SECTION 6.0

ENGINEERED SAFETY FEATURES

6.1 ENGINEERED SAFETY FEATURE MATERIALS

6.1.1 Metallic Materials

6.1.1.1 Materials Selection and Fabrication

Typical materials specifications used for ISS components in the engineered safety features are listed in Table 6.1-1. In some cases, this list of materials may not be totally inclusive. However, the listed specifications are representative of those materials used. Materials utilized conform with the requirements of the ASME Code, Section III, plus applicable and appropriate addenda and code cases.

The welding materials used for joining the ferritic base materials of the engineered safety features conform to or are equivalent to ASME Material Specifications SFA 5.1, 5.2, 5.5, 5.17, 5.18, and 5.20. The welding materials used for joining nickel-chromium-iron alloy in similar base material combination and in dissimilar ferritic or austenitic base material combination conform to ASME Material Specifications SFA 5.11 and 5.14. The welding materials used for joining the austenitic stainless steel base materials conform to ASME Material Specifications SFA 5.4 and 5.9. These materials are qualified to the requirements of the ASME Code, Section III and Section IX, and are used in procedures which have been qualified to these same rules. The methods utilized to control delta ferrite content in austenitic stainless steel weldments are discussed in the "Reactor Systems" module.

All parts of components in contact with borated water are fabricated of or clad with austenitic stainless steel or equivalent corrosion resistant material. The integrity of the safety-related components of the engineered safety features is maintained during all stages of component manufacture. Austenitic stainless steel is utilized in the final heat treated condition as required by the respective ASME Code, Section II, material specification for the particular type or grade of alloy. Furthermore, austenitic stainless steel materials used in the engineered safety features components are handled, protected, stored, and cleaned according to recognized and accepted methods which are designed to minimize contamination which could lead to stress corrosion cracking. These controls are stipulated in Westinghouse specifications. Additional information concerning austenitic stainless steel, including the avoidance of sensitization and the prevention of intergranular attack will be provided in the "Reactor Coolant System" Module. No cold worked austenitic stainless steels having yield strengths greater than 90,000 psi are used for components of the engineered safety features.

Materials utilized in engineered safety features components within the containment that would be exposed to core cooling water and containment sprays in the event of a loss-of-coolant accident are included in Table 6.1-1. These components are manufactured primarily of stainless steel or other corrosion resistant material.

Protective coatings are applied on carbon steel equipment located inside containment (see Section 6.1.2).

The integrity of the materials of construction for engineered safety features equipment when exposed to post-design basis accident conditions have been evaluated. Post-design basis accident conditions were conservatively represented by test conditions. The test program (Reference 6.1.3-1) performed by Westinghouse considered spray and core cooling solutions of the design chemical compositions, as well as the design chemical compositions contaminated with corrosion and deterioration products which may be transferred to the solution during recirculation. The effects of chlorine (chloride), and fluorine (fluoride) on austenitic stainless steels were considered. Based on the results of this investigation, as well as testing by Oak Ridge National Laboratory and others, the behavior of austenitic stainless steels in the post-design basis accident environment will be acceptable. No cracking is anticipated on any equipment even in the presence of postulated levels of contaminants, provided the core cooling and spray solution pH is maintained at an adequate level. The inhibitive properties of alkalinity (hydroxyl ion) against chloride cracking and the inhibitive characteristic of boric acid on fluoride cracking have been demonstrated.

Information concerning the degree of compliance with Regulatory Guides 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal," 1.36, "Nonmetallic Thermal Insulation for Austenitic Stainless Steel," 1.37, "Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants," and 1.44, "Control of the Use of Sensitized Stainless Steel," is provided in section 1.8.

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

The vessels used for storing engineered safety features coolants include the accumulators, core reflood tanks, and the emergency water storage tank.

The accumulators are carbon steel clad with austenitic stainless steel. Because of the corrosion resistance of these materials, significant corrosive attack on the accumulators is not expected.

The accumulators and core reflood tanks are vessels filled with borated water and pressurized with nitrogen gas. The nominal boron concentration, as boric acid, is 2500 ppm. Samples of the solution are taken periodically for checks of boron concentration. Principal design parameters of the accumulators and core reflood tanks are listed in Table 6.3-2.

The emergency water storage tank is located inside containment and provide the source of borated cooling water for core cooling and containment spray. The nominal boron concentration, as boric acid, is 2500 ppm. A description and principal design parameters of the tanks are given in Section 6.3.2.2 and Table 6.3-2.

6.1.2 Organic Materials

An estimation of the amounts of protective coatings on ISS components located inside containment is given in Table 6.1-2; the painted surfaces of this equipment comprise a small percentage of the total painted surfaces inside containment.

For large equipment requiring protective coatings (specifically itemized in Table 6.1-2), Westinghouse specifies or approves the type of coating systems utilized; requirements with which the coating system must comply are stipulated in Westinghouse process specifications, which supplement the equipment specifications. For these components, the generic types of coatings used are zinc rich silicate or epoxy based primer with or without chemically-cured epoxy or epoxy modified phenolic topcoat.

The remaining equipment requires protective coatings on much smaller surface areas and is procured from numerous vendors; for this equipment, Westinghouse specifications require that high quality coatings be applied using good commercial practices. Table 6.1-2 includes identification of this equipment and total quantities of protective coatings on such equipment.

Protective coatings for use in the reactor containment have been evaluated as to their suitability in post-design basis accident conditions. Tests have shown that certain epoxy and modified phenolic systems are satisfactory for use inside containment. This evaluation (Reference 6.1.3-2) considered resistance to high temperature and chemical conditions anticipated during a loss-of-coolant accident, as well as high radiation resistance.

Information regarding compliance with Regulatory Guide 1.54, "Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants," is provided in Section 1.8. Further compliance information has been submitted to the NRC for review via Reference 6.1.3-3 and accepted via Reference 6.1.3-4.

6.1.3 References

6.1.3-1. Whyte, D. D. and Picone, L. F., "Behavior of Austenitic Stainless Steel in Post Hypothetical Loss-of-Coolant Environment," WCAP-7798-L (Proprietary), November, 1971 and WCAP-7803 (Non-Proprietary), December, 1971.

6.1.3-2. Picone, L. F., "Evaluation of Protective Coatings for use in Reactor Containment," WCAP-7198-L (Proprietary), April, 1968 and WCAP-7825 (Non-Proprietary), December, 1971.

6.1.3-3. Letter NS-CE-1352, dated February 1, 1977, C. Eicheldinger (Westinghouse) to C. J. Heltemes, Jr. (NRC).

6.1.3-4. Letter dated April 27, 1977, C. J. Heltemes, Jr. (NRC) to C. Eicheldinger (Westinghouse).

TABLE 6.1-1 (Sheet 1 of 2)

ENGINEERED SAFETY FEATURE MATERIALS

Valves	
Bodies	SA-182, Grade F316 or SA-351, Grade CF8 or CF8M
Bonnets	SA-182, Grade F316 or SA-351, Grade CF8 or CF8M
Discs	SA-182, Grade F316 or SA-564, Grade 630 or SA-351, Grade CF8 or CF8M
Pressure retaining bolting	SA-453, Grade 660
Pressure retaining nuts	SA-453, Grade 660 or SA-194, Grade 6
Auxiliary Heat Exchangers	
Heads	SA-240, Type 304
Nozzle necks	SA-182, Grade F304; SA-312, Grade TP304; SA-240, Type 304
Tubes	SA-213, Grade TP304; SA-249, Grade TP304
Tube sheets	SA-182, Grade F304; SA-240, Type 304; SA-516, Grade 70 with Stainless Steel Cladding A-8 Analysis
Shells	SA-240 and SA-312, Grade TP304; SA-351, Grade CF8
Flanges	SA-182, Grade F304 or F316
Auxiliary Pressure Vessels, Tanks, Filters, etc.	
Shells and heads	SA-351, Grade CF8A; SA-240, Type 304; SA-264 Clad Plate of SA-537, Class 1 with SA-240, Type 304 Clad and Stainless Steel Weld Overlay A-8 Analysis
Flanges and nozzles	SA-182, Grade F304; SA-350, Grade LF2 or LF3 with SA-240, Type 304 and Stainless Steel Weld Overlay A-8 Analysis
Pipe	SA-312 and SA-240, Grade TP304 or TP316 Seamless
Pipe fittings	SA-403, Grade WP304 Seamless
Closure bolting and nuts	SA-193, Grade B7 and SA-194, Grade 2H

TABLE 6.1-1 (Sheet 2 of 2)

ENGINEERED SAFETY FEATURE MATERIALS

Auxiliary Pumps	
Pump casings and heads	SA-351, Grade CF8 or CF8M; SA-182, Grade F304 or F316
Flanges and nozzles	SA-182, Grade F304 or F316; SA-403, Grade WP316L Seamless
Piping	SA-132, Grade TP304 or TP316 Seamless
Stuffing or packing box cover	SA-361, Grade CF8 or CF8M, SA-240, Type 304 or Type 316; SA-182, Grade F304 or F316
Pipe fittings	SA-403, Grade WP316L Seamless; SA-213; Grade TP304, TP304L, TP316 or TP316L
Closure bolting and nuts	SA-193, Grade B6, B7, or B8M; SA-194, Grade 2H or 8M; SA-453, Grade 660; and Nuts SA-194, Grade 2H, 6, 7, and 8M

TABLE 6.1-2

PROTECTIVE COATINGS ON WESTINGHOUSE SUPPLIED EQUIPMENT INSIDE CONTAINMENT

Component	Painted Surface Area (ft^2)
ISS system component supports	11,230
Accumulator tanks and core reflood tanks	7,600
Remaining equipment (such as valves, auxiliary tanks and heat exchanger supports, transmitters, alarm horns, small instruments, etc.)	< 5,000

6.2 CONTAINMENT SYSTEMS

6.2.2 Containment Heat Removal System

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

Two separate systems are utilized to perform the containment heat removal function: the containment spray portion of the Integrated Safeguards System (hereafter referred to as Containment Spray System) and the containment fan cooler system. A brief discussion of the containment spray system design and operation is provided here; a detailed discussion of its ability to meet all safety related design objectives will be provided in the Containment Systems Module. Discussion of the containment fan cooler system will also be provided in the Containment Systems Module.

The containment spray function is performed by the integrated safeguards system (ISS). Those components within the ISS that perform a CSS function are the four low head pumps, the Emergency Water Storage Tank (EWST) and the associated valves, piping, and instrumentation. Within the containment, two redundant sets of spray ring headers are used to provide containment atmosphere coverage.

6.2.2.1 Design Bases

The CSS, in conjunction with the containment fan cooler system, and the containment passive heat sinks is capable of removing sufficient sensible heat and subsequent decay heat from the containment following the hypothesized LOCA or main steam line break accident to maintain the containment design pressure, in accordance with 10CFR50, Appendix A, General Design Criterion 38, "Containment Heat Removal".

The CSS is designed to remove fission products from the containment atmosphere in order to reduce the inventory of fission products available for leakage from the containment in accordance with 10CFR50, Appendix A, General Design Criterion 41, "Containment Atmosphere Cleanup".

The CSS is designed to permit appropriate periodic inspection and testing to ensure its integrity and operability in accordance with 10CFR50, Appendix A, General Design Criterion 39, "Inspection of Containment Heat Removal System", and General Design Criterion 40, "Testing of Containment Heat Removal System".

Missile protection, protection against the dynamic effects associated with the postulated rupture of piping, and seismic design are discussed in Sections 3.5, 3.6, and 3.7, respectively of the "Structural/Equipment Design" module.

6.2.2.2 System Design

Piping and instrumentation diagrams for the CSS portion of the ISS are shown in Figure 6.3-1, sheets 1 and 7. These diagrams show the relative location of CSS components, where the components tie together with other ISS components and piping, and the instrumentation and controls associated with the CSS components.

A design flow rate of ~[ ] gpm at a containment pressure of [ ] psig has (a,c)
been established for an assumed [ ] foot diameter spherical containment. This (a,c)
design flow rate is based on an assumed spray ring heder layout and nozzle type, orientation and spacing that would ensure that the maximum containment volume coverage was obtained. A SPRAYCO 1713A spray nozzle has been assumed
with a pressure drop of [ ] psig at a spray nozzle design flow rate of [ ] gpm. (a,c)
Each low head pump is capable of providing approximately [ ] gpm at a [ ] psi (a,c)
containment pressure, therefore two of the four low head pumps are required to
meet the [ ] gpm spray design flow rate. (a,c)

a. Component Design

Components within the ISS that perform a CSS function are the four low head pumps, the EWST and the associated valves, piping, and instrumentation. Design parameters for the low head pumps and EWST are provided in Table 6.3-1. Discussion of their design features is provided in Section 6.3.2.2.

Containment Spray Headers

Within the containment, two redundant sets of spray ring headers are used (see Figure 6.3-1, sheet 7). One half of each set of ring headers would be assigned to one spray subsystem. A staggered assignment of ring header sections to each spray subsystem assures the maximum containment coverage with any two low head pumps operating. For example, each low head pump would deliver to 1/2 of a inner ring, 1/2 of a middle ring, and 1/2 of an outer ring. However, the 1/2 inner ring and 1/2 outer ring would provide spray to the opposite side of the containment from the 1/2 middle ring. A second low head pump would be assigned to deliver to the matching spray headers segments so that the operation of two low head pumps delivering to matching ring header segments assure 100 percent containment coverage with 100 percent of the required spray flow.

A 90 degree relative orientation between the two sets of ring headers is also necessary to assure that the maximum containment coverage will be obtained with any two low head pumps operating. This orientation would ensure a 75 percent containment coverage with 100 percent of the required flow even if the two operating spray systems are delivering to unmatched ring header segments. For an ISS powered by four emergency electrical power trains, each low head spray pumping system can be assigned to any one of the four groups of ring headers (each group consisting of 1/2 inner, 1/2 middle, and 1/2 outer ring). For an ISS powered by two emergency electrical power trains, spray subsystems assigned to the same electrical train must be assigned to deliver to a matched set of ring headers to ensure 100 percent containment coverage with a single electrical train failure.

Spray Nozzles

The spray nozzles are hollow cone ramp bottom nozzles, type SPRAYCO 1713A (Figure 6.2.2-1). Each nozzle is flow tested over a range of inlet pressures to determine that the actual flow rate at[ ]psig meets the design flow rate of [ ]gpm (Figure 6.2.2-2). Figure 6.2.2-3 shows mean droplet size distribution. The nozzles are oriented to ensure thorough coverage of the containment volume. Typical spray patterns for these nozzles in the vertical, horizontal, and downward spray positions are provided in Figures 6.2.2-4, -5 and -6, respectively. (a,c) (a,c)

b. System Operation

In the event of a high containment pressure signal ("P" signal) during reactor power operations, the four low head pumps would receive an automatic signal to start and the containment spray header isolation valves (9009A, B, C, D and 9011A, B, C, D) would receive an automatic signal to open. The low head pumps would function as containment spray pumps and would draw suction from the EWST and deliver to the containment spray headers, which are located in the top of the containment building.

c. Component Interlocks

Component interlocks used in the different modes of ISS operation are listed in Section 6.3.2.1. Interlocks specifically utilized for CSS operations are as follows:

The containment isolation Phase "B" and containment spray initiation signal ("P") initiates the following actions:

(1) The four low head pumps start

(2) The containment spray header inner containment isolation valves open (9011 A, B, C, D)

(3) The normally open containment spray header outer containment isolation valves receive a confirmatory "P" signal to open, if closed (9009 A, B, C, D)

d. Operator Actions

No operator actions are required for CSS injection.

e. Containment Recirculation Sump

Water spilling from an RCS break and the CSS would collect in lower containment subcompartments where it is routed to the EWST. A discussion of the containment subcompartment and EWST design will be provided in the Containment Systems Module. Likewise, the Containment Systems Module will contain a discussion of debris size and sources within containment and the design features provided to preclude injection into the ISS.

6.2.2.3 Design Evaluation

Plan and elevation drawings of the containment showing the expected spray patterns will be provided in the Containment Systems Module. An analysis of the heat removal effectiveness of the sprays will also be provided.

NPSH calculations for the low head pumps are performed in accordance with the recommendations of Regulatory Guide 1.1.

A failure mode and effects analysis is provided in Table 6.2.2-2.

An estimate of the amount of debris that could be generated during a LOCA and of the amount that could be transported to the sump screens will be provided in the containment systems module.

