Millstone Power Station Unit 2
Safety Analysis Report

Chapter 6: Engineered Safety Features Systems

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6.1 GENERAL

6.1.1 DESIGN BASES

6.1.1.1 Functional Requirements

Engineered safety features is the designation given to those systems which are provided for the protection of the public and station personnel against the postulated release to the environment of radioactive products from the reactor coolant system, particularly as the result of loss-of-coolant accidents (LOCA). These safety features function to localize, control, mitigate, and terminate such incidents and to hold exposure levels below limits of 10 CFR Part 50.67.

Following a LOCA, these systems function to cool the core to limit fuel damage, to limit the magnitude and duration of pressure transients within the containment, to provide post-incident cooling for extended periods and limit fission products release. The adequacy of the design is demonstrated and the protection of the public assured by the use of the conservative assumptions outlined in Section 14.6.5 and 14.8.4 in the analysis of the effects of the LOCAs.

6.1.1.2 Design Criteria

The following criteria have been used in the design of the engineered safety features systems:

a. Safety related structures, systems, and components shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented in order to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of safety related structures, systems, and components shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.

b. Safety related structures, systems, and components shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect:

    1. Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with

sufficient margin for the limited accuracy, quality, and period of time in which the historical data have been accumulated.

2. Appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena.

3. The importance of the safety functions to be performed.

c. Safety related structures, systems, and components shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on safety related structures, systems, and components. Fire fighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components.

d. Safety related structures, systems, and components shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

e. Safety related structures, systems, and components shall not be shared between nuclear power units unless it is shown that their ability to perform their safety functions is not significantly impaired by the sharing.

6.1.2 SYSTEM DESCRIPTION

6.1.2.1 System

The engineered safety features systems are shown schematically on Figures 6.1–1, 9.9–1, and 9.9–2, and are described in detail in the subsequent sections.

The systems defined as engineered safety features are as follows:

a. The safety injection system, including as subsystems the safety injection tanks, high pressure safety injection pumps and low pressure safety injection pumps, injects borated water into the reactor coolant system. This provides cooling to limit core damage and fission product release, and assures adequate shutdown margin. The injection system also provides continuous long term post incident cooling of the core by recirculation of borated water from the containment sump.

b. The containment spray system removes heat by spraying cool borated water through the containment atmosphere. The sprayed heated water is then collected in the containment sump and cooled by the reactor building closed cooling water system through the shutdown heat exchangers and recirculated into the containment atmosphere.

c. The containment air recirculation and cooling system removes heat by passing containment air over coils cooled by the reactor building closed cooling water system.

d. The enclosure building filtration system collects and processes potential containment leakage to minimize environmental activity levels resulting from containment leakage.

e. The containment hydrogen control systems including independent systems provided to mix and monitor the hydrogen in the containment atmosphere.

The supporting systems include the engineered safety features actuation system, the normal and emergency electrical power systems, the reactor building closed cooling water system, service water and chemical and volume control system (CVCS). These systems are described in detail in Chapters 7, 8 and 9. All pneumatically operated values and dampers are designed to assume the safe position following loss of instrument air.

6.1.2.2 Components

The engineered safety features systems components are procured to detailed engineering specifications and tested to applicable codes listed in following sections.

6.1.3 SYSTEM OPERATION

The engineered safety features systems generally operate only under certain emergency conditions. Some systems operate during normal operation as the containment air recirculation and cooling system and hydrogen monitoring system. Other components such as the low pressure safety injection system and shutdown heat exchangers operate during shutdown operations.

6.1.3.1 Emergency Conditions

In the unlikely event of a LOCA or Main Steam Line Break (MSLB) accident, the engineered safety features systems with the exception of the hydrogen control system are automatically initiated to perform their respective safety function. The hydrogen control system may be manually initiated within several hours after the incident.

6.1.4 AVAILABILITY AND RELIABILITY

6.1.4.1 Special Features

All components of the engineered safety features systems and associated critical instrumentation which must operate are designed to operate in the most severe environment to which they could be exposed in the event of the worst postulated LOCA or MSLB accident. These design requirements are of primary significance for those portions of the engineered safety features systems which are located inside the containment. All components of the engineered safety features located inside containment, the auxiliary building, or the enclosure building, are environmentally qualified per 10 CFR 50.49 to operate in the most severe post-accident environment to which they are exposed.

The forces generated by the maximum hypothetical earthquake, combined with the rupture of a reactor coolant pipe, are considered in the design of the engineered safety features. The design assures that the functional capability of the system will be retained. Vessels which are connected to the engineered safety features systems are supported and restrained to allow controlled movement during this load condition, and piping is designed to accept these imposed movements. Analysis of the flexibility of the systems have been performed to verify that the piping can accept these additional vessel movements and still remain within code allowable stress limits. Flexibility calculations have been performed in accordance with the applicable codes, ASME Section III Nuclear Power Plant Components – 1971 and Power Piping ANSI B31.1.0-67. The double-ended rupture of the largest reactor coolant pipe is used as the design basis since the forces are the most severe.

The maximum post-incident temperature, pressure and humidity in the containment are found to be developed by the MSLB accident. A discussion of the analyses performed for a spectrum of break sizes, to determine these limiting service conditions, is presented in Section 14.8.2.

The pipe rupture protection requirements are listed in Table 6.1-1. The following pipe whip criteria are used in the layout of piping and location of restraints protecting the redundant engineered safety features systems.

6.1.4.1.1 Assumptions

In event of a pipe rupture in the reactor coolant system, it is assumed the only loss of engineered safety features piping is limited to those connected to that specific segment of the coolant loop.

6.1.4.1.1.1 Damage Protection Criteria

The criteria for protection from results of pipe whip or rupture inside and outside of the containment are summarized below:

a. Whipping does not preclude safe shutdown.

b. A secondary system failure does not cause a failure in the primary system.

c. No secondary system pipe whip results in the loss of its counterpart in the other secondary loop.

d. The containment liner plate is protected against a rupture on the primary system or piping that is in operation during or after a LOCA.

e. The containment liner plate is protected against main steam line whip.

f. In order to satisfy the criteria, protection against pipe whip is provided for high energy fluid systems (or portions of systems) except where:

   1. either of the following piping system conditions are met (a) the service temperature is less than 200°F, or (b) the design pressure is 275 psig or less, or

   2. the piping is physically separated (or isolated) from other piping or components by protective barriers, or restrained from whipping by plant design features, such as concrete encasement, or

   3. following a single break, the unrestrained pipe movement of either end of the ruptured pipe in any possible direction about a plastic hinge formed at the nearest pipe whip restraint cannot impact any safety related structure, system or component, or

   4. the internal energy level associated with the whipping pipe can be demonstrated to be insufficient to impair the safety function of any structure, system, or component to an unacceptable level.

   5. Pursuant to 10 CFR Appendix A, GDC 4, Leak-Before-Break (LBB) analyses when reviewed and approved by the commission grant exemption from the protection requirements against dynamic effects associated with postulated pipe ruptures. Such an exemption has been granted for the main reactor coolant loop, for the pressurizer surge line, and for the unisolable RCS portions of the safety injection and shutdown cooling piping systems. Subsequent to the commission review and approval, weld overlays were applied to dissimilar metal welds (DMWs) at the shutdown cooling, the safety injection and the pressurizer surge nozzles. A revised LBB analysis was performed for these nozzles and based on a 50.59 evaluation, commission review and approval of the DMW LLB analysis is not required to invoke the exemption from protection against pipe rupture dynamic effects for these nozzles.

g. Structural failures of piping or components, whether in safety or nonsafety grade systems, in addition to the initial postulated pipe break and its direct consequences, need not be considered.

The energy level in a whipping pipe is considered as insufficient to rupture an impacted pipe of equal or greater nominal pipe size and equal or heavier wall thickness.

6.1.4.1.1.2 Postulated Pipe Ruptures

For ASME Section III, Class I piping exceeding the pressure and temperatures conditions indicated in Section 6.1.4.1.1.1 and listed in Table 6.1-1, a pipe rupture is postulated at the following locations:

a. the terminal ends, and

b. any intermediate locations between terminal ends where the primary plus secondary stress intensities S_n (circumferential or longitudinal) derived on an elastically calculated basis under the loadings associated with one-half safe shutdown earthquake and operational plant conditions exceeds 2.0 S_m for ferritic steel, and 2.4 S_m for austenitic steel, and

c. any intermediate locations between terminal ends where the cumulative usage factor (U) derived from the piping fatigue analysis and based on all normal, upset and testing plant conditions exceeds 0.1.

NOTE: The original plant design required a minimum of two intermediate break locations by selecting arbitrary break points when the criteria in Items (b) and (c) failed to provide this minimum number. In adopting Generic Letter 87-11 and eliminating these previously postulated arbitrary intermediate breaks from the population of high energy line breaks postulated for MP2, all existing protective hardware, originally designed to mitigate the effects of these breaks, were retained. Any subsequent removal of this hardware is required to be addressed on a case-by-case basis following the requirements of GL 87-11.

For all other piping systems inside containment exceeding the pressure and temperature conditions indicated in Section 6.1.4.1.1.1 and listed in Table 6.1-1, a pipe rupture is postulated at the following locations:

a. the terminal ends, and

b. any intermediate locations between terminal ends where either the circumferential or longitudinal stress derived on an elastically calculated basis under the loadings associated with seismic events and operational plant conditions exceed 0.8 (S_h + S_A) or the expansion stresses exceed 0.8 S_A. SA and S_h are defined in Sections NC-3600 and ND-3600 of the ASME Section III Code, Winter 1972 Addenda.

NOTE: The original plant designs required a minimum of two intermediate break locations by selecting arbitrary break points when the criteria in Item (b) failed to provide this minimum number. In adopting Generic Letter 87-11 and eliminating these previously postulated arbitrary intermediate breaks from the population of high energy line breaks postulated for MP2, all existing protective hardware, originally designed to mitigate the effects of these breaks, were retained. Any subsequent removal of this hardware is required to be addressed on a case-by-case basis following the requirements of GL 87-11.

For piping systems outside containment exceeding the pressure and temperature conditions indicated in Table 6.1-4, pipe rupture is discussed in Section 6.1.4.1.1.3.

The type of pipe rupture at any postulated location, whether inside or outside containment, may be either of the following, regardless of the state of stress in the vicinity:

a. Elongated slot type failure in pipes having a nominal diameter of 4 inches and larger. (The equivalent area of which is assumed to be equal to the equivalent internal cross-sectional area of the upstream section of pipe and oriented such that the resultant force is perpendicular to the axis of the pipe.) However, elongated slot type (i.e., longitudinal) breaks are not postulated at terminal ends. Terminal ends are defined as extremities of piping runs that connect to structures, large components (e.g., vessels, pumps, etc.) or pipe anchors that act as essentially rigid constraints to thermal expansion.

b. Circumferential (Guillotine) break in pipes exceeding 1 inch nominal size (in which complete severance of the pipe is assumed perpendicular to the axis of the pipe).

In either case, the total dynamic steady thrust force in the event of a pipe rupture is computed from the following equation:

$$\frac{F_T}{A_B} = (P_2 - P_\infty) + \frac{G^2 \upsilon}{gc}$$

where:

F_T = Total thrust force

A_B = Break flow area

P_2 = Exit plane pressure

P_∞ = Pressure outside pipe prior to rupture

G = Mass flow rate per unit area

ν = Fluid specific volume

g_c = Newton's constant

A typical example of the existing pipe whip restraints designed according to the criteria in Section 5.2.5.7 of the FSAR and above is shown in Figure 6.1–2. This restraint prevents the main steam line from impacting against the containment liner plate as a result of the postulated pipe break shown. The restraint must limit both lateral and/or outward movement of the pipe at this location. Of these two conditions, the most critical one is the outward movement away from the restraint supports.

The total equivalent static reaction force of the pipe on the restraint, including the thrust coefficients and dynamic load factors, amounted to 2·PA,

where:

P = maximum normal operating pressure

A = internal cross-sectional area of the pipe

This procedure resulted in an effective static design force of 1,600 kips on the main steam line pipe whip restraint.

The pipe whip restraints inside the containment were reevaluated by conducting a dynamic analysis, considering the restraint as a single degree-of-freedom system. Since a gap must be maintained between the restraint and the pipe, due to construction tolerances and thermal considerations, the effects of a plastic collision were also considered.

The procedures to determine the effective thrust force for the dynamic analysis were revised from the original assumption and are reported above. This procedure was used in all cases except for the main feedwater line inside the containment, where the thrust force was determined by using the computer code Relaps III and the conservation of momentum equations. In all cases, the thrust force was considered as a step function, having an instantaneous rise time and maintaining a constant (maximum) level of thrust until the pipe-restraint system has come to rest.

Since the thrust force was taken as independent of time, it is also independent of displacement. Being independent of displacement, it can be shown mathematically that the dynamic analysis discussed above can be simplified to an energy balance calculation (i.e., the energy input into the restraint by the pipe equals the strain energy of the restraint responding to the pipe impact).

Employing the Conservation of Momentum for a plastic collision and conservatively neglecting the energy absorbed by bending (or hinging) of the pipe, the total deflection of the restraint is computed to be:

$$y_m = \frac{1/2 R_m y_e + Tey_g}{R_m - T}$$

where:

y_m = maximum deflection of the restraint

y_e = elastic deflection of the restraint

y_g = initial gap between pipe and restraint

R_m = (maximum elastic structural resistance + plastic structural resistance) ÷ (2)

T = thrust force

e = m_p divided by (m_p + m_r)

m_p = effective mass of the pipe

m_r = effective mass of the restraint

Figure 6.1–3 shows the idealized dynamic pipe thrust force and the pipe whip restraint force as a function of pipe deflection. Elastic deflection at this load is conservatively computed to be 0.093 inches, resulting primarily from flexure. The ultimate allowable deflection that provides resistance to the 1,600 kip force is taken to be 0.93 inches (i.e., elasto-plastic behavior, and a ductility ratio of 10 inches flexure is considered).

All pipe restraints outside the containment are designed to satisfy the requirements of Section 6.1.4.1.1.3. These pipe restraints are designed for elasto-perfectly plastic behavior, considering the impact effects resulting from gaps between the pipe and restraint. An energy balance approach similar to the one discussed above is used.

In all cases these restraints are designed as flexible structures having a ductile failure mode. As a result the dynamic load factors (measured as ratio of total restraint strength to steady thrust force) ranged from 1.2 to 2.0. Strain limits associated with these values are within 50% ultimate strain of the pipe whip restraint material. The criteria for protection against critical pipe failures for Millstone Unit 2, including the criteria, as outlined in Section 5.2.5.7 of the FSAR, are in complete accordance with Bechtel Topical Report BN-TOP-2 (Rev. 1), "Design for Pipe Break Effects," except as noted in the following items.

(1) Reference: Fluid Jet Geometry as shown in Figure 2-3 of BN-TOP-2 (Rev. 1). The jet expansion model used for Millstone Unit 2 and the referenced Figure are both shown in Figure 6.1–4 for comparison. The model presented in BN-TOP-2 consists of three regions. For subcooled water blowdown, this model assumes half-angle approach of 10 degrees uniformly in all three regions. For steam and steam/water blowdown, the jet expands to the asymptotic area at a half-angle which exceeds 10 degrees. The area remains constant in region 2 and expands again at a ten degree half-angle in region 3.

For steam and steam/water mixtures, the model used for Millstone Unit 2 assumes the jet expands to the asymptotic area (taken to be located at five inside pipe diameters from the break exit plane) at a ten degree half-angle and remains constant thereafter for the remaining extent of its zone of influence. The applicable limit for steam and steam/water mixtures is based on the premise that the expansion of the fluid jet from a postulated pipe rupture attenuates the system pressure within ten nominal pipe diameters from the source of the jet to ambient conditions as demonstrated by NUREG/CR-2913, Reference 6.1-2. Unprotected components at a distance beyond ten nominal pipe diameters from the broken pipe are considered undamaged by the jet without further analysis.

The jet shape used for cold water and non-flashing/subcooled fluid is treated as a non-expanding jet with its area equal to that of the break exit area. In this case, conservation of load effects will be assumed and the zone of influence of the jet will be considered to end only by interaction with a component or structure with the capacity to block and resist the full jet load. Therefore, the Millstone Unit 2 model provides jet pressure intensities which are more conservative than BN-TOP-2.

(2) Reference: Moment capacity for steel beam, Page 3-9 of BN-TOP-2.

$$M_u = 0.9\ f_y\ S_p \quad (1)$$

$$M_u = 1.0\ f_y\ S \quad (2)$$

where

M_u = yield moment

f_y = yield stress

S_p = plastic section modulus

S = elastic section modulus

Equation (1) is presented in the referenced BN-TOP-2 and Equation (2) is used in designing pipe whip restraints for Millstone Unit 2. Since the ratios of the plastic to elastic section moduli range from 1.1 to 1.18 with an average of 1.134 (Reference 6.1-1) for structural shapes, equation (2) becomes:

$$M_u = 0.88\ f_y S_p \quad (3)$$

Since M_u is the capacity moment for the restraint and is associated with the energy absorbing capacity of the restraint, the lesser values of M_u used in Millstone Unit 2 will result in a more conservative design than that if equation (1) is used.

(3) Reference: Pipe break configurations are shown on Figure 2-4 of BN-TOP-2. The referenced BN-TOP-2 figure and the associated discussion on jet impingement configurations and forces attribute jet impingement effects not only to full-size circumferential or longitudinal breaks, but also to cracks. Millstone Unit 2 does not consider any jet impingement effects or other dynamic

consequences resulting from pipe cracks. Through wall leakage cracks in high energy piping are evaluated for environmental consequences only (i.e., temperature, humidity, and flooding effects).

As noted within the BN-TOP-2 report, jet impingement effects are important only in the first few break diameters away from the source pipe. Since the effective diameter of a crack is based on a circle with an area equal to one-half the pipe's inside diameter times one-half the pipe's wall thickness instead of the full pipe flow area considered for other breaks, its effective diameter is significantly smaller than that of other breaks. As both the effective zone-of-influence and resulting jet force due to any break are a function of the break diameter, the dynamic effects resulting from a crack would also be significantly less than full-size break effects. Therefore, for Millstone Unit 2, jet impingement effects resulting from cracks are considered fully enveloped by the postulated full size pipe breaks.

6.1.4.1.1.3 Pipe Ruptures Outside Containment

Rupture Criteria

For all piping systems with normal operating pressure and temperature conditions exceeding those defined by operating conditions A, B and C in Table 6.1-4, a pipe rupture is postulated at the following locations:

1. the terminal ends, and

2. for stress analyzed piping, at any intermediate location between terminal ends where the calculated Primary + Secondary Stress, S, exceeds $0.8(S_h + S_A)$, or the Secondary Stress alone exceeds $0.8S_A$ where:

S = stresses under the combination of loadings associated with the normal and upset plant condition loadings and an OBE event.

S_h = basic material allowable stress at maximum (hot) temperature from the allowable stress table in the associated piping analysis design code.

S_A = allowable stress range for expansion stresses as defined in the associated piping analysis design code.

3. for unanalyzed piping, at all intermediate weld connections to elbows and other pipe fittings within the line.

4. for type and configuration of the resulting postulated pipe ruptures at each of the above locations, refer to Section 6.1.4.1.1.2,

5. In addition to the above pipe ruptures, through wall leakage cracks are postulated at those locations that results in the most adverse conditions of flooding and local environmental conditions on the adjacent safe shutdown equipment. The flow area

of leakage cracks is taken as the area equal to that of a rectangle one-half the pipe inside diameter in length and one-half the pipe wall thickness in width.

Plant Modifications Resulting From the Elimination of Arbitrary Intermediate Breaks (GL 87-11)

In adopting Generic Letter 87-11 and eliminating the previously postulated arbitrary intermediate breaks from the population of high energy line breaks postulated for MP2, all existing protective hardware, originally designed to mitigate the effects of these breaks, were retained. Any subsequent removal of this hardware is required to be addressed on a case-by-case basis following the requirements of GL 87-11.

6.1.4.1.1.4 Safe Shutdown for Pipe Rupture

A comprehensive review of MP2 design basis documentation has been performed and a methodology was developed to select safe shutdown paths. Those components necessary to bring the plant to Mode 3, Hot Standby, condition are defined by this methodology. The various alternative methods identify paths used in accomplishing the following safe shutdown functions subsequent to a High Energy Line Break (HELB):

- RCS Heat Removal
- RCS Pressure Control
- RCS Inventory Control
- Maintaining Vital Auxiliaries

General assumptions used in identifying the safe shutdown paths are described below:

- Safe shutdown for a HELB is defined as Hot Standby (Mode 3) and maintaining this condition for eight (8) hours.
- Only those high energy systems that are in service during normal plant operations are assumed to rupture.
- Offsite power is assumed to be not available if the pipe rupture results in a unit trip.
- Coincident with the postulated pipe break, a single active failure in an active component of a required safety related system is assumed.
- No other extraordinary events are postulated (i.e., fire, earthquake, etc.)

6.1.4.1.2 Design Method for Damage Prevention

Physical separation, where possible, between critical lines is utilized by routing the piping so that a ruptured line is beyond reach of another line or critical component.

The safety injection and containment spray pumps arranged in two groups of minimum safety features, each group consisting of one high pressure safety injection pump, one low pressure safety injection pump and one containment spray pump.

Each group is served by separate suction and discharge header, powered by separate sources and is physically located in separate watertight pump rooms. The third high pressure safety injection pump is interconnected to the two headers. A selection switch is provided to enable the pump to draw power from either emergency bus. The third HPSI pump is aligned to operate only upon removal from service of either of the other HPSI pumps.

Water hammer effects are minimized in the engineered safety features system by keeping process lines flooded where possible. Air pockets will be eliminated by periodic opening of isolation valves during testing and by high point vents provided on the process lines.

The safety injection system is flooded up to the connection to the reactor coolant system while the containment spray system is flooded up to the risers in containment. The remaining piping is vertical or sloped upward to eliminate air pockets.

All motor-operated valves in the safety injection and containment spray systems are opened in response to their associated actuation signals.

The 8 HPSI injection throttle valves are manually positioned to the desired open position and do not open further on an actuation signal.

Further discussion of the various methods of pipe whip protection are contained in Section 5.2.5.7.1.

The following criteria must be satisfied by components located in the containment and the enclosure building that are not seismic category I:

a. Failure of these components cannot affect safe shutdown of the reactor.

b. Failure of these components cannot affect the operation of Seismic Category I components.

c. Non seismic Category I components are located in such areas that missiles projected from their failures remain isolated from seismic I components.

Table 6.1-3 lists the Non seismic Category I components located inside the containment and enclosure building.

The components of the clean liquid waste processing systems are located at the lower elevations of containment, away from safety related equipment. The pressurizer quench tank operates at 35 psig maximum. The primary drain tank operates at 2 psig. At these relatively low operating pressures, these components do not sustain sufficient energy to become potential missiles. The cooler which is connected to the RBCCW is analyzed for the design basis earthquake to assure integrity.

The vents, drains and sample connections to the reactor coolant pressure boundary are analyzed for the design basis earthquake beyond the second isolation to the first anchor.

The containment floor drain system is embedded in concrete and vented to containment. These are atmospheric pressure and therefore, do not sustain sufficient energy to become a potential missile or to whip into Category I equipment. The sump pumps are located at the lowest elevation of containment, away from safety related equipment. The discharge pressure of the sump pumps is approximately 25 psig. This pressure is not sufficient to create a potential missile or to whip.

The components of the RV Head decontamination system are located at lower elevations in shielded compartments away from safety related systems. The system is no longer used and therefore will not generate any missiles due to rupture.

The containment elevator is completely contained within the elevator shaft structure which is a Category I structure. The stud storage racks are anchored during normal operation. The CEDM coolers are connected to the RBCCW and are analyzed for the design basis earthquake. The CEDM coolers are located on the missile shield, away from any safety related equipment. The revolving maintenance truss is analyzed for the design basis earthquake. The containment auxiliary circulation fans and duct work are located above the operating floor, away from safety related equipment.

The instrument air receiver tank, which operates at a pressure of 80 psig, is located at elevation (+) 14 feet 6 inches outside of the secondary shield wall.

The refueling pool skimmer filters are located in shielded compartments at elevation (+) 14 feet 6 inches outside the secondary shield wall. The skimmer system is in operation only during refueling.

The reactor coolant system is shielded from potential missiles by the primary and secondary shield walls and the missile shield. The steam generators are shielded by the secondary shield walls and by a doghouse extended above the operating floor.

The blowdown quench tank, heat exchanger and pump are located within a concrete enclosure through which the main steam piping is routed. The blowdown tank is located within the enclosure building proper and is normally operating at approximately 1 psig. At this low pressure the system does not sustain sufficient energy to become potential missiles or to cause the pipe to whip. The closed quench tank system operates at approximately 50 psig. This energy is not sufficient to cause damage to the Category I systems following a postulated pipe whip.

Miscellaneous duct work and unit heaters which operate at relatively low pressure shall not attain sufficient energy to cause damage to Category I systems.

6.1.4.2 Tests and Inspection

The engineered safety features system components are procured to detailed engineering specifications and tested to applicable codes as described in the subsequent section. In addition, special testing of actual or prototype components under proposed service conditions of pressure, temperature and humidity are conducted on various components. Engineered safety features system components are incorporated with provisions for on-line testing.

Engineered safety feature systems are incorporated with provisions for full system actuation and performance tests.

Components located outside the containment are accessible for periodic maintenance and inspection. Components located inside the containment are accessible during normal shutdown.

6.1.5 REFERENCES

6.1-1 Plastic Design in Steel, 2nd Edition, ASCE Manual Number 41, 1971.

6.1-2 NUREG/CR-2913, “Two-Phase Jet Loads,” January 1983.

TABLE 6.1-1 PIPE RUPTURE PROTECTION REQUIREMENTS

LINE SERVICE	CATEGORIES					
	A	B	C	D	E	F
Safety Injection Lines	X	X	X	X		X
Charging Line	X	X				X
Reactor Coolant Letdown Lines	X	X		X	X	
Steam Generator Blowdown Lines	X	X	X	X		
Feedwater Lines	X	X	X	X	X	X
Main Steam Lines	X	X	X	X	X	X
Reactor Coolant System Piping	X		X	X	X	

The following categories have been listed in Table 6.1-1 to describe the criteria mentioned:

Category A Lines that must be restrained from damaging the reactor coolant system.

Category B Lines that must be restrained from damaging the containment liner plate.

Category C Lines that must be protected from damage by ruptured reactor coolant system piping

Category D Lines that must be restrained from damaging the secondary system.

Category E Lines that must be protected from damage by the secondary system.

Category F Lines that must be protected from damage by or restrained from damaging their parallel redundant lines.

TABLE 6.1-2 OMITTED

TABLE 6.1-3 DESIGN NON-SEISMIC CATEGORY I COMPONENTS LOCATED INSIDE CONTAINMENT AND ENCLOSURE BUILDING

I. Containment Building

A. Clean Liquid Waste Processing System Components (FSAR Figure 11.1–1)

1. Primary Drain Tank and Pumps
2. Primary Drain Tank and Quench Tank Heat Exchangers
3. Associated piping and valves

B. Reactor Coolant System Components (FSAR Figure 4.1–1)

1. Quench Tank and associated piping and valves
2. Vent, sampling and drain piping and valves beyond second isolation valve

C. Drain Systems (FSAR Figure 11.1–3)

1. Sump pumps
2. All drain piping and valves for non Category I equipment beyond second isolation valve of primary pressure boundary.

D. Reactor Vessel Head Decontamination System

1. Mixing tank
2. Pump
3. Filters (2)
4. Piping and valving

E. Miscellaneous

1. Containment elevator
2. Stud storage racks
3. CEDM Coolers
4. Revolving maintenance truss
5. Containment auxiliary circulation fans and ductwork
6. Instrument air receiver tank & associated equipment
7. Refueling pool skimmer filter & associated equipment
8. Containment Surveillance camera & associated equipment

TABLE 6.1-3 DESIGN NON-SEISMIC CATEGORY I COMPONENTS LOCATED INSIDE CONTAINMENT AND ENCLOSURE BUILDING (CONTINUED)

II. Enclosure Building

A. Main Steam System Components (FSAR Figure 10.3–1)

1. Blowdown Tank
2. S. G. Blowdown Quench Tank, Heat Exchanger, Recirculation Pump, valves and associated piping

B. Containment Penetration Cooling System

1. Fans
2. Ductwork

C. Miscellaneous

1. Miscellaneous ductwork
2. Unit heaters

TABLE 6.1-4 PIPE RUPTURE CRITERIA APPLICABILITY (OUTSIDE CONTAINMENT) BASED ON NORMAL OPERATING PLANT CONDITIONS

Operating Condition	Temperature (Degrees F)	Pressure (PSIG)
A	Equal to or Greater than 200	Equal to or Greater than 275
B	Equal to or Greater than 200 [1]	Less than 275
C	Less than 200	Equal to or Greater than 275
D	Less than 200	Less than 275

Pipe Rupture postulation at MP2 is separated into four distinct groupings, which are dependent on the normal service temperature and pressure of the line; e.g., the state of temperature and pressure of the system during Normal Plant Operation (NPO) from plant heatup through power operation and plant shutdown to the hot standby condition. Where a piping system operates within the parameters of Operating Conditions A, B, or C for only a short period of its operating time (i.e., less than 2%) it is considered to be a Moderate Energy System and is treated as an Operating Condition D System.

1. Lines whose normal operating condition is defined by condition A are defined as High Energy Lines with postulated pipe rupture effects of pipe whip and jet impingement and the related effects of pressurization, flooding and environment. Includes Charging System which operates substantially above 275 psig, but less than 200°F.
2. Lines whose normal operating condition is defined either by condition B or C are defined as High Energy Lines with postulated pipe rupture effects of jet impingement and the related effects of pressurization, flooding and environment.
3. Lines whose normal operating condition is defined by A, B, or C are defined as High Energy Lines with postulated effects of piping cracks (includes flooding and environmental conditions) at the most adverse equipment locations.
4. Lines whose normal operating condition is defined by operating condition D are considered Moderate Energy Lines (MELs) and require no postulation of rupture effects.

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1 Lines with temperature ≥ 200°F, and pressures approximately atmospheric are not considered as High Energy Lines since the calculated jet impingement force will be negligible for such low pressure.

