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6.0 ENGINEERED SAFETY FEATURES

Independent and separate engineered safety features are provided for each unit. The description which is contained herein is applicable to either unit.

The central safety objective in reactor design and operation is control of reactor fission products. The methods used to assure this objective are:

1. Core design to preclude release of fission products from the fuel (Section 3.0).

2. Retention of fission products by the reactor coolant system boundary for whatever leakage occurs (Section 4.0 and Section 6.0).

3. Retention of fission products by the containment for operational and accidental releases beyond the reactor coolant boundary as well as detection of those releases. (Section 5.1 and Section 6.0).

4. Limit fission product release to minimize population exposure (Section 2.0 and Section 11.0).

The engineered safety features are the provisions in the plant which implement methods 2 and 3 (above) to prevent the occurrence or to minimize the effects of serious accidents.

The engineered safety features in this plant are the containment system, detailed in Section 5.1; the core safety injection system, detailed in Section 6.2; the containment air recirculation cooling system, detailed in Section 6.3; the containment spray system, detailed in Section 6.4; and the leak detection is detailed in Section 6.5.

Evaluation of techniques and equipment used to accomplish the central objective including accident cases are detailed in Section 5.0, Section 6.0 and Section 14.0.

6.1 CRITERIA

Criteria applying in common to all engineered safety features are given in Section 6.1.1. Thereafter, criteria which are related to engineered safety features, but are more specific to other plant features or systems, are listed and cross-referenced in Section 6.

Those criteria which are specific to one of the engineered safety features are discussed in the description of that system.

6.1.1 ENGINEERED SAFETY FEATURES CRITERIA

Engineered Safety Features Basis for Design

Criterion: Engineered safety features shall be provided in the facility to back up the safety provided by the core design, the reactor coolant pressure boundary, and their protection systems. Such engineered safety features shall be designed to cope with any size reactor coolant piping break up to and including the equivalent of a circumferential rupture of any pipe in that boundary, assuming unobstructed discharge from both ends. (GDC 37)

The design, fabrication, testing and inspection of the core, the reactor coolant system pressure boundary and their protection systems give assurance of safe and reliable operation under all anticipated normal, transient, and accident conditions. However, engineered safety features are provided in the facility to back up the safety provided by these components. These engineered safety features have been designed to cope with any size reactor coolant pipe break up to and including the circumferential rupture of any pipe assuming unobstructed discharge from both ends, and to cope with any steam or feedwater line break up to and including the main steam or feedwater headers.

The release of fission products from the reactor fuel is limited by the safety injection system which, by cooling the core, keeps the fuel in place and substantially intact and limits the metal-water reaction to an insignificant amount.

The safety injection system consists of high and low head centrifugal pumps driven by electric motors, and passive accumulator tanks which are self energized and which act independently of any actuation signal or power source.

The release of fission products from the containment is limited in three ways:

1. Blocking the potential leakage paths from the containment. This is accomplished by:

   a. A steel-lined, concrete reactor containment with testable liner weld channels.
   b. Isolation of process lines by the containment isolation system which imposes double barriers in each line that penetrates the containment.

2. Reducing the fission product concentration in the containment atmosphere by spraying chemically treated borated water which removes airborne elemental iodine vapor and particulates by washing action.

3. Reducing the containment pressure and thereby limiting the driving potential for fission product leakage by cooling the containment atmosphere using the following independent systems.

   a. Containment spray system
   b. Containment air recirculation cooling system

Reliability and Testability of Engineered Safety Features

Criterion: All engineered safety features shall be designed to provide such functional reliability and ready testability as is necessary to avoid undue risk to the health and safety of the public. (GDC 38)

A comprehensive program of plant testing is formulated for all equipment systems and system control vital to the functioning of engineered safety features. The program consists of performance tests of individual pieces of equipment in the manufacturer's shop, integrated tests of the system as a whole, and periodic tests of the actuation circuitry and mechanical components to assure reliable performance, upon demand, throughout the plant lifetime.

The initial tests of individual components and the integrated test of the system as a whole complement each other to assure performance of the system as designed and to prove proper operation of the actuation circuitry.

The engineered safety features components are designed to provide for routine periodic testing.

Missile Protection

Criterion: Adequate protection for those engineered safety features, the failure of which could cause an undue risk to the health and safety of the public, shall be provided against dynamic effects and missiles that might result from plant equipment failures. (GDC 40)

This plant-specific General Design Criterion is very similar to 10 CFR 50 Appendix A GDC 4. Under the provisions of that criterion, the dynamic effects associated with postulated pipe ruptures may be excluded from the design basis when appropriate analyses approved by the NRC demonstrate that the probability of such ruptures is extremely low. (Reference 2) Analyses have been completed for the Accumulator Injection Line piping, including a portion of the RHR return line piping (Reference 3). The NRC has approved the analyses (Reference 4 and Reference 5). As such, the original design features of the facility to accommodate the dynamic effects of an Accumulator Injection or RHR return line pipe rupture are no longer required. The balance of this section has been retained for historical perspective and to address how protection of engineered safety features from the dynamic effects of other high energy lines (main feedwater and main steam) is accomplished.

A loss-of-coolant accident or other plant equipment failure might result in dynamic effects or missiles. For engineered safety features which are required to ensure safety in the event of such an accident or equipment failure, protection is provided primarily by the provisions which are taken in the design to prevent the generation of missiles. In addition, protection is also provided by the layout of plant equipment or by missile barriers in certain cases. Reference is made to Section 5.1.2 for a discussion of missile protection.

Injection paths leading to unbroken reactor coolant loops are protected against damage as a result of the maximum reactor coolant pipe rupture by layout and structural design considerations. Injection lines penetrate the main missile barrier, which is the loop compartment wall, and the injection headers are located in the missile protected area between the loop compartment wall and the containment wall. Individual injection lines, connected to the injection header, pass through the barrier and then connect to the loops. Separation of the individual injection lines is provided to the maximum extent practicable. Movement of the injection line, associated with rupture of a reactor coolant loop, is accommodated by line flexibility and by the design of the pipe supports such that no damage outside the loop compartment is possible.

The containment structure is capable of withstanding the effects of missiles originating outside the containment and which might be directed toward it so that no loss-of-coolant accident can result.

All hangers, stops and anchors are designed in accordance with USAS B31.1, Code for Pressure Piping, and ACI 318, Building Code Requirements for Reinforced Concrete, which provide minimum requirements on material, design and fabrication with ample safety margin for both dead and dynamic loads over the life of the plant.

Engineered Safety Features Performance Capability

Criterion: Engineered safety features, such as the emergency core cooling system and the containment heat removal system, shall provide sufficient performance capability to accommodate the failure of any single active component without resulting in undue risk to the health and safety of the public. (GDC 41)

Engineered safety features provide sufficient performance capability to accommodate any single failure of an active component and still function in a manner to avoid undue risk to the health and safety of the public.

The extreme upper limits of public exposure are taken as the levels and time periods presently outlined in 10 CFR 50.67, i.e., a total effective dose equivalent (TEDE) dose in excess of 25 rem in any two hours at the exclusion radius and over the duration of the accident at the low population zone distance. The accident condition considered is the hypothetical case of a release of fission products per RG 1.183 concurrent with the total loss of all outside power. However, operation of the safety injection system, considering the single failure criterion, limits the release of fission products from the core to only the gap activity between the fuel pellet and clad.

Under the above accident condition, the containment air recirculation system and the containment spray system are designed and sized to supply the necessary post accident cooling capacity to rapidly reduce the containment pressure following blowdown and cooling of the core by safety injection. The spray system is designed to provide adequate removal of elemental iodine and particulates with partial system effectiveness. Partial effectiveness is defined as operation of a system with one active component failure. A separate reset and initiation switch for each train of safety injection allows direct manual initiation for all portions of the safeguards system.

Engineered Safety Features Components Capability

Criterion: Engineered safety features shall be designed so that the capability of these features to perform their required function is not impaired by the effects of a loss-of-coolant accident to the extent of causing undue risk to the health and safety of the public. (GDC 42)

All active components of the safety injection system (with the exception of injection line isolation valves) and the containment spray system are located outside the containment and not subject to containment accident conditions. The accumulators are located in a missile shielded area.

Instrumentation, motors, cables, penetrations, and other electrical equipment, located both inside and outside containment, are evaluated for their role in the mitigation of a design basis loss of coolant or high energy line break accident. If the equipment has an engineered safety related function and could be exposed to a potential harsh accident environment during such design basis events, it is designed and qualified to ensure the inherent capability for fulfilling the required engineered safety function throughout the equipment's installed lifetime, including the most adverse design basis environments. Current administrative procedures provide control and auditable documentation of qualification to ensure compliance with provisions and schedule requirements of applicable environmental qualification regulations.

Safety related electrical equipment purchased prior to May 23, 1980 is qualified in accordance with the provisions of the Division of Operating Reactors "Guidelines for Evaluating Environmental Qualification of 1E Electrical Equipment in Operating Reactors," (DOR Guidelines). During the purchase period of May 23, 1980 to February 21, 1983, such equipment is usually qualified in accordance with Category 1 of NUREG-0588, "Interim Staff Position on Environmental Qualification of Safety Related Electrical Equipment," which references IEEE Standard 323 1974, "Qualifying Class 1E Equipment for Nuclear Power Generating Stations." Such equipment purchased on or after February 22, 1983 is usually qualified in accordance with 10 CFR 50.49. In all cases, efforts are made to ensure compliance unless a sound reason to the contrary is demonstrated.

Each piece of electrical equipment identified as requiring environmental qualification has been evaluated for its associated design basis accident environment. Parameters typically include: temperature, pressure, chemical spray, humidity, submergence, and radiation exposure. The equipment is qualified for these parameters with appropriate margins, to ensure it will be able to fulfill its engineered safety function throughout its installed lifetime. Documentation of qualification is maintained in accordance with the provisions of 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants."

The safety injection system pipes serving each loop are anchored at the missile barrier in each loop area to restrict potential accident damage to the portion of piping beyond this point. The anchorage is designed to withstand, without failure, the thrust force of any branch line severed from the reactor coolant pipe and discharging fluid to the atmosphere. It is also desired to withstand a bending moment equal to the ultimate strength of the pipe or equivalent to that which produces failure of the piping under the action of free end discharge to atmosphere or motion of the broken reactor coolant pipe to which the emergency core cooling pipes are connected. This prevents possible failure at any point upstream from the support point, including the branch line connection, into the piping header.

Accident Aggravation Prevention

Criterion: Protection against any action of the engineered safety features which would accentuate significantly the adverse after-effects of a loss of normal cooling shall be provided. (GDC 43)

The reactor is maintained subcritical following a primary system pipe rupture accident. Introduction of borated cooling water into the core results in a net negative reactivity addition. The control rods insert and remain inserted.

The delivery of safety injection water to the reactor vessel following accidental expulsion of reactor coolant does not cause further loss of integrity of the reactor coolant system boundary.

Sharing of Systems

Criterion: Reactor facilities may share systems or components if it can be shown that such sharing will not result in undue risk to the health and safety of the public. (GDC 4)

The residual heat removal pumps and heat exchangers serve dual functions. Although the normal duty of the residual heat removal exchangers and residual heat removal pumps is performed during periods of reactor shutdown, during all plant operating periods this equipment is aligned to perform the low head safety injection function. In addition, during the recirculation phase of a loss-of-coolant accident, the capability of this system may be divided between the core cooling and the containment spray functions. Periodic demonstration testing of the system provides assurance of correct system alignment for the safety function of components.

During the injection phase, the safety injection pumps do not depend on any portion of other systems. During the recirculation phase, if reactor coolant system pressure stays high due to a small break accident, suction to the safety injection pumps is provided by the residual heat removal pumps.

During the injection phase, the containment spray pumps do not depend on any portion of other systems. During the recirculation phase of a large break LOCA, a portion of the recirculation flow from the discharge of the residual heat removal heat exchangers is provided to the suction of the containment spray pumps to support containment pressure reduction and iodine and particulate removal.

The containment air recirculation system also serves the dual function of containment cooling during normal operation and containment cooling after an accident. Since the method of operation for both cooling functions is essentially the same, the dual aspect of this system does not affect its function as an engineered safety feature.

6.1.2 RELATED CRITERIA

The following are criteria which, although related to all engineered safety features, are more specific to other plant features or systems, and therefore are discussed in other sections as listed.

Criteria	Discussion
Quality Standards (GDC 1)	Section 1.3

Performance Standards (GDC 2)	Section 4.1
Records Requirements (GDC 5)	Section 4.1
Instrumentation and Control Systems (GDC 12)	Section 7.1
Engineered Safety Features Actuation System (GDC 15)	Section 7.6
Emergency Power (GDC 39)	Section 8.1

6.1.3 GENERIC LETTER 2008-01

Generic Letter 2008-01, "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems," was issued to evaluate the systems to ensure gas accumulation is maintained less than the amount that challenges operability. The systems were evaluated and additional vents were installed as necessary. The Gas Accumulation Management Program (GAMP) ensures that gas accumulation within the safety injection and containment spray systems is identified, evaluated, trended and effectively controlled to prevent unacceptable degradation of performance. (Reference 6, Reference 7, Reference 8, and Reference 9)

6.1.4 REFERENCES

1. NRC Safety Evaluation, "Point Beach Nuclear Plant (PBNP), Units 1 and 2 -Issuance of License Amendments Regarding Use of Alternate Source Term (TAC Nos. ME0219 and ME0220)," dated April 14, 2011.
2. NRC letter, "Exemption from the requirements of 10 CFR 50 Appendix A, General Design Criterion 4," dated May 6, 1986.
3. WCAP-15107-P-A, Revision 1 "Technical Justification for Eliminating Accumulator Lines Rupture as the Structural Design Basis for Point Beach Units 1 and 2 Nuclear Plants" dated June 1, 2001.
4. NRC SE "Safety Evaluation of the Request to Apply Leak-Before-Break Status to the Accumulator Line Piping at PBNP, Units 1 and 2," dated November 7, 2000.
5. NRC SE "PBNP, Units 1 and 2 - Supplement to Safety Evaluation on Leak-Before-Break Regarding Correction of Leak Detection Capability," dated February 7, 2005.
6. Letter NRC 2008-0075, "Nine-Month Response to NRC Generic Letter 2008-01 Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems," dated October 14, 2008.
7. NRC letter, "Point Beach Nuclear Plant, Units 1 and 2 Closeout of Generic Letter 2008-01 Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal and Containment Spray Systems" (TAC Nos. MD7864 and MD7865), dated January 7, 2010.
8. Letter NRC 2009-0015, "Point Beach Nuclear Plant, Unit 1, Nine-Month Supplemental (Post-Outage) Response to NRC Generic Letter 2008-01," dated February 11, 2009.
9. NRC Safety Evaluation by the Office of Nuclear Reactor Regulation related to Amendment Nos. 251 and 255, "Managing Gas Accumulation," dated January 27, 2015.

6.2 SAFETY INJECTION SYSTEM (SI)

6.2.1 DESIGN BASIS

Redundancy of Reactivity Control

Criterion: Two independent reactivity control systems, preferably of different principles, shall be provided. (GDC-27)

In addition to the reactivity control achieved by the rod cluster control (RCC) described in Section 3.0, and the chemical and volume control system described in Chapter 9, the safety injection system provides an alternative boration path for shutdown reactivity control.

The refueling water storage tank may be aligned to the suction of the safety injection pumps as an alternative to the CVCS system. Use of this lineup requires reactor coolant system pressure to be less than the shutoff head of the safety injection pumps.

Emergency Core Cooling System Capability

Criterion: An emergency core cooling system with the capability for accomplishing adequate emergency core cooling shall be provided. This core cooling system and the core shall be designed to prevent fuel and clad damage that would interface with the emergency core cooling function and to limit the clad metal-water reaction to acceptable amounts for all sizes of breaks in the reactor coolant piping up to the equivalent of a double-ended rupture of the largest pipe. The performance of such emergency core cooling system shall be evaluated conservatively in each area of uncertainty. (GDC 44)

Adequate emergency core cooling is provided by the safety injection system (which constitutes the emergency core cooling system) which operates in three modes. These modes are delineated as passive accumulator injection, active safety injection and residual heat removal recirculation.

The primary purpose of the safety injection system is to automatically deliver cooling water to the reactor core in the event of a loss-of-coolant accident. This limits the fuel clad temperature and thereby ensures that the core will remain intact and in place with its heat transfer geometry preserved. This protection is afforded for:

1. All pipe break sizes up to and including the hypothetical instantaneous circumferential rupture of a reactor coolant loop, assuming unobstructed discharge from both ends.

2. A loss of coolant associated with the rod ejection accident.

3. A steam generator tube rupture.

The basic design criteria for loss-of-coolant accident evaluations are: (Reference 2)

1. The calculated peak cladding temperature shall not exceed 2200°F.

2. The calculated total oxidation of the cladding shall nowhere exceed 0.17 times the total cladding thickness before oxidation.

3. The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount generated if all the cladding directly surrounding the fuel were to react.

4. Calculated changes in the core geometry shall be such that the core remains amenable to cooling.

5. After the initial successful operation of the ECCS, the calculated core temperature shall be maintained at an acceptable low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

For any rupture of a steam pipe and the associated uncontrolled heat removal from the core, the safety injection system adds shutdown reactivity so that with a stuck rod, no off-site power and minimum engineered safety features, there is no consequential damage to the reactor coolant system and the core remains in place and intact.

Redundancy and segregation of instrumentation and components are incorporated to assure that postulated malfunctions will not impair the ability of the system to meet the design criteria. The system is effective in the event of loss of normal plant auxiliary power coincident with the loss of coolant, and can accommodate the failure of any single component or instrument channel to respond actively in the system. During the recirculation phase of a loss-of-coolant accident, the system can accommodate a loss of any part of the flow path since backup alternative flow path capability is provided.

The ability of the safety injection system to meet its design criteria is presented in Section 6.2.3. The analysis of the accidents is presented in Section 14.0.

Inspection of Emergency Core Cooling System

Criterion: Design provisions shall, where practical, be made to facilitate inspection of physical parts of the emergency core cooling system, including reactor vessel internals and water injection nozzles. (GDC 45)

Design provisions are made to facilitate access to the critical parts of the reactor vessel internals, injection nozzles, pipes, valves and safety injection pumps for visual or boroscopic inspection for erosion, corrosion and vibration wear evidence, and for nondestructive inspection where such techniques are desirable and appropriate.

Testing of Emergency Core Cooling System Components

Criterion: Design provisions shall be made so that components of the emergency core cooling system can be tested periodically for operability and functional performance. (GDC 46)

The design provides for periodic testing of active components of the safety injection system for operability and functional performance. Power sources are arranged to permit individual actuation of each active component of the safety injection system.

The safety injection pumps can be tested periodically during plant operation using the full flow recirculation test lines provided. The residual heat removal pumps are used every time the residual heat removal system is put into operation. Remotely operated valves can be exercised and are tested in accordance with the Inservice Testing Program filed with the NRC and based on the ASME OM Code.

Testing of Emergency Core Cooling System

Criterion: Capability shall be provided to test periodically the operability of the emergency core cooling system up to a location as close to the core as is practical. (GDC 47)

An integrated system test can be performed during the late stages of plant cooldown when the residual heat removal system is in service. This test would not introduce flow into the reactor coolant system but would demonstrate the operation of the valves, pump circuit breakers, and automatic circuitry upon initiation of safety injection.

The accumulator tank pressure and level are continuously monitored during plant operation.

The safety injection piping up to the final isolation valve is maintained full of borated water and the accumulators are maintained filled at their designated levels with borated water while the plant is in operation. The source of borated water used to fill the safety injection piping and the accumulators is the refueling water storage tank. The accumulators and injection lines will be refilled with borated water as required by using the safety injection pumps to recirculate refueling water through the injection headers. A small bypass line and a return line are provided for this purpose.

Flow in each of the high head injection header lines and in the main flow line for the residual heat removal pumps is monitored by a flow indicator. Pressure instrumentation is also provided for the main flow paths of the high head and residual heat removal pumps. Level and pressure instrumentation are provided for each accumulator tank.

Testing of Operational Sequence of Emergency Core Cooling System

Criterion: Capability shall be provided to test initially, under conditions as close as practical to design, the full operational sequence that would bring the emergency core cooling system into action, including the transfer to alternate power sources. (GDC 48)

The design provides for capability to test initially, to the extent practical, the full operational sequence up to the design conditions for the safety injection system to demonstrate the state of readiness and capability of the system. Details of the operational sequence testing are presented in Section 6.2.4.

Codes and Classifications

Table 6.2-1 tabulates the codes and standards to which the safety injection system components are designed.

Service Life under Accident Conditions

All portions of the system located within the containment are designed to operate without benefit of maintenance and without loss of functional performance for the duration of time the component is required following the accident.

6.2.2 SYSTEM DESIGN AND OPERATION

System Description

Each of the Point Beach units is provided with similar, independent facilities for emergency core cooling as described in the following pages for one unit. Adequate emergency core cooling following a loss-of-coolant accident is provided by the safety injection system shown in Figure 6.2-1. The system components operate in the following possible modes:

1. Injection of borated water by the passive accumulators.

2. Injection by the safety injection pumps drawing borated water from the refueling water storage tank.

3. Injection by the residual heat removal pumps also drawing borated water from the refueling water storage tank.

4. Recirculation of spilled coolant, injected water, and containment spray system drainage back to the reactor from the containment sump by the residual heat removal pumps, or high head pumps on small break.

The initiation signal for core cooling by the safety injection pumps and the residual heat removal pumps is the safety injection signal which is actuated by any of the following:

1. Low pressurizer pressure (two out of three)

2. High containment pressure (two out of three)

3. Low steam line pressure in either loop (two out of three per loop)

4. Manual actuation.

The containment spray system is described in Section 6.4.

Injection Phase

The principal components of the safety injection system which provide emergency core cooling immediately following a loss of coolant are two accumulators (one for each loop), the two safety injection (high head) pumps and the two residual heat removal (low head) pumps.

The accumulators, which are passive components, discharge into the cold legs of the reactor coolant piping when pressure decreases to about 750 psig, thus rapidly assuring core cooling for large breaks. They are located inside the containment, but outside the shield wall; therefore, each is protected against possible missiles.

The safety injection signal opens the low head injection line isolation valves and starts the safety injection pumps and the residual heat removal pumps. The items on Figure 6.2-1 marked with an "S" receive the safety injection signal (refer also to Figure 7.3-1.) The safety injection and residual heat removal pumps take suction from the refueling water storage tank.

The residual heat removal pumps deliver through two nozzles that penetrate the reactor vessel and the core barrel. The high head safety injection pumps deliver through two separate headers into the containment. One of the headers divides into two injection lines each of which connects to an accumulator discharge pipe close to the reactor coolant cold leg piping. The second header from the pumps divides into two branch injection lines which can either join the low head injection lines to the reactor vessel safety injection nozzles or be cross-connected to the cold leg injection lines. The isolation valves in the high head injection lines are in the normally open position when the plant is in operation.

For large breaks, the reactor coolant system would be depressurized and voided of coolant rapidly (about 10 sec. for the largest break) and a high flow rate is required to quickly recover the exposed fuel rods and limit possible core damage. To achieve this objective, one residual heat removal pump (high flow, low head) is required to deliver borated water to the core. Two pumps are available for this purpose. Delivery from these pumps supplements the accumulator discharge.

In addition, the charging pumps of the chemical and volume control system are available but are not required to augment the flow of the safety injection system.

Because the injection phase of the accident is terminated before the refueling water storage tank is completely emptied, all pipes are kept filled with water before recirculation is manually initiated. Water level indication and alarms on the refueling water storage tank give the operator ample warning to terminate the injection phase. Additional level indicators are provided in the containment sump which also gives backup indication that injection can be terminated and recirculation initiated.

For small breaks, the depressurization of the reactor coolant system can be augmented by steam dump and auxiliary feedwater addition. As is demonstrated in Section 14.3.1, use of the steam dump is not required to meet the core cooling objectives. However, it is intended that for small breaks (4 in. and smaller) steam dump(s) will be employed to facilitate the recovery from the accident, and to reduce the reactor coolant pressure to the cut-in pressure of the residual heat removal pumps.

The decision to initiate steam dump(s) will be based on the rate of decrease of reactor coolant system pressure as indicated by the pressurizer pressure compared with steam generator pressure. For large breaks (6 in. and larger), the reactor pressure drops below the steam side pressure quite rapidly. Before any gap activity could be released due to clad bursting, the reactor coolant system pressure becomes less than the steam generator pressure. As discussed in Section 14.3.2, the expected clad temperatures for break sizes 4 in. and smaller are limited to a value below which clad bursting is expected. If a small tube leak existed prior to the accident, the only activity that could be released during a steam dump would be the activity initially in the coolant. The activity released in this manner would be a fraction of that released for a full tube rupture. The consequences of a steam generator tube rupture are discussed in Section 14.2.4.

Protection against containment over-pressure following a loss-of-coolant accident or a steam line break accident is provided by the containment air recirculation cooling system (Section 6.3) and the containment spray system (Section 6.4).

Recirculation Phase

After the injection phase, coolant spilled from the break and water collected from the containment spray is cooled and returned to the reactor coolant system by the residual heat removal pumps which are aligned to take suction on the containment recirculation sump. This water is pumped back to the core and/or to the suction of the containment spray pumps through the residual heat removal heat exchangers. The system is arranged to allow either or both of the residual heat removal pumps to take over the recirculation function.

The recirculation sump lines consist of two independent and redundant 10 in. lines which penetrate the containment. Each line has one remote hydraulically-operated valve located inside containment, and one remote motor-operated valve located outside containment. Each line is run independently to the suction of a residual heat removal pump. The 10 in. drain pipes pass through sleeves in the containment structure concrete. The sleeves are welded to the liner plate and to the drain pipe with all welds inspectable. The drains pass through a second set of sleeves between the tendon gallery and the auxiliary building. The system permits long-term recirculation in the event of a passive or active component failure.

Alternative flow paths are also provided from the discharge of the residual heat removal heat exchangers for both low and high head recirculation. This is evaluated in Section 6.2.3.