6.2.2.4 Tests and Inspections

a. Preoperational Testing

The objectives and procedures of preoperational testing are to:

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

(2) Demonstrate that the spray nozzles in the containment spray header are clear of obstructions, by passing air through the test connections. The nozzle design parameters are verified by prototype testing in the vendor's facilities.

(3) Verify that the proper sequencing of valves and pumps occurs on initiation of the CSS, and demonstrate the proper operation of remotely-operated valves.

(4) Verify the operation of the low head pumps; each pump is run at minimum flow and the flow directed back to the pump suction. During this time, the minimum flow will be adjusted to that required for routine testing.

b. Operational Testing

The CSS is designed to permit periodic determination of proper system operability. The objectives and procedures of operational testing are to:

(1) Verify that the proper sequencing of valves and pumps occurs on initiation of the containment spray actuation signals, and demonstrate the proper operation of remotely-operated valves.

(2) Verify the operation of the low head pumps. Periodic testing-each pump is run at minimum flow to verify pump start and developed head. In addition, full pump flow testing capability via the full flow test line to the EWST is provided.

c. Inspection

The pressure-containing systems are inspected for leaks from pump seals, valve packings, flange joints, and safety valves during system testing. The components of the system outside the containment are accessible for leaktightness inspection during periodic flow tests.

6.2.2.5 Instrumentation Requirements

Instrumentation within the ISS is discussed in Section 6.3.5.

TABLE 6.2.2-1

CONTAINMENT SPRAY SYSTEM COMPONENT PARAMETERS

Low Head Pumps	
	See Table 6.3-1
Emergency Water Storage Tank	
	See Table 6.3-1
Spray Headers	
Number	2 sets
Spray Nozzles	
Number, per set	~ 376 (1)
, total	~ 752 (1)
Type	SPRAYCO 1713A
Design Flow per Nozzle, gpm	[(a,c)
Pressure Drop at Design Flow, psig	
Orifice Diameter, in	]

(1) Based on a [ ] ft diameter spherical containment. (a,c)

TABLE 6.2.2-2 (Sheet 1 of 1)

FAILURE MODE AND EFFECTS ANALYSIS - INTEGRATED SAFEGUARD SYSTEM (ISS)
CONTAINMENT SPRAY FUNCTION

Component	Failure Mode	CSS Function	Effect on System Operation	Failure Detection Method	Remarks
1) Low head pump No. 1 RHR/CS (Pump No. 2,3,4 analogous)	Fails to deliver working fluid	Delivery of containment spray fluid to spray headers from EWST.	Failure results in reduced redundancy of containment spray function. Spray function maintained by spray subsystem B,C,D and 100% of spray flow requirement provided by two low head pumps.	Open pump switchgear circuit breaker indication at CB. Circuit breaker overcurrent trip indication at CB. Circuit breaker close position monitor light; low-head pump discharge coolant flow indication (FI-908) at CB.	
2) Low-head pump spray header isolation valve 9011A (9011B, C, D analogous)	Fails to open on demand	Valve opens on "P" signal to admit pumped spray header	Failure results in no spray flow delivered to associated spray header. (Remaining; same as 1 above). Operator can manually open valve and restore subsystem to operation. Note continuous pump protection provided by miniflow line.	Valve position indication (closed to open position change) at CB. Valve open position monitor light and alarm at CB; low-head pump discharge coolant flow indication (FI-908) at CB.	

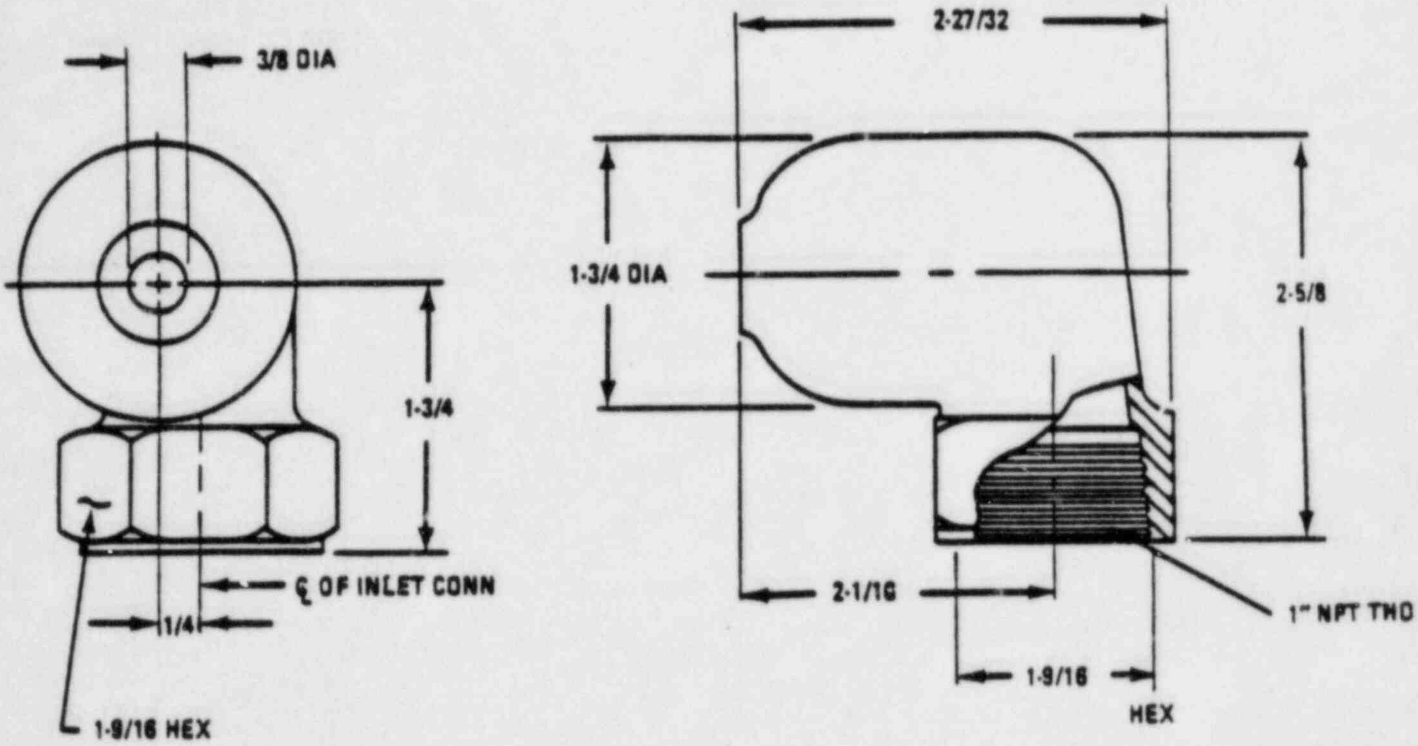


Figure 6.2.2-1 Containment Spray Nozzle (1713A Nozzle)

