6 ENGINEERED SAFEGUARDS

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6 ENGINEERED SAFEGUARDS

Engineered safeguards are provided to fulfill four functions in the unlikely event of a serious loss-of-coolant accident: 3

a. Protect the fuel cladding.

b. Insure reactor building integrity.

c. Reduce the driving force for building leakage.

d. Remove Fission products from the reactor building atmosphere. 3

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

The engineered safeguards include a core flooding system, high pressure injection equipment, the decay heat removal system, the reactor building cooling system, and the reactor building spray system. Figures 6-1 and 6-5 show the operation of these systems in the engineered safeguards mode, together with associated instrumentation and piping.

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.

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. This Section 6 will present 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.

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.

> Emergency core cooling includes pumped injection and the core flooding tanks. Pumped injection is subdivided in such a way that there are two separate and independent strings, each including both high pressure and low pressure coolant injection and each capable of providing 100 percent of the necessary core injection with the core clooding tanks. The core flooding tanks are passive components which are needed for only a short period of time after the accident, thereby assuring 100 percent availability when needed. 3

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 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 necessary to fill the fuel transfer canal during refueling operations and is connected to the injection pump suction headers by two lines, one connected to the high pressure injection pumps, and one connected to the decay heat removal pumps. Additional coolant for emergency injection supply is contained in core flooding tanks which inject coolant without fluid pumping as described later in this section. 3

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 psi during power operation or (b) a reactor building pressure of 10 psig during power operation. The low pressure 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) Two makeup pumps will be in operation (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 code flooding tanks begin emergency injection. The flow characteristic curves for each makeup pump are given in Figure 6-2. 4

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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 and one stop (isolation) valve; the system provides for automatic flooding injection with initiation of flow when the reactor coolant system pressure reaches approximately 600 psi. This injection provision does not require any electrical power, automatic switching, or operator action to insure 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 insure 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 3
building pressure of 10 psig during any accident. The flow characteristics of each decay heat pump for injection are shown in Figure 6-3; each pump is designed to deliver 3,000 gpm flow into the reactor vessel at a vessel pressure of 100 psi.

Low pressure injection, with supply from the borated water storage tank, using the decay heat pumps will continue until a low level signal is received from the tank (39 min at a combined low pressure injection and reactor building spray flow of 9,000 gpm). At this time, the operator will open the valves controlling suction from the reactor building sump, and recirculation of coolant from the sump to the reactor vessel will begin. The decay heat coolers will cool the recirculated flow, thus removing heat from the reactor building fluid and preventing further reactor building accumulation of decay heat generated by the core.

The decay heat removal pumps are located at an elevation below the reactor building sump with dual suction lines routed outside the reactor building to the pumps. In the event one suction line is unavailable for recirculation, the lines have been sized so that one line will be capable of handling the total potential recirculation flow of one 3,000-gpm decay heat removal pump and one 1,500-gpm reactor building spray pump. The NPSH available has been conservatively calculated to be greater than the NPSH requirement of the decay heat removal pumps and the reactor building spray pumps.

The calculations for available NPSH at the reactor building spray pump and the decay heat removal pump suctions will include a safety margin over and above the requirements of these pumps. The calculations will assume conservatively that minimum water levels exist in the borated water storage tank and in the reactor building, and that air pressure in the reactor building is 1 psi below normal atmospheric pressure. Final pipe sizes will be adjusted to provide a safe NPSH margin for either pump operating mode.

The heat transfer capability of each decay heat cooler as a function of recirculated water temperature is illustrated in Figure 6-4. The heat transfer capability at the saturation temperature corresponding to reactor building pressure is in excess of the heat generation rate of the core following storage tank injection.

Design data for core flooding system components are given in Table 6-1. Design data for other emergency injection components are given in Section 9 except for those shown in Figures 6-2, 6-3, and 6-4.

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 plant 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 insure 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.

Three makeup pumps are installed: one is normally operating, one can be down for maintenance, and one is required for engineered safeguards.

Table 6-1

Core Flooding System Performance and Equipment 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
Material of Construction	Carbon Steel- SS Clad
Check Valves	
Number per Flooding Line	2
Size, in.	14
Material	SS
Design Pressure, psig	2,500
Design Temperature, F	650
Isolation (Stop) Valves	
Number per Flooding Line	1
Size, in.	14
Material	SS
Design Pressure, psig	2,500
Design Temperature, F	650

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(*) Designed to ASME Section III, Class C.

Table 6-1. (Cont'd)

Piping	
Number of Flooding Lines	2
Size, in.	14
Material	SS
Design Pressure, psig	2,500
Design Temperature, F	650

6.1.3.1 Failure Analysis

The single failure analysis presented in Table 6-2 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 plant operating procedures.

The single failure analysis (Table 6-2) 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.

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 owing to the 90 F water being injected into these high temperature lines. The equipment normally operating is handling 125 F water, and hence will experience no thermal shock when 90 F water is introduced.

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 --	$\approx$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) --	$\approx$10 sec
d.	Injection valve operating time --	<10 sec
e.	Borated water storage tank outlet valves --	<10 sec
	Total (only b and c are additive)	$\approx$25 sec

6.1.3.3 Special Features

The core flooding nozzles (Figure 3-61) will be specially designed to insure 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 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 pipe, 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. The temperature, pressure, and level of these tanks will be displayed in the control room, the alarms will sound when any condition is outside the normal limits. The water will be periodically sampled and analyzed to insure 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

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(*) MSS - Manufacturers' Standardization Society.

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.

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 psi. With redundant temperature, pressure, and level indicators and alarms vailable 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 insure 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 insure compliance with the core protection criteria and final safety analyses.