The design of the containment drains are shown in Figure 6.2-2 and Figure 6.2-3. As illustrated, the containment building serves as a sump that collects the spilled coolant, injected water and containment spray system drainage. This collected water is used during the recirculation phase.

During recirculation operation the collected water is filtered through a strainer assembly over each drain before leaving the containment sump. The individual cross sectional filter flow areas in each strainer assembly are no greater than a nominal 0.066 inch diameter opening. The size of the strainer openings restricts any sizable foreign matter from entering the recirculation system.

The high head recirculation flow path via the high head safety injection pumps is required for the range of small break sizes for which the reactor coolant system pressure remains in excess of the shutoff head of the residual heat removal pumps at the end of the injection phase. The high head recirculation flow path is also required following a large break LOCA to control boric acid precipitation in the reactor vessel.

Those portions of the safety injection system located outside of the containment which are designed to circulate, under post accident conditions, radioactively contaminated water collected in the containment, meet the following requirements:

1. Shielding to maintain radiation levels within the limits set forth in 10 CFR 50.67. See Section 11.6.

2. Collection of discharges from pressure relieving devices into closed systems.

3. Means to limit radioactivity leakage to the environs, within the limits set forth in 10 CFR 50.67.

Recirculation loop leakage is discussed in Section 6.2.3.

Each recirculation sump line has two remotely operated valves. The first valve (SI-850) is located adjacent to the end of the pipe in the containment floor. The second valve (SI-851) is located in the auxiliary building. Both the SI-850 and SI-851 valves perform a safety-related function to open to allow the RHR pumps to take a suction from the containment sump during the recirculation mode of Safety Injection. The SI-850 valve performs a safety-related function in the closed direction to isolate a passive failure in the containment sump recirculation line. If the passive failure were to occur post-accident a SI-850 valve could be closed in order to maintain containment Sump B inventory and to protect the RHR system and pumps from flooding. SI-851 can be isolated in the event of a downstream passive failure. This valve is also designated as the containment isolation valve for the containment penetration. The valves are designed to withstand the temperature, pressure, and radioactivity conditions occurring during a loss-of-coolant accident. The valve operators are designed for the ambient conditions of the tendon access gallery and auxiliary building. The operators are tested to verify that they can open the valves against pressures in excess of that occurring in the containment during a loss-of-coolant accident. The passive failure of one suction line (presumably excessive packing or weld leakage) will not impair the operation of the redundant valve.

During recirculation one recirculation train will be in service which includes either of the two residual heat removal pumps and its associated residual heat removal heat exchanger. The flow will go from the discharge of the residual heat removal pump through the residual heat removal heat exchanger and then into the reactor via either a low head injection path or a high head injection path via a safety injection pump.

During the recirculation phase of a large break LOCA, a portion of the recirculation flow from the discharge of a residual heat exchangers is provided to the suction of a containment spray pump to support containment pressure reduction or iodine removal.

In the event of a failure in the operating train during recirculation, the capability exists to switch to the other independent recirculation flow path.

Cooling Water - Component Cooling Water System

During the recirculation mode, the component cooling water system is used to cool the reactor coolant as it passes through the residual heat removal heat exchanger. The component cooling water system is also used to remove heat from the RHR, SI, and containment spray pump seal coolers to maintain the integrity of the pump seals.

One of the two component cooling water pumps and one of three component cooling water heat exchangers provide the core and containment cooling function during recirculation. A total of four component cooling water heat exchangers are provided for the two units: one per unit with two shared standby units. Refer to Section 9.1.

Service Water System

The service water system is provided with a ring header and valves such that the component cooling water heat exchangers which are supplied with service water for cooling can have flow directed to them from either side of the loop header. Three of the six service water pumps are required to operate during the recirculation phase to cool the recirculation fluid and containment atmosphere in the unit suffering the accident and provide the necessary cooling for the other unit.

Changeover from Injection Phase to Recirculation Phase

The sequence, from the time of the safety injection signal, for the changeover from the injection phase to the recirculation phase is detailed in plant procedures. A summary of this sequence is as follows:

1. First, sufficient water is delivered to the containment floor to provide the required net positive suction head (NPSH) of the residual heat removal pumps to change to recirculation.

2. When RWST level is less than 60% or a large break LOCA has been identified, initial steps are accomplished to prepare for containment sump recirculation.

3. When RWST level is less than or equal to 34%, and the containment sump contains enough water to provide sufficient net positive suction head for the RHR pumps, the RHR system is lined up to take a suction from the containment sump. This assures that adequate time is provided to changeover to the recirculation phase prior to the refueling water storage tank emptying.

The changeover from injection to recirculation is effected by the operator in the control room and the operator in the field via a series of manual operations. Core cooling flow is maintained and not interrupted during the transition. (Reference 3)

Remotely operated valves for the injection phase of the safety injection system (Figure 6.2-1) which are under manual control (i.e., valves which normally are in their ready position and do not receive a safety injection signal) have their positions indicated by lights on the ready status section of the control board. At any time during operation when one of these valves is not in the ready position for injection, it is shown visually on the board.

Boric Acid Precipitation

Due to concerns regarding possible boric acid precipitation in the core after the recirculation phase is established, there is a need to eventually establish simultaneous cold leg and upper plenum injection flow. For most Westinghouse plants, this is referred to as the hot leg injection switchover time. Since Point Beach is designed with upper plenum injection capability instead of hot leg injection, this term is not quite accurate, but is used to remain consistent with the industry. The intent of the hot leg injection switchover time requirement is to flush boron precipitate out of the core to prevent flow blockages that may inhibit post-LOCA cooling.

For breaks $\geq$ 5 inches in diameter the RCS will depressurize sufficiently to allow upper plenum injection flow from the low head pumps. The high and low head injection flows during the injection phase of the event are sufficient to prevent boric acid precipitation. Cold leg injection flow from the high head pumps is secured prior to the transfer to sump recirculation, but must be reinitiated prior to the occurrence of boric acid precipitation in the reactor vessel. Boric acid precipitation is not expected to occur before 4 hours and 30 minutes after the high head pumps are secured to establish sump recirculation. Alignment for high head recirculation to the cold legs can be accomplished within 10 minutes. Additional margin has been applied to the switchover time resulting in a requirement to initiate the alignment within 3 hours and 20 minutes after the start of the LOCA event such that high head recirculation is established within 3 hours and 30 minutes. (Reference 3 and Reference 5)

For breaks between approximately 1.2 inches and 5 inches in diameter the RCS must be depressurized to enable low head upper plenum injection before the precipitation limit is reached. This is accomplished by opening one or both main steam atmospheric dump valves no later than 1 hour into the event. This will reduce the RCS pressure enough to allow low head injection within 5 to 6 hours after opening the dump valve(s). (Reference 3)

For breaks between 1.2 inches to 0.9 inches in diameter, single phase natural circulation is lost, but regained before the precipitation limit is reached. For breaks less than 0.9 inches in diameter, natural circulation is not lost. (Reference 3)

In the event of a LOCA, injection of high concentration boric acid from the boric acid storage tanks (BAST) is secured to preclude the potential for early precipitation in the reactor vessel. Limitations on RCS cooldown rate also serve to keep boric acid in solution during a small break LOCA. (Reference 3)

Location of the Major Components Required for Recirculation

[redacted]

[redacted]

The service water pumps are located in the pumphouse and the redundant piping to the component cooling water heat exchangers is run underground through the Class I portion of the turbine building.

Components

All associated components, piping, structures, and power supplies of the safety injection system are designed to Class I seismic criteria.

All components inside the containment are capable of withstanding or are protected from differential pressure changes which may occur during the rapid pressure rise to 60 psig in 10 sec.

Motors which operate only during or after the postulated accident are designed as if used in continuous service. Periodic operation of the motors and the tests of the pump motors insulation will ensure that the motors remain in a reliable operating condition.

All motors, instruments, transmitters, and their associated cables located inside the containment which are required to operate following the accident are designed to function under the post accident temperature, pressure, and humidity conditions.

Emergency core cooling components in contact with borated water or spray solution are austenitic stainless steel or equivalent corrosion resistant material and hence are compatible with the spray solution over the full range of exposure in the post accident regime. While stainless steel is subject to crevice corrosions by hot, concentrated caustic solution, the NaOH additive cannot enter the containment or emergency core cooling systems without first being diluted and partially neutralized with boric acid to a mild solution. Corrosion tests performed with simulated spray showed negligible attack, both generally and locally, in stressed and unstressed stainless steel at containment and ECCS conditions. These tests are discussed in WCAP-7153 (Reference 1).

The inspections and tests of the safety injection system components described in Section 6.2.4.

<u>Accumulators</u>

The accumulators are pressure vessels maintained filled at their designated levels with borated water and pressurized with nitrogen gas. During normal plant operation, each accumulator is isolated from the reactor coolant system by two check valves in series.

Should the reactor coolant system pressure fall below the accumulator pressure, the check valves open and borated water is forced into the reactor coolant system. Mechanical operation of the swing-disc check valves is the only action required to open the injection path from the accumulators to the core via the cold leg.

The accumulators are passive engineered safety features because the nitrogen gas forces injection; no external source of power or signal transmission is needed to obtain fast-acting, high flow capability when the need arises. One accumulator is attached to each of the cold legs of the reactor coolant system.

The design capacity of the accumulators is based on the assumption that flow from one of the accumulators spills onto the containment floor through the ruptured loop, and the flow from the remaining accumulator provides sufficient water to fill the volume outside of the core barrel below the nozzles, the bottom plenum, and one-half the core. The accumulators are carbon steel, clad with stainless steel and designed to ASME Section III, Class C. Connections for remotely draining or filling the fluid space during normal plant operation are provided.

The level of borated water in each accumulator tank is adjusted remotely as required during normal plant operations. Borated water is added from the refueling water storage tank using a high head safety injection pump. Water level is reduced by draining to the reactor coolant drain tank. Local samples of the solution in the tanks are taken for periodic checks of boron concentration.

Redundant level and pressure indicators are provided with read-outs on the control board. Each indicator is equipped with high and low level alarms.

The accumulator design parameters are given in Table 6.2-3.

Refueling Water Storage Tank

In addition to its normal duty to supply borated water to the refueling cavity for refueling operations, this stainless steel tank provides borated water to the safety injection pumps, the residual heat removal pumps and the containment spray pumps for either a loss-of-coolant accident or a steam line break accident. During plant operation it is aligned to the suction of the above pumps. It may also be aligned to the suction of the safety injection pumps to provide an alternative boration path for shutdown reactivity control.

The capacity of the refueling water storage tank is based on the requirement for filling the refueling cavity during refueling operations. This requirement is greater than the capacity required for emergency core cooling in the event of either a LOCA or steam line break accident. The minimum volume of borated water maintained in the RWST (see Table 6.2-4) assures:

1. A volume sufficient to refill the reactor vessel above the nozzles;

2. The volume of borated refueling water needed to increase the concentration of initially spilled water to a point that assures no return to criticality with the reactor at cold shutdown and all full-length control rods, except the highest worth RCC assembly, inserted into the core; and

3. A sufficient volume of water within containment to permit the initiation of recirculation.

The water in the tank is borated to a concentration which assures reactor shutdown by at least 5% Δk/k when all RCC assemblies are inserted and when the reactor is cooled down for refueling. The maximum boric acid concentration is approximately 1.8 weight percent boric acid. At 32°F, the solubility limit of boric acid is 2.2%. Therefore, the concentration of boric acid in the refueling water storage tank is well below the solubility limit of 32°F. The tank contents are heated and the piping is heat traced to prevent freezing of the water during cold weather. The tank is protected from wind chill by the containment facade.

Tank temperatures along with high and low temperature alarm lights and immersion heater control, are provided locally in the facade near the tank.

Two level indications with low level alert, low-level and low-low level alarms are provided.

A dynamic response analysis has been performed to determine the horizontal loads to be applied to this tank for the hypothetical safe shutdown earthquake. Vertical seismic loads have been applied simultaneously. Wave generation in the tank has been taken into account. A membrane stress analysis of the vertical cylindrical tank was performed considering the discontinuities at the base and top.

The design parameters are given in Table 6.2-4.

Safety Injection Pumps

The two high head safety injection pumps for supplying borated water to the reactor coolant system are horizontal centrifugal pumps driven by electric motors. Parts of the pump in contact with borated water are stainless steel or equivalent corrosion resistant material. A minimum flow bypass line is provided on each pump discharge to recirculate flow to the refueling water storage tank in the event the pumps are started under low flow or shutoff head conditions. The minimum flow line must be available for the Safety Injection pumps to be considered operable because some accidents and transients for which Safety Injection is required do not result in sufficient injection flow to provide adequate pump cooling. The nominal design parameters of these pumps are presented in Table 6.2-5 and Figure 6.2-4. The nominal pump curve is degraded when HHSI flow is credited in accident analyses (Reference 7).

Residual Heat Removal Pumps

The two residual heat removal (low head) pumps are used to inject borated water at low pressure to the reactor coolant system. They are also used to recirculate fluid from the containment floor and send it back to the reactor, to the suction of the spray pumps or to the suction of the high head safety injection pumps. These pumps are of the horizontal centrifugal type, driven by electric motors. Parts of the pumps which contact the borated water and sodium hydroxide solution during recirculation are stainless steel or equivalent corrosion resistant material. A minimum flow bypass line is provided on the discharge of the residual heat removal heat exchangers to recirculate cooled fluid to the suction of the residual heat removal pumps should these pumps be started with their normal flow blocked. The nominal design parameters of these pumps are presented in Table 6.2-5 and in Figure 6.2-5. The nominal pump curve is degraded when LHSI flow is credited in accident analyses (Reference 7).

The pressure containing parts of the pumps are castings conforming to ASTM A-351, Grade CF8 or CF8M. Stainless steel forgings are procured per ASTM A-182 Grade F304 or F316 or ASTM A336, Class F8 or F8M, and stainless plate conforms to ASTM A-240, Type 304 or 316. All bolting material conforms to ASTM A-193. Materials such as weld-deposited Stellite or Colmonoy are used at points of close running clearances in the pumps to prevent galling and to assure continued performance ability in high velocity areas subject to erosion.

All pressure containing parts of the pumps are chemically and physically analyzed and the results are checked to ensure conformance with the applicable ASTM specification. In addition, all pressure containing parts of the pump are liquid penetrant inspected in accordance with Appendix VIII of Section VIII of the ASME Boiler and Pressure Vessel Code. The acceptance standard for the liquid penetrant test is USAS B31.1, Code for Pressure Piping, Case N-10.

The pump design is reviewed with special attention to the reliability and maintenance aspects of the working components. Specific areas include evaluation of the shaft seal and bearing design to determine that adequate allowances have been made for shaft deflection and clearances between stationary parts.

Where welding of pressure containing parts is necessary, a welding procedure, including joint detail, is submitted for review and approval by Westinghouse Electric Corporation. The procedure is qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. This requirement also applies to any repair welding performed on pressure containing

parts. The pressure-containing parts of the pump are assembled and hydrostatically tested to 1.5 times the design pressure for 30 minutes.

Each pump is given a complete shop performance test in accordance with Hydraulic Institute Standards. The pumps are run at design flow and head, shutoff head and three additional points to verify performance characteristics. Where NPSH is critical, this value is established at design flow by means of adjusting suction pressure during the shop test.

Details of the component cooling and service water pumps which serve the safety injection system are presented in Section 9.0.

Heat Exchangers

The two residual heat removal heat exchangers cool the recirculated sump water. These heat exchangers are sized for the normal cooldown of the reactor coolant system. Table 6.2-6 gives the design parameters of the heat exchangers.

The ASME Boiler and Pressure Vessel Code has strict rules regarding the wall thickness of all pressure containing parts, material specifications, weld joint design, radiographic and liquid penetrant examination of materials and joints, and hydrostatic testing of the unit as well as requiring final inspection and stamping of the vessel by as ASME Code inspector.

The designs of the heat exchangers also conform to the requirements of TEMA (Tubular Exchanger Manufacturers Association) for Class R heat exchangers. Class R heat exchangers are subject to the most rigid TEMA requirements and are intended for units where safety and durability are required under severe service conditions. Items such as: tube spacing, flange design, nozzle location, baffle thickness and spacing, and impingement plate requirements are set forth by TEMA standards.

In addition to the above, additional design and inspection requirements were imposed to ensure rugged, high quality heat exchangers such as: confined-type gaskets, main flange studs with two nuts on each end to ensure permanent leaktightness, general construction and mounting brackets suitable for the plant seismic design requirements, tubes and tubesheet capable of withstanding full shell side pressure and temperature with atmospheric pressure on the tube side, ultrasonic inspection in accordance with Paragraph N-324.3 of Section III of the ASME Code of all tubes before bending, penetrant inspection in accordance with Paragraph N-627 of Section III of the ASME Code of all welds and all hot or cold formed parts, a hydrostatic test duration of not less than thirty minutes, the witnessing of hydro and penetrant tests by a qualified inspector, a thorough final inspection of the unit for good workmanship and the absence of any gouge marks or other scars that could act as stress concentration points, a review of the radiographs and of the certified chemical and physical test reports for all materials used in the unit.

The residual heat removal heat exchangers are conventional vertical shell and U-tube type units. The tubes are seal welded to the tubesheet. The shell connections are flanged to facilitate shell removal for inspection and cleaning of the tube bundle. Each unit has a SA-285 Grade C carbon steel shell, SA-234 carbon steel shell end cap, SA-213 TP-304 stainless steel tubes, SA-240 Type 304 stainless steel channel, SA-240 Type 240 stainless steel channel cover and SA-240 Type 304 stainless steel tubesheet.

Valves

All parts of valves used in the safety injection system in contact with borated water are austenitic stainless steel or equivalent corrosion resistant material. The motor operators on the injection line isolation valves are capable of rapid operation. All valves required for initiation of safety injection or isolation of the system have remote position indication in the control room.

Valving is specified for exceptional tightness and, where possible, such as for instrument valves, packless diaphragm valves are used. All valves, except those which perform a control function, are provided with backseats which are capable of limiting leakage to less than 1.0 cc per hour per inch of stem diameter, assuming no credit taken for valve packing. This design feature provides a means to minimize leakage in the event the packing fails or leaks excessively. Backseats are not normally relied upon as the primary leakage barrier. Normally closed globe valves are installed with recirculation flow under the seat to prevent leakage of recirculated water through the valve stem packing. Relief valves are totally enclosed. Control and motor-operated valves with a diameter of 2½" or greater which are exposed to recirculation flow of the residual heat removal system have sufficient packing to minimize leakage to the atmosphere.

The check valves which isolate the safety injection system from the reactor coolant system are installed near the reactor coolant piping to reduce the probability of an injection line rupture causing a loss-of-coolant accident. The high head safety injection piping is protected by a relief valve inside the containment in the test line. The relieving capacity of this valve is based on a flow several times greater than the expected leakage rate through the check and isolation valves and will also prevent overpressurization due to thermal expansion. The valve relieves to the pressure relief tank. The residual heat removal loop is protected by a relief valve in the common header leading to the reactor vessel. A second pressure relief valve is located in the residual heat removal suction piping to provide reactor coolant system overpressurization protection when operating in the cold shutdown condition. The valves are located inside the containment and relieve to the pressurizer relief tank. An additional relief valve in the residual heat removal suction piping relieves to containment sump. The gas relief valves on the accumulators protect them from pressures in excess of the design value.

Motor Operated Valves

The pressure containing parts (body, bonnet, and discs) of the motor operated valves employed in the safety injection system are designed per criteria established by the USAS B16.5 or MSS SP-66 specifications. ANSI B16.34 has replaced the criteria of USAS B16.5 for the design of flanged and welded valves. The pressure containing parts of valves manufactured since approval of B16.34 shall meet the criteria of ANSI B16.34. The body and bonnet materials for these valves are procured per ASTM A-182, F316 or A351, Gr CF 8M, or equivalent specification, except that valves of 150 lb ASA B16.5 rating may conform to A-182, F304, A351 Gr CF8 or equivalent specification. All material in contact with the primary fluid except the packing, is austenitic stainless steel or equivalent corrosion resisting material. For cast carbon steel valves greater than class 150 lb and stainless steel valves in service conditions in excess of 200 psig and 200 ^{o}F, the pressure-containing cast components are radiographically inspected as outlined in ASTM E-71, Class 1 or Class 2, E446 or equivalent. The body, bonnet, and discs are liquid penetrant inspected in accordance with ASME Boiler and Pressure Vessel Code Section VIII, Appendix VIII. The liquid penetrant acceptable standard is as outlined in USAS B31.1, Case N-10.

When a gasket is employed, the body-to-bonnet joint is designed per ASME Boiler and Pressure Vessel Code Section VIII or USAS B16.5/ANSI B16.34 with a fully trapped, controlled compression, spiral wound gasket with provisions for seal welding, or of the pressure seal design with provisions for seal welding. The body-to-bonnet bolting and nut materials are procured per ASTM A 193 and A-194, respectively.

The entire assembled unit is hydrotested as outlined in MSS SP-61 with the exception that the test is maintained for a minimum period of 30 minutes. Any leakage is cause for rejection. The seating design is of the Darling parallel disc design, the Crane flexible wedge design, or the equivalent. These designs have the feature of releasing the mechanical holding force during the first increment of travel. Thus, the motor operator has to work only against the frictional component of the hydraulic unbalance on the disc and the packing box friction. The discs are guided throughout the full disc travel to prevent chattering and provide ease of gate movement. The seating surfaces are hard faced (Stellite No. 6 or equivalent) to prevent galling and reduce wear.

The stem material is ASTM A-276, Type 316, condition B, Haynes Alloy No. 25 precipitation hardened 17-4 PH stainless steel or an equivalent material. These materials are selected because of their corrosion resistance, high tensile properties, and their resistance to surface scoring by the packing. Motor-operated valves are provided with sufficient packing to minimize leakage to the atmosphere.

The motor operator is extremely rugged and is noted throughout the power industry for its reliability. The unit incorporates a “hammer blow” feature that allows the motor to impact the discs away from the fore or backseat upon opening or closing. This "hammer blow" feature not only impacts the disc but allows the motor to attain its operational speed. Each valve is assembled, hydrostatically tested, seat-leakage tested (fore and back), operationally tested, cleaned and packaged per specifications. All manufacturing procedures employed by the valve supplier during initial construction, such as hard facing, welding, repair welding and testing, were submitted to Westinghouse for approval. Subsequent manufacturing procedures rely on vendor quality assurance programs and procurement specifications for authorization.

For those valves (SI-852A, B) which are required to open automatically on the safety injection signal, “fast operators” are provided to satisfy their functions during the ECCS injection phase. The stroke time performance requirement for SI-852A, B is 21.7 seconds and is based on the large break LOCA evaluation documented in Section 14.3.2. The IST program stroke time acceptance criteria for these valves are conservative with respect to the stroke time performance requirement. For all other valves in the system, the valve operator stroke time acceptance criteria are established to ensure that the valves are capable of performing their design functions.

Valves which must function against system pressure are designed such that they function with a pressure drop equal to full system pressure across the valve disc.

Manual Valves

The stainless steel manual globe, gate and check valves are designed and built in accordance with the following requirements.

The pressure containing parts (body, bonnet, and discs) are designed per criteria established by the USAS B16.5 specification. ANSI B16.34 has replaced the criteria of USAS B16.5 for the design

of flanged and welded valves. The pressure containing parts of valves manufactured since approval of B16.34 shall meet the criteria of ANSI B16.34. The body and bonnet materials for these valves are procured per ASTM A-182, F316 or A351, Gr CF 8M, or equivalent specification, except that valves of 150 lb ASA B16.5 rating may conform to A-182 F304, A351 Gr CF8 or equivalent specification. All material in contact with the primary fluid except the packing, is austenitic stainless steel or equivalent corrosion resisting material. The pressure-containing cast components of all gate valves and all other valves greater than 2 inch in size are radiographically inspected as outlined in ASTM E-71, E 446, E-186 or E 280, whichever is applicable or equivalent standard. The acceptance standard shall meet the requirement of severity level 2 except that D, E, F and G defects are not permissible. Radiographic inspection of reducer-to-body welds or stub-to-body welds (when employed) shall be per ASME Section VIII, UW-51 or equivalent. The acceptance standard shall be as outlined in UW-51 or equivalent. The body, bonnet, and discs are liquid penetrant inspected in accordance with ASME Boiler and Pressure Vessel Code Section III, Appendix IX. The liquid penetrant acceptable standard is as outlined in ASME Section III, USAS B31.1, Case N-10 or an equivalent standard.

When a gasket is employed, the body-to-bonnet joint is designed per ASME Boiler and Pressure Vessel Code Section VIII or USAS B16.5/ANSI B16.34 with a fully trapped, controlled compression, spiral wound gasket with provisions for seal welding, or of the pressure seal design with provisions for seal welding. A bonnetless design or a threaded connection body-to-bonnet joint with a welded canopy seal is an acceptable design. Valves smaller than 3/4 inch may have a threaded or union joint. Alternate body-to-bonnet joints that provide equivalent leak-tightness may be used as approved by the design change process. The body-to-bonnet bolting and nut materials are procured per ASTM A 193 and A-194, respectively.

The entire assembled unit is hydrotested as outlined in MSS SP-61 with the exception that the test is maintained for a minimum period of 30 minutes for gate valves and other manual valves greater than 2" in size, and a minimum period of five minutes for non-gate manual valves less than or equal to 2" in size. Any leakage is cause for rejection. The seating surfaces are hard faced (Stellite No. 6 or equivalent) to prevent galling and reduce wear.

The stem material is ASTM A-276, Type 316, condition B, Haynes Alloy No. 25 precipitation hardened 17-4 PH stainless steel or an equivalent material. These materials are selected because of their corrosion resistance, high tensile properties, and their resistance to surface scoring by the packing.

The carbon steel manual globe, gate and check valves are designed and built in accordance with the following requirements.

The carbon steel valves are built to conform with USAS B16.5. The materials of construction of the body and bonnet conform to the requirements of ASTM A105, Grade II, or A216, Grade WCB or WCC, or equivalent material specification. The carbon steel valves pass only nonradioactive fluids and are subjected to hydrostatic tests as outlined in MSS SP-61, except that the test pressure is maintained for minimum period of 30 minutes for gate valves and other manual valves greater than 2" in size, and a minimum period of five minutes for non-gate manual valves less than or equal to 2" in size.