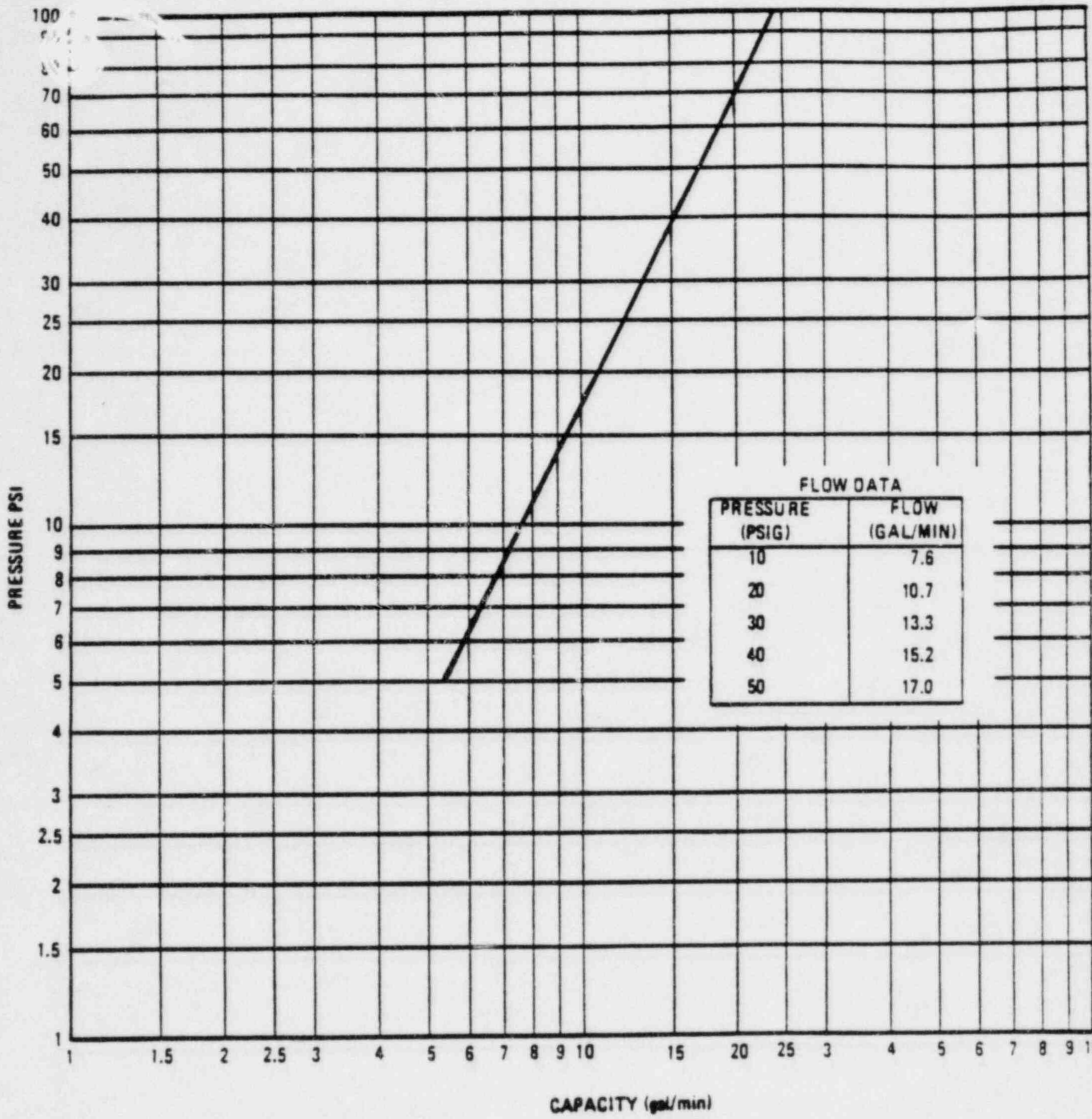


Figure 6.2.2-2 Containment Spray Nozzle Capacity Curve

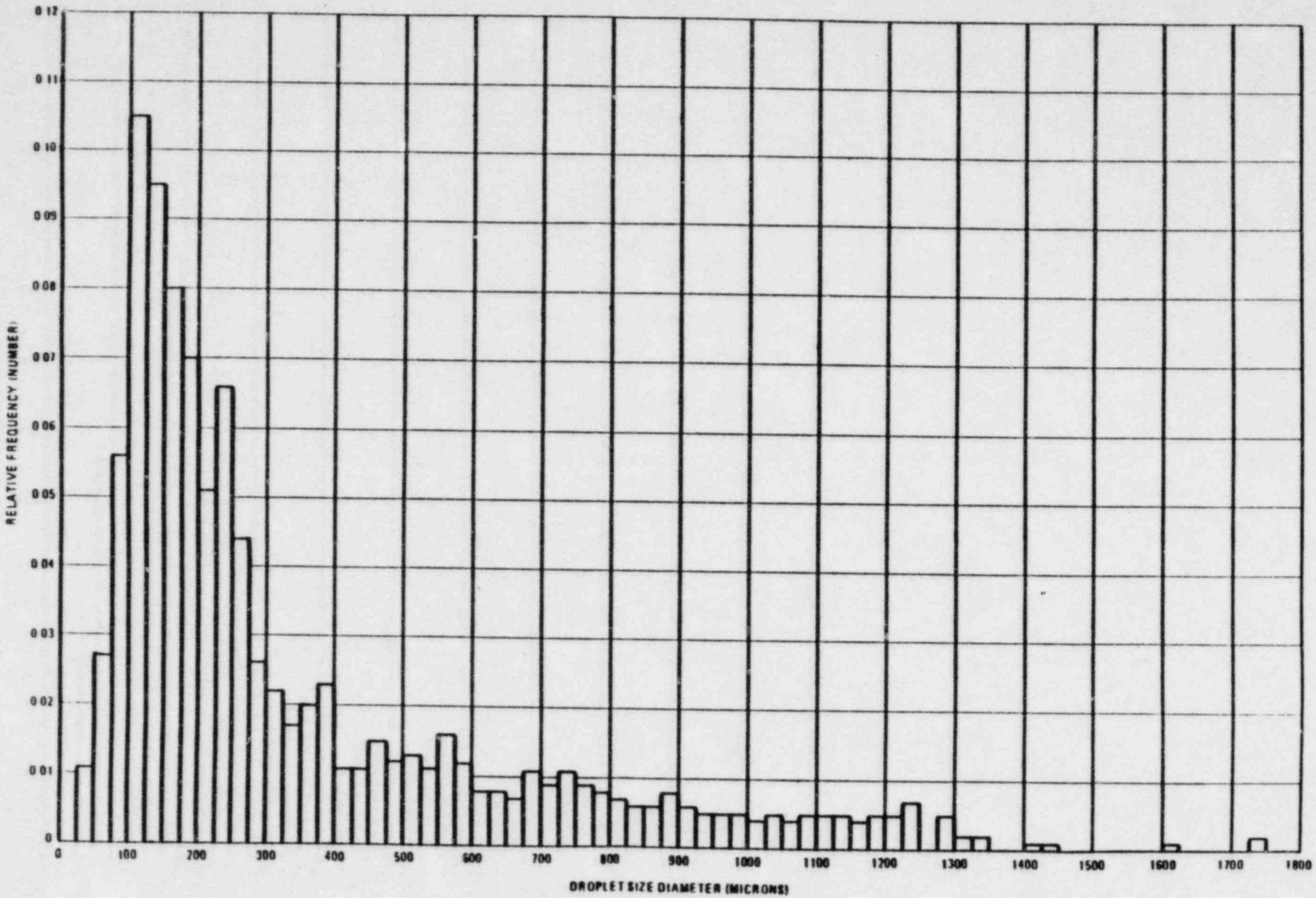


Figure 6.2.2-3 Mean Droplet Size Distribution

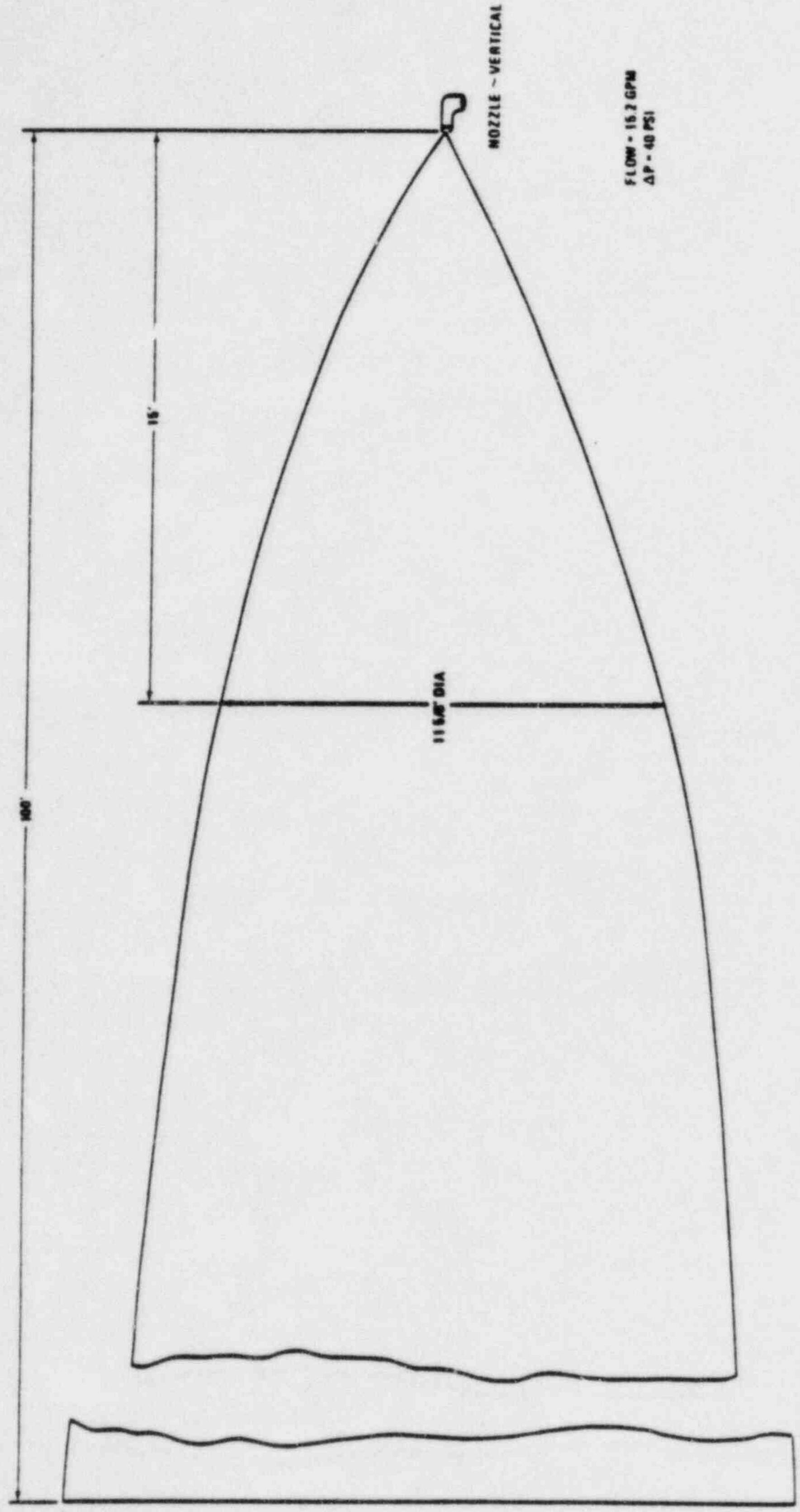
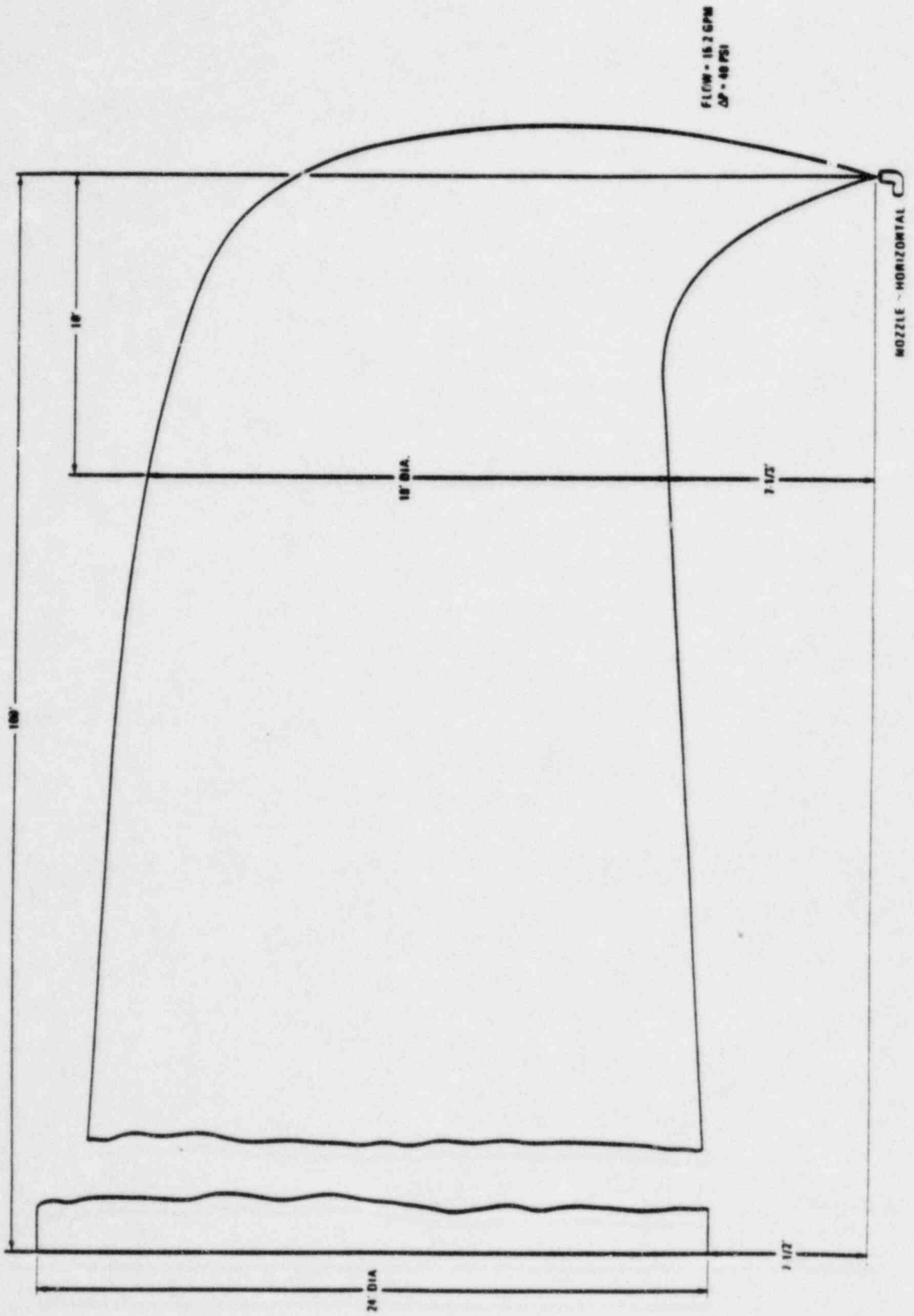


Figure 6.2.2-1 Nozzle Spray Pattern (Vertical)



FLOW = 15.2 GPM
ΔP = 40 PSI
NOZZLE - HORIZONTAL
18'
18' DIA.
7-1/2'
100'
7-1/2'
24' DIA.

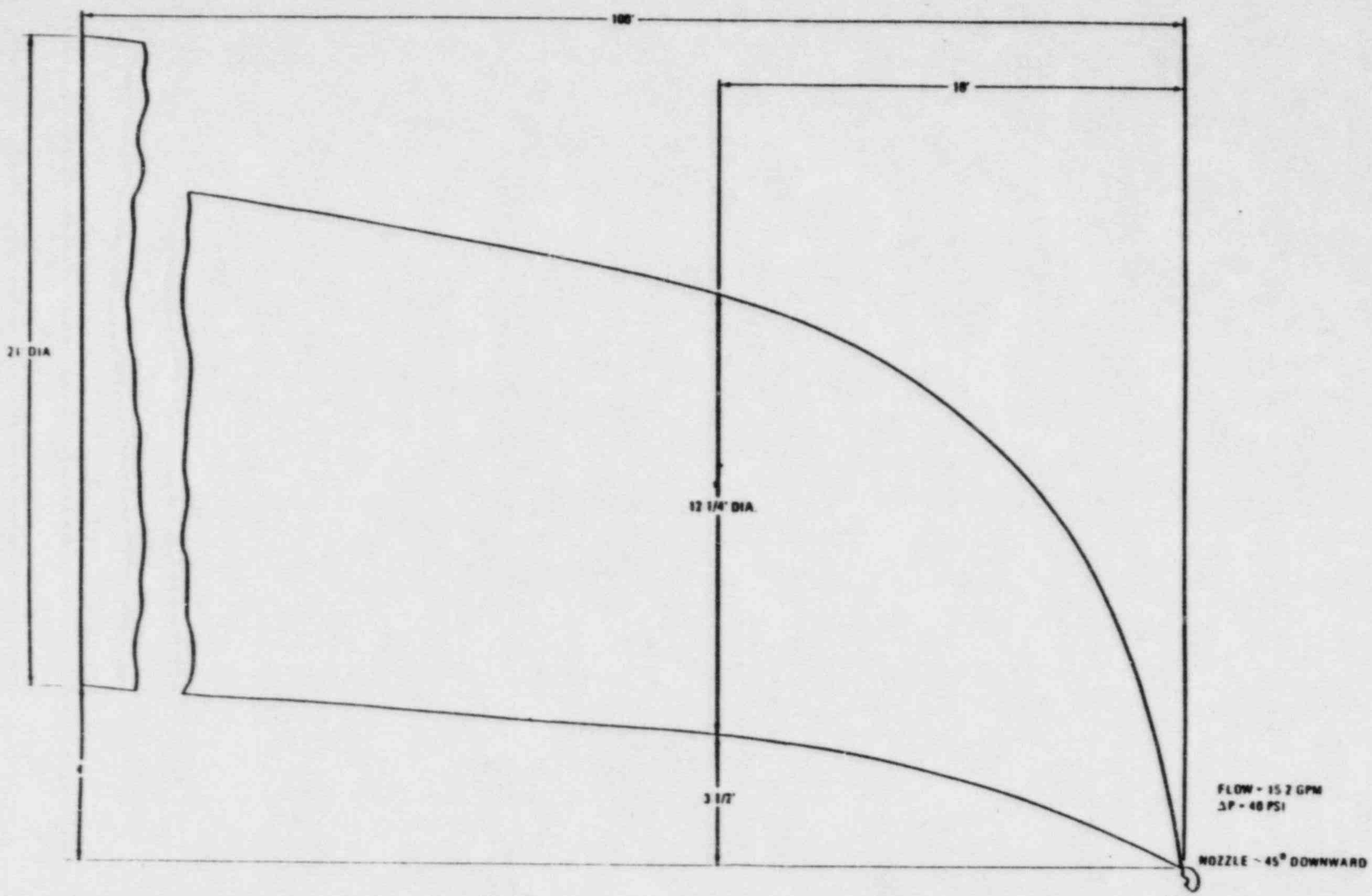


Figure 6.2.2-6 Nozzle Spray Pattern (Downward)

6.3 EMERGENCY CORE COOLING SYSTEM

6.3 1 Design Bases

The integrated safeguards system (ISS) is a safety related system which integrates the functions of the residual heat removal, emergency core cooling, and containment spray systems located in conventional nuclear power plants. It consists of high and low head pumps, residual heat removal heat exchangers, inside containment emergency water storage tank, accumulators, core reflood tanks, containment spray headers, and the associated valves, piping and instrumentation.

The primary functions of the ISS following an accident are to provide negative reactivity (boron) to bring the reactor subcritical; to provide RCS inventory control; to remove the stored and fission product decay heat from the reactor core such that fuel rod damage is prevented, to the extent that it would impair effective cooling of the core, and to reduce containment pressure, thereby preventing a breach of containment integrity and subsequent release of radioactive products to the environment.

The emergency core cooling portion of the ISS is designed to cool the reactor core as well as to provide additional shutdown capability following initiation of the following accidents:

a. Loss of reactor coolant accident (LOCA) including a pipe break or a spurious relief or safety valve opening in the reactor coolant system (RCS) which would result in a discharge larger than that which could be made up by the normal makeup system.

b. Loss of secondary coolant accident including a pipe break or a spurious relief, dump, or safety valve opening in the steam system which would result in an uncontrolled steam release or a pipe break in the feedwater system.

c. Loss of secondary side heat removal capability due to failure of all secondary side normal and safeguards systems.

d. Steam generator tube rupture accident.

The acceptance criteria for the consequences of each of these accidents is described in Chapter 15 in the respective accident analyses sections. (Note: consequences of steam break accidents are affected not only by the primary side safeguards but also by the secondary side safeguards. Refer to Chapter 15 of the "Secondary Side Safeguard" module for this accident analyses. For the steam generator tube failure analysis refer to the "Reactor Coolant System" module.

The bases used in design and for selection of ECCS functional requirements are derived from Appendix K, "Limits for Fuel Cladding Temperature," etc. following any of the above accidents as delineated in 10CFR50.46. The subsystem functional parameters are selected so that, when integrated, the Appendix K requirements are met over the range of anticipated accidents and single failure assumptions.

The reliability of the ECCS has been considered in selection of the functional requirements, selection of the particular components, and location of components and connected piping. Redundant components are provided where the loss of one component would impair reliability.

Redundant sources of the safety injection actuation signal are available so that the proper and timely operation of the ECCS will be ensured. Sufficient instrumentation is available so that a failure of an instrument will not impair readiness of the system. The active components of the ECCS are powered from separate buses which are energized from offsite power supplies. In addition, redundant sources of auxiliary onsite power are available through the use of the emergency diesel generators to ensure adequate power for all ECCS requirements. Each generator is capable of driving all pumps, valves, and necessary instruments associated with each of the four mechanical trains of the ECCS (in a four electrical train design) or two of the four mechanical trains (in a two electrical train design).

All valves required to be actuated during ECCS operation are either located to prevent vulnerability to flooding or are evaluated to ensure the consequences are acceptable. The multi-train design of the ECCS in conjunction with power removal features for certain valves provides protection against repositioning of valves due to spurious actuation coincident with an accident.

Protection of the ECCS from missiles is discussed in Section 3.5 of the "Structural/Equipment Design" module. Protection against dynamic effects associated with ruptures of piping is described in Section 3.6 and protection from flooding is discussed in Section 3.4 also of the "Structural/Equipment Design" module.

The elevated temperature of the emergency water storage tank solution during recirculation is well within the design temperature of all ECCS components. In addition consideration has been given to the potential for corrosion of various types of metals exposed to the fluid conditions prevalent immediately after the accident or during long term recirculation operations.

The environmental qualification of active ECCS equipment is discussed in Section 3.11 of the "Structural/Equipment Design" module.

6.3.2 System Design

6.3.2.1 Schematic Piping and Instrumentation Diagrams

Piping and instrumentation diagrams for the ISS are shown in Figure 6.3-1 (sheets 1 through 7) and Figure 6.3-2. These diagrams show the relative location of ECCS components and subsystems, where these components and subsystems tie together into the reactor coolant system, and instrumentation and controls associated with component and subsystem actuation. Table 6.3-1 provides a list of parameters which interface with other systems of the WAPWR Nuclear Power Block.

Component interlocks used in the different modes of system operation are as follows:

a) The Safety Injection Signal ("S") initiates the following actions:

   a. Emergency diesel generators start

   b. High head pumps start

   c. Accumulator discharge isolation valves open (if closed) (8949A, B, C, D)

   d. Core reflood tank discharge isolation valves open (if closed) (9097A, B, C, D)

   e. ISS full flow test line isolation valves close (if open) (8813A, B, C, D and 8814A, B, C, D)

   f. Accumulator fill-line isolation valves close (if open) (8823A, B)

b) The following normally closed, air operated containment isolation valves receive a confirmatory Containment Isolation Phase A Signal ("T").

   a. Accumulator nitrogen header isolation valve (8880)

   b. Core reflood tank nitrogen header isolation valve (9072)

   c. Check valve test-line isolation valves (8871 and 8964)

c) The Containment Isolation Phase B Signal ("P") initiates the following actions:

   a. Low head pumps start

   b. Containment spray header isolation valves open (9011A, B, C, D)

   c. The redundant containment spray header isolation valves open (if closed) (9009A, B, C, D)

d) Interlocks

Interlocks are provided to automatically open the accumulator and core reflood tank discharge isolation valves whenever the RCS pressure increases above the safety injection unblocking pressure. This feature allows for the inservice inspection requirement for valve stroke testing during power operations.

Interlocks are provided to automatically open the normally closed RHR heat exchanger/component cooling water isolation valves in the event that actuation signals are generated by both the safeguards protection logic ("S" signal) and the high head pump discharge header temperature protection logic (temperature elements TE-866, 867, 868 and 869). The high head pump discharge header temperature protection logic consists of one temperature element, located in each of the high head pump discharge headers, which provides a temperature signal to a corresponding single, normally de-energized temperature channel bistable. Each temperature channel is assigned to a separate protection channel set. The protection channel set, assigned to a given temperature channel, is powered by the same emergency electrical power train that the corresponding ECCS subsystem is assigned to. A temperature actuation signal would be generated when a temperature channel bistable receives a temperature signal higher than a predetermined temperature setpoint (approximately 195°F).

Additional interlocks similar to these are provided to automatically open the normally closed RHR heat exchanger/component cooling water isolation valves in the event that actuation signals are generated by the low head pump discharge header temperature protection logic (temperature elements TE-912, 913, 914 and 915).

Additional interlocks are used within the ISS to ensure proper valve alignment for normal RHR cooldown operations and to ensure proper valve alignment for the ISS standby mode during startup. These interlocks are described in Section 5.4.7.2.1.