FIGURE 6.1–1 SAFETY INJECTION P&ID (SHEET 1)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 6.1–1 SAFETY INJECTION P&ID (SHEET 2)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 6.1–1 SAFETY INJECTION P&ID (SHEET 3)

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 6.1–2 MAIN STEAM PIPE WHIP RESTRAINT

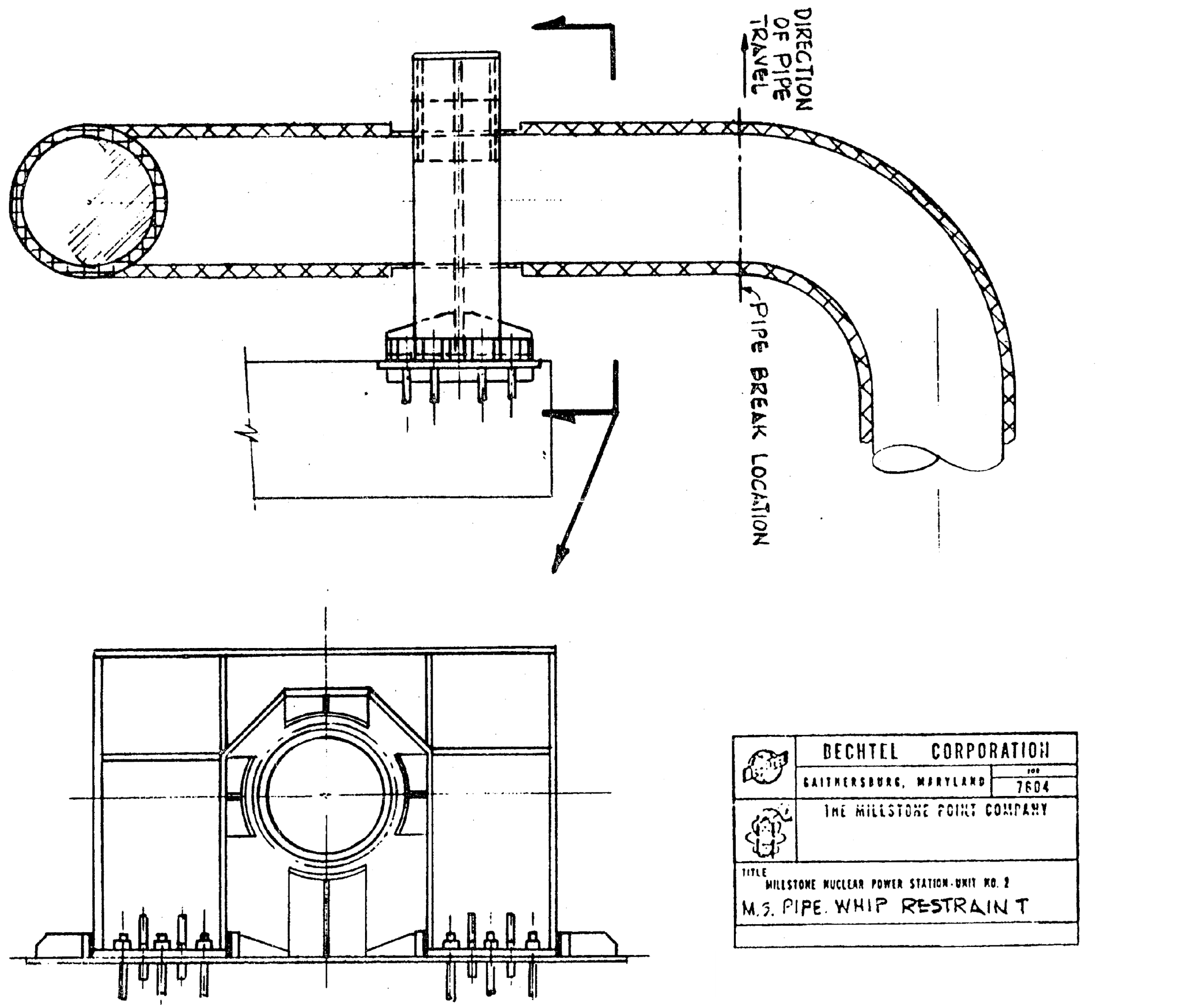

FIGURE 6.1–3 PIPE RESTRAINT DESIGN

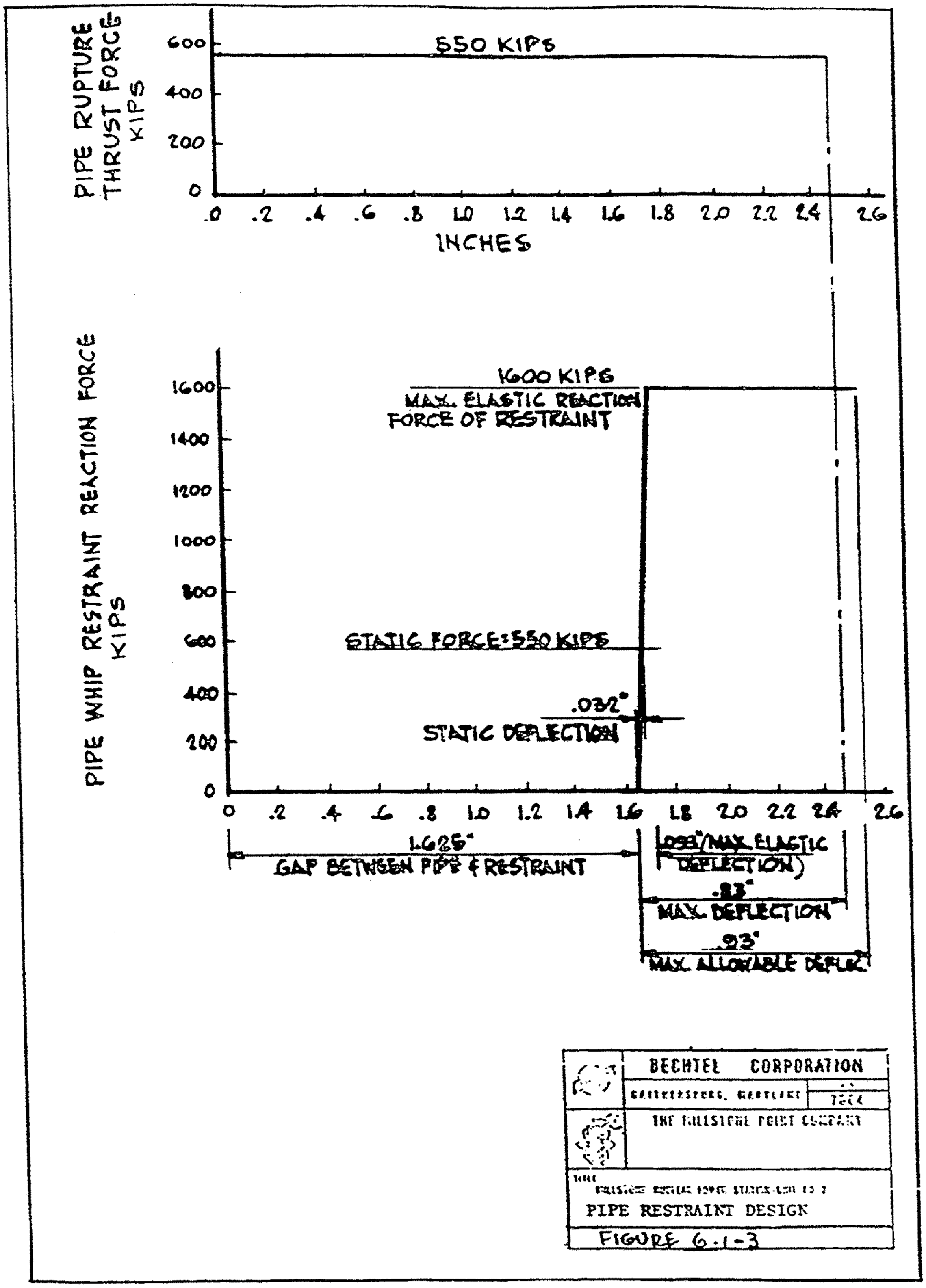

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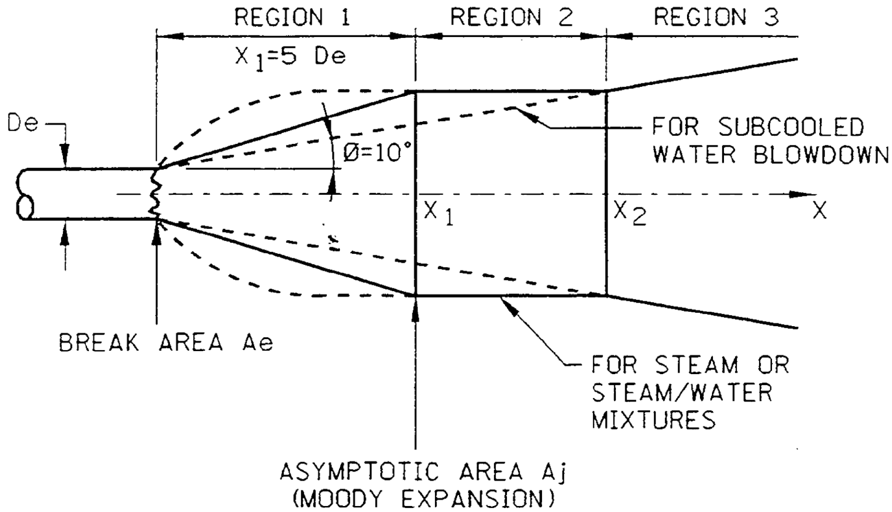
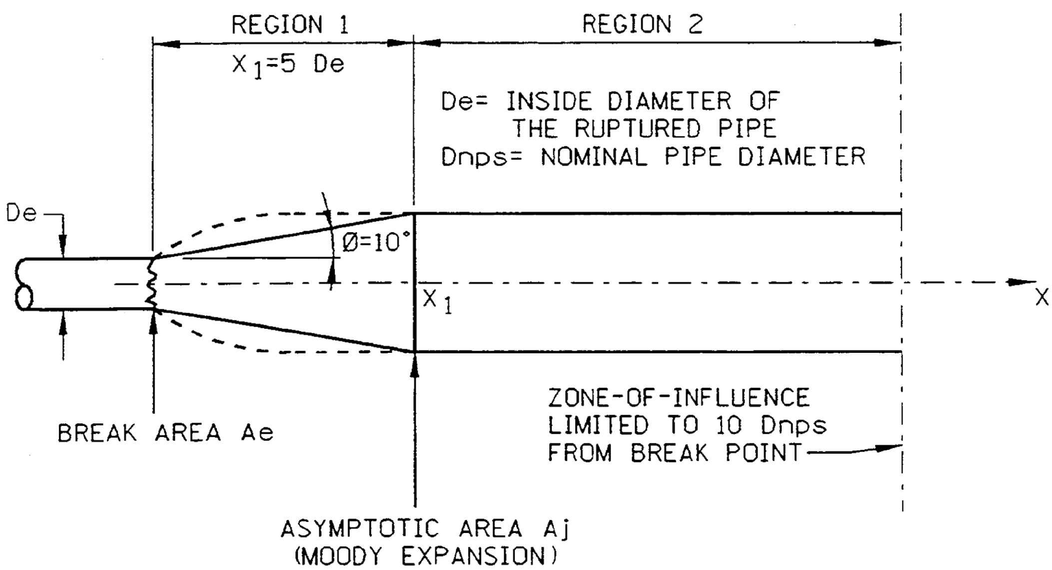
FIGURE 6.1–4 FLUID JET EXPANSION MODEL



BN-TOP-2 MODEL
(FOR REFERENCE ONLY- NOT USED ON MP2)



MP2 MODEL FOR STEAM OR STEAM/WATER MIXTURES

NOTE:
NON-FLASHING/SUBCOOLED WATER BLOWDOWN IS TREATED AS A NON-EXPANDING JET WITH CONSTANT AREA (Ae) AND FORCE.

6.2 REFUELING WATER STORAGE TANK AND CONTAINMENT SUMP

6.2.1 DESIGN BASES

6.2.1.1 Functional Requirements

The refueling water storage tank (RWST) functions to provide the initial source of borated water for the safety injection and containment spray pumps.

The containment sump functions to collect the water from the safety injection, containment spray and reactor coolant blowdown for recirculation after the water has been nearly exhausted from the RWST.

6.2.1.2 Design Criteria

The following criteria have been used in the design of the RWST and containment sump:

a. The system shall provide a reliable source of borated water for the safety injection system and the containment spray system.

b. The system shall be designed to permit inspection of important components, such as sump, tank, valves and piping to assure the integrity and capability of the system.

c. The components shall be designed to the general criteria as described in Section 6.1.

6.2.2 SYSTEM DESCRIPTION

6.2.2.1 System

The location and interconnection of the RWST and containment sump in the system are shown schematically in Figure 6.1–1.

The RWST is an atmospheric tank which stores borated water during normal operation. The RWST is the initial source of suction for the high pressure and low pressure safety injection pumps (Section 6.3) and the containment spray pumps (Section 6.4). The RWST is provided with two separate, independent outlet headers, each of which supplies borated water to each grouping of minimum engineered safety feature pumps as described in Section 6.1.4.1. The “A” RWST outlet header also supplies a suction connection that facilitates portable diesel driven RCS Injection Pump deployment. This connection supports the discharge connection described in Section 6.3.2.1 and is a defense-in depth design feature that is available for coping with an extended loss of AC power (ELAP) event. The location of this BDB RCS FLEX suction connection is shown on Figure 6.1–1, Sheet 2.

The RWST is designed to store sufficient borated water to fill the refueling cavity in the containment for refueling operations. This requires 421,000 gallons of borated water containing 1,720 ppm boron.

The containment sump is formed by the floor and the lowest elevation of containment. The borated water from the safety injection (Section 6.3), containment spray system (Section 6.4) and reactor coolant system is collected and subsequently recirculated to the pump's suction. Two 24 inch containment sump recirculation pipes are provided from the sump to the suction of the safety injection and containment spray pumps. The recirculating piping inside the containment extends approximately 11 inches above the floor Elevation (-) 22-6. A vortex breaker is provided on each containment sump recirculation pipe inlet to avoid any air ingestion.

The containment sumps are located at the bottom of the containment building at elevation (-) 22-6. The containment sump strainer has an enclosure that surrounds the pump suction pipes located in this sump. Two headers extend out from this enclosure in an eastern and northern direction. Perforated hollow fins are attached to these headers and flow is draw through these fins and into the headers and directed to the sump enclosure. The sump enclosure is solid plate and has a manway in the side to allow access to the sump for inspections.

The strainer is constructed of 304/304L SS or equivalent materials. The fins are made of thin corrugated stainless steel perforated with 1/16 inch holes. This perforation size prevents larger particles from passing and thus avoids any clogging of any downstream equipment including pump flow clearances, containment spray nozzles or HPSI throttle valves. The total filtration surface area of the strainer is approximately 6,000 square feet.

The strainer is designed to support the full flow rate from both trains of ECCS simultaneously. The strainer is a single unit that is shared by both trains. It is a passive component with no moving parts. Evaluations in accordance with Section 6.1.4 have determined that there are no credible failure modes that will cause loss of the strainer and redundant trains are not required.

The strainer is designed to accommodate the debris load from either a SBLOCA or a LBLOCA. This debris load consists of fibrous and particulate materials generated by the force of the pipe break in the steam generator cubicle. In addition, it considers latent particulate and fibrous debris from the containment walls, floors and equipment that is washed to the sumps by containment spray. The design also considers the formation of particulate due to chemical reactions between the substances suspended or dissolved in the containment sump water post accident. The head loss across the strainer, including this debris, is limited to a value that will not adversely affect the available net positive suction head for the safety injection and containment spray pumps.

The RWST capacity is adequate to provide a minimum water level in the containment sump for operation of the safety injection and containment spray pumps during post-accident operation for both LBLOCA and SBLOCA.

Engineered safety features piping connected to the containment sump is an extension of reactor containment during the recirculation mode of core and containment cooling. The following items pertain to suction piping from the sump to the first isolation valve:

a. Both spool pieces are designed, fabricated, tested and inspected in accordance with ANSI B31.7, Class II. The valves are manufactured with the ASME Code for Pumps and Valves for Nuclear Power, Class II.

b. The recirculation lines from the containment out to and including the first isolation valve are enclosed in leakage controlling encapsulation barriers. The barrier will control leakage resulting from postulated pressure failure of the pipe or valve. This leakage control function is provided by gaskets, seals, and the concrete to steel interfaces at the encapsulation embedment plates. These features will physically limit potential fluid releases from the encapsulations to an extent that does not significantly deplete the water level in the containment sump during sump recirculation; that does not impact ECCS pump NPSH requirements or measurably alter ECCS flow capabilities; and that does not pose a threat of flooding, spraying, or otherwise shorting-out the ECCS pumps in the “A” safeguards room of the Auxiliary Building. The leakage control function of the encapsulations will also assure that post accident radioactive fluids released from these structures will be collected in the “A” safeguards room or in the liquid radwaste system in the Auxiliary Building, and processed or retained in a manner that protects public health and safety. The barrier is tightly attached to the exterior concrete of the containment. The encapsulation barrier is designed for 60 psig and is in accordance with the criteria for Seismic Class I structures.

c. Pipe material is Type 304 stainless steel.

The first isolation valve in each recirculation line is a motor-operated double-disk gate valve. Rupture disks are installed to prevent the possibility of thermal expansion of trapped fluid in the valve bodies causing the valves to become pressure locked prior to initiation of sump recirculation. The rupture disks are installed in piping connected to the body drain of each isolation valve. The discharge of the rupture disks is contained within the closed piping system.

To adjust the pH of the containment sump water following a postulated LOCA, wire-mesh baskets containing trisodium phosphate dodecahydrate (TSP) are provided on the lowest level of the containment as shown on Figure 1.2–11. The baskets contain a Technical Specification required volume of solid granular TSP, a quantity sufficient to raise the sump water pH to a value equal to or greater than 7.0.

6.2.2.2 Components

The major system components and associated fabrication data are listed in Table 6.2-1.

6.2.3 SYSTEM OPERATION

6.2.3.1 Emergency Conditions

The valves on the RWST suction headers are normally in the open position. The safety injection and containment spray systems are flooded from the RWST to their respective containment isolation valves, 2-SI-615, 625, 635, 645, 616, 626, 646, 617, 627, 637, 636, 647, 2-CS-4.1A and 4.1B (Figure 6.1–1).

In the unlikely event of a LOCA, borated water from the RWST is immediately available to the pumps suction without additional active operations.

When the RWST level reaches 46 inches, the safety injection and containment spray pump suction is automatically transferred to the recirculation mode with suction from the containment sump. This is initiated by the sump recirculation actuation signal (SRAS) and is described in Section 7.3.

The recirculation mode can also be initiated manually by the operator.

The SRAS opens the isolation valving (2-CS-16.1A and 16.1B on Figure 6.1–1) on the containment sump recirculation piping and therefore, permits the pumps to take suction from the containment sump.

An external heater is provided to maintain the contents of the RWST ≥ 50°F in Modes 1 and 2, and ≥ 35°F in Modes 3 through 6 (Section 6.2.4.1). RWST temperature is monitored by temperature indication in the control room. Low water temperature is alarmed to alert operators that remedial action is required. RWST water level is indicated in the control room. Low water level alarms are provided to alert operating personnel. Sample points located within the safety features system indicate water chemistry. Provisions are incorporated for filling draining and altering the water chemistry of the tank contents. Purification of the RWST contents is provided by the spent fuel pool purification system.

Following a postulated LOCA, the TSP stored in dissolving baskets at the lowest elevation of the containment will dissolve in the sump water as the safety injection water fills the containment. Containment sump water recirculation will provide the required mixing to achieve a final pH greater than or equal to 7.0 for the sump water.

6.2.3.2 Cold Shutdown and Refueling

Following cold shutdown and after the reactor vessel head is removed, the refueling cavity is filled by the LPSI pumps with borated water from the RWST. The RWST is sized to provide a sufficient quantity of borated water to maintain a water level of 24 feet above the reactor vessel flange. Shutdown cooling operation and refueling operations are described in Section 9.3.

Following the refueling operation, the water from the refueling cavity is pumped back to the RWST.

6.2.4 AVAILABILITY AND RELIABILITY

6.2.4.1 Special Features

To assure availability of borated water for post-accident operation, the RWST is normally aligned for operation with the outlet valves opened. The tank contents are maintained ≥ 50°F in Modes 1 and 2, and ≥ 35°F in Modes 3 through 6 by recirculation through an external heat exchanger which is heated by unit steam. The supply and return connections for the RWST heating system penetrate the upper portions of the tank, above the minimum water level of 32.5 feet, to prevent excessive tank drainage following a postulated pipe rupture. The supply connection to the heat exchanger is provided with a siphon breaker to prevent siphoning of the tank following a postulated pipe rupture. The siphon breaker is located immediately above the minimum tank water level to assure suction for the RWST heating system and to minimize drainage following a postulated pipe rupture.

To maintain the RWST contents at 50°F with zero (0)°F outside air temperature, heating is required at a rate of 1.21 x 10^6 Btu/hr. The RWST borated water temperature is measured and alarmed should it decrease below 55°F. Remedial action can be taken by the operator by routing the tank contents through one shutdown cooling heat exchanger using one containment spray pump and aligning a recirculation path to the RWST by opening valves 2-SI-456 (or 2-SI-457), and 2-SI-460 (Figure 6.1–1). The RBCCW is used as the heating medium. Assuming a conservative 60°F RBCCW temperature, the tube side (RWST) water leaving temperature is 55°F.

The spent fuel pool cooling system may be used as back-up for the above to maintain the RWST contents at the required temperature.

The motor-operated isolation valves on the RWST headers remain open following the switch over to the sump recirculation mode of operation. These valves may be closed manually. However, this operation is not required for system operation. The elevated pressure within containment under post-accident conditions maintains the check valves (2-CS-14A and 14B) on the RWST headers in a closed position. Under no normal circumstance can the header from the RWST be emptied since the elevation head from the containment sump at Elevation (-) 22-6 maintains the water level in the RWST headers at this minimum elevation. The interconnection between the containment sump recirculation line the RWST header is located at Elevation (-) 30-1 5/8 and (-) 33-7.

The containment sump recirculation piping is embedded in the concrete containment floor to prevent leakage of the post-accident containment atmosphere. Although completely redundant sump recirculation piping is provided, one pipe is encased in a guard pipe for protection where both pipes are located in the same safety features pump room. Therefore, any failure of one line does not render the redundant line inoperable.

The RWST is located at grade Elevation 14-6. The containment sump inlet is located at the lowest elevation in the auxiliary building, (-) 45-6. Therefore, all suction lines are flooded to assure priming.

The Technical Specification required volume of TSP stored in the wire mesh baskets located on the containment floor is sufficient to raise the pH of the containment sump water to a value equal to or greater than 7.0 when considering the total quantity of borated water that could be available in the containment sump following a LOCA, the amount of hydrochloric acid from the degradation of electric cable insulation, and the amount of nitric acid from the irradiation of the containment air and sump water. Maintaining sump pH equal to or greater than 7.0 ensures iodine retention capability following a LOCA. Tests have demonstrated that the TSP will readily dissolve in the containment sump water. In addition TSP experiences no significant deterioration or decomposition upon storage.

6.2.4.2 Tests and Inspection

The RWST was acceptance tested in accordance with the ASME Code, Section III, Class 3. Since the RWST performs no active function, online testing is not provided. The RWST header valves underwent acceptance testing prior to initial start up. The test procedure is described in Section 13.

The RWST is accessible for periodic maintenance and inspection during normal operation.

The containment sump recirculation isolation valves (2CS-16.1A and 16.1B) may be tested for opening capabilities during normal operation. A check valve is located downstream of each of these valves to prevent flow from the RWST entering the containment.

The containment sump recirculation isolation valves undergo a preoperational test prior to start up. Test procedures are described in Section 13.

The containment sump and TSP baskets are accessible for inspection and maintenance during normal shutdown.

TABLE 6.2-1 REFUELING WATER STORAGE TANK AND CONTAINMENT SUMP

RWST	
Manufacturer Company	Richmond Engineering Company
Model Number	3736-4x6-13DV
Quantity	1
Design Pressure	Atmospheric
Design temperature (°F)	120
Shell Material	SA-240, Type 304
Net Capacity (gal.)	475,000
Code	ASME Code, Section III, Class 3 (1971 edition)
Seismic	Class 1
Piping	
Material	ASTM A-312, Type 304
2.5 inch and larger	Sch 10S
2 inch and smaller)	Sch 40S
Fittings	
2.5 inch and larger	Butt-welded except at flanged equipment
2 inch and smaller)	Socket-welded
Valves	
2.5 inch and larger	Butt-welded, ANSI 600 lb rating stainless steel
2 inch and smaller)	Socket-welded, ANSI 600 lb rating stainless steel
Standard - Piping	ANSI B 31.1.0
Code - Valves	Draft ASME Code for Pumps, and Valves for Nuclear Power, Class 2, 1968
Seismic	Class 1

TABLE 6.2-1 REFUELING WATER STORAGE TANK AND CONTAINMENT SUMP (CONTINUED)

Containment Sump

Containment Sump Recirculating Piping

Material	ASTM A-312, Type 304
24 inches	Sch 10S
Fittings	Butt-welded
Valves	Butt-welded, ANSI 150 lb rating, stainless steel
Standard	ANSI B 31.7 Class II
Seismic	Class 1

Containment Sump Screen

Quantity	1
Approximate Overall dimensions (feet):	Two branches of headers 4 feet high, one header is 42 feet long, and one is 39 feet long. They are both connected to a 6 foot wide by 12 foot long by 4 foot high enclosure over the sump inlet piping.
Material:	304 / 304L or approved equal
Fin size:	37.75 inches high by 2 inches thick by various lengths
Fin perforation opening	1/16 inch
Free area (%) approximately:	40
Seismic:	Class 1

TSP Baskets

Quantity	3
Overall dimensions (feet)	5 L x 5 x 1 H (approx.)
Material	TP 304 stainless steel
Wire Mesh	80
Quantity	2
Overall dimensions (feet)	5 L x 5 x 5 H (approximate)
Material	TP 304 stainless steel
Wire Mesh	80

6.3 SAFETY INJECTION SYSTEM

6.3.1 DESIGN BASIS

6.3.1.1 Functional Requirements

The safety injection system must function to supply core cooling in the unlikely event of a loss-of-coolant accident (LOCA) for all breaks in the reactor coolant system piping up to and including the equivalent of a double-ended break in the largest coolant pipe; i.e., up to a flow area of 19.2 square feet (Section 14.6.5). This cooling must be sufficient to ensure that consequences are within the acceptance criteria of 10 CFR 50.46. The cooling function must be maintained for extended periods of time following a LOCA – until decay heat is sufficiently low that recirculation of borated water is no longer required.

The safety injection system also must inject borated water into the reactor coolant system in order to limit fuel damage and increase shutdown margin following a main steam line rupture (Section 14.1.5).

6.3.1.2 Design Criteria

The safety injection system is designed in accordance with AEC General Design Criteria 35, 36, and 37 in Appendix A to 10 CFR Part 50 and General Criteria as described in Section 6.1.

6.3.2 SYSTEM DESCRIPTION

6.3.2.1 System

The safety injection system is treated as an integrated system consisting of three complementary subsystems; i.e., high pressure and low pressure injection subsystems which utilize centrifugal pumps, and a passive injection subsystem which maintains a reservoir of borated water under pressure in the safety injection tanks. Figure 6.1–1 shows the piping and instrumentation diagrams of the safety injection system.

The high pressure system is capable of delivering emergency coolant when the discharge pressure decreases below approximately 1200 psia. Two high pressure safety injection pumps take suction from two independent suction headers. These headers are initially supplied with borated water from the refueling water storage tank and after that tank is nearly exhausted, borated water is recirculated from the sump of the containment. The third high pressure pump is available as an installed spare.

The low pressure safety injection system utilizes two, low pressure safety injection pumps. Each of the two pumps is connected to one of the two independent suction headers to assure an adequate supply of borated water.

The water from the safety injection tanks recovers the core following a reactor coolant system blowdown to minimize core damage until the safety injection pumps can provide adequate water for reactor coolant. The tanks are designed to inject large quantities of borated water into the reactor coolant system immediately following a large pipe break. The water covers and cools the core, thereby limiting clad temperature and metal-water reaction (see Section 14.6.5. One tank is connected to each of the four reactor vessel inlet pipes. The driving head for water injection is provided by nitrogen gas pressure within the tanks at a minimum pressure of 200 psig. As the reactor coolant system pressure falls below tank pressure, check valves open in the line connecting each tank to the system. The tanks operate as a passive stored-energy safety feature; no outside power or signal is required for their operation. A remotely operated valve is provided to isolate the tanks during a normal depressurization of the reactor coolant system. Position of this valve is displayed in the control room. A vent isolation valve is provided on each tank to vent nitrogen into containment, when the tanks cannot be isolated during RCS depressurization following small break LOCA. A small drain valve controlled manually from the control room is used to drain any in-leakage from the reactor coolant system. The safety injection tanks are protected from overpressure by relief valves. Piping to each tank is arranged such that the operability of each tank can be demonstrated.

Safety injection actuation signal is initiated either when the pressurizer pressure drops below 1714 psia, or when the containment pressure rises above 4.42 psig. Diversity of the safety injection actuation signal is thus provided.

Upon initiation of safety injection, two high pressure and two low pressure safety injection pumps start and 12 safety injection line isolation valves receive signals to open, allowing water to be pumped from the refueling water storage tank into the reactor coolant system. After most of the water has been transferred from the tank, a continuous source of borated water is provided by recirculating containment sump water directly to the pump suctions. Recirculation is automatically initiated by low water level in the refueling water storage tank. Transfer to the recirculation mode may also be manually initiated.

The minimum time at which switch over to the recirculation mode (SRAS) occurs is based upon operation of two high pressure pumps, both low pressure pumps, and the two containment spray pumps. The system is designed to keep the core covered following initial safety injection. Following SRAS high pressure pump has sufficient capacity assuming spillage from a pipe break to maintain core water level.

In the recirculation mode, the high pressure safety injection pumps take suction directly from the containment sump. At the discretion of the operator, a portion of the cooled water from the containment spray system may be diverted to the suction of the high pressure injection pumps. This method of operation provides additional cooling margin, but is not necessary to meet core cooling requirements. However, there is no design basis whereby this flow path is utilized. The above description is maintained here to provide a basis for the physical plant design (i.e., valving).

The NPSH available to the high pressure safety injection (HPSI), low pressure safety injection (LPSI), and containment spray (CS) pumps has been calculated based on the following assumptions:

a. Pipe and fitting losses based on actual plant configuration;

b. Maximum and minimum combinations of HPSI, LPSI, and CS pumps operating during LOCA injection, recirculation, and boron precipitation control modes;

c. Assumed pressure drop for sump strainer and debris bed;

d. Containment pressure is equal to the saturation pressure of the containment sump water. For the recirculation modes, the containment sump temperature is 212°F and the containment pressure is 14.7 psia;

e. Minimum containment sump water level following SRAS for LBLOCA and SBLOCA.