When a gasket is employed, the body-to-bonnet joint is designed per ASME Boiler and Pressure Vessel Code Section VIII or USAS B16.5/ANSI B16.34 with a fully trapped, controlled compression, spiral wound gasket with provisions for seal welding, or of the pressure seal design

with provisions for seal welding. A bonnetless design or a threaded connection body-to-bonnet joint with a welded canopy seal is an acceptable design. Valves smaller than 3/4 inch may have a threaded or union joint. Alternate body-to-bonnet joints that provide equivalent leak-tightness may be used as approved by the design change process. The body-to-bonnet bolting and nut materials are procured per ASTM A193 and A-194, respectively.

Accumulator Check Valves

The pressure-containing parts of this valve assembly are designed in accordance with MSS SP-66. All parts in contact with the operating fluid are of austenitic stainless steel or of equivalent corrosion resistant materials procured to applicable ASTM or WAPD specifications. The cast pressure-containing parts are radiographed in accordance with ASTM E-94 and the acceptance standard as outlined in ASTM E-71. The cast pressure-containing parts, machined surfaces, finished hard facings, and gasket bearing surfaces are liquid penetrant inspected per ASME B&PV Code, Section VIII, and the acceptance standard is as outlined in USAS B31.1 Code Case N-10. The final valve is hydrotested per MSS SP-66 except that the test pressure is maintained for at least 30 minutes. The seat leakage is conducted in accordance with the manner prescribed in MSS SP-61 except that the acceptable leakage is 2 cc/hr/in nominal pipe diameter.

The valve is designed with a low pressure drop configuration with all operating parts contained within the body, which eliminates those problems associated with packing glands exposed to boric acid. The clapper arm shaft is manufactured from 17-4 PH stainless steel heat treated to Westinghouse specifications. The clapper arm shaft bushings are manufactured from stellite No. 6 material. The various working parts are selected for their corrosion resistant, tensile, and bearing properties. The disc and seat rings are forged. The mating surfaces are hard faced with stellite No. 6 to improve the valve seating life. The disc is permitted to rotate, providing a new seating surface after each valve opening.

The valves are intended to be operated in the closed position with a normal differential pressure across the disc of approximately 1,500 psi. The valves shall remain in this position except for testing and safety injection. Since the valves will not be required to normally operate in the open condition and hence be subjected to impact loads caused by sudden flow reversal, it is expected that these valves will perform their required functions without difficulty.

When the valve is required to operate, a differential pressure of less than 25 psig will shear any particles that may otherwise prevent the valve from functioning. Although the working parts are exposed to the boric acid solution contained within the reactor coolant loop, a boric acid “freeze up” is not expected with the low boric acid concentrations used.

The experience derived from the check valves employed in the emergency injection system of the Carolina-Virginia Tube Reactor in a similar system indicates that the system is reliable and workable.

The CVTR emergency injection system, normally maintained at containment ambient conditions was separated from the main coolant piping by a single 6-in. check valve. A leak detection was provided at a proper elevation to accumulate any leakage coming back through the check valve and level alarm provided a signal on excessive leakage. The pressure differential was 1,500 psi and the system was stagnant. The valve was located 2 ft. to 3 ft. from the main coolant piping

which resulted in some heatup and cooldown cycling. The CVTR went critical late in 1963 and operated until 1967 during which time the level sensor in the leak detector never alarmed due to check valve leakage.

Relief Valves

The accumulator relief valves are sized to pass nitrogen gas at a rate in excess of the accumulator gas fill line delivery rate. The relief valves will also pass water in excess of the expected leak rate, but this is not necessary because the time required to fill the gas space gives the operator ample opportunity to correct the situation. For an inleakage rate 15 times the manufacturing test rate, there will be in excess of 1,000 days before water will reach the relief valves. Prior to this, level and pressure alarms would have been actuated.

The safety injection test line relief valve is provided to relieve any pressure, above design, that might build up in the high head safety injection piping. The valve will pass a flow rate which is far in excess of the manufactured design leak rate of 24 cc/hr.

Leakage Limitations

Motor-operated valves in the residual heat removal loop that are exposed to recirculation flow are provided with sufficient packing to minimize leakage to the atmosphere.

The specified leakage across the valve disc required to meet the equipment specification and hydrotest requirements is as follows:

1. Conventional globe - 3 cc/hr/in. of nominal pipe size
2. Gate vales - 3 cc/hr/in. of nominal pipe size; 10 cc/hr/in. for 300 and 150 lb. USA standard
3. Motor-operated gate valves - 3 cc/hr/in. of nominal pipe size; 10 cc/hr/in. for 300 and 150 lb. USA standard
4. Check valves - 3 cc/hr/in. of nominal pipe size; 10 cc/hr/in. for 300 and 150 lb. USA standard
5. Accumulator check valves - 2 cc/hr/in. of nominal pipe size

Relief valves are totally enclosed. Leakage from components of the recirculation loop, including valves, is described later in this section under “Recirculating Loop Leakage.” Allowable through-seat leakage of the recirculation loop valves is controlled by the required ASME Section XI pressure test of the RHR system and the Leakage Reduction and Preventative Maintenance program. Operability determinations for these valves are made in accordance with the ASME Section XI code requirements.

Piping

All safety injection system piping in contact with borated water is austenitic stainless steel. Piping joints are welded except for the flanged connections.

The piping beyond the accumulator stop valves is designed for reactor coolant system conditions (2,485 psig, 650°F). All other piping connected to the accumulator tanks is designed for 800 psig and 300°F.

The safety injection pump suction piping (210 psig at 300°F) from the refueling water storage is designed for low pressure losses to meet NPSH (net positive suction head) requirements of the pumps.

The safety injection high pressure branch lines (1,745 psig at 300°F) are designed for high pressure losses to limit the flow rate out of a potential rupture of a branch line at the connection to the reactor coolant loop.

The safety injection test line piping (1750 psig at 100°F) is designed for the thermal operating mode during pump testing. The test line serves no other function to the safety injection system.

The piping is designed to meet the minimum requirements set forth in (1) the USAS B31.1 Code for the Pressure Piping, (2) Nuclear Code Case N-7, (3) USAS Standards B36.10 and B36.19, (4) ASTM Standards, and (5) supplementary standards plus additional quality control measures.

Minimum wall thicknesses are determined by the USAS Code formula in the power piping Section 1 of the USAS Code for the Pressure Piping. This minimum thickness is increased to account for the manufacturer's permissible tolerance of (-)12½% on the nominal wall. Purchased pipe and fittings have a specified nominal wall thickness that is no less than the sum of that required for pressure containment, mechanical strength, and manufacturing tolerance.

Thermal and seismic piping flexibility analyses are performed. Special attention is directed to the piping configuration at the pumps with the object of minimizing pipe imposed loads at the suction and discharge nozzles. Piping is supported to accommodate expansion due to temperature changes during the accident.

Pipe and fitting materials are procured in conformance with all requirements of the ASTM and USAS specifications. All materials are verified for conformance to specification and documented by certification of compliance to ASTM material requirements. Specifications impose additional quality control upon the suppliers of pipes and fittings as listed below.

1. Pipe branch lines between the reactor coolant pipes and the isolation stop valves conform to ASTM A376 and meet the supplementary requirement S6 Ultrasonic Testing.

2. Fittings conform to the requirements of ASTM A403. Fittings 3 in. and above have requirements for UT inspection similar to S6 of A376.

Shop fabrication of piping subassemblies is performed by reputable suppliers in accordance with specifications which define and govern material procurement, detailed design, shop fabrication, cleaning, inspection, identification, packaging and shipment.

Welds for pipes sized 2½ in. and larger are butt welded. Reducing tees are used where the branch size exceeds ½ of the header size. Branch connections of sizes that are equal to or less than ½ of the header size are of a design that conforms to the USAS rules for reinforcement set forth in the USAS B31.1 Code for Pressure Piping. Bosses for branch connections are attached to the header by means of full penetration welds.

All welding is performed by welders and welding procedures qualified in accordance with the ASME Boiler and Pressure Vessel Code Section IX, Welding Qualifications. The shop fabricator is required to submit all welding procedures and evidence of qualifications for review and approval prior to release for fabrication. All welding materials used by the shop fabricator must have prior approval.

All high pressure piping butt welds containing radioactive fluid, at greater than 600°F temperature and 600 psig pressure or equivalent, are radiographed. The remaining piping butt welds are randomly radiographed. The technique and acceptance standards are those outlined in UW-51 of the ASME B&PV Code, Section VIII. In addition, butt welds are liquid penetrant examined in accordance with the procedure of ASME B&PV Code, Section VIII, Appendix VIII and the acceptance standard as defined in the USAS Nuclear Code Case N-10. Finished branch welds are liquid penetrant examined on the outside and, where size permits, on the inside root surfaces.

A post bending solution anneal heat treatment is performed on hot-formed stainless steel pipe bends. Completed bends are then completely cleaned of oxidation from all affected surfaces. The shop fabricator is required to submit the bending, heat treatment and cleanup procedures for review and approval prior to release for fabrication.

General cleaning of completed piping subassemblies (inside and outside surfaces) is governed by basic ground rules set forth in the specifications. For example, these specifications prohibit the use of hydrochloric acid and limit the chloride content of service water and demineralized water.

Packaging of the piping subassemblies for shipment is done so as to preclude damage during transit and storage. Openings are closed and sealed with tight-fitting covers to prevent entry of moisture and foreign material. Flange facings and weld end preparations are protected from damage by means of wooden cover plates and securely fastened in position. The packing arrangement proposed by the shop fabricator is subject to approval.

Pump and Valve Motors - Motors in a Mild Environment

Engineered Safety Feature electrical equipment located in mild environments (i.e., an environment which does not vary significantly from normal service conditions during a design basis event) are supplied in accordance with USAS, IEEE, and NEMA standards and are periodically tested and operated as required by such standards to ensure that the motors remain in a reliable condition.

Although the motors, which are provided only to drive engineered safety features equipment, are normally run only for tests, the design loading and temperature rise limits are based on accident conditions. Normal design margins are specified for these motors to ensure that the expected lifetimes include allowance for the occurrence of accident conditions.

Motors in a Potentially Harsh Environment

Engineered Safety Feature electrical equipment located in potentially harsh environments (i.e., temperature, pressure, humidity, chemical spray or radiation changes as a result of a design basis accident) are designed and qualified to withstand their normal lifetime service environment followed by a design basis accident environment. This ensures that the equipment will be inherently capable of performing their required engineered safety function. Periodic maintenance and surveillance of the motors and their insulation systems are also accomplished to verify the reliable condition of the equipment.

Qualification tests and analysis are performed to demonstrate the adequacy of valve motor operators and motors used for engineered safety feature functions.

The normal service, harsh accident, and post-accident environments in the vicinity of the equipment are evaluated and used to develop performance specifications for the equipment. A test sample usually is then subjected to simulated accident conditions including radiation, temperature, pressure, relative humidity, and chemical spray. If aging is known to have a significant effect on equipment performance, the test sample is artificially aged prior to design basis accident exposure. The test sample's performance is evaluated during and after the simulation to ensure proper functioning.

Control of equipment qualification documentation is described in Section 6.1.1.

Electrical Supply

Details of the normal and emergency power sources for the safety injection system are presented in Section 8.0.

Protection Against Dynamic Effects

All four injection lines penetrate the containment adjacent to the auxiliary building.

The portion of the high head injection system within the containment is connected to the accumulator injection lines attached to each loop's cold leg piping and to the low head injection lines. The portion of the low head injection system within the containment is connected directly to the core deluge injection nozzles on the vessel.

For most of the routing, these lines are outside the reactor and steam generator shielding, and hence they are protected from missiles originating within these areas.

The coolant loop supports are designed to restrict the motion to about one-tenth of an inch, where as the attached safety injection piping can sustain a 3 in. displacement without exceeding the working stress range.

All hangers, stops and anchors are designed in accordance with USAS B31.1 1967 Edition, Code for Pressure Piping, and ACI 318 - 1963 Edition, Building Code Requirements for Reinforced Concrete, which provide minimum requirements on materials, design and fabrication with ample safety margins for both dead and operational dynamic loads over the life of the equipment. In addition to the normal load conditions, the requirements of Table A.5-3 for the loading combinations shown are used in design of supports. Specifically, these standards require the following:

1. All materials used are in accordance with ASTM specifications which establish quality levels for the manufacturing process, minimum strength properties, and for test requirements which ensure compliance with the specifications.

2. Qualification of welding processes and welders for each class of material welded and for types and positions of welds.

3. Maximum allowable stress values are established which provide an ample safety margin on yield strength for normal loads and ultimate strength for design basis accident or maximum hypothetical seismic loads.

NOTE: Safety related shock suppressers for Units 1 and 2 are listed in Table 6.2-11.

6.2.3 SYSTEM EVALUATION

Injection Connections and Flow to the Core

The injection lines from the accumulators, low head pumps and high head pumps are connected to the reactor coolant system to provide the maximum performance flexibility for a loss-of-coolant accident of any size or location. The performance flexibility is available not only during the injection phase, but also during the long-term recirculation.

Each accumulator is attached to a reactor coolant system cold leg. The core is therefore rapidly flooded from the bottom to provide the earliest possible cooling of the entire core and the attendant arresting of the clad temperature transient. When the accumulators reflood the bottom regions of the core, rapid steam generation causes a mixture of steam and entrained water droplets to flow through and cool the upper regions of the core.

The residual heat removal pumps (low head) deliver borated water to the core upper plenum through nozzles connected to the reactor vessel. The low head system thereby serves a basic injection function in the event of large breaks in the reactor coolant system. This function is to provide continued makeup following the successful cooling of the core by the accumulators. A second function of these pumps is to provide continued cooling during the recirculation phase.

The high head system connects to both the reactor vessel and cold legs to provide injection flow for both the steam line break and small loss-of-coolant accidents. Both high head pumps deliver to the two cold legs normally. The headers from each pump are cross connected to allow either pump to supply both the reactor vessel and cold leg connections.

Range of Core Protection

The measure of effectiveness of the safety injection system is the ability of the pumps and accumulators to keep the core flooded or to reflood the core rapidly where the core has been uncovered by (postulated) large area ruptures. The result of this performance is to sufficiently limit any increase in clad temperature below a value where emergency core cooling criteria are met (Section 6.2.1). Simulations of a sufficient number of break sizes were performed to demonstrate that the safety injection system components meet the emergency core cooling requirements. The results of the loss-of-coolant accident studies are presented in Section 14.3.

System Response

To provide protection for large area ruptures in the reactor coolant system, the safety injection system must respond to rapidly reflood the core following the depressurization and core voiding that is characteristic of large area ruptures. The accumulators act to perform the rapid reflooding function with no dependence on the normal or emergency power sources, and also with no dependence on the receipt of an actuation signal.

Operation of this system with one of the two available accumulators delivering their contents to the reactor vessel (one accumulator spilling through the break) prevents fuel clad melting and limits metal-water reaction to an insignificant amount (< 1%).

The function of the safety injection (or residual heat removal) pumps is to complete the refill of the vessel and ultimately return the core to a subcooled state. As discussed earlier, the flow from one safety injection pump or one residual heat removal pump is sufficient to complete the refill with no loss of level in the core. Moreover, there is sufficient excess water delivered by the accumulators to tolerate a delay in starting the pumps.

Initial response of the injection system is automatic, with appropriate allowance for delays in actuation of circuitry and active components. The active portions of the injection systems are automatically actuated by the safety injection signal (Section 7.0). In addition, manual actuation of the entire injection system and individual components can be accomplished from the control room. In analysis of system performance, delays in reaching the programmed trip points and in actuation of components are conservatively established on the basis that only emergency on-site power is available. The starting sequence of the safety injection pumps and related emergency power equipment is designed so that delivery of full rated flow is reached within 20 sec. after the process parameters reach the setpoints for the injection signal. See Section 8.0. The safety injection pump time delays that are used in the accident analyses include SI signal processing, sequencer time delay uncertainty, time for pump start to full flow, and emergency diesel generator delays as appropriate. The specific time delays that are assumed are discussed in Chapter 14, Section 14.2.5, Section 14.3.1 and Section 14.3.2.

Single Failure Analysis

A single active failure analysis is presented in Table 6.2-7(a). All credible active system failures are considered. The analysis of the loss-of-coolant accident presented in Section 14.0 is consistent with the single failure analysis. The most severe single failure assumed in the SI system for the small break loss-of-coolant accident (Section 14.3.1) is the loss of an electrical train due to the failure of an emergency diesel generator. This will result in the loss of one high head safety injection pump and one motor-driven AFW pump. Other equipment may also be lost (RHR pump, CCW, SW, etc.) but the high head safety injection pump and AFW pumps are the key components in providing short-term cooling capability for the SBLOCA. The most severe single failure assumed in the SI system for the large break loss-of-coolant accident (Section 14.3.2) is the loss of an RHR pump.

The failure analysis is based on the worst single failure (generally a pump failure) in both the safety injection and residual heat removal pumping systems. The analysis shows that the failure of any single active component will not prevent fulfilling the design function.

In addition, an alternative flow path is available to maintain core cooling if any part of the recirculation flow path becomes unavailable. This is evaluated in Table 6.2-7(b).

Failure analyses of the component cooling and service water system under loss-of-coolant accident conditions are described in Section 9.1 and Section 9.6, respectively.

Reliance on Interconnected Systems

During the injection phase, the high head safety injection pumps take suction on the refueling water storage tank. During the recirculation phase of the accident for small breaks, suction to a high head safety injection pump is provided by the associated residual heat removal pump.

The residual heat removal (low head) pumps are normally used during reactor shutdown operations. Whenever the reactor is at power, the pumps are aligned for low head safety injection.

Debris accumulation in the piping during construction is minimized by controlled cleanliness procedures. Moreover, the system was flushed with clean water after construction was completed to remove any debris that may have entered the system inadvertently.

Shared Function Evaluation

Table 6.2-8 is an evaluation of the main components, which have been previously discussed, and a brief description of how each component functions during normal operation and during the accident.

Passive Systems

The accumulators are a passive safety feature in that they perform their design function in the total absence of an actuation signal or power source. The only moving parts in the accumulator injection train are in the two check valves.

The working parts of the check valves are exposed to fluid of relatively low boric acid concentration contained within the reactor coolant loop. Even if some unforeseen deposition accumulated, calculations have shown that a differential pressure of about 25 psi will shear any particles in the bearing that may otherwise prevent the valve from functioning.

The isolation valve at each accumulator is closed only when the reactor is intentionally depressurized or momentarily for testing. The isolation valve is normally open and a monitor light in the control room indicates if the valve is inadvertently closed.

The check valves are normally closed, with a nominal differential pressure across the disc of approximately 1,550 psi. They remain in this position except for testing or when called upon to function. Since the valves are normally closed and are therefore not subject to the abuse of flowing fluids or impact loads caused by sudden flow reversal and seating, they do not experience any wear of the moving parts, and function as required. As the reactor coolant system is pressurized during the normal plant heatup operation, the check valves are checked for back leakage by monitoring RHR system pressure during heatup.

The accumulators can accept leakage back from the reactor coolant system without effect on their availability. Table 6.2-9 indicates that back leakage rates, over a given time period, require readjusting the level at the end of the time period. In addition, these rates are compared to the maximum allowed leak rates for manufacturing acceptance tests (20 cc/hr, i.e., 2 cc/hr/in.).

Back leakage at a rate of 5 cc/hr/in., 2½ times test, would require that the accumulator water volume be adjusted approximately once every 28 mo. This would indicate that level adjustments can be scheduled for normal refueling shutdowns and that this work can be done at the operator's convenience.

The accumulators are located inside the reactor containment and protected from the reactor coolant system piping and components by a missile barrier. Accidental release of the gas charge in the two accumulators would cause an increase in the containment pressure of approximately 0.1 psi.

During normal operation, the flow rate through the reactor coolant piping is approximately five times the maximum flow rate from the accumulator during injection. Therefore, fluid impingement on reactor vessel components during operation of the accumulator is not restricting.

Recirculating Loop Leakage

During the recirculation phase of a loss of coolant accident, the containment sump water is recirculated through portions of the Emergency Core Cooling System (ECCS) located in the operating areas of the primary auxiliary building (PAB). Postulated leakage from this equipment in the PAB or back leakage through the RWST may contribute to the offsite radiation dose and the dose received by plant operators during the accident. LOCA radiological analyses of offsite and control room dose due to this leakage conservatively assume a combined ECCS leak rate of 800 cc/min during the accident as described in FSAR Section 14.3.5. The airborne leakage from the ECCS may also contribute to the "passing plume" (radioactive cloud) which emanates direct radiation on control room operators. This direct radiation dose is analyzed in FSAR Section 11.6.

The actual ECCS leakage is not expected to exceed 400 cc/min.and is checked and controlled through the Leakage Reduction and Preventative Maintenance program. This program ensures that ECCS equipment leakage is As Low As Reasonably Achievable (ALARA), and remains below the value which forms the basis for the aforementioned radiological analyses.

During external recirculation, significant margin exists between the design and operating conditions of the residual heat removal system components, as shown in Table 6.2-10. In addition, during normal plant cooldown, operation of the residual heat removal system is initiated when the primary system pressure and temperature have been reduced to less than 400 psig and less than or equal to 350°F, respectively. Since the maximum operating conditions during recirculation are 200 psig and 250°F, significant margin also exists between normal operating and accident conditions.

Leakage detection exterior to containment is achieved through use of sump level detection. One or more pumps in the auxiliary building sump below the (-)19 ft. 3 in. level starts automatically in the event that liquid accumulates in the sump, and an alarm sounds in the control room if water accumulates above a fixed level in the sump.

Water leakage into the tendon gallery is normally pumped to the facade sump which will actuate an alarm in the control room on high level. If water begins to accumulate in the tendon gallery it will overflow through the openings in the Containment Sump A drain line-to-sleeve grout to the associated unit's A train RHR pipeway and then to the Train A RHR pump room. Openings in the Sump A drain-to-sleeve grout are required to be at least 0.8 square inches and no more than 15.2 square inches to provide sufficient area for drainage but not adversely affect the negative pressure in the primary auxiliary building (Reference 6 and Reference 8).

Each RHR pump is located in an individual compartment which is equipped with a floor drain and separated equipment drains. The floor drain from each compartment flows through an individual pipe to the sump. Two 75 gpm sump pumps transfer the leakage to the waste disposal system. Valving is provided to permit the operator to individually isolate the residual heat removal pumps. The supply and discharge piping and valves for the RHR pumps are located in a pipeway adjacent to the pump compartments. A seven ft. high wall divides the pipeway into two sections, each of which drains into a pump compartment through a 4-inch by 4-inch opening at floor level. The RHR pump seal failure rate is 50 gpm.

The RHR cubicle drain valves are maintained in the closed position. If a RHR pump seal failure occurred with the drain valves in the closed position, a RHR pump room high level alarm would eventually be indicated in the control room. The cubicle could then be drained to the sump by opening the drain valve. If flooding in EL.-19' occurred due to a source other than a failed RHR pump seal, the fluid would collect in the center cubicle (cubicle between the Unit 1 and Unit 2 RHR pumps) and flow to the sump via the floor drains. The flow path to the RHR pump cubicle would remain isolated.

Pump NPSH Requirements - Residual Heat Removal Pumps

The NPSH of the residual heat removal pumps is evaluated for normal plant shutdown operation, and both the injection and recirculation phase operation of the design basis accident. Recirculation operation gives the limiting NPSH requirement. The available NPSH is determined from the containment water level, and the pressure drop in the suction piping from the sump to the pumps. During recirculation phase of a large break LOCA where RHR pump flow is sent to both the reactor vessel and the suction of the containment spray pump, maximum RHR pump flow requirements are set by system alignment to ensure RHR pump NPSH. Status lights are available on the main control boards to allow the operator to confirm the proper alignment of the containment spray pump discharge valves and to confirm that the preset throttle position has been reached for the SI-852A & B RHR pump core deluge valves. Flow instrumentation is available on the main control boards to allow the operators to monitor the operation of the containment spray and RHR systems during the ECCS recirculation phase of a LOCA. (Reference 4)

Coating debris can also play a role in affecting the available NPSH during post-LOCA ECCS recirculation operation. A program has been instituted at PBNP that provides adequate assurance that the applicable requirements for the procurement, application, inspection, and maintenance of Service Level I coatings in containment are implemented, and that maintains a detailed inventory of degraded and non-conforming coatings to ensure the coatings are maintained within the evaluated limits of design basis analyses for the ECCS. Refueling frequency coatings inspections ensure the total inventory of coatings remain bounded by the analyses.

Safety Injection Pumps

The NPSH for the safety injection pumps is evaluated for both the injection and recirculation phase of operation of the design basis accident. The end of the injection phase operation gives the limiting NPSH requirement. The NPSH available is determined from the elevation head and vapor pressure of the water in the refueling water storage tank, and the pressure drop in the suction piping from the tank to the pumps.

6.2.4 REQUIRED PROCEDURES AND TESTS

Inspection Capability

All components of the safety injection system can be inspected periodically to demonstrate system readiness. The pressure containing systems can be inspected for leaks from pump seals, valve packing, flanged joints and safety valves during system testing.

In addition, to the extent practical, the critical parts of the reactor vessel internals, injection nozzles, pipes, valves and safety injection pumps can be inspected visually or by boroscopic examination for erosion, corrosion, and vibration wear evidence, and for nondestructive test inspection where such techniques are desirable and appropriate.

System Testing

Operational sequence testing of the safety injection system is performed during reactor shutdown in accordance with Technical Specification surveillance requirements. These tests demonstrate emergency diesel generator operation and automatic sequencing of safeguards loads during a loss of offsite power to each 4160 V emergency bus in conjunction with an ESF actuation signal (see Section 8.8.3 for description of emergency diesel generator loading). The tests also demonstrate that each automatic ECCS valve actuates in response to an actual or simulated SI signal.

