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6. ENGINEERED SAFEGUARDS

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6. ENGINEERED SAFEGUARDS

Engineered safeguards for the nuclear unit are provided to fulfill four functions in the unlikely event of a serious loss-of-coolant accident:

a. Protect the fuel cladding.

b. Ensure reactor building integrity.

c. Reduce the driving force for building leakage.

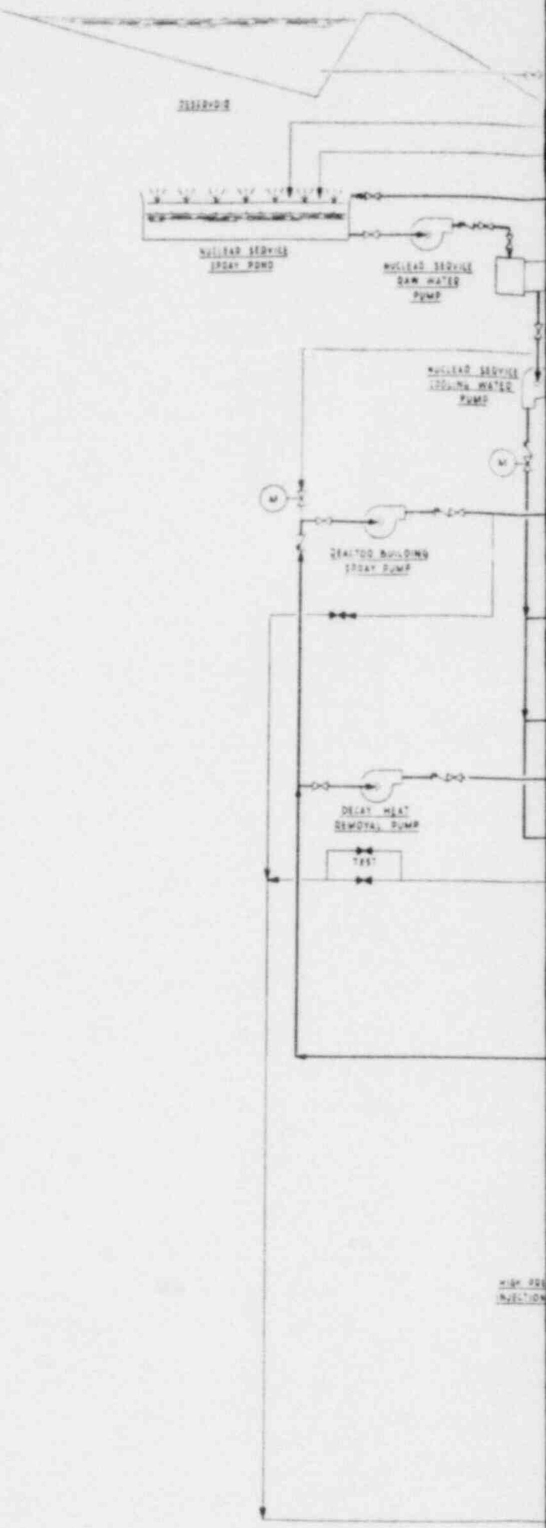
d. Remove fission products from the reactor building atmosphere.

Emergency injection of coolant to the reactor coolant system satisfies the first function above, while building atmosphere cooling and washing satisfy the latter three functions. Each of these operations is performed by two or more systems which, in addition, employ multiple components to ensure operability. All equipment requiring electrical power for operation is supplied by the emergency electrical power system as described in 8.2.3.

Engineered safeguards are separated into two completely independent trains of equal capability. Either train is capable of handling the entire emergency coolant injection and emergency cooling load. Failure of either train can not affect the other. Each engineered safeguards train, as shown in Figure 6.0-1, envelops core flooding tanks, high pressure and low pressure coolant injection, reactor building emergency cooling system and reactor building spray and iodine removal system with associated heat rejection system. 2

Applicable codes and standards for design, fabrication, and testing of components used as safeguards are listed in the introduction to Section 9, and seismic requirements are given in Section 2. The safety analysis presented in Section 14 demonstrates the performance of installed equipment in relation to functional objectives with assumed failures.

Some of the engineered safeguards functions noted above are accomplished with the post-accident use of equipment serving normal functions. The design approach is based on the belief that regular use of equipment provides the best possible means for monitoring equipment availability and conditions. Because some of the equipment used serves a normal function, the need for periodic testing is minimized. In cases where the equipment is used for emergencies only, the systems have been designed to permit meaningful periodic tests. Additional descriptive information and design details on equipment used for normal operation are presented in Section 9. Section 6 presents design bases for safeguards protection, equipment operational descriptions, design evaluation of equipment, failure analysis, and a preliminary operational testing program for systems used as engineered safeguards. 2


RESERVOIR
NUCLEAR SERVICE SPRAY POND
NUCLEAR SERVICE RAW WATER PUMP
NUCLEAR SERVICE COOLING WATER PUMP
M
M
REACTOR BUILDING SPRAY PUMP
DECAY HEAT REMOVAL PUMP
TEST
HIGH PRE
INJECTION

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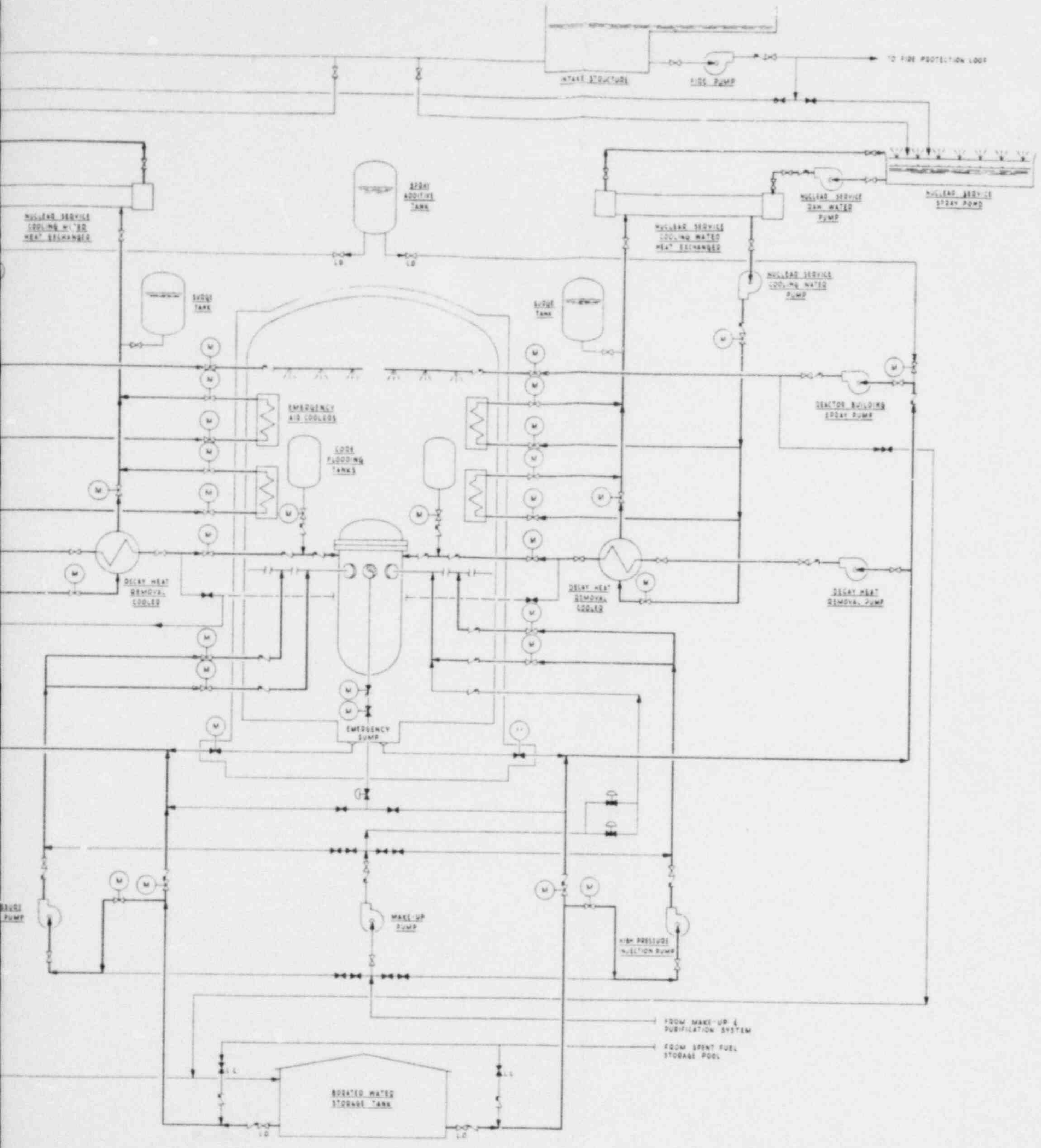

FIGURE 6.0-1
ENGINEERED SAFEGUARDS SYSTEMS

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6.1 EMERGENCY INJECTION

6.1.1 DESIGN BASES

The principal design basis for emergency injection is as follows:

> Emergency core injection is provided to prevent clad melting for the entire spectrum of reactor coolant system failures ranging from the smallest leak to the complete severance of the largest reactor coolant pipe.

