow alarm at MCB. RHR pump discharge pressure (PI-614) at MCB. Open pump switchgear circuit breaker indication at MCB. Circuit breaker close position monitor light and alarm for components at MCB. Common breaker trip alarm at MCB.	The RHR pump is sized to deliver reactor coolant through the RHR heat exchanger to meet plant cooldown requirements and is used during plant cooldown and startup operations. The pump circuit group monitoring of breaker is aligned to close on actuation by an SIS.
12. SI pump PEM01A (PEM01B analogous)	Fails to deliver working fluid	Injection - cold legs of RC loops	Failure reduces redundancy of providing emergency coolant to the RCS from the RWST at high RCS pressure (1,520 psi). Fluid flow from PEM01A will be lost. Minimum flow requirements for IHSI will be met by PEM01B delivering working fluid.	SI pumps discharge pressure (PI-919) at MCB. SI pump discharge flow (FI-918) at MCB. Open pump switchgear circuit breaker indication at MCB. Circuit breaker close position monitor light and alarm for group monitoring of componenets at MCB. Common breaker trip alarm at MCB.	Pump circuit breaker aligned to close on actuation by an SIS
13. Motor-operated gate valve 8811A (8811B analogous)	Fails to open on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing fluid from the containment sump to the RCS during recirculation. PEJ01A will not provide recirculation flow. Minimum LHSI flow requirements will be met through opening of isolation valve 8811B and recirculation of fluid by PEJ01B.	Same methods of detection as those stated for item 2. In addition, failure may be detected through monitoring of RHR pump return line to cold legs flow indication (FI-618) and RHR pump discharge pressure (PI-614) at MCB.	Valve is actuated to open by an SIS in coincidence with two out of four "low-low-1 level" RWST signals. Valve is electrically interlocked from remotely being opened from MCB by isolation valves 8812A, 8701A, and 8702A.

TABLE 6.3-5 (Sheet 5)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
14. Motor-operated gate valve 8812A (8812B analogous)	Fails to close on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing flow isolation of containment sump from RWST. No effect on safety for system operation. Alternate check isolation valve 8958A provides back-up isolation.	Same methods of detection as those stated for item 1.	Valve is electricallyinterlocked with isolation valve 8811A and may not be opened unless valve 8811A is closed.
15. Motor-operated gate valve 8716A (8716B analogous)	Fails to close on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing LHSI/RHR pump train separation for recirculation of fluid to cold legs of RCS. No effect on safety for system operation. Alternate isolation valve 8716B provides back-up isolation for LHSI/RHR pump train separation.	Same methods of detection as those stated for item 1.	
16. Motor-operated globe valve 8813	Fails to close on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing isolation of IHSI pumps miniflow line isolation from RWST. No effect on safety for system operation. Alternate isolation valves 8814A and 8814B in each pump's miniflow line provide back-up isolation.	Same methods of detection as those stated for item 1.	Valve is electrically interlocked with isolation valves 8804A and 8804B and may not be opened unless these valves are closed.
17. Motor-operated globe valve 8814 (8814B analogous)	Fails to close on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing isolation of PEM01A miniflow isolation from RWST. No effect on safety for system operation. Alternate isolation valve 8813 in main miniflow line provides back-up isolation.	Same methods of detection as those stated for item 1.	Same remark as that stated for item 16.

TABLE 6.3-5 (Sheet 6)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
18. Motor-operated gate valve 8804A	Fails to open on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing NPSH to suction of HHSI/CH pumps from LHSI/ RHR pumps. No effect on safety for system operation. Minimum NPSH to HHSI/CH pump suction will be met by flow from PEJ01B via cross-tie line and opening of isolation valve 8807A or 8807B and isolation valve 8804B.	Same methods of detection as those stated for item 2.	Valve is electrically interlocked with isolation valves 8814A, 8814B, 8813, 8701A, and 8702A. Valve cannot be opened unless valve 8813 or valves 8814A and 8814B are closed and valve 8701A or 8702A is closed.
19. Motor-operated gate valve 8804B	Fails to open on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing NPSH to suction of IHSI pumps from LHSI/RHR pumps. No effect on safety for system operation. Minimum NPSH to IHSI suction will be met by flow from LHSI/RHR pump 1 via cross-tie line and opening of isolation valve 8807A or 8807B and isolation valve 8804A.	Same methods of detection as those stated for item 2.	Valve is electrically interlocked with isolation valves 8814A, 8814B, 8813, 8701B, and 8702B. Valve cannot be opened unless valve 8813 or valves 8814A and 8814B are closed and valve 8701B or 8702B is closed.
20. Motor-operated gate valve 8807A (8807B analogous)	Fails to open on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing fluid flow through cross-tie between suction of HHSI/CH pumps and IHSI pumps. No effect on safety for system operation. Alternate isolation valve 8807B opens to provide back-up flow path through cross-tie line.	Same methods of detection as those stated for item 2.	

TABLE 6.3-5 (Sheet 7)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
21. Motor-operated gate valve 8806A (8806B analogous)	Fails to close on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing flow isolation of IHSI pump suction from RWST. No effect on safety for system operation. Alternate check isolation isolation valve 8926A provides back-up isolation.	Same methods of detection as those stated for item 1.	
22. Motor-operated gate valve LCV-112D (LCV-112E analogous)	Fails to close on demand	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing flow isolation of suction of HHSI/CH pumps from RWST. No effect on safety for system operation. Alternate check isolation valve 8546 provides back-up isolation.	Same methods of detection as those stated for item 2.	
23. RHR pump PEJ01A (PEJ01B analogous)	Fails to deliver working fluid	Recirculation - cold legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to the RCS from the containment sump. Fluid flow from PEJ01A will be lost. Minimum recirculation flow requirements for LHSI flow will be met by PEJ01B delivering working fluid.	Same methods of detection as those stated for item 11.	
24. SI pump PEM01A (PEM01B analogous)	Fails to deliver working fluid	Recirculation - cold or hot legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to the RCS from the containment sump to cold legs of RC loops via RHR and SI pumps. Fluid flow from PEM01A will be lost. Minimum recirculation flow requirements for IHSI flow will be met by PEM01B delivering working fluid.	Same methods of detection as those stated for item 12.	

TABLE 6.3-5 (Sheet 8)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
25. Motor-operated gate valve 8809A	Fails to close on demand	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to the RCS from the containment sump to hot legs of RC loops. Fluid flow from PEJ01A will continue to flow to cold legs of RC loops. Minimum recirculation flow requirements to hot legs of RC loops will be met by PEJ01B recirculation fluid to RC hot legs via IHSI pumps.	Same methods of detection as those stated for item 1.	
26. Motor-operated gate valve 8716A (8716B analogous)	Fails to open on demand	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to the RCS from the containment sump to the hot legs of RC loops. Fluid flow from PEJ01A will be lost. Minimum recirculation flow requirements to hot legs of RC loops will be met by PEJ01B recirculating fluid to RC hot legs via HHSI/SI pumps.	Valve position indication (closed to open position change) at MCB. Valve close position monitor light and alarm at MCB. In addition, RHR pump discharge pressure (PI-614) at MCB.	
27. Motor-operated gate valve 8840	Fails to open on demand	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to the RCS from the containment sump to the hot legs of RC loops via LHSI/RHR pumps. Minimum recirculation flow requirements to hot legs of the RCS will be met by PEJ01B recirculating fluid to the RC hot legs via PEM01A and PEM01B.	Same methods of detection as those stated for item 2. In addition, RHR pump discharge pressure (PI-614) at MCB.	

TABLE 6.3-5 (Sheet 9)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
28. Motor-operated gate valve 8809B	Fails to close on demand	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to the RCS from the containment sump to hot legs of RC loops. Fluid flow from PEJ01B will continue to flow to cold legs of RC loops. Minimum recirculation flow requirements to hot legs of RC loops will be met by PEJ01A recirculating fluid to RC hot legs.	Same methods of detection as these stated for item 1.	
29. Motor-operated gate valve 8821A (8821B analogous)	Fails to close on demand	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing flow isolation of HHSI/SI pump flow to cold legs of RC loops. No effect on safety for system operation. Alternate isolation valve 8835 provides back-up isolation against flow to cold legs of RC loops.	Same methods of detection as those stated for item 1.	
30. Motor-operated gate valve 8802A (8802B analogous)	Fails to open on demand	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to hot legs of RCS from the containment sump via IHSI pumps. Minimum recirculation flow requirements to hot legs of RC loops will be met by PEJ01A recirculating fluid from containment sump to hot legs of RC loops and PEM01B recirculating fluid to hot legs 1 and 4 of RC loops through the opening of isolation valve 8802B.	Same methods of detection as those stated for item 2. In addition, SI pump discharge pressure (PI-919) and flow (FI-918) at MCB.	

TABLE 6.3-5 (Sheet 10)

Component***	Failure Mode	ECCS Operation Phase	Effect on System Operation*	Failure Detection Method**	Remarks
31. Motor-operated gate valve 8835	Fails to close on demand	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing flow isolation of IHSI pump flow to cold legs of RC loops. No effect on safety for system operation. Alternate isolation valves 8821A and 8821B in cross-tie line between IHSI pumps provide back-up isolation against flow to cold legs of RC loops.	Same methods of detection as those stated for item 1.	
32. RHR pump 1 (pump 2 analogous)	Fails to deliver working fluid	Recirculation - hot legs of RC loops	Failure reduces redundancy of providing recirculation of coolant to the RCS from the containment sump to the hot legs of RC loops. Fluid flow from PEJ01A will be lost. Minimum flow requirements to hot legs of RC loop will be met by PEJ01B recirculating fluid to RC hot legs via IHSI pumps.	Same methods of detection as those stated for item 11.	
33. Normal Charging Pump (PBG04)	PB03 fails to trip on SI and pump continues to run.	Injection-cold legs of RC loops.	Failure increases flow to RCS through RCP seals and the Boron Injection Header. Maximum and minimum analyzed safeguard flow is unaffected.	Increased flow through BGFI215A&B and EMFI0917A&B; BGHIS3 indicates ‘RUN’ after SIS.	

TABLE 6.3-5 (Sheet 11)

List of acronyms and abbreviations

CH	-	Charging	RWST	-	Refueling water storage tank
HHSI	-	High head safety injection (refers to PBG05A, PBG05B)	SI	-	Safety injection
IHSI	-	Intermediate head safety injection (refers to PEM01A, PEM01B)	VCT	-	Volume control tank
LHSI	-	Low head safety injection (refers to PEJ01A, PEJ01B)			
LOCA	-	Loss-of-coolant accident			
MCB	-	Main control board			
NPSH	-	Net positive suction head			

TABLE 6.3-6 SINGLE ACTIVE FAILURE ANALYSIS FOR EMERGENCY CORE COOLING SYSTEM COMPONENTS

Component	Malfunction	Comments
Injection Phase		
1. Pumps		
a. ECCS centrifugal charging	Fails to start	Two provided; evaluation based on operation of one.
b. Safety injection	Fails to start	Two provided; evaluation based on operation of one.
c. Residual heat removal	Fails to start	Two provided; evaluation based on operation of one.
2. Automatically operated valves		
a. Boron injection header isolation		
(1) Inlet	Fails to open	Two parallel lines; one valve in either line required to open.
(2) Outlet	Fails to open	Two parallel lines; one valve in either line required to open.
b. Deleted		
c. ECCS centrifugal charging pumps		
(1) Suction line from refueling water storage tank	Fails to open	Two parallel valves; only one valve required to open.

TABLE 6.3-6 (Sheet 2)

Component	Malfunction	Comments
(2) Discharge line to the normal charging path	Fails to close	Two valves in series; only one valve required to close.
(3) Miniflow bypass line	Fails to close	Two parallel valves; only one valve required to close.
(4) Suction from volume control tank	Fails to close	Two valves in series; only one valve required to close.
Recirculation Phase		
1. Valves operated automatically during switchover to recirculation		
a. Residual heat removal pumps		
(1) Suction line from containment sump	Fails to open	Two parallel lines; only one containment sump valve in either line required to open.
(2) Suction line from refueling water storage	Fails to close	Check valve in series with a gate valve in each parallel line; operation of only one valve in each line required.
2. Valves operated manually from the control room		
a. Safety injection pump suction line from refueling water storage tank	Fails to close	Check valve in series with two gate valves in each parallel line; operation of only one valve in each line required.

TABLE 6.3-6 (Sheet 3)

Component		Malfunction	Comments
b.	ECCS centrifugal charging pump suction line from refueling water storage tank	Fails to close	Check valve in series with a gate valve in each parallel line; operation of only one valve in each line required.
c.	High head and intermediate head pump suction line at discharge of residual heat exchanger	Fails to open	Separate and independent paths to safety injection pumps and ECCS charging pumps take suction from discharge of residual heat exchangers; operation of only one valve required.
d.	Residual heat removal cross-connect line	Fails to close	Two valves in series; operation of one required.
e.	Safety injection pump miniflow lines	Fails to close	Two parallel valves provided in series with a third; operation of either both parallel valves or the single series valve required.
f.	Safety injection/charging cross-connect line in suction header	Fails to open	Two parallel valves provided; operation of one required.
g.	Safety injection/residual heat removal hot leg isolation valves	Fails to open	Three flow paths available; adequate flow to core is assured by any two.
h.	Safety injection/residualheat removal cold leg isolation valves	Fails to close	Redundant valves provided with suitable arrangements.