The safety injection piping up to the final isolation valve is maintained full of borated water, and the accumulators are maintained filled at their designated levels with borated water, while the plant is in operation. The accumulator pressure and level are continuously monitoried during plant operation. The accumulators and injection lines are refilled with borated water as required by using a safety injection pump to recirculate refueling water through the injection lines. A small test line is provided for this purpose in each injection header.

Flow in each of the high head injection lines and in the flow lines for the residual heat removal pumps is monitored by flow indicators. Pressure instrumentation is also provided for the main flow paths of the safety injection and residual heat removal pumps.

Component Testing

Inservice testing requirements are described in the PBNP Inservice Testing Program and the IST Background Document.

Each active component of the safety injection system can be individually actuated on the normal power source at any time during plant operation to demonstrate operability. The test of the safety injection pumps employs the full flow recirculation test line which connects back to the refueling water storage tank. Remotely operated valves are exercised and actuation circuits tested. The automatic actuation circuitry, valves and pump breakers also may be checked during integrated system tests performed during a planned cooldown of the reactor coolant system.

A test system is provided to periodically verify back-leakage through each RCS Event V Pressure Isolation Valve (PIV) is within limits. The accumulator discharge check valves (SI-867A/B) are Event V PIVs and are tested with this system. (See TRM 4.16, RCS PIV Leakage Program).

If leakage through a check valve should become excessive, the isolation valve (SI-841A/B) would be closed and an orderly shutdown initiated to repair the check valve. The performance of the check valves in this application has been carefully studied and it is concluded that it is highly unlikely that the accumulator lines would have to be closed because of leakage.

The isolation valves are closed and de-energized when the reactor coolant system is intentionally depressurized to ≤1000 psig to allow for RCS cooldown and depressurization without discharging the accumulators into the RCS or requiring depressurization of the accumulators.

The recirculation piping was initially hydrostatically tested at 150% of design pressure of each portion of the loop. The entire loop is also pressurized during periodic testing of the engineered safety features components. The recirculation piping is also leak tested at the time of the periodic retests of the containment.

Since the recirculation flow path is operated at a pressure in excess of the containment pressure, it is hydrotested during periodic retests at the recirculation operating pressures. This is accomplished by running each pump utilized during recirculation (safety injection, spray, and residual heat removal pumps) in turn and checking the discharge and recirculation test lines. The suction lines are tested by running the residual heat removal pumps and opening the flow path to containment spray and safety injection pumps in the same manner as described above.

During the above test, all system joints, valve packings, pump seals, leakoff connections, or other potential points of leakage are visually examined. Valve gland packing, pump seals, and flanges are adjusted or replaced as required to reduce the leakage to acceptable proportions.

Emergency Operating Procedures

The requirement to establish simultaneous upper plenum injection and cold leg injection to control boric acid precipitation following a LOCA is incorporated into the emergency operating procedures. The transfer from containment spray recirculation to cold leg recirculation via the safety injection pumps within 10 minutes is considered to be a time critical operator action. The emergency operating procedures direct operators to prevent inadvertent precipitation by limiting depressurization and cooldown during small breaks in the event that boiling in the reactor vessel exists for an extended period of time with the RCS pressure above the shutoff head of the RHR pumps. The procedures also ensure that BAST injection is promptly terminated during all LOCAs to preclude early boric acid precipitation. (Reference 3)

6.2.5 REFERENCES

1. WCAP-7153, “Investigation of Chemical Additives for Reactor Containment Sprays,” M. J. Bell, et al, March 1968, (Proprietary).

2. 10 CFR 50.46, “Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Nuclear Power Reactors.”

3. NRC Safety Evaluation, “Point Beach Nuclear Plant (PBNP), Units 1 and 2 - Issuance of License Amendments Regarding Extended Power Uprate (TAC Nos ME1044 and ME1045),” dated May 3, 2011.

4. NRC Safety Evaluation, "Point Beach Nuclear Plant (PBNP), Units 1 and 2 - Issuance of License Amendments Regarding Use of Alternate Source Term (TAC Nos. ME0219 and ME0220)," dated April 14, 2011.

5. Westinghouse calculation CN-LIS-08-67, "Point Beach Units 1 and 2 (WEP/WIS) Extended power Uprate (EPU) Post-LOCA long Term Cooling (LTC)," Rev 2, dated April 16, 2011.

6. NRC SE dated September 18, 2006, "Point Beach Nuclear Plant, Units 1 and 2 - Evaluation of Event Notification 42129 (TAC Nos. MC9035 and MC9036)."

7. Calculation 2006-0021, ECCS System Accident Analysis Inputs, Revision 0.

8. Engineering Change EC, 11416, Revision 1, closed January 27, 2009.

Table 6.2-1 SAFETY INJECTION SYSTEM - CODE REQUIREMENTS

Component	Code
Refueling Water Storage Tank	API 650
Residual Heat Exchanger	
Tube Side	ASME Section III, Class C
Shell Side	ASME Section VIII
Accumulators	ASME Section III, Class C
Valves	USAS B16.5/ANSI B16.34
Piping	USAS B31.1

Table 6.2-2 (DELETED)

This information is considered historical information, and is described in FFDSAR Table 6.2-3.

Table 6.2-3 ACCUMULATOR DESIGN PARAMETERS

Number (per unit)	2
Type	Stainless steel clad/carbon steel
Design pressure, psig	800
Design temperature, °F	300
Operating temperature, °F	70-120
Normal pressure, psig	750
Minimum pressure, psig	700
Total volume, ft^3	1,750
Minimum water volume at operating conditions, ft^3	1,100
Boron concentration (as boric acid), ppm	2,700 to 3,100
Relief valve setpoint, psig*	800

* The relief valves have soft seats and are designed and tested to ensure they are leak tight such that the minimum accumulator pressure defined in Technical Specifications is maintained.

Table 6.2-4 REFUELING WATER STORAGE TANK DESIGN PARAMETERS

Number (per unit)	1
Material	Stainless steel
Total volume, gal.	289, 504
Minimum volume, (solution) gal.	275,000
Normal pressure, psig	Atmospheric
Minimum operating temperature, °F	40
Design pressure, psig	Atmospheric
Design temperature, °F	200
Boron concentration (as boron), ppm	2,800 to 3,200

Table 6.2-5 PUMP PARAMETERS

<u>Safety Injection Pump Design Parameters</u>	
Number (per unit)	2
Type	Horizontal Centrifugal
Design Pressure, psig	1,750
Design Temperature, °F	300
Design Flow Rate, gpm	700
Runout Flow Rate, gpm	1,233
Design Head, ft	2,600
Shutoff Head, ft	3,400
Material	11-13 Chrome
Motor H.P.	700
<u>Residual Heat Removal Pump Design Parameters</u>	
Number of Pumps (per unit)	2
Type	Horizontal Centrifugal
Design Pressure, psig	600
Design Temperature, °F	400
Design Flow, gpm	1,560
Design Head, ft.	280
Runout Flow Rate, gpm	2,500
Material	Austenitic Stainless Steel
Shutoff Head, ft.	335
Motor H.P.	200

Table 6.2-6 RESIDUAL HEAT EXCHANGERS DESIGN PARAMETERS

Number (per unit)	2	
Design Heat Duty, BTU/hr (Normal)	24.15×10^6	
Design UA, BTU/hr/°F	0.745×10^6	
Design Cycles (85°F-350°F)	200	
Type	Vertical Shell and U-Tube	
	Tube-Side	Shell-Side
Design Pressure, psig	600	150
Design Flow, lb/hr	0.763×10^6	1.375×10^6
Inlet Temperature, °F	160	100
Outlet Temperature, °F	128.4	117.3

Table 6.2-7(a) SINGLE FAILURE ANALYSIS - SAFETY INJECTION SYSTEM

Component	Malfunction	Comments
A. Accumulator (Injection phase)	Delivery to broken loop	Totally passive system with one accumulator per loop. Evaluation based on one accumulator delivering to the core and one spilling from ruptured loop.
B. Pump (Injection Phase):		
1. High Head Safety Injection	Fails to start	Two provided. Small break LOCA evaluation assumes operation of one pump based on loss of an electrical train due to failure of an emergency diesel generator. Large break LOCA evaluation does not assume a single failure of a high head SI pump, but assumes a single failure of an RHR pump which is more limiting.
2. Residual Heat Removal	Fails to start	Two provided. Evaluation based on operation of one.
3. Component Cooling*	Fails to start	Two provided. One required for recirculation cooling.
4. Service Water	Fails to start	Six provided. Evaluation based on operation of three. (See also Section 9.6.)
C. Automatically Operated Valves (Normally closed; open on SIS - Injection Phase)		
1. Residual Heat Removal Pump Discharge Isolation Valves to Reactor Vessel Injection (SI-852A/B)	One valve fails to open	One valve provided for each LHSI train: one train required for injection.
D. Manual and Remote-Manual Operated Valves (Repositioned for Recirculation Phase)		
1. Containment Sump Recirculation Isolation Valves (SI-850A/B, SI-851A/B)	One valve fails to open	Two valves provided in series in each independent sump recirculation line. One line (one pair of valves) required to open for recirculation.
2. RHR Heat Exchanger Discharge to SI Pump Suction Isolation Valves (SI-857A/B)	One valve fails to open	One valve provided for each SI train; one SI train required for piggyback operation.
3. SI Test Line to RWST Isolation Valves (SI-897A/B)	One valve fails to close	Two valves provided in series; One valve required to close for isolation.
4. SI Pump Suction from RWST Isolation Valves (SI-896A/B) for piggyback operation	One valve fails to close	One valve provided in each SI train; one SI train required for piggyback operation.
5. RHR Pump Suction from RWST Isolation Valves (SI-856A/B)	One valve fails to close	One valve provided in each LHSI train (in series with a check valve); one LHSI train required for recirculation.
6. Residual Heat Removal Pump Discharge Isolation Valves to Reactor Vessel Injection (SI-852A/B)	One valve fails to throttle	One valve provided for each LHSI train; one train required for piggyback operation.

* Recirculation Phase: The status of all active components of the safety injection system is indicated on the main control board.

Table 6.2-7(b) LOSS OF RECIRCULATION FLOW PATH

	Flow Path		Indication of Loss of Flow Path	Alternative Flow Path
A.	Low Head Recirculation			
	From containment to reactor core via one of the two residual heat removal pumps and the associated residual heat exchanger and a low head injection line.	1.	No flow in low head injection line associated with the operating residual heat removal pump. (Flow monitor in each injection line.)	Via the separate and independent low head recirculation train from containment to reactor core via the second residual heat removal pump, the associated residual heat exchanger, and the second low head injection header.
		2.	High flow in low head injection line as (1), above.	
B.	High Head Recirculation			
	From containment to high head injection lines via one of the two residual heat removal pumps, the associated residual heat exchanger, the associated high head injection pump suction line and the high head injection pump.	1.	No (or low) flow in the high head injection lines. (One flow monitor in each line.)	If flow to the high head injection lines is not established by opening the cross connection between the residual heat exchanger and the suction of the safety injection pump, then the separate and independent flow path to the second high head pump is established (from the containment via second residual heat removal pump, the associated residual heat exchanger and the associated high head injection pump suction line).
		2.	High flow in one high head injection line, low (or zero) flow in the second high head line.	Close the cross connect between the two discharges of the two injection pumps and utilize the injection pump (and associated supply train from containment) which is supplying the high head injection line which registered the low flow.

NOTE: As shown on Figure 6.2-1, there are valves at all locations where alternative flow paths are provided.

Table 6.2-8 SHARED FUNCTIONS EVALUATION

Component	Normal Operating Function	Normal Operating Arrangement	Accident Function	Accident Arrangement
Refueling Water Storage Tank (1/Unit)	Storage tank for refueling operations	Lined up to suction of safety injection residual heat removal, and spray pumps	Source of borated water for emergency core cooling systems	Lined up to suction of safety injection, residual heat removal, and spray pumps
Accumulators (2/Unit)	None	Lined up to cold legs of reactor coolant piping	Supply borated water to core promptly	Lined up to cold legs of reactor coolant piping
Safety Injection Pumps (2/Unit)	None	Lined up to reactor vessel and/or cold legs of reactor coolant piping	Supply borated water to core	Lined up to reactor vessel and/or cold legs of reactor coolant piping
Residual Heat Removal Pumps (2/Unit)	Supply water to loop to remove residual heat during shutdowns	Lined up to take suction from refueling water storage tank and deliver to reactor vessel Lineup for plant shutdowns is described in Section 9.2.	Supply borated water to core through reactor vessel nozzles and to containment spray pump or safety injection pump suction.	Lined up to take suction from refueling water storage tank and deliver to reactor vessel during injection phase. Lined up to take suction from the containment sump and deliver water to reactor vessel and containment spray pump suction or safety injection pump suction during recirculation.
Service Water Pumps [a](6)	Supply lake cooling water to component cooling heat exchangers	Two pumps in service during operation of both units (see Section 9.6.2)	Supply lake cooling water to component cooling heat exchangers and containment fan coolers, and AFW pump bearings. Also provides alternate source of water to AFW pump suction.	Three pumps in service during operation of both units (see Section 9.6.2)
Residual Heat Exchangers (2/Unit)	Remove residual heat from core during shutdown	Lined up for recirculation Lineup for plant shutdowns is described in Section 9.2.	Cool water in containment sump for core cooling and containment spray	Lined up for recirculation
Component Cooling Heat Exchangers (4)[b†]	Remove heat from component cooling water	One heat exchanger in service per unit	Cool water for residual heat exchangers, residual and S.I. pump seals and bearings (during recirculation)	One heat exchanger in service.

a. Shared
b. One for each unit during normal operation; two serve as shared standby heat exchangers
† One pump and one heat exchanger also required on the second Unit for both phases of the accident (injection and recirculation)

Table 6.2-9 ACCUMULATOR INLEAKAGE*

Time Period Between Level Adjustments	Observed Leak Rate cc/hr	(Observed Leak Rate) (Max. Allowed Design)
1 month	1,410	70.7
3 months	470	23.5
6 months	235	11.7
9 months	157	7.8
1 year	118	5.9
10 years	11.8	0.6

* A total of 36 cu. ft., added to the initial amount, can be accepted in each accumulator before an alarm is sounded.

Table 6.2-10 RESIDUAL HEAT REMOVAL SYSTEM DESIGN, OPERATION AND TEST CONDITIONS

	Pumps	Heat Exchangers	Valves	Pipes and Fittings
Design Conditions				
Pressure, psig	600	600	665	700
Temperature, °F	400	400	400	400
Operating Conditions (Max)*				
Pressure, psig	200	200	200	200
Temperature, °F	210	210	210	210
Test Pressure, psig	1200	900	1100	900
Allowable Pressure at Operating Temp, psig	>600	>600	>690	>850

* During post loss-of-coolant recirculation.
The maximum temperature downstream of RHR heat exchangers is 210°F. The maximum temperature from the containment sump to the RHR heat exchangers is 250°F.

Table 6.2-11 SAFETY RELATED SNUBBERS UNIT 1

Page 1 of 2

ID	LOCATION/ELEVATION	NOMINAL RATING
HS-1	"A" Main Steam Line-West/100′	497 kip
1HS-2	"A" Main Steam Line-East/100′	497 kip
1HS-3	"B" Main Steam Line-West/100′	497 kip
1HS-4	"B" Main Steam Line-East/100′	497 kip
1HS-5	"A" SG Side-North/66′	449 kip
1HS-6	"A" SG Side-Middle/66′	449 kip
1HS-7	"A" SG Side-South/66′	449 kip
1HS-8	"B" SG Side-North/66′	449 kip
1HS-9	"B" SG Side-Middle/66′	449 kip
1HS-10	"B" SG Side-South/66′	449 kip
1HS-11	"A" Main Feed Line Below 66′/61′	11 kip
1HS-12	SIS Line-Regen HX Cubicle/34′	11 kip
1HS-13	SIS Line at 21' in Overhead/40′	11 kip
1HS-14	REMOVED FROM SERVICE	
1HS-15	Containment Spray Header/120′	11 kip
1HS-16	Containment Spray Header/120′	11 kip
1HS-17	REMOVED FROM SERVICE	
1HS-18	REMOVED FROM SERVICE	
1HS-19	Incore Detector Tube Bundle in Keyway/3′	11 kip
1HS-20	Incore Detector Tube Bundle in Keyway/3′	11 kip
HS-601R-37A	PZR PORV Header/76′	3 kip
HS-601R-73	PZR SRV Relief Line/80′	11 kip
HS-601R-80	PZR SRV Relief Line/80′	11 kip
HS-601R-90	SRV Discharge Piping	27.3 kip
HS-601R-92A1	SRV Discharge Piping West	27.3 kip
HS-601R-92A2	SRV Discharge Piping East	27.3 kip
HS-2501R-15	PZR PORV Header/78′	11 kip
HS-2501R-22A	PZR PORV Header/78′	3 kip
HS-2501R-43	PZR PORV Header/77′	11 kip
HS-2501R-51	PZR PORV Header/77′	11 kip
EB-2-H7	REMOVED FROM SERVICE	
EB-2-H17	REMOVED FROM SERVICE	
R-EB-2-1	REMOVED FROM SERVICE	
R-EB-2-3	REMOVED FROM SERVICE	
R-EB-2-4	REMOVED FROM SERVICE	
R-EB-2-6	REMOVED FROM SERVICE	
R-EB-2-7	REMOVED FROM SERVICE	
AC-601R-3-R-350	REMOVED FROM SERVICE	
AC-601R-3-R-356	REMOVED FROM SERVICE	

Table 6.2-11 SAFETY RELATED SNUBBERS UNIT 2
Page 2 of 2

ID	LOCATION/ELEVATION	NOMINAL RATING
2HS-21	REMOVED FROM SERVICE	
2HS-22	Beneath Valve 2-541 in "A" Loop Cubicle/41′	11 kip
2HS-23	SIS Line-46' East Side/50′	11 kip
2HS-24	In Overhead by 21' Keyway Access/36′	11 kip
2HS-25	Regen HX Cubicle/34′	11 kip
2HS-26	SIS Line-46' Near East Stairs/34′	11 kip
2HS-27	In Keyway/3′	11 kip
2HS-28	REMOVED FROM SERVICE	
2HS-29	PZR SV Discharge Header in PZR Cubicle/80′	11 kip
2HS-30	PZR SV Discharge Header in PZR Cubicle/80′	11 kip
2HS-31	In Keyway/3′	11 kip
2HS-32	"A" Main Steam Line-East/100′	497 kip
2HS-33	"A" Main Steam Line-West/100′	497 kip
2HS-34	"B" Main Steam Line-East/100′	497 kip
2HS-35	"B" Main Steam Line-West/100′	497 kip
2HS-36	"A" SG Side-North/66′	449 kip
2HS-37	"A" SG Side-Middle/66′	449 kip
2HS-38	"A" SG Side-South/66′	449 kip
2HS-39	"B" SG Side-North/66′	449 kip
2HS-40	"B" SG Side-Middle/66′	449 kip
2HS-41	"B" SG Side-South/66′	449 kip
HS-601R-37	PZR PORV Header/78′	15 kip
HS-601R-93	PZR Safety Valve Discharge Line	17.6 kip
HS-601R-95B	PZR Safety Valve Discharge Line	23.7 kip
HS-2501R-15	PZR PORV Header/78′	11 kip
HS-2501R-21A	PZR PORV Header/78′	3 kip
HS-2501R-43	PZR PORV Header/77′	11 kip
HS-2501R-49	PZR PORV Header/77′	3 kip
2R-EB-2-1	REMOVED FROM SERVICE	
2R-EB-2-2	REMOVED FROM SERVICE	
2R-EB-2-3	REMOVED FROM SERVICE	
2R-EB-2-4	REMOVED FROM SERVICE	
2R-EB-2-5	REMOVED FROM SERVICE	
2R-EB-2-6	REMOVED FROM SERVICE	
2R-EB-2-7	REMOVED FROM SERVICE	
EB-8-H206	REMOVED FROM SERVICE	

Figure 6.2-1 UNIT 2 SAFETY INJECTION SYSTEM (Sheet 1)

[redacted]

Figure 6.2-1 UNIT 2 SAFETY INJECTION SYSTEM (Sheet 2)

[redacted]

Figure 6.2-1 UNIT 2 SAFETY INJECTION SYSTEM (Sheet 3)

[redacted]

Figure 6.2-2 SIS DRAINS - ELEVATION

[redacted]

Figure 6.2-3 CONTAINMENT DRAINS - PLAN

[redacted]

Figure 6.2-4 SAFETY INJECTION PUMP PERFORMANCE CHARACTERISTICS

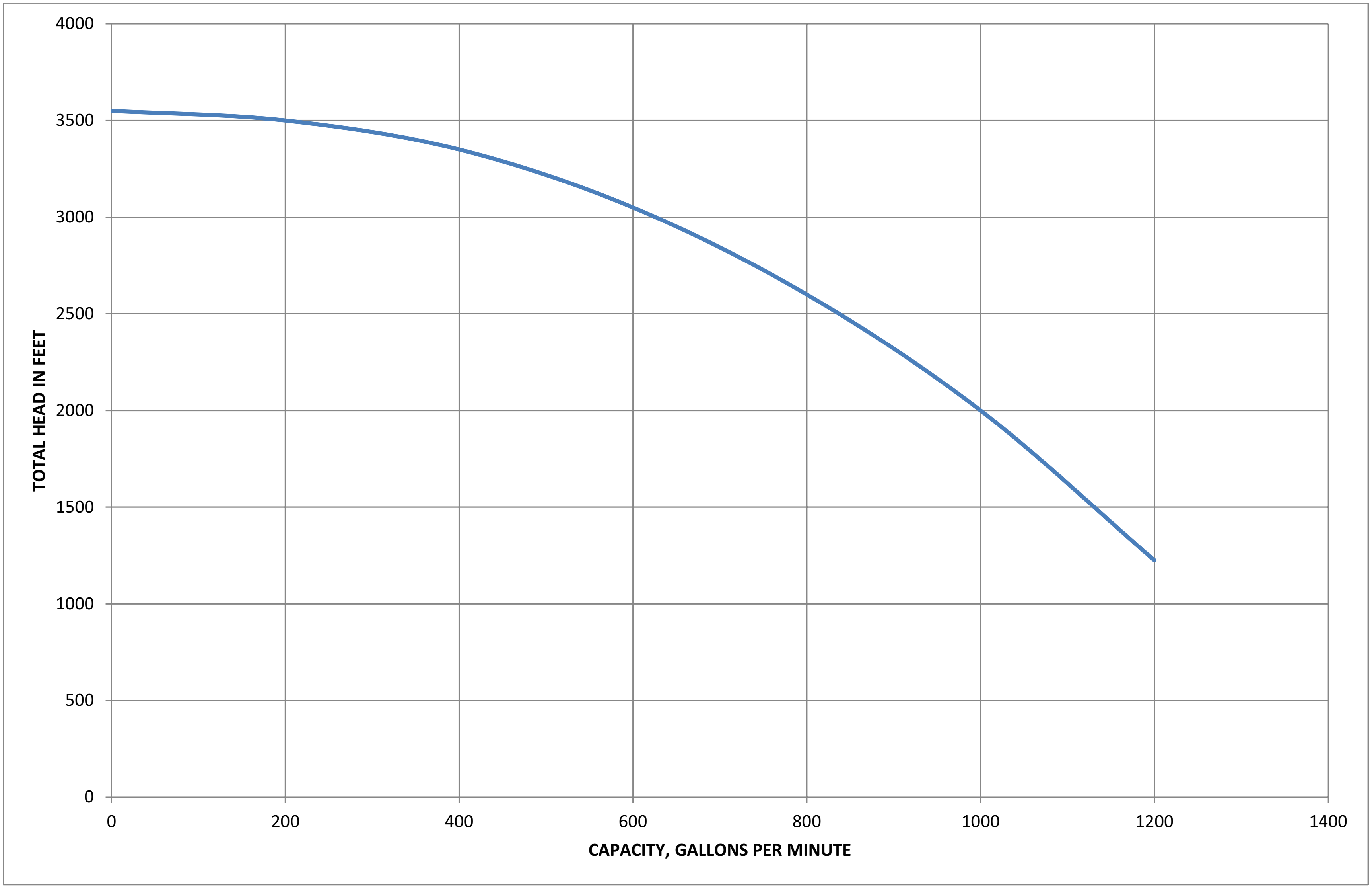
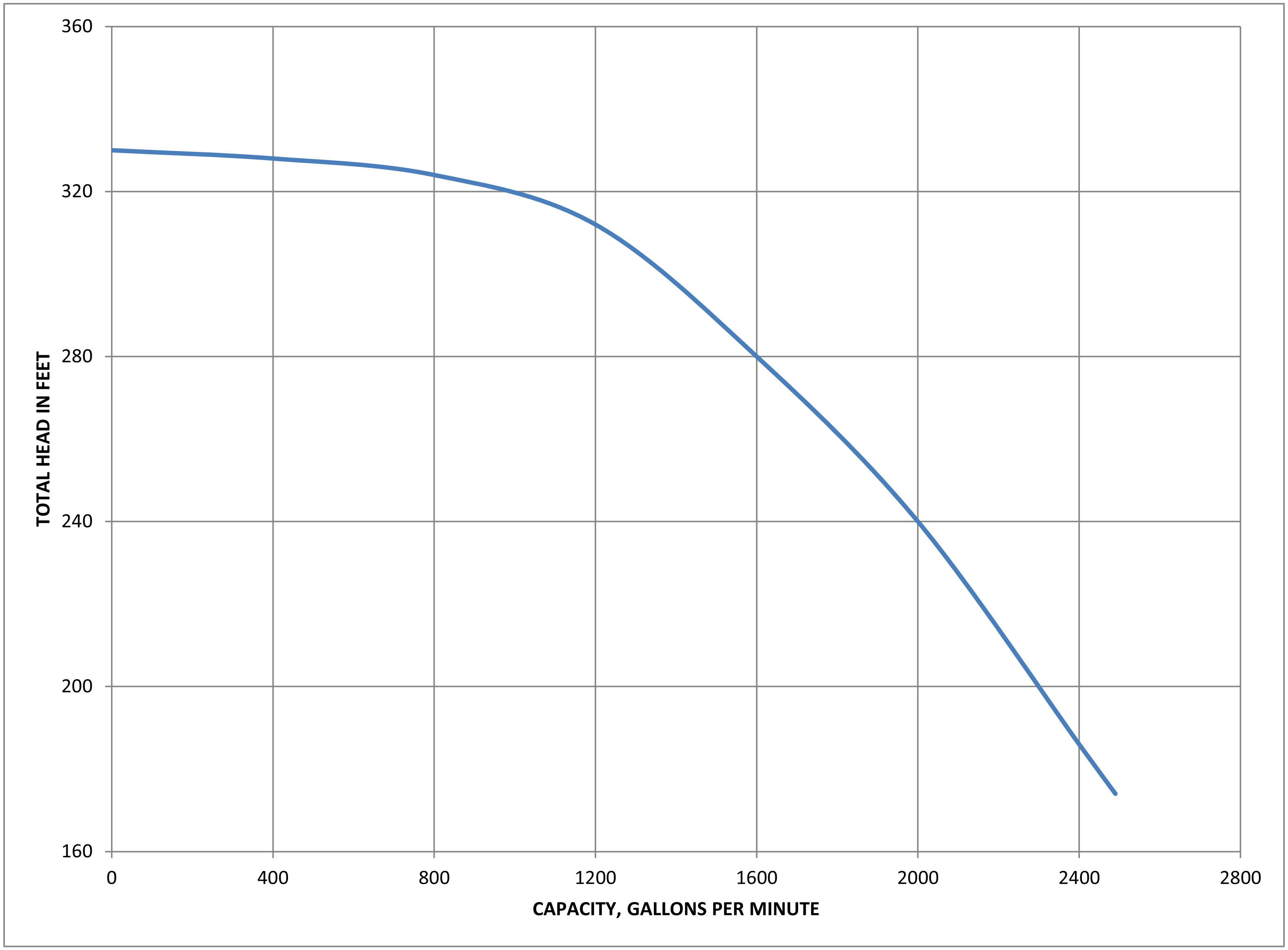


Figure 6.2-5 RHR PUMP PERFORMANCE CHARACTERISTICS



6.3 CONTAINMENT AIR RECIRCULATION COOLING SYSTEM (VNCC)

6.3.1 DESIGN BASES

Containment Heat Removal Systems

Criterion: Where an active heat removal system is needed under accident conditions to prevent exceeding containment design pressure, this system shall perform its required function, assuming failure of any single active component. (GDC 52)

Adequate heat removal capability for the containment is provided by two separate engineered safety features systems which use different engineering principles. These are the containment spray system, whose components are described in Section 6.4, and the containment air recirculation cooling system, whose components operate as described in Section 6.3.2.