High pressure injection is provided to prevent uncovering of the core for small coolant piping leaks at high pressure and to delay uncovering of the core for intermediate-sized leaks. The core flooding system and the decay heat removal system (which provides low pressure injection) are provided to recover the core at intermediate-to-low pressures so as to maintain core integrity during leaks ranging from intermediate to the largest size. This equipment has been conservatively sized to limit the temperature transient to a clad temperature of 2,300 F or less.

6.1.2 DESCRIPTION

Figure 6.1-1 is the schematic flow diagram for the emergency injection and associated instrumentation.

Emergency injection fluid, pumped to the reactor coolant system during safeguards operations, is supplied in each case from the borated water storage tank. This tank contains the volume of borated water necessary to fill the fuel transfer canal during refueling operations and is connected to the injection pump suction headers by two lines. Additional coolant for emergency injection supply is contained in core flooding tanks which inject coolant without fluid pumping as described later in this section. 2

Emergency injection into the reactor coolant system will be initiated in the event of a) an abnormally low reactor coolant system pressure of 1,800 psig or b) a reactor building pressure of 10 psig during power operation. Either of these signals will automatically increase high pressure injection flow to the reactor coolant system with the following changes in the operating mode of the makeup and purification system described in Section 9: (a) the high pressure injection pumps will start and come on the line, (b) the stop valves in each injection supply line to the makeup and decay heat pumps will open, and (c) the injection valve in each of four injection lines will open. Emergency high pressure injection will continue until reactor coolant system pressure has dropped to the point where core flooding tanks begin emergency injection. The flow characteristic curves for each makeup pump are given in Figure 6.1-2. 2

The core flooding system is composed of two flooding tanks, each directly
connected to a reactor vessel nozzle by a line containing two check valves
1 and one stop valve. The system provides for automatic flooding injection
with initiation of flow when the reactor coolant system pressure reaches
approximately 600 psig. This injection provision does not require any
electrical power, automatic switching, or operator action to ensure supply
of emergency coolant to the reactor vessel. Operator action is required
only during reactor cooldown, at which time the stop valves in the core
flooding lines are closed to contain the contents of the core flooding
tanks. The combined coolant content of the two flooding tanks is sufficient
to recover the core hot spot assuming no liquid is contained in the
reactor vessel, while the gas overpressure and flooding line sizes are
sufficient to ensure core reflooding within approximately 25 sec after the
largest pipe rupture has occurred.

The decay heat removal system (described in Section 9) is normally maintained
on standby during power operation and provides supplemental core
flooding flow through the two core flooding lines after the reactor coolant
system pressure reaches 135 psi. Emergency operation of this system will
be initiated by a reactor coolant system pressure of 200 psi or by a reactor
building pressure of 10 psig during any accident. The flow character-
2 istics of each decay heat pump for injection are shown in Figure 6.1-3;
each pump is designed to deliver 3,000 gpm flow into the reactor vessel
3 at a vessel pressure of approximately 100 psi.

Low pressure injection, with supply from the borated water storage tank,
1 using the decay heat removal pumps will continue until a low level signal
2 is received from the tank (minimum of 36 minutes at the maximum combined
flow of all low and high pressure injection and reactor building spray
2 pumps of 10,000 gpm). At this time, the operator will open the recircula-
tion valves controlling suction from the reactor building emergency sump,
1 and flow of coolant from the sump to the reactor vessel and spray headers
will begin, closing the check valve from the borated water storage tank.

The decay heat removal pumps are located at an elevation below the reactor
building emergency sump with dual suction lines routed outside the reactor
building to separate pump suction headers. The borated water storage
tank and spent fuel pool are also connected to each of these headers.
The pumps are in individual compartments interconnected by a doorway seven
feet above the floor. Each compartment is provided with an individual sump
and pump to handle minor pump seal and packing leakage and equipment failures.
In case of major rupture in either compartment, there will be a high
sump level signal. Valves in the lines passing into, out of, or through
2 the compartment can be remotely operated to shut off all sources of possible
flooding.

The shut-off valves in the reactor building emergency sump suction lines are jacketed to protect the valves from missile damage and to contain leakage in the unlikely event of valve body failure.

Preliminary calculations indicate that the available NPSH at the decay heat removal pumps and reactor building spray pump's suction will be met with a water level at the top of the 4 ft 6 in. deep sump. Specifically, the reactor building total pressure will exceed the sump water vapor pressure by 2.2 psi at the time recirculation starts. This overpressure is equivalent to 5.3 feet of water head. To this is added 15.0 feet static head below the bottom of the sump. The friction loss through a single line at a full 4,500 gpm flow is calculated to be 4.0 feet giving an NPSH of 16.3 feet at the pumps. Thus, a minimum NPSH of 16.3 feet is provided compared to the required NPSH of 14.75 feet for the decay heat removal pumps (Figure 6.1-3) and 15 feet for the reactor building spray pumps. In all calculations, credit has been taken only for the reactor building pressure above the sump water vapor pressure during the time these pumps would be first operating in the recirculation mode. 2

The heat transfer capability of each decay heat cooler as a function of recirculated water temperature is illustrated in Figure 6.1-4. The heat transfer capability at the saturation temperature corresponding to reactor building pressure is in excess of the heat generation of the core.

Design data for core flooding system components are given in Table 6.1-1.

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TABLE 6.1-1
CORE FLOODING SYSTEM PERFORMANCE AND EQUIPMENT DATA

Component	Data
Core Flooding Tanks *	
Number	2
Design Pressure, psig	700
Normal Pressure, psig	600
Design Temperature, F	300
Operation Temperature, F	110
Total Volume, ft^3/Tank	1,410
Normal Water Volume, ft^3/Tank	940
2 Material of Construction	Carbon Steel - s.s. Lined
Check Valves	
Number per Flooding Line	2
Size, in.	14
Material	SS
Design Pressure, psig	2,500
Design Temperature, F	650
Stop Valves	
Number per Flooding Line	1
Size, in.	14
Material	SS
Design Pressure, psig	2,500
Design Temperature, F	650
Piping	
Number of Flooding Lines	2
Size, in.	14
Material	SS
Design Pressure, psig	2,500
Design Temperature, F	650

* Designed to ASME Section III, Class C.

[redacted]

6.1.3 DESIGN EVALUATION

In establishing the required components for the emergency injection, the following factors were considered:

a. The probability of a major reactor coolant system failure is very low.

b. The fraction of a given component lifetime for which the component is unavailable because of maintenance is estimated to be a small part of lifetime. On this basis, it is estimated that the probability of a major reactor coolant system accident occurring while a protective component is out for maintenance is two orders of magnitude below the low basic accident probability.

c. The equipment downtime for maintenance in a well-operated station often can be scheduled during reactor shutdown periods. When maintenance of an engineered safeguard component is required during operation, the periodic test frequency of the remaining equipment can be increased to ensure availability.

d. Where the systems are designed to operate normally or where meaningful periodic tests can be performed, there is also a low probability that the required emergency action would not be performed when needed. That is, equipment reliability is improved by using it for other than emergency functions.

e. Two high pressure injection pumps and one identical makeup pump are installed. One make-up pump is operating normally and can be taken out of service for maintenance by temporarily using one of the high pressure injection pumps. Only one high pressure injection (or makeup) pump is required for engineered safeguards. 2

6.1.3.1 Failure Analysis

The single failure analysis presented in Table 6.1-2 is based on the assumption that a major loss-of-coolant accident had occurred. It was then assumed that an additional malfunction or failure occurred either in the process of actuating the emergency injection systems or as a secondary accident effect. All credible failures were analyzed. For example, the analysis includes malfunctions or failures such as electrical circuit or motor failures, stuck check valves, etc. It was considered incredible that valves would change to the opposite position by accident if they were in the required position when the accident occurred. In general, failures of the type assumed in this analysis should be unlikely because a program of periodic testing and service rotation of standby equipment will be incorporated in the Station operating procedures.

[redacted]

TABLE 6.1-2
SINGLE FAILURE ANALYSIS - EMERGENCY INJECTION

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Component	Malfunction	Comments and Consequences
A. <u>High Pressure Injection</u>		
1. Electric motor valve at makeup tank outlet.	Valve remains open.	When the tank is empty, tank pressure would be less than the high-pressure injection pump suction pressure (with borated water storage tank on the line), thus preventing the release of hydrogen from the tank to the pump suction line.
2. Electric motor-operated suction valve for makeup H.P. injection pumps from borated water storage tank.	Fails to open.	Similar valve in other high pressure injection pump line will deliver required flow.
3. H. P. injection pump.	Out for maintenance.	A high pressure and make-up pump will still be available. Only one pump is required for engineered safeguards.
4. H. P. injection pump	Fails (stops).	Other high pressure injection pump will deliver the required flow.
5. H.P. Injection pump isolation valve.	Left inadvertently closed.	See Item A-3 above. Valves will normally be left open since the check valve in each pump discharge will prevent backflow. Operating procedures will call for pump isolation valves to be closed only for maintenance.