6.1.4 TEST AND INSPECTIONS

All active components, as listed in Table 6-3, 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 6-2

Single Failure Analysis-Emergency Injection

Component	Malfunction	Comments and Consequences	
A. High Pressure Injection			
1. Stop-check 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.	17
2. Power operated valve in engineered safeguard suction header connected to borated water storage tank.	Fails to open.	Similar valve in other safeguard string will deliver required flow to redundant engineered safeguard pumps.	17
3. Makeup pump.	Out for maintenance.	Two pumps will still be available. Only one pump is required for engineered safeguards.	
4. Makeup pump.	Fails (stops).	Other makeup pump delivers required flow.	
5. Makeup pump isolation valve.	Left inadvertently closed.	See Item A4 above. Valves will normally be left open since the check valve in each pump discharge will prevent back-flow. Operating procedures will call for pump isolation valves to be closed only for maintenance.	

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Table 6-2 (Cont'd)

Component	Malfunction	Comments and Consequences
6. Makeup pump discharge check valve.	Sticks closed.	This is considered incredible since the pump discharge pressure of 2,700 psi at no flow would tend to open even a very tightly stuck check disc.
7. Pressurizer level control valve.	Fails to close.	No consequences.
8. Seal injection control valve.	Fails to close.	Injection flow through this line would be small compared to the flow through the two injection lines due to the high flow resistance of the reactor coolant pump seals.
9. Power operated valve in high-pressure injection line.	Fails to open.	Flow from one pump will go through the alternate line. Other pump will operate as normal.
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.

Table 6-2 (Cont'd)

	Component	Malfunction	Comments and Consequences	
12.	Manual normally closed valve from decay heat coolers to makeup pumps.	Inadvertently left open.	No significant consequences. A small percentage of LP injection flow will be bypassed to HP suction.	17
13.	Manual normally closed valve from decay heat coolers to makeup pumps.	Stuck closed and cannot be opened.	Similar valve in other makeup pump string will leliver required flow.	17
14.	Double manual valves connecting pump lines.	Inadvertently left open.	Not credible that both valves will inadvertently be left open.	
B.	Core Flooding System			
1.	Flooding line check valve.	Sticks closed.	This is considered incredible based on the valve size and opening pressure applied.	
C.	Decay Heat Removal System			
1.	Check valve at reactor vessel.	Sticks closed.	This is considered incredible since these valves will be used periodically during decay heat remova, and the opening force will be approximately 5,000 pounds.	
2.	Power-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.	

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Table 6-2 (Cont'd)

Component	Malfunction	Comments and Consequences
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.
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 post-accident 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.
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.
10. Check valve in engineered safeguard suction header connected to borated water storage tank.	Sticks closed.	Alternate line will permit required flow. 17
11. Power operated valve permitting suction from reactor building sump.	Fails to open.	Two lines and valves are provided. One will provide the required flow, 17

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Table 6-2 (Cont'd)

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 strainers will be provided.
13. Dual manual valves connecting outlet of decay heat coolers.	Inadvertently left open.	Not credible that both valves will be inadvertently left open because of administrative controls. 3
14. Power-operated valves permitting suction from reactor building sump.	Inadvertently and prematurely opened after LOCA.	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. 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,

Table 6-2 (Cont'd)

Component	Malfunction	Comments and Consequences
		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. 3 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.

Table 6-3

Emergency Injection Equipment Performance Testing

Makeup Pumps	One pump is operating continuously. The other two 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.
Makeup Pump Suction Valves	The makeup tank water level will be raised to equalize the pressure exerted by the storage tank and 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.
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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6.2 REACTOR BUILDING ATMOSPHERE COOLING AND WASHING

6.2.1 DESIGN BASES

Emergency building atmosphere cooling and washing is provided to limit post-accident building pressures to design values and reduce the post-accident level of fission products in the building atmosphere.

Reactor building air recirculation and cooling units, backed up by reactor building sprays, are used for emergency atmosphere cooling. Chemical additives contained in the building sprays are used to reduce post-accident fission product concentrations in the building atmosphere.

6.2.2 DESCRIPTION

The schematic flow diagram of the emergency reactor building atmosphere cooling and associated instrumentation is given in Figure 6-5.

Emergency and normal cooling are performed with the same basic units. Each unit contains normal and emergency cooling coils and a single speed fan. During normal plant operation, chilled water from the plant main water chillers is circulated through the normal cooling coils. For emergency cooling, all units will operate under post-accident conditions with the heat being rejected to the service water system. Each of these units can remove 60×10^6 Btu/hr under peak reactor building temperature conditions. Figure 6-6 shows the heat exchange characteristics versus building ambient conditions for these units. The design data for the cooling units are shown in Table 6-4. 17

Table 6-4

Reactor Building Cooling Unit Performance and Equipment Data
(Capacities are on a per unit basis)

	Emergency	Normal	
No. Installed	4	4	
No. Required	4	3	
Type Coil	Finned Tube	Finned Tube	
Peak Heat Load, Btu/hr	60×10^6	1.15×10^6	17
Fan Capacity, cfm	30,000	30,000	
Reactor Building Atmosphere Inlet Conditions			
Temperature, F	286	110	
Steam Partial Pressure, psia	54	--	
Air Partial Pressure, psia	20	--	
Total Pressure, psig	59	Atmospheric	
Cooling Water Flow, gpm	1,200	130	
Cooling Water Inlet Temperature, F	85	50	
Cooling Water Outlet Temperature, F.	185	68	

Simultaneously with the air recirculation cooling, reactor building sprays are supplied with water by two pumps which take suction on the borated water stor-

age tank until this coolant source is exhausted. The sodium thiosulfate chemical additive required for the reactor building sprays is supplied from a storage tank connected by dual lines containing power operated and stop-check valves to the suction of the spray pumps. Sufficient sodium thiosulfate is injected into the borated water to create a 1 wt % concentration in the
reactor building water inventory. Sodium hydroxide in a quantity sufficient 17
to achieve a reactor building water inventory pH of 9.5 is injected into the borated water flowing through the engineered safeguards suction headers from a storage tank provided with dual discharge lines containing power-operated valves and stop-check valves. After the supply from the borated water storage tank is exhausted, the spray pumps take suction from the reactor building sump recirculation line. This continued spraying serves to reduce the reactor building atmosphere to the temperature of the reactor building sump.