TABLE 6.3-7 EMERGENCY CORE COOLING SYSTEM RECIRCULATION PIPING PASSIVE FAILURE ANALYSIS LONG-TERM PHASE

Flow Path	Indication of Loss of Flow Path	Alternate Flow Path
Low Head Recirculation		
From containment sump to accumulator injection via the residual heat removal pumps and the residual heat exchangers	Accumulation of water in a residual heat removal pump compartment or auxiliary building sump	Via the independent, identical low head flow path, utilizing the second residual heat exchanger and residual heat removal pump
Intermediate Head and High Head Recirculation		
From containment sump to the high head injection header and accumulator injection lines via residual heat removal pump, residual heat exchanger, and the high head and intermediate injection pumps	Accumulation of water in a residual heat removal pump compartment or the auxiliary building sump	From containment sump to the high head injection header and accumulator injection lines via alternate residual heat removal pump, residual heat exchanger, safety injection and ECCS charging pumps

TABLE 6.3-8 SEQUENCE OF CHANGEOVER OPERATION FROM INJECTION TO RECIRCULATION

The operator initiates component cooling water to the RHR heat exchangers and terminates cooling water to the fuel pool cooling heat exchangers as the level in the RWST nears the low-low-1 level setpoint. Without being stopped, the RHR pumps are realigned for the recirculation mode by the automatic opening of the sump isolation valves, which occurs upon receipt of the RWST low-low-1 level signal and an SIS. The isolation valve in each RHR suction line from the RWST is then automatically closed. The following remote manual operator actions from the control room are required to complete the changeover operation from the injection mode to the recirculation mode.

1. Close the motor-operated isolation valves in the safety injection pump miniflow lines (EM-HV-8814 A and B or BN-HV-8813).

2. Close the two remote motor-operated valves in the crossover line downstream of the residual heat removal heat exchangers (EJ-HV-8716A and B).

3. Open the two parallel motor-operated valves in the common suction line between the ECCS charging pumps and the safety injection pumps (EM-HV-8807A and B).

4. Open the motor-operated valve in the line from the RHR pump PEJ01A discharge to the ECCS charging pump suction and the motor-operated valve in the line from the number RHR pump PEJ01B discharge to the safety injection pump suction (EJ-HV-8804 A and B).

5. Close the two motor-operated valves in the lines from the RWST to the safety injection pumps (BN-HV-8806A and B).

6. Close the two motor-operated valves in the lines from the RWST to the ECCS charging pumps (BN-LCV-0112D and E).

TABLE 6.3-9 EMERGENCY CORE COOLING SYSTEM SHARED FUNCTIONS EVALUATION

Component	Normal Operating Arrangement	Accident Arrangement
Refueling water storage tank	Lined up to suction of safety injection and residual heat removal pumps	Lined up to suction of ECCS centrifugal charging, safety injection and residual heat removal pumps
ECCS centrifugal charging pumps	Lined up for charging service suction from volume control tank, discharge via normal charging line	Suction from refueling water storage tank, discharge lined up to inlet of boron injection header. Valves for realignment meet single failure criteria
Residual heat removal pumps	Lined up to cold legs of reactor coolant piping; EJ-HV-8716A and B and EJ-HV-8809A and B are maintained open during operating modes 1-3 in order that either RHR pump is able to inject to all four RCS cold legs.	Lined up to cold legs of reactor coolant piping
Residual heat exchangers	Lined up to cold legs of reactor coolant piping	Lined up to cold legs of reactor coolant piping

TABLE 6.3-10 NORMAL OPERATING STATUS OF EMERGENCY CORE COOLING SYSTEM COMPONENTS FOR CORE COOLING

Number of safety injection pumps operable	2
Number of ECCS centrifugal charging pumps operable	2
Number of RHR pumps operable	2
Number of RHR heat exchangers operable	2
RWST volume, gallons, (nominal)	406,921
Boron concentration in RWST, ppm (nominal)	2,350-2,500
Boron concentration in accumulator tank, ppm (nominal)	2,300-2,500
Number of accumulator tanks	4
Minimum accumulator pressure, psig	602
Nominal accumulator water volume, ft^3	850
System valves, interlocks, and piping required for the above components which are operable	All

TABLE 6.3-11 RWST OUTFLOW (LARGE BREAK) - NO FAILURES

Step[1]	Time Required Per[2][3] Step (sec)	RWST Outflow[4][5] Per Step (gpm)	Change in RWST Volume Per Step (gal)	Total RWST Volume Change (gal)
RHR Pump Switchover	40[6]	20,736[7]	13,824	13,824
1	40	9,402	6,268	20,092
2	45	9,402	7,052	27,144
3	45	9,402	7,052	34,196
4[8]	45	9,402	7,052	41,248
5	45	7,612	5,709	46,957
6	45	7,612	5,709	52,666
Lo-Lo-2 Level Alarm	4.75 min.[9]	7,612	36,185	88,851
Minimum ECCS Transfer Volume Allowance				88,851

NOTES:

(1) See Table 6.3-8 for a description of ECCS pump switchover steps 1 through 6.

(2) Valve operating times are maximum operating times.

(3) Time required to complete the required action includes a conservative 30 seconds for operator response time for each manual procedure.

TABLE 6.3-11 (Sheet 2)

(4) Flow rates are based on the following

RHR pump	=	4,867 gpm per pump
CCHG pump	=	481 gpm per pump
SI pump	=	414 gpm per pump
CS pump	=	3,806 gpm per pump

(5) The flow rate in this column is assumed to occur during the entire time interval for its respective step. This is conservative, since valve repositioning may reduce the flow rate during the time interval.

(6) Valves 8812 A/B do not start to automatically close until valves 8811 A/B are fully open.

(7) Flow out of the RWST during switchover includes allowances for both pumped flow to the RCBS and containment and backflow to the containment sump.

(8) Following the completion of this step, all ECCS pumps are aligned with suction flow from the containment sump. The containment spray pumps continue to take suction from the RWST until the RWST low-low-2 level alarm informs the operator to initiate switchover of the containment spray system.

(9) This time represents the minimum time available after the completion of step 6 before the RWST Lo-Lo-2 Level Alarm setpoint is reached.

TABLE 6.3-11A RWST OUTFLOW DURING CONTAINMENT SPRAY SWITCHOVER (LARGE BREAK) - NO FAILURES

Time (1) Interval	Time Required(2)(3) Per Interval (sec)	RWST Outflow(4)(5) Per Interval (gpm)	Change in RWST Volume Per Interval (gal)	Total RWST Volume Change (gallons)
A	30	7,612	3,806	3,806
B	30	7,004	3,502	7,308
C	30	4,568	2,284	9,592
D	90	3,655	5,483	15,075
Minimum Containment Spray Transfer Volume Allowance				15,757

(1) See Table 6.2.2-3 (Sheet 2) for a description of Containment Spray pump switchover time intervals A through D.

(2) Valve operating times are maximum operating times.

(3) Time required to complete the required action includes a conservative 30 seconds for operator response time for each manual procedure.

(4) Flow rates are based on the following:

CS pump = 3,806 gpm per pump

(5) For Containment Spray pump switchover time intervals, credit is taken for the throttling of flow as the sump valves open and as the RWST valves close.

TABLE 6.3-12 RWST OUTFLOW DURING ECCS AND CONTAINMENT SPRAY SWITCHOVER (LARGE BREAK - WORST SINGLE FAILURE[10])

Step/time[1] Interval	Time Required Per[2][3] Step/Interval (sec)	RWST Outflow Per[4][5][6] Step/Interval (gpm)	Change in RWST Volume Per Step/Interval (gal)	Total RWST Volume Change (gallons)
RHR Pump Switchover	40[7]	20,736	13,824	13,824
Additional Time fromRHR pump switchover to the time the RHR Pump is turned off	135	15,069	33,906	47,730
Time from RHR pump stop to RHR pump restart	60	10,202	10,202	57,932
1	40	9,402	6,268	64,200
2	45	9,402	7,052	71,252
3	45	9,402	7,052	78,304
4[8]	45	9,402	7,052	85,356
5	45	7,612	5,709	91,065
6[9]	45	7,612	5,709	96,774
A	30	7,612	3,806	100,580
B	30	7,004	3,502	104,082
C	30	4,568	2,284	106,366
D	90	3,655	5,483	111,849
Minimum ECCS and Containment Spray Transfer Volume Allowance				113,034

TABLE 6.3-12 (Sheet 2)

NOTES:

(1) See Table 6.3-8 for a description of ECCS pump switchover steps 1 through 6. See Table 6.2.2-3 for a description of containment spray pump switchover time intervals A through D.

(2) Valve operating times are maximum operating times.

(3) Time required to complete the required action includes a conservative 30 seconds for operator response time for each manual procedure.

(4) Flow rates are based on the following:

RHR pump	=	4,867 gpm per pump
CCHG pump	=	481 gpm per pump
SI pump	=	414 gpm per pump
CS pump	=	3,806 gpm per pump

(5) The flow rate in this column is assumed to occur during the entire time interval for its respective ECCS pump switchover step. For Containment Spray pump switchover time intervals, credit is taken for the throttling of flow as the sump valves open and as the RWST valves close.

(6) Flow out of the RWST during switchover includes allowances for and backflow to the containment sump.

(7) Valves 8812 A/B do not start to automatically close until valves 8811 A/B are fully open.

(8) Following the completion of this step, all ECCS pumps are aligned with suction flow from the containment sump.

TABLE 6.3-12 (Sheet 3)

(9) The RWST Lo-Lo-2 level alarm is reached prior to the completion of the ECCS switchover. Therefore, following completion of the ECCS switchover, the operator will immediately proceed with containment spray pump switchover.

(10) Based on a large break LOCA in conjunction with a single failure of one of the RWST to residual heat removal pump isolation valves (8812 A or 8812 B fails to close on demand).

6.4 HABITABILITY SYSTEMS

The control room habitability systems include missile protection, radiation shielding, radiation monitoring, carbon dioxide, carbon monoxide, and smoke detection capability, control room filtration, pressurization and air conditioning, lighting, personnel support, and manual fire protection. These habitability systems are provided to permit access to and occupancy of the control room during normal plant operations, as well as during and following emergency conditions.

The ventilation and air-conditioning equipment discussed in this section is the same control room and control building equipment discussed in Section 9.4.1, Control Building HVAC. This section only addresses emergency service requirements and responses, including operation of control room ventilation and air-conditioning equipment under emergency conditions. Lighting systems are discussed fully in Section 9.5.3, and are not discussed herein. Other equipment and systems are described only as necessary to define their connection with control room habitability and, accordingly, reference is made to other appropriate sections.

A non-perishable food supply capable of sustaining 5 men for 10 days shall be maintained within the confines of the control room envelope. A supply of bottled water shall be maintained within the confines of the control room envelope and shall be available in quantities sufficient to reconstitute any dried food and to serve as a source of drinking water for 5 men for 10 days. Standard-man values shall be used for the drinking water consumption rate.

An emergency medical supply kit shall be permanently installed within the confines of the control room envelope.

Seven self-contained breathing apparatus units shall be maintained in the control room envelope with 3 hours of air for 5 watchstanders. The compressed air bottles shall be placed so as not to cause damage to vital equipment or interference with operation if they fall. Operator training on these devices shall be in compliance with ANSI Z88.2-1980. Since respiratory protection equipment will be maintained within the control room evelope, time required to don the equipment is minimal. Testing and maintenance provisions shall be in accordance with the manufacturer's recommendations.

6.4.1 DESIGN BASES

6.4.1.1 Safety Design Bases

The control room filtration, pressurization, and air-conditioning systems, the radiation monitoring system, the emergency lighting system, and the isolation dampers in the control building supply air, exhaust, and access control exhaust ducting are treated as safety-related items and are required to function under emergency conditions. These habitability systems are required to function following a DBA and to enable the plant operators to achieve and/or maintain the plant in a safe shutdown condition. The following safety design bases are met:

SAFETY DESIGN BASIS ONE - The habitability systems are housed within a structure capable of withstanding the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC-2).

SAFETY DESIGN BASIS TWO - The habitability systems are designed to remain functional after an SSE and to perform their intended function following a postulated hazard, such as a fire, internal missiles, or pipe break (GDC-3 and 4).

SAFETY DESIGN BASIS THREE - Habitability system redundancy is provided so that safety functions can be performed, assuming a single active component failure coincident with a loss of offsite power.

SAFETY DESIGN BASIS FOUR - The habitability systems are designed so that the active components are capable of being tested during plant operation. Provisions are made to allow for inservice inspection of appropriate components of the control room air-conditioning system.

SAFETY DESIGN BASIS FIVE - The habitability systems are designed and fabricated according to codes consistent with the quality group classification assigned by Regulatory Guide 1.26 and the seismic category assigned by Regulatory Guide 1.29. The power supply and control functions are in accordance with Regulatory Guide 1.32.

SAFETY DESIGN BASIS SIX - The capability to isolate all nonsafety-related HVAC system penetrations of the control building boundary is provided, if required, so that the occupation and habitability of the control room will not be compromised.

SAFETY DESIGN BASIS SEVEN - The radiation exposure of control room personnel throughout the duration of any one of the postulated DBAs discussed in Chapter 15.0 does not exceed the guideline values of GDC-19.

SAFETY DESIGN BASIS EIGHT - Throughout the duration of any one of the postulated hazardous chemical releases discussed in Section 2.2 of the Site Addendum or DBAs discussed in Chapter 15.0 of the FSAR, the habitability systems maintain the control room atmosphere at environmental conditions suitable for occupancy per GDC-19. The habitability systems comply with Regulatory Guides 1.78 and 1.95.

SAFETY DESIGN BASIS NINE - The control room ventilation system is capable of automatic transfer from its normal operational mode to its emergency mode upon detection of airborne radiation resulting in exposure of control room personnel in excess of GDC-19 limits.

6.4.1.2 Power Generation Design Bases

The control room ventilation and air-conditioning system power generation design bases are discussed in Section 9.4.1.1.2.