The calculated available NPSH for the HPSI, LPSI, and CS pumps based on the above assumptions is greater than required NPSH for all operating modes evaluated.

The assumption that the containment pressure will be equal to the saturation pressure of the containment sump water was used in these NPSH calculation. In this method of calculating available NPSH, no credit is taken for increased containment pressure above the saturation pressure of the containment sump water.

The operator is not required to perform any immediate actions in the event of a LOCA except to reaffirm that automatic action of equipment and the notification and protection of plant personnel is under way. Operator actions following a LOCA are provided in plant Emergency Operating Procedures.

The safety injection water contains at least 1720 ppm of boron; consequently, the safety injection system also provides additional shutdown capability whenever the system is required to operate. This shutdown capability assists in maintaining the reactor subcritical following the rapid cooldown of the reactor coolant system caused by a rupture of a main steam line (see Section 14.1.5). The negative reactivity provided by the safety injection system exceeds the minimum required for cold shutdown.

The low pressure safety injection pumps are also used to supply coolant flow to remove heat from the reactor following reactor shutdown and to maintain a suitable temperature for refueling and maintenance operations (Refer to Section 9.3).

The system does not differ in any significant respect from those described in other C-E applications such as Calvert Cliffs (Docket Number 50-317 and 50-318) and Palisides (Docket Number 50-255).

The High Pressure Safety Injection system contains a discharge connection that facilitates portable diesel driven RCS Injection Pump deployment. This connection is a defense-in-depth design feature that is available for coping with an external loss of AC power (ELAP) event. The location of the discharge BDB RCS FLEX connection is shown on Figure 6.1–1, Sheet 2.

6.3.2.2 Components

high pressure Safety Injection Pump

The high pressure safety injection pumps are sized to ensure that one high pressure pump will keep the core covered at the start of recirculation, assuming spillage outbreak in one leg at atmospheric pressure.

The requirements for boron injection for the steam line break and the injection requirements for small break sizes are also analyzed to ensure that the pumps are adequately sized. The high pressure pumps are designed for the thermal transient conditions of 40°F to 300°F in ten seconds and 300°F to 40°F in ten seconds.

The high pressure pumps are seven-stage horizontal centrifugal units. Mechanical seals are used and are provided with leakoffs to the radwaste system which collects any leakage past the seals. The seals are designed for operation with a pumped fluid temperature of 350°F. To permit extended operation under these conditions, a portion of the pump fluid is externally cooled by the RBCCW system and recirculated to the seals. The pump motor is capable of starting and accelerating the pump to full speed with only 70 percent of rated voltage in eight seconds. The pumps are provided with drain and flushing connections to permit reduction of the radiation before maintenance. The pressure containing parts of the pump are stainless steel with internals selected for compatibility with boric acid solutions. The materials selected were analyzed to ensure that differential expansion during the design transient can be accommodated. The following inspections and tests were performed on the high pressure safety injection pumps:

a. materials used for pressure containing parts were inspected in accordance with techniques and acceptance standards of the Draft ASME Code for Pumps and Valves for Nuclear Power, Class II, dated November, 1968;

b. pressure-containing parts were hydrostatically tested in accordance with API Standard 610.

The pumps are provided with minimum flow protection to prevent damage resulting from operation against a closed discharge. One Millstone Unit 2 pump was subjected to the following transient tests:

The pump was operated under conditions where suction temperature both increased 260°F in ten seconds and dropped 260°F in ten seconds. The pump was operated at rated speed for over ten minutes following the test in order to demonstrate satisfactory survival of the transient.

A full-scale hydraulic test was performed on each Millstone Unit 2 pump assembly. All pump test setups, test procedures and instrumentation were in accordance with the Standards of the Hydraulic Institute and the ASME Power Test Code, PTC-8.2. This included verification of satisfactory operation at the stated NPSH. Figure 6.3–2 shows the pump performance obtained during the hydraulic testing.

The high pressure pump data are shown in Table 6.3-2.

The design temperature for the high pressure safety injection pumps is based upon the saturation temperature of the reactor coolant at the containment design pressure, about 300°F, plus a design tolerance of 50°F, resulting in design temperature of 350°F. The design pressure for the high pressure pumps is based upon the sum of the containment spray pump shutoff head and the shutoff head of the high pressure pump.

low pressure Safety Injection Pumps

The low pressure safety injection pumps are vertical, single-stage centrifugal units equipped with mechanical face seals backed up by a bushing, with a leakoff to collect the leakage past the seal. To permit extended operation at the design temperature of 350°F, a portion of the pump discharge is cooled by reactor building closed cooling water and is used to cool the seals. The pump motor is capable of starting and accelerating the pump to full speed with only 70 percent of rate voltage with eight seconds. The pumps are provided with drain and flushing connections to permit reduction of radiation levels before maintenance. The pressure-containing parts are fabricated from stainless steel; the internals are selected for compatibility with boric acid solutions. The pumps are provided with minimum flow protection to prevent damage when starting against a closed system. The low pressure pump data are summarized in Table 6.3-2.

The following inspections and tests were performed on the low pressure safety injection pumps:

a. materials used for pressure-containing parts were inspected in accordance with techniques and acceptance standards of Draft ASME Code for Pumps and Valves for Nuclear Power, Class II, dated November, 1968;

b. pressure-containing parts were hydrostatically tested in accordance with API Standard 610.

A full-scale hydraulic test of the pumps was performed. Figure 6.3–3 shows the pump performance obtained during the testing.

"One Millstone Unit 2 pump was subject to a transient test consisting of operating while its suction temperature was increased 260°F in less than ten seconds. The pump was operated at rated speed for over ten minutes following the transient to demonstrate satisfactory survival of the test."

The design temperature for the low pressure safety injection pumps is based upon the temperature of the reactor coolant at the initiation of shutdown cooling, about 300°F nominal, plus a design tolerance of 50°F, resulting in 350°F. The design pressure for the low pressure pumps is based upon the sum of the maximum pump suction pressure, which occurs at the initiation of shutdown cooling, and the pump shutoff head. This yields a nominal design pressure of 500 psig.

Safety Injection Tanks

The four safety injection tanks are used to flood the core with borated water following a depressurization as a result of a LOCA.

The volume of water in the safety injection tanks is selected so that the contents of three of the four tanks injecting into the reactor coolant system following the worst LOCA will cover the top of the core.

The tank gas/water fractions, gas pressure, and outlet pipe size are selected to ensure sufficient safety injection is available such that 10 CFR 50.46 criteria are met for all postulated LOCAs.

The tanks contain borated water at a minimum boron concentration of at least 1720 ppm. The tanks are pressurized with nitrogen at a minimum pressure of 200 psig.

Level and pressure instrumentation is provided to monitor the availability of the tanks during plant operation. The position of the motor operated isolation valves (SI 614, 624, 634 and 644) between the safety injection tanks and headers is displayed by the use of lights on the main control boards. An alarm is annunciated if any of these valves are closed. Signals are also provided to open any of these valves on SIAS, or when RCS pressure during plant heatup increases to approximately 280 psig.

The tanks are provided with vent isolation valves SI-613, 623, 633 and 643 which are assisted by nitrogen from the tanks for remote operation.

Provisions have been made for sampling, filling, draining, venting and correcting boron concentration. The tanks are carbon steel internally clad with Type 304 stainless steel. Design construction and overpressure protection are in accordance with the ASME Code Section III, Class C, 1968 Edition through Summer 1969 Addendum. The data summary for the safety injection tanks is given in Table 6.3-2.

Shutdown Cooling Heat Exchanger

The shutdown cooling heat exchangers are used to remove decay and sensible heat during plant cooldowns and cold shutdowns. The units are sized to hold refueling water temperature (130°F) with the design RBCCW temperature (95°F) 27.5 hours after shutdown following an infinite period of operation.

The units are further specified to accept a 40°F to 289°F transient in ten seconds when the containment spray pump suction is switched to the containment sump. During this period of operation, the tube-side flow is specified as the output of two containment spray pumps and the reactor building closed cooling water inlet temperature is specified at 115°F. The units are designed and constructed to the standards of ASME, Section III, Class C; and TEMA Class R requirements. The units are of a U-tube design with two tube-side passes and one shell-side pass. The tubes are austenitic stainless steel and the shell is carbon steel.

The design parameters for the shutdown heat exchangers are found in Table 6.3-3, Section 6.3. Data on containment spray pump operation is available in Table 6.4-1, Section 6.4. Data on reactor building closed cooling water system operation is available in Table 9.4-1, Section 9.4. A description of integrated system performance during a Main Steam Line Break or LOCA is contained in Section 14.8.2.

Table 9.3-1 shows the design cases for the shutdown heat exchangers for accident transients.

The design temperature and pressure for the shutdown cooling heat exchangers are compatible with the design temperature and pressure for the low pressure safety injection pumps (see Section 6.3.2.2).

Safety Injection Piping

The safety injection system piping is fabricated of austenitic stainless steel and conforms to the standards set forth in ANSI B31.7. Flexibility and seismic loading analyses have confirmed the structural adequacy of the system piping.

Piping is shop fabricated in accordance with the ANSI B31.7, Nuclear Power Piping. The piping is field erected and tested in accordance with ASME Section III, 1971. Material and shop welds were inspected, tested and documented in accordance with the applicable class of B31.7. Valves are manufactured in accordance with the Draft ASME Code for Pumps and Valves for Nuclear Power, dated November 1968. The material and welds were inspected, tested and documented to the same code.

6.3.3 SYSTEM OPERATION

6.3.3.1 Emergency Conditions

A condition which causes a sufficiently low pressurizer pressure or high containment pressure will result in a safety injection actuation signal (SIAS). This signal will start the two high pressure safety injection pumps, both low pressure safety injection pumps, open 12 safety injection system isolation valves and close the four check valve leakoff lines at the safety injection tanks. (The SIAS also performs some functions in the Chemical and Volume Control System; see Figures 7.3–2A through 7.3–2D.) The 8 HPSI injection throttle valves are manually positioned to the desired open position.

When reactor coolant system pressure falls below approximately 1200 psia, the high pressure safety injection pumps start delivering flow through both high pressure headers.

If reactor coolant pressure falls below approximately 200 psig, the passive pressurized safety injection tanks will start delivering borated water into each cold leg along with the low pressure safety injection pumps. In the event of a Small Break LOCA, the Safety Injection Tanks (SITs) will begin discharging borated water into the RCS when the RCS pressure falls below approximately 200 psig. During recovery from a Small Break LOCA, once the operators have control over the plant cooldown and depressurization, it is undesirable to have the SITS completely discharge to the point where nitrogen is introduced into the RCS. Therefore, the operators are directed to close the SIT outlet valves once RCS pressure is reduced.

If a single failure loss of power to the SIT outlet MOV(s) was to occur, the SIT(s) would be unisolable from the control room. Therefore, the operator would be directed to operate the SIT venting system and depressurize the SIT(s) by bleeding off nitrogen cover pressure.

The safety injection pumps initially draw borated water from the refueling water storage tank (RWST). This tank has sufficient water volume to supply safety injection flow assuming two high pressure and two low pressure safety injection pumps and two containment spray pumps are running. When the refueling water storage tank is nearly empty, a sump recirculation actuation signal (SRAS) from refueling water storage tank water level closes the minimum flow recirculation lines, opens the isolation valves in the two lines from the containment sump and shuts down the low pressure safety injection pumps. The refueling water storage tank outlet valves remain open initially during the transfer to the recirculation mode to preclude the loss of supply to a high pressure safety injection pump in the unlikely event the isolation valve in the containment sump line should experience delay in opening. Back flow through either refueling water storage tank suction line is prevented by check valves. In addition, the operator may manually close the refueling water storage tank outlet valves after verifying the opening of the containment sump line valves. The earliest automatic recirculation (SRAS) would occur is when 2 LPSI, 2 HPSI, and 2 CS pumps are in operation following a SIAS and the RWST contains the minimum Technical Specification volume. The recirculation mode can also be initiated manually by the operator.

The ESF pump minimum-flow recirculation line contains two series air-operated stop valves whose SRAS function is to close and prevent sump water from being returned to the RWST.

These valves are provided with key-lock switches in the Control Room to disable the valves open during normal operations to ensure a recirculation flow path for the low pressure safety injection pumps. The valves are enabled to be closed by placing the key-lock switches to “operate” prior to recirculation following a LOCA.

In the recirculation mode the high pressure safety injection pumps take suction from the containment sump. The safety injection flow spilling from the break in the reactor coolant system is cooled by mixing in the containment sump with the cooled containment spray water.

During normal operation, the containment sump recirculation lines between motor operated valves (2-CS-16.1A and 2-CS-16.1B) and the high pressure safety injection pumps (See Figure 6.1–1) will be filled with stagnant water. The portion of piping between the containment sump inlets and the motor-operated valves is designed to be full of water.

These portions of line will flood gradually as the sump level rises. In portions of the lines where air pockets would form, vent and fill connections are provided.

Figure 6.3–1 shows the routing of the recirculation lines and the provisions for venting air that may be trapped on these lines. The internal dimensions of the piping and the valves are specified in Table 6.3-5.

The analysis of the design basis accident for the safety injection system (Section 14.6.5) is performed assuming that only a minimum amount of the system components function during the LOCA. Minimum safety injection is defined as follows:

a. For a cold leg large break LOCA, the entire contents of one of the four passive safety injection tanks spill through the break and is not available for emergency core cooling. For a Small Break LOCA downstream of the ECCS Injection location, ECCS is injected into the broken loop and the portion of this injection which spills out the break is calculated as a part of the transient simulation. For a hot leg break, all four safety injection tanks discharge into the intact cold legs;

b. One of the two online, high pressure safety injection pumps functions. For a cold leg large break, the flow from one of the four injection lines is assumed to be spilled via the break. For a cold leg small break, flow is injected into the broken loop and the portion of this injection which spills out the break is calculated as part of the transient simulation. For a hot leg break, the entire pump discharge reaches the core;

c. One of the two low pressure safety injection pumps functions. For a cold leg break, one-half of this pump’s discharge reaches the core. For a hot leg break, the entire discharge from this pump reaches the core.

The assumed maximum delay time for operation of the safety injection pumps is 45 seconds after the SIAS, a 45 second delay for the LPSI system and a 25 second delay for the HPSI system. This is based on the assumption that outside power has been lost and includes an allowance for the start up and loadings of the emergency diesel generators. These and other conservative assumptions are given in the Loss of Coolant Analysis, Section 14.6.5.

The safety injection system can provide both long term cooling and boron precipitation control in the event of a LOCA. This is accomplished by simultaneous injection to both the hot and cold legs of the RCS. Hot leg injection is necessary for cold leg breaks to provide a flushing flowpath through the core region such that boric acid solubility limits are not reached during post-LOCA boiloff periods. The preferred method of boron precipitation control is to employ one LPSI pump to inject via the shutdown cooling system warmup and return line piping, past 2-SI-400, 2-SI-709, 2-SI-651 and 2-SI-652, into the RCS hot leg. Cold leg injection would be provided by a HPSI pump and also by LPSI flow diverted through at least one of the four LPSI injection lines. No more than two of the LPSI injection valves 2-SI-615, 625 and 645 are to be open in this configuration and valve 2-SI-635 cannot be open in combination with any other open LPSI injection valve.

An alternate method of providing boron precipitation flushing flow is to use HPSI pump P-41A to inject via the charging system header to the pressurizer auxiliary spray line and thus to the hot leg through the pressurizer surge line. This alternate alignment is provided by flow past manually opened 2-CH-440 and 2-CH-340 through the regenerative heat exchanger, and past 2-CH-517 to the auxiliary spray line. Normal HPSI injection lines to the cold leg from pump P-41A are blocked by closing 2-SI-617, 627, 637 and 647. In this arrangement, cold leg injection is accomplished by the LPSI system.

Adequate flushing flow to preclude boron precipitation as well as adequate long term cooling are provided by either the preferred LPSI or alternate HPSI hot leg injection methods.

6.3.3.2 Cold Shutdown and Refueling

To obtain cold shutdown, operation of the system is discussed in Section 9.3. During the refueling, the shutdown cooling heat exchangers are aligned with the low pressure safety injection pumps and used to cool the refueling water.

6.3.4 AVAILABILITY AND RELIABILITY

6.3.4.1 Special Features

The design basis and system requirements during a DBI are met with the operation of the safety injection tanks and one high pressure and one low pressure safety injection pump, delivering rated flow and assuming spillage through the break as defined in Section 6.3.3.1. During recirculation, one high pressure safety injection pump has sufficient capacity to maintain the water level in the reactor vessel above the core.

Ability to meet the core protection criteria is assured by the following design features:

a. A high capacity passive system (safety injection tanks) which requires no power source and will supply large quantities of borated water to rapidly recover the core after a major LOCA up to a break of the largest reactor coolant system pipe.

b. low pressure and high pressure pumping and water storage systems with internal redundancy which will inject borated water to provide core protection for reactor coolant system break sizes equal to and smaller than the largest line connected to the reactor coolant system (the 12 inch pressurizer surge lines or the shutdown cooling and safety injection lines). The pumping systems also provide borated water to keep the core covered and to continue cooling the core after the passive water supply has been exhausted. In addition, the high pressure system will remove reactor core decay and sensible heat during long term operation after the reactor coolant system rupture. Instrumentation and sampling provisions allow monitoring of the recirculated coolant.

c. Separated pump rooms and redundant pumping systems which will permit minimum safety features equipment to operate should one pump room flood in the event of a passive failure during long term operation.

d. Redundant on site power supplies in the form of two emergency diesel generators, each of which has sufficient capacity for minimum safety features operation.

e. All active components which must function individually for the system to meet the performance criteria stated for core protection can be tested during reactor operation. Instrument sensors are tested for function at operating conditions. In addition, extensive shop and preoperational tests are performed to verify adequate component and system operation.

f. Most of the active components are located outside the containment where they are protected from incident-generated missiles and from post-incident environmental conditions. Those active components located inside the containment need only operate for a short time period after the accident.

g. The four injection lines are arranged such that movement of a ruptured reactor coolant pipe will not cause a subsequent failure of injection lines in non ruptured loops. The maximum movement of the reactor coolant pipe at the injection nozzle in the non ruptured loop will not damage the injection line.

h. The safety injection system have been designed to meet the single failure criterion. This includes the fluid systems and the electrical control and instrument systems. All pumps and critical power-operated valves can be actuated from their respective switch gear or control centers.

i. All components, piping, cabling structures, power supplies, etc., in the safety injection support systems are designed to Class 1 seismic criteria.

Effectiveness of the safety injection system to satisfy the criteria stated for core protection can be shown by the blowdown and refill transient curves following a LOCA. This analysis is presented in Section 14.6.5, Loss-of-Coolant Accident. The analysis shows that 10 CFR 50.46(b), “Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Plants,” is satisfied by this design.

The high pressure safety injection system is designed to minimize the amount of equipment which must operate when a safety injection signal is received. All valves not required to operate on initiation of safety injection are either isolated from the safety injection flow path or locked in the safety injection position during operation. Administrative controls ensure that the locked valves are in the correct position.

Three parallel pumps are provided in the high pressure system. One pump is available as a spare. These pumps are located outside the containment. The pump rooms are in a controlled access area.

The pump room location outside of the containment is most favorable for extended operation and equipment life following a major LOCA. This location is accessible for service and inspection of the engineered safety features systems components during plant operation and during the period of long term cooling following the postulated LOCA.

The pumps are appropriately segregated in separate watertight rooms. This arrangement permits access to and operability of those pumps required for minimum safety features operation.

Redundant flow paths are provided from the discharge of the high pressure injection headers. These headers, in turn, both supply the four individual safety injection lines, one leading to each cold leg of the reactor coolant system. Normally closed, power-operated valves isolate the two high pressure safety injection headers from each other and also provide the capability to switch the discharge from the pumps to either header.

Normal plant operating procedures include routine testing to ensure the operability of the pumps. The attention given to the selection of these pumps, the redundancy of power supplied, the design margins, and the fact that multiple pumps are installed assures a high degree of pump availability.

The high pressure safety injection valves are designed for 2735 psig. These valves are located outside of the containment and are thus not subjected to the environmental conditions existing in the containment following any LOCA. The attention given to the selection of these valves, design margins, and the fact that eight high pressure safety injection valves are in parallel assure a high degree of valve availability. Both header supply valves are normally open.

Four high pressure safety injection valves on one header are powered from one emergency power bus. The remaining four high pressure safety injection valves are powered from the second emergency power bus. The valves are equipped with remote position indicators in the control room. The 8 HPSI injection throttle valves are manually positioned to the desired open position and do not open further on an actuation signal.

During recirculation the high pressure safety injection pumps continue to operate, taking suction from the containment sump. The pump recirculation lines, the heat exchangers, the containment spray pumps, and the recirculation suction headers are arranged to provide two independent flow paths. The low pressure safety injection pumps can also be used for recirculation, if necessary.

The low pressure safety injection system is also designed to minimize the amount of equipment which must operate when a safety injection signal is received. All valves not required to operate on initiation of safety injection are either isolated from the safety injection flow path or locked in the safety injection position during operation. Administrative controls insure that the locked valves are in the correct position.

Normal plant operations, augmented by routine testing, insure the operability of the pumps. The attention given to the selection of these pumps, the redundancy of power supplied, the design margins, and the fact that two pumps are supplied assures a high degree of pump availability.

The power-operated, low pressure injection valves are located outside of the containment and are thus not subjected to the environmental conditions existing in the containment following any LOCA. The attention given to the selection of these valves, design margins, and the fact that four low pressure safety injection valves are in parallel assure a high degree of valve availability. The safety injection valves are open automatically on initiation of safety injection.

Should the inadvertent closure of valve 2-SI-306 in the Low Pressure Injection System line occur, it would result in the inability of that system to perform its function following a LOCA. It is equipped with both a power (pneumatic) actuator and a manual overriding actuator connected to opposite sides of the valve plug shaft. Each half of the valve plug shaft is splined into the valve plug. The power actuator is a spring-to-open diaphragm type. To prevent inadvertent closure by this device, solenoid valve HV-306, which is located in the pneumatic signal line to the diaphragm of the actuator, will be electrically disabled during plant operation to prevent air pressure from reaching the diaphragm. As a result, the actuator spring will hold the valve plug in an open position. Spring force is sufficient to hold the valve in the open position. To provide additional assurance that the valve will not close, the manual operator on the opposite side of the shaft is pinned and locked to the handwheel to prevent movement of the valve plug due to the mechanical advantage of the handwheel drive nut. Also the handwheel is locked in position to prevent inadvertent operation. Thus, multiple means are provided to assure that valve 2-SI-306 will remain in an open position during all operations except shutdown cooling and that it will allow the system to perform its function following a LOCA.

The four safety injection tanks comprise a completely independent and redundant source of low pressure injection water which requires no outside signal or source of power operation. The analysis in Section 14.6.5 shows that core recovery will occur for all postulated LOCAs such that 10 CFR 50.46 acceptance criteria are met.

A failure modes and effects analysis has been performed of the safety injection system. The analysis for both the injection and recirculation modes of operation can be found in Table 6.3-6.

From the analysis, it has been concluded that the SIS can withstand any single failure as defined therein and still perform its intended function.

There is no undue risk to the health and safety of the public from the failure of a single active component during the injection mode of operation or from a single failure of any passive or active component during the recirculation mode of operation.

The failure mode analysis presented in Table 6.3-6 was performed using the following assumptions.

a. The SIS is composed of the electrical, instrumentation and fluid segments. In compliance with single failure criteria, only one failure is assumed to occur in the system; e.g., a failure of a diesel generator cannot occur simultaneously with a safety injection valve failure.

b. Only one active failure is considered for injection mode of the safety injection operation. For the recirculation mode, the single failure considered can be either active or passive.

c. Failure to respond to an external signal is considered an active failure.

d. Failure of valve internals, including check and stop valves, is a passive failure. Passive failures are considered in the recirculation phase only, no earlier than 24 hours after an accident.

e. The transition to the recirculation mode of operation occurs upon initiation of recirculation from the sump.

f. The analysis considers only failures or malfunctions which occur during the time period of SIS operation. Failures or malfunctions that might occur during normal reactor operation are not considered.

Abbreviations used in the Table 6.3-6 are:

CRI - Control Room Indication

HPSI - high pressure Safety Injection

LPSI - low pressure Safety Injection

SIAS - Safety Injection Actuation Signal

SRAS - Sump Recirculation Actuation Signal

RWST - Refueling Water Storage Tank

RCS - Reactor Coolant System

SIS - Safety Injection System

An administrative error analysis has been performed which evaluates the effect of improper positioning of administratively controlled safety injection system valves. The results of this analysis can be found in Table 6.3-7.

The HPSI and LPSI systems may be relied upon to provide long term cooling and boron precipitation flushing flow in the event of a LOCA. A break size of sufficient magnitude that the reactor coolant system is not filled at 8 to 10 hours after the start of the accident requires a simultaneous hot and cold leg injection alignment to provide both long term cooling and boron precipitation control because the break location is unknown.

Operator action both inside and outside the control room would be required to align for simultaneous injection.

The preferred method of boron precipitation control is to have LPSI pump injection to the RCS hot leg past opened valves 2-SI-400, 709, 651 and 652 in the shutdown cooling system warmup and suction piping. Some of the LPSI flow would be diverted to the cold leg by having at most two of valves 2-SI-615, 625 and 645 open. LPSI injection valve 2-SI-635 cannot be open in combination with any other open LPSI injection valve. The ability to align an alternate vital power source to 2-SI-651 in the shutdown cooling return line ensures single-failure criteria are met when aligning for boron precipitation control. Cold leg injection is provided by a HPSI pump and the diverted LPSI flow.

An alternate method of boron precipitation and long term cooling can be accomplished by aligning HPSI pump P-41A to the charging header past valves 2-CH-440, 340, the regenerative heat exchanger and 2-CH-517 for injection to the RCS hot leg through the pressurizer auxiliary spray line and surge line. The ability to align an alternate vital power source to 2-CH-517 and 2-CH-519 in the charging lines ensures single-failure criteria are met.

Adequate margin to HPSI and LPSI pump NPSH exists for the various boron precipitation control alignments.

A failure modes and effects analysis has been completed for post-LOCA periods of combined hot and cold leg injection necessary for boron precipitation control and long term cooling. The results of this analysis are presented in Table 6.3-8.

See Section 14.6.5.3 for a description of boron precipitation control and long term cooling under post-LOCA conditions.

6.3.4.2 Tests and Inspections

Each safety injection pump is shop tested for hydraulic performance at sufficient head-capacity points to generate complete performance curves. Figures 6.3–2 and 6.3–3 show the resultant curves for one high pressure and one low pressure safety injection pump, respectively.

Nondestructive examinations are performed on all pressure-retaining components of each safety injection pump and tank in accordance with the Draft ASME Code for Pumps and Valves for Nuclear Power, Class II, 1968, and ASME Boiler and Pressure Vessel Code, 1968 Edition through Summer 1969 Addendum, Section III, Class C, respectively. The safety injection system undergoes a preoperation test prior to plant startup. The test procedure is described in Chapter 13.

The following preoperational tests and checks are planned:

1. Each of the high pressure safety injection (HPSI) pumps will be capacity tested while discharging into the reactor vessel through the HPSI injection lines. Tests will be run with various discharge heads to verify pump capacity over the range of break sizes where its function is of most importance. During these tests, flow distribution through the four HPSI line flow orifices will be checked.

2. Each of the low pressure safety injection (LPSI) pumps will be capacity tested while discharging into the reactor vessel through the (LPSI) injection lines. Tests will be run with discharge heads associated with maximum, design and minimum recirculation flow rates. During these tests, flow distribution through the four LPSI line flow orifices will be checked.

3. Each diesel generator will be tested to check its ability to pick up and operate ECCS equipment.

4. A simulated SIAS signal will be used to verify functional operation of all valves and pump breakers.

5. A simulated sump recirculation actuation signal (SRAS) will be impressed on each detector and functional operation of all valves and pump breakers.

6. Each Safety Injection tank will be tested by allowing its contents to be discharged into the reactor. Tank volume and pressure change versus time will be checked.

Periodic tests and inspections of the Safety Injection System components and subsystems are performed to insure proper operation in the event of an accident. The scheduled tests and inspections are necessary to verify system operation reliability since during normal plant, safety injection system components are aligned for emergency operation and serve no other function. The tests defined permit a complete checkout on the subsystem and component level during normal plant operation. Satisfactory operability of the complete system may be verified during normal scheduled refueling shutdowns. The test data recorded during the periodic testing provides positive assurance of the system to perform its intended function. Deteriorated performance will be detected by comparison of the periodic performance test data to the preoperational test data.

Routine operational testing of major portions of the logic circuits, pumps and power-actuated valves in the safety injection system is described in Section 7.3.

The pumps are located outside the containment for access and to permit maintenance during normal plant operations. A recirculation line is provided on the discharge of each pump. Periodic testing will be performed by recirculating water back to the refueling water storage tank.

Surveillance requirements to verify that the safety injection system will respond promptly and perform its intended function, if required, are given in Sections 4.5.1 and 4.5.2 of the Technical Specifications.