6.3.2.2 Equipment and Component Descriptions

The ECCS consists of four identical and separate mechanical subsystems, which are powered from either two or four separate and redundant emergency electrical power trains, and receive actuated signals from either two or four separate and redundant actuated cabinets.

The basic ECCS configuration consists of:

a. Four pumping modules each containing one high head and one low head pump.

b. An emergency water storage tank (EWST) located inside the containment building.

c. Four accumulators

d. Four core reflood tanks

e. Four residual heat removal (RHR) heat exchangers.

The accumulators, core reflood tanks, and RHR heat exchangers are located inside the containment building. It is proposed that the four pumping modules be housed in containment pressure pump enclosures (CPPE) in order to encompass all piping and components associated with any post-accident recirculation of highly radioactive fluid within a containment boundary. This total encapsulation concept for the ECCS eliminates the potential for post-accident releases of highly radioactive liquid or gases into the auxiliary building and subsequently into the environment.

The four pumping modules, are totally independent and identical to each other. The ECCS concept recommends that two of the modules be located adjacent to the containment 180 degrees apart from the other two modules. This arrangement is shown schematically in Figure 6.3-3. Each pumping module contains one low head pump, one low head pump miniflow heat exchanger, one high head pump and the associated piping and valves necessary for these pumps to perform their intended safety functions.

The four high head pumps are the primary ECCS pumps. In the event that a safety injection ("S") signal were initated, these pumps would start automatically and inject coolant directly into the reactor vessel downcomer. Each high head pump is aligned to take suction from the Emergency Water Storage Tank (EWST) located inside the containment and to deliver directly to the reactor vessel. All valves in this flow path are normally open. Therefore, the only action required to establish emergency core cooling is the automatic starting of the high head pumps. There are no piping interconnections between these four separate high head subsystems. The four high head pumps are sized such that one high head pump provides sufficient injection flow to prevent core uncovery for small LOCAs up to at leas. 6 inch diameter break size.

Each high head pumping system is provided with the normally closed flow path to a corresponding RCS hot leg. Several hours after a LOCA all ECCS pumping systems could be temporarily realigned for hot leg recirculation to ensure termination of boiling within the core.

In the event of a steam break accident the high head pumps inject borated water into the Reactor Coolant System (RCS) with sufficient shutdown reactivity to compensate for the change in the RCS volume and counteract any reactivity increase caused by the resulting system cooldown. The high head pumps would continue injecting borated water following a steam break until the initial RCS volume had been reestablished with borated water to prevent the possibility of a return to criticality.

The EWST provides a continuous suction source for the high and low head pumps thus eliminating the realignment from a conventional plant Refueling Water Storage Tank (RWST) to the containment sump. In the event of any LOCA, the coolant spills to the EWST thus establishing a continuous recirculation path between the EWST, the high head pumps, and the RCS. Since the EWST is located inside the containment, the initial EWST water temperature is approximately 100°F compared to the minimum 32°F RWST temperature which can exist in a conventional plant, thereby reducing the potential for thermal shock to the RCS. The conventional realignment from the 32°F RWST water temperature to a maximum 300°F containment sump water temperature imposes a thermal transient on the safety injection equipment, which has been essentially eliminated by the EWST arrangement.

The four accumulators are primarily responsible for rapidly refilling the reactor vessel lower plenum and downcomer following a major blowdown of the RCS that would occur with a large or intermediate LOCA. The accumulator represent passive injection subsystems which deliver coolant to the RCS via the four RCS cold legs. The accumulators are high pressure, low resistance, high flow systems.

The four core reflood tanks provide a diverse/passive means to reflood or supplement the reflooding of the core thus eliminating the need for large capacity low head safety injection pumps. The core reflood tanks represent passive injection subsystems which deliver coolant to the RCS via the four reactor vessel injection nozzles. These passive subsystems are low pressure, high resistance, low flow systems. Since the core reflooding phase occurs over a finite time period and imposes the largest flow requirement on the safeguards pumps, the core reflood tanks provide a means to reduce the flow requirement on the pumping system as well as provide a diverse and passive means to meet the large break LOCA functional requirement. The four core reflood tanks and the four high head pumps provide eight (8) separate means for injecting coolant directly into the reactor vessel. Any combination of five of these eight entities are sufficient to meet the large break LOCA functional requirements.

One RHR heat exchanger is installed in each of the four high pressure injection headers that are routed from the four high head pumps to the four reactor vessel ISS injection nozzles. These high pressure heat exchangers are located inside the containment building. In the event of a LOCA, these heat exchangers are available to remove heat from the EWST recirculation water regardless of the break size since they are located in the high head pump flow path to the reactor vessel.

Pertinent design and operating parameters for ECCS components are given in Table 6.3-2.

The component design and operating conditions are specified as the most severe conditions to which each respective component is exposed, during either normal plant operation or operation of the ECCS following any postulated event. For each component, these conditions are considered in relation to the code to which it is designed. By designing the components in accordance with applicable codes, and with due consideration for design and operating conditions, the fundamental assurance of structural integrity and operability of the components is maintained. Components of the ECCS are designed to withstand the appropriate seismic loadings, in accordance with their safety class. All discharge piping is water solid during plant operation. Thus water hammers in the injection lines are precluded.

The elevated temperature of the sump solution during recirculation is well within the design temperature of all ECCS components. In addition, consideration has been given to the potential for corrosion of various types of metals exposed to the fluid conditions prevalent immediately after the accident or during long-term recirculation operations.

The following is a discussion of the major components of the ECCS.

6.3.2.2.1 High Head Pumps

Each high head pump could be either a multistage, vertical or horizontal centrifugal pump driven by an air or water cooled induction motor. The primary function of these pumps is to provide a high pressure source of coolant to the RCS in the event of a LOCA or a steam line break accident. In conjunction with an emergency RCS depressurization capability, they provide a bleed and feed means for emergency core cooling in the event of a loss of secondary side heat removal capability. These pumps also provide a bleed and feed means to emergency borate the RCS to cold shutdown concentration in conjunction with an emergency letdown path. A secondary function of these pumps is to provide a means for filling or adding borated water to the four accumulators and the four core reflood tanks from the EWST.

These pumps are protected against extremely low flow or no flow operations by a normally open miniflow path, downstream of each pump, which permits the pump to recirculate a minimum flow back to the EWST, located inside the primary containment building. A containment isolation valve is located in each miniflow path, with power normally removed from the valve to prevent inadvertent closure.

The high head pumps are sized such that one high head pump provides sufficient injection flow to prevent core uncovery for small LOCA's up to at least 6 inch diameter break size.

Analyses are performed to determine the net positive suction head (NPSH) available from the EWST. These analyses consider elevation head and piping losses, with no credit taken for containment overpressure. Consequently, this approach meets the regulatory position stated in Regulatory Guide 1.1.

Design parameters for the high head pumps are provided in Table 6.3-2. A pump performance curve is provided in Figure 6.3-4.

6.3.2.2.2 <u>Low Head Pumps</u>

Each low head pump could be either a multistage vertical or horizontal centrifugal pump driven by an air or water cooled induction motor. The primary function of these pumps is to recirculate coolant through the core and through the RHR heat exchangers during plant cooldown and plant shutdown operations. During these operations the low head pumps are aligned to take suction from the RCS hot legs and to deliver to the reactor vessel injection nozzles. In the event of a large-break LOCA or a steam line break accident these pumps function as containment spray pumps and take suction from the EWST and deliver to the containment ring headers. The low head pumps are sized such that one low head pump provides approximately [ ] (a,c)
containment pressure, therefore two of the four low head pumps are required to meet the [ ] gpm spray design flow rate. If spray recirculation is not (a,c)
required during a long-term post-accident core cooling phase, the pumps can be aligned for direct vessel injection and can perform a long-term emergency core cooling recirculation function. The pumps can also be used to return the refueling water from the refueling canal back to the EWST prior to the plant startup operations.

The pumps are protected against extremely low flow or no flow operation by a miniflow path in conjunction with a miniflow heat exchanger in parallel with each pump. A flow path from the discharge header of each pump is routed to the miniflow heat exchanger and from the miniflow heat exchanger to the pump suction. The shell sides of the miniflow heat exchangers are connected to the component cooling water system.

Like the high head pumps, analyses are performed to determine the NPSH available to these pumps from the EWST in accordance with Regulatory Guide 1.1.

Design parameters for the low head pumps are provided in Table 6.3-2. A pump performance curve is provided in Figure 6.3-5.

6.3.2.2.3 Accumulators

One accumulator is provided for each of the four RCS cold legs. The accumulators are partially filled with borated water and pressurized with nitrogen gas. The four accumulators are provided primarily for the purpose of delivering a large flow rate of borated water to the reactor vessel in the event of a rapid depressurization of the RCS following a large RCS pipe rupture. This large flow rate would initiate the refilling of the reactor vessel and a reflooding of the core. The accumulators are also effective in providing sufficient water to recover the core in the event of a slower depressurization of the RCS following a smaller RCS break.

During normal operations, the accumulator discharge isolation valves are normally open; therefore, each accumulator is isolated from the RCS by two check valves in series. Should the RCS pressure decrease below the normal accumulator pressure, the pressurized nitrogen gas contained in the accumulator would expand, forcing the borated water from the accumulator through the check valves and into the RCS.

The time after the accident and the rate at which borated water is ejected from the accumulators and into the RCS are dictated by the depressurization rate of the RCS which is a function of the break size.

It is assumed that in the event of any LOCA the entire water volume of one accumulator spills directly to the containment through the postulated break in one of the RCS cold legs. It is further assumed that all the water injected into the RCS during the blowdown phase following the double-ended rupture of a RCS cold leg is also lost to the containment. Therefore, only the water volume remaining in three of the four accumulators following the RCS blowdown is available for refilling the reactor vessel lower plenum and downcomer and for initiating the reflooding of the core.

The accumulator gas volume is fixed by the water volume setpoint. The accumulators are initially pressurized from a remote nitrogen supply and are normally isolated from that supply during normal operations. The accumulator pressure can be adjusted, as required, during normal plant operation. Relief valves are provided on each accumulator to prevent overpressurization. Connections that are provided for initially filling the accumulators are also used for remotely adjusting the water level and boron concentration during normal plant operations, as required. A line is provided from the discharge of two high head pumps to the common accumulator fill line for the purpose of adding water to the accumulators from the EWST while they are at their normal pressure.

Water can be removed from the accumulators by opening the appropriate valves in the test line and permitting flow to return to the EWST. Periodic checks of the accumulator boron concentration are made through the sampling system.

Redundant level and pressure indicators are provided on each accumulator with readouts on the main control board. Each indicator is equipped with high and low-level alarms. The margin between the minimum operating pressure or level and the maximum operating pressure or level provides a range of acceptable operating conditions. The band width is sufficient to minimize the frequency of adjustments in the accumulator pressure or level required to compensate for leakage.

The design parameters for the accumulators are provided in Table 6.3-2.

6.3.2.2.4 Core Reflood Tanks (CRTs)

Four core reflood tanks are provided, with the discharge line of each tank connected to one of the four reactor vessel injection nozzles. The four core reflood tanks are provided primarily for the purpose of supplementing the high head pumps injection flow rate during the post-accident core reflood phase when the largest core reflood rate demand occurs. It should be noted that there are many similarities between the core reflood tanks and the accumulators.

The core reflood tanks are partially filled with borated water and pressurized with nitrogen gas. During normal operations, the core reflood tank isolation valves are normally open; therefore, each core reflood tank is isolated from the RCS by two check valves in series. Should the RCS pressure decrease below the normal core reflood tank pressure, the pressurized nitrogen gas contained in the core reflood tank would expand, forcing the borated water from the core reflood tank through the check valves and into the RCS.

The time after the accident and the rate at which borated water is ejected from the core reflood tanks and into the RCS are dictated by the depressurization rate of the RCS which is a function of the break size, the flow restricting orifice in the discharge header of each core reflood tank, the initial core reflood tank pressure and the core reflood tank gas volume. The core reflood tank discharge headers are high resistance lines compared to the low resistance accumulator discharge headers.

The core reflood tank gas volume is fixed by the water volume setpoint. The core reflood tanks are initially pressurized from a remote nitrogen supply and are normally isolated from that supply during normal operations. The core reflood tank pressure can be adjusted, as required, during normal plant operation. Relief valves are provided on each core reflood tank to prevent overpressurization. Connections that are provided for initially filling the core reflood tanks are also used for remotely adjusting the water level and boron concentration during normal plant operations, as required. A line is provided from the discharge of two high head pumps to the common accumulator fill line for the purpose of adding water to the core reflood tanks from the EWST while they are at their normal operating pressure.

Water can be removed from the core reflood tanks by opening the appropriate valves in the test line and permitting flow to return to the EWST. Periodic checks of the core reflood tank boron concentration are made through the sampling system.

Redundant level and pressure indicators are provided on each core reflood tank with readouts on the main control board. Each indicator is equipped with high and low-level alarms. The margin between the minimum operating pressure or level and the maximum operating pressure or level provides a range of acceptable operating conditions. The band width is sufficient to minimize the frequency of adjustments in the accumulator pressure or level required to compensate for leakage.

The design parameters for the core reflood tanks are provided in Table 6.3-2.

6.3.2.2.5 Emergency Water Storage Tank (EWST)

The EWST is located at the lower elevation inside the containment building and provides a continuous suction source for the high and low head pumps, thereby eliminating the switchover from injection to recirculation. The EWST and loop compartments would be arranged to minimize the containment cleanup in case of minor accidents, such as reactor coolant pump seal failure or instrument line breaks. Any discharge from the pressurizer relief tank should also be routed to this tank. The required water volume depends on the Refueling Canal Volume which is not expected to exceed [ ] gallons. (a,c)

Analyses are performed to determine the minimum water level in the EWST during recirculation. These analyses consider the amount of water trapped in lower containment compartments and the delay time for water to return to the EWST.

The design parameters for the EWST are provided in Table 6.3-2.

6.3.2.2.6 Residual Heat Removal (RHR) Heat Exchangers

Four RHR heat exchangers are provided, with one RHR heat exchanger assigned to each of the four subsystems. Each exchanger is sized to remove [ ] percent of (a,c) the design residual heat load. These heat exchangers are installed vertically and are located inside the primary containment building. They are shell and U-tube designs with two tube passes. The tubes are designed for a maximum pressure of [ ] psig and the shell for [ ] psig. (a,c)

Normally the RHR heat exchangers are in the direct flow path between the high head pumps and reactor vessel injection nozzles. In the event of a LOCA, the high head pumps would recirculate borated water from the EWST through the RHR heat exchangers and into the reactor vessel. When the EWST water temperature increases to approximately 195°F, the component cooling water flow path to the RHR heat exchanger shell would be opened automatically to transfer heat from the containment to the ultimate heat sink. During normal residual heat removal cooling operation the low head pumps recirculate reactor coolant through the tube side of these heat exchangers. Heat is transferred from the reactor coolant to the component cooling water that is pumped through the shell side of the RHR heat exchanger by the component cooling water system.

The design parameters for these RHR heat exchangers are provided in Table 6.3-2.

6.3.2.2.7 Low Head Pump Miniflow Heat Exchangers

A heat exchanger is provided in the miniflow line of each of the four low head pumps to protect the pumps from potential damage in the event they were operated for extended periods of time with all discharge flow paths blocked. Miniflow from the pump discharge passes through the tube side of the heat exchanger before returning to the pump suction. Component cooling water is recirculated through the shell of each heat exchanger to transfer the heat from the coolant to the ultimate heat sink.

The design parameters for the miniflow heat exchangers are provided in Table 6.3-2.

6.3.2.2.8 Valves

Design features employed to minimize valve leakage include:

a. Where possible, packless valves are used.

b. Other valves which are normally open, except check valves and those which perform a control function, are provided with backseats to limit stem leakage.

c. Normally closed globe valves are installed with recirculation fluid pressure under the seat to prevent stem leakage of recirculated (radioactive) water.

d. Relief valves are enclosed, i.e., they are provided with a closed bonnet.

Motor-Operated Gate Valves

The seating design of all motor-operated gate valves is of the crane flexible wedge design. These designs release the mechanical holding force during the first increment of travel so that the motor operator works only against the frictional component of the hydraulic unbalance on the disc and the packing box friction. The discs are guided throughout the full disc travel to prevent chattering and to provide ease of gate movement. The seating surfaces are hard faced to prevent galling and to reduce wear.