6.4.2 SYSTEM DESIGN

6.4.2.1 Definition of Control Room Envelope

The control room envelope includes the control room and all areas in or adjacent to the control room containing plant information and equipment that may be needed during an emergency, including pantry, sanitary facilities, and control room air-conditioning equipment rooms.

6.4.2.2 Ventilation System Design

The control room emergency ventilation systems consist of the control room air-conditioning system, the control room filtration system, and the control room pressurization system.

The control room air-conditioning system and the control room filtration system serve only the control room and the adjacent control room air-conditioning equipment rooms (FSAR Figures 1.2-13 and 1.2-25). The pressurization system serves the ESF switchgear rooms (FSAR Figure 1.2-24), the mechanical and electrical equipment rooms (FSAR Figure 1.2-24), the lower cable spreading room (FSAR Figure 1.2-25), the upper cable spreading room (FSAR Figure 1.2-26), and the control room air-conditioning equipment rooms. All major equipment located in those areas is shown on the above referenced figures.

The control building (including the control room) HVAC systems are described in Section 9.4.1 and shown in Figure 9.4-1. Codes and standards applicable to the control building HVAC systems are listed in Table 3.2-1. Elevation and plan views are shown in Figures 1.2-25, 1.2-27, and 1.2-28.

The control room air-conditioning system is a recirculation system. The control room air-conditioning system along with the control room filtration system are designed to control the level of airborne contamination in the control room atmosphere and to control the temperature and humidity for personnel safety and comfort.

Upon actuation of the system to the emergency mode of operation, as outlined in Section 9.4.1, the control building exhaust isolation dampers and the control building supply air isolation dampers close; the air-conditioning system switches to emergency recirculation.

Redundant control room emergency pressurization units are used to pressurize the control room envelope during emergency recirculation.

Redundant radiation monitors are provided to control ventilation system operation. The radiation monitors along with the redundant carbon monoxide/carbon dioxide monitors are located in the control building supply air system ductwork, downstream of the supply unit. Chlorine monitors are not required per Section 2.2.3.1.3 of the Callaway Site Addendum.

6.4.2.3 Leaktightness

During the emergency mode of operation, the control room is maintained at an overpressure of 1/8 inch w.g. (minimum) by the control room pressurization system to prevent infiltration from surrounding areas of unfiltered air. Potential leakage paths are listed in Section 9.4.1.2.3.

For an analysis of the radiological consequences to the control room occupants in the unlikely event of a LOCA, see Section 15.6.5.

6.4.2.4 Interaction With Other Zones and Pressure-Containing Equipment

The control room envelope is isolated and pressurized during the accident involving the release of radioactive gases in the surrounding zones. The control room air-conditioning system is operated in the emergency recirculation mode, with outside filtered air used to maintain control room pressurization.

The control room pressurization system maintains the control room at a slight positive pressure during emergency operation. If smoke is detected in the control building supply air system, it is alarmed in the control room.

Although those doors which form a part of the control room pressure boundary open outward, they are designed to maintain their specified leaktightness (0.10 cfm leakage per linear foot) at a positive control room pressure of 1/8 inch w.g.

There is no equipment, such as batteries, located within the control room boundary, that emits noxious gases. The only potential sources for the release of any gases into the control room are the discharge of the fire extinguishers, discharge of the Halon system into the cable trenches and chases, and leakage of the control room air-conditioning unit refrigerant. The release of any one of these gases would not result in a toxicity level that would be hazardous to the control room operators. All piping not connected or related to control room equipment is routed outside the pressurized boundary. Portable self-contained breathing apparatus are readily available for use by the control room operators.

6.4.2.5 Shielding Design

A description of the radiation sources and shielding required to maintain the habitability of the control room during normal operations and during the course of postulated accidents is provided in Section 12.3. The shielding design is based on the requirements specified in GDC-19. A plan view drawing of the control room and associated structures identifying distances and shield thicknesses is shown in Figure 12.3-3.

6.4.3 SYSTEM OPERATIONAL PROCEDURES

NORMAL MODE - Control room ventilation system operation in the normal mode is described in Section 9.4.1.2.3. Normal operation of the fire protection system is described in Section 9.5.1.

EMERGENCY MODE - Control room ventilation system operation in the emergency mode is described in Section 9.4.1.2.3.

6.4.4 DESIGN EVALUATIONS

Safety evaluations are numbered to correspond with the safety design bases.

SAFETY EVALUATION ONE - The safety-related portions of the habitability systems are located in the auxiliary and control buildings. These buildings are designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other appropriate natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of these buildings.

SAFETY EVALUATION TWO - The safety-related portions of the habitability systems are designed to remain functional after an SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to assure that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

SAFETY EVALUATION THREE - The system design for the safety-related portions of the habitability systems provides for complete redundancy, and, as indicated by Table 9.4-5, no single failure will compromise the systems' safety functions. All vital power can be supplied from either onsite or offsite power systems, as described in Chapter 8.0.

SAFETY EVALUATION FOUR - The habitability systems are initially tested with the program given in Chapter 14.0. Periodic inservice functional testing is done in accordance with Section 6.4.5.

Section 6.6 provides the ASME Boiler and Pressure Vessel Code, Section XI requirements that are appropriate for portions of the control room air-conditioning system.

SAFETY EVALUATION FIVE - Section 3.2 delineates the quality group classification and seismic category applicable to the safety-related portions of these systems and supporting systems. All the power supplies and control functions necessary for safe functioning of the safety-related portions of the habitability systems are Class 1E, as described in Chapters 7.0 and 8.0.

SAFETY EVALUATION SIX - Section 9.4.1.2.3 describes the provisions made to assure the isolation of the control room.

SAFETY EVALUATION SEVEN - The direct radiation exposure rate of a control room occupant throughout the duration of any one of the postulated DBAs discussed in Chapter 15.0 does not exceed 0.5 mr/hr whole-body, and thus will not exceed GDC-19 requirements. A detailed discussion of the dose calculation model for control room operators is discussed in Appendix 15A. Control room shielding design, based on the most limiting design basis LOCA fission product release, is discussed in Section 12.3.

SAFETY EVALUATION EIGHT - Throughout the duration of any of the postulated hazardous chemical releases discussed in Section 2.2 or DBAs discussed in Chapter 15.0, the habitability system maintains the control room environmental conditions below those established by Regulatory Guides 1.78 and 1.95 and GDC-19. Compliance with Requlatory Guides 1.78 and 1.95 is provided in Tables 6.4-1 and 6.4-2, respectively.

SAFETY EVALUATION NINE - Upon detection of high radiation in the induction trunk, the control room ventilation system is capable of automatic transfer from normal to emergency mode to minimize the exposure of control room personnel.

6.4.5 TESTS AND INSPECTIONS

Testing and inspection of control room HVAC systems are described in Section 9.4.1.4.

The emergency mode of the control room HVAC system will undergo an acceptance test to verify that the system will maintain a 1/8-inch w.g. positive pressure in the emergency zone. Testing complies with Regulatory Guide 1.95, as described in Table 6.4-2.

The control room is classified as Type B per Regulatory Guide 1.78. Since the air exchange rate exceeds 0.06 air exchanges per hour for the control room, periodic testing of the control room pressurization system is not required per the exclusion provisions of Regulatory Guides 1.78 and 1.95. This periodic testing is not required for the Callaway plant based on the adequacy of a 400 cfm (nominal with tolerance of (+) 40 cfm, (-) 40 cfm) pressurization flow rate (Reference 1).

6.4.6 INSTRUMENTATION REQUIREMENTS

Safety-related instrumentation and isolation signals are discussed in Sections 9.4.1.2.3 and 7.3.

Indication of all fan operational status is provided in the control room.

An indication of the position of all isolation dampers is provided in the control room.

All instrumentation associated with filtration units complies with Regulatory Guide 1.52, as described in Table 9.4-2.

Alarms indicate induction trunk airborne radioactivity per the nominal values listed in Table 11.5-3, and carbon monoxide/carbon dioxide concentrations of 25 ppm and 0.25 percent, respectively. A smoke detector is also provided in the control building supply air intake with an alarm in the control room.

A discussion of the range, alarm points, isolation setpoint, and minimum sensitivity for the redundant radiation monitors installed in the control building supply air induction trunk is presented in Section 11.5.

6.4.7 REFERENCE

1. NRC Staff Meeting Summary for June 26, 1975, dated September 8, 1975.

TABLE 6.4-1 COMPARISON OF THE DESIGN TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.78, DATED JUNE 1974 TITLED "ASSUMPTIONS FOR EVALUATING THE HABITABILITY OF A NUCLEAR POWER PLANT CONTROL ROOM DURING A POSTULATED HAZARDOUS CHEMICAL RELEASE"

Regulatory Guide 1.78 Position	Union Electric Position
In evaluating the habitability of a nuclear power plant control room during a postulated hazardous chemical release, the following assumptions should be made:	
1. If major depots or storage tanks of hazardous chemicals such as the chemicals listed in Table C-1 of the guide are known or projected to be present within a five-mile radius of the reactor facility, these chemicals should be considered in the evaluation of control room habitability. Whether a major depot or storage area constitutes a hazard is determined on the basis of the quantity of stored chemicals, the distance from the nuclear plant, the inleakage characteristics of the control room, and the applicable toxicity limits (see Regulatory Position 4 for definition). Table C-2 gives the criteria to be used in evaluating the hazards of chemicals to control rooms. A procedure for adjusting the quantities given in Table C-2 to appropriately account for the toxicity limit of a specific chemical, meteorology conditions of a particular site, and air exchange rate of a control room is presented in Appendix A of this guide.	1. See Site Addendum, Section 2.2.

TABLE 6.4-1 (Sheet 2)

Regulatory Guide 1.78 Position	Union Electric Position
Chemicals stored or situated at distances greater than five miles from the facility need not be considered because, if a release occurs at such a distance, atmospheric dispersion will dilute and disperse the incoming plume to such a degree that there should be sufficient time for the control room operators to take appropriate action. In addition, the probability of a plume remaining within a given sector for a long period of time is quite small.	
2. If hazardous chemicals such as those indicated in Table C-1 are known or projected to be frequently shipped by rail, water, or road routes within a five-mile radius of a nuclear power plant, estimates of these shipments should be considered in the evaluation of control room habitability. The weight limits of Table C-2 (adjusted for the appropriate toxicity limit, meteorology, and control room air exchange rate) apply also to frequently shipped quantities of hazardous chemicals. Shipments are defined as being frequent if there are 10 per year for truck traffic, 30 per year for rail traffic, or 50 per year for barge traffic. If the quantity, per shipment, of hazardous chemicals frequently shipped past a site is less than the adjusted quantity shown on Table C-2 for the control room type being evaluated, the shipments need not be considered in the analysis.	2. See Site Addendum, Section 2.2.

TABLE 6.4-1 (Sheet 3)

Regulatory Guide 1.78 Position	Union Electric Position
3. In the evaluation of control room habitability during normal operation, the release of any hazardous chemical to be stored on the nuclear plant site in a quantity greater than 100 pounds should be considered. Any hazardous chemical stored onsite should be accompanied by instrumentation that will detect its escape, set off an alarm, and provide a readout in the control room.	3. Complies per Callaway's Hazrdous Chemical Control Program.
4. The toxicity limits should be taken from appropriate authoritative sources, such as those listed in the References section. For each chemical considered, the values of importance are the human detection threshold and the maximum concentration that can be tolerated for two minutes without physical incapacitation of an average human (i.e., severe coughing, eye burn, or severe skin irritation). The latter concentration is considered the "toxicity limit." Table C-1 gives the toxicity limits (in ppm by volume and mg/m^3) for the chemicals listed. Where these data are not available, a determination of the values to be used will be made on a case-by-case basis.	4. See Site Addendum, Section 2.2. Toxicity limits based on the immediately-dangerous-to-life-and-health (IDLH) exposure levels established by the National Institute for Occupational Safety and Health (NIOSH), as accepted in Revision 1 to Regulatory Guide 1.78 (December 2001), may be used in lieu of the limits originally specified in Regulatory Guide 1.78 (June 1974).
5. Two types of industrial accidents should be considered for each source of hazardous chemicals; maximum concentration chemical accidents and maximum concentration-duration chemical accidents.	5. See Site Addendum, Section 2.2.

TABLE 6.4-1 (Sheet 4)

Regulatory Guide 1.78 Position	Union Electric Position
a. For a maximum concentration accident, the quantity of the hazardous chemical to be considered is the instantaneous release of the total contents of one of the following: (1) The largest storage container falling within the guidelines of Table C-2 and located at a nearby stationary facility, (2) the largest shipping container (or for multiple containers of equal size, the failure of only one container unless the failure of that container could lead to successive failures) falling within the guidelines of Table C-2 and frequently transported near the site, or (3) the largest container stored onsite (normally the total release from this container unless the containers are interconnected in such a manner that a single failure could cause a release from several containers.) For chemicals that are not gases at 100°F and normal atmospheric pressure but are liquids with vapor pressures in excess of 10 torr, consideration should be given to the rate of flashing and boiloff to determine the rate of release to the atmosphere and the appropriate time duration of the release. The atmospheric diffusion model to be used in the evaluation should be the same as or similar to the model presented in Appendix B of this guide.	