TABLE 6.3-1 OMITTED

TABLE 6.3-2 PRINCIPAL DESIGN PARAMETERS OF THE SAFETY INJECTION SYSTEM

Injection Water Boron Concentration (ppm)	1720
High-Pressure Safety Injection Pumps	
Manufacturer	Ingersoll-Rand
Quantity	3
Type	Seven-stage Horizontal Centrifugal
Motor Voltage, volts	4160
Design Pressure, psig	1600
Design Temperature, °F	350
* Design Flow (per pump), gpm (excluding minimum flow)	315
* Design head, ft.	2500
Pumped fluid	Water (Borated)
Temperature of Pumped Fluid, °F	35-300
Shutoff Head, ft	2850
* Maximum Flow, gpm	640
* Head at Maximum Flow (one pump), ft	1620
Material	ASTM-A-351 Gr CF8M
Horsepower (motor)	400
Shaft Seal	Mechanical
Acceleration Time, seconds (at rated voltage)	4
Minimum Flow, gpm	20
* NPSH Available (minimum), ft (at 640 gpm)	21.9
* NPSH Required at 640 gpm, ft	20
Design Maximum Suction Pressure, psig	250
Low-Pressure Safety Injection Pumps	
Quantity	2
Type	Single stage Vertical Centrifugal
Motor Voltage, volts	4160
Manufacturer	Ingersoll-Rand
Design Pressure, psig	500

TABLE 6.3-2 PRINCIPAL DESIGN PARAMETERS OF THE SAFETY INJECTION SYSTEM (CONTINUED)

Design Temperature, °F	350
Design Flow (per pump), gpm (excluding min. flow)	3000
* Design Head, ft	350
* Pumped Fluid	Water (Borated)
Temperature of Pumped Fluid, °F	35-300
Shutoff Head, Ft	420
* Maximum Flow, gpm	4500
* Head at Maximum Flow (one pump), ft	275
Basic Material	ASTM A351 GR CF8M
Horsepower	400
Seals	Mechanical
Acceleration Time, seconds (at rated voltage)	4
* NPSH Available (minimum), ft (at 3000 gpm)	25
* NPSH Required at 3000 gpm, ft	13
Design Maximum Suction Pressure, psig	300
Minimum Flow, gpm	100
Safety Injection Tanks	
Manufacturer	Air Preheater Co.
Quantity	4
Total Volume, each, ft^3	2019
Water Volume, ft^3, nominal	1137
Water Volume, ft^3, minimum	1080
Design Pressure, psig	250
Operating Pressure, psig, nominal	215
Operating Pressure, psig, minimum	200
Design Temperature, °F	200
Operating Temperature, °F	120
Relief Valve Setpoint, psig	250
Height, inches	399.75
Outside Diameter, inches	109 3/4

TABLE 6.3-2 PRINCIPAL DESIGN PARAMETERS OF THE SAFETY INJECTION SYSTEM (CONTINUED)

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* The pump flows, heads, and NPSH values presented in this table are based on the original design specifications. The pumps will actually operate over a range of conditions during safety injection, sump recirculation, long-term cooling and boron precipitation control post LOCA. System hydraulic and NPSH analyses have been performed for these operational modes based on the pump design and degraded capacities.

Note: The original design basis for available NPSH was based on a total sump recirculation flow on one suction header of 2980 gpm (consisting of 1 CS pump flow of 1700 gpm and 2 HPSI pumps flow of 640 gpm each).

TABLE 6.3-3 SHUTDOWN COOLING HEAT EXCHANGER DATA

Manufacturer	Engineers & Fabricators, Inc.
Quantity	2
Type	Shell and Tube
Codes	
Tube Side, Shell Side	ASME Section III, Class C 1968 Edition through Summer 1969 Addendum
Tube Side	
Fluid	Reactor Coolant, 1.5 wt. % Boric Acid
Design Pressure, psig	500
Design Temperature, °F	400
Maximum pressure drop at rated flow, psi	10
Materials	Austenitic Stainless Steel
Shell Side	
Fluid	Reactor Building Closed Cooling Water
Design Pressure, psig	150
Design Temperature, °F	250
Maximum pressure drop at rated flow, psi	10
Material	Carbon Steel
Heat Exchanger Design Parameters (1) (Shutdown Cooling Mode)	
Tube Side	
Flow, Million lb/hr	1.5
Inlet Temperature, °F	130
Outlet Temperature, °F	111.9
Shell Side	
Flow, Million lb/hr	2.41
Inlet Temperature, °F	95
Outlet, Temperature, °F	106.3
Heat Load, Million Btu/hr	27.2
Service Transfer Rate, Btu/hr - ft^2 - °F	256

(1) Refer to Table 9.3-1 for shutdown cooling minimum design basis parameters.

TABLE 6.3-4 OMITTED

TABLE 6.3-5 INTERNAL DIMENSIONS OF CONTAINMENT SUMP RECIRCULATION PIPING AND VALVES

Pipe

Component	Internal Diameter (inches)
24"-HCB-1	23.5
8"-HCB-1	8.329
8"-GCB-3	8.125
6"-GCB-3	6.357

Valves

Component	Internal Diameter (inches)
2-CS-16.1A, B	23.25
2-CS-15A, B	23.5
2-SI-401, 410	8.0
2-SI-402, 470	6.0
2-SI-411, 412	8.0

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
HPSI Loop Flow Indicator (4)	Malfunction	None	Comparison of Flow to Other Flow Indicators and Valve Position Indicators	CRI	
HPSI Valve (8)	Fails to open	None	Flow Indication, Pressure Indication, Valve position Indication	CRI	The valves are normally open and positioned in the throttled position.
Pump Discharge Isolation Valve (3)	None	None, "Locked Open" valve	N/A *	N/A *	
Pump Minimum Flow Recirculation Stop Valve (3)	None	None, "Locked Open" valve	N/A *	N/A *	
HPSI Pump (3)	a. Fails to Start	Loss of HPSI flow from 1 pump	Pump Motor Lights, Header Pressure	CRI	Flow from at least one pump available.
	b. Stops	Loss of HSPI flow from 1 pump	Pump Motor Lights, Header Pressure	CRI	Flow from at least one pump available.
Pump Suction Isolation Valve (2)	None	None, "Locked Open" valve	N/A *	N/A *	

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION (CONTINUED)

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
HPSI Discharge Check Valve (4)	Fails Closed	1. Valve in ruptured loop-no effect.	Flow Indication, Pressure Indication	CRI	Flow is sufficient to cool core.
		2. Valve in nonrupture loop --at least 67% of HPSI flow from 2 pumps reaches core.			
HPSI Loop Flow Indicator (4)	Malfunction	None	Comparison of flow to other flow indicators and Valve Position Indicators	CRI	Balancing of flow is not essential during long-term cooling.
Check Valve Associated with HPSI Valves (8)	Fails Closed	1. Valve in ruptured loop--no effect.	Flow Indication, Pressure Indication	CRI	Flow is sufficient to cool core.
		2. Valve in nonruptured loop--at least 70% of HPSI flow from 2 pumps reaches core			

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION (CONTINUED)

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
HPSI Valve (8)	Fails Closed	1. Valve in ruptured loop--no effect.	Flow Indication, Pressure Indication	CRI	
		2. Valve in nonruptured loop but flow to core still greater than minimum required	Valve Position Indication		
HPSI Pump Discharge Relief Valve (3)	Fails Open	Partial Loss of HPSI flow	None	CRI	Loss of flow will be insignificant.
Pump Discharge Isolation Valve (3)	Fails Closed	Loss of HPSI flow from 1 pump	Flow Indication, Pressure Indication	CRI	At least 1 HP pump available. Each pump is full capacity.
Pump Minimum Flow Recirculation Stop Valve (3)	Fails Closed	None, valve is not necessary after RAS	None		
Pump Discharge Check Valve (3)	Fails Closed	Loss of HPSI flow from 1 pump	Flow Indication, Pressure Indication	CRI	At least 1 HP pump is available.

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION (CONTINUED)

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
HPSI Pump (3)	a. Stops	Loss of HPSI flow from 1 pump	Pump Motor Lights, Header Pressure	CRI	At least 1 HP pump is available
	b. Seal Failure	Slight reduction in output from affected pump	Sump Level Alarm	CRI	At least 1 HP pump is available
	c. Loss of Seal Coolant	Loss of HPSI flow from 1 pump	None	None	At least 1 HP pump is available
Pump Suction Isolation Valve (2)	Fails Closed	Loss of suction to 1 HP pump	Pressure Indication, Possible Flow Indication	Local CRI	At least 1 HP pump is available
Pump Suction Check Valve (2)	a. Fails Closed (no cooled suction)	Loss of suction to 1 pump	Pressure Indication, Possible Flow Indication	CRI	At least 1 HP pump is available
	b. Fails Open (cooled suction)	Loss of suction to 1 pump	Flow Indication, Pressure Indication	CRI	At least 1 HP pump is available
Cooled Suction Isolation Valve (2)	Fails Closed when cooled suction is desired	Loss of cooled suction to the suction header	Pressure Indication, Flow Indication	CRI	Pump design is based on suction from the containment sump without use of the shutdown heat exchangers.

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION (CONTINUED)

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
Safety Injection Pump Minimum Flow Recirculation Stop Valve (2)	Fails Open	None	Valve Position Indicator	CRI	2 Valves are in series.
LPSI Valve (4)	Fails to Open	1. Valve in ruptured loop - no effect	Valve Position Indication	CRI	50% of flow from one L.P.S.I. pump is adequate
		2. Valve not in ruptured loop - at least 50% of LP flow reached core	Flow Indication, Pressure Indication		
L.P.S.I. Segment to Shutdown Cooling Heat Exchange Isolation Valve (1)	None	None	N/A *	N/A *	
Shutdown Cooling Flow Control Valve (1)	None	None	N/A *	N/A *	Failed open valve
Pump Discharge Isolation Valve (2)	None	None	N/A *	N/A *	Locked open valves
Pump Minimum Recirculation Stop Valve (2)	None	None	N/A *	N/A *	Locked open valves

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION (CONTINUED)

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
LPSI Pump (2)	a. Fails to Start	Loss of L.P.S.I. flow from one pump	Pump Indication Lights	CRI	Other pump starts.
	b. Stops	Loss of L.P.S.I. flow from one pump	Flow Indication	CRI	Other pump starts simultaneously. Each pump is full capacity
	c. Fails to stop with the SRAS	Pumps may cavitate unless flow is reduced	Pump Indication Lights, Flow Indicator Fluctuations	CRI	Operator may stop pumps or close LPSI valves. Operator action ensures pressure drop in ECCS suction strainer remains within design limits.
Pump Suction Isolation Valve (2)	None	None	N/A *	N/A *	Locked open valves
S.I. Tank Isolation Valve (4)	a. None	None	N/A *	N/A *	Valves are maintained open with closing coil removed
	b. Fails to close following Small Break LOCA	Intrusion of nitrogen into the RCS at low RCS pressure	SI tank level and pressure; pressurizer pressure < 600 psia	CRI	Vent Isolation valves on affected tanks can be operated remotely to release nitrogen into containment
Drain and Fill Isolation Valve (4)	None	None, valve is "Fail Closed" valve	N/A *	N/A *	
Check Valve Leakage Control Valve (4)	None	None, valve is "Fail Closed" valve	N/A *	N/A *	

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION (CONTINUED)

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
S.I. Tank Purge Valve (4)	None	None, valve is "Fail Closed" valve	N/A *	N/A *	
N_2 Supply Line Stop Valve	None	Valve is "Fail Closed" valve	N/A *	N/A *	
S.I. Tank Vent Isolation Valves	a. None	None, valves are "Fail Closed"	N/A *	N/A *	
	b. Fails to open to bleed nitrogen following SBLOCA	Nitrogen intrusion into RCS	Valve position indication	CRI	Single failure of SIT outlet valve already considered. Therefore, this failure is not applicable
Refueling Water Storage Tank, Tank Isolation Valve (2)	Inadvertently closed during use of tank	Loss of suction to affected pumps	Valve Position Indication, Flow Indication	CRI	Second full capacity suction line available. Potential damage to isolated pumps.
Sump Isolation Valve (2)	Inadvertently opened during use of refueling water tank	None. Check valve restricts flow	Valve Position Indication. Possible loss of flow	CRI	Operator Error. Operator should detect abnormal valve position by indicator lights.
RWS Tank Check Valve (2)	a. Fails Closed	None during long-term cooling	None	None	
	b. Fails Open	None-Isolation valve in series stops flow to RWS tank	None	None	

TABLE 6.3-6 SAFETY INJECTION SYSTEM FAILURE MODE ANALYSIS HIGH PRESSURE SAFETY INJECTION (CONTINUED)

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	EFFECT ON SYSTEM	METHOD OF DETECTION	MONITOR	REMARKS
RWS Tank Isolation Valve (2)	Inadvertently Open during recirculation cooling	None - Check valve restricts flow to RWS tank	Valve Position Indication	CRI	Operator error. Operator should detect position indicator light and close valve.
Sump Isolation Valve (2)	Inadvertently closed during recirculation cooling	Loss of suction to one pump header	Valve Position Indication	CRI	Operator error. Full flow is available through parallel leg. Operator should detect position indicator light and open valve. Potential damage to isolated pumps.
Suction Line Between Containment Wall and Isolation Valve (2)	Leakage	None - Piping Encapsulated	None	None	
Sump Check Valve (2)	a. Fails Closed	Loss of suction to one pump header.	None	None	Full flow is available through parallel leg.
	b. Fails Open	None	None	None	Potential damage to isolated pumps.

* Not applicable where no failure mode is indicated.

TABLE 6.3-7 ADMINISTRATIVE ERROR ANALYSIS-SAFETY INJECTION SYSTEM VALVES

Valve Number	Normal Position	Administrative Error Position	Result
SI-306	Locked Open	Closed	Low pressure safety injection flow not available.
SI-402	Locked Open	Closed	Closure of one of these valves will result in no flow from its associated high-pressure safety injection (HPSI) pump. One pump remains.
SI-406	Locked Open	Closed	
SI-428	Locked Open	Closed	
SI-470	Locked Open	Closed	
SI-653	Closed	Open	Loss of isolation between two HPSI headers. No effect during injection.
SI-655	Closed	Open	
SI-411	Closed	Open	Separation of the two redundant HPSI paths is lost during recirculation.
SI-412	Closed	Open	
SI-432	Locked Open	Closed	No flow from associated low- pressure safety injection (LPSI) pump. One pump remains.
SI-435	Locked Open	Closed	
SI-444	Locked Open	Closed	
SI-447	Locked Open	Closed	
SI-421	Locked Open	Closed	Loss of safety injection pump minimum flow. Slight increase in injection flow.
SI-423	Locked Open	Closed	
SI-425	Locked Open	Closed	
SI-449	Locked Open	Closed	
SI-450	Locked Open	Closed	
SI-452	Locked Closed	Open	Some of flow from one containment spray (CS) pump will be injected into Reactor Coolant System through LPSI header.
SI-453	Locked Closed	Open	
SI-456	Closed	Open	No effect
SI-457	Closed	Open	
SI-662	Closed	Open	One HPSI pump will take suction from discharge of one CS pump. Partial loss of CS flow.
SI-663	Closed	Open	

TABLE 6.3-7 ADMINISTRATIVE ERROR ANALYSIS-SAFETY INJECTION SYSTEM VALVES (CONTINUED)

Valve Number	Normal Position	Administrative Error Position	Result
SI-654	Locked Open	Closed	HPSI flow not available through associated header.
SI-656	Locked Open	Closed	
SI-657	Closed	Open	No effect
SI-659	Open	Closed	Loss of minimum flow for all pumps. Slight increase in injection flows. Valves controlled by key lock switches to disable them open during normal operation.
SI-660	Open	Closed	
SI-460	Locked Closed	Open	No effect on safeguards system performance.
SI-461	Closed	Open	
SI-462	Closed	Open	
SI-463	Locked Closed	Open	
SI-661	Closed	Open	No effect
SI-611	Closed	Open	No effect on safeguards system performance.
SI-621	Closed	Open	
SI-631	Closed	Open	
SI-641	Closed	Open	
SI-612	Closed	Open	If any one of these valves is in the incorrect position, it will result in an inability to maintain its corresponding safety injection tank within the Technical Specifications requirements. Redundant alarms will alert the plant operator who will take corrective action.
SI-622	Closed	Open	
SI-632	Closed	Open	
SI-642	Closed	Open	
SI-613	Closed	Open	
SI-623	Closed	Open	
SI-633	Closed	Open	
SI-643	Closed	Open	

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
1. Loss of Facility Z1 (**B51**) coincident with SIAS	LPSI	LPSI	1. B HPSI train (using P41C pump)	P42B LPSI Pump via 2-SI-306 through 2-SI-651 and 2-SI-652
	1. 2-SI-651, 2-SI-615, 2-SI-625 remain closed	Open 2-SI-651 with Facility Z2 power.	2. P42B LPSI pump via 2-SI-645	
	2. P42A LPSI pump out of service	Close 2-SI-635		
	3. 125V DC (DV10) will not be available (battery has 8 hour coping factor)	Open 2-SI-400 and 2-SI-709		
	HPSI	HPSI		
	1. 2-CH-518 fails open due to loss of DC power (unused)	Verify B HPSI train in service to cold leg injection		
	2. A HPSI train out of service	Close 2-SI-636 and 2-SI-646		

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL (CONTINUED)

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
2. Loss of Facility Z2 (**B61**) coincident with SIAS	LPSI	LPSI	P42A LPSI pump via 2-SI-615 and 625	HPSI pump P41A via 2-CH-517 to pressurizer auxiliary spray line
	1. 2-SI-652, 2-SI-635, 2-SI-645 remain closed	Establish LPSI to cold leg injection 2-SI-615 & 625 are open		
	2. P42B LPSI pump train out of service			
	3. 125V DC (DV20) will not be available (battery has 8 hour coping factor)			
	HPSI	HPSI		
	1. 2-CH-517 fails closed due to Facility Z2 DC battery	Power 2-CH-517 and 2-CH-519 with 125V DC (DV10)		
	2. 2-CH-519 fails open	Align A HPSI pump to pressurizer auxiliary spray line via: Open 2-CH-340, 440 and 517		
	3. B HPSI train out of service	Close 2-CH-518 and 2-CH-519		

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL (CONTINUED)

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
3. Loss of Facility Z1 (**B51**)Post SIAS	LPSI	LPSI	1. B HPSI train (using P41C pump)	P42B LPSI Pump via 2-SI-306 through 2-SI-651 and 2-SI-652
	1. 2-SI-651 remains closed	Open 2-SI-651 with Facility Z2 power	2. P42B LPSI pump via 2-SI-615 and 625	
	2. 2-SI-615 and 2-SI-625 remain open	Close 2-SI-635 and 2-SI-645		
	3. LPSI P42A out of service	Open 2-SI-400 and 2-SI-709		
	4. 125V DC (DV10) will not be available (battery has 8 hour coping factor)			
	HPSI	HPSI		
	1. 2-CH-518 fails open due to loss of DC power (unused)	Verify B HPSI train in service to cold leg injection		
	2. HPSI P41A out of service	Close 2-SI-616 and 626		

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL (CONTINUED)

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
4. Loss of Facility Z2 (**B61**) Post SIAS	LPSI	LPSI	P42A LPSI pump via 2-SI-635 and 645	P41A HPSI pump via 2-CH-517 to pressurizer auxiliary spray line
	1. 2-SI-652 remains closed	Establish LPSI to Cold Leg Injection		
	2. 2-SI-635 and 2-SI-645 remain open	Close 2-SI-615 and 2-SI-625		
	3. 125V DC (DV20) will not be available (battery has 8 hour coping factor)			
	HPSI	HPSI		
	1. 2-CH-517 fails closed due to Facility Z2 DC battery	Power 2-CH-517 and 2-CH-519 with 125V DC (DV10)		
	2. 2-CH-519 fails open	Align P41A HPSI pump to pressurizer auxiliary spray line via: Open 2-CH-340, 440 and 517		
	3. HPSI P41C pump out of service	Close 2-CH-518 and 2-CH-519		

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL (CONTINUED)

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
5. Loss of 125V DC (**DV10**) coincident with SIAS	LPSI	LPSI	1. B HPSI train (using P41C pump)	P42B LPSI Pump via 2-SI-306 through 2-SI-651 and 2-SI-652
	1. Facility Z1 Diesel is shut down	Open 2-SI-651 with Facility Z2 power	2. P42B LPSI pump via 2-SI-645	
	2. P42A LPSI pump out of service	Close 2-SI-635		
	3. 2-SI-615, 2-SI-625 remain closed	Open 2-SI-400 and 2-SI-709		
	4. 2-SI-651 remains closed			
	HPSI	HPSI		
	1. 2-CH-518 fails open (unused)	Verify B HPSI train in service to cold leg injection		
	2. P41A HPSI train out of service	Close 2-SI-636 and 646		

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL (CONTINUED)

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
6. Loss of 125V DC (**DV20**) coincident with SIAS	LPSI	LPSI	P42A LPSI via 2-SI-615 and 625	P41A HPSI pump via 2-CH-517 to pressurizer auxiliary spray line
	1. Facility Z2 Diesel is shut down	Establish LPSI to Cold Leg Injection		
	2. P42B LPSI pump out of service	2-SI-615 & 625 are open		
	3. 2-SI-635 and 2-SI-645 remain closed			
	4. 2-SI-652 remains closed			
	HPSI	HPSI		
	1. 2-CH-517 fails close	Power 2-CH-517 and 2-CH-519 with 125V DC (DV10)		
	2. 2-CH-519 fails open	Align P41A HPSI pump to pressurizer auxiliary spray line via: Open 2-CH-340, 440 and 517		
	3. B HPSI train out of service	Close 2-CH-518 and 2-CH-519		

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL (CONTINUED)

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
7. Mechanical Failure of a LPSI pump	P42A or P42B LPSI pump fails to operate	<u>LPSI</u>	P42A or P42B LPSI via 2-SI-645	P42A or P42B LPSI pump via 2-SI-306 through 2-SI-651 and 2-SI-652
		Align the operating LPSI pump hot leg injection	HPSI B train	
		2-SI-645 is open	Close 2-SI-636 & 646	
		Close 2-SI-615, 625 and 635		
8. Mechanical or Loss of Air Failure of 2-SI-306	2-SI-306 is pinned and locked at preset throttled open position and remains open. Therefore, this case is not considered a credible failure case.			
9. Mechanical Failure of 2-SI-651, 2-SI-652, 400 or 709	Failure of any one of these valves will disable LPSI hot leg injection.	Establish HPSI to Hot Leg Injection	One LPSI pump through any two of the four LPSI injection valves.	P41A HPSI pump via 2-CH-517 to pressurizer aux spray line

TABLE 6.3-8 FAILURE MODES AND EFFECTS ANALYSIS FOR BORON PRECIPITATION CONTROL (CONTINUED)

Single Failure	Effects of Failure	Actions Required	Cold Leg Injection Path	Boron Precip Control Path
10. Mechanical Failure of P41A HPSI pump or 2-CH-340, 440, 429, 517, 518 or 519	A HPSI train out of service	None	1. B HPSI train (using P41C pump) 2. P42A/B LPSI pump via2-SI-645	P42A/B LPSI pump via 2-SI-306 through 2-SI-651 and 2-SI-652
11. Mechanical Failure of 2-SI-635	2-SI-635 remains open	Establish HPSI to Hot Leg Injection	One LPSI pump through any two of the four LPSI injection valves	P41A HPSI pump via 2-CH-517 to pressurizer auxiliary spray line

FIGURE 6.3–1 SAFETY INJECTION AND CONTAINMENT SPRAY PUMPS SUCTION PIPING

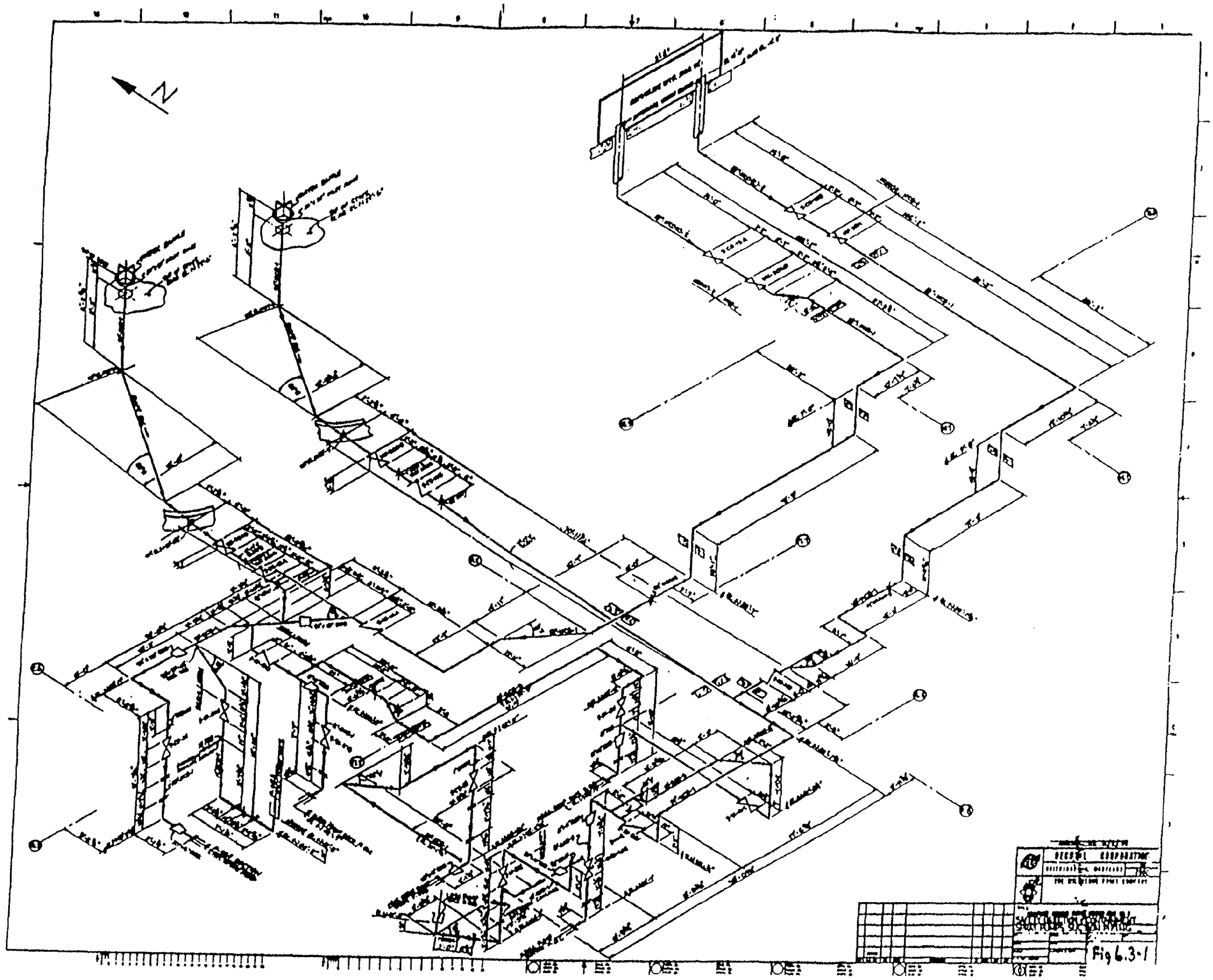


FIGURE 6.3–2 HIGH PRESSURE SAFETY INJECTION PUMP PERFORMANCE

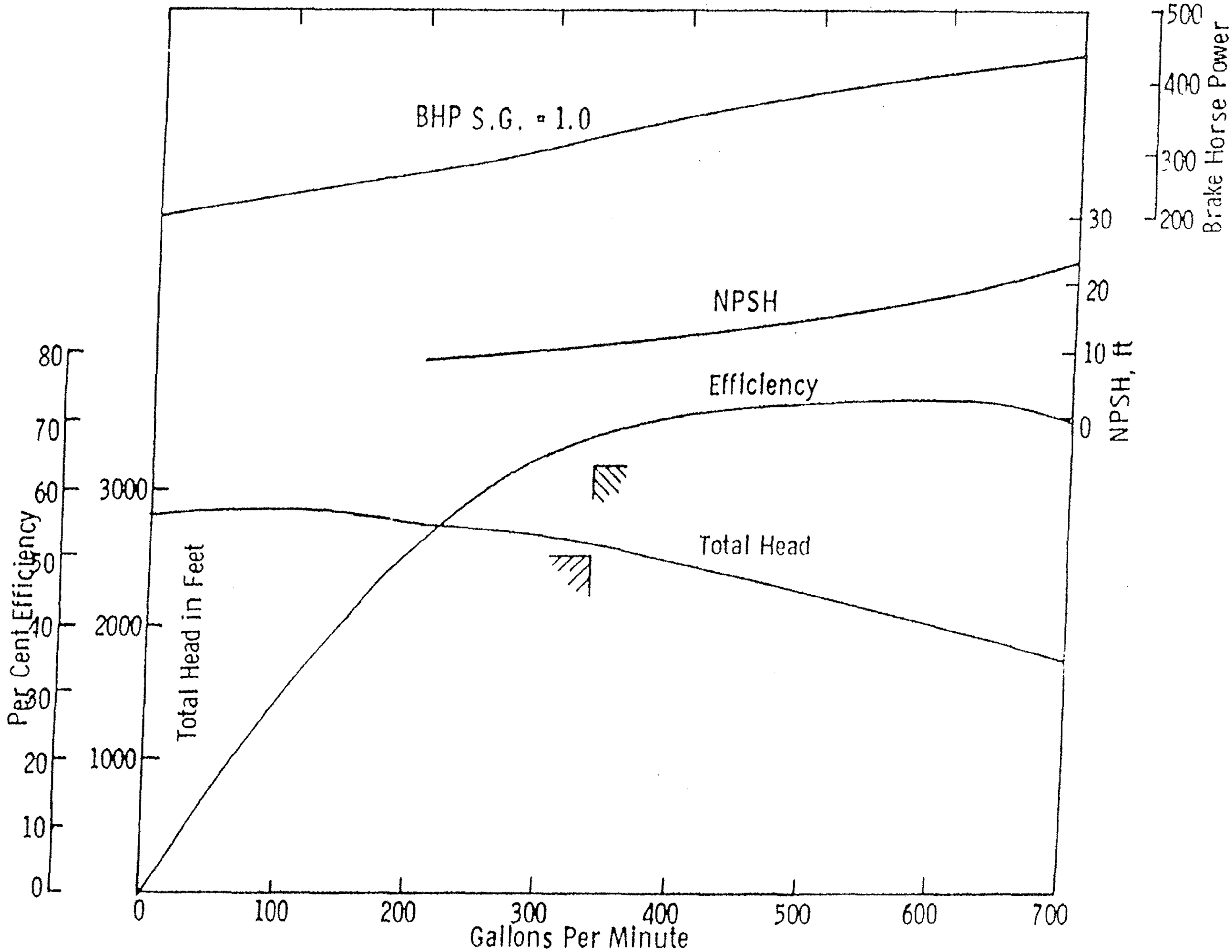
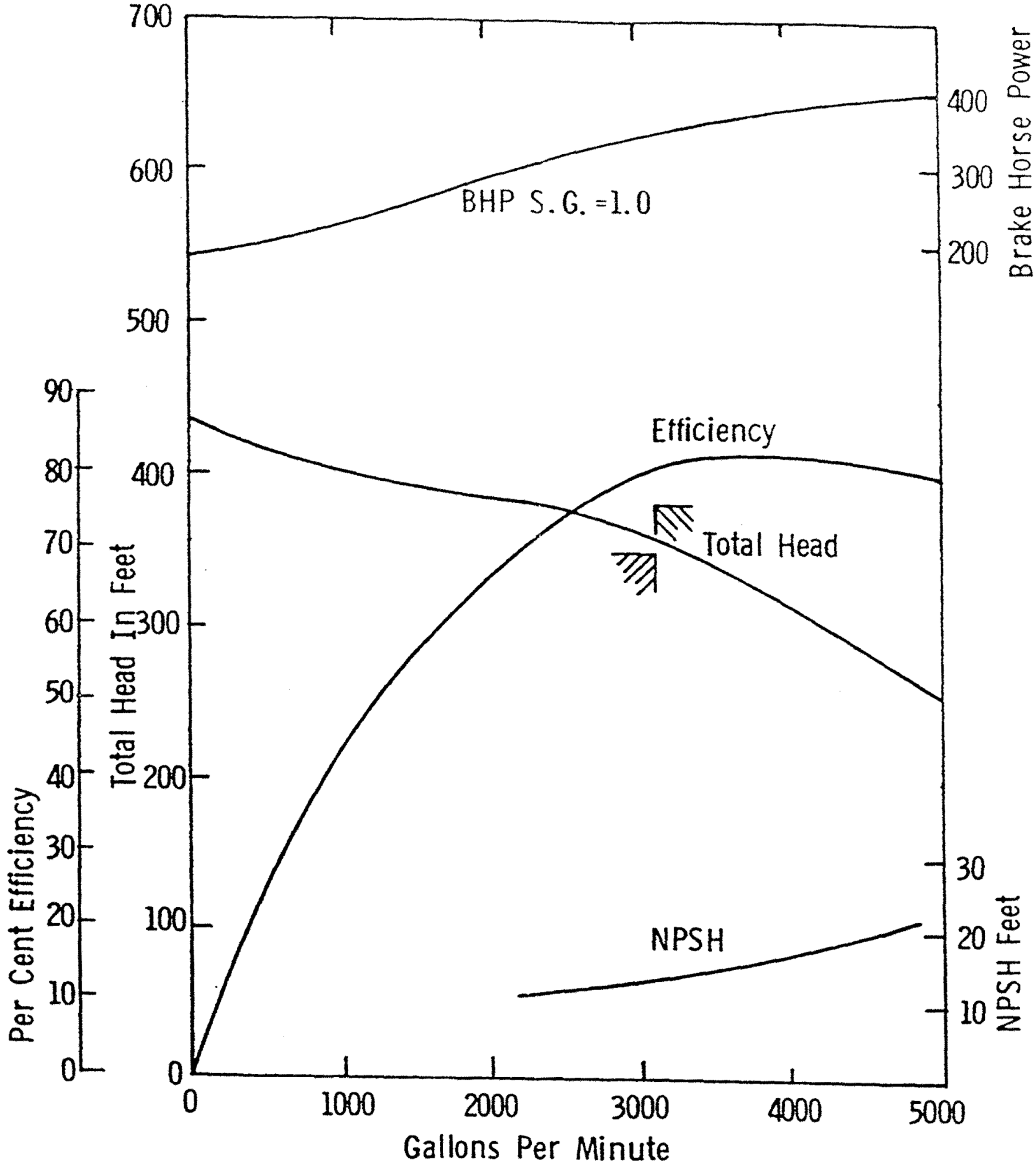


FIGURE 6.3–3 LOW PRESSURE SAFETY INJECTION PUMP PERFORMANCE



6.4 CONTAINMENT SPRAY SYSTEM

6.4.1 DESIGN BASES

6.4.1.1 Functional Requirements

The containment spray system functions as an engineered safety feature to limit the containment pressure and temperature after a loss-of-coolant accident (LOCA) and Main Steam Line Break (MSLB) accident and thus reduces the possibility of leakage of airborne radioactivity to the outside environment. The containment spray system in conjunction with the containment air recirculation and cooling system (described in Section 6.5) provides sufficient heat removal capability to limit the post-accident containment pressure and structural temperature below the design values of 54 psig and 289°F, respectively (Section 14.8.2) by directing sprays of cooled borated water downward from the upper regions of the containment.