The containment air recirculation cooling system is designed to recirculate and cool the containment atmosphere in the event of a loss-of-coolant accident and thereby ensure that the containment pressure cannot exceed its design value of 60 psig at 286°F (100% relative humidity). Although the water in the core after a loss-of-coolant accident is quickly subcooled by the safety injection system, the containment air recirculation cooling system is designed on the conservative assumption that the core residual heat is released to the containment as steam.

The design of the containment air recirculation cooling system also complies with GDC's 4, 37, 38 and 41 as described in Section 6.1.

Two of the four containment cooling units and one of two containment spray pumps will provide sufficient heat removal capability to maintain the post-accident containment pressure below the design value, assuming that the core residual heat is released to the containment as steam.

Portions of other systems which share functions and become part of this containment cooling system when required are designed to meet the criteria of this section. Neither a single active component failure in such systems during the injection phase nor an active or passive failure during the recirculation phase will degrade the heat removal capability of containment cooling.

Inspection of Containment Pressure-Reducing Systems

Criterion: Design provisions shall be made to the extent practical to facilitate the periodic physical inspection of all important components of the containment pressure-reducing systems, such as pumps, valves, spray nozzles, torus, and sumps. (GDC 58)

Design provisions are made to the extent practical to facilitate access for periodic visual inspection of all important components of the containment air recirculation cooling system.

Testing of Containment Pressure-Reducing Systems Components

Criterion: The containment pressure-reducing systems shall be designed to the extent practical so that components, such as pumps and valves, can be tested periodically for operability and required functional performance. (GDC 59)

The containment air recirculation cooling system is designed to the extent practical so that the components can be tested periodically and, after any component maintenance, for operability and functional performance.

Testing of Operational Sequence of Containment Pressure-Reducing Systems

Criterion: A capability shall be provided to test initially under conditions as close as practical to the design and the full operational sequence that would bring the containment pressure-reducing systems into action, including the transfer to alternate power sources. (GDC 61)

Means are provided to test initially to the extent practical the full operational sequence of the air recirculation cooling system, including transfer to the emergency power supply.

Combustible Gas Control

10 CFR 50.44(b)(1): All containments must have a capability for ensuring a mixed atmosphere.

A mixed atmosphere in the containment following a LOCA takes into consideration the layout and arrangement of the containment internal structures, and active and passive mixing mechanisms. Active mixing mechanisms include air recirculation via the VNCC system through the various containment compartments and areas, and mixing promoted by the momentum transfer due to spray droplets (Reference 17).

Performance Requirements

The VNCC System performs the following safety-related function:

The VNCC System shall remove heat from the containment following a loss of coolant accident or main steam line break inside containment to limit containment temperatures and pressures to less than containment design limits. These accidents are described in detail in FSAR Section 14.3.2 and Section 14.2.5. The containment LOCA integrity evaluation is described in Section 14.3.4. The fans and cooling coils continue to remove heat after the loss of coolant accident and support the reduction of containment pressure to less than half of the containment peak pressure within the first 24 hours.

The VNCC System also performs the non-safety related function of removing the normal heat loss from equipment and piping in the reactor containment during normal plant operation as described in FSAR Section 5.3.

The following objectives are met to provide the engineered safety features functions:

1. Each of the two fan cooler trains, consisting of two fan cooler units, must be capable of transferring heat at the rate of 60×10^6 BTU/hr from the containment atmosphere at the post accident design conditions, i.e., a saturated air-steam mixture at 60 psig and 286°F.

   The establishment of basic heat transfer design parameters for the cooling coils of the fan cooler units, and the calculation by computer of the overall heat transfer capacity are discussed in Reference 15, Reference 16, and Reference 19. Among the topics covered are

selection of the tube side fouling factor, effect of air side pressure drop, effect of moisture entrainment in the air-steam mixture entering the fan coolers, and calculation of the various air side to water side heat transfer resistances.

2. In removing heat at the design basis rate, the cooling coils are capable of discharging the resulting condensate without impairing the flow capacity of the unit and without raising the exit temperature of the service water to the boiling point during steady-state conditions.

   The equipment is designed to operate at the post accident conditions at 60 psig and 286°F for three hours, followed by operation in an air-steam atmosphere at 20 psig and 220°F for an additional 21 hours. The equipment design will permit subsequent operation in the air-steam atmosphere at 5 psig and 155°F for an indefinite period.

All components are capable of withstanding or are protected from differential pressures which may occur during the rapid pressure rise to 60 psig in ten seconds.

Where other systems are required to function as part of the containment air recirculation cooling system, such systems are designed to meet the performance objective of this system.

Where portions of these systems are located outside of containment, the following features are incorporated in the design for operation under post accident conditions:

1. Means for isolation of any section, and
2. Means to detect and control radioactivity leakage into the environs, to the limits consistent with guidelines set forth in 10 CFR 50.67 (Reference 18).

6.3.2 SYSTEM DESIGN AND OPERATION

A schematic arrangement of a containment air recirculation cooling and filtration system is shown in Figure 6.3-1. Individual system components and their supports meet the requirement for Class I (Seismic) structures and each component is isolated from fan vibration.

<u>Containment Cooling System Characteristics</u>

The containment air recirculation system consists of four fan cooler units, a duct distribution system, and the associated instrumentation and controls.

The fan cooler units are located in a missile-protected area near the containment wall.

Each fan cooler unit consists of a roughing filter bank (filter media are installed during refueling outages with a significant potential for a dusty containment atmosphere), expanded metal screen, plate-fin cooling coils, and fan and motors. To meet the performance requirements during both normal and post accident conditions, each of the four fan cooler units is provided with two separate vane axial fans. The two fans operate in parallel, but are of different design. One fan (the accident fan) and motor are especially designed for the high pressure, temperature and density following a loss-of-coolant accident. The second fan (the normal fan) and motor in the unit are designed for normal operation, and are not required to operate in the post accident atmosphere.

Gravity-operated back-draft dampers in the discharge duct work of the units isolate any inactive air handling unit from the duct distribution system. In addition, a gravity-operated back-draft damper is installed on the normal fan discharge to prevent back flow through the normal fan when it is stationary and the accident fan is in operation. Dampers open automatically when the associated unit is started. Duct work distributes the cooled air to the various containment compartments and areas. The accident flow sequence through each air handling unit is as follows: expanded metal screen, cooling coils, accident fan, back-draft duct damper, distribution duct header.

The four containment cooling accident fans are of the vane axial, nonoverloading, direct drive type. In the post accident environment, each accident fan is capable of providing a minimum flow rate of 33,500 cfm. The heat sink for the fan coolers is provided by the service water system. See FSAR Table 14.3.4-24 and Table 14.3.4-25 for analysis parameters and fan cooler performance data for the LOCA containment integrity analysis (Reference 17, Reference 18).

In removing heat at the design basis rate, the cooling coils are capable of discharging the resulting condensate without impairing the flow capacity of the unit and without raising the exit temperature of the service water to the boiling point during steady-state conditions. Since condensation of water from the air-steam mixture is the principal mechanism for removal of heat from the post accident containment atmosphere by the cooling coils, the coil fins will operate as wetted surfaces under these conditions. Entrained water droplets added to the air-steam mixture, such as by operation of the containment spray system, will therefore have essentially no effect on the heat removal capability of the coils. To ensure no boiling (two-phase flow) occurs at the cooler outlets during the steady-state conditions, downstream service water valves are set in a throttled position to raise the pressure in the cooling coils. (Reference 2)

During the transient conditions which follow the LOCA coincident with a loss of offsite power (about the first minute), boiling may occur in the containment fan coolers. The loss of power to service water pumps may cause the service water flow to stop and the cooling coils to drain prior to the restoration of power. This high-temperature, low-pressure condition inside the cooling coils may cause a temporary boiling condition which would delay initiation of the heat removal function. This postulated delay has been evaluated. (Reference 2) In addition, Service Water pipe and pipe supports are designed to accommodate design basis load combinations described in FSAR Appendix A.5, including pipe displacements and hydraulic loads that may result from water hammer in the containment fan cooler return lines. (Reference 6 through Reference 13)

<u>Actuation Provisions</u>

During accident conditions, actuation of all four fan cooler units is by the automatic starting sequence initiated by the safety injection signal. Capability also exists for manual actuation from the control room. The flow path through the accident fan is the same for normal and post accident operation. Back flow through the normal fan when it is stationary and the accident fan is in operation is prevented by the gravity-operated back-draft damper in the normal fan discharge.

Only the accident fan in each fan cooler unit is connected to the emergency power bus. Depending on the availability of emergency power, either all four, or at least two of these accident fans will be started after an accident with loss of offsite power. Reference is made to Section 8.0.

The nonaccident fans are tripped off when the motor control centers serving them are tripped on safety injection initiation. Overload protection for all fan motors is provided at the switchgear by overcurrent trip devices. If offsite power were available and both the normal and accident fans in each fan cooler unit were operating, these overload devices would trip the fan and motor not designed for accident duty.

The breakers for all fan motors can be operated manually from the control room. The accident fans can also be operated by their 480 V feed breaker in the cable spreading room.

Flow switches and temperature elements for each fan cooler unit indicate air is circulating in accordance with the design arrangement. Temperature indicators and accident fan low flow alarms are provided in the control room. Periodic air flow measurements are taken to evaluate accident fan performance. Each fan, accident and normal, has a vibration alarm and light on the main control board C01 in the control room.

Flow Distribution and Flow Characteristics

The duct distribution system is designed to promote good mixing of the containment air and ensures that the recirculation cooled air will reach all areas requiring ventilation. The distribution system is represented schematically by the ventilation system flow diagram, Figure 5.3-1.

The system includes a ring header and branch ducts to the primary compartments for distribution of cooled air from the fan cooler discharge. The cooled air is circulated upward from the lower primary compartments, through the steam generator compartments to the operating floor level. The ring header also discharges air to the containment above the operating floor level. Air that has risen to the containment dome is drawn by the fans through two branch ducts which follow the contour of the containment dome upward on opposite sides of the containment. These ducts take suction at the highest point in the center of the containment. Since all four air handling units discharge into a common ring header, no space in the containment is dependent on a single air handling unit for cooling and ventilation.

The temperature of the air returning to the air handling units will be essentially the ambient existing in the containment vessel.

The steam-air mixture from the containment entering the fan cooler units during the accident will be at approximately 286°F and have a maximum density of 0.204 pounds per cu. ft. The fluid will enter the cooling coils at these conditions. Part of the water vapor will condense on the cooling coils, and the air leaving the coils will be saturated at a temperature slightly below 286°F.

The fluid will remain in this condition as it flows into the fan, but will pick up some sensible heat from the fan and fan motor before flowing into the distribution header. This sensible heat will increase the dry-bulb temperature slightly above 286°F and will decrease the relative humidity slightly below 100%.

Cooling Water for the Fan Cooler Units

The cooling water requirements for all four fan cooling units during a loss-of-primary-coolant accident and recovery are supplied by three of the six service water pumps. The service water system is described in Section 9.0.

Each fan cooler unit is supplied by a separate line from the containment service water header located outside the containment. (See Figure 9.6-2) Each supply line is provided with a shutoff valve and drain valve. Similarly, each fan cooler unit discharge line is provided with a shutoff valve and drain valve. This allows each cooler to be isolated individually for draining and maintenance.

The cooling water discharged from the cooling coils is monitored for radioactivity by routing a small bypass flow from each unit through a common radiation monitor. Upon indication of radioactivity in the effluent, each cooler discharge line is monitored individually to locate the defective cooling coil. The service water system is pressurized inside the containment. During normal operation the service water system supply and return pressure for the ventilation coolers can be above or below the containment design pressure of 60 psig. Following a loss-of-coolant accident, the service water supply and return pressure for the ventilation coolers is normally below the containment design pressure of 60 psig. However, since the cooling coils and service water lines form a closed system inside the containment, no contaminated leakage is expected into these units. Alarms are provided in the control room.

Flow and temperature indication is provided outside containment for service water flow from each cooling unit. In addition, service water inlet and outlet temperatures are indicated locally inside containment on one of the four cooling units.

During normal plant operation, flow through the cooling units is limited by an orifice in the common return header for containment temperature control purposes. There are two parallel bypass lines, each with an independent, full flow isolation valve which opens automatically in the event of an engineered safety feature actuation signal to bypass the orifice. Either valve is capable of passing the full flow required for all four fan cooling units. An alarm is provided in the control room which actuates on low flow in any of the cooling water return lines.

Environmental Protection

All system control and instrumentation devices required for containment accident conditions are located to minimize the danger of control loss due to missile damage.

All fan parts, back-draft dampers, cooling coils and fins and ducts in contact with the containment fluid are protected against corrosion. The fan motor enclosures, electrical insulation and bearings are designed for operation during accident conditions.

All of the air handling units are located outside the loop compartment wall (which serves as a missile barrier) at various elevations adjacent to the containment wall. The distribution header and service water cooling piping are also located outside the shield. This arrangement provides missile protection for all components.

Components - Roughing Filters

The roughing filters may be in service during refueling outages with a significant potential for a dusty containment atmosphere to remove dust and other particulate matter from the air stream before it enters the cooling coil section. They are efficient for removal of the larger dust particles, and offer a resistance to air flow of approximately 0.2 in. of water when installed.

The filters are of fire resistant construction, with the media composed of a removable glass fiber mat backed up by an expanded metal screen. The expanded metal screen is in continuous service during normal or accident modes of operation.

Accident Fan Motor Units

The accident fans are driven by totally enclosed, water cooled, 150 horsepower, induction type, 3 phase, 60 cycle, 460 volt, 1800 rpm motors with Westinghouse Thermalastic insulation. Significant motor details are as follows:

1. Insulation

   Class F (NEMA rated total temperature 155°C) Thermalastic. The basic MICA structure has high voltage turn-to-turn and coil-to-ground insulation. It is impregnated and coated to give a homogeneous insulation system which is highly impervious to moisture. Internal leads and the terminal box-motor interconnection are given special design consideration to assure that the level of insulation matches or exceeds that of the motor.

2. Heat Exchanger

   An air-to-water heat exchanger is connected to the motor to form an entirely enclosed cooling system. Air is ducted from the motor through the cooling coils and back to the motor. Two vent valves per unit permit accident ambient (increasing containment) pressure to enter the motor-air system so the bearings will not be subjected to differential pressure. It also assures pressure equalization as the containment pressure is reduced by the containment cooling systems. Water connections are welded throughout, except for the flanged connections to the heat exchanger, and are supplied from the service water header. The drain is piped to the containment fan cooler drain system.

3. Bearings

   The motors are equipped with high temperature grease-lubricated ball bearings as would be required if the bearings were subjected to incident ambient temperatures.

4. Conduit (Connection) Box

   The motor leads are brought out of the frame through a seal and into an oversized conduit box.

Cooling Coils

The coils are fabricated of copper plate fins vertically oriented on copper tubes. Air and water flow paths are arranged for counter flow. The coils are provided with drain pans and drain piping to prevent flooding during accident conditions. This condensate is drained to the containment sump.

Ducting

The ducts are designed to withstand the sudden release of reactor coolant system energy and energy from associated chemical reactions without failure due to shock or pressure waves by incorporation of pressure relieving devices along the ducts which open at slight overpressure, approximately 1.0 psi. The ducts are designed and supported to withstand thermal expansion during an accident. Where flanged joints are used, joints are provided with gaskets suitable for temperatures to 300°F.

Back-draft dampers are provided in the discharge ducting of the recirculation system to prevent backflow through an inactive unit. In addition, a damper is installed on the normal fan discharge to prevent back flow through the normal fan when it is stationary and the accident fan is in operation. All dampers are gravity operated, i.e., the damper opens due to the air pressure produced by the fan, and is counterbalanced with weights to close when this portion of the system is inactive.

All ductwork, damper blades, and seating surfaces are constructed of, or coated with, corrosion resistant surfaces.

Electrical Supply

Details of the normal and emergency power sources are presented in Section 8.0.

Further information on the components of the containment air recirculation cooling system is given in Section 5.3.

6.3.3 SYSTEM EVALUATION

Range of Containment Protection

The containment air recirculation cooling system provides the design heat removal capacity for the containment following a loss-of-coolant accident assuming that the core residual heat is released to the containment as steam. The system accomplishes this by continuously recirculating the air-steam mixture through cooling coils to transfer heat from containment to service water.

The performance of the containment air recirculation cooling system in pressure reduction is discussed in Section 14.3.4. Two of the four containment cooling fans and one of two containment spray pumps will provide sufficient heat removal capability to maintain the post accident containment pressure below the design value assuming that the core residual heat is released to the containment as steam.

The VNCC system provides a well mixed containment atmosphere with a turnover rate of approximately four air changes per hour based on 67,000 cfm flow per train and a containment volume of approximately 1 million cubic feet.

System Response

The starting sequence of the containment cooling fans and the related emergency power equipment is designed so that delivery of the minimum required air and cooling water flow is reached in a time consistent with plant design. In the analysis of the containment pressure transient, Section 14.3.4, a delay time of 84 sec. was assumed for the initiation of containment cooling fans.

Single Failure Analysis

A failure analysis has been made on all active components of the system to show that the failure of any single active component will not prevent fulfilling the design function. This analysis is summarized in Table 6.3-1. The analysis of the loss-of-coolant accident presented in Section 14.0 is consistent with the single failure analysis.

Reliance on Interconnected Systems

The containment air recirculation cooling system is dependent on the operation of the electrical and service water systems. Cooling water to the coils is supplied from the service water system. Six service water pumps are provided, only three of which are required to operate during the post accident period. One diesel generator is capable of supplying the required emergency power.

Shared Function Evaluation

Table 6.3-2 is an evaluation of the main components which have been discussed previously and a brief description of how each component functions during normal operation and during the accident.

Reliability Evaluation of the Accident Fan Cooler Motor

The basic design of the motor and heat exchanger, as described herein, is such that the accident environment is prevented, in any major sense, from entering the motor winding, or when entering in a very limited amount (equalizing motor interior pressure), the incoming atmosphere is directed to the heat exchanger coils where moisture is condensed. If some quantity of moisture should pass through the coil, the changed motor interior environment would "clean up" in that interior air continually recirculates through the heat exchanger.

It should be noted that the motor insulation hot spot is not expected to exceed normal temperature even under accident conditions.

During the lifetime of the plant, these motors perform part of the normal heat removal service and, as such, are loaded only to approximately 50 h.p.

The bearings are designed to perform in the accident ambient temperature conditions. However, the bearing housing internals are cooled by the heat exchanger. It is expected that bearing temperatures would not exceed 125°C by any significant amount even under accident conditions.

The insulation has high resistance to moisture, and tests performed indicate the insulation system would survive the accident ambient moisture condition without failure. The heat exchanger system for preventing moisture from reaching the winding therefore provides a design margin. In

addition, it should be noted that at the time of the postulated accident, the load on the fan motor would increase, internal motor temperature would increase, and would therefore tend to drive any moisture present out of the windings. Additionally, the motors are furnished with insulation margin beyond the operating voltage of 460 V.

Following the accident rise in pressure, a rather slow rise, as far as equalizing pressure in the small volumes of the motor-heat exchanger is concerned, it is not expected that there will be significant mixing of the motor (closed system) environment and the containment ambient.

The heat exchanger has been designed using a very conservative fouling factor. However, if surface fouling reduces the capability of the heat exchanger by one-third, the motor would still have a normal life expectancy, even under accident conditions.

Environmental tests of the motor unit are described in Reference 4. Proof testing went beyond any simulation need to meet plant requirements, actually including nine separate accident cycles. To further demonstrate the ruggedness of the motor, windings were directly exposed to containment conditions in three of these cycles. Absence of damage from these rigorous tests confirms that the motor unit is more than adequate for the intended service.

Fan Cooler Motor Insulation Irradiation Testing

The testing program has been completed on the effects of radiation on the WF-8AC "Thermalastic" (Westinghouse Electric Corporation Trademark) epoxy insulation system used in the reactor containment fan cooler motor. Test description and results are presented in Reference 5.

Irradiation of form wound motor coil sections was accomplished up to exposure levels exceeding that calculated for the design basis loss-of-coolant accident. Three coil samples received the following treatment sequence: irradiation, high potential test, vibration test, high potential test and breakdown voltage test. Nine coil samples received an alternate treatment sequence: thermal aging, high potential test, irradiation, high potential test, vibration test. (Six of nine coil samples - high potential test and breakdown voltage test.)

All coil samples passed the high potential tests. The breakdown voltage levels of all coils were well in excess of those required by the design, and clearly indicate that the reactor containment fan cooler motor insulation system will perform satisfactorily following exposure to the radiation levels calculated for the design basis accident.

Fan Cooler Motor Lubricant Irradiation Testing

This section summarizes the results of tests performed on samples of unirradiated and irradiated Chevron BRB-2 lubricant, which is equivalent to grease used in the containment fan cooler fan bearing as well as the motor bearing (note that Chevron BRB-2 is now obsolete). The results of these tests indicate that the shear stability, or consistency, of the grease is increased by irradiation to levels anticipated in the containment following a design basis accident. The consistency of the grease following irradiation remained within the most common recommended consistency for ball bearing application (NLGI #2).

The purpose of this test program was to establish the effect of irradiation on the bearing lubricant used on both the containment fan cooler motor and fan bearing. The maximum calculated one year integrated dose on the bearing lubricant, using the design basis accident (TID-14844) with no credit for fission product removal from the containment atmosphere other than by natural decay, is 1.5×10^8 rads and would be experienced by the fan bearings. The motor bearings would receive a lesser exposure due to self shielding effects of the motor housings.

Samples of the lubricant were placed in a vented 1.5 in. × 12 in. aluminum tube. The tube was then placed adjacent to a 34 kilo-curie cobalt 60 source and irradiated for a period of 79 hours. Dosimetry measurements were made at various locations in the tube using Dupont light blue calibration paper 300 MS-C, #CB-91639.

Following exposures to average levels of 1.2×10^8 rads, 1.5×10^8 rads, and 1.8×10^8 rads, the irradiated grease along with unirradiated grease taken from the same supply were subjected to the Micro Cone Penetration Test using standard apparatus conforming to ASTM D1403-56T.

The results of the penetration test are presented on the table below. In general, it was found that as exposure was increased, the grease underwent a change in thickness function to the point that at 1.8×10^8 rads, sufficient change had taken place to cause the grease to increase in consistency to an NLGI #2 rating, as the grease was "worked" or sheared, rather than decrease as in the unirradiated grease. The most commonly used greases for ball bearing applications such as those in the containment fan cooler, have consistencies ranging between NLGI #1 and #3.

Understanding of the data listed in the Irradiation Testing table may be afforded by listing the industry standard for lubricating greases below:

NLGI Lubricating Grease Consistency Classification

Consistency Number	ASTM Worked Penetration at 77°F
0	355 to 385
1	310 to 340
2	265 to 295
3	220 to 250
4	175 to 205
5	130 to 160
6	85 to 115

A consistency of No. 0 implies a very soft semifluid grease, with numbers 1, 2, 3, etc., indicating progressively stiffer grease up to No. 6 which indicates a stiff, tacky water pump lubricant type material.

CONTAINMENT FAN COOLER - MOTOR AND FAN BEARING LUBRICANT IRRADIATION TESTING

Micro-Cone Penetration

Sample	Unworked	60 Strokes	500 Strokes	1,000 Strokes	50,000 Strokes
Unirradiated Chevron BRB-2	308	320	368	370	>400
Irradiated BRB-2 1.2×10^8R	300	300	308	324	400
Irradiated BRB-2 1.5×10^8R	308	288	292	298	364
Irradiated BRB-2 1.8×10^8R	340	320	304	296	280

Based on the test results from irradiation and ASTM micro-cone penetration measurements, Chevron BRB-2, undergoes no significant change in properties, as measured in terms of consistency.