2

TABLE 6.1-2 Continued

Component	Malfunction	Comments and Consequences	
6. H. P. Injection pump discharge check valve.	Sticks closed.	This is considered incredible since the pump discharge pressure of 2,700 psig at no flow would tend to open even a very tightly stuck check disc.	2
7. Pressurizer level control valve.	Fails to close.	No consequences.	2
8. Seal injection control valve.	Fails to close.	Injection flow through this line would be small compared to the flow through the injection lines due to the high flow resistance of the reactor coolant pump seals.	2
9. Electric motor-operated valve in high-pressure injection line.	Fails to open.	Flow from one pump will go through the alternate line. Other pump will operate normally.	2
10. Check valve in injection line (inside reactor building).	Sticks closed.	See comment on Item A-6 above.	
11. Injection line inside reactor building.	Rupture	Flow rate indicators in the four injection lines would indicate the gross difference in flow rates. Check valve in the injection line would prevent additional loss of coolant from the reactor. The line is protected from missiles by reactor coolant system shielding.	2

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[redacted]

TABLE 6.1-2 Continued

Component	Malfunction	Comments and Consequences
B. <u>Core Flooding System</u>		
1. Flooding line check valve.	Sticks closed.	This is considered incredible based on the valve size and opening pressure applied.
C. <u>Decay Heat Removal System</u>		
1. Check valve at reactor vessel.	Sticks closed.	This is considered incredible since these valves will be used periodically during decay heat removal, and the opening force will be approximately 5,000 pounds.
2. Electric motor-operated injection valve.	Fails to open.	Second injection line will deliver required flow.
3. Safety valve.	Stuck open.	Loss of injection flow is small since valve is small.
4. Decay heat cooler.	Isolation valve left closed.	Other heat exchanger will take required injection flow and remove required heat. Valves will be closed only for maintenance of heat exchanger.

TABLE 6.1-2 Continued

Component	Malfunction	Comments and Consequences
5. Decay heat cooler.	Massive rupture.	Not credible. During normal decay heat removal operation, heat exchanger will be exposed to higher pressure and approximately the same temperature as the postaccident temperature and pressure.
6. Decay heat cooler.	Out for maintenance.	Remaining heat exchanger will take required injection flow.
7. Decay heat pump isolation valve.	Left closed.	Remaining pump will deliver required injection flow. 2
8. Decay heat pump discharge check valve.	Sticks closed.	See comment on Item C-1 above.
9. Decay heat pump.	Fails to start.	Remaining pump will deliver required injection flow. 2
10. Electric motor-operated stop valve or check valve at borated water storage tank outlet.	Sticks closed.	Alternate line will permit required flow. 2
11. Electric motor valve permitting suction from reactor building sump.	Fails to open.	Two valves are provided; one will provide required flow. These valves need not be actuated until 36 minutes after start of accident which provides time for manual operation. 2

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TABLE 6.1-2 Continued

Component	Malfunction	Comments and Consequences
12. Reactor building sump outlet pipe.	Becomes clogged.	Clogging of a single line does not impair function because of the dual sump line arrangement, the size of the lines, and the sump design. The two recirculation lines take suction from the different portions of the sump. A grating will be provided over the sump, and additional heavy duty screens will be provided.
13. Reactor building sump recirculation valve.	Valve opens with empty sump.	The emergency procedures will be well established and rehearsed. Therefore, it is not considered reasonable that the operator would inadvertantly open the valve before it is prudent. If the valve is opened after about 3-1/2 minutes following the accident, sufficient coolant inventory will be present in the reactor building sump to maintain a flooded suction for the decay heat removal pumps. Under these circumstances cooling will be provided in the recirculation mode. 1 In the event that a valve in the sump line is opened before 3-1/2 minutes, the decay heat removal and reactor building spray pumps in that pump train would lose suction. The pumps in the alternate train would provide required cooling. 2

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TABLE 6.1-2 Continued

Component	Malfunction	Comments and Consequences
14. Reactor building sump recirculation valve.	Opened before borated water storage tank is empty.	The consequences of this operator error would depend on the reactor building pressure at the time the valve was opened. If the building pressure were below the static pressure at the borated water storage tank, the pumps would continue to take suction from the storage tank and there would be some flow from the storage tank into the sump. However, since this water will become available when recirculation begins, there are no resultant consequences. If the building pressure is greater than the static pressure of the storage tank at the time of the valve opening, the flow of borated water from the storage tank would be cut off by the closing of the check valve in the borated water suction line.

1

TABLE 6.1-2 Continued

Component	Malfunction	Comments and Consequences	
		The high pressure injection pumps would continue drawing from the storage tank. The decay heat removal and reactor building spray pumps would take suction from the sump. The hot sump water would be cooled in the decay heat removal coolers before the L. P. injection. The hot sump water would however, cause a drop in the reactor building spray cooling efficiency. The reactor building emergency coolers would continue to operate at 100% capacity and would more than adequately compensate for the loss of spray cooling efficiency. As soon as the building pressure drops below the borated storage tank static pressure, the pumps would resume taking suction from the storage tank.	1 1
15. Dual manual valves connecting suction headers.	Inadvertantly left open	Not credible that both valves will be inadvertantly left open because of administrative controls.	2

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[redacted]

The single failure analysis (Table 6.1-2) and the dynamic postaccident performance analysis (Section 14) of the engineered safeguards considered capacity reduction as a result of equipment being out for maintenance or as a result of a failure to start or operate properly. This amounts to adding another factor of conservatism to the analyses because good operating practice requires repairing equipment as quickly as possible. Plant maintenance activities will be scheduled so that the required capacity of the engineered safeguards systems will always be available in the event of an accident.

The adequacy of equipment sizes is demonstrated by the postaccident performance analysis described in Section 14, which also discusses the consequences of achieving less than the maximum injection flows. There is sufficient redundancy in the emergency injection systems to preclude the possibility of any single credible failure leading to core melting. 2

6.1.3.2 Emergency Injection Response

The emergency high-pressure injection valves are designed to open within 10 sec. One makeup pump is normally in operation, and the pipe lines are filled with coolant. The four high-pressure injection lines contain thermal sleeves at their connections into the reactor coolant piping to prevent overstressing of the pipe juncture when 90 F water is injected into these high temperature lines during emergency operation. The equipment normally operating is handling 125 F water, and hence will experience no thermal shock when 90 F water is introduced. 2

Injection response of the core flooding system is dependent upon the rate of reduction of reactor coolant system pressure. For a maximum hypothetical rupture, the core flooding system is capable of reflooding the core to the hot spot within a safe period after a rupture has occurred.

Emergency low pressure injection by the decay heat removal system will be delivered within 25 sec after the reactor coolant system reaches the actuating pressure of 200 psig. This anticipated delay time consists of these intervals:

a.	Total instrumentation lag -	≈ 1 sec
b.	Emergency power source start -	< 15 sec
c.	Pump motor startup (from the time the pump motor line circuit breaker closes until the pump attains full speed) -	≈ 10 sec
d.	Injection valve opening time -	< 10 sec
e.	Borated water storage tank outlet valves -	< 10 sec
	Total (only b and c are additive)	≈ 25 sec

6.1.3.3 Special Features

The core flooding nozzles (Figure 3.2-61) will be specially designed to ensure that they will safely take the differential temperatures imposed by the accident condition. Special attention also will be given to the ability of the injection lines to absorb the expansion resulting from the recirculating water temperature.

For most of their routing, the emergency injection lines will be outside the reactor and steam generator shielding, and hence protected from missiles originating within these areas. The portions of the injection lines located between the primary reactor shield and the reactor vessel wall are 2 not subject to missile damage because there are no credible sources of missiles in that area. To afford further missile protection, a high-pressure injection line connects to each reactor coolant inlet line and the two core flooding nozzles are located on opposite sides of the reactor vessel.

All water used for emergency injection fluid will be maintained at a minimum concentration of 2,270 ppm of boron (13,000 ppm boric acid). The temperature, pressure, and level of these tanks will be displayed in the control room, and alarms will sound when any condition is outside the normal limits. The water will be periodically sampled and analyzed to ensure proper boron concentration.

6.1.3.4 Check Valve Leakage - Core Flooding System

The action that would be taken in the case of check valve leakage would be a function of the magnitude of the leakage.

Limited check valve leakage will have no adverse effect on reactor operation. The valves will be specified to meet the tightness requirements of MSS-SP-61, "Hydraulic Testing of Steel Valves." * For these valves, this amounts to a maximum permissible leakage of 140 cc/hr per valve. Two valves in series are provided in each core flooding line; hence, leakage should be below this value.