During shutdown or refueling, as a back-up to support maintenance activities of the shutdown cooling system, a containment spray system pump can be aligned to cool the spent fuel pool (see Section 9.5).

6.4.1.2 Design Criteria

The following criteria have been used in the design of the containment spray system:

a. The system has two redundant, independent subsystems, each having 50 percent of the required heat removal capability.

b. The system has suitable subsystem and component alignments to assure operation of the complete subsystem with its associated components.

c. Capabilities are provided to assure system operation using either on site power (assuming off site power is not available) or off site electrical power.

d. A single failure in either subsystem does not affect the functional capability of the other subsystem.

e. The system is designed to permit inspection of important components, such as containment sump, containment spray pumps, heat exchangers, spray nozzles, valves, and piping to assure the integrity and capability of the subsystem.

f. The containment spray system is designed to permit appropriate periodic pressure and functional testing to assure: (1) structural and leak-tight integrity of its components; (2) operability and performance of the active components of the system; (3) operability of the active components of the system as a whole. Under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation shall be demonstrated. This includes operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system.

g. The system is consistent with the design criteria as described in Section 6.1.

h. The components of the containment spray system are designed to operate in the most severe post-accident environment described in Section 6.1.

i. The containment spray pumps are designed in accordance and with the conditions given in Safety Guide 1.

6.4.2 SYSTEM DESCRIPTION

6.4.2.1 System

The containment spray system is shown schematically in Figure 6.1–1. The containment spray system consists of two identical, redundant, independent subsystems, each with a heat removal capability of 120 x 10^6 Btu/hr under design post-accident conditions. Each containment spray system consists of a containment spray pump, shutdown cooling heat exchanger, spray nozzles, piping, valves and instrumentation. The refueling water storage tank serves as the source of water and is described in Section 6.2. The shutdown cooling heat exchangers are described in Section 6.3.

Containment integrity is maintained following the limiting containment transient, the design basis MSLB, by utilizing one containment spray subsystem in combination with two containment air recirculation and cooling units (Section 6.5). This combination has a heat removal capability of 280 million Btu/hr under design post-accident conditions (Section 14.8.2). The heat sink for the containment spray system is shown in Figure 6.4–9.

The system is designed assuming the containment spray water is heated to the average temperature of the containment atmosphere while falling through the steam-air mixture within the containment. In order that the spray droplets approach thermal equilibrium during the fall, a minimum distance of 65 feet is provided between the spray nozzles and the highest obstruction in the containment.

Each spray subsystem is provided with spray headers oriented to provide near equal distribution within the containment cross section.

The containment spray header locations and spray nozzle orientations are shown in Figure 6.4–1. There are two different types of nozzles employed in the system as listed in Table 6.4-1. Of the 193 total nozzle locations, 64 are Lechler model 372.975.17.BL which deliver 8 gpm of flow at a 40 psid pressure differential. The remaining nozzles are Spraco model 1713A with a flow capacity of 15 gpm at the same 40 psid differential pressure. The mass-mean droplet diameter for the Lechler nozzles is less than that for the Spraco nozzles. Typical spray patterns for the Spraco nozzles are shown in Figures 6.4–2, 6.4–3 and 6.4–4 while spray patterns for the Lechler nozzles are given in Figure 6.4–4A.

The containment volume which is effectively sprayed, given a single failure of one containment spray train, is approximately 75% of the total containment net free volume.

6.4.2.2 Components

The major system components and associated fabrication and performance data are listed in Table 6.4-1.

6.4.3 SYSTEM OPERATION

The containment spray system operates only under certain emergency conditions. With the exception of the cold shutdown and refueling conditions, valve alignment for all other operating modes is as described under emergency conditions.

During shutdown or refueling, as a back-up to support maintenance activities of the shutdown cooling system, a containment spray system pump can be aligned to cool the spent fuel pool (see Section 9.5).

6.4.3.1 Emergency Conditions

In the event of a LOCA or MSLB accident, the containment spray system is automatically initiated by the containment spray actuation signal (CSAS) as described in Section 7.3. The containment spray pumps initially take suction from the refueling water storage tank. When low level is reached in this tank, the pump suction, in the absence of operation action, is automatically transferred to the containment sump by a sump recirculation actuation signal (SRAS) as described in Section 7.3. The recirculated spray water is cooled by the shutdown heat exchangers prior to discharge into the containment through the spray headers. The RBCCW serves as the cooling medium and is discussed in Section 9.4. Emergency power is provided by the emergency buses as described in Section 8.3.

To prevent the refuel pool from capturing water, the pool drain line isolation valves are locked open during the operating cycle and a screened enclosure is installed over the two drain openings in the floor of the refuel pool.

System operation and performance is monitored in the control room. The containment spray pumps are monitored by the pump pressure gauges, motor trip alarms, and flow metering to indicate abnormal operation. The tube side of the shutdown heat exchangers is monitored by system water temperature to indicate abnormal heat exchanger operation. The shell side of the shutdown heat exchanger is described in Section 9.4.

The motor-operated valve in each containment spray header opens automatically upon the containment spray actuations signal (CSAS). The position of these valves is monitored in the control room.

The manual valves in the system are aligned for containment spray operation and are administratively locked in their respective operating positions.

The operation of the refueling water storage tank (RWST) and containment sump are described in Section 6.2.

6.4.3.2 Cold Shutdown and Refueling

During refueling operations the shutdown heat exchanger is isolated from the containment spray system and aligned with the low pressure safety injection system for shutdown cooling operations (see Section 6.3). This alignment is made by closing manual valves 2-CS-3A and 2-CS-3B on the containment spray pump discharge and 2-CS-4A and 2-CS-4B downstream of the shutdown heat exchanger, and opening the manual isolation valves upstream and downstream of the shutdown heat exchanger to the low pressure safety injection header 2-SI-452, 453, 456 and 457. This alignment is made only after the safety injection actuation signal is blocked (see Section 7.3).

During shutdown or refueling, as a backup to support maintenance activities of the shutdown cooling system, a containment spray system pump can be aligned to cool the spent fuel pool (see Section 9.5.

6.4.4 AVAILABILITY AND RELIABILITY

6.4.4.1 Special Features

The components of the containment spray system are designed to general requirements including seismic response as described in Section 6.1. All components are protected from missile damage and pipe whip by physically separating duplicate equipment, as described in Section 6.1.

To assure the availability of water to the pumps, separate suction headers from the refueling water storage tank are provided for the spray pump located in the two separate and shielded pump rooms, which house the pumps of the engineered safety features systems. Each of the two pump rooms contains one spray pump, one low pressure safety injection pump and one high pressure safety injection pump. Two separate headers, one to each of these pump rooms, are also provided from the containment sump.

The containment spray pumps are located in the lowest elevation of the auxiliary building at Elevation (-) 45-6 to assure a flooded suction. This assures pump priming and protects the mechanical seals in the spray pumps. In this location, the available NPSH is always greater than the required NPSH (see Table 6.4-1).

To assure adequate design margins, the minimum available NPSH for the containment spray pumps is conservatively calculated during the recirculation mode in accordance with Safety Guide 1. Refer to Section 6.3.2.1 for assumptions used in calculating.

To increase system reliability, the containment spray pump motors have the capacity to start with the motor-operated valves on the discharge header fully opened.

The refueling water storage tank (RWST) and containment sump assure sources of water for the containment spray system. These components are described in Section 6.2.

A failure mode analysis is given in Table 6.4-2.

Inadvertent initiation of the spray system does not affect the safety of the unit, since within the containment all the instruments are drip-proof or weatherproof, all the motors are drip-proof or totally enclosed and signal cable runs are enclosed in waterproof jackets. All piping or equipment insulation which may come in contact with sprays are of the metal reflective type or jacketed to prevent large quantities of water from penetrating the insulation. Small amounts of seepage do not present any significant thermal shock to hot equipment.

Inadvertent operation of the system is monitored by pressure, flow and valve position indicators for the operator, so the situation would be quickly observed and remedial action taken.

The design basis case for containment pressure analysis is a Main Steam Line Break accident at zero power with the single failure of vital bus cabinet VA-10 and VA-20. The analysis assumes that one train of containment spray and one train (two units) of containment air recirculation (CAR) are also operable. The containment pressure response based on all other combinations of equipment which would be available assuming any other single failure is bounded by this assumed single failure.

Following a LOCA, the containment spray efficiency decreases with the containment post accident steam/air mass ratio (hence with containment temperature and pressure). The efficiency of the containment air recirculation and cooling units remains relatively constant since these units are designed to remove sensible heat (FSAR Section 6.5). The spray system, even operating at a lower efficiency over the long term, in combination with the containment air recirculation and cooling units, provides ample heat removal capabilities.

6.4.4.2 Test and Inspections

Each containment spray pump was shop tested for hydraulic performance at sufficient head-capacity points to generate complete performance curves. These performance tests were run for design NPSH at runout conditions and calculated back to rated conditions. This containment spray pump performance test curve is shown in Figure 6.4–8.

Nondestructive examinations were performed on all pressure-retaining components of each containment spray pump in accordance with the Draft ASME Code for Pumps and Valves for Nuclear Power, Class II, 1968.

Both types of spray nozzles listed in Table 6.4-1 were performance tested to assure the desired flow at a specified pressure drop across the nozzle is achieved. The 129 Spraco nozzles are capable of delivering 15 gpm of flow at a 40 psid pressure difference while the remaining 64 Lechler nozzles deliver 8 gpm at the same pressure drop. Type, location and orientation of the spray nozzles is shown in Figure 6.4–1. The containment spray nozzle performance characteristics for both types of nozzles are provided in Figure 6.4–7.

The containment spray system underwent a preoperation test prior to startup. The test is described in Section 13.

Provisions are incorporated for on-line testing of the active components in the containment spray system during normal unit operation. The automatically actuated containment spray pumps and motor-operated valves are tested for operability by manually initiating (Section 7.3.4.2.1) the CSAS for each component. Valve operation can be verified by position indication in the control room and locally by visual inspection. Pump operation is indicated by local pressure indication and by status lights in the control room.

Operability testing, response time testing and inservice testing of the containment spray system and its components are performed as required by plant Technical Specifications in accordance with plant procedures.

The design and location of the containment spray pumps and shutdown cooling heat exchangers permit access for periodic testing and maintenance during normal operation.

TABLE 6.4-1 CONTAINMENT SPRAY SYSTEM COMPONENT DESIGN PARAMETERS

Containment spray pumps

Manufacturer	Goulds Pump
Model Number	3736-4x6-13DV
Quantity	2
Type	Vertically split, horizontally centrifugal with mechanical seals backed up with an auxiliary gland
Material	Casing ASTM A351 Gr CF8M; Bolting A-193 B7; Impeller A-296 Gr CG8M
Design temperature (°F)	300
Fluid pumped	Borated water (≥1720 ppm)
Codes	Draft ASME Code for Pumps and Valves for Nuclear Power, Class II, 1968; Standards of Hydraulic Institute
Seismic	Class 1

Containment spray pump motor

Manufacturer	General Electric
Horsepower rating (hp)	250
Horsepower rating (hp)	B
Type	Induction
Frame designation	8188S
Codes	NEMA, MG-1
Seismic	Class 1

TABLE 6.4-1 CONTAINMENT SPRAY SYSTEM COMPONENT DESIGN PARAMETERS (CONTINUED)

	Mode of Operation	
	Injection	**Recirculation**
* Capacity (each) (gpm)	1350 **	1650 **
* Head (ft)	450	360
* NPSH available (ft)	64.0	27.0
* NPSH required (ft)	15.5	21.0
Brake horsepower (bhp)	202	215

Temperature transient (°F)	50 to 300 inch, 10 seconds
Pump speed (rpm)	3560
Fluid pH	5.5 to 10.5

Piping, Fittings and Valves

Suction

Pipe Sizes	**Wall Thickness**
2 inch and smaller	Schedule 40S
2.5 inch and larger	Schedule 10S

Material	ASTM A-312, Type 304
Design pressure (psig)	60
Design temperature (°F)	300
Standard	ANSI B-31.7 Class II
Seismic	Class 1

TABLE 6.4-1 CONTAINMENT SPRAY SYSTEM COMPONENT DESIGN PARAMETERS (CONTINUED)

Construction

Piping	Valves
2 inch and smaller; Socket welded	2 inch and smaller: Socket-welded 600 lb ANSI rating, stainless steel ***
2.5 inch and larger: Butt-welded except at flanged equipment	2.5 inch and larger: Butt-welded, 150 lb ANSI rating, stainless steel

Discharge

Pipe Sizes	Wall Thickness
3 inch and smaller	Schedule 40S
4 inch through 6 inch	Schedule 10S
8 inch through 14 inch	Schedule 20

Material	ASTM A-312, Type 304
Design pressure (psig)	500
Design temperature (°F)	300
Standard	ANSI B-31.7, Class II; ANSI B-31.1.0 Modified (inside containment)
Code (valves)	Draft ASME Code for Pumps and Valves for Nuclear Power, Class II, 1968
Seismic	Class 1

Construction

Piping	Valves
2 inch and smaller: Socket welded	2 inch and smaller: Socket welded, 600 lb ANSI rating, stainless steel ***
2.5 inch and larger: Butt welded except flanged equipment	2.5 inch and larger: Butt welded, 300 lb ANSI rating, stainless steel

TABLE 6.4-1 CONTAINMENT SPRAY SYSTEM COMPONENT DESIGN PARAMETERS (CONTINUED)

Spray nozzles

	Manufacturer	
	Spraco	Lechler
Model number	1713A	372.975.17.BL
Quantity	129	64
Type	Ramp Bottom	Ramp Bottom
Pattern	Hollow Cone	Hollow Cone
Material	Type 304 or 316 stainless	Type 316 Stainless
Nozzle size (inches)	1, 3/8 inch orifice	3/4, 0.28 inch orifice
Rated flow, each (gpm)	15	8
Rated pressure drop (psid)	40	40

---

* The pump flows, heads, and NPSH values presented in this table are based on the original design specifications. The pumps will actually operate over a range of conditions during containment spray from the RWST following a SIAS and from the containment sump following SRAS. System hydraulic and NPSH analyses have been performed for these operational modes based on the pump design and degraded capacities.

** Includes 50 gpm for minimum flow recirculation.

*** 600 pound ANSI rating represents minimum requirements. 800 pound ANSI rating valves are utilized on a case-by-case basis.

TABLE 6.4-2 CONTAINMENT SPRAY SYSTEM FAILURE MODE ANALYSIS

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	METHOD OF DETECTION & MONITOR	DETRIMENTAL EFFECT ON SYSTEM	CORRECTIVE ACTION	RESULTANT SYSTEM STATUS	REMARKS
Motor-operated Valves (2) HV3010, HV3011	Fail as is	Position indication. CRI	None	Repair operator	Normal operation, valve normally open	Valve can be manually operated.
Motor-operated Valves (2) HV3008, HV3009	Fail as is	Position indication CRI	Loss of one (1) containment sump recirculation line	Repair operator	One header out of service. Alternate header is operable	One header sufficient for containment cooling with combination of two containment air recirculation & cooling units.
Containment Spray Pump (2)	Pump stops	Pressure indication & flow indication	Loss of water flow in CTMT spray header	Isolate pump and repair	One containment spray header out of service, alternate containment spray header in normal operation	One containment spray header sufficient for emergency cooling.
Motor-operated Valves (2) VHV3021, HV3022	Fail to open on CSAS	Pressure indication & flow indication. All CRI	Loss of flow from one containment spray header	Repair operator	One containment Spray header out of service, alternate containment Spray header in operation	One containment Spray header sufficient for emergency cooling

FIGURE 6.4–1 AREA 5 PIPING CONTAINMENT SPRAY AND HYDROGEN PURGE

The figure indicated above represents an engineering controlled drawing that is Incorporated by Reference in the MPS-2 FSAR. Refer to the List of Effective Figures for the related drawing number and the controlled plant drawing for the latest revision.

FIGURE 6.4–2 CONTAINMENT SPRAY NOZZLES SPRAY PATTERNS (1713A NOZZLE SPRAYING HORIZONTALLY)

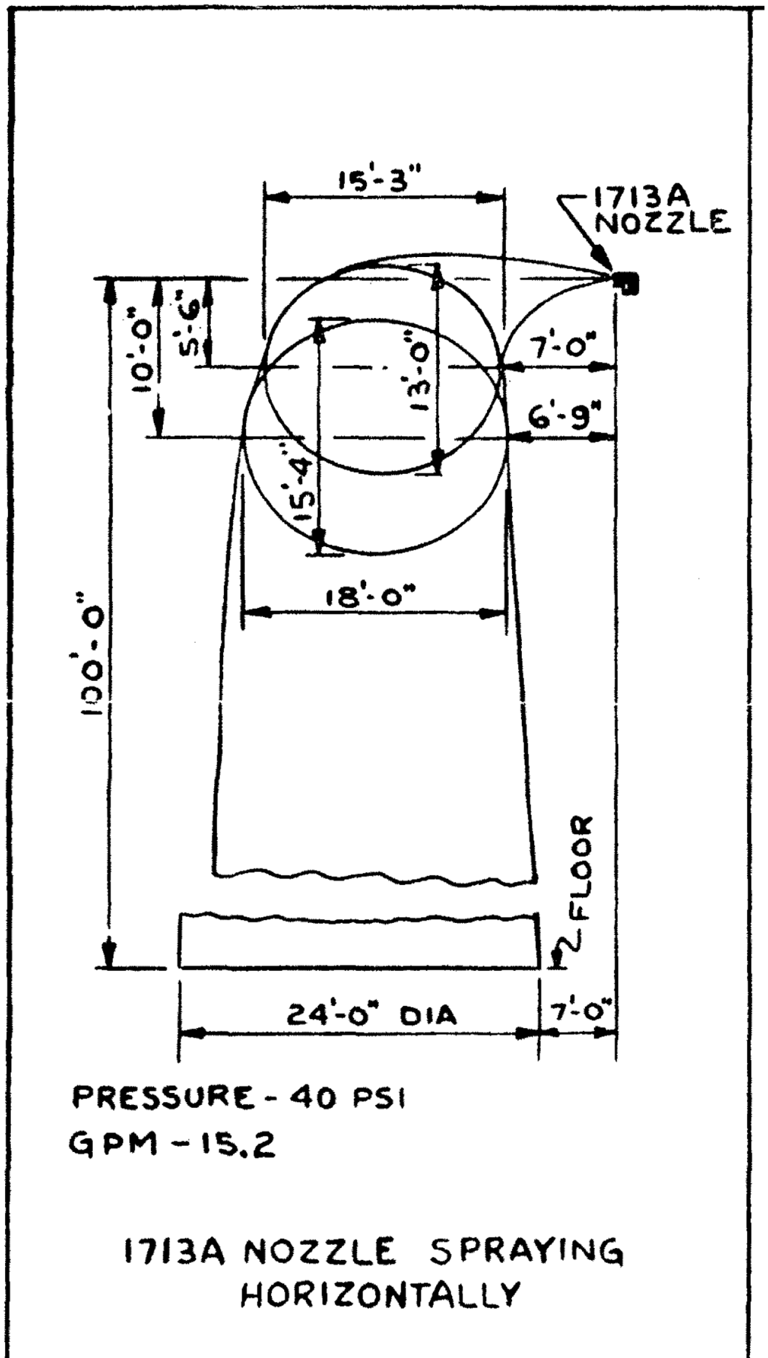


FIG. 6.4-2

FIGURE 6.4–3 CONTAINMENT SPRAY NOZZLES SPRAY PATTERNS (1713A NOZZLE SPRAYING DOWNWARD ON 45°)

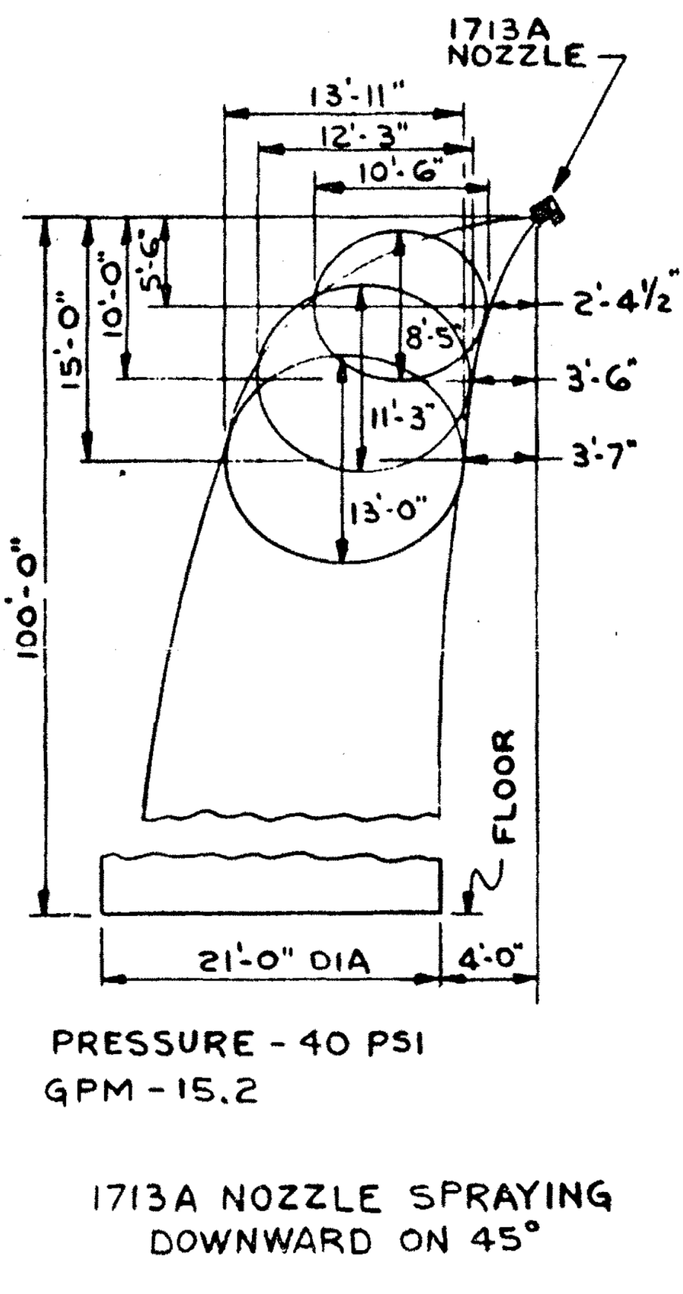


FIG. 6.4-3

FIGURE 6.4–4 CONTAINMENT SPRAY NOZZLES SPRAY PATTERNS (1713A NOZZLE SPRAYING VERTICALLY DOWNWARD)