6.3.4 REQUIRED PROCEDURES AND TESTS

Inspection Capability

Access is available for visual inspection of the containment air recirculation system components including fans, cooling coils, louvers and ductwork.

Testing - Component Testing

The containment cooling fans were shop tested for conformance to the AMCA (Air Moving and Conditioning Association) ratings performance criteria using air at standard conditions.

Application of conventional fan laws verify their ability to perform as designed under post accident conditions.

The fan motors are designed to operate in continuous normal service and under post accident containment conditions. Periodic operation of the motors and tests of the insulation ensure that the motors remain in a reliable operating condition. As described in Section 6.3.3, tests of a typical fan motor were conducted under conditions simulating the post accident environment in representative pressurized water reactor containments to verify the ability of the motors to operate through the peak accident conditions and to continue to operate thereafter under the post accident conditions.

System Testing

Each fan cooling unit was tested after installation for proper flow and distribution through the duct distribution system. Three of the fan cooling units are used during normal operation. The unit not in use can be started from the control room to verify readiness.

Each fan cooler unit is tested periodically to verify proper operation of the accident fans, backdraft dampers and service water bypass valves.

Operational Sequence Testing

Periodic tests can be conducted to demonstrate proper sequencing of the accident fan motor supplies to the emergency diesel generators in the event of loss of outside power. These tests can be conducted at the time the diesel generators are tested.

6.3.5 REFERENCES

1. VPNPD-96-081, Technical Specification Change Request 192, Modifications to Technical Specifications 15.3.3, "Emergency Core Cooling System Auxiliary Cooling Systems, Air Recirculation Fan Coolers, and Containment Spray," dated September 30, 1996
2. NRC Safety Evaluation Report dated July 9, 1997, "Issuance of Amendments Re: Technical Specification Changes For Revised System Requirements To Ensure Post-Accident Containment Cooling Capability."
3. NPL 97-0315, Supplement to Technical Specification Change Request 192, dated June 3, 1997
4. WCAP-7829, Fan Cooler Motor Unit Test, Westinghouse Proprietary, April 1972.
5. WCAP-7343-l, Topical Report - Reactor Containment Fan Cooler Motor Insulation Irradiation Testing, Westinghouse (Proprietary), July 1969.
6. SE 98-053, Unit 1 Service Water Pipe Support Modifications (Inside Containment) - Revised Thermal Mode and Hydraulic Loads, Approved March 26, 1998.
7. SE 97-191, Service Water Pipe Support Modifications (Unit 1 Outside Containment) - Revised Thermal Mode and Hydraulic Loads, Approved November 6, 1997.
8. SE 2001-0014, MR 98-024*J, Unit 1 Containment Fan Cooler and Fan Motor Cooler Replacement, Approved March 14, 2001.
9. SCR 2002-0093, MR 98-024*Y, Unit 1 "C" and "D" Containment Fan Cooler Replacement, March 22, 2002.
10. SE 98-141, MR 96-064*C, Service Water Pipe Support Modifications (Inside Containment) - Revised Thermal Mode and Hydraulic Loads, Approved October 29, 1998.
11. SE 98-142, MR 96-064*D, Service Water Pipe Support Modifications (Unit 2 Outside Containment) - Revised Thermal Mode and Hydraulic Loads, Approved October 29, 1998.

12. SE 2000-0099, MR 98-024*K, Unit 2 Containment Fan Cooler and Fan Motor Cooler Replacement, Approved October 6, 2000.

13. EVAL 2001-003, MR 98-024*X, Unit 2 “C” and “D” Containment Fan Cooler Replacement, Approved November 4, 2001.

14. Calculation 129187-M-0022, “Verification of Adequacy of Containment Fan Cooler Units During Normal Operation Under Extended Power Uprate (EPU) Conditions,” Revision 1, dated December 16, 2008.

15. Calculation 98-0172, “Containment Fan Cooler Service Water Acceptance Criteria,” Revision 4, dated September 2, 2011.

16. Holtec Report No. HI-2002418, “Thermal Performance of Containment Fan Coolers,” Revision 1, dated September 20, 2000.

17. NRC Safety Evaluation, “Point Beach Nuclear Plant (PBNP), Units 1 and 2 - Issuance of License Amendments Regarding Extended Power Uprate (TAC Nos. ME1044 and ME1045),” dated May 3, 2011.

18. NRC Safety Evaluation, “Point Beach Nuclear Plant (PBNP), Units 1 and 2 -Issuance of License Amendments Regarding Use of Alternate Source Term (TAC Nos. ME0219 and ME0220),” dated April 14, 2011.

19. Holtec Report No: HI-2002409-01, “Containment Fan Cooler Performance Testing,” dated June 7, 2000.

20. SCR 2013-0188-01, “Reduction of CFC Heat Removal Requirement,” dated November 21, 2013.

Table 6.3-1 SINGLE FAILURE ANALYSIS - CONTAINMENT AIR RECIRCULATION COOLING SYSTEM

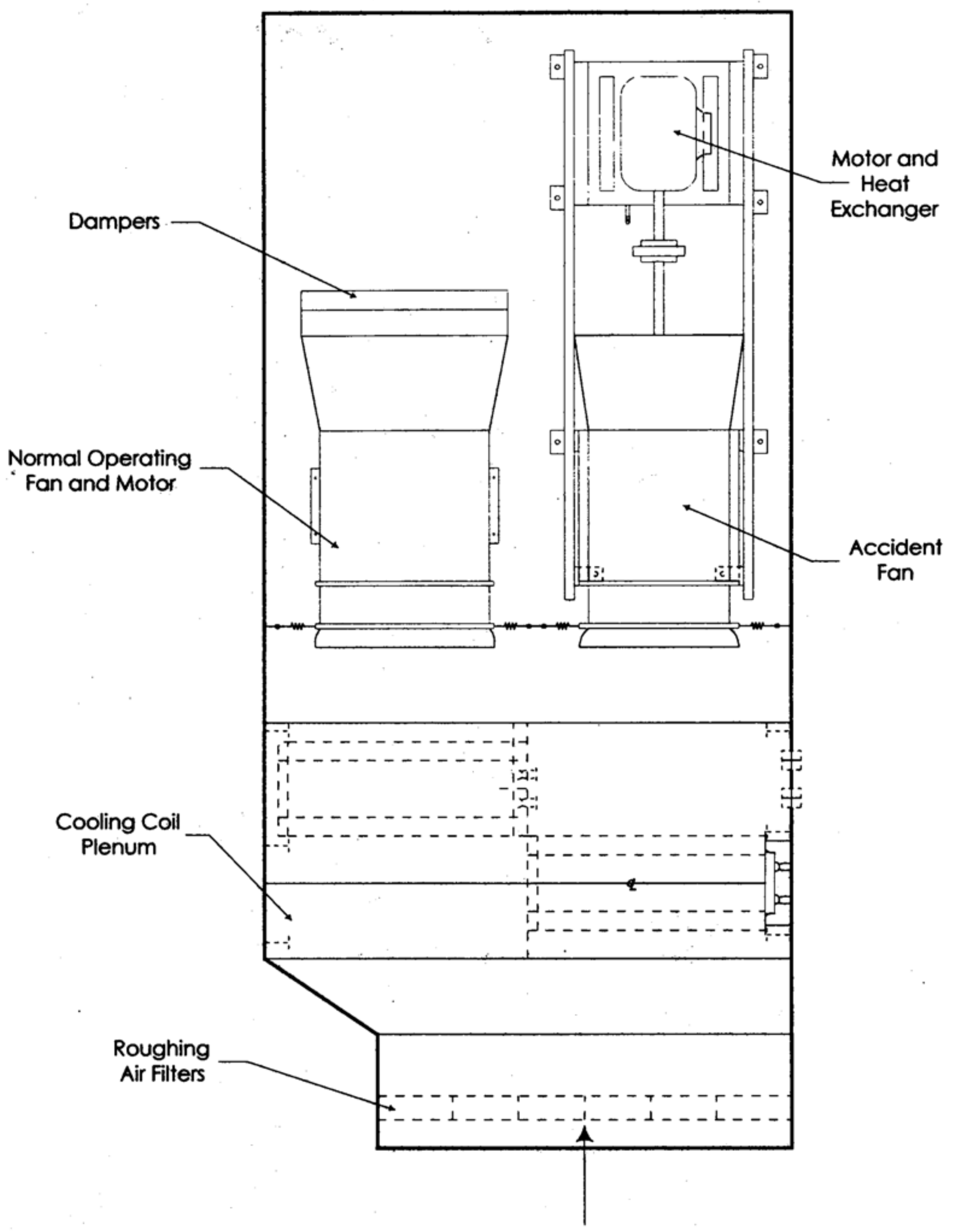
	Component	Malfunction	Comments and Consequences
A.	Containment Accident Fan Cooling	Fails to start	Four provided. Evaluation based on two fans and one containment spray pump operating
B.	Service Water Pumps	Fails to start	Six provided. Three required for operation.
C.	Automatically Operated Valves: (Open on automatic engineered safety features actuation sequence signal)		
	Service water discharge from fan cooler units	Fails to open	Two full-flow valves for four fan cooler units. Operation of one valve required.

Table 6.3-2 SHARED FUNCTION EVALUATION

	Containment Fan Cooling Unit	Service Water Pumps (6)
Normal Operating Function:	circulate and cool containment atmosphere	supply lake cooling water to fan units
Normal Operating Arrangement:	three fan cooler units in service*	two pumps in service
Accident Function:	circulate and cool containment	supply lake cooling water to CCW heat exchangers, containment fan coolers, and alternate suction source to AFW pumps
Accident Arrangement:	two fan cooler units in service with operation of the accident fan required	three pumps in service

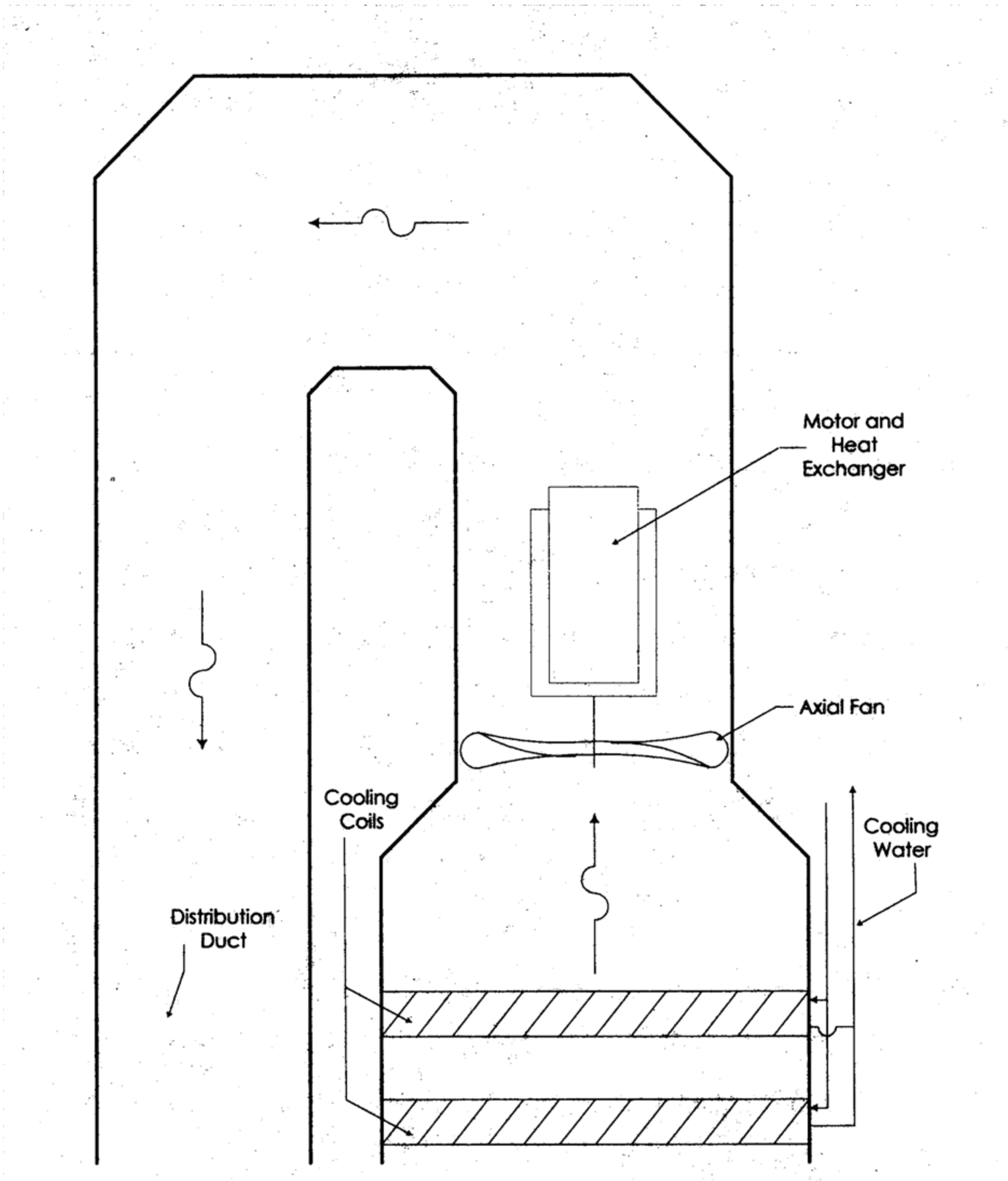
* Four air cooling units may be required to maintain containment temperature within Technical Specification limits if service water temperature increases beyond 75°F (Reference 14).

Figure 6.3-1 FAN COOLER UNIT SCHEMATIC
Sheet 1 of 2



FAN COOLER UNIT SCHEMATIC
FIGURE 6.3-1 (Sheet 1 of 2) (06/98)

Figure 6.3-1 FAN COOLER UNIT SCHEMATIC
Sheet 2 of 2



FAN COOLER UNIT SCHEMATIC
FIGURE 6.3-1 (Sheet 2 of 2) (06/98)

6.4 CONTAINMENT SPRAY SYSTEM

6.4.1 DESIGN BASES

The containment spray system has the following safety related functions:

1. Containment heat removal following a LOCA or main steam line break inside containment.

2. Iodine and particulate removal from the containment atmosphere following a LOCA.

3. Transfer of sodium hydroxide from the spray additive tank to the containment sump.

Containment Heat Removal System

A combination of one spray pump and two containment cooling fans will provide sufficient heat removal capability to maintain the LOCA post accident containment pressure below the design value of 60 psig at 286°F (100% R.H.), assuming that the core residual heat is released to the containment as steam. Containment pressure and temperature transients for loss-of-coolant accidents are presented in Section 14.3.4. The steam pipe rupture accident is discussed in Section 14.2.5.

Inspection of Containment Pressure Reducing Systems

Criterion: Design provisions shall be made to the extent practical to facilitate the periodic physical inspection of all important components of the containment pressure reducing systems, such as pumps, valves, spray nozzles and sumps. (GDC 58)

Where practicable, all active components and passive components of the containment spray systems are inspected periodically to assure system readiness. The pressure containing systems are inspected for leaks from pump seals, valve packing, flanged joints and safety valves. During operational testing of the containment spray pumps, the portions of the systems subjected to pump pressure are inspected for leaks. Design provisions for inspection of the safety injection system, which also functions as part of the containment spray system, are described in Section 6.2.4.

Testing of Containment Pressure - Reducing Systems Components

Criterion: The containment pressure reducing systems shall be designed, to the extent practical, so that active components, such as pumps and valves, can be tested periodically for operability and required function performance. (GDC 59)

All active components in the containment spray systems are adequately tested both in pre-operational performance tests in the manufacturer's shop and in-place testing after installation. Thereafter, periodic tests are also performed after any component maintenance. Testing of the components of the safety injection system used for containment spray purposes is described in Section 6.2.4.

The component cooling water pumps and the service water pumps which supply the cooling water to the residual heat exchangers are in operation on a relatively continuous schedule during plant operation. Those pumps not running during normal operation may be tested by changing the operating pump(s).

Testing of Containment Spray Systems

Criterion: A capability shall be provided to the extent practical to test periodically the delivery capability of the containment spray system at a position as close to the spray nozzles as is practical. (GDC 60)

Permanent test lines for all the containment spray loops are located so that all components up to the isolation valves at the containment may be tested. These isolation valves are checked separately.

The air test lines, for checking that spray nozzles are not obstructed, connect downstream of the isolation valves. Air flow through the nozzles is monitored by the use of a smoke generator or telltales.

Testing of Operational Sequence of Containment Pressure Reducing Systems

Criterion: A capability shall be provided to test initially under conditions as close as practical to the design and the full operational sequence that would bring the containment pressure-reducing systems into action, including the transfer to alternate power sources. (GDC 61)

Capability is provided to test initially, to the extent practical, the operational startup sequence beginning with transfer to alternate power sources and ending with near design conditions for the containment spray system, including the transfer to the alternate emergency diesel generator power source.

Inspection of Air Cleanup Systems

Criterion: Design provisions shall be made to the extent practical to facilitate physical inspection of all critical parts of containment air cleanup systems, such as ducts, filters, fans, and damper. (GDC 62)

Access is available for visual inspection of the containment spray system components.

Testing of Air Cleanup Systems Components

Criterion: Design provisions shall be made to the extent practical so that active components of the air cleanup systems, such as fans and dampers, can be tested periodically for operability and required functional performance. (GDC 63)

All active components of the containment spray system are adequately tested both in pre-operational performance tests in the manufacturer's shop and in-place testing after installation. Thereafter, periodic tests are also performed after component maintenance.

Testing Air Cleanup Systems

Criterion: A capability shall be provided, to the extent practical, for on-site periodic testing and surveillance of the air cleanup systems to ensure (a) filter bypass paths have not developed, and (b) filter and trapping materials have not deteriorated beyond acceptable limits. (GDC 64)

Permanent test lines are provided for the containment spray headers and located so that all components up to the isolation valve at the containment may be tested. These isolation valves are checked separately. Air test lines for checking the spray nozzles are connected downstream of the isolation valves. Air flow through the nozzles is monitored by a smoke generator or telltales.

Testing of Operational Sequence of Air Cleanup Systems

Criterion: A capability shall be provided to test initially under conditions, as close to design as practical, the full operational sequence that would bring the air cleanup systems into action, including the transfer to alternate power sources and the design air flow delivery capability. (GDC 65)

Means are provided to test initially under conditions, as close to design as is practical, the full operational sequence that would bring the containment spray system into action, including transfer to the emergency diesel generator power source.

Combustible Gas Control

10 CFR 50.44(b)(1): All containments must have a capability for ensuring a mixed atmosphere.

A mixed atmosphere in the containments following a LOCA takes into consideration the layout and arrangement of the containment internal structures, and active and passive mixing mechanisms. Active mixing mechanisms include air recirculation via the containment ventilation (VNCC) system through the various containment compartments and areas, and mixing promoted by the momentum transfer due to spray droplets. (Reference 9)

Performance Objectives

A design basis function of the containment spray system, in combination with the containment cooling fans, is to provide sufficient heat removal capability to maintain the post accident containment pressure below the design pressure assuming that the core residual heat is released to the containment as steam. This protection is afforded for all pipe break sizes up to and including the hypothetical instantaneous circumferential rupture of a reactor coolant pipe. Either of two trains containing a pump and associated valving and spray headers are independently capable of spraying 1070 gpm of borated water from the RWST into the containment building. During the recirculation phase of a LOCA response, either train can spray at least 900 gpm into the containment building.

A second function served by the containment spray system is to remove elemental iodine and particulates from the containment atmosphere should they be released in the event of a loss-of-coolant accident. The analysis showing the system's ability to limit off-site dose to within 10 CFR 50.67 limits after a hypothetical loss-of-coolant accident is presented in Section 14.3.5.

A third function of the containment spray system is to provide sufficient sodium hydroxide from the spray additive tank to achieve the required sump pH level in order to prevent chloride induced stress corrosion cracking and maintain iodine in the iodate form that will stay in solution.

The spray system is designed to operate over an extended time period, following a primary coolant system failure. It has the capability of reducing the containment post accident pressure and consequent containment leakage taking into account any reduction due to single failures of active components.

Portions of other systems which share functions and become part of the containment cooling system, when required, are designed to meet the criteria of this section. Any single failure of active components in such systems does not degrade the heat removal capability of containment cooling.

Those portions of the spray systems located outside of the containment which are designed to circulate radioactively contaminated water collected in the containment, under post accident conditions, meet the following requirements:

1. Adequate shielding to maintain radiation levels within the limits of 10 CFR 50.67 (Section 11.6).

2. Collection of discharges from pressure relieving devices into closed systems.

3. Means to limit radioactivity leakage to the environs, to maintain radiation dose within the limits set forth in 10 CFR 50.67.

Recirculation loop leakage is discussed in Section 6.2.3.

System active components are redundant. System piping located within the containment is redundant and separable in arrangement unless fully protected from damage which may follow any primary coolant system failure. System isolation valves relied upon to operate for containment cooling are redundant, with automatic actuation or manual actuation.

Service Life

All portions of the system located within containment are designed to withstand, without loss of functional performance, the post accident containment environment and operate without benefit of maintenance for the duration of time to restore and maintain containment conditions at near atmospheric pressure.

Codes and Classifications

Table 6.4-1 tabulates the codes and standards to which the containment spray system components are designed.

6.4.2 SYSTEM DESIGN AND OPERATION

System Description

Adequate containment cooling and removal of elemental iodine and particulates are provided by the Containment Spray System shown in Figure 6.2-1, whose components operate in sequential modes. These modes are:

1. Spray a portion of the contents of the refueling water storage tank into the entire containment atmosphere using the containment spray pumps. During this mode, the contents of the spray additive tank (sodium hydroxide) are mixed into the spray stream to provide adequate iodine removal from the containment atmosphere by a washing action.

2. Recirculation of water from the containment sump is provided by diversion of a portion of the recirculation fluid from the discharge of the residual heat removal heat exchanger to the suction of the respective spray pump after injection from the refueling water storage tank has been terminated.

The bases for the selection of the various conditions requiring system actuation are presented in Section 14.0.

The principal components of the containment spray system which provide containment cooling and removal of elemental iodine and particulates following a loss-of-coolant accident consist of two pumps, one spray additive tank, spray ring headers and nozzles, and the necessary piping and valves. The containment spray pumps and the spray additive tank are located in the auxiliary building and the spray pumps take suction directly from the refueling water storage tank. Each containment spray pump has two motor operated discharge valves configured in a parallel arrangement and powered from the same safeguards train as the associated pump. The flow path through one of the two discharge valves includes a flow restricting orifice.

The containment spray system also utilizes the two residual heat removal pumps, two residual heat exchangers and associated valves and piping of the safety injection system for the recirculation phase of containment cooling and iodine removal.

Injection Phase

During the period of time that the spray pumps draw from the refueling water storage tank, each spray pump will cause spray additive to be added to the refueling water by using a liquid eductor and the spray pump discharge. The fluid passing from the spray additive tank will then mix with the fluid entering the pump suction to produce a solution having an appropriate pH value. The pH of the sump contents must be high enough to maintain iodine in the iodate form that will stay in solution. The pH must be low enough to meet the environment qualification of equipment. The results will be a solution suitable for the removal of iodine. The minimum RWST level to ensure sufficient NPSH to the spray pumps is dependant on the number of pumps drawing water from the RWST (Reference 17).

The spray system will be actuated by the coincidence of two sets of two out of three hi-hi containment pressure signals. This starting signal will start the pumps and open the discharge valves to the spray header. The valves associated with the spray additive tank will be opened automatically two minutes after the containment spray signal is actuated. Sodium hydroxide will flow to the suction of the spray pumps and mix with refueling water prior to being discharged through the spray nozzle into the containment. If required, the operator can manually actuate the entire system from the control room and, periodically, the operator will actuate system components to demonstrate operability.

The system design conditions were selected to be compatible with the design conditions for the low pressure injection system since both of these systems share the same suction line.

The system is designed such that if the spray pump is running from a manual or automatic safeguards system start, and loss of all AC should occur, the spray pump will automatically restart when AC is restored. Also, if a containment spray signal occurs simultaneously with a safety injection signal and a loss of all AC, the spray pump will start in an appropriate time sequence to accommodate diesel loading.

Recirculation Phase

After the injection operation, it is expected that containment pressure reduction can be accomplished with the containment fan cooler units, and returning all of the recirculated water to the core. In this mode, the bulk of the core residual heat is transferred directly to the sump by the spilled coolant to be eventually dissipated through the residual heat exchanger once the sump water becomes heated. The heat removal capacity of two of the four fan coolers is sufficient to remove the corresponding energy addition to the vapor space resulting from steam boil off from the core assuming flow into the core from one residual heat removal pump at the beginning of recirculation without exceeding containment design pressure; hence, it is not expected that continued spray operation would be required for containment cooling. However, spray operation is required for a period of time during the recirculation phase for removal of elemental iodine and particulates after a hypothetical loss-of-coolant accident as discussed in Section 14.3.5. Spray flow during the recirculation phase is reduced by fully closing the spray pump discharge valve in the flow path not containing the flow restricting orifice.

Cooling Water

The cooling water for the residual heat removal heat exchangers has been described in Section 6.2.

Changeover

The procedure for the changeover of the residual heat removal pumps from injection to recirculation has been described in Section 6.2. The alignment of the containment spray pump suction to the discharge of the residual heat removal heat exchanger is accomplished manually by the operator from the control room via a series of valve alignments. RHR and spray flows are established by the preset throttle position of the SI-852A and SI-852B RHR to reactor vessel injection valves and the orifice in the open spray pump discharge valve flow path. The transfer from injection to recirculation spray can be accomplished within 20 minutes. (Reference 10)

Indication

Remotely operated valves of the containment spray system which are under manual control (i.e., valves which normally are in their ready position and do not receive a containment spray signal) have their positions indicated on a common portion of the control board. At any time during operation when one of these valves is not in the ready position for injection, it is shown visually on the control board. Flow indication is available on the main control boards to allow operators to monitor the operation of the containment spray and RHR systems during the recirculation phase.