Leakage across these check valves can have three effects: (a) it can cause a temperature increase in the line and core flooding tank, (b) it can cause a level and resultant pressure increase in the tank, and (c) it can cause dilution of the borated water in the core flooding tank. Leakage at the rate mentioned above causes insignificant changes in any of these parameters. A leakage of 140 cc/hr causes level increase in the tank of less than 1 in./mo. The associated temperature and pressure increase is correspondingly low.

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* MSS - Manufacturers' Standardization Society

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If it were assumed that the leakage rate is 100 times greater than specified, then there would still be no significant effect on reactor operation since the level change would be approximately 2 in./day. A 2-in. level change will result in a pressure increase of approximately 10 psig. With redundant temperature, pressure, and level indicators and alarms available to monitor the core flooding tank conditions, the most significant effect on reactor operations is expected to be a more frequent sampling of tank boric acid concentration.

To ensure that no temperature increase will occur in the tank, even at higher leakage rates, the portion of the line between the two check valves and the line to the tanks will be left uninsulated to promote convective losses to the building atmosphere.

In summary, reactor operation may continue with no adverse effects coincident with check valve leakage. Maximum permissible limits on core flooding tank parameters (level, temperature, and boron concentration) will be established to ensure compliance with the core protection criteria and final safety analyses.

6.1.4 TEST AND INSPECTIONS

All active components, as listed in Table 6.1-3, of the emergency injection systems will be tested periodically to demonstrate system readiness. In addition, normally operating components will be inspected for leaks from pump seals, valve packing, flanged joints, and safety valves.

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TABLE 6.1-3
EMERGENCY INJECTION EQUIPMENT PERFORMANCE TESTING

	Equipment	Test
3	H.P. Injection pump	One makeup pump is operating continuously. The two H.P. Injection pumps will be periodically tested.
	High Pressure Injection Line Valves	The remotely operated stop valve in each line will be opened partially one at a time. The flow devices will indicate flow through the lines.
2	H.P. Pump Suction Valves	The makeup tank water level will be raised to equalize the pressure exerted by the borated water storage tank. The valves will then be opened individually and closed.
	Decay Heat Pumps	In addition to use for shutdown cooling, these pumps will be tested singly by opening the borated water storage tank outlet valves and the bypasses in the borated water storage tank fill line. This will allow water to be pumped from the borated water storage tank through each of the injection lines and back to the tank.
	Borated Water Storage Tank Outlet Valves	The operational readiness of these valves will be established in completing the pump operational test discussed above. During this test, each of the valves will be tested separately for flow.
	Low Pressure Injection Valves	With pumps shut down and borated water storage tank outlet valves closed, these valves will be opened and reclosed by operator action.
	Valve for Suction from Sump	With pumps shut down and borated water storage tank outlet valves closed, these valves will be opened and reclosed by operator action.
2	(Deleted)	
	Valves in Core Flooding Injection Lines	Valves can be operated during each shutdown to determine performance. Isolation valves will be closed to contain water in core flooding tanks during shutdown.

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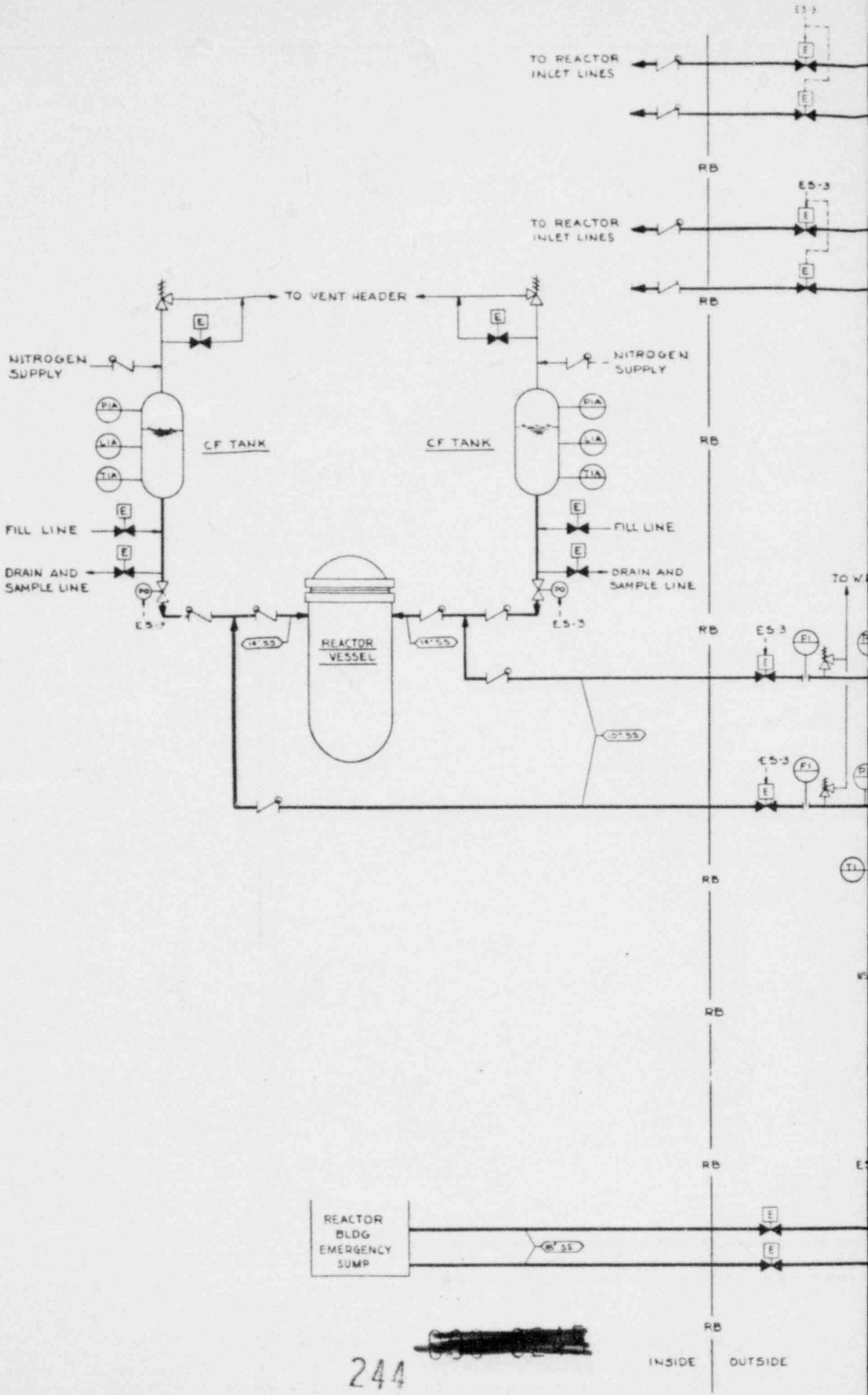

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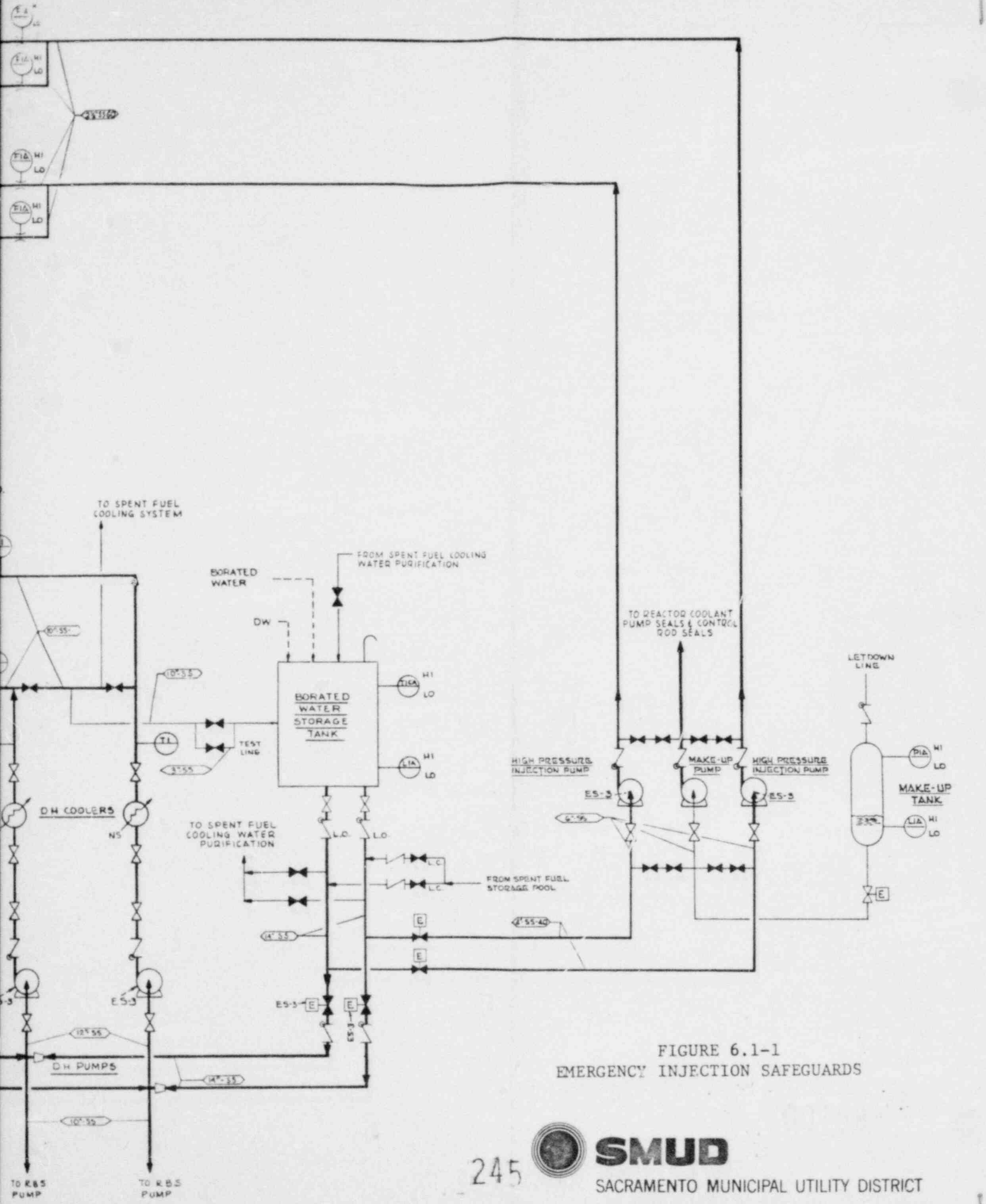