Design data for the reactor building spray system components are given in Table 6-5, and the flow characteristics of the reactor building spray pumps are given in Figure 6-7. Design data for components of the reactor building cooling and decay heat removal systems used in this phase of engineered safeguards operation are given in Section 9 and supplemented by Figures 6-3, 6-4, 6-6, and 6-7 of this Section.

Table 6-5

Reactor Building Spray System Performance and Equipment Data
(Capacities are on a per unit basis.)

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	
Sodium Thiosulfate Tank		
Number	1	
Volume, Ft^3	2,700	
Material	SS	
Design Pressure, psi	50	
Design Temperature, F	150	
Sodium Thiosulfate Concentration, wt %	30	
Sodium Hydroxide Tank		
Number	1	
Volume, Ft^3	1,728	17
Material	CS	
Design Pressure, psi	50	
Design Temperature, F	150	
Sodium Hydroxide Concentration, wt %	20	
Spray Header		
Number	2	
Spray Nozzles per Header	96	

6.2.3 DESIGN EVALUATION

This function of cooling the reactor building atmosphere 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, basic washing concept, and chemical additive will serve to reduce fission product levels in the building atmosphere.

For the first 30-40 min. 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 per cent of the heat removal capacity of the reactor building cooling system.

The reactor building spray system design is based on the spray water being raised to the temperature of the reactor building in 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 post-accident reactor building pressure below the design value:

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 line from the borated water storage tank and the tank itself with the high and low pressure injection safeguards.

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 fulfilling of the design functions. This analysis is shown in Table 6-6. 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 post-accident conditions.

Table 6-6

Single Failure Analysis-Reactor Building Atmosphere Cooling and Washing

Component	Malfunction	Comments and Consequences
1. Reactor building spray nozzles.	Clogged.	Large number of nozzles (96 on each of two headers) renders clogging of significant number of nozzles as incredible. 17
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.	This is considered incredible due to large opening force available at pump shutoff head.
4. Motor-operated valve in spray header line.	Fails to open.	Second header delivers 50 per cent flow.
5. Spray pump isolation valve.	Left closed.	Flow and cooling capacity reduced to 50 per cent of design. In combination with emergency coolers, 150 per cent of total design requirement is still provided.
6. Reactor building spray pump.	Fails to start.	Flow and cooling capacity reduced to 50 per cent of design. In combination with emergency coolers, 150 per cent of total design requirement is still provided.
7. Reactor building cooling unit fan.	Stops.	Emergency cooling by the other operating units with supplemental cooling by the sprays.
8. Reactor building 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.

Table 6-6 (Cont'd)

Component	Malfunction	Comments and Consequences
9. Reactor building 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 will also be inspectable and protected against credible missiles. Cooling with these units will be supplemented by the sprays.
10. Reactor building 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 psi at 650 F for all sizes. Piping is inspectable and protected from missiles. Maximum actual internal pressure will be less than 200 psi at temperatures below 300 F.
11. Pneumatically operated valve at inlet penetration.	Sticks closed.	Second water supply valve serves two of the four cooling units (50% of the required emergency cooling capacity). In combination with sprays, 150 percent of total design requirement is still provided. 17
12. Pneumatically operated valve at outlet penetration	Fails to open.	Comments for Item 11 apply.
13. Power-operated valve at sodium thiosulfate storage tank outlet.	Fails to open.	Valve in line connected to redundant spray headers will permit flow to sprays on 50 percent capacity redundant spray header. 17

6.2.3.2 Reactor Building Cooling Response

Air recirculation is establish through the chilled water coils during normal operation through three of the four building ventilation units. Under accident conditions the chilled water coils are bypassed and air is recirculated through the service water coils in all four ventilation units. This action is initiated when the reactor building pressure increases to 4 psi. Cooling continues until the building pressure reaches near-atmospheric, and the decay heat removal system is placed into emergency service, recirculating and cooling fluid from the reactor building sump. 17

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

The total time to delivery of reactor building sprays is approximately 1 min 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 doors, or other protective features, will be incorporated into the design to maintain postaccident 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 buildihg at postaccident conditions. In this location, the systems in the reactor building are protected from credible missiles and from flooding during postaccident operations. Also, this location provides shielding so that the design radiation dose level allows for maintenance, repair, and inspections to be performed during power operation. See 11.2.1.1, Radiation Protection Design Bases.

The design of the Reactor Building cooling units is different from any other application. The units will be approximately 9' wide by 16' long by 11' high. Four units are required. Each unit will consist of one roughing filter of the renewable media type, one set of chilled water cooling coils to be used for normal cooling, one set of service water cooling coils to be used for emergency cooling, followed by a vane axial type fan. The fan will be mounted vertically on top of the unit. A relief damper will be provided on top of the unit between the chilled water coils and the service water coils. The relief damper will be a counter balanced type that will open at a preset pressure differential. The damper will open in case of a pressure increase in the Reactor Building thereby permitting the internal pressure in the unit to equalize with the external pressure. The unit however will be designed to withstand 60 psia external pressure with the damper closed. The damper will also allow the saturated air in the Reactor Building to by-pass the filter and the chilled water cooling coils and to go through only the service water cooling coils. The decrease in pressure drop due to the by-passing of the filter and chilled water cooling coils will permit the fan in the unit to handle the necessary quantity of air for cooling purposes at the same speed as required for normal operation, thereby precluding the necessity of two speed motors with their necessary additional controls and wiring. 17

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 plant operation.

6.2.4 TESTS AND INSPECTIONS

Active components of the ventilation units will normally be in service. Valving on the cooling coils can be periodically cycled, thus placing the coils into service periodically during operation.

The active components of the reactor building spray system will be tested on a regular schedular as follows:

Reactor Building Spray Pumps	These pumps will be tested singly by opening the valves in the test line and the borated water storage tank outlet valves. Each pump in turn will be started by plant 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 closed, low pressure air will be blown through the test connections.