TABLE 6.4-1 (Sheet 5)

Regulatory Guide 1.78 Position	Union Electric Position
b. For a maximum concentration-duration accident, the continuous release of hazardous chemicals from the largest safety relief valve on a stationary, mobile, or onsite source falling within the guidelines of Table C-2 should be considered. Guidance on the atmospheric diffusion model is presented in Regulatory Guide 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Boiling Water Reactors," and Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Pressurized Water Reactors."	
6. The value of the atmospheric dilution factor between the release point and the control room that is used in the analysis should be that value that is exceeded only 5 percent of the time. When boiloff or a slow leak is analyzed, the effects of density on vertical diffusion may be considered if adequately substantiated by reference to data from experiments. Density effect of heavier-than-air gases should not be considered for releases of a violent nature or for material that becomes entrained in the turbulent air near buildings.	6. See Site Addendum, Section 2.2.

TABLE 6.4-1 (Sheet 6)

Regulatory Guide 1.78 Position	Union Electric Position
7. For both type of accidents described in Regulatory Position 5 above, the capability of closing the air ducts of the control room with dampers and thus isolating the control room should be considered in the evaluation of control room habitability. In particular, the time required to shut off or redirect the intake flow should be justified. The detection mechanism for each hazardous chemical should be considered. Human detection may be appropriate if the buildup of the hazardous chemical in the control room is at a slow rate due to slow air turnover. The air flows for infiltration, makeup, and recirculation should be considered for both normal and accident conditions. The volume of the control room and all other rooms that share the same ventilating air, during both normal conditions and accident conditions, should be considered. The time required for buildup of a hazardous chemical from the detection concentration to the toxicity limit should be considered. Table C-3 of the guide contains a sample list of the chemical and control room data needed for the evaluation of control room habitability.	7. See Site Addendum, Section 2.2 for those hazardous chemicals stored onsite. Refer to Table 6.4-2, "Comparison of the Design to Regulatory Positions of Regulatory Guide 1.95" for chlorine hazard analysis.
8. In the calculation of the rate of air infiltration (air leaking into the control room from ducts, doors, or other openings) with the control room isolated and not pressurized, use of the following assumptions is suggested:	8. See below.
a. A pressure differential of 1/8-inch water gauge across all leak paths.	a. Complies.
b. The maximum design pressure differential for fresh air dampers on the suction side of recirculation fans.	b. Not applicable. Control room isolation isolates all systems and stops all fans which penetrate the control room boundary.

TABLE 6.4-1 (Sheet 7)

Regulatory Guide 1.78 Position	Union Electric Position
9. When the makeup air flow rate required to pressurize the control room is calculated, a positive pressure differential of 1/4-inch water gauge should be assumed in the control room relative to the space surrounding the control room	9. Complies, however a pressure differential of 1/8-inch watergauge has been accepted by the NRC.
10. To account for the possible increase in air exchange due to ingress or egress, an additional 10 cfm of unfiltered air should be assumed for those control rooms without airlocks. This additional leakage should be assumed whether or not the control room is pressurized.	10. No unfiltered inleakage is assumed due to ingress or egress because of the two-door vestibule configuration at Callaway.
11. If credit is taken in the evaluation for the removal of hazardous chemicals by filtration or other means, the experimental basis for the dynamic removal capability of the removal system for the particular chemical being considered should be established.	11. Complies. No credit is taken for removal.
12. Concurrent chemical release of container contents during an earthquake, tornado, or flood should be considered for chemical container facilities that are not designed to withstand these natural events. It may also be appropriate to consider release from a single onsite container or pipe coincident with the radiological consequences of a design basis loss-of-coolant accident, if the container facilities are not designed to withstand an earthquake.	12. See Site Addendum, Section 2.2.

TABLE 6.4-1 (Sheet 8)

Regulatory Guide 1.78 Position	Union Electric Position
13. If consideration of possible accidents for any hazardous chemical indicates that the applicable toxicity limits may be exceeded, self-contained breathing apparatus of at least one-half hour capacity or a tank source of air with manifold outlets and protective clothing, if required, should be provided for each operator in the control room. Additional air capacity with appropriate equipment should be provided if a chemical hazard can persist longer than one-half hour. For accidents of long duration, sufficient air for six hours (coupled with provisions for obtaining additional air within this time period) is adequate. Each operator should be taught to distinguish the smells of hazardous chemicals peculiar to the air. Instruction should a periodic refresher course. Practice drills should be conducted to ensure that personnel can don breathing apparatus within two minutes.	13. Not Applicable. This is not necessary since there is no adverse effect on the plant or control room from hazardous materials. See Site Addendum Section 2.2.
14. Detection instrumentation, isolation systems, filtration equipment, air supply equipment, and protective clothing should meet the single-failure criterion. (In the case of self-contained breathing apparatus and protective clothing, this may be accomplished by supplying one extra unit for every three units required.)	14. The single failure criterion is met, as described in Sections 6.4 and 9.4.1 and in the Site Addendum, Section 2.2.

TABLE 6.4-1 (Sheet 9)

Regulatory Guide 1.78 Position	Union Electric Position
15. Emergency procedures to be initiated in the event of a hazardous chemical release within or near the station should be written. These procedures should address both maximum concentration accidents, and maximum concentration-duration accidents and should identify the most probable chemical releases at the station. methods of detecting the event by station personnel, both during normal workday operation and during minimum staffing periods (late night and weekend shift staffing), should be discussed. Special instrumentation that has been provided for the detection of hazardous chemical releases should be described, including sensitivity, action initiated by detecting instrument, level at which this action is initiated, and Technical Specification limitations on instrument availability. Criteria should be defined for the isolation of the control room, for the use of protective breathing apparatus or other protective measures, and for orderly shutdown or scram. Criteria and procedures for evacuating nonessential personnel from the station should also be defined. Arrangement should be made with federal, state, and local agencies or other cognizant organizations for the prompt notification of the nuclear power plant when accidents involving hazardous chemicals have occurred within five miles of the plant.	15. See Site Addendum, Section 2.2.

TABLE 6.4-2 COMPARISON OF THE DESIGN TO REGULATORY POSITIONS OF REGULATORY GUIDE 1.95, REVISION 1, DATED JANUARY 1977, TITLED "PROTECTION OF NUCLEAR POWER PLANT CONTROL ROOM OPERATIONS AGAINST AN ACCIDENTAL CHLORINE RELEASE"

Regulatory Guide 1.95 Position	Union Electric Position
Control room operators should be protected against the effects of an accidental chlorine release as described below.	
1. Liquified chlorine should not be stored within 100 meters of a control room or its fresh air inlets. (Small quantities for laboratory use, 20 pounds or less, are exempt.)	1. See Site Addendum, Section 2.2.
2. If a chlorine container having an inventory of 150 pounds or less is stored more than 100 meters from the control room or its fresh air inlets, the capability for manual isolation of the control room should be provided.	2. The capability for remote manual isolation is provided. (Section 9.4.1 has been changed; it no longer refers to chlorine-initiated isolation.)
3. For single container quantities exceeding 150 pounds, the maximum allowable chlorine inventory in a single container stored at specified distances from the control room or its fresh air inlet is given in Table 1 for control room Types I through VI (described below). For each control room type, the maximum allowable chlorine inventory in a single container is given as a function of distance from the control room. If there are several chlorine containers, only the failure of the largest container is normally considered unless the containers are interconnected in such a manner that failure of a single container could cause a chlorine release from several containers.	3. Complies with requirement of Type I control room. See Site Addendum, Section 2.2.
a. Type I control rooms should include the following protective features:	

TABLE 6.4-2 (Sheet 2)

Regulatory Guide 1.95 Position	Union Electric Position
(1) Quick-response chlorine detectors located in the fresh air inlets. Within 10 seconds after arrival of the chlorine, detection should initiate complete closure is isolation dampers to the control room.	(1) Chlorine monitors are not required for the Callaway Plant per Section 2.2.3.1.3 of the Callaway Site Addendum.
(2) A normal fresh air makeup rate of less than one air change per hour. The fresh air inlet should be at least 15 meters above grade.	(2) Complies.
(3) Low-leakage construction with an equivalent air exchange rate of less than 0.06 hr^{-1} when all penetrations are exposed to a 1/8-inch water gage pressure differential. Construction details should be provided to show that this limit is met.	(3) Leakage criteria complies for 1/8-inch differential. Applicable construction details are shown in Figure 6.4-1.
(4) Low-leakage dampers or valves installed on the upstream side of recirculation fans or other locations where negative systems pressure exists and where inleakage from chlorine-contaminated outside air is possible.	(4) Not applicable. See above position on 3.a.(1).
b. Type II control rooms should include the protective features of Paragraph a, except that the isolation time should be 4 seconds or less rather than 10 seconds or less.	b. Not applicable.
c. Type II control rooms should include the protective features of Paragraph a, except that the normal fresh air makeup rate should be limited to 0.3 air change per hour or less.	c. Not applicable.

TABLE 6.4-2 (Sheet 3)

Regulatory Guide 1.95 Position	Union Electric Position
d. Type IV control rooms should include the protective features of Paragraph a, except that the isolation time and the normal air exchange rate should be equal to or less than 4 seconds and 0.3 air change per hour, respectively. In addition, the control room isolated air exchange rate should be reduced to 0.015 air change per hour or less (see description of required leak rate verification test in Regulatory Position 5).	d. Not applicable.
e. Type V control rooms should include the protective features of Paragraph a, with the addition of remote chlorine detectors located at the chlorine storage and unloading location. These additional detectors should be placed and the detector trip points adjusted so as to ensure detection of either a leak or a container rupture. A detector trip signal should accomplish automatic isolation of the control room before chlorine arrives at the isolation dampers. The detector trip signal should also set off an alarm and provide a readout in the control room. An alternative to the installation of remote detectors would be to provide an isolation system using local detectors but having an isolation time of effectively zero. This can be accomplished by ensuring that the time required for chlorine to travel from the chlorine detector to the isolation damper.	e. Not applicable.

TABLE 6.4-2 (Sheet 4)

Regulatory Guide 1.95 Position	Union Electric Position
f. Type VI control rooms should include the protective features in Paragraph e, except that the control room isolated air exchange rate should be reduced to 0.015 air change per hour or less. For isolated exchange rates between 0.015 hr^{-1} and 0.06 hr^{-1}, linear interpolation of the weights given for control room Types V and VI in Table 1 can be made. Verification testing is required within this range of exchange rates (see Regulatory Position 5).	f. Not applicable.
4. The following should be applied to all control room types (I through VI):	4.See below.
a. Immediately after control room isolation, the emergency recirculating charcoal filter or equivalent equipment designed to remove or otherwise limit the accumulation of chlorine within the control room should be started up and operated.	a. See position on 3.a.(1).
b. Steps should be taken to ensure that the isolated exchange rate is not inadvertently increased by design or operating error. For instance, the following should be considered:	b. See below.
(1) An administrative procedure should require that all doors leading to the control room be kept closed when not in use.	(1) Security system alarms indicate open doors leading to the control room, thus closure of these doors is administratively controlled.

TABLE 6.4-2 (Sheet 5)

Regulatory Guide 1.95 Position	Union Electric Position
(2) Ventilation equipment for the control room and for the adjacent zones should be reviewed to ensure that enhanced air exchange between the isolated control room and the outside will not occur (e.g., if there is a chlorine release, exhaust fans should be stopped and/or isolated from the control room ventilation zone by low-leakage dampers or valves).	(2) Complies. Automatic isolation of the control room also automatically stops all fans and isolates all systems which penetrate the control building boundary. Also see position on 3.a.(1).
(3) A control room exit leading directly to the outside of the building should have two low-leakage doors in series.	(3) Not applicable.

TABLE 6.4-2 (Sheet 6)

Regulatory Guide 1.95 Position	Union Electric Position
c. The use of full-face self-contained pressure-demand-type breathing apparatus (or the equivalent) and the use of protective clothing should be considered in the development of a chlorine release emergency plan. Because calculations indicate that chlorine concentrations may increase rapidly, emergency plan provisions and rehearsal of these provisions are necessary to ensure donning of breathing apparatus on detection of high chlorine concentrations. Storage provisions for breathing apparatus and procedures for their use should be such that operators can begin using the apparatus within two minutes after an alarm. Adequate air capacity for the breathing apparatus (at least six hours) should be readily available onsite to ensure that sufficient time is available to transport additional bottled air from offsite locations. This offsite supply should be capable of delivering several hundred hours of bottled air to members of the emergency crew. A minimum emergency crew should consist of those personnel required to maintain the plant in a safe condition, including orderly shutdown or scram of the reactor. As a guideline, a minimum of five units of breathing apparatus should be provided for the emergency crew.	c. Not applicable. Callaway does not have a risk of chlorine release, as per Site Addendum 2.2. Self-contained breathing apparatus (SCBAs) are available to control room personnel, but are not credited for the control room habitability analysis.
d. The air supply apparatus should meet the single failure criterion and be designated Seismic Category I. (In the case of self-contained breathing apparatus, the single failure criterion may be met by supplying one extra unit for every three units required.)	d. Not applicable. Callaway does not have a risk of chlorine release, as per Site Addendum 2.2. Self-contained breathing apparatus (SCBAs) are available to control room personnel, but are not credited for the control room habitability analysis.

TABLE 6.4-2 (Sheet 7)

Regulatory Guide 1.95 Position	Union Electric Position
The isolation system components should be of a quality that ensures high reliability and availability. One method to meet these goals is to provide a system that meets the requirements of IEEE-279, "Criteria for Protection Systems for Nuclear Power Generating Stations." In all cases, the isolation system, recirculating filter system, and air conditioning system should meet IEEE-279 since they are required to maintain a habitable environment in the control room during design basis radiological events.	Complies.
Specific acceptance criteria for the chlorine detection system and allied actuating electronics are as follows:	
(1) Chlorine Concentration Level. Detectors should be able to detect and signal a chlorine concentration of 5 ppm.	(1) Not applicable.
(2) System Response Time. The system response time, which incorporates the detector response time, the valve closure time, and associated instrument delays, should be less than or equal to the required isolation time.	(2) Not applicable.