Where a gasket is employed for the body to bonnet joint, it is either a fully trapped, controlled compression, spiral wound asbestos gasket with provisions for seal welding, or it is of the pressure seal design with provisions for seal welding. The valve stuffing boxes are designed with a lantern ring leakoff connection with a minimum of a full set of packing below the lantern ring and a minimum of one-half of a set of packing above the lantern ring. A full set of packing is defined as a depth of packing equal to 1-1/2 times the stem diameter.

The motor operator incorporates a "hammer blow" feature that allows the motor to impact the discs away from the backseat upon opening or closing. This "hammer blow" feature not only impacts the disc but allows the motor to attain its operational speed prior to impact.

Manual Globe, Gate and Check Valves

Gate valves are either wedge design or parallel disc and are straight through. The wedge is either split or solid. All gate valves have backseat and outside screw and yoke.

Globe valves, "T" and "Y" style are full ported with outside screw and yoke construction.

Check valves are spring loaded lift piston types for sizes 2 inches and smaller, swing type for sizes 2-1/2 inches to 4 inches and tilting disc type for sizes 4 inches and larger.

Stainless steel check valves have no penetration welds other than the inlet, outlet and bonnet. The check hinge is serviced through the bonnet.

The stem packing and gasket of the stainless steel manual globe and gate valves larger than 2 inches are similar to those described above for motor-operated valves. Carbon steel manual valves are employed to pass non-radioactive fluids only and therefore do not contain the double packing and seal weld provisions.

Accumulator/CRT Check Valves (Swing-disc)

The accumulator/CRT check valves are designed with a low pressure drop configuration with all operating parts contained within the body.

During normal operation the check valves are in the closed position with a nominal differential pressure across the disc of approximately 1650 psi (accumulators) and 2050 psi (CRTs). Since the valves remain in this position except for testing or when called upon to open following an accident, and are therefore not subject to the abuse of flowing operation or impact loads caused by sudden flow reversal and seating, they do not experience significant wear of the moving parts, and are expected to function with minimal back-leakage. This back-leakage can be checked via the test connection as described in subsection 6.3.4.

Relief Valves

Relief valves are installed in various sections of the ECCS to protect lines which have a lower design pressure than the RCS. The valve's stem and spring adjustment assembly are isolated from the system fluids by a bellows seal between the valve disc and spindle. The closed bonnet provides an additional barrier for enclosure of the relief valves. Table 6.3-3 lists the system relief valves with their capacities and setpoints.

Accumulator/CRT Motor-Operated Valve Controls

As part of the plant shutdown administrative procedures, the operator is required to close these valves. This prevents a loss of accumulator/CRT water inventory to the RCS and is done after the RCS has been depressurized below the safety injection unblock setpoint. The redundant pressure and level alarms on each accumulator/CRT would remind the operator to close these valves if they were inadvertently left open. Power is disconnected after the valves are closed.

During plant startup, the operator is instructed, via procedures, to energize and open these valves when the RCS pressure reaches the safety injection unblock setpoint. Monitor lights in conjunction with an audible alarm will alert the operator should any of these valves be left inadvertently closed once the RCS pressure increases beyond the safety injection unblock setpoint. Power is disconnected after the valves are opened.

The accumulator/CRT isolation valves are not required to move during power operation or in a post-accident situation.

The accumulator/CRT isolation valves receive an "S" signal to ensure that they are open in the event of an accident which initiates safety injection.

For further discussions of the instrumentation associated with these valves refer to subsection 6.3.5.

6.3.2.3 Applicable Codes and Classifications

Codes and classifications applicable to the ECCS are delineated in Section 3.2. Conformance to General Design Criteria specified in Appendix A to 10CFR50 is discussed in Section 3.1.

6.3.2.4 Material Specifications and Compatability

Materials employed for engineered safety feature (ESF) components are discussed in section 6.1. Materials for ISS components are selected to meet the applicable material requirements of the codes in Section 3.2 and the following additional requirements:

a. All parts of components in contact with borated water are fabricated of or clad with austenitic stainless steel or equivalent corrosion resistant material.

b. All parts of components in contact (internal) with sump solution during recirculation are fabricated of austenitic stainless steel or equivalent corrosion resistant material.

c. Valve seating surfaces are hard faced with Stellite Number 6 or equivalent to prevent galling and to reduce wear, except soft seat valves - i.e., accumulator gas supply/isolation valves.

d. Valve stem materials are selected for their corrosion resistance, high tensile properties, and resistance to surface scoring by the packing.

6.3.2.5 System Reliability

Reliability of the ECCS is considered in all aspects of the system from initial design to periodic testing of the components during plant operation. The ECCS is a fully redundant safety-related system with a mechanical subsystem design powered by either 2 or 4 electrical power trains. The system has been designed and proven by analysis to withstand any single credible active failure during injection or any single active or passive failure during recirculation or operator error and maintain the performance objectives desired in subsection 6.3.1. Separate trains of pumps, heat exchangers and flow paths are provided for redundancy. The initiating signals for the ECCS are derived from independent sources as measured from process (e.g, pressurizer low pressure) or environmental (e.g, containment high pressure) variables. Redundant as well as functionally independent variables are measured to initiate the Safeguards signal. Each train is physically separated and protected where necessary so that a single event cannot initiate a common failure. Power sources are divided into independent trains supplied from the separate emergency buses supplied from offsite power. Sufficient diesel generating capacity is maintained on site to provide required power to each train. The diesel generators and their auxiliary systems are completely independent and dedicated to one or two of the trains.

The preoperational testing program ensures that the systems as designed and constructed will meet the functional requirements as calculated in design. The ECCS is designed with the ability for on-line testing of most components so the availability and operational status can be readily determined. In addition to the above, the integrity of the ECCS is ensured through examination of critical components during the routine inservice inspection.

The reliability program extends to the procurement of ECCS components such that only designs which have been proven by past use in similar applications are acceptable for use. The quality assurance program as described in Chapter 17 ensures receipt of components only after manufacture and test to the applicable codes and standards.

6.3.2.5.1 Active Failure Criteria

The failure of a powered component, such as a piece of mechanical equipment, component of the electrical supply system or instrumentation and control equipment, to act on command to perform its design function is considered an active failure. Examples include the failure of a motor-operated valve to move to its correct position, the failure of an electrical breaker or relay to respond, the failure of a pump, fan, or diesel generator to start, etc.

The failure mode and effects analysis (FMEA; provided in Table 6.3-4,) demonstrates the ability of the ECCS to withstand any single active failure. The analysis illustrates that the ECCS can sustain an active failure in either the short or long term and still meet the required level of performance for core cooling.

Since the short term operation of the active components of the ECCS following a secondary side rupture or a steam generator tube rupture is similar to that following a LOCA, the same analysis is applicable and the ECCS can sustain the failure of any single active component and still meet the level of performance for the addition of shutdown reactivity.

6.3.2.5.2 Passive Failure Criteria

The structural failure of a static component that limits the components's effectiveness in carrying out its design long-term function is considered a passive failure. Examples include cracks in pipes, sprung flanges, valve packing leaks, or pump seal failures.

The four mechanical subsystems associated with the ECCS can sustain a single passive failure in one of the four subsystems and still provide three intact flow paths from the EWST to the direct vessel injection nozzles. Only one of the four subsystems is required during long term core cooling phase to maintain the core in a covered condition and effect the removal of decay heat.

6.3.2.5.3 Detection and Termination of Leaks

Means for collecting, detecting and terminating any post accident recirculation leakage are provided for the four subsystem modules located outside the primary containment building. Each of the four pumping modules are contained in totally separate safeguard component areas. These safeguard component areas are specifically dedicated to house all subsystem pumps, valves, piping and containment penetration which would be utilized to recirculate radioactive coolant during any normal cooldown or post accident recirculation process.

Any post accident recirculation leakage outside the containment building, would be contained within the individual safeguard component areas. Redundant leak detection devices are provided in each safeguards component area to alert the operator of any excessive leakage. Control room monitor and alarms are provided for each of these devices to provide the operator with a simple means for identifying which ISS subsystem is leaking and for verifying that the leak has been terminated once corrective action is taken.

The operator could terminate that leakage by stopping the pumps in the affected compartment and by closing the corresponding sump isolation and pump discharge valves. The safeguards component areas are designed such that any leakage in one compartment could have no impact on the equipment in the other three safeguards component areas. Further, the leakage in one compartment could not cause the actuation of the leak detection alarms associated with the other compartments.

The proposed containment pressure pump enclosures (CPPEs) are designed to perform all the functions of the safeguard component area with an additional internal design pressure requirement which is consistent with the containment design pressure. With each ISS pumping module housed in separate containment pressure pump enclosure (CPPE), the postulated post-accident release of liquid or gases into the adjacent auxiliary building and subsequently into the environment has essentially been eliminated.

Any post-accident or normal cooldown leakage would be totally contained by the proposed CPPEs. A small sump pit with two redundant safeguard sump pumps is provided in each enclosure. In the event of leakage inside the CPPE, the sump pumps would automatically start and pump the leakage back into the in-containment EWST. Redundant level, pressure and radiation instrumentation would provide the operator with precise diagnostic information with regard to the quantity of leakage and/or leakage rate.

Since the CPPEs provide a means for collecting and returning the leaking fluid to the containment, the operation of the leaking subsystem does not have to be immediately shutdown. If needed, this subsystem could be utilized to perform its safety function with little or no radiological impact. The CPPEs are designed to totally contain highly improbable nondesign base failures such as a major pipe rupture of any post accident or normal cooldown recirculation piping.

The provisions for leakage detection within the ECCS meet the recommendations of NUREG-0737, Item III.D.1.1.

6.3.2.5.4 Lag Times

Lag times for initiation and operation of the ECCS are limited by pump startup time and consequential loading sequences of these motors onto the safeguard buses. All valves are normally in the position conducive to safety; therefore, valve operation time is not considered for these valves. If there is no loss of offsite power, all pump motors and valve motors are loaded immediately onto the safeguard buses according to the sequencer. Safeguard pumps are capable of obtaining operating speed and rated flow within 5 seconds of receipt of the start signal. In the case of loss of offsite power, a delay is assumed for the diesel to start and to obtain operating speed and voltage prior to the safeguard pumps being sequenced onto the safeguard buses.

6.3.2.5.5 Potential Boron Precipitation

Boron precipitation in the reactor vessel is prevented by a backflush of water through the core. After ~ 24 hours the high head pumps would be aligned to provide injection flow directly into the hot legs. After several hours of hot leg recirculation, one or more of the high head pumps would be realigned to deliver directly into the reactor vessel injection nozzle, thus establishing a simultaneous flow to the reactor vessel downcomer and the RCS hot legs.

6.3.2.6 Protection Provisions

The provisions taken to protect the system from damage that might result from dynamic effects are discussed in Section 3.6. The provisions taken to protect the system from missiles are discussed in Section 3.5. The provisions to protect the system from seismic damage are discussed in Sections 3.7, 3.9 and 3.10. Thermal stresses on the RCS are discussed in Section 3.9. All of these sections are located in the "Structural/Equipment Design" module.

6.3.2.7 Provisions for Performance Testing

Full flow test lines are provided for performance testing which permits both the high and low head pumps to recirculate fluid from the EWST through the RHR heat exchangers and back to the EWST. This permits full flow testing of most of the ISS system as well as individual components. These test lines and instrumentation are shown in Figure 6.3-2. In addition, all pumps have miniflow lines for use in periodic operability testing. Additional information on testing can be found in paragraph 6.3.4.2.

6.3.2.8 Manual Actions

The ECCS requires no operator action during the short term (injection phase) following a large-break LOCA, other than monitoring the operation of the pumps.

In the event of a small-break LOCA, a slower RCS depressurization rate, which is a function of the break size, would occur. Should the leak rate be larger than that which could be made up by the CVCS through the normal charging path, an "S" signal would eventually be initiated automatically. Upon receipt of the "S" signal, the four high head pumps would start.

In the event that the LOCA was sufficiently small (and offsite power was available) such that the normal charging system could prevent the pressurizer from being emptied, the plant operator could initiate procedures for a normal cooldown prior to the initiation of the "S" signal. One of the first indications that there was a possible small-break would be a frequent or continuous makeup to the volume control tank from the reactor makeup control system, initiated by a volume control tank low-level signal. The next indication, depending on the size of the leak, would be a pressurizer low-level alarm that would automatically isolate the CVCS letdown line. If the pressurizer pressure and level continued to decrease after letdown isolation, the charging flow rate could exceed the reactor makeup control system makeup capacity; therefore, a volume control tank low-low-level signal would be initiated. This signal would automatically realign the suction of the charging pumps from the volume control tank to the spent fuel pit.

Following this type of small RCS leak, some indicated level in the pressurizer would be essential during any cooldown procedure initiated by the operator. The operator should therefore use the charging system to its maximum capability, if required, to maintain water in the pressurizer. Should the pressurizer level continue to decrease slowly until there were no level indication, the operator should initiate the "S" signal manually from the main control room.

6.3.2.8.1 Recirculation Phase

The actions required in a conventional nuclear power plant to realign the ECCS for long term, sump recirculation are not required for the WAPWR. Since the low and high head pumps take suction directly from the EWST located inside containment, no valve realignment or operator action is required for continuous emergency core cooling operation. The amount of water initially within the EWST is in excess of the amount required to provide adequate NPSH to the pumps, allowing for water holdup within the containment during recirculation.

6.3.2.8.2 Hot Leg Recirculation Phase

Approximately 24 hours after the accident, hot leg recirculation is initiated. The following manual operator actions are required to complete the switchover to a hot leg recirculation mode. It is assumed that both electrical power trains A and B are available and that the four high head pumps are operating. (No single failure has occurred).

a. Verify that the high head mini-flow valves are open (8824A, B, C, D)

b. Close the reactor vessel injection header isolation valves (8807A, B, C, D)

c. Open the hot-leg header isolation valves (8810A, B, C, D)

After completing the preceding procedures, the switchover to the hot leg recirculation mode will be accomplished. Each high head pump would be aligned to deliver flow directly to a corresponding RCS hot leg.

In the event that a single failure has resulted in a complete loss of power from one of the electrical power trains in conjunction with a LOCA and a loss of offsite power, the hot leg switchover procedures would be essentially the same as the preceding procedure. The operator could follow this procedure with the understanding that those valves without power do not have to be repositioned. As a result, for a two electrical train system only two of the four subsystems would by operating and delivering flow to two RCS hot legs. For a four electrical train system only three of the four subsystems would be operable.

After several hours of hot leg injection; one or more of the high head pumps would be realigned to deliver directly to the reactor vessel injection nozzles, thus establishing a simultaneous flow to the reactor vessel downcomer and the RCS hot legs.

6.3.3 Performance Evaluation

The ECCS provides protection from accidents as discussed in Section 6.3.1. The following discussion, supplemented by Chapter 15 analyses, provides a summary of system performance under the various accident conditions.

The Chapter 15 accidents that either result in or are affected by ECCS operation are as follows:

a. Increase in heat removal by the secondary system

1. Inadvertent opening of a steam relief or safety valve

2. Steam system piping failure

b. Decrease in heat removal by the secondary system

   1. Feedwater system pipe break

c. Decrease in reactor coolant system inventory

   1. Steam generator tube rupture

   2. Loss of coolant accident (LOCA) from a spectrum of postulated piping breaks within the system

   3. Spectrum of rod cluster control assembly (RCCA) ejection accidents

d. Increase in reactor coolant system (RCS) inventory

   1. Inadvertent operation of the ECCS during power operation.

Emergency core cooling system actuation may occur from any of the following:

a. Low pressurizer pressure signal

b. Low steamline pressure signal

c. High containment pressure

d. Manual actuation

Safety injection signal actuation will rapidly close all feedwater control valves and feedwater isolation valves, trip the main feedwater pumps, and close the feedwater pump discharge valves.

Further, the actuation signal will start the high head safety injection pumps. The pumps then pump 2,500 ppm borated water from the EWST directly to the reactor vessel.

6.3.3.1 Inadvertent Opening of a Steam Generator Relief or Safety Valve

Discussion

The most severe core conditions resulting from an accidental depressurization of the main steam system are associated with an inadvertent opening of a single steam dump, relief, or safety valve The results and conclusion of this analysis can be found in the Secondary Side Safeguards module.

6.3.3.2 Small Break Loss-of-Coolant Accident

Discussion

A LOCA is defined as a rupture of the RCS piping or of any line connected to the system from which the break flow exceeds the flow capability of the normal makeup/charging system. Ruptures of small cross sections will cause expulsion of the coolant at a rate which can be accommodated by the normal CVCS charging pumps which would maintain an operational water level in the pressurizer, permitting the operator to execute an orderly shutdown.