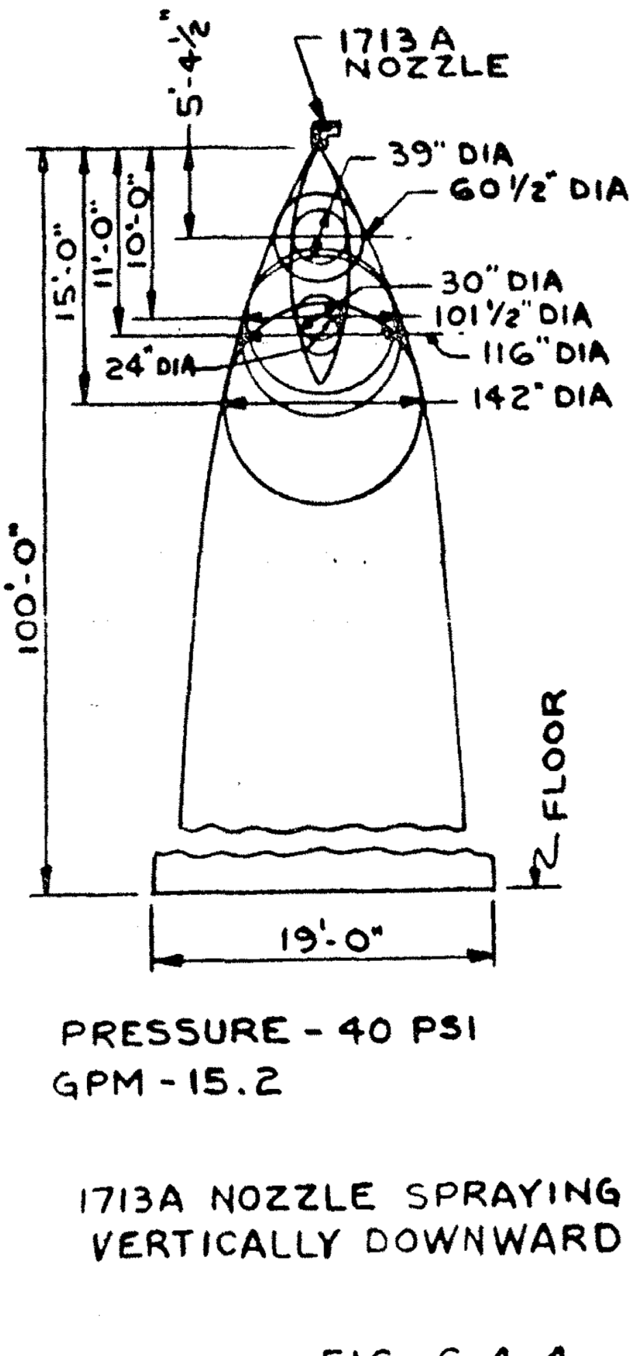


FIG. 6.4-4

FIGURE 6.4–4A TYPICAL SPRAY COVERAGE PATTERNS

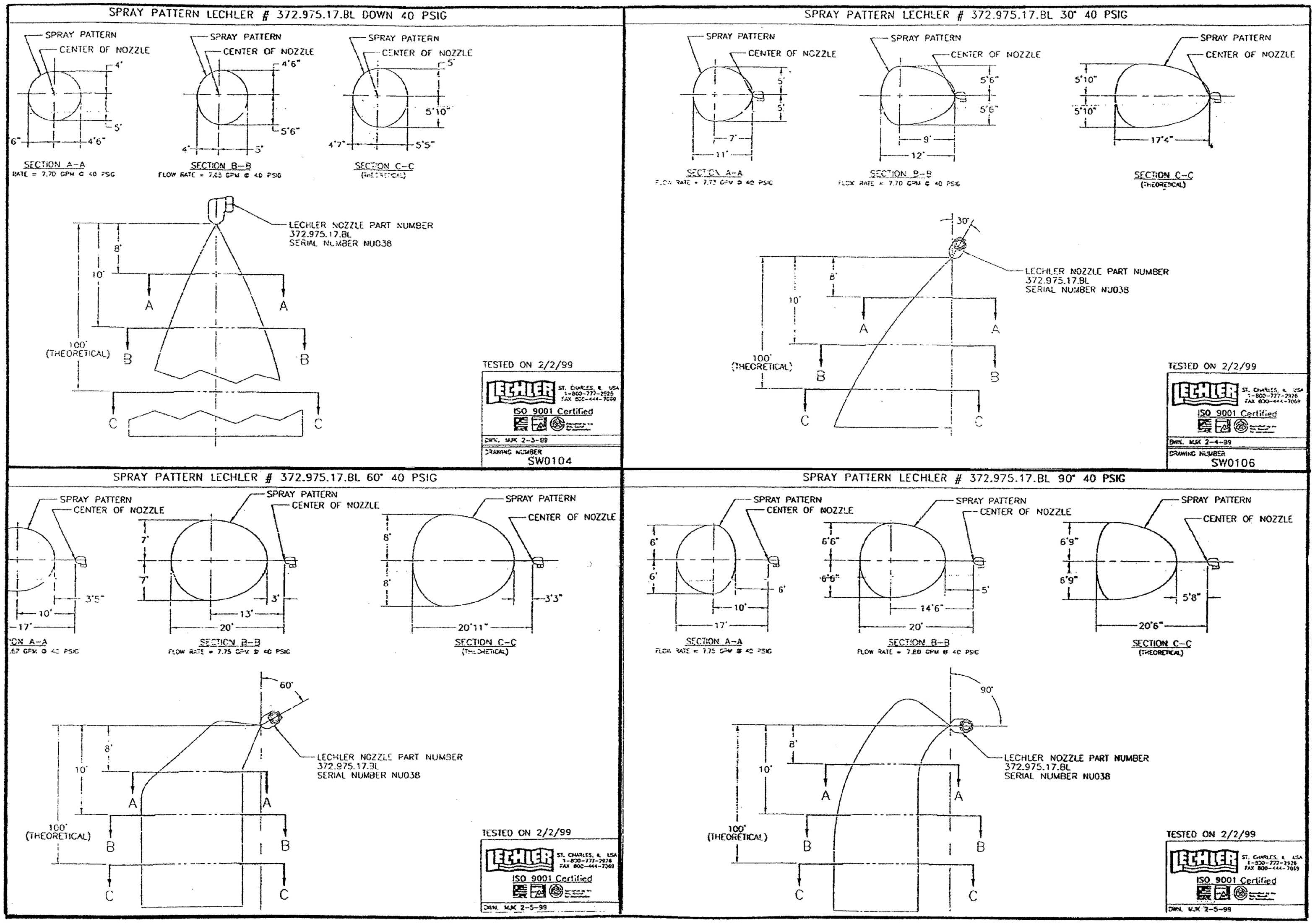


FIGURE 6.4–5 NOT USED

FIGURE 6.4–6 NOT USED

FIGURE 6.4–7 CONTAINMENT SPRAY NOZZLE PERFORMANCE CHARACTERISTICS

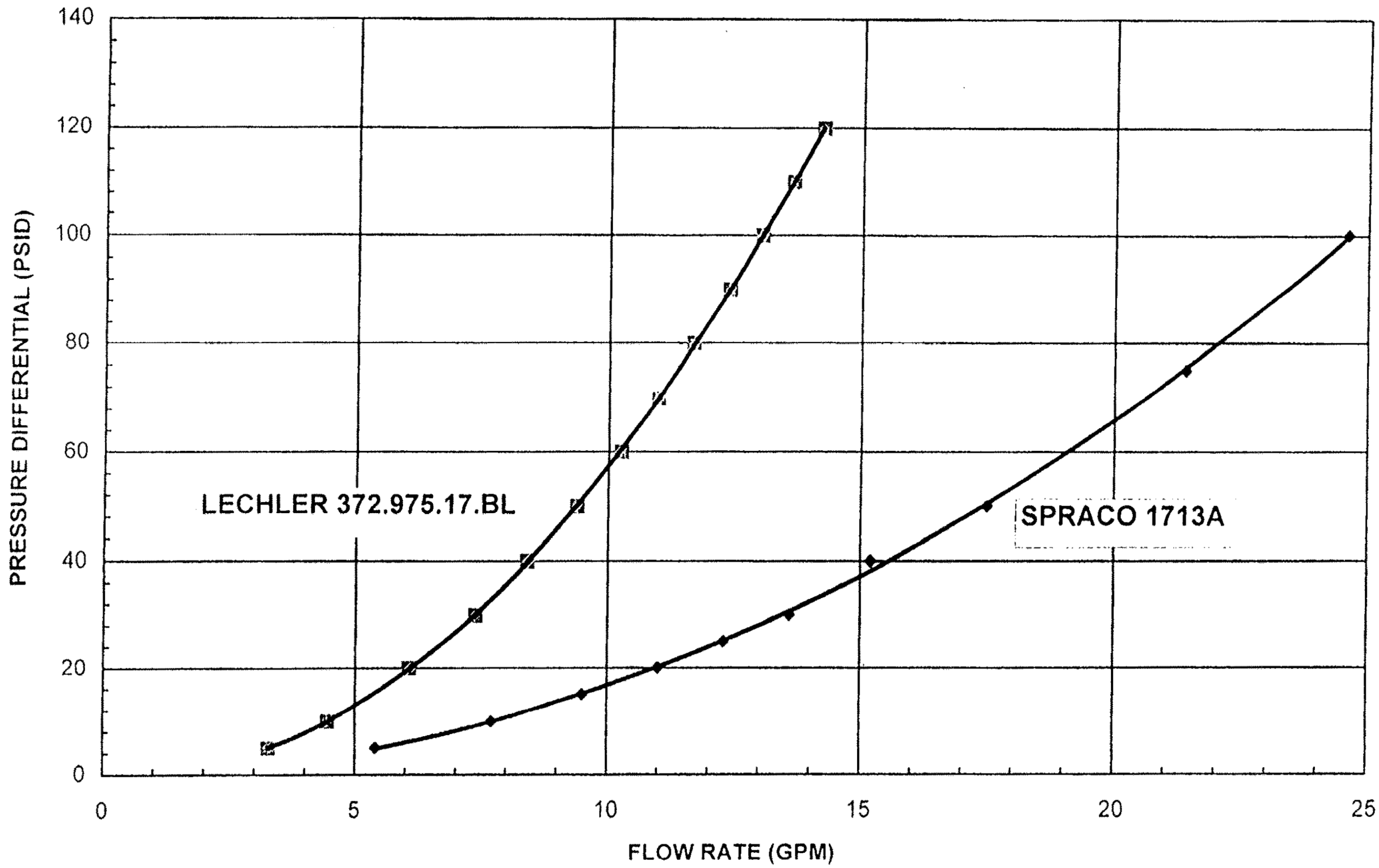


FIGURE 6.4–8 CONTAINMENT SPRAY PUMP PERFORMANCE CHARACTERISTICS.

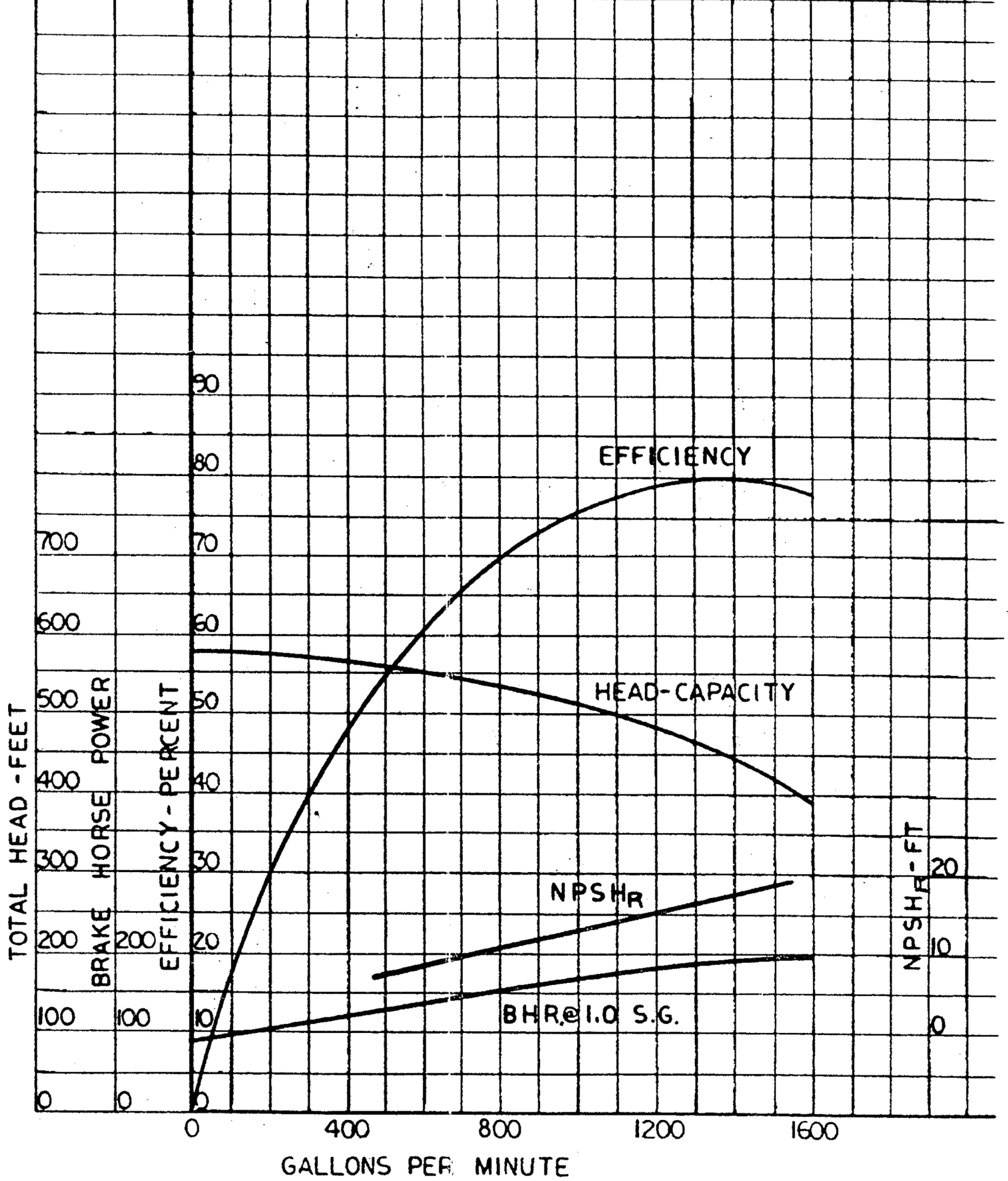
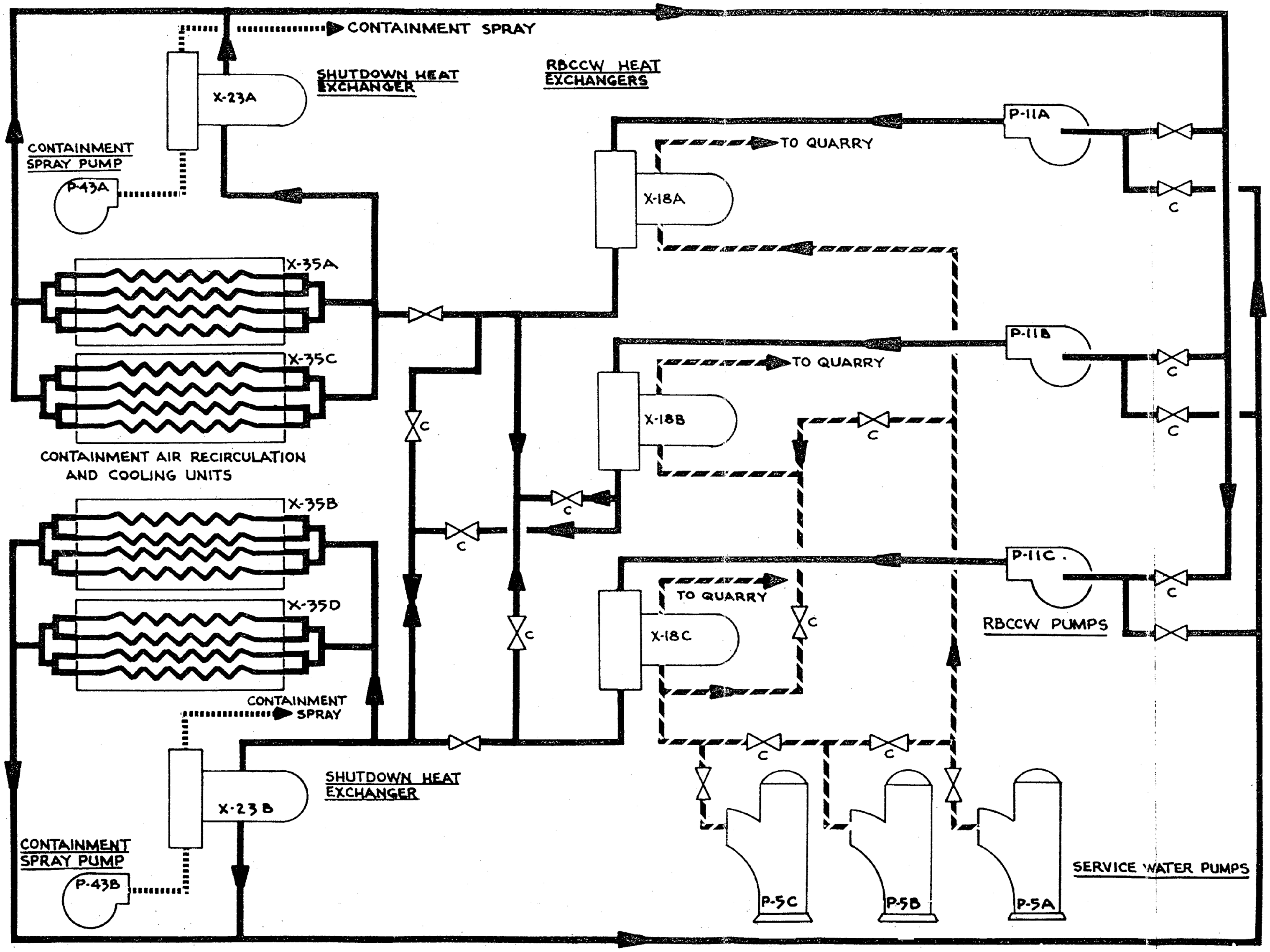


FIGURE 6.4–9 CONTAINMENT HEAT REMOVAL SYSTEMS SINK SCHEMATIC



6.5 CONTAINMENT AIR RECIRCULATION AND COOLING SYSTEM

6.5.1 DESIGN BASES

6.5.1.1 Functional Requirements

The function of the containment air recirculation and cooling system is to remove heat from the containment atmosphere during normal operation. In the event of a Loss-of-Coolant-Accident (LOCA) or Main Steam Line Break (MSLB) accident, the system, in conjunction with the containment spray system described in Section 6.4, provides a means of cooling the containment atmosphere to reduce the containment building pressure and thus reduce the leakage of airborne and gaseous radioactivity.

The containment air recirculation and cooling system is independent of the safety injection and containment spray systems. It is sized such that, assuming the most adverse containment heat-removal single failure, following a LOCA or MSLB accident, two of the four containment air recirculation units in conjunction with one train of the containment spray system limits the containment pressure and structural temperature to less than the containment design values (54 psig, 289°F).

6.5.1.2 Design Criteria

The following criteria have been used in the design of the containment air recirculation and cooling system:

a. The system has two redundant, independent and separate subsystems, each consisting of two containment air recirculation and cooling units.

b. The system has suitable subsystem and component alignment to assure operation of the complete subsystem with its associated components.

c. Capabilities are provided to assure that the system can operate using either on site power (assuming off site power is not available) or with off site electrical power.

d. The containment air recirculation and cooling system is designed to permit inspection of important components, such as cooling coils, fans, motors and reactor building closed cooling water (RBCCW) piping to assure the integrity and capability of the system.

e. The containment air recirculation and cooling system is designed to permit appropriate periodic pressure and functional testing to assure: (1) structural and leak-tight integrity of its components; (2) operability and performance of the active components of the system; and, (3) operability of the active components of the system as a whole. Under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation, including operation of applicable portions of the protection system, the transfer between normal and emergency power sources, and the operation of the associated cooling water system shall be demonstrated.

The system is designed to the criteria described in Section 6.1.

The components of the containment air recirculation and cooling system are designed to operate in the most severe postaccident environment as described in Section 6.1.

6.5.2 SYSTEM DESCRIPTION

6.5.2.1 System

The containment air recirculation and cooling system is shown schematically in Figure 9.9–1.

The containment air recirculation and cooling system is designed to maintain the containment normal ambient temperature at 120°F with three of the four units operating. Each unit is designed for 2.2 x 10^6 Btu/hr, one-third of the normal containment heat load.

Each containment air recirculation and cooling unit is designed for removing 80 x 10^6 Btu/hr under Main Steam Line Break accident or LOCA conditions prior to the containment Sump Recirculation Actuation Signal (SRAS). Following the SRAS, a portion of the Reactor Building Closed Cooling Water (RBCCW) flow is directed through the shutdown cooling heat exchanger to cool the sump water prior to being sprayed into containment. RBCCW is isolated to nonvital inside containment loads by manual closure of 2-RB-30.1 A/B and 2-RB-37.2A/B. The resulting RBCCW flow is reduced from 2000 gpm (prior to SRAS) to 1600 gpm per CAR cooling unit. This flow reduction, coupled with the reduction in containment air/steam temperature at the time of SRAS, results in a reduction in the containment heat removal capability of a CAR cooling unit from 80 million to 60 million Btu/hr. Two containment air recirculation and cooling units in combination with one containment spray pump (see Section 6.4.2.1) provide complete containment cooling capabilities under post-accident conditions. Each component in this combination is powered from the same emergency power source (Section 8.3) and is provided with cooling water from the same RBCCW header (Figure 9.4–2). This combination is designed for removing 280 x 10^6 Btu/hr. The heat sink for the containment air recirculation and cooling system is shown in Figure 6.4–9.

While the failure of both trains of the containment spray system requires multiple failures and is beyond the licensing design basis of the plant, following a LOCA, containment cooling may be provided by three of the four containment air recirculation and cooling units without the containment spray system. This combination is designed for removing 240 x 10^6 Btu/hr under LOCA conditions. However, following a MSLB accident, the combination of three containment air recirculation and cooling units does not provide adequate containment heat removal. A MSLB accident can result in a dry steam blowdown. With a dry steam blowdown, the potential exists for a significant increase in and superheating of the containment steam/air temperature above 289°F. In the design basis event/Section 14.8.2), the initiation of the containment sprays quickly reduces the containment air/steam temperature to saturation conditions, below 289°F. Without containment sprays following a MSLB accident, the potential exists that the containment air/ steam temperature remain above 289°F for extended periods of time, possibly resulting in an excessive heatup of structures and equipment inside containment.

The containment air recirculation and cooling system is designed to maintain an ambient temperature within the containment of 120°F during normal operation. The duct work distribution system is routed to provide cooling air near all major components.

The reactor cavity cooling air is supplied by two independent, physically separated air supply headers. These are located on opposite sides of the reactor cavity. The two air supply headers are fed by a common plenum, which in turn, is fed by the four (4) CAR Fans.

The cavity cooling system is designed to supply air at a maximum of 91°F to the bottom of the cavity and to the reactor vessel supports and nuclear instruments in the reactor cavity. The maximum estimated air temperature at the permanent reactor cavity seal plate is 132°F.

Air is supplied directly in the vicinity of the steam generators, reactor coolant pumps and motors and pressurizer. Additional air is supplied in the lower regions of the steam generator compartments. As the air is heated by sensible heat, a stack effect is created within the steam generator compartments.

Air is supplied directly into the pressurizer skirt assembly to provide a suitable environment for the pressurizer heaters. The ambient temperature in this region is limited to 120°F.

Air is supplied directly to cool the concrete interface where the concrete is in contact with environment operating above 150°F. In all cases, the concrete does not exceed 150°F the containment during normal operation.

Each of the four containment air recirculation and cooling units consists of a direct drive two-speed vaneaxial fan, eight cooling coil sections and steel housing which forms an integral air handling units.

Each coil house is equipped with eight individual coils piped to supply and return manifolds which connect to the RBCCW system.

The four containment air recirculation and cooling units (CARs) are arranged in two groups. Each group includes two CAR units that share an independent RBCCW supply header. Each header branches into two supply lines, one supply line to each of the two CAR units in the group (Refer to Figure 9.4–5).

Each of the four RBCCW supply lines has an air-operated stop valve for its associated CAR unit (for example: 2-RB-28.1A for one of the four units). Each of these four RBCCW supply stop valves is normally open and deenergized. Each of these valves is designed to fail in the open position.

Each of the four CAR units has an RBCCW return line that has two air-operated stop valves in a parallel arrangement (for example, valve 2-RB-28.2A and 2-RB-28.3A for one of the four CAR units). Each of the air-operated control valves in the four sets of return line valves can be operated from the control room. One of the two control valves in each return line set (e.g., 2-RB-28.3A in the example set) opens automatically on receipt of a safety injection signal (SIAS).

There are twenty air temperature measuring instruments located in the containment. Eight of these measure the containment atmosphere air temperature in different locations in the containment, including one location within the reactor cavity. By use of an eight position selector switch and a temperature indicator located on the main control board, the containment air temperature at the eight locations can be monitored in the main control room. In addition, the temperature readings are inputted into the computer. The other 12 temperature measuring instruments are associated with the various ventilation systems. These measurements are also inputted into the computer.

A malfunction in the cavity cooling system is indicated by an increase in cavity air temperature and also by an increase in the containment air temperature since these areas are served by the same air distribution system. The limiting conditions for operation is the primary containment average temperature of 120°F as described in the Technical Specification 3.6.1.5. During normal plant operation the CAR coolers are designed to maintain the cavity concrete temperature below 150°F.

6.5.2.2 Components

Ductwork for the containment air recirculation and cooling system outside the secondary shield wall is galvanized steel containing 1.25 oz/square foot of zinc. Inside the steam generator compartment duct work is 18-8, ANSI Type 304 stainless steel with a 2B mill finish. Transverse duct work joints are welded flange with angle reinforcing. Longitudinal seams are continuously welded.

Materials of construction and performance data for system components are listed in Tables 6.5-1 and 6.5-2, respectively. The fan performance curve is shown in Figure 6.5–1. The coil performance is shown in Figure 6.5–2.

Codes and Standards:

Cooling coils	ASME Section VIII
Fan	AMCA 211A
Motors	IEEE STD-334-1971, NEMA, MG-1
Duct work	SMACNA, High Velocity Standards
Seismic	Class 1 (Ductwork Class 2)

6.5.3 SYSTEM OPERATION

6.5.3.1 Normal Operations

During normal operation, the 120°F containment air is recirculated through the containment air recirculation and cooling system by the vaneaxial fans. The fans operate normally at high speed. Air is supplied through the duct work system into the steam generator compartments and reactor cavity at approximately 91°F. The cooling air is heated, by the sensible heat, to 120°F as natural circulation occurs.

The RBCCW system supplies cooling water at 85°F maximum to the cooling coils of each CAR unit (Section 9.4). During normal operation, the full sized valve in each of the four sets of two parallel RBCCW return valves (e.g., for one CAR unit, 2-RB-28.3A) is positioned according to the containment heat load requirements. (Each of these same full sized RBCCW return valves also provides service during a LOCA). Additionally, during normal operation, the corresponding smaller (6 inch diameter) return line valve in each parallel set is open.

During normal operation, three of the four containment air recirculation and cooling units are required to provide sufficient sensible cooling.

The loss of the normal containment cooling system is not considered credible.

However, postulating the above event, the containment temperature and pressure response would distinguish this occurrence from the LOCA. The containment conditions following the design basis accident (DBA) are described in Section 14.8.2). Assuming the loss of normal cooling event, the containment temperature would increase approximately 40°F for a one (1) psi increase in containment pressure. Therefore, for this event there is an elevated containment temperature to a relatively small increase in containment pressure. Other minor accidents, less severe than the DBA, would result in the elevated temperature and relatively large increase in pressure since additional mass is being introduced into the containment free volume. Thus, the postulated loss of normal cooling capability could be distinguished from an accident condition.

Section 3.6.1.5 in the Technical Specification states the containment temperature limit. Safety related instrumentation exposed to the containment atmosphere is capable of withstanding 150°F on a continuous basis.

In the unlikely event that the fusible link plates and blowout plates open during normal operation, the containment air distribution system would be out of service. As a result, the cool air from the containment air recirculation and cooling units would be discharged outside the secondary shield wall. However, the stack effect created by the temperature gradient within the steam generator compartments would induce portions of this cool air inside the compartments. Although partial cooling does exist, potential hot spots could be present around major components. Temperature elements located throughout the containment will alarm any elevated temperature condition. Upon receipt of a high-temperature alarm on the plant computer, the operator will take action in accordance with plant procedures.

6.5.3.2 Leak Rate Testing

The operation of the Containment Air recirculation and Cooling systems are not required during the Integrated Leak rate test. During the initial containment pressurization, the units may be operated to remove the heat from compression through RBCCW as the cooling medium. The fans and motors operate at low speed to reduce horsepower requirements at these elevated pressure conditions.

The units may be operated during the test, if required.

The units may operate without cooling water during the post-test containment depressurization to provide heating.

6.5.3.3 Emergency Conditions

Upon receipt of a SIAS, the idle containment air recirculation and cooling unit is automatically started on the low speed setting. Simultaneously, the running units are switched from their normal operating high speed setting to low-speed operation. The full flow (10 inch diameter) RBCCW valves at the outlet of each cooler are also opened upon receipt of the SIAS. (Figure 9.4–2)

With off site power available under this mode of operation, three units are switched to low speed and the fourth is started on low speed as described above. Each of two emergency buses carries the load of two containment air recirculation and cooling units.

Each CAR fan coil unit is provided with blowout doors equipped with fusible links downstream of the fan discharge. At high temperature in the containment environment after either a LOCA or a MSLB, these fusible links melt disengaging the doors allowing them to swing open. This allows air to circulate through the path of least resistance as described in Section 6.5.4.1.

The containment air recirculation and cooling units assist in uniform mixing of combustible gas within the containment environment as described in Section 6.6.2.1.

6.5.3.4 Refueling

The containment air recirculation and cooling units may be operated at reduced speed during refueling operations. The units provide mixing with the containment purge air (see Section 9.9.2) for uniform temperatures throughout the containment.

6.5.4 AVAILABILITY AND RELIABILITY

6.5.4.1 Special Features

The components of the containment air recirculation and cooling system are designed to the general requirements including seismic response as described in Section 6.1. Components are protected from missile damage and pipe whip by physical separation of duplicate equipment as described in Section 6.1.

The cooling units are designed to operate for the life of the station. There are no belts or flexible couplings; the motor is directly connected to the fan wheel.

Failure of the normal electrical power supply automatically places all four fans on emergency electric power source. A failure mode analysis is given in Table 6.5-3.

Associated system components, such as piping, valves, and instrumentation are located outside the secondary shield to minimize the possibility of missile damage.

The ductwork system which is located on the containment air recirculation fan discharge, downstream of the blowout doors, is not required during post-accident operation. To assure an unrestricted flow path, 4 doors downstream of the discharge of each fan open via the melting of the high-temperature fusible links. These doors consist of galvanized steel sheets attached rigidly to the duct work system by means of UL rated fusible links.

The fusible links are nominally rated at 165°F ± 7% based on the UL allowable tolerance for fusible links. Each containment air recirculation unit is provided with blowout doors equivalent to 30 square feet of flow area. This flow area is greater than the fan outlet area. This assures fan operability and prevents flow restrictions following any possible duct work failure during post-accident conditions. All blowout doors plates are hinged to the ductwork to prevent their becoming credible missiles after separation.

The post-accident distribution system is designed to discharge the air in four (4) horizontal directions from each unit through the openings left by the fusible link plates. Under design conditions, it is assumed that the existing duct work is restricted such that all the air is discharged through these openings. The throw (distance traveled by the air stream before reaching terminal velocity) is approximately 100 feet. Under these conditions, the discharge from the upper unit is well beyond the intake region of the lower unit, thus preventing any short circuiting. The air streams drop off toward the end of the throw and tend to settle toward the bottom of containment due to the slightly lower temperatures. This creates secondary stack effects throughout these regions of containment.

It is anticipated, but not necessary, that portions of the ductwork distribution system remains intact. This provides greater air distribution throughout containment. However, the velocity of air, and hence the throw, through the fusible link plate openings would be much less. This could create a slight short circuiting effect. Since the units are located one above the other, the bottom unit may suction portions of the discharge from the upper unit. However, this has negligible effect on the performance of the units since, during the short term, the units will be removing latent and not sensible heat. That is, the discharge temperature from the units will be only a few degrees lower than the inlet temperature. The effect of short circuiting is slightly more pronounced as the containment post-accident temperature begins to decrease, as the units are removing more sensible heat. However, at this time, the containment heat removal requirements are much less than the heat removal capabilities of the containment air recirculation and cooling units. Short circuiting is not expected to affect the performance of the system.

The containment air recirculation system in the post-accident mode of operation provides local containment cooling. The containment spray system is utilized in conjunction with the containment air recirculation and cooling system to provide a uniform containment atmosphere.

Relief dampers are provided for the ductwork headers on the side of the main CAR fan discharge plenum outside of the secondary shield wall. These dampers are provided to prevent a pressure front from reaching the containment air recirculation and cooling units through the ductwork system. The relief dampers are held closed by tension springs of Type 301 stainless steel. The springs are designed to permit the damper to be fully open (out from the duct) at a three-psi pressure differential. Each main ductwork header is provided with 30 square feet of relief area.

The condensate leaving the cooling coils is collected in individual drip pans. These pans cascade the liquid into the housing drain. The air side coil face velocity is approximately 180 fpm under LOCA conditions. This low velocity reduces moisture carry-over from the coils.

Each housing is equipped with two four-inch drains with loop seals. Clogging of these drains does not render the unit inoperable. Under this postulated case, the housing water level rises and overflows through the coil sections before reaching the fan inlet. The curb supporting the cooling coils extends approximately six inches above the housing floor and the fan inlet extend approximately 15 inches above the housing floor.

The fin pitch is 8.5 fins per inch of cooling coil length. With this pitch, water logging of the coil fins under post-accident conditions is minimized to avoid any problem.

A fouling factor of 0.0005 for the water side is included in the coil ratings. Demineralized water (RBCCW) fouling factor of 0.0005 is recommended by the Tubular Exchangers Manufacturing Association (TEMA). The water side of the cooling coil tubes is equipped with removable plugs on the return bends of the coils to permit cleaning.