FIGURE 6.1-1
EMERGENCY INJECTION SAFEGUARDS

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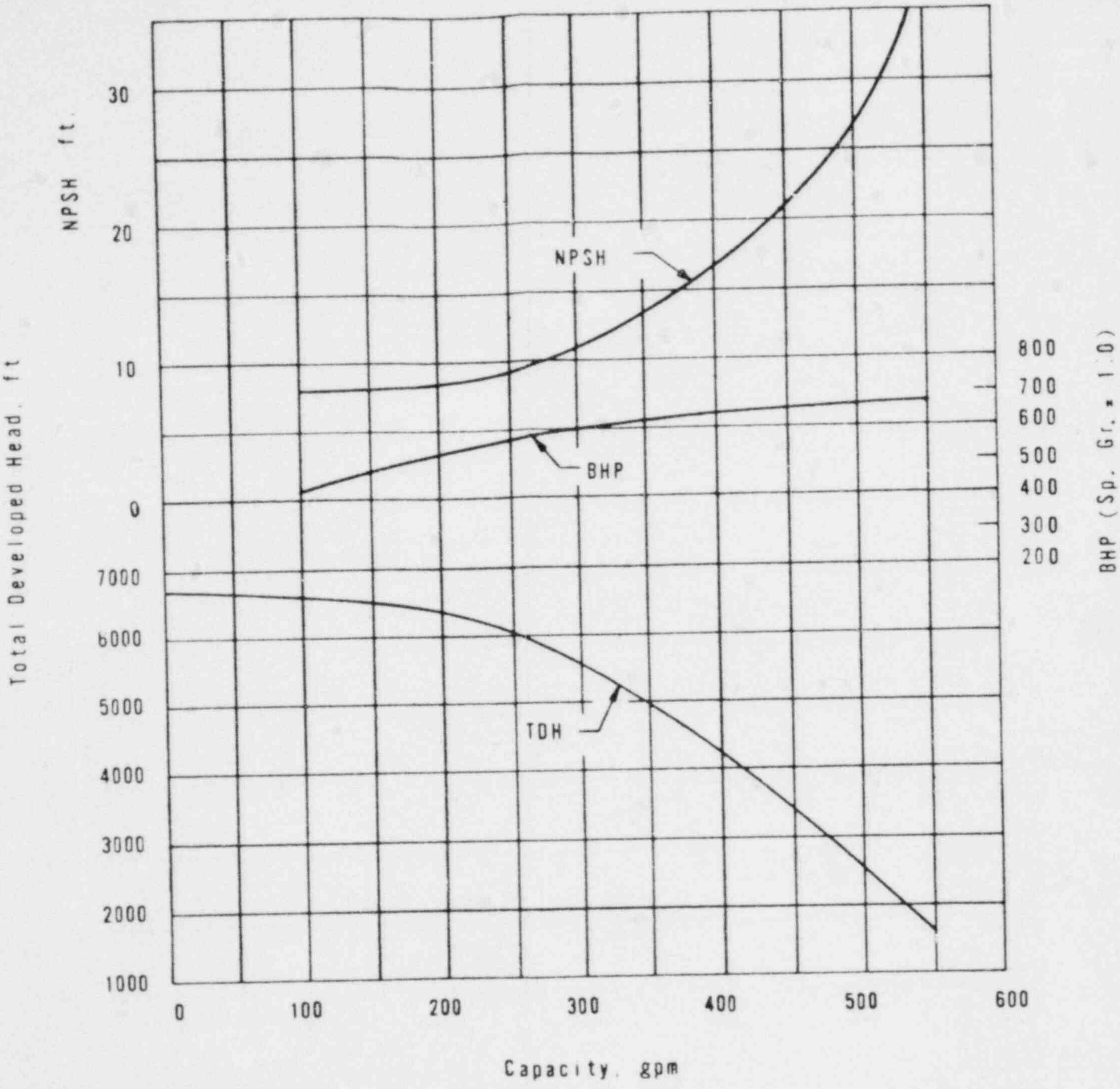

FIGURE 6.1-2
MAKEUP PUMP CHARACTERISTICS

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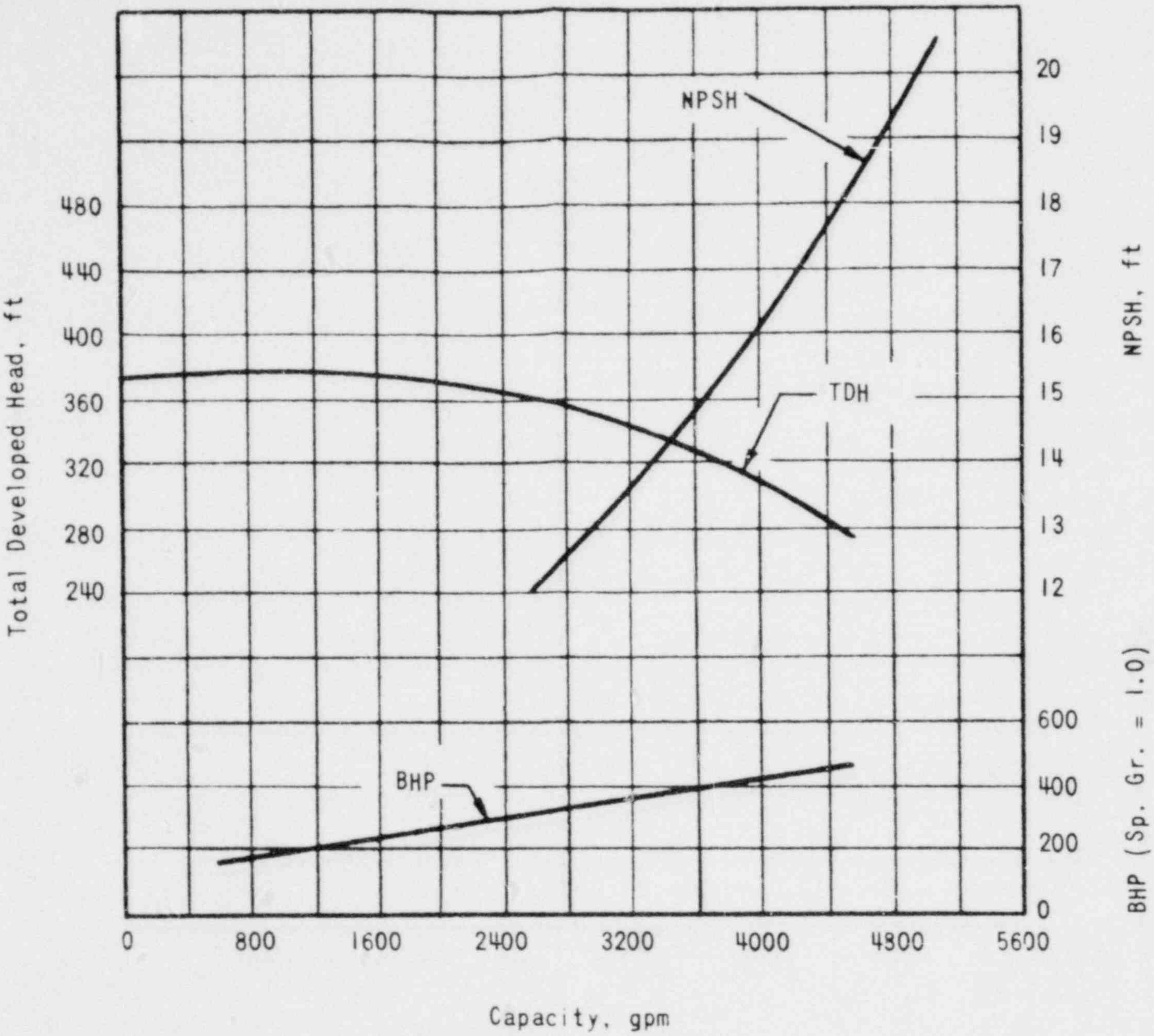