Components

All associated components, piping, structures, and power supplies of the containment spray system are designed to Seismic Class I criteria.

The containment spray system shares the refueling water storage tank liquid capacity with the safety injection system. Refer to Section 6.2.2 for a detailed description of this tank.

Pumps

The two containment spray pumps are of the horizontal centrifugal type driven by electric motors. These motors can be powered from both normal and emergency power sources.

The design head of the pumps is sufficient to deliver rated capacity with a minimum level in the refueling water storage tank against a head equivalent to the sum of the design pressure of the containment, the head to the uppermost nozzles, and the line and the nozzle pressure losses. Pump motors are direct-coupled and large enough for the maximum power requirements of the pumps. The materials of construction are stainless steel or equivalent corrosion resistant materials. The nominal design parameters of these pumps are presented in Table 6.4-2 and in Figure 6.4-1. The nominal pump curve is degraded when containment spray flow is credited in accident analyses (Reference 11).

The containment spray pumps are designed in accordance to the specifications discussed for the pumps in the safety injection system, Section 6.2.

The pump motors are direct-coupled and nonoverloading to the end of the pump curve.

Details of the component cooling water pumps and service water pumps, which serve the safety injection system, are presented in Section 9.0.

Spray Nozzles

The spray nozzles, of the ramp bottom design, are not subject to clogging by particles less than 1/4 in. in maximum dimension, and are capable of producing a mean drop size of approximately 1,000 microns in diameter with the spray pump operating at design conditions and the containment at design pressure.

During spray recirculation operation, the water is filtered through a strainer assembly before leaving the containment sump. The individual cross sectional filter flow areas in the strainer assembly are no greater than a nominal 0.066 inch diameter opening. [redacted]

Spray Additive Tank

The capacity of the tank is sufficient to contain enough sodium hydroxide solution which, upon mixing with the refueling water from the refueling water storage tank and the borated water contained within the accumulators and primary coolant, will bring the concentration of sodium hydroxide in the containment to maintain a pH within the acceptable range of 7.0 to 10.5. The minimum pH in the containment sump needed to keep iodine in the iodate form is 7.0. A pH of greater than 7.0 assures the iodine removed by the spray is retained in the sump. The maximum pH is based on Equipment Qualification considerations and is set at 10.5 (Reference 16). The design pressure of the tank is greater than the sum of the refueling water storage tank head and the total developed head of the containment spray pumps at shutoff. A level indicating alarm is provided in the control room if, at any time, the solution tank contains less than the required amount of sodium hydroxide solution. Periodic sampling confirms that proper sodium hydroxide concentration exists in the tank.

The tank design parameters are given in Table 6.4-3.

A materials compatibility review for the spray additive tank and associated equipment during long-term storage of sodium hydroxide is presented below. The exposure conditions are shown in Table 6.4-4. The materials for the various components are shown in Table 6.4-5. The corrosion rates for the various materials at or near the long-term exposure conditions with air contamination are shown in Table 6.4-6. The resistance of most of the materials in Table 6.4-5 to caustic cracking at the exposure conditions listed in Table 6.4-4 has been reported by Logan (Reference 1) (See Figure 6.4-2). No caustic cracking of 17-4 PH (Reference 2) or stellite has been reported.

The effect of carbon dioxide from air exposure on corrosion of iron is shown in Figure 6.4-3 (Reference 3). At pH 14, no additional corrosion is observed over that observed in a carbon dioxide free solution. In the Point Beach system, a nitrogen blanket is continuously maintained over the sodium hydroxide solution in the spray additive tank, thus, essentially eliminating any carbon dioxide contamination of the solution.

The Nordel (Reference 4) rubber diaphragm material was exposed in 33 wt.% sodium hydroxide solution at 110^{o}F for six months and found to be unaffected by the simulated spray additive tank solution. The completely unchanged appearance of Nordel rubber after six months exposure in sodium hydroxide solution indicates that integrity of the Nordel rubber diaphragm in the spray additive tank valves is not affected by long-term exposure to spray additive solution.

The integrity of the structural materials in the spray additive tank system would not be adversely affected even using the corrosion rates presented in Table 6.4-6 where air contamination is present. In the Point Beach system, where nitrogen blanketing of the spray additive tank prevents air contamination, the corrosion rates would be even lower with even less effect on the material integrity.

Diamond Shamrock Company (Reference 5) reported no galling of steel valves occurred after exposure to 50% sodium hydroxide at 120°F to 140°F for greater than three years. One would expect equivalent or superior performance for stainless steel valves.

The total corrosion product released to the spray additive tank as oxide would be less than 1,000 grams per year with aerated solution and would be much less with the air-free solution.

This small quantity of corrosion product should not present any problems with clogging of delivery lines.

No sodium hydroxide precipitation will occur for a 30 wt.% solution if the temperature of the tank and liners are maintained above 35°F. Since this system is located in an area of the auxiliary building which is continuously heated, no solid sodium hydroxide would be present and therefore no clogging of the lines could occur.

<u>Heat Exchangers</u>

The two residual heat removal heat exchangers which are used during the recirculation phase are described in Section 6.2.

Valves

The valves for the containment spray system are designed in accordance to the specifications discussed for the valves in the safety injection system. Valving descriptions and valve details are shown in Section 5.2.2 and 6.2.2.

Piping

The piping for the containment spray system is designed in accordance to the specifications discussed for the piping in the safety injection system (Section 6.2). The system is designed for 150 psig at 300°F on the suction side of the spray pumps and 300 psig at 300°F on the discharge side up to the nozzles in the containment. Test lines for the containment spray pumps are designed for 550 psig at 100°F. 100°F corresponds to the thermal operating mode of the pump test.

Motors for Pumps and Valves

The motors for the containment spray system are designed in accordance to the specifications discussed for motors in the safety injection system. Spray pump control is such that if the spray pump is running from an automatic or manual safeguards system start and a loss of AC occurs, the pump will be automatically restarted when AC is restored. Also, the spray pump control circuitry is such that if a containment spray signal simultaneous with a safety injection signal and loss of AC occurs, the pump will start in an appropriate sequence to accommodate diesel loading.

Electrical Supply

Details of the normal and emergency power sources are presented in the discussion of the electrical system, Section 8.0.

Environmental Protection

The spray headers are located outside and above the reactor and steam generator concrete shield. During operation, a missile shield also provides missile protection for the area immediately above the reactor vessel. The spray headers are therefore protected from missiles originating within the shield.

All of the active components of the containment spray system are located outside the containment, and hence are not required to operate in the steam-air environment produced by the accident.

Material Compatibility

Parts of the system in contact with borated water, the sodium hydroxide spray additive, or mixtures of the two are stainless steel or an equivalent corrosion resistant material.

6.4.3 SYSTEM EVALUATION

Range of Containment Protection

One containment spray pump and two of the four containment cooling fans will provide sufficient heat removal capability to maintain the post accident containment pressure below the design

value, assuming that all the core residual heat is released to the containment as steam. This applies for all reactor coolant pipe sizes up to and including the hypothetical instantaneous circumferential rupture of a reactor coolant pipe. After the injection phase, either train of the recirculation system provides sufficient cooled recirculated water to keep the core flooded. With a recirculation train in operation, two of the four fan coolers are sufficient to remove the heat addition. It is not expected that continued spray operation would be required for containment cooling.

During the injection and recirculation phases, the spray water is raised to the temperature of the containment in falling through the steam-air mixture. The minimum fall path of the droplets is approximately 70 ft. from the lowest spray ring headers to the operating deck. The actual fall path is longer due to the trajectory of the droplets sprayed out from the ring header. Heat transfer calculations, based upon 1,000 micron droplets, show that thermal equilibrium is reached in a distance of approximately 5 ft. Thus, the spray water reaches essentially the saturation temperature. The model for spray droplet heat removal is discussed in Section .

At containment design pressure, 60 psig, 1,070 gpm of sodium hydroxide/ boric acid solution is injected into the containment atmosphere by one spray pump. At containment design temperature, 286^{o}F, the total heat absorption capability of one spray pump is about 110×10^{6} BTU/hr based on addition of 100^{o}F refueling water. During the recirculation phase, spraying 900 gpm of water from the sump into the containment atmosphere can be continued with one spray pump. The sump water is cooled with a residual heat removal heat exchanger, and the resulting heat removal is sufficient to continue to limit the containment pressure well below design.

Fission Product Removal Effectiveness

In addition to heat removal, the spray system is effective in scrubbing fission products from the containment atmosphere. However, quantitative credit is taken only for absorption of reactive and/or soluble forms of inorganic iodine and particulates in the analysis of the hypothetical accident (Section 14.3.5). A discussion of the effectiveness of containment spray as a fission product trapping process is contained in Appendix C. The iodine and particulate spray coefficients, spray duration time, and other assumptions relating to the modeling of removal of activity from the containment following a large break LOCA are described in FSAR Section 14.3.5.

During post accident operation of the containment spray system, dilution and partial neutralization of the NaOH additive occurs in two stages: first, as the 30 wt.% NaOH mixes with refueling water in the spray pump suction piping, and, second, as the spray solution combines with emergency core cooling water in the containment sump. The protective coatings used within the containment will not deteriorate in a post accident environment in a manner that would reduce the performance capabilities of the engineered safety feature system as per the evaluation presented in WCAP-7198L (Reference 15), as well as the coating program described in Section 1.4 and 6.2.3.

In the early minutes of the sump mixing stage, there is potentially an excess of H_3BO_3 due to the introduction of the contents of the accumulators, the inventory of the reactor coolant system, and the contents of the RWST.

During the injection period, boric acid and sodium hydroxide are mixed and added to the containment via the spray headers. Approximately 30% of the available sodium hydroxide will enter the containment during the injection phase, during which time the spray pH will be between ~8.5 and 9.5. Prior to commencing containment sump recirculation, the flow of sodium hydroxide to the spray pump suction is stopped to prevent a high pH spray to containment that otherwise would occur during recirculation. During the recirculation period, the sump pH will be within the acceptable range of 7.0 to 10.5. The minimum pH in the containment sump needed to keep iodine in the iodate form is 7.0. The pH of the sump water will remain above 7 for 30 days post-LOCA. The maximum pH is based on Equipment Qualification considerations and is set at 10.5. (Reference 10, Reference 16)

The capacity of one containment spray pump will provide sufficient removal of elemental iodine and particulates to ensure post accident fission product leakage would not result in exceeding the dose limits of 10 CFR 50.67. This is evaluated in Section 14.3.5.

System Response

The starting sequence of the containment spray pumps and their related emergency power equipment is designed so that delivery of the minimum required flow is reached within the time assumed in the containment integrity analysis (Section 14.3.4). As described previously, the initiation of the addition of sodium hydroxide to the spray flow is automatic with capability for operator override.

Single Failure Analysis

A failure analysis has been made on all active components of the system to show that the failure of any single active component will not prevent fulfilling the design function. This analysis is summarized in Table 6.4-7.

In addition, each spray pump is supplied from the discharge of one of the two residual heat removal heat exchangers. As described in Section 6.2.3, these two heat exchangers are redundant and can be supplied with recirculated water via separate and redundant flow paths. The analysis of the loss-of-coolant accident presented in Section 14.0 reflects the single failure analysis.

Reliance on Interconnected Systems

The containment spray system initially operates independently of other engineered safety features following a loss-of-coolant accident. For extended operation in the recirculation mode, water is supplied through the residual heat removal pumps. Spray pump seal water cooling is supplied from the component cooling loop.

During the recirculation phase, some of the flow leaving the residual heat exchangers may be bled off and sent to the suction of either the containment spray pumps or the high head safety injection pumps. Minimum flow requirements will be set for the flow being sent to the core and for the flow being sent to the containment spray pump suction. Sufficient flow instrumentation is provided so that the operator can perform appropriate flow adjustments with the remote throttle valves in the flow path as shown in Figure 6.2-1.

Normal and emergency power supply requirements are discussed in Section 8.0.

Shared Function Evaluation

Table 6.4-8 is an evaluation of the main components which have been discussed previously and a brief description of how each component functions during normal operation and during the accident.

Containment Spray Pump NPSH Requirements

The Net Positive Suction Head (NPSH) for the containment spray pumps was evaluated for both the injection and recirculation phases of operation (Reference 17).

During the injection phase the spray pump takes suction from the RWST. Available NPSH is dependant on the RWST level, RWST temperature, and the number of systems taking water from the RWST. Plant operating procedures ensure adequate water levels are maintained in the RWST such that spray pump NPSH requirements are satisfied.

During the recirculation phase the spray pump takes suction from the RHR system (the discharge of the RHR heat exchangers) which takes suction from the containment sump. There is adequate NPSH for the Containment Spray pumps during recirculation spray operation, with both the RHR and the Containment Spray pumps injecting, as long as containment spray is aligned through the reduced flow path and the SI-852 valves are throttled to the intermediate position. The available NPSH is adequate without crediting containment sump suction pressure in excess of normal atmospheric pressure.

6.4.4 REQUIRED PROCEDURES AND TESTS

Inspection Capability

All components of the containment spray system can be inspected periodically to demonstrate system readiness. The pressure containing systems are inspected for leaks from pump seals, valve packing, flanged joints and safety valves during system testing. During the operational testing of the containment spray pumps, the portions of the system subjected to pump pressure are inspected for leaks.

Component Testing

All active components in the containment spray system are tested both in pre-operational performance tests in the manufacturer's shop and in-place testing after installation. The containment spray pumps can be tested singly using the full flow recirculation line. Each pump in turn can be started by operator action and checked for flow establishment. The spray injection valves can be tested with the pumps shut down.

The spray additive tank valves can be opened periodically for testing. The contents of the tank are periodically sampled to determine that the proper solution is present.

The containment spray nozzle availability is tested by blowing smoke or a gas mixture through the nozzles and observing the flow through the various nozzles in the containment visually or by telltales.

During these tests, the equipment was visually inspected for leaks. Leaking seals, packing, or flanges were tightened to eliminate any leak. Valves and pumps are operated and inspected after any maintenance to ensure proper operation.

System Testing

Permanent test lines for all containment spray loops are located so that the system, up to the isolation valves at the spray header, can be tested. These isolation valves can be checked separately.

The air test lines, for checking the spray nozzles, connect downstream of the isolation valves. Air flow through the nozzles is monitored by the use of a smoke generator or telltales.

Operational Sequence Testing

The functional test of the safety injection system described in Section 6.2.4 demonstrates proper transfer to the emergency diesel generator power source in the event of loss of power. A test signal simulating the containment spray signal is used to demonstrate operation of the spray system up to the isolation valves on the pump discharge.

6.4.5 REFERENCES

1. The Stress Corrosion of Metals by H. L. Logan, John Wiley & Sons, Inc. New York, 304 and 316 Stainless Steel, page 138, 410 Stainless Steel, page 101, A-516 - GR-70, Page 44.

2. Letter from R. R. Gaugh, Armco Steel of Data from an Armco Internal Report, dated September 26, 1969, to D. D. Whyte.

3. Corrosion Causes and Prevention by F. N. Speller, McGraw Hill Book Company, Inc., New York, 1951, page 195.

4. Nordel is a product of Dupont de Nemours and Company.

5. Personal communication with Robert Sheppard, Assistant Plant Manger, Divisional Technical Center of Diamond Shamrock Company, Painsville, Ohio.

6. A Guide to Corrosion Resistance, J. P. Polar (Climax Molybdenum).

7. Corrosion Data Survey (1960 Edition), Shell Development Company.

8. Metals Handbook, 8th Edition, Volume 1, Properties and Selection of Metals, Page 670 (American Society for Metals).

9. NRC Safety Evaluation, "Point Beach Nuclear Plant (PBNP), Units 1 and 2 - Issuance of License Amendments Regarding Extended Power Uprate (TAC Nos. ME1044 and ME1045)," dated May 3, 2011.

10. NRC Safety Evaluation, "Point Beach Nuclear Plant (PBNP), Units 1 and 2 -Issuance of License Amendments Regarding Use of Alternate Source Term (TAC Nos. ME0219 and ME0220)," dated April 14, 2011.

11. Calculation 2006-0021, ECCS System Accident Analysis Flow Inputs, Revision 0.

12. Not Used

13. Not Used

14. Not Used

15. WCAP-7198L, “Evaluation of Protective Coatings for Use in Reactor Containment,” Revision 0, April 1968.

16. Point Beach Calculation 2000-0036, “pH of Post LOCA Sump and Containment Spray,” Revision 2.

17. Calculation N-92-086, “ECCS Pump Protection,” Revision 4.

Table 6.4-1 CONTAINMENT SPRAY SYSTEM-CODE REQUIREMENTS

Component	Code
Spray Additive Tank	ASME Section III Class C
Valves	USAS B16-5/ANSI B16.34
Piping (including headers and spray nozzles)	USAS B31.1

Table 6.4-2 CONTAINMENT SPRAY PUMP DESIGN PARAMETERS

Quantity	2/Unit
Design pressure, discharge, psig	300
Design temperature, °F	300
Design flow rate, gpm	1200
Design head, ft.	475
Shutoff head, ft.	550
Motor HP	200
Type	Horizontal-Centrifugal

Table 6.4-3 SPRAY ADDITIVE TANK DESIGN PARAMETERS

Number	1/Unit
Total volume, gal.	5,100
Minimum volume at operating conditions (solution), gal.	2,675
NaOH concentration, wt. %	30
Design temperature, °F	300
Design pressure, psig	300
Material	304 stainless steel cladding on steel A-516, GR-70

Table 6.4-4 EXPOSURE CONDITIONS

Temperature, °F	110
Nitrogen Overpressure	Slight positive pressure
Sodium Hydroxide Concentration, wt. %	30
Oxygen Concentration - Normal	Nitrogen blanketed
Carbon Dioxide Concentration - Normal	Nitrogen blanketed

Table 6.4-5 COMPONENT MATERIALS

Component	Material
Spray Additive Tank	304 stainless steel cladding on steel A-516, GR-70
Piping	304 stainless steel
Valve Bodies	304 and 316 stainless steel
Valve Seats	Austenitic stainless steel or Stellite
Valve Stems	17-4 PH and 410 stainless steel
Valve Diaphragm	Ethylene-Propylene Dipolymer (Nordel rubber by Dupont)

Table 6.4-6 CORROSION RATES

Material	Temperature F	NaOH Concentration wt.%	Aeration	Corrosion Rates, mils/yr	Reference No.
304 S/S	136	22 to 50	Yes	<0.1	6
316 S/S	l25	30	Yes	<2	7
Steel	l79	30 to 50	Yes	<20	7
410 S/S	l25	30	Yes	<2	7
17-4 PH	l76	30	Yes	3 to 6	2
Stellite	l50	50	Yes	<0.6	8
Nordel Rubber	ll0	33	Yes	<0.004	9

Table 6.4-7 SINGLE FAILURE ANALYSIS - CONTAINMENT SPRAY SYSTEM

Component	Malfunction	Comments and Consequences
A. Spray Nozzles	Clogged	Large number of nozzles (180) renders clogging of a significant number of nozzles as incredible.
B. Pumps		
l. Containment Spray Pump	Fails to start	Two provided. Evaluation based on operation of one pump in addition to two out of four containment cooling fans operating during injection phase and operation of one pump in the recirculation phase.
2. Residual Heat Removal Pump	Fails to start	Two provided. Evaluation based on operation of one pump during recirculation phase.
3. Service Water Pump	Fails to start	Six provided. Operation of three pumps during recirculation required.
4. Component Cooling	Fails to start	Two provided. Operation of one pump during recirculation required.
C. Automatically operated valves: (Open on coincidence of two 2/3 high (Hi-Hi) containment pressure signals)		
1. Containment Spray Pump Discharge Isolation Valve	Fails to open	Four provided (two per train) Evaluation based on operation of one train in addition to two out of four containment cooling fans operating during injection phase.
D. Valve Operated from Control Room		
1. Injection		
a. Spray Additive Tank Outlet Isolation Valve	Fails to open	Two provided. Operation of one required.
2. Recirculation		
a. Containment sump recirculation isolation	Fails to open	Two lines in parallel each with two valves in series. One line required.
b. Containment spray pump isolation valve from residual heat exchangers	Fails to open	Two valves provided. One normally closed valve per line. Operation of one required.
c. Residual heat removal pump suction isolation from refu-eling water storage tank line	Fails to close	Check valve in series with an isolation valve in the suction line to each pump. Operation of one valve in each line required.

Table 6.4-8 SHARED FUNCTIONS EVALUATION

Component	Normal Operating Function	Normal Operating Arrangement	Accident Function	Accident Arrangement
Spray Additive Tank	None	Lined up for spray water diversion	Source of sodium hydroxide for spray water	Lined up to spray eductor
Containment Spray Pumps (2)	None	Lined up to spray headers	Supply spray water to containment atmosphere	Lined up to spray headers

NOTE: Refer to Section 6.2 for a brief description of the refueling water storage tank, residual heat removal pumps, service water pumps, component cooling pump, residual heat exchangers and component cooling heat exchangers which are also associated either directly or indirectly with the containment spray system.