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 require 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 to perform all operations necessary for mitigation of the accident within acceptable dose limits in the event of an MHA.

6.3.2 SUMMARY OF POSTACCIDENT RECIRCULATION AND LEAKAGE CONSIDERATIONS

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 tests 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.

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. of 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 less than 200 F when recirculation occurs.

6.3.4 DESIGN BASIS LEAKAGE

The design basis leakage quantities derived from these assumptions for postaccident sump recirculation are tabulated in Table 6-7.

6.3.5 LEAKAGE ANALYSIS CONCLUSIONS

It may be concluded from this analysis (in conjunction with the MHA discussion and analysis in 14.2.2.4.4) that leakage from Engineered Safeguards equipment outside the reactor building does not pose a public safety problem.

Table 6-7

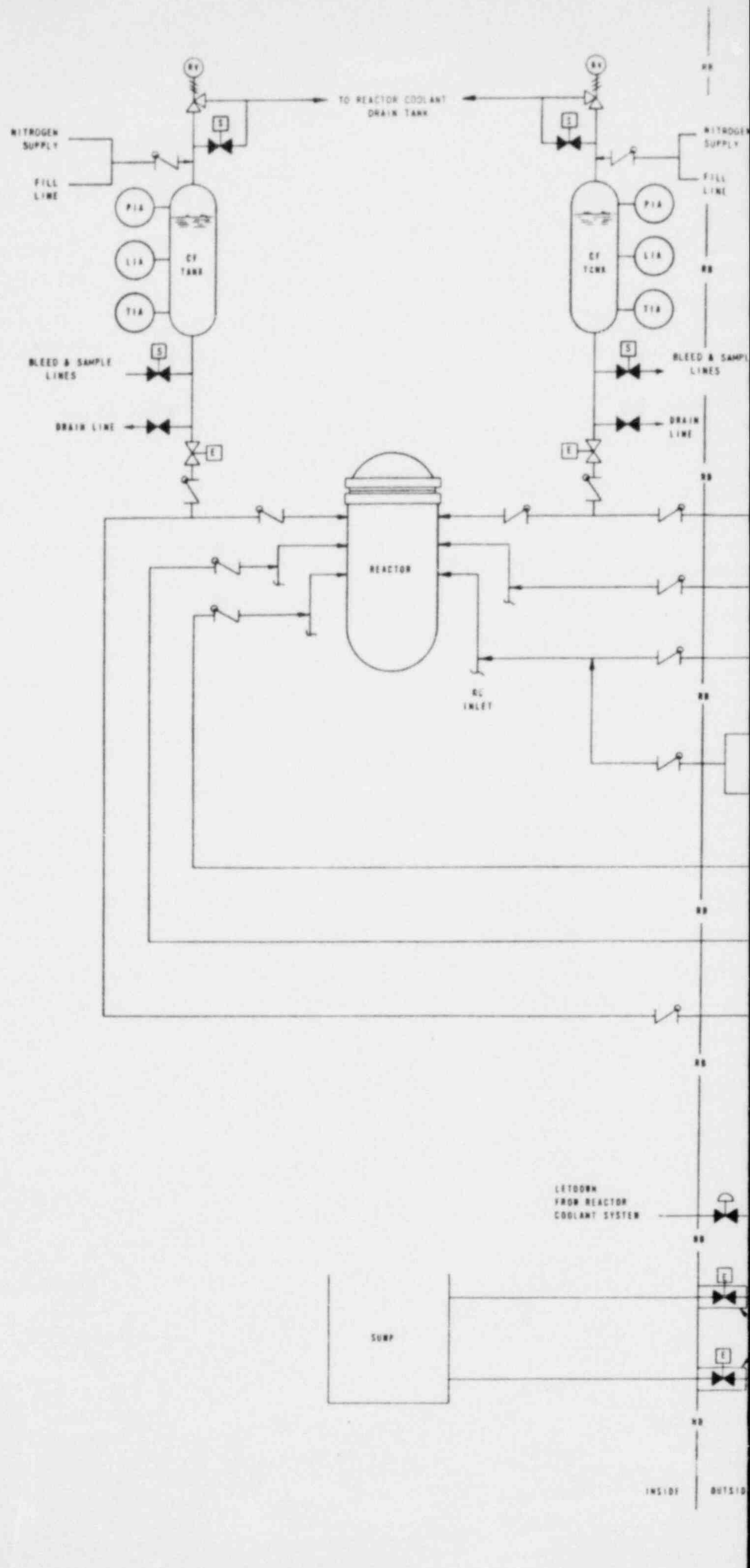
Leakage Quantities to Auxiliary Building Atmosphere

Leakage Source	No. Of Sources	Per Source Drop/Min	Total cc/hr
a. Pump Seals			
Decay heat pumps	2	50	300
Spray pumps	2	50	300
b. Flanges (a)	114	10	3,320
c. Process Valves	35	1	105
d. Instrumentation Valves	25	1	75
e. Valve Seats at Boundaries	11	(b)	750
Total			4,850