TABLE 6.4-2 (Sheet 8)

Regulatory Guide 1.95 Position	Union Electric Position
(3) Single Failure Criteria. The chlorine detection system should be redundant and physically separate to accomplish decoupling of the effects of unsafe environmental factors, electric transients, physical accidents, and component failure. Local detectors should consist of two physically separate channels for each fresh air inlet. Each channel should consist of a separate power supply, detector, actuating electronics, and interconnecting cabling. Remote detectors should also consist of two separate channels having detectors located at the chlorine unloading facility.	(3) Not applicable.
(4) Seismic Qualification. The chlorine detection system should be designated as Seismic Category I and be qualified as such.	(4) Not applicable.
(5) Environmental Qualification. The detection system should be qualified for all expected environments and for severe environments that could clearly lead to or be a result of chlorine release. The installation should ensure that they are protected from adverse temperature effects.	(5) Not applicable.

TABLE 6.4-2 (Sheet 9)

Regulatory Guide 1.95 Position	Union Electric Position
(6) Maintenance, Testing, and Calibration. The manufacturer's maintenance recommendations are acceptable provided they follow sound engineering practice and are compatible with the proposed application. A routine operational check should be conducted at one-week intervals. Verification testing and calibration of the chlorine detectors and verification testing of the system response time should be conducted at six-month intervals.	(6) Not applicable.
5. The gross leakage characteristic of the control room should be determined by pressurizing the control room to 1/8-inch water gage and determining the pressurization flow rate. (The use of a higher pressure differential is acceptable provided the flow rate is conservatively adjusted to correspond to 1/8-inch water gage). For air exchange rates of less than 0.06 hr^{-1}, periodic verification testing should be performed. An acceptable method for periodic testing would be the use of a permanently installed calibrated pressurization fan. The system would have a known pressure-versus-flow characteristic so that the leak rate could be determined by measuring the control room pressure differential. Testing should be conducted at least every six months and after any major alteration that may affect the control room leakage.	5. Complies. Pressurization flow rate is 400 cfm nominal with tolerance of (+) 40 cfm, (-) 40 cfm. The air exchange rate is greater than 0.06 per hour. Therefore, periodic testing will not be conducted.

TABLE 6.4-2 (Sheet 10)

Regulatory Guide 1.95 Position	Union Electric Position
6. Emergency procedures to be initiated in the event of a chlorine release should be provided. Methods of detecting the event by station personnel, both during normal workday operation and during minimum staffing periods (late night and weekend shift staffing), should be discussed. Instrumentation that has been provided for the detection of chlorine should be described including sensitivity; action initiated by detecting instrument and level at which this action is initiated; technical specification limitations on instrument availability; and instructions for maintenance, calibration, and testing. Criteria should be defined for the isolation of the control room, for the use of protective breathing apparatus and other protective measures, and for maintenance of the plant in a safe condition including the capability for orderly shutdown or scram of the reactor. Criteria and procedures for evacuating nonessential personnel from the station should also be defined.	6.Not applicable.

6.5 FISSION PRODUCT REMOVAL AND CONTROL SYSTEMS

Several plant features serve to reduce or limit the release of fission products following a postulated LOCA or fuel handling accident. This section provides a discussion of the function of the containment, containment spray system, and emergency filter systems to mitigate the consequences of an accident. The design of each of these engineered safety features is discussed in other referenced sections. Chapter 15.0 addresses the radiological consequences of postulated accidents and demonstrates the adequacy of the fission product removal and control systems.

Other sections provide the design bases and safety evaluations, which demonstrate that the design and construction of these systems is commensurate with acceptable practices for engineered safety features. This includes, but is not limited to, assuring redundancy, isolation from nonsafety-related systems, seismic classification, compliance with Regulatory Guide 1.52, suitability of material for the intended service, Class 1E power supply from onsite or offsite sources, qualification testing, and the capability for inspection and testing.

6.5.1 ENGINEERED SAFETY FEATURE (ESF) FILTER SYSTEMS

The ESF filter systems include the emergency exhaust system, discussed in Sections 9.4.2 and 9.4.3, and the control building HVAC systems, discussed in Sections 6.4 and 9.4.1. The emergency exhaust system would operate following a LOCA to control and remove fission product releases from the auxiliary building. It also would operate after a fuel handling accident to control and remove fission product releases from the fuel building (see Section 9.4.2). The control building HVAC systems operate to maintain control room habitability by removing fission products from air entering the control room (see Section 6.4). This section discusses the design basis and safety evaluation of the functional requirements of the ESF filter systems.

6.5.1.1 Design Basis

6.5.1.1.1 Safety Design Basis

SAFETY DESIGN BASIS ONE - An emergency exhaust system is provided to reduce the fission product release from the plant, following a fuel handling accident in the fuel building or a LOCA that could potentially result in radioactive leakage into the auxiliary building.

SAFETY DESIGN BASIS TWO - A control building HVAC system is provided to isolate the control building and provide the control room with a filtered supply of fresh air.

6.5.1.1.2 Power Generation Design Basis

The ESF filter systems have no power generation design basis.

6.5.1.2 System Design

6.5.1.2.1 General Description

The emergency exhaust system is shown in Figure 9.4-2, and the control building HVAC system is shown in Figure 9.4-1. A detailed description of these systems is provided in Sections 9.4.1, 9.4.2, and 9.4.3.

The ESF filter systems comply with Regulatory Guide 1.52, as discussed in Table 9.4-2.

Table 6.5-1 lists the system design parameters used in the radiological consequences analysis presented in Chapter 15.0.

6.5.1.2.2 Component Description

The emergency exhaust system components are described in Sections 9.4.2 and 9.4.3. The control room HVAC system components are described in Section 9.4.1.

6.5.1.2.3 System Operation

In the event of a LOCA, the emergency exhaust system functions to limit and reduce the potential release of fission products from the auxiliary building. Specific details of system operation following a LOCA are provided in Section 9.4.3.

In the event of a fuel handling accident in the fuel building, the emergency exhaust system functions to reduce the fission product release from the fuel building. Specific details of system operation following a fuel handling accident are provided in Section 9.4.2.

In the event of a LOCA or fuel handling accident, the control building HVAC systems function to isolate the control building and provide the control room with a filtered supply of air. Specific details of system operation following a LOCA are discussed in Section 9.4.1.

6.5.1.3 Safety Evaluation

Safety evaluations are numbered to correspond to the safety design bases given in Section 6.5.1.1.1.

SAFETY EVALUATION ONE - Table 6.5-1 lists the ESF filtration systems' design parameters used to determine the radiological consequences for the postulated accidents analyzed in Chapter 15.0. The results of these analyses demonstrate that the emergency exhaust system reduces and controls fission products released from the fuel building following a fuel handling accident or released from the auxiliary building following a LOCA, such that the offsite radiation exposures are within the guidelines of

10 CFR 100. The safety evaluations which demonstrate the design and construction of the ESF filtration systems are provided in Sections 9.4.2 and 9.4.3.

SAFETY EVALUATION TWO - The results of the analyses described in Chapter 15.0 demonstrate that the control building HVAC systems reduce and control fission product release to the control room following a LOCA, such that radiation exposures of control room personnel are within the requirements of GDC-19. The safety evaluations which demonstrate the design and construction of these control building HVAC systems are provided in Sections 9.4.1 and 6.4.

6.5.1.4 Tests and Inspections

Tests and inspections for ESF filter systems are described in Sections 9.4.1.4, 9.4.2.4, and 9.4.3.4.

6.5.1.5 Instrumentation Requirements

Instrumentation and controls are provided to facilitate automatic operation and remote control of the system and to provide continuous indication of system parameters. Further descriptions are provided in Sections 9.4.1.5, 9.4.2.5, and 9.4.3.5.

6.5.1.6 Materials

The materials used for ESF filtration systems were chosen considering the environmental conditions and are commensurate with acceptable construction practices.

6.5.2 CONTAINMENT SPRAY SYSTEM

The containment spray system (CSS) is an ESF, the functions of which are to reduce pressure and temperature in the containment atmosphere following a postulated LOCA or MSLB inside containment and to remove radioactive fission products from the containment atmosphere. These functions are performed by spraying a chemical solution into the containment atmosphere through a large number of nozzles on spray headers located in the containment dome. Reduction of pressure and temperature in the containment with the CSS is discussed in Section 6.2.2.1.

Radioiodine in its various forms is the fission product of primary concern in the evaluation of a LOCA. It is absorbed by the containment spray from the containment atmosphere. To enhance this iodine absorption capacity of the spray, the spray solution is adjusted to an alkaline pH which promotes iodine hydrolysis, in which iodine is converted to nonvolatile forms tending to plate out on containment structures or to be retained in the containment recirculation sumps.

The physical characteristics of the CSS are discussed in Section 6.2.2.1. Discussed herein is the containment spray system's fission product removal capability following a LOCA.

6.5.2.1 Design Bases

6.5.2.1.1 Safety Design Bases

SAFETY DESIGN BASIS ONE - The CSS is designed to provide an equilibrium sump solution pH of greater than or equal to 7.1 following the complete dissolution of the trisodium phosphate stored in baskets adjacent to the containment recirculation sumps.

SAFETY DESIGN BASIS TWO - The CSS is capable of reducing the iodine and particulate fission product inventories in the containment atmosphere such that the offsite radiation exposures resulting from a design basis LOCA are within the plant siting dose guidelines of 10 CFR 100.

Additional safety design bases are included in Section 6.2.2.1, in which the capability of the spray system to remove heat from the containment atmosphere is discussed.

6.5.2.1.2 Power Generation Design Basis

The CSS has no power generation design basis.

6.5.2.2 System Design

6.5.2.2.1 General Description

The spray additive tank has been retired in place and associated lines have been capped, as shown schematically in Figure 6.2.2-1.

Initially, water from the refueling water storage tank (RWST) is used for containment spraying followed by water from the containment recirculation sumps.

Those parts of the system in contact with containment spray fluids, are stainless steel or an equivalent corrosion-resistant material.

The trisodium phosphate (TSP-C) baskets constructed of stainless steel mounted to carbon steel supports contain sufficient TSP-C to bring the equilibrium sump fluid to a minimum pH of 7.1 upon mixing with the borated water from the refueling water storage tank, the accumulators, and reactor coolant. This assures continued iodine retention effectiveness of the sump water during the recirculation phase.

The spray header design, including the number of nozzles per header, nozzle spacing, and nozzle orientation, is provided in Section 6.2.2.1 and shown in Figures 6.2.2-2 and 6.2.2-4. Each spray header layout is oriented to provide more than 90-percent area coverage at the operating deck of the reactor building.

Total containment free volume, unsprayed containment free volume, specific unsprayed regions and volumes, and post-accident ventilation between sprayed and unsprayed volumes are provided in Table 6.5-2. Operability of dampers, ductwork, etc., for which credit is taken post-accident is discussed in Section 6.2.2.2.

6.5.2.2.2 Component Description

The containment spray additive tank, located at El. 2,000 feet in the auxiliary building, is a stainless steel tank that has been retired in place.

Component descriptions of the nozzles are provided in Section 6.2.2.1. Special tests performed on the spray nozzles include capacity and droplet size distribution. Figures 6.5-1, 6.5-2, and 6.5-3 provide the test results for the spray nozzles (Ref. 1).

The spray nozzle was flow tested at a range of inlet pressures from 3 to 100 psig to determine that the actual flow at 40 psi differential across the nozzle was in accordance with the design value of 15.2 gpm, as depicted in Figure 6.5-1.

Droplet-size distribution measurements were performed at the design pressure differential of 40 psi and the design flowrate of 15.2 gpm. At these conditions, the spray distribution was obtained by measuring the spray volume distribution in two perpendicular planes over a timed interval (Ref. 1).

For the droplet size distribution measurement, a television camera and light source were mounted on a flat beam. A protective covering was constructed with a slot which allowed spray droplets to fall between the camera and light source. Measurements of drop count in each micron increment were recorded at 4-inch increments from the outer edge of the spray cone to the spray axis.

At the design pressure, the droplet size distribution was recorded by high speed photographic methods. The droplet images were measured, and droplets with a diameter in the micron increment being counted were registered. Figure 6.5-2 shows the relative frequency for each droplet size. The results of testing performed on the spray nozzle are provided in Table 6.5-2. The containment spray envelope reduction factor as a function of post-LOCA containment saturation temperature is provided in Figure 6.5-4. This envelope reduction factor was applied to the throw distance and elliptic coverage values presented in Table 6.5-2.

6.5.2.2.3 System Operation

Summary of the design basis LOCA and MSLB chronology for the CSS is presented in Table 6.2.2-3.

The spray system is actuated either manually from the control room or on coincidence of two-out-of-four CSAS containment pressure signals. Either of these actuation mechanisms starts the containment spray pumps and opens the discharge valves to the spray headers.

On actuation, approximately 5 percent of each spray pump's discharge flow is recirculated.

When the refueling water storage tank has reached its specified low-low-2 level limit, recirculation spray flow is manually initiated. The operator can remotely initiate recirculation flow by use of either or both of the spray pumps. Sections 6.2.2.1.5 and 6.5.2.5 address the instrumentation and information displays available to the operator, in order for manual switchover of the CSS to take place.

System flow rates and the duration of operational modes are presented in Section 6.2.2.1.2.3.