The maximum break size for which the normal makeup system can maintain the pressurizer level is obtained by comparing the calculated flow from the RCS through the postulated break against the charging pump makeup flow at normal RCS pressure (2,250 psia). A makeup flow rate from one normal CVCS charging pump is more than adequate to sustain pressurizer pressure at 2,250 psia for a
break of a [ ] inch diameter. This size break corresponds to a loss of RCS (a,c)
inventory of approximately [ ] lb/sec. (a,c)

The "S" signal stops normal feedwater flow by closing the main feedwater line isolation valves and initiates emergency feedwater flow. The analyses deal with breaks of less than 1.0 ft^2 in area, where the high head pumps play an important role in the initial core recovery because of the slower depressurization of the RCS.

Results and Conclusions

The analysis of these breaks has shown that the ECCS safety injection pumps together with accumulators, provide sufficient core flooding to keep the calculated peak clad temperature below required limits of 10CFR50.46. In addition, one high head pump provides sufficient injection flow to prevent core uncovery for small LOCAs up to a 6.0 inch break size. Hence, adequate protection is afforded by the ECCS in the event of a small break LOCA.

6.3.3.3 Large Break Loss of Coolant Accident

Discussion

A major LOCA is defined as a rupture 1.0 ft^2 or larger of the RCS piping including the double-ended rupture of the largest pipe in the RCS or of any line connected to that system.

Should a major break occur, depressurization of the RCS results in a rapid pressure decrease. Reactor trip occurs when the pressurizer low pressure trip setpoint is reached. The ECCS is also actuated when the appropriate pressurizer low pressure setpoint is reached. Reactor trip and safety injection system actuation may be provided by a high containment pressure signal depending on the actual break size. These countermeasures will limit the consequences of the accident in two ways:

a. Reactor trip and borated water injection provide additional negative reactivity insertion to supplement void formation in causing rapid reduction of power to a residual level corresponding to fission product decay heat.

b. Injection of borated water ensures sufficient flooding of the core to prevent excessive clad temperatures.

When the pressure falls below approximately 600 psig, the accumulators begin to inject borated water. When the RCS pressure decreases below the core reflood tank normal operating pressure (approximately 200 psig), the core reflood tanks would begin injecting borated water into the reactor vessel downcomer region. This flow rate would supplement the reflooding of the core. The conservative assumption is made that the water injected bypasses the core and goes out through the break until the expulsion or entrainment mechanisms responsible for the bypassing are calculated not to be effective. This conservatism is consistent with the acceptable features of ECCS evaluation models as defined by Appendix K, 10CFR50.

The pressure transient in the reactor containment during a LOCA affects ECCS performance in the following ways: the time at which end of blowdown occurs is determined by zero break flow which is a result of achieving pressure equilibrium between the RCS and the containment. In this way, the amount of water bypass is also affected by the containment pressure, since the amount of accumulator water discharged during blowdown is dependent on the length of the blowdown phase and RCS pressure at end of blowdown.

During the reflood phase of the transient, the density of the steam generated in the core is dependent on the existing containment pressure. The density of this steam affects the amount of steam which can be vented from the core to the break for a given downcomer head, the core reflooding process, and thus the ECCS performance. It is through these effects that containment pressure affects ECCS performance.

For breaks up to and including the double ended severance of a reactor coolant pipe, the ECCS will limit the clad temperature to below 2,200°F and assure that the core will remain in place and substantially intact with its essential heat transfer geometry preserved. Table 15.6.4-2 shows the ECCS sequence of events.

Results and Conclusions

For breaks up to and including the double-ended severance of a reactor coolant pipe, the ECCS will meet the acceptance criteria as presented in 10CFR50.46. That is:

a. The calculated peak fuel element clad temperature is less than 2,200°F

b. The amount of fuel element cladding that reacts chemically with water or steam does not exceed 1 percent of the total amount of Zircaloy in the reactor.

c. The clad temperature transient is terminated at a time when the core geometry is still amenable to cooling. The cladding oxidation limits of 17 percent are not exceeded during or after quenching.

d. The core temperature is reduced and decay heat is removed for an extended period of time, as required by the long-lived radioactivity remaining in the core.

6.3.3.4 Major Secondary System Pipe Failure

Discussion

The steam release from a rupture of a main steam pipe would result in an increase in energy removal from the RCS causing a reduction of coolant temperature and pressure. In the presence of a negative moderator temperature coefficient, the cooldown results in an insertion of positive reactivity. There is an increased possibility that the core will become critical and return to power A return to power following a steam pipe rupture is a potential problem; however, analysis demontrates that the core is ultimately shut down by the injected boric acid. .

Minimum capability for injection of boric acid (2,500 gpm) solution is assumed corresponding to the most restrictive single failure in the ECCS system. For the cases where offsite power is assumed to be available, the high head pumps are assumed to start immediately upon receipt of the "S" signal and to achieve full speed in five seconds. The water initially within the high head pump piping is assumed to be swept into the RCS (with no credit taken for its boron) before the 2,500 ppm water from the EWST reaches the core. For the cases where offsite power is assumed not to be available, an additional 10 second delay is assumed to start the diesels. The necessary ECCS equipment are then loaded onto the diesels according to the sequencer.

See the "Secondary Side Safeguards" module for the results and conclusions of this analysis.

6.3.3.5 Steam Generator Tube Failure

The accident examined is the complete severance of a single steam generator tube at power.

Assuming normal operation of the various plant control systems, the following sequence of events is initiated by a tube rupture:

a. Pressurizer low pressure and low level alarms are actuated and charging pump flow increases in an attempt to maintain pressurizer level. On the secondary side, there is a steam flow/feedwater flow mismatch before the trip as the feedwater flow to the affected steam generator is reduced due to the additional break flow which is now being supplied to that unit.

b. The steam generator blowdown liquid monitor and the condenser offgas radiaton monitor will alarm, indicating a sharp increase in radioactivity in the secondary system and will automatically terminate steam generator blowdown.

c. Continued loss of reactor coolant inventory leads to a reactor trip signal generated by low pressurizer level or over temperature ΔT. The "S" signal automatically terminates normal feedwater supply and initiates emergency feedwater addition. After reactor trip, the break flow reaches equilibrium at the point where incoming safety injection flow is balanced by outgoing break flow. The resultant break flow persists from plant trip until operator action is taken to bring the primary system and the faulted steam generator secondary system pressures into equilibrium.

d. The reactor trip automatically trips the turbine and, if offsite power is available, the steam dump valves open permitting steam dump to the condenser. In the event of a coincident station blackout, the steam dump valves would automatically close to protect the condenser. The steam generator pressure would rapidly increase resulting in steam discharge to the atmosphere through the steam generator safety and/or power operated relief valves.

See the "Reactor Coolant System" module for the results and conclusions of this analysis.

6.3.3.6 Feedwater System Pipe Break

Discussion

A major feedwater line rupture is defined as a break in a feedwater line large enough to prevent the addition of sufficient feedwater to the steam generators to maintain shell side fluid inventory in the steam generators. If the break is postulated in a feedwater line between the inside containment check valve and the steam generator, fluid from the affected steam generator may also be discharged through the break. Further, a break in this location could preclude the subsequent addition of emergency feedwater to the affected steam generator. (A break upstream of the feedwater line inside containment check valve would affect the nuclear steam supply system only as a loss of feedwater).

Depending upon the size of the break and the plant operating conditions at the time of the break, the break could cause either an RCS cooldown (by excessive energy discharge through the break) or an RCS heatup. Potential RCS cooldown resulting from a secondary pipe rupture is evaluated in Section 15.1.5. Therefore, only the RCS heatup effects are evaluated for a feedwater line rupture.

A feedwater line rupture reduces the ability to remove heat generated by the core from the RCS for the following reasons:

a. Feedwater flow to the steam generators is reduced. Since feedwater is subcooled, its loss may cause reactor coolant temperatures to increase prior to reactor trip.

b. Fluid in the steam generator may be discharged through the break, and would then not be available for decay heat removal after trip.

c. The break may be large enough to prevent the addition of any main feedwater after trip.

The secondary side safeguards system functions to ensure the availability of sufficient feedwater to the unaffected steam generators so that:

a. No substantial overpressurization of the RCS occurs (less than 110 percent of design pressures); and

b. Sufficient liquid in the RCS is maintain so that the core remains in place and geometrically intact with no loss of core cooling capability.

A safety injection signal from either low steamline pressure or high containment pressure initiates flow fo cold borated water into the RCS. The amount of ECCS flow is a function of RCS pressure.

The results and conclusions of this analysis can be found in the "Secondary Side Safeguards" module.

6.3.3.7 Inadvertent Operation of the Emergency Core Cooling System During Power Operation

Discussion

Spurious operation at power could be caused by operator error or a false electrical actuation signal. A spurious signal may originate from any of the safety injection actuation channels.

Following the actuation signal, the high head pumps will start automatically. However, since the shutoff head of the high head pumps is less than reactor coolant system (RCS) pressure, no flow will be delivered to the RCS. The passive accumulator injection system and the passive core reflood tanks also provide no flow at normal RCS pressure.

An "S" signal normally results in a reactor trip followed by a turbine trip. However, it cannot be assumed that any single fault that actuates ECCS will also provide a reactor trip. If a reactor trip is generated by as spurious signal, the operator should determine if the signal was transient or steady state in nature. For a spurious occurrence, the operator would terminate the high head pumps and maintain the plant in the hot shutdown condition. If a reactor trip does occur, the RCS pressure will remain above the shutoff head of the high head pumps so that no SI flow will be injected to the RCS.

Conclusions

Results of the analysis show that spurious ECCS operation without immediate reactor trip presents no hazard to the integrity of the RCS.

6.3.4 Tests and Inspections

6.3.4.1 ECCS Performance Tests

Preliminary operational testing of the ECCS can be conducted during the hot functional test of the RCS following flushing and hydrostatic testing, with the system cold and the reactor vessel head removed. Subsequent system performance testing can be conducted during each major fuel reloading operation with each subsystem aligned to take suction from the EWST and to deliver to the EWST via the system test line. Each pump can also inject into the reactor vessel, with the overflow from the reactor vessel spilling into the refueling canal. Simultaneously, the safety injection block switch is reset and the breakers on the lines supplying off site power are tripped manually so that operation of the emergency diesels is tested in conjection with the ECCS. This test should provide information including the following facets:

a. Satisfactory safety injection "S" signal generation and transmission.

b. Proper operation of the emergency diesel generators, including sequential load pickup.

c. Pump starting times.

d. Pump delivery rates.

Separate flow tests of the low head and high head pumps should be conducted during any system performance test operation to verify the pump head/flow characteristics. In addition, these tests are required to establish/verify flows in conjunction with the required pump discharge flow rates for both the reactor vessel injection and hot leg injection modes of operation. During these tests, the pumps are aligned to take suction from the EWST and to discharge into the reactor vessel through the injection lines. More specifically, the system performance tests are required to ensure that the appropriate sized flow-restricting orifice plates are installed in the high head pump miniflow lines and the high head and low head pump discharge headers.

Each accumulator and core reflood tank is filled with water from the and pressurized with nitrogen with the motor-operated valve on the discharge line closed. The valve is opened and the accumulator and core reflood tank allowed to discharge into the reactor vessel as part of the operational startup testing with the reactor vessel head off.

6.3.4.2 Reliability Tests and Inspections

Routine periodic testing of ECCS components and all necessary support systems at power is planned. Valves which operate after a LOCA are operated through a complete cycle, and pumps are operated individually in this test on their miniflow lines.

If such testing indicates a need for corrective maintenance, the redundancy of equipment in these systems permits such maintenance to be performed without shutting down or reducing load under certain conditions. These conditions include considerations such as a period within which the component should be restored to service and the capability of the remaining equipment to provide the minimum required level of performance during such a period.

Following completion of any required maintenance, the full flow system test line can be utilized to verify that the affected components have been restored and that the system meets its ECCS functional flow requirements, with the reactor at full power.

During periodic system testing, a visual inspection of pump seals, valve packings, flanged connections, and relief valves is made to detect leakage. Inservice inspection provides further confirmation that no significant deterioration is occurring in the ISS pressure boundary.

To implement the periodic component testing requirements, technical specifications will be established. The technical specifications specify requirements for test frequency, acceptability of testing, and measured parameters. A description of the inservice inspection program is also included in the technical specifications. ISS components and systems are designed to meet the intent of ASME B&PV Code, Section XI for inservice inspection.

6.3.5 Instrumentation Requirements

6.3.5.1 Engineered Safeguards Actuation Signals

The ISS is compatible with either a two or four train emergency electrical power system. If a four train emergency electrical power system is selected, four separate actuation trains and four separate protection logic trains would be provided. If a two train emergency electrical power system is selected, two separate actuation trains and two separate protection logic trains would be provided.

The actuation signal that initiates the ISS high head pumps is referred to as the "S" signal. The actuation signal that initiates the ISS low head pumps is referred to as the "P" signal. Section 6.3.2.1 lists the other system operations that are also automatically initiated upon receipt of the "S" and "P" signals.

The signals that are generated by the protection logic and used to initiate the "S" signal are the following;

a. Pressurizer trip signal, produced by two-out-of-four (2/4) pressurizer low-pressure signals

b. Hi-1 containment pressure trip signal, produced by two-out-of-four (2/4) containment Hi-1 pressure signals

c. Steam line low-pressure signal, produced by two-out-of-four (2/4) steam line low-pressure signals in one line

d. Excessive cooldown, produced by low T-cold signals in one loop coincident with either a neutron flux of below 10 percent or a reactor trip

e. Manual safety injection actuation from the control board

The actuation signal that initiates containment isolation phase A and containment ventilation isolation is referred to as the "T" signal. The "T" signal is initiated from the same protection logic signals that produced the "S" signal, except that a separate manual actuation switch is provided on the control board that permits the operator to initiate containment isolation phase A actuation without initiating the ECCS. In addition, the "S" signal reset is separate from the "T" signal reset.

The actuation signal that initiates spray actuation and containment isolation phase B is referred to as the "P" signal. The signals that are generated by the protection logic and used to initiate the "P" signal are the following:

a. Hi-3 containment pressure trip signal, produced by two-out-of-four (2/4) containment Hi-3 pressure signals

b. Manual actuation from control board

6.3.5.2 Instrumentation

The following is a description of the pressure, flow, temperature and level instrumentation channels required for the proper operation and monitoring of the ISS. The channels which are assigned instrument channel numbers in the 900 series are associated with the low head pumps. The 800 series numbers are associated primarily with the high head pumps.

6.3.5.2.1 Pressure

a. High Head Pump Suction Pressure (PI-850, 851, 852, and 853)

   There is a local readout pressure indicator in the suction line of each high head pump for use during preoperational testing operations.

b. High Head Pump Discharge Pressure (PT-854, 855, 856, and 857)

   There is a pressure transmitter in the discharge line of each high head pump for use during preoperational and periodic testing operations. Readout is on the main control board.

c. Low Head Pump Suction Pressure (PI-900, 901, 902, and 903)

   There is a local readout pressure indicator in the suction line of each low head pump for use during preoperational testing operations.

d. Low Head Pump Discharge Pressure (PT-904, 905, 906, and 907)

   There is a pressure transmitter in the discharge line of each low head pump for use during preoperational and periodic testing operations. Readout is on the main control board.

e. Check Valve Test-Line Header Pressure (PI-970)

   There is a local readout pressure indicator in the common check valve test-line header used to indicate backleakage during periodic check valve leakage tests.

f. Accumulator Pressure (PT-960, 961, 962, 963, 964, 965, 966, and 967)

There are two pressure transmit.ers with main control board readouts on each of the four accumulators. Each instrument is set to alarm in the control room if the accumulator pressure deviates by more than a set amount from the normal operating pressure.

g. Core Reflood Tank Pressure (PT-2000, 2001, 2002, 2003, 2004, 2005, 2006, and 2007)

There are two pressure transmitters with main control board readouts on each of the four core reflood tanks. Each instrument is set to alarm in the control room if the core reflood tank pressure deviates by more than a set amount from the normal operating pressure.