FIGURE 6.1-3
DECAY HEAT REMOVAL
PUMP CHARACTERISTICS

Emergency Design Conditions

Injection Water Flow Per Cooler - 3,000 gpm
Nuclear Service Water Flow Per Cooler - 3,000 gpm
Nuclear Service Water Inlet Temperature - 95 F

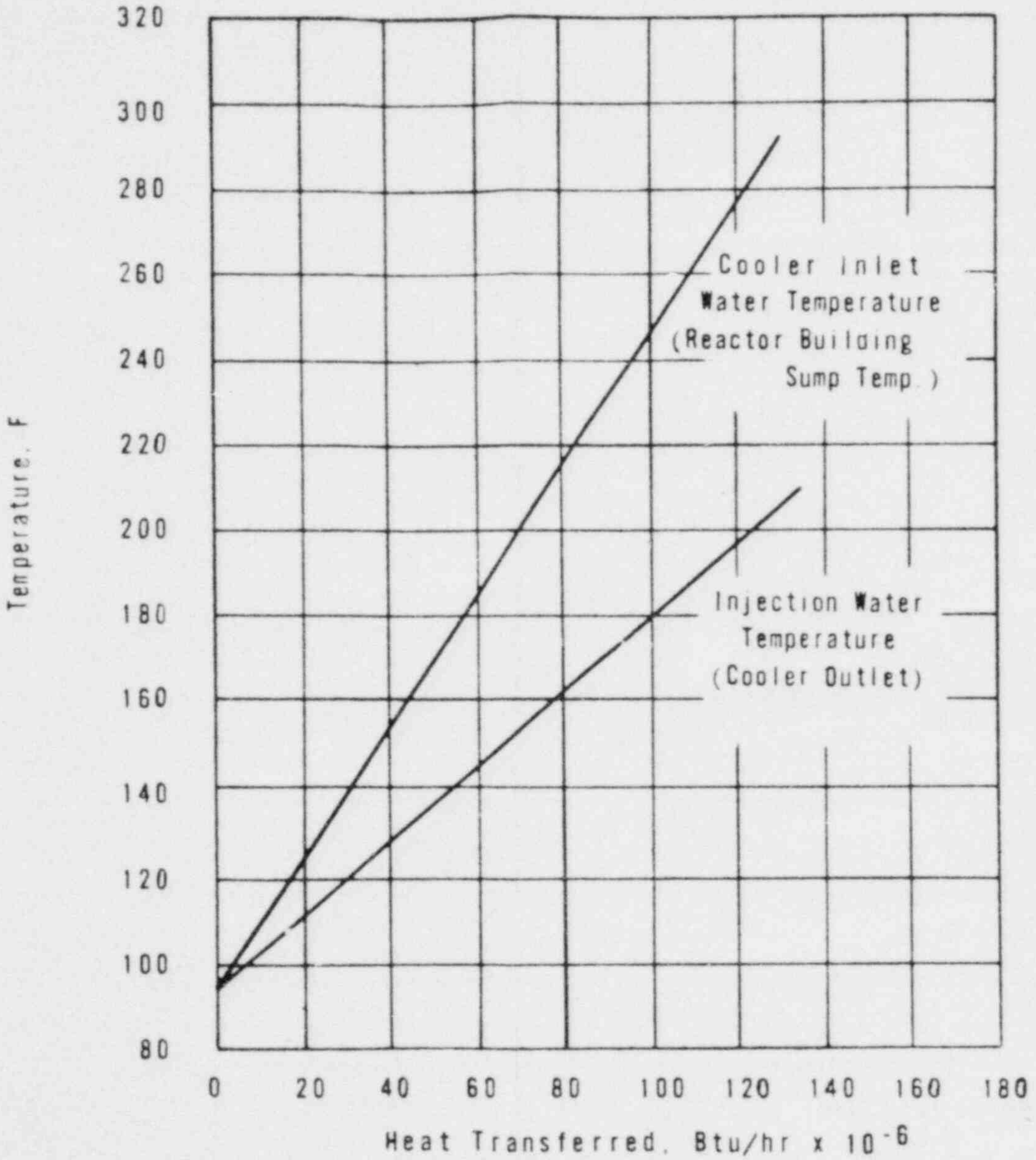

FIGURE 6.1-4
DECAY HEAT REMOVAL
COOLER CHARACTERISTICS

6.2 REACTOR BUILDING ATMOSPHERE COOLING AND WASHING

6.2.1 DESIGN BASES

Emergency building atmosphere cooling and washing is provided to reduce the postaccident level of fission products in the building atmosphere. Spray additives contained in the building sprays are used to reduce postaccident fission product concentrations in the building atmosphere. 2

6.2.2 DESCRIPTION

The schematic flow diagram of the reactor building emergency atmosphere cooling and washing and associated instrumentation is given in Figure 6.2-1. Four emergency cooling units, each of 25% capacity will be provided. Each unit contains a single coil sized for emergency service, and a direct-driven fan. For emergency cooling, all units will operate under post-accident conditions with the heat being rejected to the nuclear service cooling water system. Each of these units can remove 60 x 10^6 Btu per hour under peak reactor building temperature conditions. The design data for the cooling units are shown in Table 6.2-1. 2

The reactor building sprays are supplied with water by two pumps which take suction on the borated water storage tank until this source is exhausted. 1
The spray additive required for the reactor building sprays is supplied from a storage tank connected by electric motor operated stop check valves, interlocked to open only when the reactor building spray pump motors are operating. 2

TABLE 6.2-1
REACTOR BUILDING EMERGENCY COOLING UNIT PERFORMANCE AND EQUIPMENT DATA
(capacities are on a per unit basis)

Equipment Data	Duty	
No. of Units Installed	4	2
No. Required	4	
Type Coil	Finned Tube	
Peak Heat Load, Btu/hr	60 x 10^6	
Fan Capacity, cfm	40,000	
Reactor Building Atmosphere Inlet Conditions		
Temperature, F	286	
Steam Partial Pressure, psia	~ 53	
Air Partial Pressure, psia	~ 21	
Total Pressure, psig	59	
Cooling Water Flow, gpm	1,500	4
Cooling Water Inlet Temperature, F	95	2
Cooling Water Outlet Temperature, F	175	4

Two sets of high efficiency and charcoal filters each with 54,500 cfm capacity are provided for normal containment air cleanup and can be used for removal of fission products in the containment volume.

2 Sufficient spray additive is injected into the borated water to create an appropriate concentration in the reactor building water inventory.

After the supply from the borated water storage tank is exhausted, the spray pumps take suction from the reactor building sump recirculation lines. 2 This continued spraying serves to equalize the reactor building atmosphere and the reactor building sump temperature.

Design data for the reactor building cooling and spray system components are given in Tables 6.2-1 and 6.2-2. Design data for components of the decay heat removal systems used in this phase of engineered safeguards operation are given in Section 9 and supplemented by Figures 6.1-3 and 6.1-4 of this section.

6.2.3 DESIGN EVALUATION

The function of cooling the reactor building atmosphere, after safety injection, is fulfilled by either of the two methods described above, and redundancy of equipment within both methods will provide for protection of building integrity. The reactor building sprays, through duplication, 2 basic washing concept, and spray additive will serve to reduce fission product levels in the building atmosphere.

TABLE 6.2-2
REACTOR BUILDING SPRAY SYSTEM PERFORMANCE AND EQUIPMENT DATA
(capacities are on a per unit basis)

Component	Data
Reactor Building Spray Pumps	
Number	2
Flow, gpm	1,500
Developed Head at Rated Flow, ft	430
Motor Horsepower, hp	250
Material	SS
Design Pressure, psi	300
Design Temperature, F	300
2 Spray Additive Tank	
Number	1
Volume, ft^3	1,500
Material	SS
Design Pressure, psi	50
2 Design Temperature, F	150
Spray Header	
Number	2
Spray Nozzles per Header	375

250

[redacted]

For the first 30 to 40 minutes following the maximum blowdown loss-of-coolant accident, i.e., during the time that the reactor building spray pumps take their suction from the borated water storage tank, this system provides more than 100 percent of the heat removal capacity of the reactor building cooling system.

The reactor building spray system design is based on the process of the spray water being raised to the temperature of the reactor building while falling through the steam-air mixture within the building. Detailed evaluation of system performance is presented in Section 14. Each of the following equipment arrangements will provide sufficient heat removal capability to maintain the postaccident reactor building temperature to that which may be required for fission product removal.

a. Reactor building spray system.

b. All emergency units in the reactor building cooling system.

c. Two emergency cooling units and the reactor building spray system at one-half capacity.

The reactor building spray system shares the suction lines from the borated water storage tank and the tank itself with the high and low pressure injection systems.