Design operation of the CSS is such that LOCA iodine removal requirements are fulfilled during the injection phase and the amount of TSP-C provided is sufficient to ensure long-term iodine retention. Following a large break LOCA, the containment spray during the injection phase will be a boric acid solution having a pH of about 4.5. The desired pH level is greater than 7.0 to assure iodine retention in the sumps, to limit corrosion and the associated production of hydrogen, and to limit chloride induced stress-corrosion cracking of austenitic stainless steels. To adjust the sump solution pH into the desired range, a minimum of 9000 pounds of trisodium phosphate dodecahydrate (NA_3PO_4 • 12 H_2O • 1/4 NaOH) is stored in two baskets, one adjacent to each containment recirculation sump, at an elevation to assure TSP-C disolution. This amount of trisodium phosphate is sufficient to assure that the equilibrium sump solution pH will be greater than or equal to 7.1. The containment iodine removal credit assumed in the calculation of offsite doses following a LOCA is provided in Table 15.6-6.

6.5.2.3 Safety Evaluation

The safety evaluations are numbered to correspond to the safety design bases.

SAFETY EVALUATION ONE - The system's capability to reduce the airborne fission product inventory is based on the surface area of the spray solution for removal during injection and on sump solution pH for retention during recirculation, and on the system's capability to provide spray for essentially all regions of the containment, considering post-accident conditions.

During injection, the effectiveness of the spray against elemental iodine vapor is chiefly determined by the rate at which fresh solution surface area is introduced into the containment atmosphere, as discussed in Reference 3. The first-order spray removal coefficient calculated per Reference 3, as discussed in Section 6.5A.3, is 37 hr^{-1}. Thus, the elemental iodine removal coefficient of 10 hr^{-1} used in Section 15.6.5 is conservative. The minimum equilibrium sump pH of 7.1 assures iodine retention in the recirculated spray liquid.

The system is designed to provide a spray solution during the recirculation phase with a minimum equilibrium pH of 7.1. The mass of TSP-C in the baskets results in this minimum pH level in the sumps.

The worst case concentration during the injection phase would be greater than or equal to 4.0 but less than 7.0 when water from the refueling water storage tank is sprayed directly to the containment. The injection phase is the only time that this pH = 4.0 condition could exist. The injection phase is short (1 hour) relative to the entire spray duration (approximately 24 hours). During the spray recirculation phase, the equilibrium pH range is 7.1-8.1. This spray is directed through the same spray headers and, therefore, should rinse all of the previously sprayed components (for a period of approximately 23 hours).

The minimum equilibrium sump pH of 7.1 is based on the Technical Specification minimum of 9000 lbm of TSP-C in the baskets and the maximum sump solution boric acid concentration of 2500 ppm boron. With the Technical Specification maximum of 14,300 lbm of TSP-C in the baskets and the minimum sump solution boric acid concentration of 1971 ppm boron, the maximum equilibrium sump pH would be less than 8.1.

The previously evaluated upper bound for containment spray pH of 11.0 will continue to be cited, consistent with Section 3.11(B).1.2.2, for the purpose of performing EQ reviews.

Another issue that has been reviewed is the unlikely, but possible, event in which an initially concentrated solution of TSP-C occupies the stagnant volume of an inoperable sump. This situation would not last for long since, as the recirculated sump fluid is cooled in the RHR heat exchangers, sufficient buoyancy-driven circulation within containment will result to displace the stagnant solution and eventually yield a uniform, equilibrium solution.

SAFETY EVALUATION TWO - The spray iodine removal analysis is based on the assumptions that:

a. Only one out of two spray pumps is operating

b. The ECCS is operating at its maximum capacity

The spray system is assumed to spray approximately 85 percent of the total containment net free volume. This volume consists of those areas directly sprayed plus those volumes which have good communication with the directly sprayed volumes. The remaining 15 percent of the containment free volume has restricted communication with the sprayed volumes and is assumed to be unsprayed. A description of the unsprayed volumes is presented in Table 6.5-2.

The performance of the spray system was evaluated at the containment post-LOCA calculated saturation temperature corresponding to the calculated peak pressures and containment design pressure provided in Table 6.2.1-2. The net spray flow rate of 3,131 gpm (see Table 6.5-2) per train was used in the calculations described in Appendix 6.5A.

Based on Regulatory Guide 1.4, three species of airborne iodine are postulated to exist in the containment atmosphere following a LOCA. These are elemental, particulate, and organic species.

It has been assumed in these evaluations of spray removal effectiveness that organic iodine forms are not removed by the containment spray. A limited credit for the removal of airborne particulates and elemental iodine has been taken in the offsite and control room dose calculation, assuming that the spray removal rate is 0.45 hr^{-1} until a decontamination factor of 50 is attained for particulates and that spray removal rate is 10/ hr^{-1} until a decontamination factor (DF) of 28.7 is attained for elemental iodine. These assumptions underestimate the actual amounts of iodine removed and thus result in calculated accident doses higher than could realistically be expected.

Utilizing the dose analysis input parameters indicated above, in Table 6.5-2, and in Appendix 15A, the dose analysis of Section 15.6.5 demonstrates that offsite radiation exposures resulting from a design basis LOCA are within the plant siting dose guidelines of 10 CFR 100.

Appendix 6.5A provides the model used to calculate the iodine removal coefficients provided in Table 6.5-2.

6.5.2.4 Tests and Inspections

CSS tests and inspections are discussed in Section 6.2.2.1.4, including spray nozzle tests and inspections.

6.5.2.5 Instrumentation Requirements

Containment spray instrumentation is discussed in Section 6.2.2.1.5.

6.5.2.6 Materials

The chemical compositions of the containment spray fluid entering the spray header during the injection phase of containment spray and the containment spray fluid in the system during the recirculation phase of containment spray (containment recirculation sump solution) are provided in Table 6.5-5.

None of the materials used is subject to decomposition by the radiation or thermal environment.

The corrosion of materials in the NSSS and the containment building, resulting from the spray solution used for iodine absorption, has been tested by the Reactor Division at ORNL (Ref. 2). The spray solutions provided in Table 6.5-5 result in negligible corrosion, based on these studies.

TSP-C does not undergo radiolytic decomposition in the post-LOCA environment. Sodium has a low neutron absorption cross section and will not undergo significant activation.

With respect to the potential for decomposition, TSP-C is stable to at least 158°F. Temperatures 158°F may result in the loss of H_2O from the TSP-C but will not affect its caustic properties.

6.5.3 FISSION PRODUCT CONTROL SYSTEMS

6.5.3.1 Primary Containment

The containment consists of a prestressed post-tensioned, reinforced concrete structure with cylindrical walls, hemispherical dome, and base slab lined with a welded quarter-inch carbon steel liner plate, which forms a continuous, leaktight membrane. Details of the containment structural design are discussed in Section 3.8. Layout drawings of the containment structure and the related items are given in the general arrangement drawings of Section 1.2.

The containment walls, liner plate, penetrations, and isolation valves function to limit the release of radioactive materials, subsequent to postulated accidents, such that the resulting offsite doses are less than the guideline values of 10 CFR 100. Containment parameters affecting fission product release accident analyses are given in Appendix 15A.

Long-term containment pressure response to the design basis LOCA is shown in Figure 6.2.1-1. Relative to this time period, the CSS is operated to reduce iodine concentrations and containment atmospheric temperature and pressure commencing with system initiation, at approximately 60 seconds, as shown in Table 6.2.2-3 and ending when containment pressure has returned to normal. For the purpose of post-LOCA dose calculations discussed in Chapter 15.0, two dose models have been assumed, the 0-2 hour case and the 0-30 day case, as shown in Appendix 15A.

The containment minipurge system may be operated for personnel access to the containment when the reactor is at power, as discussed in Section 9.4.6.

Redundant, safety-related hydrogen recombiners are provided in the containment as the primary means of controlling postaccident hydrogen concentrations. A hydrogen purge system is provided for backup hydrogen control. See Section 6.2.5.3 (Safety Evaluation Eight).

Containment combustible gas control systems are discussed in detail in Section 6.2.5.

6.5.3.2 Secondary Containment

This section is not applicable to SNUPPS.

6.5.4 ICE CONDENSER AS A FISSION PRODUCT CLEANUP SYSTEM

This section is not applicable to SNUPPS.

6.5.5 REFERENCES

1. Spraying Systems Company Topical Report No. SSCO-15215-1C-304SS-6.3-NP, April 1977, "Containment Spray Nozzles for Nuclear Power Plants"

2. "Design Considerations of Reactor Containment Spray Systems, The Corrosion of Materials in Spray Solutions," ORNL-TM-2412Part III, December 1969

3. NUREG-0800, Standard Review Plan Section 6.5.2, Revision 2, “Containment Spray as a Fission Product Cleanup System,” December 1988.

TABLE 6.5-1 ESF FILTRATION SYSTEMS INPUT PARAMETERS TO CHAPTER 15.0 ACCIDENT ANALYSIS

Emergency exhaust filter adsorber unit efficiencies (percent)	90
Emergency exhaust system flowrate (SCFM)	9,000
Control room filter adsorber unit efficiency (percent)	95
Control room air conditioning system flowrate (SCFM) per train	
Filtered intake from control building	440
Filtered recirculation from control room	1,360

TABLE 6.5-2 INPUT PARAMETERS AND RESULTS OF SPRAY IODINE REMOVAL ANALYSIS

Core power rating	3,565 MWt
Total containment free volume	2.50×10^6 ft^3
Unsprayed containment free volume	<15.0 percent
Area coverage at the operating deck	
Design	>90 percent
Calculated	>93 percent
Mixing rate between sprayed and unsprayed volumes	85,000 cfm
Dose model	One region
Minimum vertical distance to operating deck from lowest spray header	118 feet - 2 in.
Net spray flow rate per train, injection Phase	3,131 gpm
Number of spray pumps operating	1
Spray solution pH	4.0 - 7.0 (injection phase)
	≥ 7.1 (recirculation phase at equilibrium)
Elemental iodine absorption coefficient, λs, used In LOCA offsite and control room dose calculations	10 hr^{-1} (1)
Calculated λs	25.7 hr^{-1} (2) 37 hr^{-1}
Particulate iodine absorption coefficient, λp, used in LOCA offsite and control room dose calculations	0.45 hr^{-1} (3)
Calculated λp	0.73 hr^{-1} (4)
Spray drop size, design	See Figure 6.5-2
Schmidt number (See Section 6.5A.2)	11.58
Gas diffusivity (See Section 6.5A.2)	0.064 /sec
Partition coefficient (See Section 6.5A.2)	5,000

TABLE 6.5-2 (Sheet 2)

Gas phase mass transfer coefficient (See Section 6.5A.3)	9.5 ft/min
Terminal mass-mean drop velocity (See Section 6.5A.3)	790 ft/min
Partition coefficient (See Section 6.5A.3)	1100

---

(1) Until DF = 28.7.

(2) λs of 25.7 hr^{-1} was calculated in Section 6.5A.2 and used in the EQ dose calculations discussed in Section 3.11(B).1.2.2 λs of 37 hr^{-1} was calculated in Section 6.5A.3 but 10 hr^{-1} was used in the offsite and control room dose calculations discussed in Section 15.6.5.

(3) Until DF = 50.

(4) λp of 0.73 hr^{-1} was calculated in Section 6.5A.1 and used in the EQ dose calculations.

TABLE 6.5-2 (Sheet 3)
SPRAY NOZZLE TEST RESULTS

Nozzle droplet spectrum	Figure 6.5-2
Nozzle capacity curve	Figure 6.5-1
Nozzle mass median diameter versus pressure drop	Figure 6.5-3
Number mean diameter	526 micron @ 40 psi
Volume mean diameter	831 micron @ 40 psi
Number median diameter	325 micron @ 40 psi

Nozzle Orientation	Throw Distance*	Elliptic Coverage*
Vertical-down	0 ft	10 ft-0 in. x 10 ft-0 in.
7.5° off vertical-down	2.5 ft	10 ft-0 in. x 10 ft-0 in.
15° off vertical-down	3.75 ft	10 ft-0 in. x 10 ft-0 in.
30° off vertical-down	5.0 ft	10 ft-0 in. x 10 ft-0 in.
40° off vertical-down	7.3 ft	10 ft-6 in. x 11 ft-0 in.
Horizontal	10.6 ft	12 ft-6 in. x 12 ft-0 in.
30° off horizontal-up	10.8 ft	13 ft-0 in. x 12 ft-6 in.

---

* Based on 100-foot drop and post-LOCA saturation temperature.