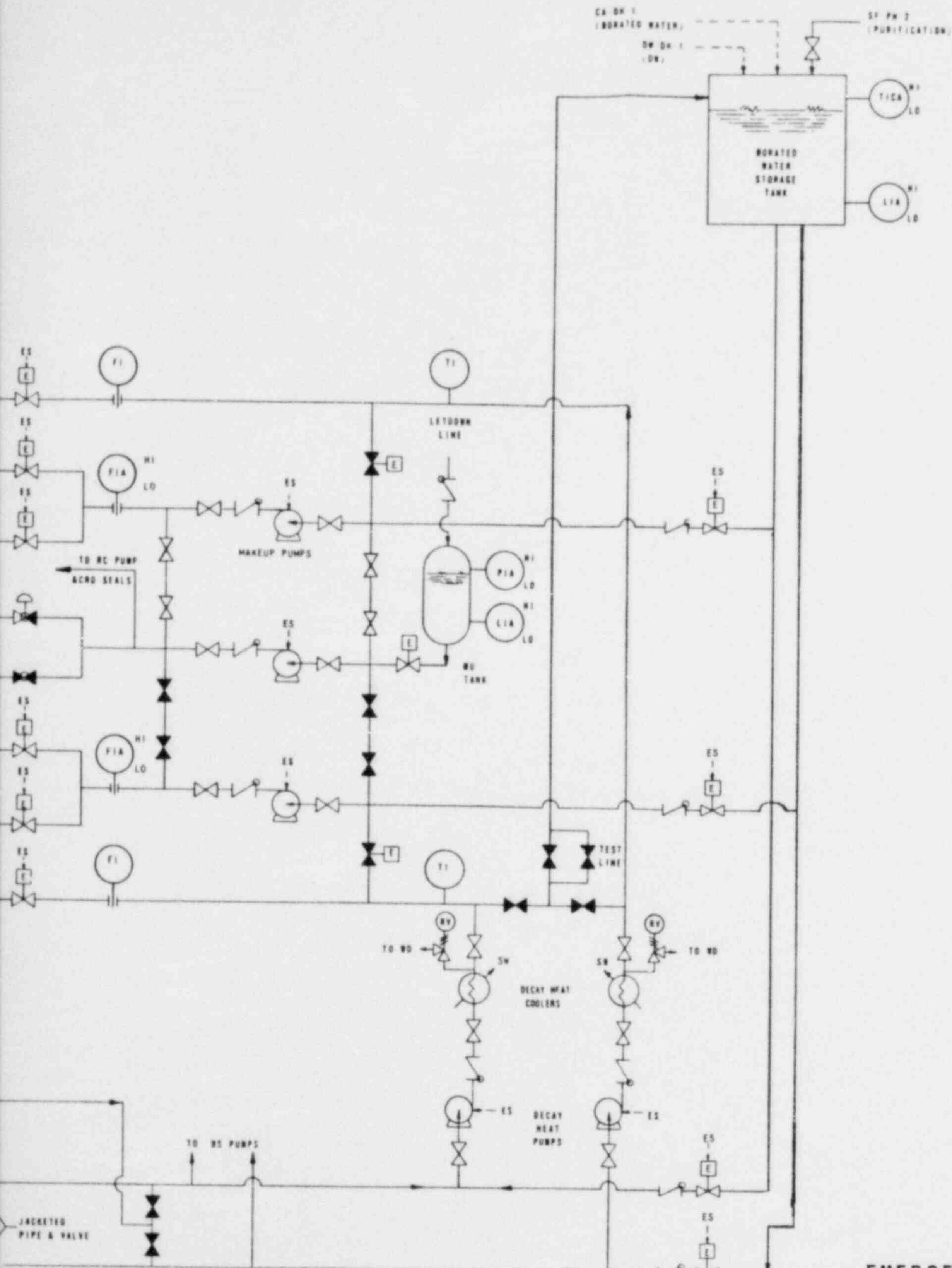
3

(a) Assumes process and boundary valves, and process components are flanged.

(b) Assumes 10 cc/hr/in. of nominal disc diameter.



TO REACTOR COOLANT DRAIN TANK
NITROGEN SUPPLY
FILL LINE
PIA
LIA
TIA
CF TANK
BLEED & SAMPLE LINES
DRAIN LINE
REACTOR
RL INLET
RB
LETDOWN FROM REACTOR COOLANT SYSTEM
SUMP
INSIDE