6.2.3.1 Failure Analysis

A single failure analysis has been made on all active components of the systems used to show that the failure of any single active component will not prevent the fulfilling of the design functions. This analysis is shown in Table 6.2-3. Assumptions inherent in this analysis are the same as those presented in 6.1.3 in regard to valve functioning, failure types, etc. Results of full and partial performance of these safeguards are presented in Section 14 under analysis of postaccident conditions.

6.2.3.2 Reactor Building Cooling Response

Air recirculation is established within 35 seconds after the building pressure reaches 4 psig by the four reactor building emergency cooling units. Cooling coils in these ventilation units are supplied with cooling water from the nuclear service cooling water system after reactor building pressure increases to 4 psig. This mode of cooling continues until the building pressure reaches near-atmospheric. 2

The reactor building spray system will also be activated by a single parameter signal. Two of three signals signifying high reactor building pressure will start the reactor building spray pumps, open the reactor building spray inlet valves, and open the suction valves from the borated water storage tank and the spray additive valves. The system components may also be actuated by operator action from the control room for performance testing. 2

[redacted]

TABLE 6.2-3
SINGLE FAILURE ANALYSIS - REACTOR BUILDING ATMOSPHERE COOLING AND WASHING

Component	Malfunction	Comments and Consequences
1. Reactor Building spray nozzles.	Clogged.	Large number of nozzles (375 on each of two headers) renders clogging of significant number of nozzles as incredible.
2. Reactor Building spray header.	Rupture.	This is considered incredible due to low operating pressure differential.
3. Check valve in spray header line.	Sticks closed.	Second header and emergency cooling units will provide 150 percent design cooling capacity. This is considered incredible due to large opening force available at pump shutoff head.
4. Electric motor operated valve in spray header line.	Fails to open.	Second header and Reactor Building emergency cooling units will provide 150 percent of design base cooling requirement.
5. Spray pump isolation valve.	Left closed.	Flow and cooling capacity reduced to 50 percent of design. In combination with emergency coolers, 150 percent of total design requirement is still provided.
6. Reactor Building spray pump.	Fails to start.	Flow and cooling capacity reduced to 50 percent of design. In combination with emergency coolers, 150 percent of total design requirement is still provided.
7. Reactor Building emergency cooling unit.	Fails to start.	Emergency cooling by the other operating units with supplemental cooling by the sprays, 175 percent of total design requirement is still provided.

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TABLE 6.2-3 Continued

Component	Malfunction	Comments and Consequences	
8. Reactor Building emergency cooling unit.	Rupture of cooling coil.	The tubes are designed for 200 psi and 300 F which exceeds maximum operating conditions. Tubes are protected against credible missiles. Hence, rupture is not considered credible.	2
9. Reactor Building emergency cooling unit.	Rupture of casing and/or ducts.	Consideration will be given during detailed design to the dynamic forces resulting from the pressure buildup during a postaccident situation. The units can be inspected and will be protected against credible missiles. Cooling with these units will be supplemented by the sprays.	2
10. Reactor Building emergency cooling units.	Rupture of system piping.	Rupture is not considered credible since all piping is Schedule 40, permitting an allowable working pressure of at least 500 psig at 650 F for all sizes. Piping is inspectable and protected from missiles. Maximum actual internal pressure will be less than 200 psig at temperatures below 300 F.	2 2
11. Electric motor-operated valve at inlet penetration to emergency cooling unit.	Sticks closed.	Should a valve fail to open, the remaining cooling units plus the reactor building spray system will supply 175% design cooling capacity.	2
12. Electric motor-operated valve at outlet penetration from emergency cooling unit.	Fails to open.	Comments for Item 11 apply.	2

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TABLE 6.2-3 Continued

Component	Malfunction	Comments and Consequences
13. Check valve at spray additive storage tank outlet.	Fails to open.	Alternate check valve will permit full flow required for sprays.

2

[redacted]

The expected lag time for the foregoing operations is the same as for the low pressure injection (6.1.3.2), and the total time to delivery of reactor building sprays is approximately 25 seconds after building pressure reaches 10 psi.

6.2.3.3 Special Features

The casing design for the ventilation units will be of a conventional nature unless additional analysis shows the possibility of pressure wave collapse. In that event, quick, inward-opening hinged louvers, or other protective features, will be incorporated into the design to maintain post-accident operability. The ventilation units are located outside the concrete shield for the reactor vessel, steam generators, and reactor coolant pumps at an elevation above the water level in the bottom of the reactor building at post accident conditions. In this location, the systems in the reactor building are protected from credible missiles and from flooding during post-accident operations.

The spray headers of the reactor building spray system are located outside and above the reactor and steam generator concrete shield. During operation, a shield also provides missile protection for the area immediately above the reactor vessel. The spray headers are therefore protected from missiles originating within the shield. The spray pumps are located outside the reactor building and are thus available for operative checks during station operation.

6.2.4 TESTS AND INSPECTIONS

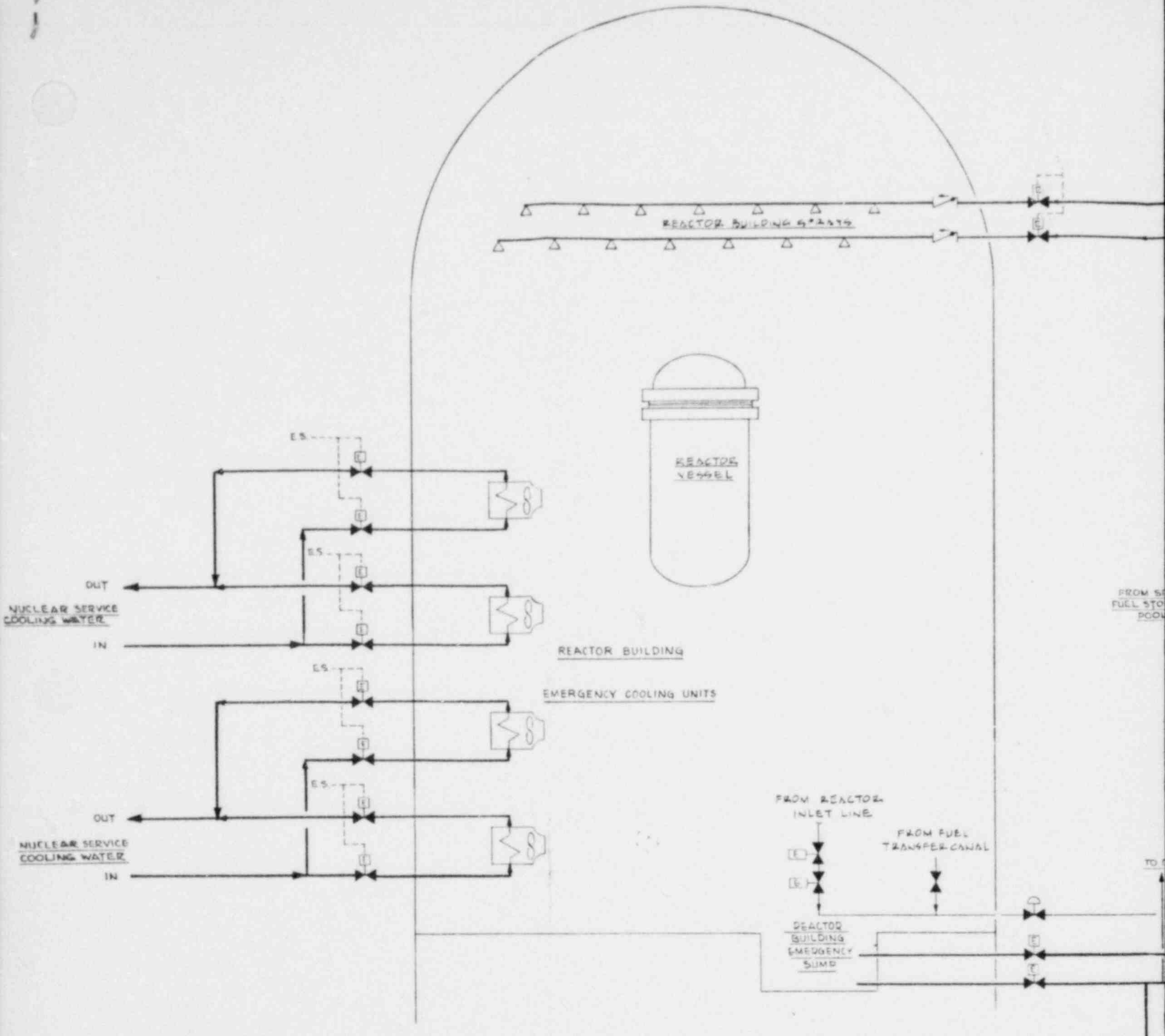
Active components of the emergency cooling units will be periodically tested. 2

Components of the reactor building spray system will be tested on a regular schedule as follows:

Reactor Building Spray Pumps	These pumps will be tested singly by closing the spray header valves and opening the valves in the test line and the borated water storage tank outlet valves. Each pump in turn will be started by station operator action and checked for flow establishment to each of the spray headers. Flow will also be tested through each of the borated water storage tank outlet valves by operating these valves.
Borated Water Storage Tank Outlet Valves	These valves will be tested in performing the pump test listed above.
Reactor Building Spray Injection Valves	With the pumps shut down and the borated water storage tank outlet valves closed, these valves will each be opened and closed by operator action.