Figure 6.4-1 CONTAINMENT SPRAY PUMP PERFORMANCE CHARACTERISTICS

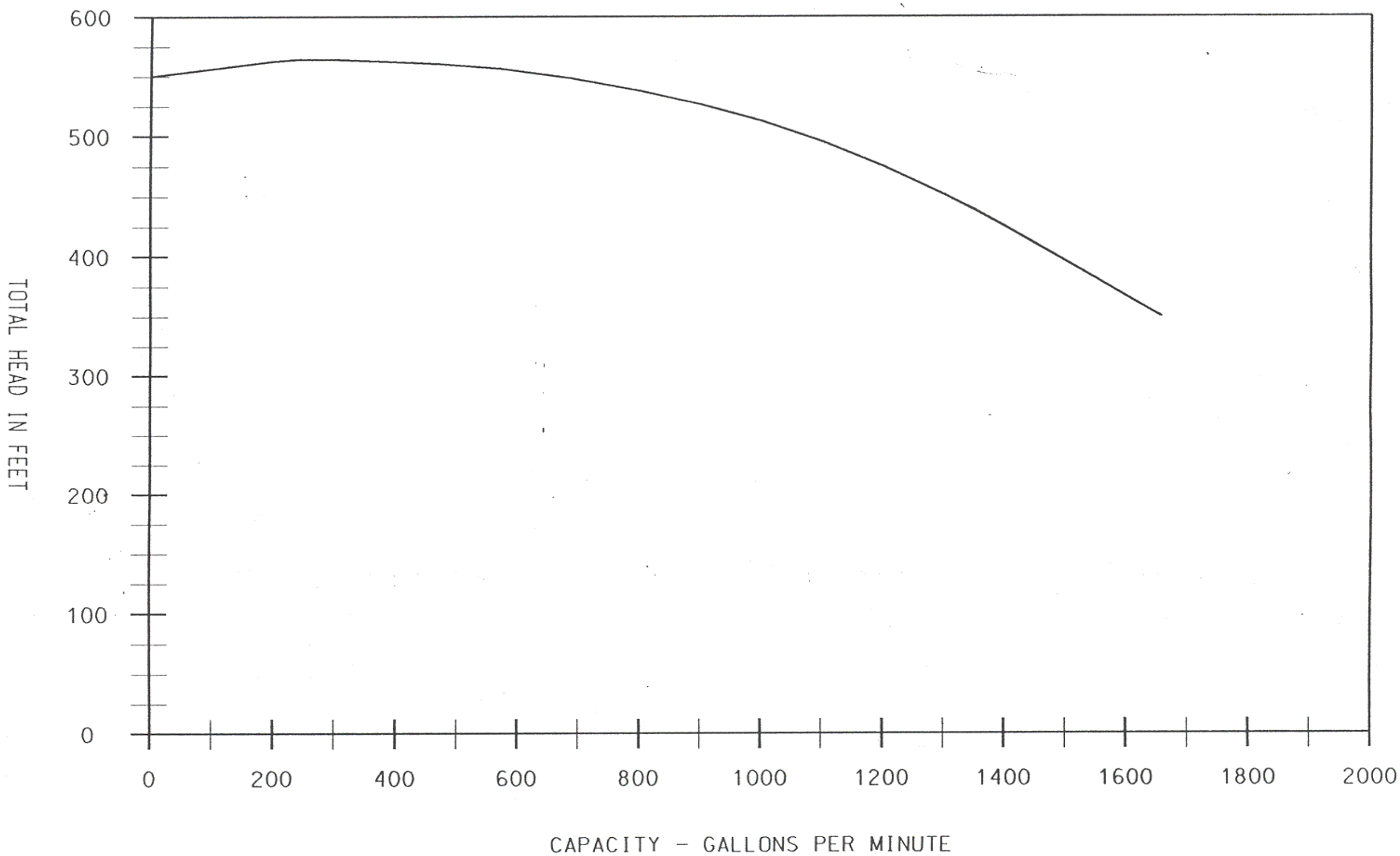


Figure 6.4-2 TEMPERATURE - CONCENTRATION RELATION FOR CAUSTIC CORROSION OF AUSTENITIC STAINLESS STEEL

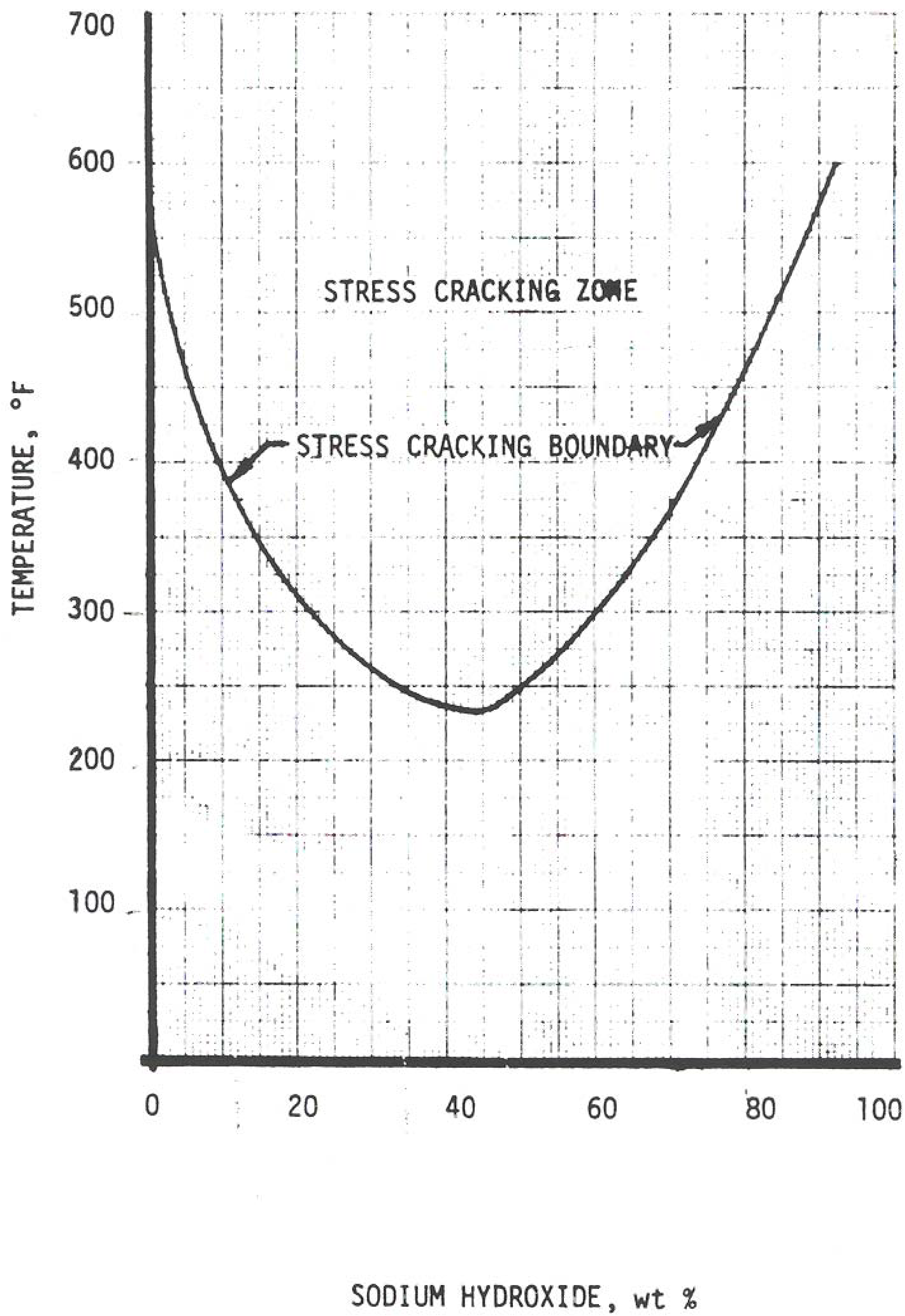
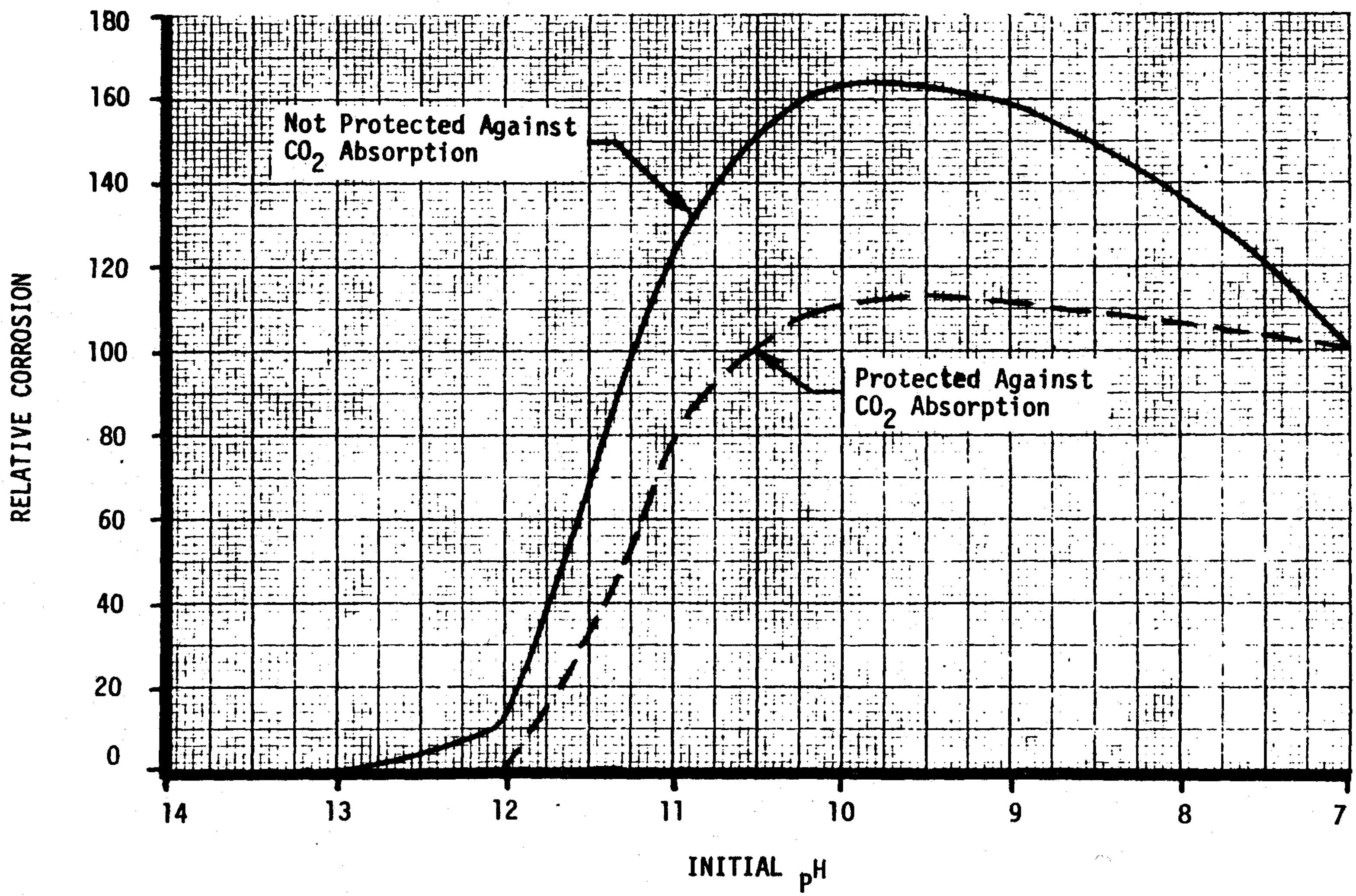


Figure 6.4-3 EFFECT OF CARBON DIOXIDE ON CORROSION OF IRON IN NaOH SOLUTION



6.5 LEAKAGE DETECTION SYSTEMS

The leak detection systems reveal the presence of significant leakage from the reactor coolant, residual heat removal, and component cooling systems.

6.5.1 DESIGN BASIS

Monitoring Reactor Coolant Leakage

Criterion: Means shall be provided to detect significant uncontrolled leakage from the reactor coolant pressure boundary. (GDC 16)

Positive indications in the control room of leakage of coolant from the reactor coolant system to the containment are provided by equipment which permits continuous monitoring of containment air activity and humidity, and of runoff from the air recirculation units and containment floor drains to containment Sump A. This equipment provides indication of normal background which is indicative of a basic level of leakage from primary systems and components. Any increase in the observed parameters is an indication of change within the containment, and the equipment provided is capable of monitoring this change. The basic design criterion is the detection of deviations from normal containment environmental conditions including air particulate activity, gaseous activity, humidity, condensate and floor drain runoff and, in addition, in the case of gross leakage, the liquid inventory in the process systems and containment sump. See Section 15.4.3 for additional information regarding leak detection requirements for leak-before-break analyses.

Criterion: Means shall be provided for monitoring the containment atmosphere and the facility effluent discharge paths for radioactivity released from normal operations, from anticipated transients, and from accident conditions. An environmental monitoring program shall be maintained to confirm that radioactivity releases to the environs of the plant have not been excessive. (GDC 17)

The following are monitored for radioactivity concentrations during normal operation, anticipated transients, and accident conditions: the containment atmosphere, the exhausts from the 54 in. auxiliary and service building vent, the 46 in. drumming area vent, the 36 in. containment area vents, the 4 in. combined air ejector exhaust vent, the service water discharge from the containment fan coolers, the component cooling loop liquid, the liquid phase of the secondary side of the steam generator, waste disposal system liquid discharge, spent fuel pool heat exchanger service water return, waste distillate discharge, gas stripper building ventilation exhaust, service water discharge, wastewater effluent, steam line atmospheric release, and the condenser air ejector. GDC 17 is also addressed in Section 11.4, Radiation Protection. A continuing environmental monitoring program, discussed in Section 2.0, is maintained.

Principles of Design

The principles for design of the leakage detection systems can be summarized as follows:

1. Increased leakage could occur as the result of failure of pump seals, valve packing glands, flange gaskets, or instrument connections. The maximum leakage rate calculated for these types of failures is 50 gpm which would be the anticipated flow rate of water through the pump seal if the entire seal were wiped out and the area between the shaft and housing were completely open.

2. The leakage detection systems shall not produce spurious annunciation from normal expected leakage rates but shall reliably annunciate increasing leakage.

3. Increasing leakage rate shall be annunciated in the control room. Operator action will be required to isolate the leak in the offending system.

6.5.2 SYSTEM DESIGN AND OPERATION

Various methods are used to detect leakage from either the reactor coolant, residual heat removal or component cooling systems. Although described to some extent under each system description, all methods are included here for completeness.

Reactor Coolant System

During normal operation and anticipated reactor transients, the following methods are employed to detect leakage from the reactor coolant system.

Containment Air Radiation Monitoring System

The Containment Air Radiation Monitoring System is a subsystem of the Radiation Monitoring System described in Section 11.5. The primary purpose of the equipment is to sample and monitor containment air for radioactive particulates and noble gases. Additional capability for sampling, venting, and quantifying releases and release rates is also provided by the system. The typical system alignment and essential components are shown in Figure 6.5-1.

The system is comprised of a particulate and noble gas sampling pallet, valving controls, flow instrumentation, tubing, and air pumps. The design of the system allows for continuous sampling of containment air, sampling of the containment purge exhaust stack, venting the containment air, sampling of containment air via test connections, obtaining a post accident sample of containment atmosphere, and flushing post accident atmosphere from sampling lines. Automatic valves providing remote alignment for most sampling MODES can be controlled from the Auxiliary Safety Instrumentation Panels (ASIP) in the control room. Manual operations are required at the RE-211/212 cubicles for samples taken either post accident or via test connections. For post accident sampling, manual operations are performed outside the RE-211/212 cubicle. Containment penetrations serve to provide containment air to the equipment and a return path for discharge to the containment.

The containment atmosphere post-accident sampling system, in conjunction with associated sampling equipment and procedure guidance, is designed to meet the requirements of NUREG-0737, Item II.B.3. This included obtaining and analyzing a sample without radiation exposure to any individual exceeding the criteria of 10 CFR 50, Appendix A, GDC 19, i.e., 5 rem whole body, 75 rem extremities. The system is designed to allow sampling containment up to containment pressure of 60 psig (Reference 2, Reference 3, Reference 6 and Reference 7).

The heart of the particulate-noble gas detection system lies in the sampler assembly and associated radiation detectors. Air is drawn into the system by activating a motor-driven sample pump. The sample pump takes a suction on the selected source (containment atmosphere, purge exhaust stack, facade) and draws the air through a dual-chamber sampler assembly. The two

chambers of the sampler assembly are connected for series sample flow. Air entering the first chamber passes through a fixed filter paper assembly. Particles in the air are trapped on the filter paper which is monitored by a beta scintillation detector (RE-211). After passing through the filter paper, the air sample is then routed to the second chamber, a fixed, cylinder-shaped volume monitored by another beta scintillation detector (RE-212). This detector serves to monitor activity from activated noble gases.

The beta scintillation detectors used to detect activity in both the particulate and noble gas sampler assembly chambers are identical. They are aluminum, cylindrically shaped, 2-inch diameter scintillation detectors, utilizing an aluminized mylar (1.6 mg/cm^2) window and a 0.010 inch thick plastic beta crystal. These detectors are lead shielded to mitigate detection of area gamma radiation. The particulate monitor is capable of detecting particulate activity in concentrations as low as 10^{-8} μCi/cc, with a range of 10^{-8} to 10^{-3} μCi/cc. The noble gas monitor will sense gaseous activity in the range of 10^{-7} to 10^{-1} μCi/cc.

The output of the detectors is fed to interface boxes, which act as signal conditioners for input to a data acquisition module (DAM). The DAM is polled by control terminals (CTs), located in the control room and the Technical Support Center (TSC).

The system has the following modes of operation:

1. Containment Sample - Air from containment is drawn through the particulate and noble gas sampler and is pumped back into containment.

2. Containment Sample with Continuous Vent - Air from containment is drawn through the particulate and noble gas sampler and is pumped back into containment. In addition, a path for the discharge of containment air to the atmosphere through the containment purge exhaust stack filters is opened.

3. Stack Sample - Air from the containment purge exhaust stack is drawn through the particulate and noble gas sampler and is pumped back to the stack or containment.

4. Purge - Air from the facade is drawn through the particulate and noble gas sampler and is pumped to the purge exhaust stack or containment.

5. Independent Sample - Containment air is drawn through system test connections by sampling equipment independent of RE-211/212.

6. Post accident sample - RE-211/212 are isolated and an eductor is used to draw a sample from containment for lab analysis. After sampling, the system will be flushed with an inert gas.

The control function of the containment air monitors is to initiate containment ventilation isolation (CVI). The initiation of CVI is based upon a high alarm signal from the noble gas monitor (RE-212) only. The reason for using only the noble gas monitor vice using both monitors (particulate and noble gas) is that the particulate monitor (RE-211) is a fixed-filter monitor which would require an alarm output based on a trend.

The CVI signal based on the noble gas monitor high alarm will close the containment purge supply and exhaust duct valves. In addition, the CVI signal will also secure continuous vent operation. The CVI signal does not interrupt the monitoring of containment air.

Containment High Range Radiation Monitors

These radiation monitor channels are used for monitoring post-accident containment conditions. [redacted] The ion chambers have a range of 10°-10^8 R/hr with indication on 1(2) C20 in the control room.

Humidity Detector

The humidity detection instrumentation offers another means of detection of leakage into the containment. Although this instrumentation has not nearly the sensitivity of the air particulate monitor, it has the characteristics of being sensitive to vapor originating from all sources within the containment, including the reactor coolant, main steam, and feedwater systems. Plots of containment air dewpoint variations above a baseline maximum established by the cooling water temperature to the air coolers should be sensitive to incremental leakage equivalent to 2 to 10 gpm.

The sensitivity of this method depends on cooling water temperature, containment air temperature variation, and containment air recirculation rate.

Condensate Measuring System

This leak detection method is based on the principle that the condensate collected by the cooling coils under equilibrium conditions plus liquid collected by the containment floor drains matches the leakage of water and steam from systems within the containment.

The containment cooling coils are designed to remove the sensible heat generated within the containment. The resulting large coil surface area has the effect that the exit air from the coils has a dewpoint temperature which is very nearly equal to the cooling water temperature.

Measurement of the condensate drained from each of the fan cooler units is made to determine condensation rate. This volume in conjunction with the floor drain run-off to the condensate measuring system determines the leak rate.

Should a leak occur, the condensation rate will increase above the previous steady state due to the increased vapor content of the fan cooler air intake. The time required for the new equilibrium rate to be reached varies with the initial containment conditions, service water temperature and the conditions of the reactor coolant at the leak location (Reference 5). The condensate measuring system meets the leak before break performance requirement of detecting RCS leakage of 1 gpm in 4 hours (Reference 4). Readout of the condensate measuring device level channel is provided in the control room. A high level alarm is provided to alert the operator to significant increases in the condensate flow rate.

Component Cooling Liquid Monitor

This channel continuously monitors the component cooling system for activity indicative of a leak of reactor coolant from either the reactor coolant system or the recirculation or residual heat removal system. A scintillation counter is located in an inline well at the component cooling pump suction header. The detector assembly output is amplified by a preamplifier, processed by a discriminator and pulse shaper, and then is carried to its electronic channel on the data acquisition module (DAM) where it is counted and processed. Control terminals (CTs) in the control room and Technical Support Center (TSC) poll the DAMs for this information. A high activity alarm would be annunciated at the unit Auxiliary Safety Instrumentation Panel (ASIP) as well as the radiation monitoring system control terminals.

The range of this monitor is 10^{-5} to 10^{0} μCi/cc.

Condenser Air Ejector Gas Monitor

This channel monitors the discharge from the air ejector exhaust header of the condensers for gaseous radiation which is indicative of a primary-to-secondary system leak. The gas discharge is routed via a radioactivity decay duct to the auxiliary building vent.

The detector output is transmitted to the radiation monitoring system control terminal in the control room. High activity alarm indications are displayed on the ASIP annunciator in addition to the radiation monitoring system control terminals.

A beta sensitive plastic scintillation detector is used to monitor the gaseous radiation level. The detector is inserted into an inline fixed volume container which includes adequate shielding to prevent background radiation from interfering with detector sensitivity. The range of this monitor is 10^{-7} to 10^{-2} μCi/cc.

Steam Generator Liquid Sample Monitor

This channel monitors the liquid phase of the secondary side of the steam generator for radiation. Secondary side radiation indicates a primary-to-secondary system leak and provides backup information to that of the condenser air ejector gas monitor. Samples from the bottom blowdown lines of each of the two steam generators are mixed to a common header and the common sample is continuously monitored by a scintillation counter and holdup tank assembly. Upon indication of a high radiation level, each steam generator is manually sampled in order to determine the source. This sampling sequence is achieved by manually selecting the desired unit to be monitored and allotting sufficient time for sample equilibrium to be established (approximately 1 min.). A high radiation alarm is located near the detector. The range of this monitor is 10^{-7} to 10^{-2} μCi/cc.

A scintillation crystal (NaI)/photomultiplier tube combination, mounted in a sample well, is used to monitor liquid effluent activity. Lead shielding is provided to reduce the background level so it does not interfere with detector sensitivity. The inline, fixed-volume container is an integral part of the detector unit.

Leakage Detection

During hot shutdown, personnel can enter the containment and make a visual inspection for leaks. The location of any leak in the reactor coolant system would be determined by the presence of boric acid crystals near the leak. The leaking fluid transfers the boric acid outside the reactor coolant system and the process of evaporation deposits crystals.

If an accident involving gross leakage from the reactor coolant system occurred, it could be detected by the following methods.

Pump Activity

During normal operation, two charging pumps are operating with one in manual and one in automatic. If a gross loss of reactor coolant to another closed system occurred which was not detected by the methods previously described, the speed of the charging pump would indicate the leakage.

The leakage from the reactor coolant will cause a decrease in the pressurizer liquid level that is within the sensitivity range of the pressurizer level indicator. The speed of the charging pump in automatic will automatically increase to try to maintain the equivalence between the letdown flow and the combined charging line flow and flow across the reactor coolant pump seals. If the pump reaches a high speed limit, an alarm is actuated.

A break in the primary system would result in reactor coolant flowing into the containment sump. Gross leakage to this sump would be indicated by the frequency of operations necessary to clear the containment sump high liquid level alarms.

Liquid Inventory

Gross leaks might be detected by unscheduled increases in the amount of reactor coolant makeup water which is required to maintain the normal level in the pressurizer. This is inherently a low precision measurement, since makeup water is necessary as well for leaks from systems outside the containment.

A large tube side to shell side leak in the nonregenerative (letdown) heat exchanger would result in reactor coolant flowing into the component cooling water and a rise in the liquid level in the component cooling water surge tank. The operator would be alerted by a high water alarm for the surge tank and high radiation and temperature alarms actuated by monitors at the component cooling water pump suction header.

A high level alarm for the component cooling water surge tank and high radiation and temperature alarms actuated by monitors at the component cooling pump suction header could also indicate a thermal barrier cooling coil rupture in a reactor coolant pump. However, in addition to these alarms, high temperature and high flow on the component cooling outlet line from the pump would activate alarms.

Gross leakage might also be indicated by a rise in the normal containment sump level. High level in this sump will actuate an alarm.

Residual Heat Removal System

The residual heat removal system removes residual and sensible heat from the core and reduces the temperature of the reactor coolant system during the second phase of plant shutdown.

Leakage from the residual heat removal loop during normal operation would be detected by the component cooling system radiation monitor (see analysis of detection of leakage from the reactor coolant system in this section).

The two residual heat removal pumps are located in separate shielded and isolated rooms outside of the containment. Radiation monitoring of this area is provided by the plant vent gas monitoring system. Alarms in the control room alert the operator when the activity exceeds a preset level. Small leaks to the environment could be detected with these systems within a short time after they occurred.

Should a large tube side to shell side leak develop in a residual heat exchanger, the water level in the component cooling surge tank would rise, and the operator would be alerted by a high water alarm. Radiation and temperature monitors at the component cooling water pump suction header will also signal an alarm.

Leakage from the residual heat removal pumps is drained to one sump that serves both units. The sump is equipped with two sump pumps.

Component Cooling System

Leakage from the component cooling system inside the reactor containment might be detected by the humidity detector and/or the condensate measuring system (see section on reactor coolant system leak detection for a description of these systems).

Visual inspection inside the containment is possible during normal operations.

If the leakage is from a part of the component cooling system outside the containment, it would be directed by floor drains to an auxiliary building sump. The auxiliary building sump pumps then transfer the leakage to the waste holdup tank.

Service Water System

The containment fan cooler service water monitor checks the containment fan service water discharge lines for radiation indicative of a leak from the containment atmosphere into the service water. Upon indication of a high radiation level, each heat exchanger is individually sampled to determine which unit is leaking. This sampling sequence is achieved by manually selecting the desired unit to be monitored and allotting sufficient time for sample equilibrium to be established (approximately 1 minute).

The range of this monitor is 10^{-7} to 10^{-2} μCi/cc.

Gross leakage of service water due to a faulty cooling coil in the containment air recirculation cooling system can be detected by stopping the fans and continuing the cooling water flow. Any significant cooling water leakage would be seen as flow into a collecting pan.

6.5.3 SYSTEM EVALUATION

Provisions are made for the isolation and containment of any leakage. The provisions made for leakage are designed to prevent uncontrolled leaking of reactor coolant, residual heat removal or component cooling water. This is accomplished by (1) isolation of the leak by valves, (2) designing relief valves to accept the maximum flow of water from the worst possible leak, (3) supplying redundant equipment which allows a standby component to be placed in operation while the leaking component is repaired, and (4) routing the leakage to various sumps and holdup tanks.

Various provisions for leakage avert unmonitored leakage from the reactor coolant, residual heat removal, and component cooling systems.

<u>Reactor Coolant System</u>

When significant leakage from the reactor coolant system is detected, action is taken to prevent the release of radioactivity to the atmosphere outside the plant.

If the containment radiogas activity exceeds a preset level on the containment radiogas monitor, the containment vent valves are automatically closed (if open).

A high radiation alarm actuated by the steam generator liquid sample monitor initiates closure of the isolation valves in the blowdown lines, sample lines, and blowdown tank condensate drain lines.

If the component cooling system radiation monitor signals a high radiation alarm, the valve in the component cooling surge tank vent line automatically closes to prevent gaseous activity release.

If a leak from the reactor coolant system to the component cooling system was a gross leak, or if the leak could not be isolated from the component cooling system before the inflow completely filled the surge tank, the relief valve on the surge tank would lift. The discharge from this valve is routed to the waste holdup tank in the auxiliary building.

A large leak in the reactor coolant system pressure boundary, which does not flow into another closed loop, would result in reactor coolant flowing into the containment sump.

<u>Residual Heat Removal System</u>

If leakage from the residual heat removal system into the component cooling system occurs, the component cooling radiation monitor will actuate an alarm and the valve in the component cooling surge tank vent line is automatically closed to prevent gaseous radioactivity release. If the leaking component (i.e., a residual heat exchanger) could not be isolated from the component cooling system before the inflow completely filled the surge tank, the relief valve on the surge tank would lift and the effluent would be discharged to the waste holdup tank.

Gross leakage from the section of the residual heat removal system inside the containment, which does not flow into another closed loop, would result in reactor coolant flowing into the containment sump.

Other leakage provisions for the residual heat removal system are discussed in Section 9.2.

Component Cooling System

Gross leakage from the section of the component cooling system inside the containment which does not flow into another closed loop will flow into the containment sump. Outside the containment, major leakage would be drained to an auxiliary building sump. From here it is pumped to the waste holdup tank.

Other provisions made for leakage from the component cooling system are discussed in Section 9.1.

6.5.4 REQUIRED PROCEDURES AND TESTS

The inservice inspection requirements are described in the PBNP Inservice Testing Program.

6.5.5 REFERENCES

1. Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident", Rev. 2.

2. NUREG 0737, Item II.B.3, "Post-Accident Sampling Capability".

3. NRC Safety Evaluation "Post-Accident Sampling System (NUREG-0737, II.B.3)," dated December 22, 1982.

4. NRC SE, "PBNP, Units 1 and 2, Supplement to Safety Evaluation on Leak-Before-Break Regarding Correction of Leak Detection Capability (11/14/15-S1)," dated February 7, 2005.

5. Calculation 97-0117, Rev. 2, "Evaluation of Sump A Condensate Collection Provisions for Detection of Reactor Coolant System Leakage" and associated 50.59 screening SCR 2006-0235.

6. SE 97-096, "Unit 2 Post-Accident Sample System Upgrades (MR 97-057)," approved June 12, 1997.

7. SE 97-145, "Unit 1 Post-Accident Sample System Upgrades (MR 97-056)," approved July 24, 1997.

Figure 6.5-1 UNIT 1 CONTAINMENT RADIATION MONITORING SYSTEM

[redacted]