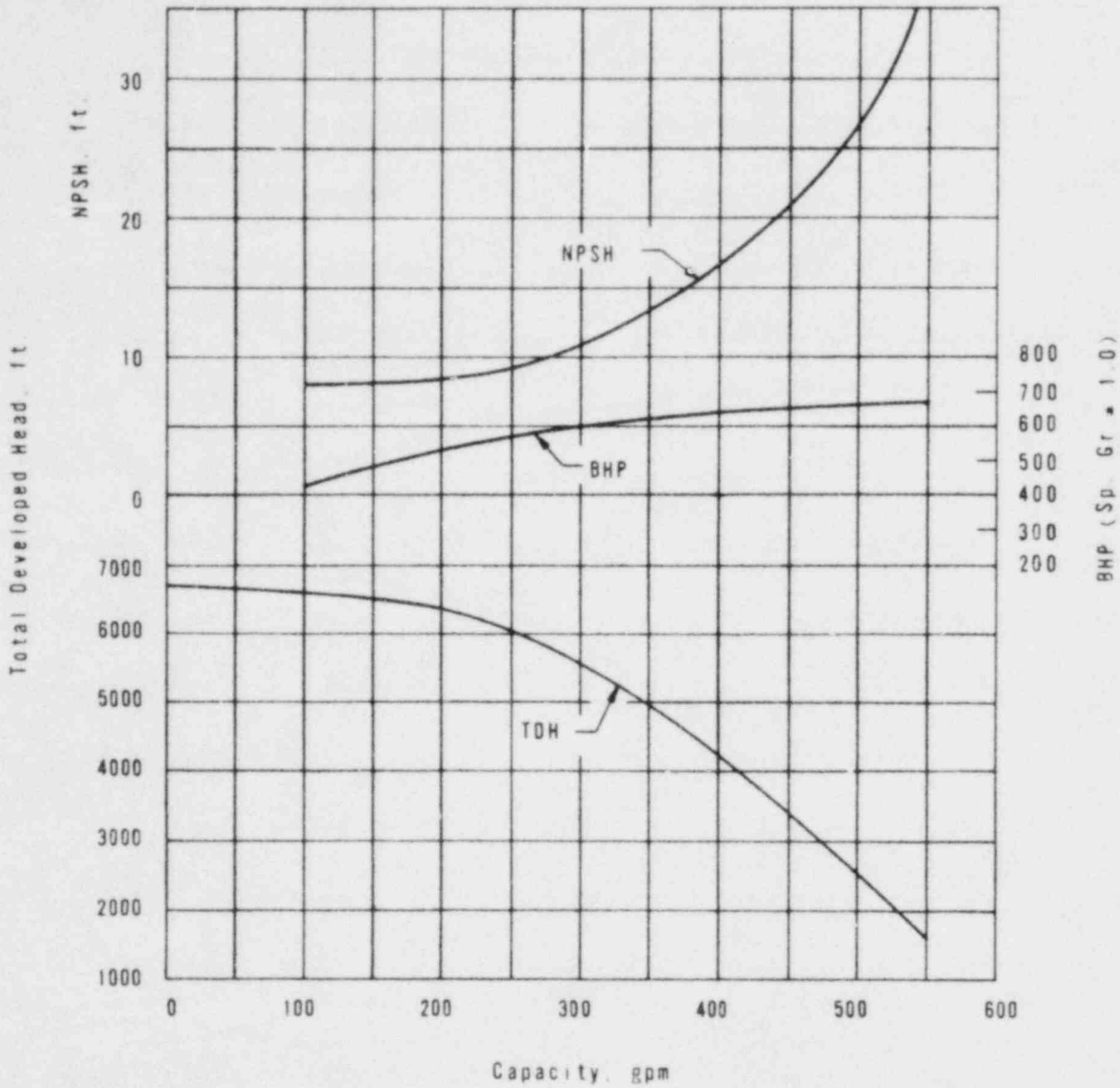


NOTE
FOR LEGEND & NOMENCLATURE
SEE FIGURE 9-1

EMERGENCY INJECTION
SAFEGUARDS

Figure 6-1

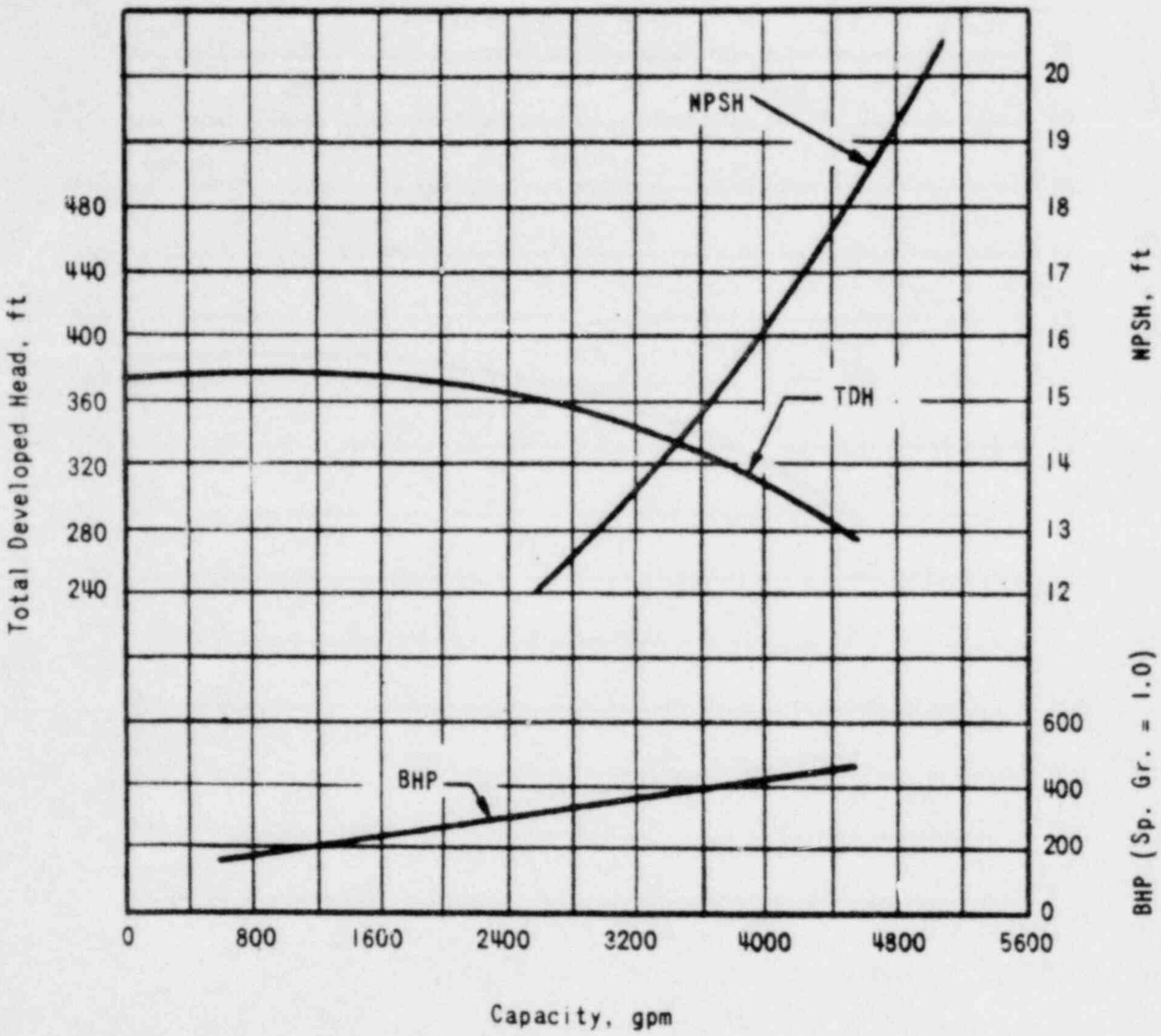
Supplement 3



MAKE-UP PUMP CHARACTERISTICS

FIGURE 6-2

REVISED 2-8-68

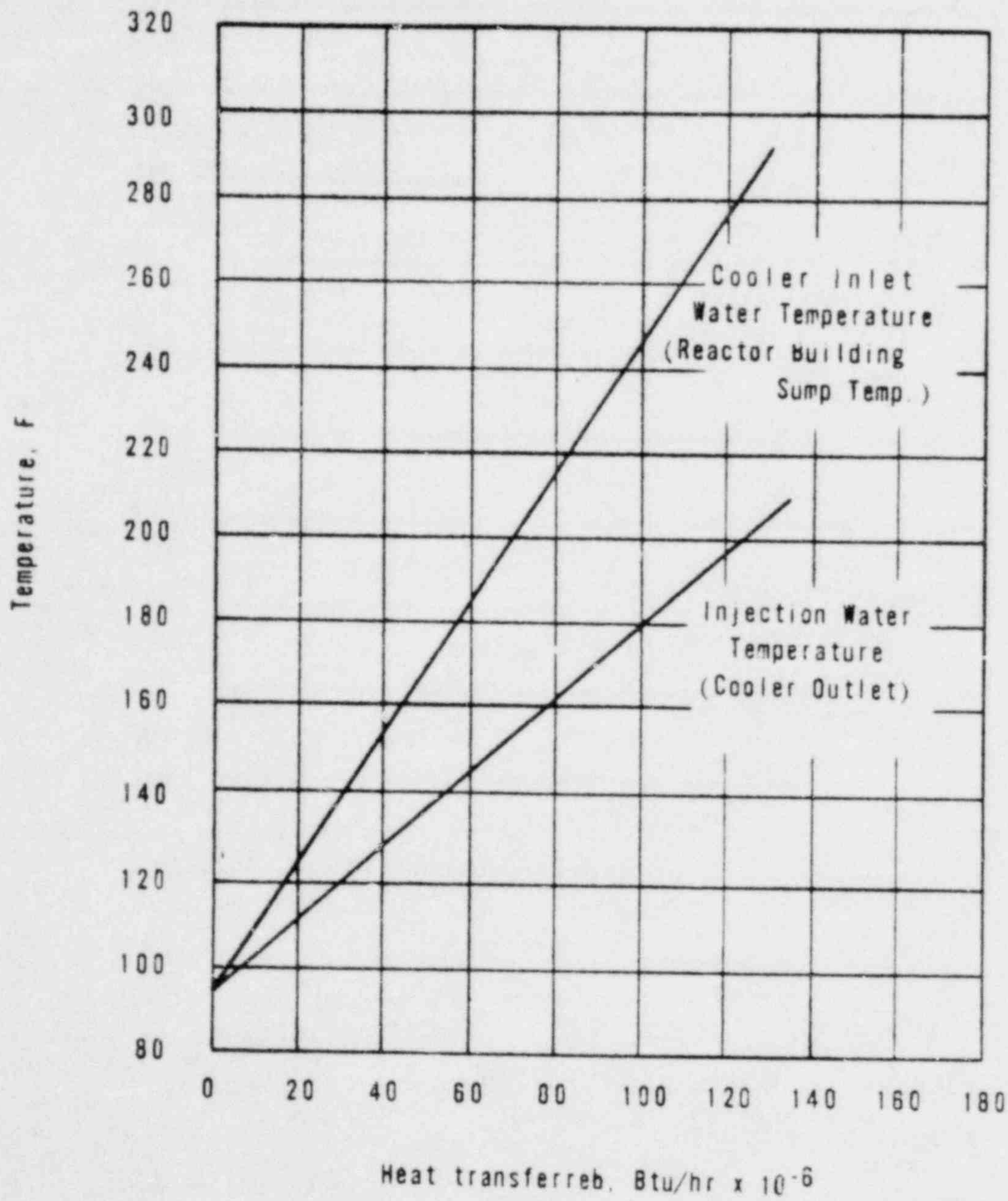