The cooler housing is designed to ensure no loss of function when subjected to a pressure differential of 2 psi. The housing is open on four sides through the cooling coil sections and through the base by the fan barrel. Each of the four sides of the housing is approximately 40 percent free area through the coil face. This provides ample free paths to minimize differential pressure during the post-accident transient-pressure condition.

A simplified analysis was performed on the containment air recirculation and cooling units to demonstrate that the units will not experience a differential pressure greater than 2.0 psi during the post-incident conditions. The following is a summary of that analysis:

1. It was assumed that a given cooler was pressurized with air to a pressure of 2.0 psig.

2. Assuming air to be a perfect gas, the change in mass from atmospheric pressure to 2.0 psig was calculated.

3. Based on the 2.0 psi per second post-accident pressure transient, the mass flow rate, and hence, the volumetric flow rate, can be calculated.

4. Assuming the pressure drop across the coil banks is proportional to the square of the flow rate, for any given flow rate the corresponding pressure drop across the coil banks, and hence the cooler housing, can be calculated.

Based on the above-simplified analysis, a flow rate less than 7,000 CFM (normal flow rate is 70,000 CFM) was calculated based on the 2.0 psi per second pressure transient. The drop across the coil banks is much less than 0.10 inches w.g., which is negligible. This allows a factor of about 100 inches converting the model from the perfect gas to the post-accident steam-air mixture. The difference in densities between the model assumed (0.075 lb/ft^3) and the design post-accident atmosphere (0.18 lb/ft^3) is about a factor of 2. Therefore, there is adequate margin to demonstrate that the containment coolers will not experience a pressure gradient across the housing of 2 psi.

Each Containment Air Recirculation and Cooling unit is provided with a vibration-sensing switch. In the event of excessive, sustained vibration at the fan assembly, the switch will provide an alarm in the Control room.

The valves in the normal cooling water outlet lines (6 inches) will be open during normal operation and valves in the parallel emergency outlet lines (10 inches) can be opened from the control room and the flow rate can be monitored at any time.

The maximum RBCCW temperature on the discharge side of the containment air recirculation and cooling unit coils is 234°F during design post-accident conditions. The RBCCWS operates under pressure, approximately 50 psia in the downstream piping. The saturation temperature corresponding to this operating pressure is approximately 280°F. Therefore, the RBCCW temperature at the discharge side of the CAR units is approximately 46°F below saturation. In addition, the RBCCW surge tank (Section 9.4.2.1) maintains a minimum static head on the CAR coolers, corresponding to about 30 psia. The saturation temperature corresponding to this pressure is 250°F.

6.5.4.2 Tests and Inspections

The major components of the containment air recirculation and cooling system are tested for performance and integrity to assure its ability to operate within the containment post-accident environment.

The cooling coil sections are similar to a coil section which has been previously tested and has demonstrated the capability of condensing steam at conditions equal to or greater than the LOCA design conditions. The coil section performance test results are compared to computed data and the comparison is then used to predict the performance of the full-size coil assembly. A topical report, W-CAP-7336-L, verifying the performance of similar coils for this application was filed by Westinghouse with the NRC.

The fans and motors are similar to those which were tested and demonstrated as having the capability of starting and operating in the post-accident environment. Testing is conducted in accordance with the Draft IEEE Standard 334-1971. Westinghouse is preparing to file topical report, W-CAP-7829, on the test results. Topical reports, W-CAP-7343-L and W-CAP-9003, for the motor insulation and cable splice were filed with the NRC by Westinghouse. A complete commercial motor test is performed before and after the simulated LOCA tests on the production model motor.

Each fan and motor was tested as a unit to assure characteristic performance curves. Fan ratings are in accordance with Air Moving and Conditioning Association (AMCA) Standard Test Code 211-A.

All stators used in qualified Class 1 motors (such as these) are given a voltage test in water before assembly in a motor.

Hydrostatic testing was performed on the cooling coil sections in accordance with ASME Code Section VIII requirements. The cooling coil tubes were nondestructively tested in accordance with ASTM Standard E-243-68.

The containment air recirculation and cooling system ductwork is leak tested and balanced in accordance with Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Standards.

Provisions are incorporated into system design for online testing during normal operation. Each group of two containment air recirculation and cooling units is tested separately. In accordance with applicable Technical Specifications and corresponding procedures, during Modes 1, 2, and 3, CAR unit emergency RBCCW outlet valves and slow CAR fan speeds are tested. The testing of the remotely operated RBCCW valves is performed by operating the corresponding manual control switch. The testing of slow fan speeds is also performed by use of manual control switches in the control room. The positions of the valves and fan speeds are verified by status lights in the control room.

The testing of these components during Modes 1, 2, and 3 does not use any manual initiation of SIAS. Such a manual SIAS actuation would result in unnecessary starting of diesel generators and unnecessary RBCCW flow transients.

Additionally, in accordance with Technical Specifications required surveillance frequencies, during outages, manual SIAS actuations are used for testing automatic actuation circuitry for emergency operation of CAR units, as well as other integrated safeguard features.

The fusible link blowout doors (plates) were tested as part of the initial plant pre-operational test of the containment air recirculation and cooling system. The blowout doors were tested for disengaging to open to allow an air flow path from the ductwork as the local ambient temperature exceeded 170°F. The blowout doors are mounted with compressed springs between the blowout doors and the ductwork to provide a spring action for an initial disengaging push to open the blowout doors, when the fusible links melt.

Assuming a failure of the fusible link plate to disengage, there would be a partial loss of that containment air recirculation and cooling unit. Each unit is provided with four (4) plates to insure at least partial flow. Should one of the four (4) plates on a given unit fail, there would be only a partial loss of flow due to the increased system resistance.

A preoperational test of the containment air recirculation and cooling system was performed prior to start up. The test procedure is described in Section 13.

Equipment and associated components located in the containment are accessible for inspection and maintenance during shutdown.

In lieu of test results under 10 CFR 50, Appendix J. Type C testing, the “T-Ring” seats on the containment isolation valves, for the RBCCW supply and return lines for the Containment Air Recirculation and Cooling heat exchangers, will be replaced based on observed degradation. These valves are not in the Type C testing program because the valves are open during accident conditions. This eliminates a commitment made under letter A06107 dated 1/16/87 under Docket Number 50-336.

TABLE 6.5-1 CONTAINMENT AIR RECIRCULATION AND COOLING UNITS MATERIALS OF CONSTRUCTION

Fans (F-14A/B/C/D)

Type	Vaneaxial
Standard	AMCA 211-A
Seismic Class	1

Motor

Type	Induction
Standard	NEMA
Seismic Class	1

Cooling Coils (X-35A/B/C/D)

Type	Water (RBCCW)
Standard	ASME Section VIII
Seismic Class	1

Ductwork

Type	In Accordance With Specification M-506
Standard	SMACNA
Seismic Class	1

TABLE 6.5-2 CONTAINMENT AIR RECIRCULATION AND COOLING UNITS PERFORMANCE DATA

Per Unit	Normal	Post-incident (prior to SRAS)
Heat removal capability (Btu/hr)	2.2×10^6 (nominal rating)	80×10^6 (nominal rating)
Air flow (cfm)	70,000 (nominal rating)	34,800 (nominal rating)
Static pressure (inches wg)	2.98	0.53
Brake horsepower (bhp)	70.0	18
Static efficiency (%)	56	50.7
RPM	1760	875
Motor horsepower, (hp)	75	37.5
Air temperature, inlet/outlet (°F)	120/90.9	289/281.8
Water temperature, inlet/outlet (°F)	85/94	130/210
Water side pressure drop (feet H_20)	3	25
Water flow rate (gpm)	* 500	2000

Note:

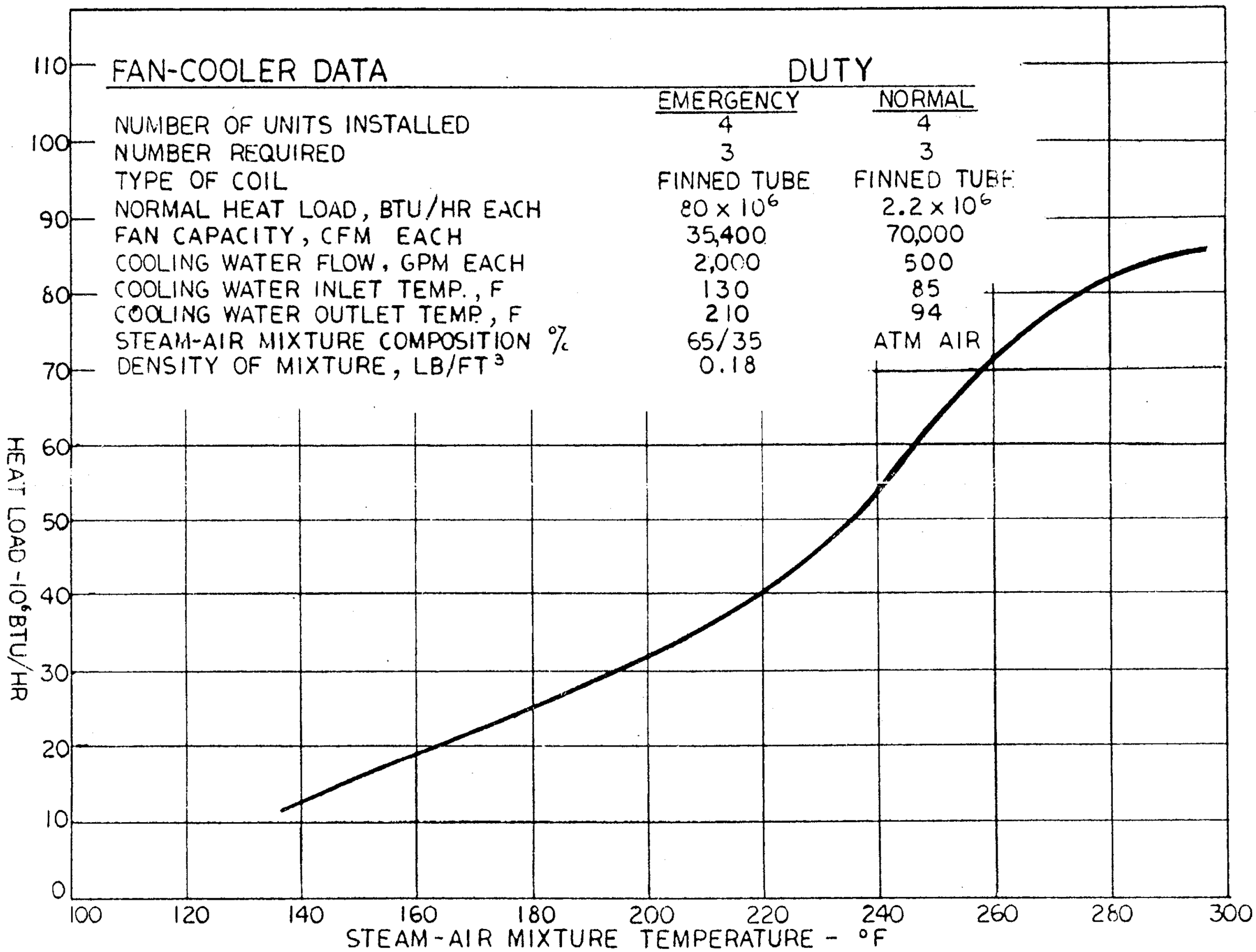
* The cooling water flow through the CAR coolers is maintained at approximately 2000 gpm during normal operation to maintain RBCCW pump flow closer to the normal pump design conditions.

TABLE 6.5-3 CONTAINMENT AIR RECIRCULATION AND COOLING SYSTEM

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	METHOD OF DETECTION & MONITOR	DETRIMENTAL EFFECT ON SYSTEM	CORRECTIVE ACTION	RESULTANT SYSTEM STATUS	REMARKS
Housing CTMT cooling unit (4)	Housing failure (Air bypasses cooling coils)	Temperature sensing device if available	Loss of cooling	Unit taken out of service	One unit out of service, three alternate units operable	Sufficient containment cooling provided by two units in combination with one containment spray subsystem or by two (2) containment spray subsystems.
Cooling coils (Eight (8) per unit)	Tube header of manifold rupture	Temperature sensing device, if available	Loss of cooling	Same as above	Two units on RBCCW Header taken out of service	Sufficient containment cooling by a combination of two (2) units with one (1) containment spray subsystem.
Fans (4)	Fails to operate	Status lights CRI	Loss of air flow	Same as above	One unit out of service, three alternate units operable	Same as Item 1
Fusible ink plates (4)	Fails to open	None	Partial loss to complete loss of air flow depending upon degree of restriction in ductwork system	None	Partial to complete loss of one unit, three alternate units operable	Same as Item 1

FIGURE 6.5–1 CONTAINMENT AIR RECIRCULATION AND COOLING UNIT FAN PERFORMANCE CURVE

FIGURE 6.5–2 CONTAINMENT AIR RECIRCULATION AND COOLING UNIT COIL PERFORMANCE CHARACTERISTICS



6.6 CONTAINMENT POST-ACCIDENT HYDROGEN CONTROL SYSTEM

The hydrogen recombiner portion of the Post-Accident Hydrogen Control System is installed, but not used for any mitigating function. The hydrogen recombiners, associated controls and alarms have been isolated awaiting abandonment. The following section describes the recombiners as originally installed and operated.

6.6.1 DESIGN BASES

6.6.1.1 Functional Requirements

The post-accident hydrogen control system functions to control the concentration of hydrogen which may be released within the reactor containment atmosphere following postulated accidents.

6.6.1.2 Design Criteria

The following criteria have been used in the design of the containment post-accident hydrogen control system:

a. Each system has two redundant, independent subsystems, each capable of performing the functional requirements.

b. The system has suitable subsystem and component alignments to assure operation of the complete subsystem with its associated components.

c. Capabilities are provided to assure the system operation with on site power (assuming off site power is not available) or with off site electrical power.

d. A single failure of an active component in either subsystem will not affect the functional capability of the other subsystem.

e. The system is designed to permit periodic inspection of important components such as hydrogen recombination units, fans, filters, valves, piping, ductwork and analyzers to assure the integrity and capability of the system.

f. The post-accident hydrogen control system is designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leak-tight integrity of its components; (2) the operability and performance of the active components of the system, and (3) the operability of the system as a whole. Under conditions as close to the design as practical, the performance will be demonstrated of the full operational sequence that brings the system into operation, including operation of applicable portions of the protection system and the transfer between normal and emergency power sources.

g. The post-accident hydrogen control system is designed to the general criteria as described in Section 6.1.

h. The components of the containment post-accident hydrogen control system are designed to operate in the most severe post-accident environment as described in Section 6.1.

i. The post-accident hydrogen control system is designed in accordance with the conditions given in Regulatory Guide 1.7.

6.6.2 SYSTEM DESCRIPTION

6.6.2.1 System

The post-accident hydrogen control system is shown schematically in Figure 9.9–2.

The post-accident hydrogen control system includes independent, fully redundant subsystems to mix and monitor the hydrogen concentration in the containment following a loss-of-coolant accident.

The uniform mixing of the containment post-accident atmosphere is provided by the post-accident recirculation (PIR) system. This (PIR) system is provided inside the containment to mix any hydrogen accumulated in the upper portion of the containment with the rest of the containment atmosphere.

The post-accident recirculation system takes suction from the highest points in the containment and discharges air to the minus 3 foot elevation area of containment. Two CAR fans and coolers remove air from the minus 3 foot elevation area, and dilute this mixture with additional containment air and discharges it into the lower elevations of containment. Each PIR system is designed for one air change per hour from the upper 20 percent of the containment volume.

Two full capacity, completely redundant, hydrogen concentration monitoring systems are provided outside the containment for periodic or continuous analysis of hydrogen concentration in the containment atmosphere.

Each train of the hydrogen monitoring system consists of a sensor module located in the east electrical penetration room elevation 14 feet 6 inches, a remote calibration module located in the railroad and truck access bay elevation 14 feet 6 inches, and a control room module located in control room panel C101. Recorders in control room panel C101 provide indication and a permanent record of the hydrogen concentration.

The main control room and the remote calibration module are accessible at all times. Access to the sensor modules under post-accident conditions is not necessary. Control of all system functions including performing calibrations is available from the remote calibration modules. In addition, the control room module provides system power status indication, system alarms and system start control to the control room personnel. Since the two trains of the hydrogen monitoring system are completely independent, no single failure can prevent operating personnel from initiating hydrogen sampling or reading hydrogen concentration from the control room.

Hydrogen concentration measurements are made by two identical subsystems each of which monitors a sample from the containment atmosphere. High hydrogen concentration is alarmed at two volume percent.

Each hydrogen monitoring system draws containment gases through a small diameter sample line which limits the flow rate and reduces the sample transit time. From the analyzer, the sample is returned to the system from which it is drawn.

The active means for reducing the hydrogen concentration in the containment following a postulated accident are provided by hydrogen recombination subsystems. The recombiners have no mitigating function.

Each of the recombiners is capable of 100 SCFM.

The hydrogen recombiners are located within the containment and consist of two completely independent, full capacity thermal type recombiner units.

One recombiner unit is located on the operating floor at Elevation 38 feet 6 inches. The second unit is at Elevation 14 feet 6 inches.

The containment hydrogen-air atmosphere is circulated across electric heating elements. The influent is heated to approximately 1100°F at which temperature the recombination reaction takes place. Containment air is induced into the recombiner unit by the natural draft created by the temperature differential between influent and effluent. Additional driving forces are not required.

A method for hydrogen reduction in the containment following a LOCA is the hydrogen purge system. The hydrogen purge operation, is not credited in accident analysis. During purging operations, the hydrogen concentration is reduced by providing makeup air from the instrument air or station air compressors using containment atmosphere sample return line penetrations into the containment, and by remotely opening the containment isolation valves (2-EB-91 & 2-EB-92, or 2-EB-99 & 2-EB-100) to their respective 6 inch line connecting with the Enclosure Building Filtration System (EBFS) common plenum.

Each purge train includes a passive flow control station, consisting of a manual valve (in the open position) in the 6-inch line (valve 2-EB-193 Train “A” or valve 2-EB-194 Train “B”), and a small 1.5 inch bypass line equipped with a flow element and a remote flow indicator.

The containment purge flow is mixed with the enclosure building filtration system and is passed through the EBFS charcoal filters discharging through the Millstone Stack.

The hydrogen purge system does not need to be redundant or be designed Seismic Category I, consistent with the recommendations of Regulatory Guide 1.7, Rev. 2, except insofar as portions of the system constituting part of the primary containment boundary or containment filters.

The instrument air, used for purging, ties into line 1"-HCD-118 upstream of valve 2-AC-20 and enters the containment through penetration 87, (Figure 9.11–1). The station air used for purging ties into line 1"-HCD-117 upstream of valve 2-AC-15 and enters the containment through penetration 62, (Figure 9.11–1). Two capped branch connections are also provided downstream of valves 2-AC-20 and 2-AC-15 for a temporary emergency air supply.

If the air compressors are not available after a LOCA, there is adequate time to restore the system to service. Portable air compressors can be connected to the capped connections provided for emergencies.

Since the purging of containment atmosphere could increase the radiological dose to the public, this system is initiated only when hydrogen concentration must be reduced due to a threat to containment integrity as the result of a beyond design basis accident.

6.6.2.2 Components

The components of the hydrogen purge system are described with the EBFS in Section 6.7.2.2. The major components with associated fabrication and performance data are listed in Table 6.6-1.

The Hydrogen Recombiner units supplied by Westinghouse, consist of two 100 percent capacity recombiners, thermal (electric) type, of completely passive design with no moving parts and with operating controls mounted on control boards located in the Main Control Room. Environment tests under simulated conditions have been performed by Westinghouse with results verifying the integrity and reliability of their units.

The hydrogen monitoring system is supplied by Whittaker Safety Systems. Two redundant trains are supplied each consisting of a sensor module, a remote calibration module, and a control room module.

Each sensor module contains valves, sensors, heat trace and a sample pump. Connections to the sample stream supply and return, calibration gases and Containment Air Post Accident Sampling System are provided. The hydrogen sensors use electrochemical gas measurement technology. The sensor modules are located in the east electrical penetration room elevation 14 feet 6 inches. The maximum air temperature in this room will be 140°F and maximum relative humidity will be 100 percent after a LOCA. Access to the sensor modules is not required for system operation or to perform system calibrations.

The sensor module will take a sample from the containment atmosphere and return it to containment after measuring the hydrogen concentration. Provisions to divert the sample stream to the Containment Air Post Accident Sampling System prior to returning it to containment are provided. Operation of the Containment Air Post Accident Sampling System with the hydrogen monitoring system discharge will not interrupt the ability to monitor hydrogen concentration.

Each remote calibration module contains a microprocessor, controls and relays necessary for operation, self-monitoring, performing calibrations and interfacing with the control room. Control room annunciation is provided for high hydrogen, system trouble and low ambient temperature local to the remote calibration modules. The system range is 0 to 10 percent hydrogen. Calibration of the system is performed using calibration gases with 1 percent and 4 percent hydrogen. The remote calibration modules and the calibration gas bottles are located in the railroad and truck access bay elevation 14 feet 6 inches, which is accessible after a LOCA.

Each train has a control room module located in control room panel C101 which interfaces with the remote calibration module. Each control room module has system 120 VAC and 480 VAC status lights, alarms for loss of power, system trouble and high hydrogen, and a control switch for initiating hydrogen monitoring from the control room. Control room display of hydrogen concentration is provided on a recorder also located on control room panel C101.

The hydrogen monitoring system is QA Category 1. Two redundant trains of equipment meet the design and separation requirements for Class 1E and are powered from separate Class 1E power sources. Piping, tubing and other equipment is Seismic Class 1. The monitor system must be operable following, but not necessarily during a SSE. Pressure boundaries which are an extension of the containment building atmosphere are designed to maintain their integrity during a SSE.

Qualification tests for the hydrogen monitoring equipment include seismic testing, pressure testing and performance testing.

6.6.3 SYSTEM OPERATION

6.6.3.1 Emergency Conditions

In the unlikely event of a LOCA, the post-accident hydrogen control system is manually initiated by operation action. All subsystems are initiated and monitored in the control room.

The PIR system is initiated within the first few hours following the LOCA. The system takes suction from the dome region where the initial local concentration of hydrogen is anticipated. This potential hydrogen-air mixture is conveyed through carbon steel piping headers and exhausted near the inlet of the containment air recirculation and cooling units located on the minus three foot level of containment (Section 6.5) where it is diluted with the containment environment from lower elevations.

The operation of the PIR system can be monitored in the control room by indicating lights and motor trip alarms.

Two redundant, independent hydrogen monitors are provided for sampling during post-accident operation. Continuous sampling is manually initiated from the Control Room. Recorders provide the operators with visual indications of the measured hydrogen concentration between zero to ten volume percent. Grab sampling of containment atmosphere can be taken from the post-accident sample system (PASS) containment air remote operator modules C102A & B located at elevation 14 feet 6 inches of the auxiliary building.

In accordance with Regulatory Guide 1.7 Rev. 3, within 90 minutes following the initiation of safety injection, the hydrogen monitors are required to be fully functional.

The hydrogen recombiner system may be manually initiated from the control room. The operation of the recombiners is monitored in the control room by indicating lights and measurement of the effluent temperature. Performance of the recombiners is monitored by measurements of the local concentration of hydrogen in the containment by the monitoring system.

Operating at rated capacity of 100 scfm of hydrogen-air mixture, each recombiner removes two scfm of free hydrogen from the containment atmosphere when the hydrogen concentration is at least two percent by volume.

The hydrogen purge system is provided as an active means for reducing the local buildup of hydrogen. This operation is initiated manually.

The overall performance of the containment post-accident hydrogen control system is monitored by the recorders located in the control room. Each hydrogen monitoring system is set to alarm at two volume percent containment hydrogen concentration.

6.6.4 AVAILABILITY AND RELIABILITY

6.6.4.1 Special Features

The components of the containment post-accident hydrogen control system are designed to the general requirements, including seismic response, as described in Section 6.1. All components are protected from missile damage and pipe whip by physical separation of duplicate equipment, as described in Section 6.1.

To assure availability, all components located within containment are designed to withstand the pressure and temperature transients conditions resulting from a LOCA. Each PIR subsystem is provided with carbon steel suction headers to assure system integrity following the LOCA. Ductwork is not used in the PIR system. The motors associated with the PIR fans are designed to operate in a containment post-accident environment.

The PIR fans are located outside the secondary shield wall, below the operating floor, at an elevation well above the post-accident water level. In this location the fans are protected against credible missiles and flooding.

The PIR fans are completely redundant, are powered from independent emergency sources and are physically separated in the containment. A failure mode analysis of the PIR system is given in Table 6.6-4.

The hydrogen monitoring system includes two independent, fully redundant monitoring subsystems. Both are physically separated and located outside the containment. Independent emergency power sources are provided for each subsystem.

If the normally aligned Instrument Air System is unavailable, a safety related backup bottled air supply subsystem provides the source of air required to open the Containment Isolation Valves required to establish a flow path for the Hydrogen Monitoring System post-accident. The backup bottled air supply system to the Hydrogen Monitoring System is not independent as both trains of inside and outside CIVs are supplied operating air by the same supply header (one supply header to the inside valves and one supply header to the outside valves), however, it is designed to meet Single Failure Criteria.

The hydrogen recombiner systems are completely redundant, are supplied from independently emergency power supplies and are physically separated. Each recombiner unit is designed to withstand the temperature and pressure transient following a LOCA and to operate under post-accident conditions. Both units are located well above the flood level in the containment and physically separated for missile protection.

The containment has redundant penetrations and pipe headers for the hydrogen purge systems and are physically separated for protection from credible missiles. Each hydrogen purge system is provided with independent valving and instrumentation and powered from independent emergency sources. Prior to initiation of the hydrogen purge system, the EBFS electric heaters, X-61A/B, are manually taken out of service. The EBFS is described in Section 6.7. Ductwork is utilized outside the containment only, under atmospheric pressure conditions.

Each hydrogen purge valve is provided with an auxiliary air accumulator to assure an air supply for post-accident operation. The cylinder air-operated valves if open, are closed by the accumulator air assuming a failure of the normal instrument air system (Section 9.11). Air is available in the accumulator for opening the purge valves, if required, for hydrogen control. Each accumulator is sized for four open or close operations.

The hydrogen purge containment isolation valves inside containment are designed to fail in their last position. These valves are normally closed and are therefore, expected to be closed during the LOCA condition.

Intermittent system operation or system isolation can be controlled by the outside containment isolation valve. These valves are provided with handwheels for manual operation should instrument air be unavailable.

Precautions have been taken in the design of the equipment, their support structures and building structures in the containment to avoid probable pockets or enclosures where hydrogen build-up could occur locally. Provisions have been incorporated for ventilation holes, sloping concrete floor slabs, openings and other means of allowing locally generated hydrogen to flow upward in the containment.

The major source of hydrogen generation following the accident is the containment sump. Since the sump region will be at a higher temperature than the dome region due to the cool containment spray water (Section 6.4) entering the containment, a stack effect will be created. Therefore, it is assumed that the higher energy hydrogen-air mixture from the containment sump region will tend to rise toward the dome. Vent areas, such as the floor grating outside of the secondary shield wall, around the steam generators and over the reactor coolant pump motors, offer negligible resistance to this induced flow. Taking a cross-section of the containment at the operating floor (elevation 38 feet 6 inches), the ratio of the free area created by the grating and other openings to the cross-section area of the containment is 70 percent. Conservation analyses estimate an induced flow in the order of 15,000 CFM from one steam generator compartment at the containment conditions one (1) day after the accident. Although this flow rate decreases with containment post-incident temperature and pressure, the mechanism of transport is established.

Although the hydrogen concentration will tend to equalize itself, the PIR system accelerates this process by maintaining a slight negative pressure in the containment dome region, thereby supplementing the natural buoyancy forces, and by mixing the dome hydrogen-air mixture through the containment air recirculation and cooling units with lower level mixtures, thereby assuring a uniform mixture throughout the containment.

Each hydrogen recombiner unit is capable of 100 scfm to assure the reduction of hydrogen concentration and to shorten the duration of operation. The backup hydrogen purge system processes the containment effluent through the EBFS charcoal filters prior to discharge through the 375 foot Millstone stack.

Sufficient emergency electrical power is available to operate the post-accident hydrogen control components.

6.6.4.2 Tests and Inspection

The post-accident recirculation fans and motors are similar to those which are tested for starting and operating within the containment post-accident environment. Engineering data are provided to substantiate the extrapolation of environmental tests which are conducted at Joy Manufacturing Company on nuclear containment motors (Section 6.5.4.2) which are similar to the motors provided for the PIR fans. Components, materials, standards, method of manufacture and design criteria of the PIR fan motors are of identical origin and application to those motors tested by Joy. The only variation is in the motor size with relative horsepower and RPM. The tests performed by Joy are in accordance with the Draft IEEE Standard 334-1971. Identical QA records and reports are maintained on both the motors.

The motors used in the postincident recirculation units are made by Reliance Electric Company. Prototype motors have been successfully tested in a steam-air environment, hence the manufacturer does not consider a production test as described above to be necessary.

Prototype testing included a four hour run followed by four two-hour runs in a 300°F ambient. Record bearing temperatures were of the order of 300°F, and winding temperatures were of the order of 360-400°F. Each of the above cycles were separated by two, two hour runs in an ambient of 200-220°F.

Since this is a totally enclosed motor, no boric acid crystals can enter the internal air passages. All external air is directed along the ribbed motor enclosure.

No qualification test can insure that a motor has a service life greater than that demonstrated by service experience to date. It demonstrates that the equipment, in an aged condition, is capable of operating in a post design basis event environment for a period at least as long as the test cycles.

One of the two PIR fans has been rated in accordance with Air Moving and Conditioning Association (AMAC) Standard 211A.

The PIR system is incorporated with provisions for on-line testing. Each subsystem is tested individually. The PIR fan is manually initiated from the control room and is monitored for operation by motor trip alarms.

Full system tests are conducted during shutdown.

The PIR system is located within containment. The PIR fans are located near the operating floor to permit access for inspection and maintenance during shutdown.

The hydrogen monitoring system design has provisions for performing calibrations without accessing the sensor module in the east electrical penetration room elevation 14 feet 6 inches. The calibration process is initiated and controlled from the remote calibration module in the railroad and truck access bay elevation 14 feet 6 inches. The calibration process utilizes calibration gases of 1 percent hydrogen in nitrogen and 4 percent hydrogen in nitrogen. The gas cylinders with the calibration gases are located in the railroad and truck access bay near the remote calibration modules.