TABLE 6.5-2 (Sheet 4)
UNSPRAYED CONTAINMENT FREE VOLUME

Unsprayed Region	Volume (ft^3)
Pressurizer enclosure and overhang	26,511
Region below the four RC pump hatches	44,245
Pressurizer safety valve enclosure	14,392
Region below the four containment coolers	49,964
Pressurizer spray valve enclosure	8,920
Region under Integrated Head Assembly and associated components	7,759
Elevator machine room and elevator shaft	16,596
Region under concrete flooring used for structural strength and shielding	182,821
Total unsprayed free volume	351,208
Percentage of free volume unsprayed	~14.1%

TABLE 6.5-3 DELETED

SPRAY ADDITIVE SUBSYSTEM - DESIGN PARAMETERS

TABLE 6.5-4 DELETED

SPRAY ADDITIVE SUBSYSTEM - SINGLE FAILURE ANALYSIS

TABLE 6.5-5 CONTAINMENT SPRAY SYSTEM FLUID CHEMISTRY

I.	Containment Sump Fluid pH Control Agent	
	Trisodium Phosphate Dodecahydrate (TSP-C)	
	$(Na_3PO_4 \bullet 12H_2O \bullet 1/4NaOH)$	9000 lbm minimum
	Temperature range, °F	50-120
II.	Sprayed Fluid - Injection Phase	
	Aqueous solution, pH	4.0-7.0
	Chloride, ppm, max	100
	Fluoride, ppm, max	100
	Boric acid, ppm boron, max/min	2,500/2,350
	Temperature range, °F	37-120
III.	Sprayed Fluid - Recirculation Phase	
	Aqueous solution, pH	7.1 (at equilibrium)-11.0
	Boric acid, ppm boron, max/min	2,500/1,971
	Temperature range, °F	120-264
IV.	Final Equilibrium Recirculation Sump Fluid	
	Aqueous solution, pH	7.1-8.1
	Boric acid, ppm boron, max/min	2,500/1,971
	Temperature range, °F	120-255

APPENDIX 6.5A - IODINE REMOVAL MODELS FOR THE CONTAINMENT SPRAY SYSTEM

6.5A.1 PARTICULATE IODINE MODEL

The spray washout model for aerosol particles is represented in equation form as follows:

$$\lambda P = \frac{3hEF}{2dV} \tag{6.5A-1}$$

Where:

λP	=	spray removal constant for particles
h	=	drop fall height
E	=	total collection efficiency for a single drop
F	=	spray volumetric flow rate
d	=	mean drop diameter
V	=	volume of sprayed region

The capture of particles by falling drops results from Brownian diffusion, diffusiophoresis, interception, and impaction. Early in the injection phase, particles are removed mainly by impaction. Following injection, when the larger particles have already been removed, the removal rate is controlled by diffusiophoresis, which is the collection of particulates by steam condensing on the spray drops. The single drop collection efficiency, E, is taken as 0.0015, the minimum value observed in experimental tests (Ref. 1). The minimum collection efficiency, 0.0015, was only attained after the major fraction of airborne particles was removed. For early time periods, the removal rates were much higher than the minimum values ultimately reached. Per Reference 11, it is conservative to assume that E/D is 10 per meter initially (i.e., 1% efficiency for spray drops of one millimeter in diameter), changing abruptly to one per meter after the aerosol mass has been depleted by a DF of 50 (i.e., 98% of the particulate mass is ten times more readily removed than the remaining 2%). Using the 831 micron mean drop diameter identified in Table 6.5-2 and the minimum collection efficiency of 0.0015 from Reference 1, E/D would be 1.8 per meter which is consistent with the value from Reference 11 after a DF of 50 is attained.

The spray removal constant (λP) for particulate iodine has been calculated to be 0.73/hr, based on equation 6.5A-1, and used in Section 3.11(B).1.2.2.

A limited and conservative credit for spray removal of airborne particulates containing iodine has been taken in Section 15.6.5, assuming the spray removal constant is 0.45/hr, until a decontamination factor of 50 is reached, following the postulated LOCA (see Table 6.5-2).

Particle spray removal constants considerably larger and of longer duration than those conservatively chosen above have been reported from the Battelle Northwest Containment Systems Experiment (Ref. 2) and by the Oak Ridge National Laboratories Nuclear Safety Pilot Plant (Ref. 4).

6.5A.2 ELEMENTAL IODINE MODEL FOR EQ DOSE CALCULATIONS

The spray system, by virtue of the large surface area provided between the droplets and the containment atmosphere, will afford an excellent means of absorbing elemental radioactive iodine released as a consequence of a LOCA. The rate of absorption is largely dependent on the concentration of radioiodine in the air surrounding the drops.

The following discussion is based on the pH dependent correlation for the elemental iodine spray removal constant discussed in Reference 12 and used in the EQ dose calculations of Section 3.11(B).1.2.2 (see Equations 6.5A-9 and 6.5A-17). Section 6.5A.3 discusses the surface area dependent correlation for the elemental iodine spray removal constant discussed in Reference 11 and used in the offsite and control room dose calculations of Section 15.6.5. Both of these correlations are applicable for the injection phase only.

The basic model of the containment atmosphere and spray system is given by Parsley (Ref. 4). The containment atmosphere is viewed as a "black box" having a sprayed volume, V, and containing iodine at some uniform concentration Cg. Liquid enters at a flow of F volumes per unit time, containing iodine at a concentration of CL1, and leaves at the same flow, at concentration CL2. A material balance for the containment vessel as a function of time is given by:

$$-VdCg = F(CL2 - CL1)dt. \tag{6.5A-2}$$

Where:

CL1	=	the iodine concentration in the liquid entering the dispersed phase, gm/cm^3
CL2	=	the iodine concentration in the liquid leaving the dispersed phase, gm/cm^3
V	=	sprayed volume of containment, cm^3
Cg	=	the iodine concentration in the containment atmosphere, gm/cm^3
F	=	the spray volumetric flow rate, cm^3/sec
t	=	spray time, sec

A drop absorption efficiency, E, which may be described as the fraction of saturation, is defined as:

$$E = (CL2 - CL1)/(CL^* - CL1) \qquad (6.5A\text{-}3)$$

In addition, the equilibrium distribution of iodine between the vapor and liquid phases is given by:

$$H = CL^*/Cg \qquad (6.5A\text{-}4)$$

Where:

H = the iodine partition coefficient (gm/liter of liquids)/(gm/liter of gas)

CL^* = the equilibrium concentration in the liquid, gm/cm^3

Substitution of equation 6.5A-4 into equation 6.5A-3 yields

$$E = (CL2 - CL1)/(HCg - CL1) \qquad (6.5A\text{-}5)$$

Solving equation 6.5A-5 for (CL2 - CL1) and inserting the result into equation 6.5A-2 gives

$$-(V)dCg = EF(HCg - CL1)dt \qquad (6.5A\text{-}6)$$

During the injection phase, CL1 = 0, so that

$$-(V)dCg = (EFHCg)dt \qquad (6.5A\text{-}7)$$

Equation 6.5A-7 can be integrated to solve for Cg. The concentration of iodine in the containment atmosphere during injection as a function of time is given by:

$$Cg = Cg_o \exp[-EHFt/V] \qquad (6.5A\text{-}8)$$

Where:

Cg_o = the initial iodine concentration in the containment atmosphere, gm/cm^3

Equation 6.5A-8 is applicable up to the time the spray solution is recirculated and is based on the following assumptions:

a. Cg is uniform throughout the containment

b. There are no iodine sources after the initial release

c. The concentration of iodine in the spray solution entering the containment is zero

From equation 6.5A-8, the spray removal constant, ls, is given by

$$\lambda s = \frac{EHF}{V} \tag{6.5A-9}$$

The above equation for λ is independent of the models on which the numerical evaluation of the drop absorption efficiency, E, and the iodine partition coefficient, H, may be based.

Absorption efficiency for elemental iodine may be calculated from the time-dependent diffusion equation for a rigid sphere, with the gas film mass transfer resistance as a boundary condition. This mass transfer model was suggested by L. F.

Parsley (Ref. 4), who gives the solution to the diffusion equation, with the above given boundary condition, as:

$$E = 1 \sum_{n=1}^{\infty} \frac{6Sh^2 \exp-(\alpha_n^2 \theta_f)}{[\alpha_n^2 + (Sh)(Sh-1)]\alpha_n^2} \tag{6.5A-10}$$

Where:

Sh	=	the dimensionless group = $k_g\ a/HD_L$
a	=	the drop radius, cm
k_g	=	the gas phase mass transfer coefficient, cm/sec
D_L	=	the liquid diffusivity, cm^2/sec
θ_f	=	the dimensionless drop residence time
α_n	=	the eigenvalues of the solution

It should be noted that this solution, which applies to the rigid drop model, is based on the assumption that molecular diffusion is the only mechanism by which iodine is transported from the surface to the interior of the drop. Since a high degree of mixing is expected in the drops, particularly in the presence of sizeable temperature and concentration gradients, it is apparent that this stagnant drop model presents a conservative approach to the calculation of iodine absorption by the drops.

The gas phase mass transfer coefficient required for the above calculation is computed by the equation of Ranz and Marshall (Ref. 5).

$$k_g = \frac{D_g}{d}(2 + 0.6Re^{0.5}Sc^{0.33}) \qquad (6.5A\text{-}11)$$

Where:

d	=	drop diameter, cm
D_g	=	diffusivity of iodine in the gas film surrounding the drop, cm^2/sec
Re	=	Reynold's number of the drop = $\rho vd/\mu$
Sc	=	Schmidt number of the atmosphere = $\mu/\rho Dg$
ρ	=	density of the atmosphere, g/cm^3
v	=	velocity of the drop, cm/sec
μ	=	absolute viscosity of the atmosphere, g/cm.sec

A more conservative numerical value of E is obtained from equation 6.5A-12 given below, which is quoted by Postma and Pasedag (Ref. 6):

$$E = 1 - \exp\left[-\frac{6k_g t_e}{d\left(H + \frac{k_g}{k_L}\right)}\right] \qquad (6.5A\text{-}12)$$

Where:

E	=	drop absorption efficiency
k_L	=	liquid phase mass transfer coefficient, cm/sec
t_e	=	drop exposure time, sec
d	=	drop diameter, cm
H	=	equilibrium partition coefficient

Equation 6.5A-12 is based on a model in which it is assumed that the drop consists of an outer stagnant film and a well-mixed interior. Though this model is basically nonconservative compared with the stagnant drop model represented by equation 6.5A-10, conservatism is introduced into equation 6.5A-12 when the following expression is used for k_L:

$$k_L = \frac{2\pi^2 D_L}{3d} \qquad (6.5A\text{-}13)$$

Where:

D_L = diffusivity of iodine in the liquid drop, cm^2/sec

d = drop diameter, cm

Equation 6.5A-13 results from a truncated approximation (Ref. 6) to the rigid drop diffusion equation due to Griffith (Ref. 7). Griffith's approximation is conservative in that it predicts lower absorption than would be predicted without such approximation for stagnant drop absorption.

The numerical value of E obtained from equation 6.5A-12 is more conservative than the one obtained from equation 6.5A-10, as shown by Postma and Pasedag (Ref. 6) by comparing them with the numerical value of E based upon another model. The reference model chosen by Postma and Pasedag (Ref. 6) for comparison is the completely well mixed model in which the solution in the entire drop, including the interior as well as the gas-liquid interface, is in equilibrium with the iodine concentration in the gas phase outside the drop. The expression in this reference model is:

$$E = 1 - \exp\left(-\frac{6k_g t_e}{dH}\right) \qquad (6.5A\text{-}14)$$

The absorption efficiency is a function of the drop diameter, the gas phase mass transfer coefficient, diffusivity of iodine in the liquid drop, the partition coefficient, and the drop exposure time.

Eggleton's equation (Ref. 8) for the equilibrium elemental iodine decontamination factors, DF, is given by:

$$DF = 1 + H(VL)/(VG) \qquad (6.5A\text{-}15)$$

Where:

H = equilibrium iodine partition coefficient

DF = ratio of the initial iodine concentration in the containment atmosphere to the equilibrium iodine concentration in the containment atmosphere = Cg_o/Cg

VG = net free containment volume minus VL

VL = volume of liquid in the containment sumps plus overflow from the sumps, which may be used for calculation of the partition coefficient, H, for a given value of the DF. Equation 6.5A-15 was not used in the EQ dose calculations discussed in Section 3.11(B).1.2.2; instead, a numerical value of 5,000 for H, the minimum found from Containment Systems Experiment (CSE) tests (Refs. 9 and 10) for sodium hydroxide spray, was used in the evaluation of λ. While a value of 5000 for H was used to calculate the elemental iodine spray removal constant of 25.7 hr^{-1} used in the EQ dose calculations, it is noted that Section 6.5A.3 calculates an elemental iodine spray removal constant of 37 hr^{-1}. In any event, for dose calculations the spray removal constant is not as important as the DF in determining EQ doses.

Since the spray does not consist of a uniform droplet size, a spectrum of drop sizes and their corresponding volume percentage (for the specific nozzle design) were used to determine the individual spray removal constant for each droplet size. The total spray removal constant is equal to the sum of the individual spray removal constants, i.e.:

$$\lambda = \sum_{i=1}^{n} \lambda_i = \sum_{i=1}^{n} \sum_{\ell=1}^{m} \lambda_{i_\ell} \qquad (6.5A\text{-}16)$$

Since the drop exposure time, t_e, is dependent on distance from the spray header to the operating deck, and each spray header consists of ring headers (ℓ) located at various levels, λ_i was calculated for each spray ring header (ℓ), utilizing the appropriate drop distance for each header.

Therefore,

$$\lambda_{i_\ell} = \frac{E_{i_\ell} H F_{i_\ell}}{V} \qquad (6.5A\text{-}17)$$

Where:

E_{i_ℓ} = collection efficiency for a single drop of micron increment i for ring header ℓ

F_{i_ℓ} = spray flow rate for micron increment i for header ℓ

and,

$$F_{i_\ell} = (F_i/\text{nozzle}) \cdot (N_\ell) \qquad (6.5A\text{-}18)$$

Where:

$$F_i/\text{nozzle} = \frac{(15.2\text{gpm})(N_i)\cdot(V_i)}{\sum_{i=1}^{n} N_i V_i}$$

N_ℓ = number of nozzles on ring header ℓ

N_i = number frequency for micron increment i (Figure 6.5-2)

V_i = volume of a drop in micron increment i

As the spray solution enters the high-temperature containment atmosphere, steam will condense on the spray drops. The amount of condensation is easily calculated by a mass balance of the drop:

$$mh + m_c h_g = m' h_f$$

where:

m and m' = the mass of the drop before and after condensation, lbs

m_c = the mass of condensate, lbs

h = the initial enthalpy of the drop, Btu/lb

h_g and h_f = The saturation enthalpy of water vapor and liquid, Btu/lb

The increase in each drop diameter in the distribution, therefore, is given by:

$$\left(\frac{d'}{d}\right)^3 = \left(\frac{v}{v_f}\right)\cdot\left(\frac{h_g - h}{h_{fg}}\right)$$

Where:

vf	=	the specific volume of liquid at saturation, ft^3/lb
v	=	the specific volume of the drop before condensation, ft^3/lb
h_{fg}	=	the latent heat of evaporation, Btu/lb
h_g	=	the enthalpy of steam at saturation, Btu/lb
d and d'	=	the drop diameter before and after condensation, cm

Postma and Pasedag (Ref. 6) conclude that condensation will tend to increase the iodine washout rate due to the increased volume of the spray. Their effect has been conservatively ignored.