DECAY HEAT REMOVAL PUMP CHARACTERISTICS

Figure 6-3

Emergency Design Conditions

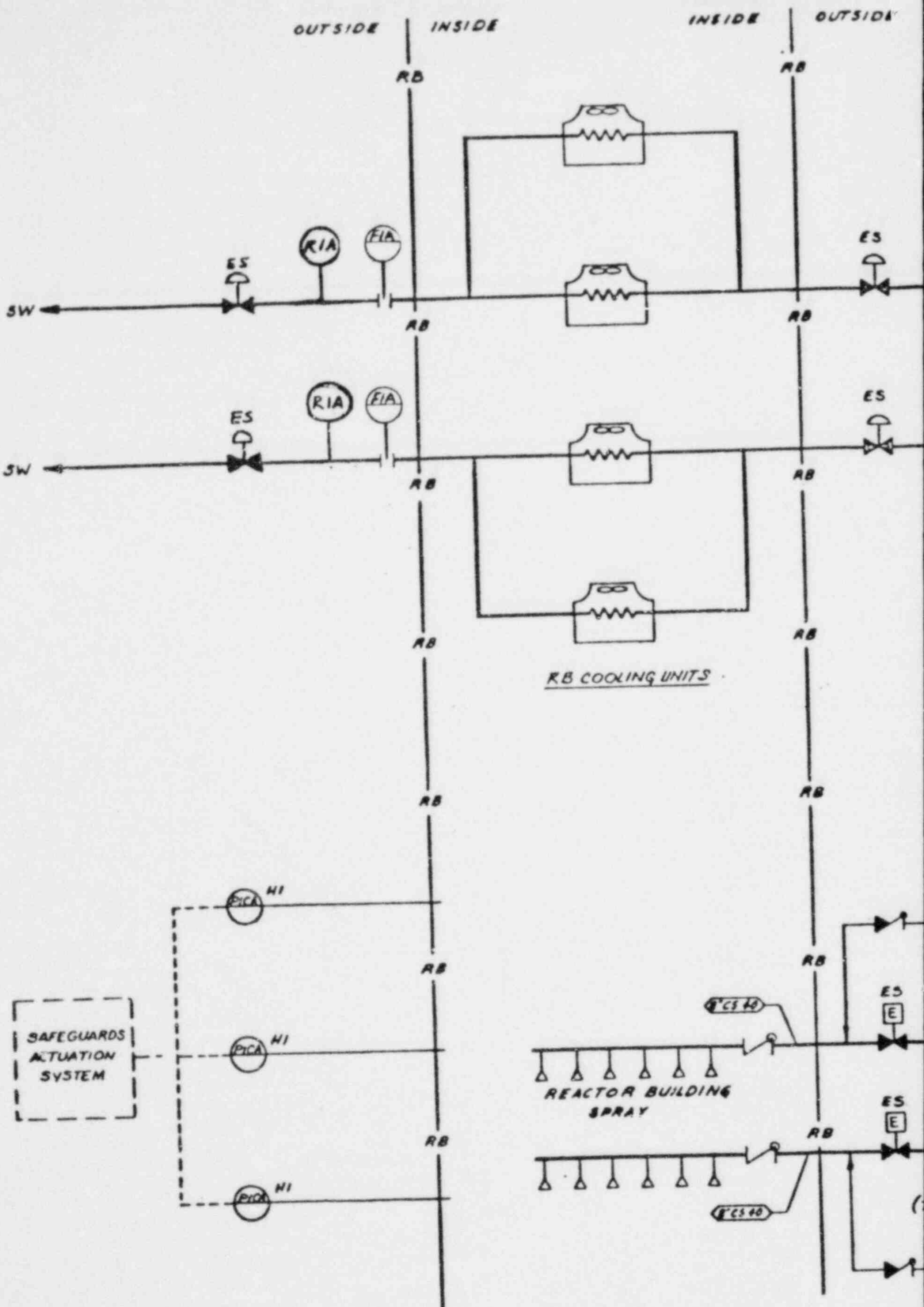
Injection Water Flow Per Cooler - 3000 gpm
Decay Heat Service Water Flow Per Cooler - 3000 gpm
Decay Heat Service Water Inlet Temperature - 95 F