6.3.5.2.2 Flow

a. High Head Pump Discharge Flow (FT-858, 859, 860, and 861)

There is one flow element and transmitter with control board readout in the discharge line of each high head pump for use during emergency core cooling operation, preoperational and periodic testing operations, and for flow indication of boric acid makeup during emergency or abnormal conditions leading to a cold shutdown.

b. High Head Pump Miniflow Flow (FT-862, 863, 864, and 865)

There is one flow element and transmitter with control board readout in each high head pump miniflow line for use during preoperational and periodic testing operations and during any emergency core cooling or emergency boration operation. A low flow alarm is provided on the main control board.

c. Low Head Pump Discharge Flow (FT-908, 909, 910, and 911)

There is one flow element and transmitter with control board readout in the discharge line of each low head pump for use during emergency containment spray operations, long-term core cooling operations, normal cooldown operations, and preoperational and periodic testing operations. A low flow alarm is provided for each transmitter to annunciate a decrease in cooldown flow.

d. Core Reflood Tank Flow (FT-2020, 2021, 2022, and 2023)

There is one flow element and transmitter with control board readout in the discharge line of each core reflood tank for use during preoperational and periodic testing operations and monitoring the core reflood tank performance during emergency core cooling operations.

e. Check Valve Test-Line Header Flow (FI-971A, and B)

There are two local readout flow indicators in the common check valve test-line header use to indicate backleakage during periodic check valve leakage tests. These indications provide a high and low-range capability.

6.3.5.2.3 Temperature

a. High Head Pump Discharge Header Temperature (TE 866, 867, 868, and 869)

There is one temperature element in the discharge header of each high head pump with readout on the main control board. These temperature transmitters are used to provide input to temperature channel bistables that are part of the protection logic used to initiate component cooling water flow to the corresponding RHR heat exchangers. The automatic opening of the RHR heat exchanger/component cooling water isolation valves would be initiated only in the event that actuation signals are generated by both the safeguards protection logic "S" signals and the high head pump discharge temperature protection logic. A temperature actuation signal would be generated when a temperature channel bistable receives a temperature signal higher than a predetermined temperature setpoint.

b. Low Head Pump Discharge Header Temperature (TE-912, 913, 914, and 915)

There is one temperature element in the discharge header of each low head pump with readout on the main control board. These temperature transmitters represent the inlet temperatures to each RHR heat exchanger and they are recorded, in conjuntion with the RHR heat exchanger outlet temperature (TE-924, 925, 926, and 927), by a dual-point recorder on the main control board to indicate the delta temperature reduction of the RHR flow.

These temperature elements are also used to provide input to temperature channel bistables that are part of the protection logic used to ensure that component cooling water flow is initiated to the corresponding RHR heat exchangers. The automatic opening of the RHR heat exchanger/component cooling water isolation valves would be initiated in the event that actuation signals were generated by the RHR pump discharge temperature protection logic. A temperature actuation signal would be generated when a single temperature channel bistable receives a temperature signal from a corresponding temperature element, higher than a pre-determined temperature setpoint.

c. RHR Heat Exchanger Outlet Temperature (TE-924, 925, 926, and 927)

There is a temperature element in the outlet of each RHR heat exchanger downstream of the flow bypass return. Readout is on the main control board. The temperature is recorded in conjunction with the RHR heat exchanger inlet temperature (TE-912, 913, 914, and 915) on the main control board by a dual-point recorder to indicate the delta temperature reduction of RHR flow.

d. RHR Heat Exchanger Outlet Temperature - Local (TI-916, 917, 918, and 919)

There is a temperature indicator in the outlet of each RHR heat exchanger. It provides a means of performance verification and heat balance when used in conjunction with the RHR heat exchanger inlet temperature indication of TE-912, 913, 914, 915.

6.3.5.2.4 Level

a. EWST (LT-880, 881, 882, 883)

A minimum of four level instruments are recommended for the EWST, located inside the containment. These level transmitters are used to provide inputs to level channel bistables that are part of the EWST low level protection logic. These level channels are classified as post-accident monitoring equipment.

The EWST level transmitters are used to provide level indication and the following alarms in the main control room:

(1) High (HI) Level Alarm

This alarm would indicate an excessive level in the EWST.

(2) Low (LO) Level Alarm

This alarm would indicate that the EWST water level was less than that required by the technical specifications during normal operations. This alarm ensures an adequate water level exists in the EWST for use during any postulated LOCA.

(3) Low-Low (LO-LO) Level Alarm

This alarm would indicate that the minimum post-accident water level setpoint had been reached. This alarm would be produced on receipt of the EWST low level actuation signal. The EWST low level actuation signal would be initiated when two out of four EWST LO-LO level channel bistables received a EWST level signal lower than the predetermined LO-LO level setpoint. Each of the four EWST level bistables receive a level signal from a separate EWST level transmitter and each level channel is assigned to a separate vital instrument bus. These LO-LO level bistables are normally de-energized and would be energized at the LO-LO setpoint.

It should be noted that the EWST normal inventory will be sufficient to ensure that this LO-LO level would never be reached for any postulated accident conditions. This LO-LO level setpoint would be based on a minimum allowable level in the EWST (above the EWST floor elevation) to ensure that adequate NPSH is available for the high head and low head pump operation.

b. Accumulator (LT-950, 951, 952, 953, 954, 955, 956, and 957)

There are two level transmitters with control board readout on each accumulator. Each instrument is set to alarm if the accumulator level deviates by more than a set amount from the normal operating level.

c. Core Reflood Tank (LT-2010, 2011, 2012, 2013, 2014, 2015, 2016, and 2017)

There are two level transmitters with control board readout on each core reflood tank. Each instrument is set to alarm if the core reflood tank level deviates by more than a set amount from the normal operating level.

6.3.5.2.5 Critical Function Valve Alarm

In addition to the previously discussed alarms, interlocks are provided for the four normally open core reflood tank isolation valves (9097A, B, C, D) and the four normally open accumulator isolation valves (8949A, B, C, D) so that an alarm would be initiated in the main control room whenever one of these valves is not fully open RCS pressure above the safety injection unblocking pressure. Two alarms are provided for each valve. One alarm is actuated by a motor-mounted limit switch while the other alarm is activated by a stem-actuated limit switch. The stem-actuated limit switch alarm would repeat at given intervals.

6.3.5.2.6 Monitor Lights

Monitor status lights are provided on the main control board for all pumps and valves that are required to function as a part of the engineered safeguard systems. These monitor lights are provided specifically to alert the operator should the operation or position of a component be incorrect with respect to its required status during normal full-power operation or any one of the post-accident operational phases (injection and cold leg recirculation, or hot leg recirculation). In addition to using the monitor status lights, the majority of the ECCS valves use an annunciator alarm system, which is specifically provided to actuate an alarm in the main control room should one of these valves be mispositioned during the normal full-power operations.

The monitor light system consists of a series of light boxes grouped in a specific fashion on the main control board. Each light box represents a particular safety-related component. In general, the component monitor lights should not be illuminated when the plant is at normal full-power operation. The monitor lights should be illuminated only when the operation/position of any component is changed from its normal full-power operational status. Therefore, with only a few exceptions, any illuminated monitoring light during normal full-power operations would indicate that a component was positioned or operating improperly. However, the correct position or operation of a component during normal full-power operations may not be the correct position for that component during one of the post-accident operational phases. For those components, an illuminated monitor light during a particular post-accident operational phase could indicate that the component had been properly positioned or was operating properly.

For this reason, the monitor lights are divided into several major groups, with each group containing only those monitor lights that have the same status regardless of the operational status of the plant. For example, all the monitor lights in one specific group may be dark during the normal full-power operation and injection phase, whereas that same group of monitor lights may all be illuminated during the cold leg and hot leg recirculation phases.

This grouping of monitor lights, therefore, provides a relatively simple means for indicating on the main control board any improperly positioned or operating component during any phase of operation. In summary, any monitor light out of phase with the other monitor lights in that specific grouping would indicate that the corresponding component was improperly positioned or improperly operating.

TABLE 6.3-1 (Sheet 1 of 2)

WAPWR ISS INTERFACE PARAMETERS (WITHIN NUCLEAR POWER BLOCK)

Component Cooling Water	Temperature In	Temperature Out	Number	Safety Class
			(a,c)	
RHR pump motor			4	3
RHR heat exchanger			4	3
RHR miniflow - heat exchanger			4	3
Power Supply - 4000 V; 1E				
RHR pump motor			4	(1E)
High head pump motor			4	(1E)
HVAC				
RHR pump compartment			4	*
High head pump compartment			4	*

* Motor IEEE 323, Cat. I
Power Supply 460 V, 1E
ASME MS
Coils, Service Water -
Safety Class 3, exit
temperature 85 degrees-F

TABLE 6.3-1 (Sheet 2 of 2)

WAPWR ISS INTERFACE PARAMETERS (WITHIN NUCLEAR POWER BLOCK)

	Number	Safety Class
Power Supply - 460 V, 1E		
MOV 12 inch	4	2
MOV 10 inch	4	2
MOV 8 inch	12	2
MOV 8 inch	8	1
MOV 6 inch	24	2
MOV 4 inch	8	2
MOV 2 inch	4	2
Instrument Air Supply		
Valve air operator 4 inch	4	2
Valve air operator 3 inch	6	2
Accumulator test lines	4	NNS
Drain connections	32	NNS
Relief points to PRT	12	NNS
Relief points to vent system	16	NNS
Letdown to CVCS	4	2
EWST makeup from CVCS	2	NNS
EWST supply to SFPCS	2	3
EWST return from SFPCS	2	NNS
Sample lines	12	NNS
N_2 supply points	2	NNS

TABLE 6.3-2 (Sheet 1 of 6)

INTEGRATED SAFEGUARDS SYSTEM COMPONENT PARAMETERS

High Head Pumps

Number	4
Type	Horizontal or Vertical
Runout Flow Rate, gpm	(a,c)
Runout Head, ft	
Design FLow Rate, gpm	
Design Head, ft	
Shutoff Head, ft	
Miniflow, gpm	
Motor Capacity, bhp	
Speed, rpm	
Discharge Design Pressure, psig	
Suction Design Pressure, psig	
Design Temperature, °F	
NPSH Required, at pump suction (ft)	
NPSH Available at pump suction (ft)	
Seismic Category	I
Design Code	ASME III, Class 2

(1) Based on a horizontal pump.

TABLE 6.3-2 (Sheet 2 of 6)

INTEGRATED SAFEGUARDS SYSTEM COMPONENT PARAMETERS

Low Head Pumps (Spherical containment only)

Number	4
Type	Horizontal or Vertical
Runout Flow Rate, gpm	(a,c)
Runout Head, ft	
Design FLow Rate, gpm	
Design Head, ft	
Shutoff Head, ft	
Miniflow, gpm	
Motor Capacity, bhp	
Speed, rpm	
Discharge Design Pressure, psig	
Suction Design Pressure, psig	
Design Temperature, °F	
NPSH Required, at pump suction (ft)	
NPSH Available at pump suction (ft)	
Seismic Category	I
Design Code	ASME III, Class 2

(1) Based on a horizontal pump.

TABLE 6.3-2 (Sheet 3 of 6)

INTEGRATED SAFEGUARDS SYSTEM COMPONENT PARAMETERS

Accumulators

Number	4	
Design Pressure, psig		(a,c)
Design Temperature, °F		
Operating Temperature, °F		
Normal Operating Pressure, psig		
Tank Volume, ft^3		
External Pressure, psig		
Boron Concentration, ppm		
Seismic Category	I	
Design Code	ASME III, Class 2	
Material	Carbon, SS clad	

Core Reflood Tanks

Number	4	
Design Pressure, psig		(a,c)
Design Temperature, °F		
Operating Temperature, °F		
Normal Operating Pressure, psig		
Tank Volume, ft^3		
External Pressure, psig		
Boron Concentration, ppm		
Seismic Category	I	
Design Code	ASME III, Class 2	
Material	Carbon, SS clad	

TABLE 6.3-2 (Sheet 4 of 6)

INTEGRATED SAFEGUARDS SYSTEM COMPONENT PARAMETERS

Emergency Water Storage Tank

Number	1	(a,c)
Total Volume, gal		
Normal Pressure, psig		
Minimum Temperature, °F		
Design Temperature, °F		
Boron Concentration, ppm		
Seismic Category	I	
Design Code	ASME III, Class 2	
Material	SS	

TABLE 6.3-2 (Sheet 5 of 6)

INTEGRATED SAFEGUARDS SYSTEM COMPONENT PARAMETERS

RHR Heat Exchangers

Number	4	(a,c)
Type		
Installation		
Design Heat Transfer, Btu/hr		
Approximate UA, Btu/ hr-°F		

	Shell Side	Tube Side	(a,c)
Design Pressure, psig			
Design Temperature, °F			
Design Flow rate, lb/hr			
GPM			
Design Inlet Temperature, °F			
Design Outlet Temperature, °F			
Normal Cooldown Operating Pressure, psig			
Maximum Allowable ΔP			
Material			
Design Code			
Fluid			

TABLE 6.3-2 (Sheet 6 of 6)

INTEGRATED SAFEGUARDS SYSTEM COMPONENT PARAMETERS

Low Head Pump Miniflow Heat Exchangers

Number	4	
Type	[	] (a,c)
Installation		
Design Heat Transfer, Btu/hr		
Approximate UA, Btu/hr °F	]	

	Shell Side	Tube Side	
Design Pressure, psig	[	]	(a,c)
Design Temperature, °F			
Design Flow, lb/hr			
GPM			
Design Inlet Temperature, °F			
Design Outlet Temperature, °F			
Maximum Allowable ΔP			
Material			
Design Code			
Fluid			

TABLE 6.3-3

INTEGRATED SAFEGUARDS SYSTEM RELIEF VALVE DATA

Valve Location	Description	Fluid Discharged	Fluid Inlet Temperature, Normal]F	Set Pressure (psig)	Back Pressure, Normal (psig)	Back Pressure, Developed psig)	Capacity	(a,c)
8815 A,B,C,D Check valve	Recirculation test line piping over-pressure relief	Water						
8850 A,B,C,D	High head pump suction from EWST	Water						
8857	Accumulator N2 supply header	N2						
8855 A,B,C,D	Accumulator to containment	N2						
9010 A,B,C,D Check valve	Containment spray header piping over-pressure relief	Water						
9019 A,B,C,D Check valve	RHR suction piping from RCS	Water						
9020 A,B,C,D	RHR heat exchanger discharge	Water						
9021 A,B,C,D	RHR suction piping from RCS	Water						
9074	CRT N2 supply header	N2						
9075 A,B,C,D	CRT to containment	N2						
9022 A,B,C,D	Low head pump suction from EWST	Water						

TABLE 6.3-4 (Sheet 1 of 2)

FAILURE MODE AND EFFECTS ANALYSIS - INTEGRATED SAFEGUARD SYSTEM (ISS)
EMERGENCY CORE COOLING FUNCTION
ACTIVE FAILURES - POST-ACCIDENT OPERATION

Component	Failure Mode	ECCS Function	Effect on System Operation	Failure Detection Method	Remarks
General Comment - The portions of the ISS required to operate to effect the initial phase emergency core cooling namely; cold leg injection, following any posulated LOCA are those involved with the high head safety injection, and passive SI accumulator and core reflood tank injection. No valve repositioning is required for these functions to occur, therefore, the failure modes and effects delineating classical active failures is limited to the HHSI pumps.					
1) High head safety injection Pump No. 1 APHH (HHSI Pumps Nos. 2,3 and 4 analogous)	Fails to deliver working fluid	ECCS injection cold and hot leg coolant delivery	Failure reduces redundancy of pumps provided for the delivery of emergency coolant to RCS from Emergency Water Storage Tank (EWST). Fluid flow from HHSI pump No. 1 will be lost. Minimum flow requirements will be met by HHSI No. 2, 3 or 4 (1 HHSI for breaks up to at least 6" equivalent pipe diameter) or by any combination of 3 remaining HHSI pumps and Core Reflood Tanks (passive-4 provided) such that any 5 deliver flow (for DEGCL break)	HHSI pump No. 1 discharge coolant flow indication (FI-858) discharge pressure indication (PI-854), and miniflow flaw indication (FI-862) at CB. Circuit breaker overcurrent trip indication at CB. Circuit breaker close position monitor light and alarm at CB.	The pump circuit breaker is aligned to close on actuation by an "S" signal
2) Motor operated gate valve 8807A (8807B,C,D analogous for HHSI pumps Nos. 2,3,4, respecively)	Fails to close on demand (Normally open)	Normally provide a flow path from HHSI pump No. 1 to direct reactor vessel injection. Must be closed to permit switch to hot leg injection mode.	Failure results in inability to provide hot leg injection from HHSI pump No. 1. Minimum hot leg injection capability provided by redundant HHSI) hot leg injection paths in subsystems 2, 3, and 4. Cold leg injection via direct vessel injection path may continue.	Valve position indication (open to closed position change) at CB. Pump discharge flow indication (FI-858) at CB.	Operator establishes flow to hot legs of RCS loops after ~ 24 hours of cold leg injection.