The drop exposure time calculated is based on the assumption that the drops were sprayed in such a manner that the initial downward velocity of the drops at the spray ring header elevation was zero. The drops fall under the effect of gravity from the spray ring header to the operating deck. The minimum height is given in Table 6.5-2. As the drop size increases, the average exposure time decreases from about 20 to 5 seconds. Incorporating the above parameters into equation 6.5A-16 with the sprayed containment volume, V, and assuming a single spray header flow rate, the value of the spray removal coefficient calculated (25.7 hr^{-1}) is presented in Table 6.5-2.

The resulting elemental iodine spray removal constant is greater than 10/hr. A conservative removal constant of 10/hr is assumed and used in the design basis LOCA evaluations presented in Section 15.6.5.

6.5A.3 ELEMENTAL IODINE MODEL FOR OFFSITE AND CONTROL ROOM DOSE CALCULATIONS

As discussed in Reference 11, the effectiveness of the spray during the injection phase against elemental iodine vapor is chiefly determined by the rate at which fresh solution surface area is introduced into the containment atmosphere. The rate of solution created per unit gas volume in the containment atmosphere may be estimated as (6F/VD), where F is the spray volumetric flow rate, V is the volume of the sprayed region, and D is the mean diameter of the spray drops. The first-order spray removal constant for elemental iodine, λ_s, may be taken to be:

$$\lambda_s = \frac{6k_g TF}{VD}$$

where k_g is the gas phase mass transfer coefficient and T is the drop fall time (or drop exposure time), which may be estimated by the ratio of the average fall height to the terminal velocity of the average drop. The above expression represents a first-order approximation if a well-mixed droplet model is used for spray absorption efficiency. This expression is valid for λ_s values equal to or greater than 10 per hour but less than 20 per hour. Using this expression and the values contained in Table 6.5-2 a value of 37 hr^{-1} is calculated. A value of 10 per hour will continue to be used in the dose calculations of Section 15.6.5.

Spray removal of elemental iodine continues until the DF of Equation 6.5A-15 is reached. Although the VL term in Equation 6.5A-15 represents the volume of the sumps plus any overflow from the sumps, it is conservative to just use the volume of the sumps for VL since a lower DF will result. The value for the partition coefficient, H, in Equation 6.5A-15 was taken from Figure 6 of Reference 13 using the 323°K plot at 14 hours (representative of the average conditions during a LOCA). The value of 1100 used is considered to be conservative since the sump fluid temperature at 14 hours would be greater than 323°K per Figure 6.2.1-7 and Figure 6 of Reference 13 shows that higher temperatures would be associated with higher partition coefficients. The resulting DF is calculated to be 28.7

6.5A.4 REFERENCES

1. Hilliard, R. K., Coleman L. F., "Natural Transport Effects of Fission Product Behavior in the Containment System Experiment," BNWL-1457, Battelle Pacific Northwest Laboratories, Richland, Washington, December 1970.

2. Hilliard, R. K., et al, "Removal of Iodine and Particulates from Containment Atmospheres by Sprays - Containment Systems Experiment Interim Report," BNWL-1244, 1970.

3. Perkins, J. F., "Decay of U235 Fission Products," Physical Science Laboratory, RR-TR-63-11, U.S. Army Missile Command Redstone Arsenal, Alabama, July 25, 1963.

4. Parsley, Jr., L. F., "Design Considerations of Reactor Containment Spray Systems - Part VII," ORNL TM 2412, Part 7, 1970.

5. Ranz, W.E., and Marshall, Jr., W.R., "Evaporation from Drops," Chemical Engineering Progress 48, 141-46, 173-80, 1952.

6. Postma, A. K., and Pasedag, W. F., "A Review of Mathematical Models for Predicting Spray Removal of Fission Products in Reactor Containment Vessels," WASH-1329, U.S. Atomic Energy Commission, June 1974.

7. Griffiths, V., "The Removal of Iodine from the Atmosphere by Sprays," Report No. AHSB(S)R45, United Kingdom Atomic Energy Authority, London, 1963.

8. Eggleton, A. E. J., "A Theoretical Examination of Iodine-Water Partition Coefficient," AERE (R)-4887, 1967.

9. Postma, A. K., Coleman, L. F., and Hilliard, R. K., "Iodine Removal from Containment Atmospheres by Boric Acid Spray," BNP-100, Battelle-Northwest, Richland, Washington, 1970.

10. Coleman, L. F., "Iodine Gas-Liquid Partition," Nuclear Safety Quarterly Report, February, March, April 1970, BNWL-1315-2, Battelle-Northwest, Richland, Washington, p. 2.12-2.19, 1970.

11. NUREG-0800, Standard Review Plan Section 6.5.2, Revision 2, “Containment Spray as a Fission Product Cleanup System,” December 1988.

12. ANSI/ANS-56.5-1979, “PWR and BWR Containment Spray System Design Criteria.”

13. E.C. Beahm, W. E. Shockley, C. F. Weber, S. J. Wisbey, and Y. M. Wang, “Chemistry and Transport of Iodine in Containment,” NUREG/CR-4697, October 1986.

6.6 INSERVICE INSPECTION OF CLASS 2 AND 3 COMPONENTS

This section addresses the preservice and inservice inspections of quality group B and C (ASME Boiler and Pressure Vessel Code, class 2 and 3) components. Preservice and inservice inspections are covered by the applicable edition of Section XI of the ASME Code, including addenda, per 10 CFR 50.55a(g), with certain exceptions whenever specific written relief is granted by the NRC per 10 CFR 50.55a(g)(6)(i) or when Code Cases are incorporated per 10 CFR 50.55a(b)(5). The inservice testing of pumps and valves in accordance with the requirements of Subsections ISTB and ISTC of the ASME OM Code is discussed in Section 3.9(B).

In addition, Callaway initially submitted separate preservice and inservice inspection program documents, including pumps and valves, which complied with “NRC Staff Guidance for Complying with Certain Provisions of 10 CFR 50.55a(g)--Inservice Inspection Requirements.” Subsequent inservice inspection program documents are prepared in accordance with the 10-year update requirements in 10 CFR 50.55a and submitted to the NRC for initial approval. The inspection program documents identify the applicable Section XI edition and addenda and provide the details to the areas subject to examination, method of examination, extent and frequency of examination, and applicable Code Cases. ‘Relief Requests’ seeking relief from applicable code requirements are submitted to the NRC and become part of the inservice inspection program upon approval by the NRC. The repair and replacement program identifies the applicable Section XI edition and addenda, applicable Code Cases and relief requests, and provides the administrative controls for performing repairs and replacements.

Additional exceptions may be identified and reported to the NRC after plant operation, as specified in 10 CFR 50.55(g) (5)(iv).

6.6.1 COMPONENTS SUBJECT TO INSPECTION

The ASME Section XI Class 2 and 3 components are classified in accordance with the definitions of the 1974 Edition of the ASME Boiler and Pressure Vessel Code, Section III, Paragraph NA-2140. All Class 2 components, other than those exempted by Paragraph IWC-1220, are inspected in accordance with the requirements of Subsection IWC of Section XI of the ASME Boiler and Pressure Vessel Code.

In lieu of the above for Class 2 and 3 piping welds, a risk- informed ISI program (RI-ISI) was implemented in accordance with ASME Section XI and 10 CFR 50.55a.

6.6.2 ACCESSIBILITY

The physical arrangement of the components (such as piping, pumps, and valves) and supports is designed to allow personnel access to welds requiring inservice inspection to the maximum extent practical. Modifications to the initial plant design have been incorporated where practical to provide proper inspection access. Removable insulation has been provided on those piping systems requiring volumetric and surface inspection.

In addition, the placement of pipe hangers and supports with respect to the welds requiring inspection has been reviewed and modified, where necessary, to reduce the amount of plant support required in these areas during inspection.

Working platforms have been provided in many areas required to facilitate the servicing of pumps and valves. Temporary platforms, scaffolding, and ladders are provided to gain access to the piping welds. The surface of the welds requiring ultrasonic or surface examination within the inspection boundary has been prepared to permit effective examination.

An inservice inspection design review was undertaken to evaluate access requirements of the ASME Boiler and Pressure Vessel Code with subsequent design modifications and/or inspection technique development to ensure Code compliance, as required, to the extent practical. The provisions for suitable access for inservice examinations will minimize the time required for these inspections to be performed and reduces the amount of radiation exposure to both plant and examination personnel.

Space is provided to handle and store insulation, structural members, shielding, and similar material related to the inspection. Suitable hoists and other handling equipment have also been provided. Lighting and sources of power for the inspection equipment will be provided at appropriate locations.

6.6.3 EXAMINATION TECHNIQUES AND PROCEDURES

Inspection techniques, inspection frequencies, and evaluation of Class 2 examination data are in accordance with the technical requirements of the ASME Boiler and Pressure Vessel Code, Section XI. Furthermore, the ultrasonic examination of ferritic, austenitic, and dissimilar metal components are performed in accordance with IWA-2232.

The visual, surface, and volumetric examination techniques and procedures are written in accordance with the requirements of Section XI, Subarticle IWA-2200.

The liquid penetrant (PT) or magnetic particle (MT) methods are used for surface examinations and radiography (RT) or ultrasonic (UT) methods (manual or remote) are used for volumetric examinations. Manual UT techniques are used for most volumetric examinations of Class 2 components. All reportable indications are mapped and records are made of maximum signal amplitude, depth below the scanning surface, and length of the reflector. The data compilation format is such as to provide for comparison of data from subsequent examinations. Radiographic techniques may be used where ultrasonic techniques are not applicable. For areas where manual surface examinations or direct visual examinations are performed, all reportable indications are mapped with respect to size and location in a manner to allow comparison of data to subsequent examinations.

In lieu of the above for Class 2 and Class 3 piping welds, a risk- informed ISI program (RI-ISI) was implemented, in accordance with ASME Section XI and 10 CFR 50.55a.

Class 3 components are examined in accordance with the requirements of Article IWD. Class 3 piping welds are selected and examined per a risk-informed ISI program (RI-ISI) developed in accordance with ASME Section XI and 10 CFR 50.55a.

6.6.4 INSPECTION INTERVALS

The inservice inspection schedule for Class 2 system components is developed in accordance with the requirements of Subarticles IWA-2400 and IWC-2400.

The schedule for the inspection of Class 3 system components is developed in accordance with the requirements of Subarticles IWA-2400 and IWD-2400.

The inspection interval, as defined in Subarticle IWA-2400 of Section XI, is a 10-year interval of service. These inspection intervals represent calendar years after the reactor facility has been placed into commercial service. The interval may be extended by as much as one year to permit inspections to be concurrent with plant outages. All of the examinations required by Subarticles IWC-2400 and IWD-2400 were performed completely, once, prior to initial plant startup. Inservice examinations are primarily performed during normal plant outages, such as refueling shutdowns or maintenance shutdowns occurring during the inspection interval. However, inservice examinations may be performed while the unit is on-line if radiological and operational conditions permit access to the components.

6.6.5 EXAMINATION CATEGORIES AND REQUIREMENTS

Inservice inspection categories and requirements for Class 2 and 3 components and piping are in agreement with Table IWC-2500-1 and IWD-2500-1, respectively.

Inservice examinations for Class 2 and 3 components meet the requirements of Subarticles IWC-2400 and IWD-2400, respectively.

6.6.6 EVALUATION OF EXAMINATIONS

Evaluation of examination results of Class 2 components are in accordance with Article IWC-3000 of the ASME Code, Section XI.

Evaluation of examination results of Class 3 components are in accordance with Article IWD-3000.

Repairs of Class 2 and Class 3 components are in accordance with Article IWA-4000.

6.6.7 SYSTEM PRESSURE TEST

Class 2 systems subject to pressure tests are tested in accordance with Articles IWA-5000 and IWC-5000 and Table IWC-2500-1.

Class 3 systems subject to pressure tests are tested in accordance with Articles IWA-5000 and IWD-5000 and Table IWD-2500-1. For systems, or portions of systems, required to be hydrostatically tested each inspection interval, the provisions of an applicable ASME Code Case as documented in the ISI program plan may be used to perform a system leakage test in lieu of the system hydrostatic test.

6.6.8 AUGMENTED INSERVICE INSPECTION TO PROTECT AGAINST POSTULATED PIPING FAILURE

An augmented inservice inspection program is conducted on selected high-energy piping between the required pipe break restraints located inside and outside the containment beyond the isolation valves. This program is conducted in accordance with the Electric Power Research Institute Report “Extension of the EPRI Risk-Informed Inservice Inspection (RI-ISI) Methodology to Break Exclusion Region (BER) Program” 1006937 Rev, 0-A. This methodology is referred to as the RI-HELB methodology.

Details on high energy line break criteria, including break exclusion boundaries, are provided in Section 3.6 of the FSAR.

The selected welds are examined using volumetric techniques once in each inspection interval.

High-energy fluid piping systems are defined as those fluid systems that, during normal plant conditions (i.e., reactor startup, operation at power, hot standby, and reactor cooldown to cold shutdown conditions), are in operation or maintained pressurized under either or both of the following conditions:

a. Maximum operating temperature exceeds 200°F.

b. Maximum operating pressure exceeds 275 psig.