Reactor Building Spray Nozzles	Under the conditions specified for the previous test, and with the reactor building spray valves alternately open, smoke will be blown through the test connections.
2 Spray Additive Valve Test	These valves will each be opened and closed by operator action from the control room. During the test the normally-locked open valve will be closed.

[redacted]


REACTOR BUILDING SPRAYS
REACTOR VESSEL
E.S.
E.S.
E.S.
E.S.
OUT
NUCLEAR SERVICE COOLING WATER
IN
OUT
NUCLEAR SERVICE COOLING WATER
IN
REACTOR BUILDING
EMERGENCY COOLING UNITS
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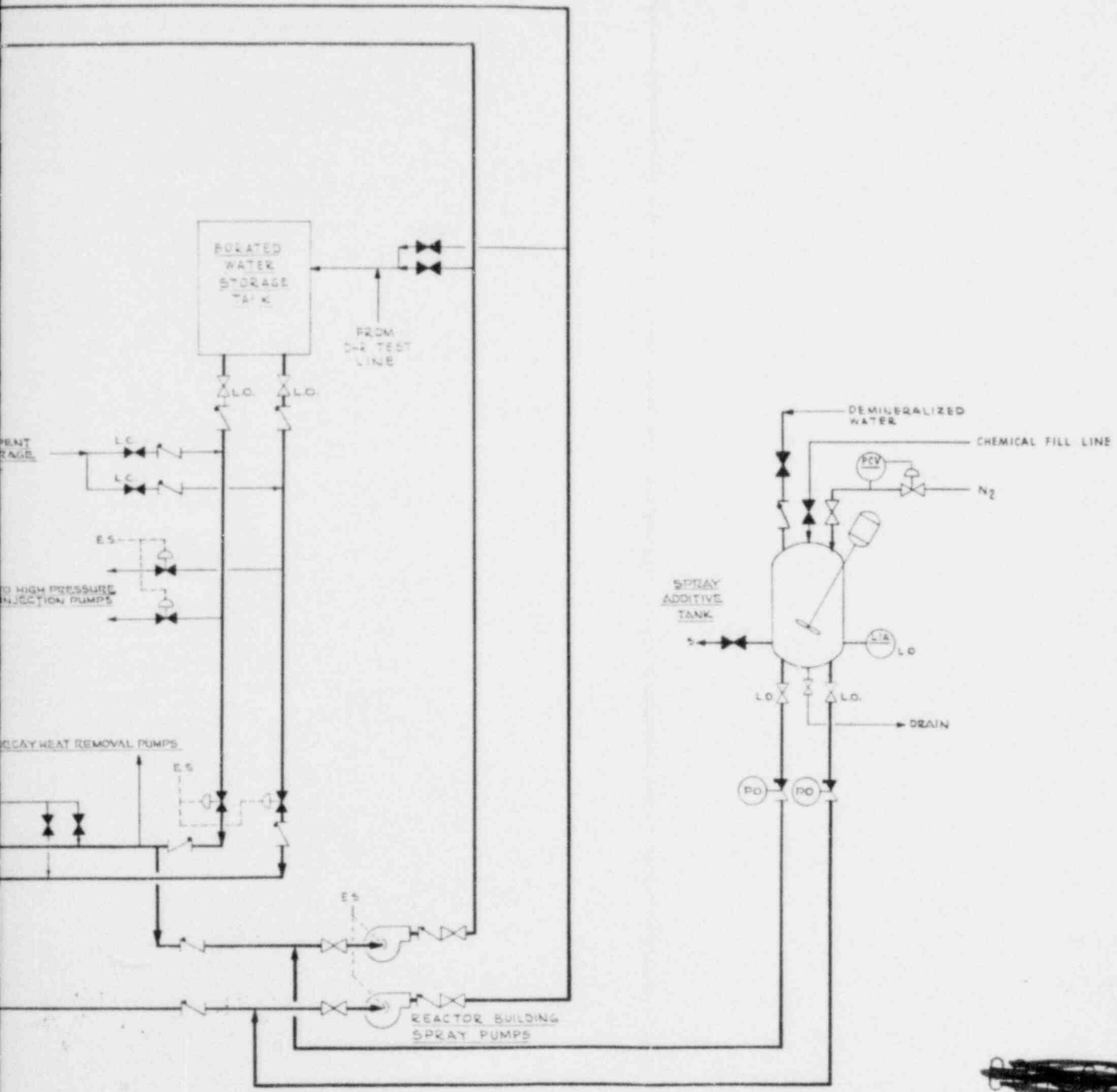

[redacted]

FIGURE 6.2-1
REACTOR BUILDING
EMERGENCY COOLING

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SMUD

SACRAMENTO MUNICIPAL UTILITY DISTRICT

Amendment 2

6.3 ENGINEERED SAFEGUARDS LEAKAGE AND RADIATION CONSIDERATIONS

6.3.1 INTRODUCTION

The use of normally-operating equipment for engineered safeguards' functions and the location of some of this equipment outside the reactor building requires that consideration be given to direct radiation levels after fission products have accumulated in these systems with leakage from these systems. Although the engineered safeguards' equipment is designed for control room operation following an accident, long-term postaccident operation could necessitate manual operation of certain valves.

The shielding for components of the engineered safeguards is designed to provide protection for personnel while performing all operations necessary for mitigation of the accident without exceeding acceptable dose limits.

6.3.2 SUMMARY OF POSTACCIDENT RECIRCULATION AND LEAKAGE CONSIDERATION

Following a loss-of-coolant accident and exhaustion of the borated water storage tank, reactor building sump recirculation to the reactor vessel and the reactor building sprays is initiated.

While the reactor auxiliary systems involved in the recirculation complex are closed to the auxiliary building atmosphere, leakage is possible through component flanges, seals, instrumentation, and valves.

The leakage sources considered are:

a. Valves

    (1) Disc leakage when valve is on recirculation complex boundary.

    (2) Stem leakage.

    (3) Bonnet flange leakage.

b. Flanges

c. Pump stuffing boxes

While leakage rates have been assumed for these sources, maintenance and periodic testing of these systems will preclude all but a small percentage of the assumed amounts. With the exception of the boundary valve discs, all of the potential leakage paths may be examined during periodic test or normal operation. The boundary valve disc leakage is retained in the other closed systems and therefore, will not be released to the auxiliary building.

[redacted]

While valve stem leakage has been assumed for all valves, the manual valves in the recirculation complex are backseating.

6.3.3 LEAKAGE ASSUMPTIONS

Source	Quantities
a. Valves - Process	
(1) Disc leakage	10 cc/hr/in. or nominal disc diameter
(2) Stem leakage	1 drop/min
(3) Bonnet Flange	10 drops/min
b. Valves - Instrumentation	
Bonnet flange and stem	1 drop/min
c. Flanges	10 drops/min
d. Pump Stuffing Boxes	50 drops/min

For the analysis, it was assumed that the water leaving the reactor building was at 281 F. This assumption is conservative since this peak temperature would only exist for a short period during the postaccident condition. Water downstream of the coolers was assumed to be 115 F. The auxiliary building was assumed to be at 70 F and 30 percent relative humidity. Under these conditions, approximately 22 percent of the leakage upstream of the coolers and 4 percent of the leakage downstream of the coolers would flash into vapor. For the analysis, however, it was assumed that 50 percent of the leakage upstream of the coolers would become vapor because of additional heat transfer from the hot metal.

6.3.4 DESIGN BASIS LEAKAGE

The design basis leakage quantities derived from these assumptions for postaccident sump recirculation are tabulated in Table 6.3-1.

6.3.5 LEAKAGE ANALYSIS CONCLUSIONS

It may be concluded from this analysis (in conjunction with the discussion and analysis in Section 14) that leakage from engineered safeguards' equipment outside the reactor building does not pose a public safety problem.

[redacted]

TABLE 6.3-1
LEAKAGE QUANTITIES TO AUXILIARY BUILDING ATMOSPHERE

Leakage Source	No. of Sources	Per Source, drops/min	Total, cc/hr	Liquid Phase, cc/hr	Vapor Phase, cc/hr	
a. Pump Seals						
Decay heat pumps	2	50	300	150	150	2
Spray pumps	2	50	300	150	150	
b. Flanges *	114	10	3,320	1,800	1,520	
c. Process Valves	35	1	105	68	37	
d. Instrumentation Valves	25	1	75	72	3	
e. Valve Seats at Boundaries	11	**	750	580	170	
Total			4,850	2,820	2,030	2

* Assumes process and boundary valves, and process components are flanged.

** Assumes 10 cc/hr/in. of nominal disc diameter.

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[redacted]