TABLE 6.3-4 (Sheet 2 of 2)

FAILURE MODE AND EFFECTS ANALYSIS - INTEGRATED SAFEGUARD SYSTEM (ISS)
EMERGENCY CORE COOLING FUNCTION
ACTIVE FAILURES - POST-ACCIDENT OPERATION

Component	Failure Mode	ECCS Function	Effect on System Operation	Failure Detection Method	Remarks
3) Motor operated gate valve 8810A (8810B,C,D Analogous for HHSI pumps Nos. 2, 3, 4, respectively	Fails to open on demand (Normally closed)	Normally provides hot leg injection line isolation. Must be opened to permit switch over to hot leg injection mode.	Failure results in inability to provide hot leg injection from HHSI pump No. 1. Minimum hot leg injection capabilty provided by redundant HHSI/hot leg injection paths in sub-systems 2, 3, and 4. Cold leg injection via direct vessel injection path may be reestablished.	Valve position indication (closed to open position change) at CB. Pump discharge flow indication (FI-858) at CB.	a) Operator establishes flow to hot legs of RCS after ~24 hours of cold leg injection. b) Power locked out from valve during normal plant operation. Operator restores power to valve during switch-over to hot leg injection.
4) Temperature control channel T-866 (867, 868, 869 analogous) for HHSI pumps Nos. 2,3 4, respectively	Fails such that high injection fluid temperature is indicated	Initate CCW flow to shell side of RHR heat exchanger No. 1	Failure of temperature channel will result in CCW flow being provided to shell side of RHR HX No. 1 before EWST water has been (a,c) heated up to [ ] setpoint. No adverse effect on ECCS operation results. Operator can manually terminate CCW supply until CCW flow is initiated on other subsystems.	Corresponding temperature channels in subsystems 2, 3, and 4 provide redundant indication of ECCS injection flow.	No operator action required

Figure 6.3-1 ISS Piping and Instrumentation Diagram
(See following Preliminary Westinghouse drawing
Sheets 1-7)

(a,c)

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Figure 6.3-1 ISS Piping and Instrumentation Diagram (Sheets 1-7)

OCTOBER, 1983

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(a,c,e)

Figure 6.3-2 ISS Process Flow Diagram
(One of Four Subsystems)

NOTES TO FIGURE 6.3-2
ECCS AND CONTAINMENT SPRAY MODES

(a,c,e)

Location	Fluid	Pressure Psig	Temperature °F	Flow gpm(1)	Flow lb/sec
1	EWST water				
2	EWST water				
3	EWST water				
4	EWST water				
5	EWST water				
6	EWST water				
7	EWST water				
8	EWST water				
9	EWST water				
10	EWST water				
11	EWST water				
12	EWST water				
13	EWST water				
14	EWST water				
15	EWST water				
16	EWST water				
17	EWST water				
18	CRT water				
19	ACC water				
20	EWST water				
21	EWST water				
22	EWST water				
23	Containment atm				
24	Nitrogen				
25	Nitrogen				

(1) At reference conditions 100°F and o psig, maximum flows indicated.

NOTES TO FIGURE 6.3-2 (Cont)
NORMAL RHR MODE

Location	Fluid	Pressure Psig	Temperature °F	Flow gpm[1]	Flow lb/sec
					(a,c,e)
1	EWST water				
2	EWST water				
3	EWST water				
4	EWST water				
5	EWST water				
6	Reactor coolant				
7	Reactor coolant				
8	Reactor coolant				
9	Reactor coolant				
10	Reactor coolant				
11	EWST water				
12	Reactor coolant				
13	Reactor coolant				
14	Reactor coolant				
15	Reactor coolant				
16	Reactor coolant				
17	EWST water				
18	CRT water				

NOTES TO FIGURE 6.3-2 (Cont)
NORMAL RHR MODE

Location	Fluid	Pressure Psig	Temperature °F	Flow gpm(1)	Flow lb/sec
19	ACC water				
20	Reactor coolant				
21	Reactor coolant				
22	Reactor coolant				
23	Containment atm				
24	Nitrogen				
25	Nitrogen				

(a,c,e)

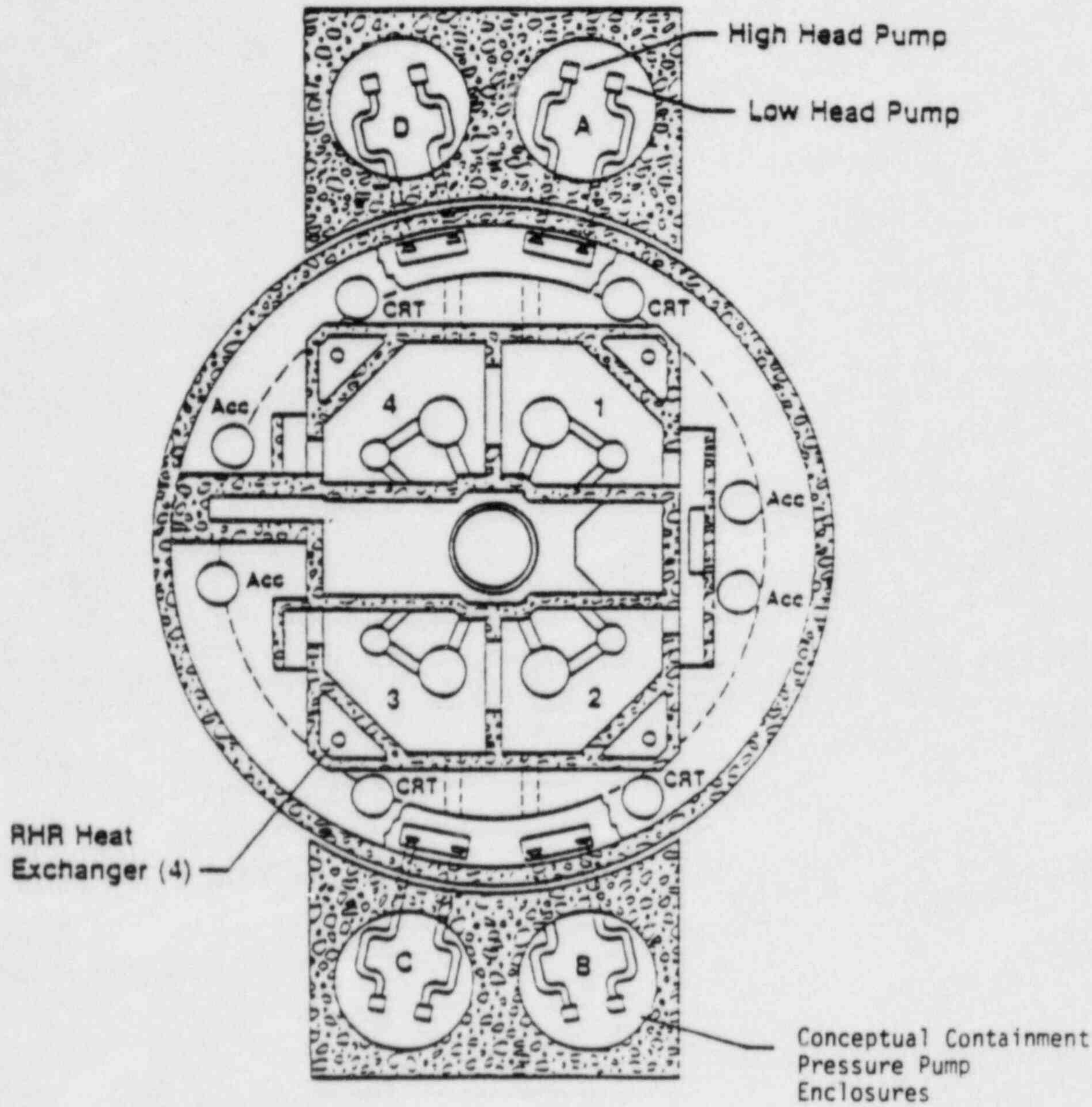

FIGURE 6.3-3 CONCEPTUAL CONTAINMENT PLAN

Figure 6.3-4 ISS High Head Pump Performance Curve
1800 PSI/Shutoff/1000 GPM Runout

(a,c)

FIGURE 6.3-5 ISS LOW HEAD PUMP PERFORMANCE CURVE

(a,c)

6.5 FISSION PRODUCT REMOVAL AND CONTROL SYSTEMS

6.5.2 Containment Spray System (Fission Product Removal)

The containment spray system (CSS) is a subsystem of the integrated safeguards system (ISS). Following a postulated loss-of-coolant accident (LOCA), the CSS sprays the interior of the containment to reduce the containment temperature and pressure and to remove airborne iodine activity from the containment atmosphere.

The basic description of the CSS is provided within Section 6.2.2. Included in Section 6.2.2 are the descriptions of the various components of the CSS and the discussion of the containment heat removal function of the CSS. The actuation times for the CSS are event dependent and are described in the individual accident analyses.

6.5.2.1 Design Bases (For Fission Product Removal)

The CSS provides a boric acid spray injection solution with a pH in the range of 5.0 to 6.0. The final recirculation sump solution will be adjusted to a pH in the range of 8.0 to 10.5 to minimize chloride induced stress corrosion of austenitic stainless steel components. This sump solution pH adjustment will be accomplished by a system (to be described) that is independent of the CSS.

Fifty percent of the core equilibrium iodine inventory is assumed to be released to the containment. The traditional Licensing Basis Evaluation assumes that 95.5 percent of the released iodine is elemental, 2 percent is organic and 2.5 percent is particulate.(1) All of this iodine is released to the containment atmosphere and is available to leak to the environment. The Westinghouse Basis Evaluation, which bases the iodine source term on data obtained from the accident at Three Mile Island Unit 2, assumes that following a LOCA, iodine will be present in the reactor coolant primarily as non-volatile iodides. Only a small fraction of the iodine inventory is considered to be volatile organic iodides (CH_3I). The Westinghouse Basis Evaluation conservatively assumes that 48 percent of the released iodine is elemental, 47.5 percent is nonvolatile organic iodide, 2 percent is volatile organic and 2.5 percent is particulate. A comparison of the traditional Licensing basis and the Westinghouse basis, which is based on recent TMI data, is found in Section 15.6.4.

The CSS reduces the elemental iodine inventory in the containment atmosphere until a decontamination factor (DF)* of 200 is achieved. Removal of elemental iodine from the containment atmosphere also occurs by way of deposition (see paragraph 6.5.2.3.2). The CSS also removes particulates from the containment atmosphere. The extent to which credit is taken for particulate removal is discussed in paragraph o.5.2.3.

Additional design bases associated with the heat removal capability of the CSS are presented in subsection 6.2.2.

6.5.2.2 System Design (For Fission Product Removal)

There are two independent sets of spray ring headers located in the containment dome region. One half of each set of ring headers is assigned to one of the four CSS trains.

The spray nozzles used are SPRACO model 1713A. The nozzles are the ramp bottom, swirl chamber type with a discharge orifice diameter of 3/8 inch. The nozzles cannot clog since there are no internal parts, such as swirl vanes, and the maximum particle size entrained in the spray flow is limited to 1/8 inch by the emergency sump screen mesh. Spray drop-size distribution is presented in figure 6.5.2-1 and is discussed in detail in reference 2. The spray system operating modes, water sources, and initiation signals are described in Section 6.2.2.

Approximately 80 percent of the net free containment volume is sprayed. This volume consists of the containment volume above the operating deck and the regions below the operating deck impinged directly by the spray. The mixing rate between the sprayed and unsprayed containment volumes is assumed to be the minimum safeguards containment cooler air flowrate.

6.5.2.3 Design Evaluation

6.5.2.3.1 Spray Removal of Airborne Iodine

Containment spray system performance is evaluated using a spray model developed by Westinghouse. The model considers the effects of spray drop-size distribution, droplet coalescence, gas and liquid phase mass transfer resistance, drop trajectories, and condensation of steam on the drops.

The elemental iodine removal capability of the containment spray is described in terms of the individual spray droplets. The behavior of the aggregate spray is related to the behavior of the individual drops, by means of a drop-size distribution function.

An advantage to using this microscopic approach is the ability to derive the model from first principles. Thus, the model is free of any scaling factors which would be required to extrapolate laboratory test data to a full-size reactor containment.

The CIRCUS (Calculation of Iodine Removal in the Containment Using Spray) computer code is used to analyze the elemental iodine removal effectiveness of the containment spray system. A detailed description of the mathematical models used in the code can be found in reference 3. The elemental iodine removal analysis assumes that the containment spray system is operating at minimum capacity (2 of 4 trains of equipment) and the ISS is operating at maximum capacity. Although the CSS will operate for a 2 hours or longer, no spray removal of elemental iodine is assumed after a decontamination factor (DF) of 200 is achieved for the containment atmosphere.

The particulate washout coefficient is calculated by the method outlined in reference 4. Removal of particulate iodine is assumed for the duration of the spray period.

The spray system performance was evaluated at the peak containment pressure postulated to occur following a LOCA. Presented in figure 6.5.2-2 is the spray reduction factor as a function of post-LOCA containment saturation temperature. In the determination of operating deck coverage, the reduction factor was applied to both the spray throw distance and the spray envelope diameter.

The spray nozzle capacity curve is presented in Figure 6.5.2-3.

The containment will be sprayed continuously for a minimum of 2 hours. The containment spray pumps (low head ISS pumps) start automatically and continue to circulate water from the EWST to the spray headers, to the containment sump and back to the EWST.

Table 6.5.2-1 lists typical input parameters and results of the spray iodine removal analysis.

6.5.2.3.2 Deposition Removal of Airborne Iodine

The deposition removal coefficient for elemental iodine is determined based on guidance of Reference 5. For conservatism, deposition is assumed to occur only on surfaces coated with epoxy paint. Credit is taken for approximately one quarter of the surface area in the containment. Deposition removal of iodine is assumed to continue until a DF of 200 is achieved for the containment atmosphere.

6.5.2.4 Tests and Inspection

Refer to subsection 6.2.2 for a description of provisions for testing the CSS.

6.5.2.5 Instrumentation Requirements

Refer to subsection 6.2.2 for a description of the CSS instrumentation.

6.5.2.6 Materials

Refer to subsection 6.1 for a discussion of typical engineered safety features materials chemistry.

6.5.2.7 References

1. NRC Standard Review Plan 6.5.2, "Containment Spray as a Fission Product Cleanup System."

2. Sanford, M. O., "SPRACO Model-1713A Nozzle Spray Drop-Size Distribution," WCAP-8258-R1 (nonproprietary).

3. Somers, E. V. and Sanford, M. O., "Iodine Removal by Spray in the Joseph M. Farley Station Containment," WCAP-8376 (nonproprietary).

4. WASH-1329, "A Review of Mathematical Models for Predicting Spray Removal of Fission Products in Reactor Containment Vessels," Postma, A. K. and Pasedag, W. F.

5. NRC NUREG/CR-0009, "Technological Bases for Models of Spray Washout of Airborne Contaminants in Containment Vessels."

TABLE 6.5.2-1 (Sheet 1 of 2)

TYPICAL INPUT PARAMETERS AND RESULTS OF SPRAY IODINE REMOVAL ANALYSIS

	(a,c)
Total containment free volume (ft^3)	
Unsprayed containment free volume (%)	
Area coverage at the operating deck (%)	
Mixing rate between sprayed and unsprayed volumes (ft^3/min)	
Containment model	
Miminum vertical distance to operating deck from lowest spray header (ft)	
Design spray flowrate per pump, (gpm) at 45 psig containment pressure	
Number of spray pumps operating	
Spray solution pH	
Final Sump pH (~ 24 hours)	
Partition factor between liquid and gas phases	
Average spray drop diameter (microns)	
Elemental iodine spray removal coefficient (hrs^{-1})	
Particulate iodine spray removal coefficient (hrs^{-1})	

TABLE 6.5.2-1 (Sheet 2 of 2)

TYPICAL INPUT PARAMETERS AND RESULTS OF SPRAY IODINE REMOVAL ANALYSIS

Elemental iodine wall deposition coefficient	
Sprayed surface (hr^{-1})	(a,c)
Unsprayed surface (hr^{-1})	
Wall deposition elemental iodine decontamination-factor for combined effects of spray removal and deposition	
Area in containment subject to iodine deposition, i.e., coated with epoxy paint (ft^2)	