The hydrogen purge system is incorporated with provisions for on-line testing. The hydrogen purge valves are tested with the EBFS as described in Section 6.7.4.2. Purge valves 2-EB-91, 92, 99, and 100 opening is monitored by position indication in the control room.

Each purge valve is tested periodically to assure the operability of the accumulator tank. The normal air supply is isolated and operation is provided by the accumulator.

Purge valve elastomers and shaft packing are adjusted and/or replaced based on 10 CFR 50, Appendix J, Type C test results.

[1]Note: ORNZ-4749, VC4-Chemistry, Analytical Chem. Div. Annual Progress Report, September 30, 1971

TABLE 6.6-1 CONTAINMENT POST ACCIDENT HYDROGEN CONTROL SYSTEMS COMPONENT DESCRIPTION

PIR Fan (F-18A/B)

Type	Vaneaxial
Flow (CFM)	7,000 (nominal rating)
Standard	AMCA 211-A
Seismic Class	1

PIR Fan Motor

Type	Squirrel Cage Induction
Horsepower rating, (hp)	25
Code	NEMA
Seismic Class	1

Hydrogen Monitoring System

Manufacturer	Whitaker Safety Systems
Model	Containment Atmosphere Monitoring System
Accuracy	+/- 0.2% Hydrogen
Ambient Temperature	40 to 140°F (Analyzer and Remote Cabinets)
Sample Temperature	300°F
Sample Pressure	-5 to 65 psig

Hydrogen Recombiner

Manufacturer	Westinghouse
Quantity	2
Type	Thermal (electric)
Capacity	100 SCFRM
Power Input	75 kW
Housing Material	Stainless Steel 300 series
Inner Structure	Inconel 600
Heater Element Sheath	Incoloy 800
Maximum Sheath Temperature	1550°F
Temperature at Heater Outlet	1150°F to 1400°F
Exhaust Temperature	100°F above ambient

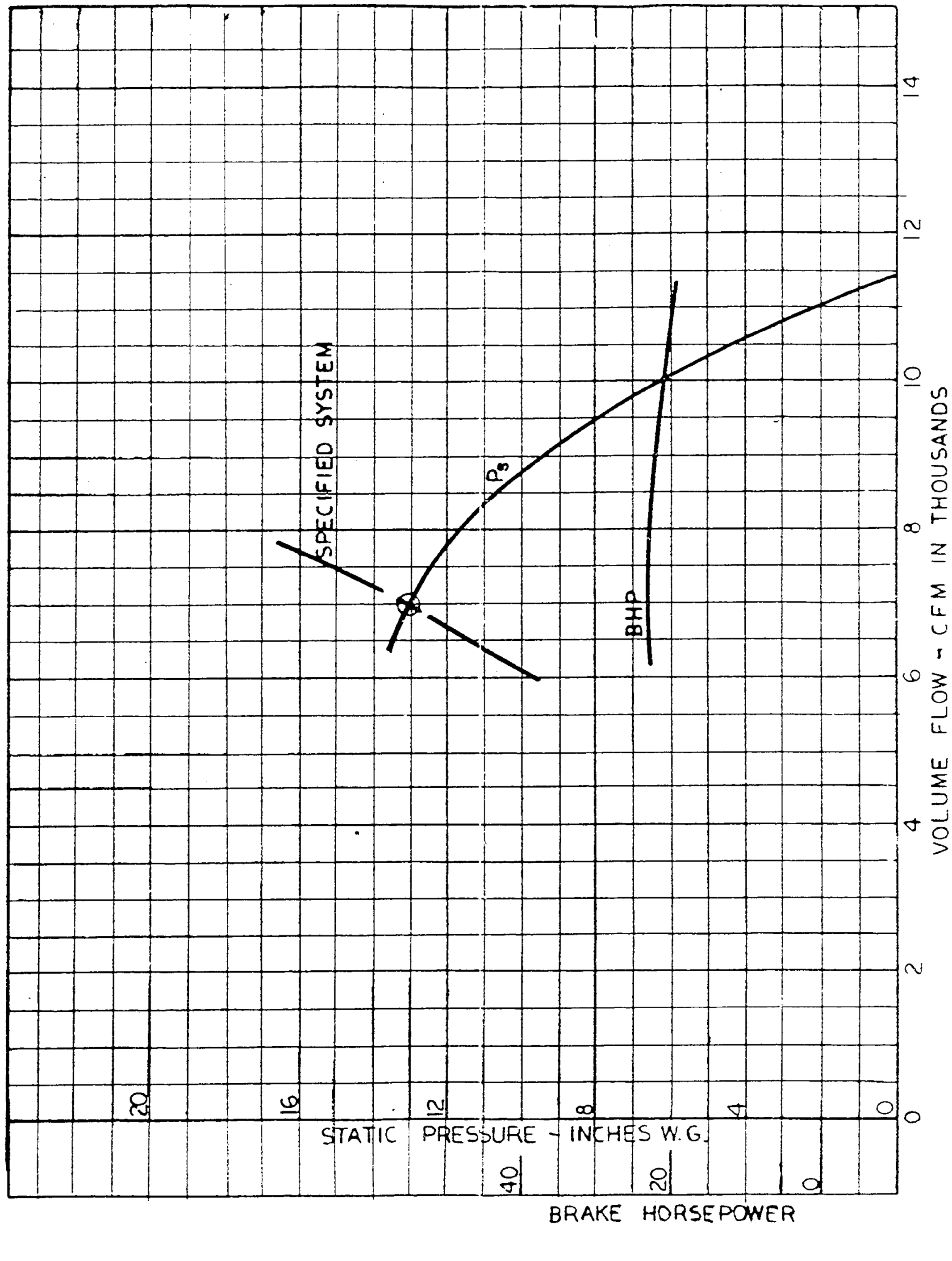
TABLE 6.6-2 DELETED BY FSARCR 04-MP2-018

TABLE 6.6-3 OMITTED

TABLE 6.6-4 POST-INCIDENT RECIRCULATION SYSTEM FAILURE MODE ANALYSIS

COMPONENT IDENTIFICATION & QUANTITY	FAILURE MODE	METHOD OF DETECTION & MONITOR	DETRIMENTAL EFFECT ON SYSTEM	CORRECTIVE ACTION	RESULTANT SYSTEM STATUS	REMARKS
PIR Fan (2)	Fails to start	Status light	Loss of one subsystem	None	One subsystem taken out of service	Redundant PIR Subsystem is available.
Pipe header	Rupture	None	Partial loss of suction from containment dome region	None	One subsystem does not perform the intended function	Same as above.

FIGURE 6.6–1 POST-INCIDENT RECIRCULATION FAN PERFORMANCE CHARACTERISTICS



6.7 ENCLOSURE BUILDING FILTRATION SYSTEM

6.7.1 DESIGN BASES

6.7.1.1 Functional Requirements

The functions of the enclosure building filtration system (EBFS) are to collect and process potential containment leakage, to minimize environmental activity levels resulting from sources of containment leakage following a loss-of-coolant accident (LOCA). The enclosure building filtration region (EBFR) contains potential containment leakage. Throughline leakage that can bypass the EBFR is discussed in Section 5.3.4. The EBFS is also designed to reduce the concentration of combustible gas built up in the containment following a LOCA in conjunction with the Hydrogen Purge System (Section 6.6). Although not credited in the fuel handling accident and cask drop analyses, EBFS is capable of being automatically or manually aligned to minimize the consequences of those accidents.

6.7.1.2 Design Criteria

The following criteria have been used in the design of the EBFS:

a. The system has two redundant, independent subsystems, each fully capable of the functional requirement.

b. The system has suitable subsystem and component alignments to assure operation of the complete subsystem and with its associated components.

c. Capabilities are provided to assure the system operation with either on-site power (assuming off site power is not available) or with off site electrical power.

d. A single failure of an active component in either subsystem will not affect the functional capability of the other subsystem.

e. The EBFS is designed to permit periodic inspection of important components such as fans, motors, filters, filter frames, ductwork, dampers, piping and valves to assure the integrity and capability of the system.

f. The EBFS is designed to permit appropriate periodic pressure and functional testing to assure (1) the structural and leak tight integrity of its components, (2) the operability and performance of the active components of the system, and (3) the operability of the system as a whole. Under conditions as close to the design as practical, the performance is demonstrated of the full operational sequence that brings the system into operation, including operation of applicable portions of the protection system and the transfer between normal and emergency power sources.

g. The EBFS is designed to the general requirements as described in Section 6.1.

h. The components of the EBFS are designed to operate in the most severe post-accident environment as described in Section 6.1, with the exception of the electric heaters, X-6/A/B.

i. The EBFS is designed to support the Hydrogen Purge System (Section 6.6) in accordance with the conditions given in Safety Guide 7. However, consistent with Regulatory Guide 1.7, Rev. 2, a backup hydrogen purge system is not required to satisfy the safety-related function to control post-accident containment hydrogen. Therefore, the backup hydrogen purge system is no longer credited for hydrogen control.

6.7.2 SYSTEM DESCRIPTION

6.7.2.1 System

The EBFS is shown schematically in Figures 9.9–1 and 9.9–2. The EBFR includes the region between the containment and the enclosure building, the penetrations rooms and the engineered safety feature equipment rooms.

The EBFS is designed to establish and maintain a negative pressure of 0.25 inches w.g. within the EBFR immediately following a LOCA and to reduce airborne radioactive products to the environment by filtration prior to release of air through the Millstone Stack. Neglecting wind and stack effects, each EBFS train has the capability to maintain the EBFR under the minimum negative pressure of 0.25 inches w.g. The required minimum negative pressure can be achieved using both trains or either train of the redundant filtration systems.

The EBFS is located external to the containment in an enclosed area adjacent to the enclosure building. The EBFS exhausts air from all areas of the EBFR. Makeup air is induced into the EBFR by infiltration through building cracks, doors, and penetrations between the EBFR and outside or surrounding structures, as well as from potential containment leakage. The entire system is designed to operate under negative pressure up to the fan discharge. In all cases, the flow rate from this region exceeds the total maximum containment leakage rate.

The in-leakage into the EBFR was originally estimated using analytical and experimental leakage data (Reference 6.7-1). This leakage rate included a conservative containment leakage rate of 0.03 containment volumes per day. The design in-leakage rate was established at a factor of 3.0 greater than the estimated in-leakage rate. The leak tightness of the containment is independent of the operation of the EBFS and is established through Integrated Leak Rate Testing (ILRT) (Section 5.2.8.1).

The original Bechtel building specification for the enclosure building (Reference 6.7-2), required that all metal siding and metal roof decking be designed to withstand the pressure created by a wind load of 140 mph (Section 5.3) at the girt spacing shown on the design drawings, and with a maximum deflection of L/180 of span under load. In addition to the wind pressure, the metal siding and roof decking shall also withstand a differential pressure equivalent to 2 inches water gauge and maintain air tightness for the completed installation. On May 25, 1972, a test

(Reference 6.7-3) was performed based on the Specification (Reference 6.7-2) for a “negative pressure of 2 inches of water plus a wind pressure of 140 miles per hour.” The total test pressure of 9.75 inches w.g. was used and the leak-tightness capability was established at this pressure. The calculated maximum negative pressure (Reference 6.7-1) demonstrates that during two parallel fans operation, the EBFR negative pressure is less than the tested limit of 9.75 inches w.g.

The EBFS consists of independent, full redundant fans, filter banks, heating elements, isolation dampers, and ductwork with the exception of common plenums. Charcoal filters installed are demonstrated by tests to have a bypass leakage efficiency above 99 percent, and by a laboratory test to have an iodine removal efficiency above or equal to 95 percent in accordance with Technical Specification requirements.

The prefilters are provided to remove coarse airborne particles to prolong high efficiency particulate air (HEPA) filter life. The HEPA filters are provided to remove fine airborne particles that penetrate the prefilters. The activated coconut shell charcoal filters are impregnated to remove methyl iodine as well as elemental iodine contaminates resulting from a LOCA or a spent fuel handling accident in the spent fuel pool.

Electric heaters (X-61A/B), rated at 25 kW each, are provided to maintain the entering air stream relative humidity (RH) to the charcoal filters below 90 percent. They are also required to be operated per Technical Specification surveillance requirements. These heaters may not be available throughout a LOCA due to high radiation. However, analyses considering the maximum possible relative humidity within the Enclosure Building Filtration Region during a LOCA, or a REA, or within the Fuel Handling area during a Fuel Handling Accident, determined that the entering EBFS air stream remains below 90 percent RH without the heaters. The electric heaters are energized when the fan is on and deactivated manually prior to initiation of Hydrogen purge.

The EBFS fans are belt driven centrifugal fans capable of operating singly or in parallel with the redundant system. EBFS fan operating parameters are shown in Table 6.7-1. A failure mode analysis for the EBFS is given in Table 6.7-2.

Ductwork for that portion of the EBFS located outside the enclosure building is round and/or rectangular. Longitudinal seams are continuously welded air tight.

The EBFS may be used for containment cleanup during cold shutdown and refueling (Modes 5 and 6). The EBFS can be operated in combination with the containment purge system (Section 9.9.2) for containment cleanup of minor releases of radioactivity. These interconnections between the two systems are shown in Figures 9.9–1 and 9.9–2. This process may be initiated to reduce activity levels prior to purging the containment.

When using the EBFS to purge containment, either train or both trains may be used to perform this activity. The incoming flow path is provided by opening the following dampers: 2-AC-1, 3, 4, & 5 and the exhaust flow path is provided by opening 2-AC-6 and 2-AC-7. Since the purge supply fan, F-23, is not activated, the purge rate is a function of the EBFS train(s) capacity.

The EBFS may also be used to vent (depressurize) the containment under all modes of operation, through the hydrogen purge system, by opening the six inch line valves 2-EB-99/100, or 2-EB-91/92.

The EBFS discharges to the Millstone stack. Containment cleanup is initiated manually by operator action. The connections to the EBFS are automatically closed by an EBFAS to assure system integrity for post-accident operations.

6.7.2.2 Components

The major components with their associated fabrication and performance data are listed in Table 6.7-1.

6.7.3 SYSTEM OPERATION

6.7.3.1 Emergency Conditions

In the unlikely event of a LOCA, the EBFS is automatically initiated by the EBFAS as described in Section 7.3. Air is exhausted from the EBFR, processed through the filter banks and discharged through underground piping to the Millstone 375 foot stack. Redundant on site emergency power is provided by the diesel generators as described in Section 8.3.

System performance is monitored in the control room. Differential pressure across the filter units indicates filter dust loading and replacement requirements. Low flow conditions are alarmed in the control room and local flow indication is provided upstream of each filter unit. A temperature sensor is located within each enclosure filter unit in the vicinity of the charcoal elements to alarm excessive temperature.

The pneumatically operated dampers are normally closed to isolate the filter unit. These dampers open automatically upon the EBFAS and are designed to fail in the open position. The positions of all power operated dampers are indicated in the control room.

The EBFS is designed to reduce the concentration of combustible gas buildup in the containment following a LOCA by controlled purging operations. This operation is described in Section 6.6.3.

Prior to initiation of the hydrogen purge system, the electric heaters in the EBFS filter units are manually taken out of service by tripping electric heater supply breaker. The backup purge operation is described in Section 6.6.2.1.

6.7.4 AVAILABILITY AND RELIABILITY

6.7.4.1 Special Features

The enclosure building structure is designed to retain structural integrity subsequent to a seismic event. However, the EBFS is not designed to be functional subsequent to a safe shutdown earthquake (SSE). All components are protected from missile damage and pipe whip by physically separating duplicate equipment as described in Section 6.1.

The reliability of the EBFS is assured by providing two independent, with the exception of common ductwork plenums, full capacity subsystems. Each subsystem is capable of maintaining the design negative pressure within the EBFR and of discharging into the 375 foot stack.

Differential pressure is measured from various locations within the EBFR including four locations within the enclosure building proper. The acceptance criteria is that each EBFS train individually establish a minimum negative pressure of greater than or equal to 0.25 inches w.g. in the EBFR within one minute after an enclosure building filtration actuation signal (EBFAS). Neglecting wind and stack effects, each EBFS train has the capability to maintain the EBFR under the minimum negative pressure of 0.25 inches w.g. The acceptance criteria of 0.25 inches w.g. assures that the EBFR will be maintained at a negative or neutral pressure precluding exfiltration under most meteorological conditions. With one EBFS train exhausting the EBFR, the combined effects of certain wind and stack pressures may cause positive pressures in the upper regions of the enclosure building. The potential exfiltration and radiological consequences due to positive pressure in the upper regions of the enclosure building, were analyzed and determined to be fully bounded by the radiological consequences of the low wind speed LOCA case presented in Section 14.8.4.

The EBFR is constructed to limit leakage as described in Section 5.3. Piping, cable tray and ductwork penetrations through the EBFR boundary are sealed with foam or insulation to decrease leakage. All doors into the EBFR are designed to minimize leakage. Containment penetrations into the EBFR are described in Section 5.2.6 and Section 5.3. The metal siding is constructed to limit leakage as described in Section 6.7.2.1.

The EBFS fans F25A/B are fully redundant and are powered from separate emergency sources. The EBFS fans are connected on the suction side by cross-tie ductwork which is provided with a parallel arrangement of electric motor-operated dampers which are likewise powered from separate emergency sources. These dampers are normally closed but can be opened by operator action following a fan failure. The design of the EBFS is such that it renders a loss of cooling air to the filters due to fan failure as incredible. The EBFS requires no additional decay heat removal system. Cooling air is always available, but not necessary (Section 6.7.4.1.1), to prevent iodine desorption and, therefore, ignition of the charcoal elements.

Each subsystem has a nominal design flow of 9,000 CFM. The fan performance curve is shown in Figure 6.7–1.

A failure mode analysis for the EBFS is given in Table 6.7-2. Although there are common plenums, all ductwork is considered a passive component whose failure is not credible.

6.7.4.1.1 Minimum Air Flow Required to Prevent Desorption of Radionuclides

The charcoal filter elements within the EBFS are analyzed to ensure adequate iodine removal capacity, and residual heat removal capabilities following any single failure. The analysis assumed iodine loading is limited to one EBFS unit, and concluded:

- Iodine loading of the enclosure building charcoal filters at 30 days post-accident is 0.267 milligrams of iodine per gram of charcoal, or approximately 11% of Regulatory Guide 1.52 design loading.

- No minimum flow is necessary to maintain the charcoal temperature below 200°F.

However, a temperature sensor is mounted within each filter unit, in the vicinity of the charcoal beds. This sensor provides alarm capability in the control room at 200°F or less.

6.7.4.1.2 Single Failure Evaluation

The containment and enclosure building purge system functions to maintain a suitable environment in the containment building (during Modes 5 and 6) or the enclosure building during any mode of operation (see Section 9.9.2).

As noted in Table 9.9-2 of the FSAR, the containment and enclosure building purge system is a nonsafety-related system. Purge system isolation dampers 2-AC-1 and 2-AC-11, including control circuits, are safety related since they receive a containment isolation actuation signal (CIAS) to close to isolate the enclosure building in the event of a LOCA. For the same reason, the controls for purge fan F23 are also safety related.

Simultaneous occurrence of a LOCA and a seismic event is not a design basis for Millstone Unit 2. Although the enclosure building structure is designed to retain structural integrity subsequent to a seismic event, the EBFS is not designed to be functional subsequent to an SSE. Maintaining a negative pressure in the enclosure building after an SSE is not assured mainly because the sheet metal siding may not remain intact. The original design for the purge supply and exhaust ductwork is nonsafety related and nonseismic.

FSAR Question 6.15.4 addressed single failure (failure to close on CIAS) for dampers 2-AC-1 (purge supply) and 2-AC-11 (purge exhaust). The response to Question 6.15.4 documented the basis for concluding that with an assumed single failure of 2-AC-1 to close, the minimum negative pressure of 0.25 inches w.g. can be maintained within the EBFR. The response noted that the evaluation was conservative for a postulated single failure of the exhaust damper 2-AC-11.

Since the installation of damper 2-AC-130 eliminates the 2-AC-1 damper single failure, there is assurance that the EBFS can maintain an adequate negative pressure within the EBFR as described in Section 6.7.2.

The containment and enclosure building purge inlet was modified with the installation of a counterbalanced gravity damper (2-AC-130) to provide redundancy for isolation damper 2-AC-1. This design change was a system upgrade to mitigate a postulated single failure of the Facility 1 CIAS signal to 2-AC-1.

The Main Exhaust System (MES) fans will trip on a CIAS actuation signal as described in Section 9.9.9.4.1, to mitigate the consequences of the 2-AC-11 single failure vulnerability. If the postulated single failure of 2-AC-11 occurred the MES fans will automatically trip. The enclosure building integrity is maintained by the design of the enclosure building as described in Section 6.7.2.1.

FSAR Question 6.17 addressed single failure (failure to open on CIAS) of enclosure building purge isolation dampers 2-AC-3 and 2-AC-8. The response stated that the assumed single failure of either damper was acceptable.

A design basis review of enclosure building isolation dampers 2-AC-1 and 2-AC-11 is documented in Millstone Unit 2 Nuclear Engineering Design and Program Services Department records.

6.7.4.2 Tests and Inspections

Individual components of the EBFS are tested to assure performance.

Prefilters are of the throwaway type to be replaced as necessary.

The HEPA filters characteristics are in accordance with MIL-STD-282 standard.

Each HEPA filter bank is tested, in place, periodically. The testing media will be Dioctyl-phthalate (DOP).

Charcoal filters are initially shop performance-tested and methyl iodide tracers for efficiency and Freon for leakage. After installation the charcoal filter banks were tested in place with Freon to ensure that there is no leakage across the filter bank and that the charcoal elements are not damaged. Each charcoal filter housing is provided with test canisters which contain a sample specimen of the charcoal used in the filter elements. These test canisters are analyzed periodically by an independent laboratory to determine remaining charcoal filter life and replacement requirements.

Each fan and motor is tested as a unit to assure characteristic performance curves. Fan ratings are in accordance with AMCA Standard Test Code 211-A.

The EBFS ductwork is leak tested and balanced in accordance with SMACNA Standards.

Provisions are incorporated to test the entire system for performance during normal operation. Each EBFS fan is tested simultaneously with the associated power operated valves and instrumentation, but independently from the redundant subsystem.

The EBFAS is initiated to start the fan and open the filter unit isolation dampers. The fan is tested at some point on the fan performance curve other than shutoff. Fan flow is verified by measuring the pressure differential across the filter elements. Opening of the power-operated dampers is monitored by the damper position indication in the control room. Since the containment purge ducts are vented back into the enclosure building by fail open dampers, additional testing is not necessary.

The EBFS is tested periodically to assure the negative pressure is maintained within the EBFR. EBFR negative pressure is monitored by differential pressure indicators located throughout the EBFR.

The EBFS undergoes a preoperational test prior to startup. The test procedure is described in Section 13.

The system equipment is fully accessible during all normal operation for maintenance and performance testing, including replacement of filter elements. The equipment is accessible for inspection and maintenance on components outside of the air stream during accident conditions.

6.7.5 REFERENCES

6.7-1 "Conventional Buildings for Reactor Containment," NAA-SR-10100, dated May 1965, issued by Atomics International, a Division of North American Aviation Incorporated.

6.7-2 Bechtel Specification Number 7604-A-16A, Section 12.0, "Design Criteria."

6.7-3 Pittsburgh Testing Laboratory witnessed an "Air Infiltration Test," on Siding and Roof Deck Mock-up, of the enclosure building, for Elwin G. Smith Division, Cyclops Corporation.

TABLE 6.7-1 ENCLOSURE BUILDING FILTRATION SYSTEM COMPONENT DESCRIPTION

Fans F-25A & F-25B	
Type	Belt driven
Capacity (nominal each)	9,000 cfm
Standard	AMCA-211-A
Seismic Class	1
Motors	
Horsepower rating, hp	25
Code	Nema, MG-1
Seismic Class	1
Electric Heaters X-61A & X-61B	
Power rating, kW	25
Code	UL approved
Seismic Class	1
Particulate Filters (Non-QA)	
Quantity per unit	9
Type (prefilter)	Throwaway
HEPA Filters	
Quantity per unit	9
Type	High capacity
Rated air flow per filter	
at 1.30 inches wg	1,500 cfm
at 0.87 inches wg	1,000 cfm
Standard	MIL-STD-282

TABLE 6.7-1 ENCLOSURE BUILDING FILTRATION SYSTEM COMPONENT DESCRIPTION (CONTINUED)

Charcoal Filters	
Quantity per unit (Trays)	27
Charcoal type	CNN-816 Activated coconut shell
Rated nominal air flow per unit	9,000 cfm
Standard	ANSI N-509
Ductwork	
Material/Type	IAW Specification M-506
Standard	SMACNA
Seismic Class	1
Piping, valves and fittings	
A. Suction	
Pipe sizes	Wall thickness
2.5 to 10 inches	SCH40
12 to 48 inches	0.375 inches wall
Material	Seamless ASTM A-53B (containment)
	Seamless ASTM A-333 (penetration)
Design pressure (psi)	60
Design temperature (°F)	289
Code	ANSI B-31.1.0 (containment)
	ANSI B-31.7 Class II (penetration)
Seismic	Class I
Construction	
Piping	2.5 inches and larger: butt-welded except at flanged equipment
Valves	2.5 inches and larger: butt-welded (except Butterfly Valves) 150 lb ANSI rating carbon steel
B. Discharge	
Pipe sizes	Wall thickness

TABLE 6.7-1 ENCLOSURE BUILDING FILTRATION SYSTEM COMPONENT DESCRIPTION (CONTINUED)

2 inches and smaller	Schedule 80
2.5 inches to 10 inches	Schedule 40
12 inches and larger	0.274 wall
Material	Seamless ASTM A-53A or B
Design Pressure (psi)	50
Design Temperature (°F)	120
Standard	ANSI B-31.1.0
Seismic	Class I
Construction	
Piping	2.5 inches and larger: butt-welded except at flanged equipment
	2 inches and smaller: 300 lb M.I. Screwed
Valves	2 inches and smaller: 125 lb WSP, screwed bronze
Ductwork	
Seismic	Class 1

TABLE 6.7-2 ENCLOSURE BUILDING FILTRATION SYSTEM FAILURE MODE ANALYSIS

Component Identification & Quantity	Failure Mode	Method of Detection & Monitor	Detrimental Effect On System	Corrective Action	Resultant System Status	Remarks
EBFS/AES Filtration Fan F-25A/25B	Fails to operate	Status lights on C01 Low flow alarm on RC 22	Loss of one subsystem	Monitor charcoal heatup and utilize opposite train	Redundant system operable	Both trains are automatically started upon EBFAS/AEAS signal. Each unit has 100% capacity. Utilize cross connect line for charcoal temperature control if needed.
Electric Heater X-61A/61B	Fails to operate	None See remarks*	None See remarks**	None	See remarks **	Both trains are automatically started upon EBFAS/AEAS signal. Each unit has 100% capacity. * There is a local status light at the unit, which may be off limits to personnel during LOCA or a Spent Fuel Pool Accident. ** Analyses determined that the entering air stream remains below 90% R.H. without heaters.

TABLE 6.7-2 ENCLOSURE BUILDING FILTRATION SYSTEM FAILURE MODE ANALYSIS (CONTINUED)

Component Identification & Quantity	Failure Mode	Method of Detection & Monitor	Detrimental Effect On System	Corrective Action	Resultant System Status	Remarks
Filter Unit L-29A/ 29B	N/A See remarks	Charcoal beds temperature computer alarm points: AD8772 & AD8776	Possible charcoal bed heating	Opposite train available. Utilize cross-country line to maintain charcoal temperature if required	Redundant system operable	The filter unit itself and its components, HEPA filters, charcoal filters are passive components. However, if the air flow over the charcoal beds is cut off (i.e., fan fails), charcoal beds could heat up due to decaying iodine.
EBFS Plenum FD 2-HV-37A/37B	N/A See remarks	N/A	N/A	N/A	N/A	Fire damper is deemed a passive component.
EBFS Isolation Damper to Filter Unit 2-EB-40/50	Fails as is See remark	Status lights on C01	None	None	Redundant system operable	Open on EBFAS. Close on AEAS if EBFSAS not present.
EBFS/AES Common Isolation Damper to Filter Unit 2-EB-41/ 51	FO Fails open See remarks	Status lights on C01	None	None	Redundant system operable	Open on EBFAS or on AEAS.
Filter Fan F-25A/ 25B Isolation Discharge Damper 2-EB-42/52	FO Fails open See remarks	Status lights on C01	None	None	Redundant system operable	Open on EBFAS or on AEAS.

TABLE 6.7-2 ENCLOSURE BUILDING FILTRATION SYSTEM FAILURE MODE ANALYSIS (CONTINUED)

Component Identification & Quantity	Failure Mode	Method of Detection & Monitor	Detrimental Effect On System	Corrective Action	Resultant System Status	Remarks
Filter Fan F-25A/ 25B Discharge Damper (Backdraft/ weighted) 2-EB-43/ 54	Fails as is See remarks	None	None	None	Redundant system operable	This damper function is to prevent gross recirculation in the idle train if damper 2-EB-42/52 fails open.
AES Isolation Damper to Filter Unit 2-EB-60/61	Fails closed NC Normally closed See remarks	Status lights on C01	None	None	Redundant system operable	Open on AEAS if EBFAS is not present.
Charcoal Beds Bypass Cooling Line Damper 2-EB-76/77	Fails as is NC Normally Closed See remarks	Status lights on C01	None	None	Redundant Cooling Path Available	If the air flow over the charcoal beds is cut off (i.e. fan fails), charcoal beds could heat up due to decaying iodine.
Purge Plenum Fire Damper 2-EB-131	N/A See remarks	N/A	N/A	N/A	N/A	Fire damper is deemed a passive component.
Hydrogen 6 inch Purge Line from Containment Penetration number 82 to EBFS Plenum Valve 2-EB-193	N/A See remarks	None	See remarks	See remarks	See remarks	Hydrogen Purge mode is manually controlled. These valves are normally open. These valves are passive components.

TABLE 6.7-2 ENCLOSURE BUILDING FILTRATION SYSTEM FAILURE MODE ANALYSIS (CONTINUED)

Component Identification & Quantity	Failure Mode	Method of Detection & Monitor	Detrimental Effect On System	Corrective Action	Resultant System Status	Remarks
Hydrogen 6 inch Purge Line from Containment Penetration number 83 to EBFS Plenum Valve 2-EB-194						
All EBFS/AES vital ductwork	N/A See remarks	N/A	N/A	N/A	N/A	Ductwork is deemed a passive component.

FIGURE 6.7–1 ENCLOSURE BUILDING FILTRATION SYSTEM FAN PERFORMANCE CURVE