DECAY HEAT REMOVAL COOLER CHARACTERISTICS

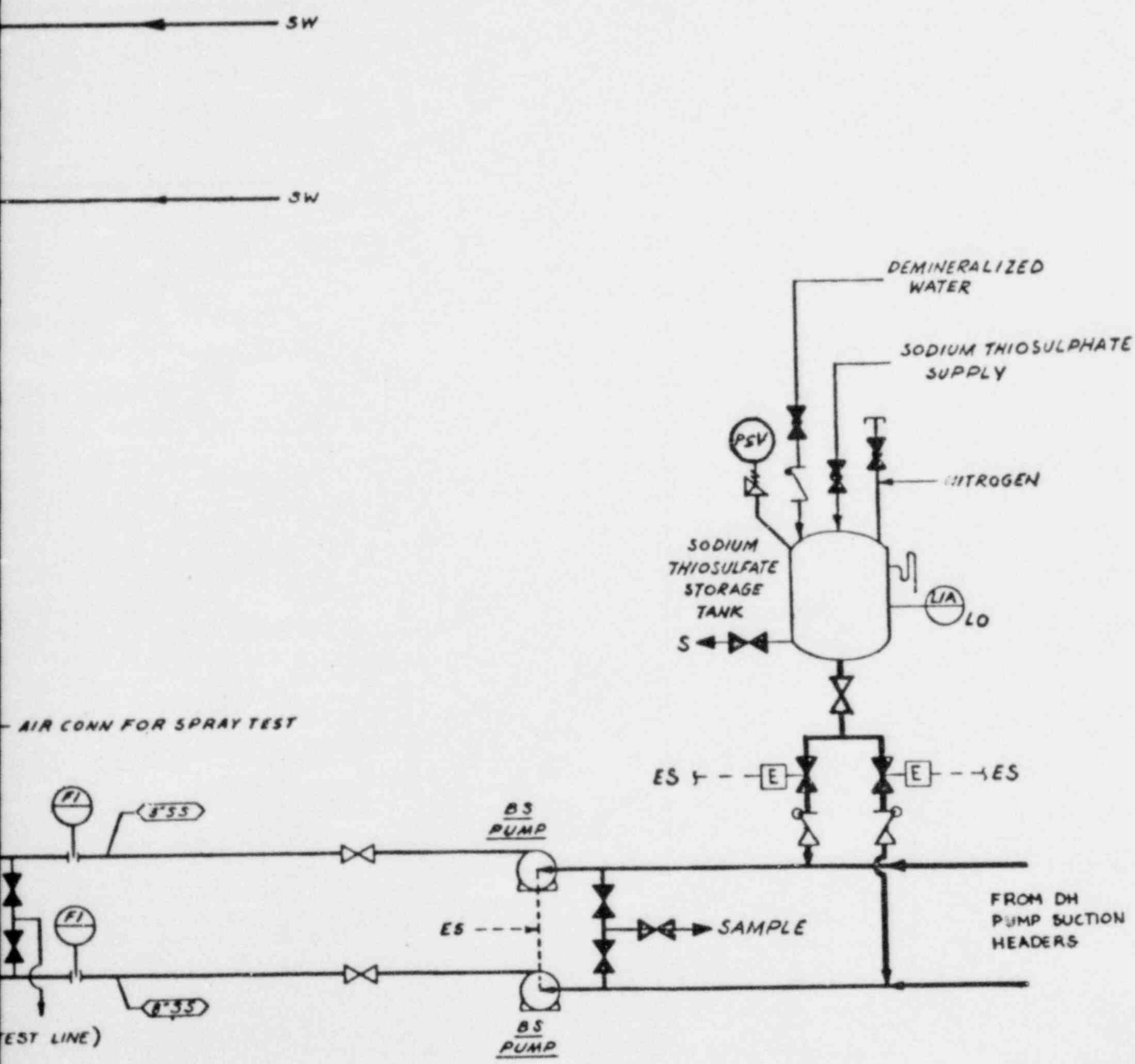
FIGURE 6-4

REVISED 2-8-68



OUTSIDE
INSIDE
INSIDE
OUTSIDE
RB
ES
RIA
FIA
SW
RB COOLING UNITS
PICA
HI
SAFEGUARDS ACTUATION SYSTEM
REACTOR BUILDING SPRAY

98

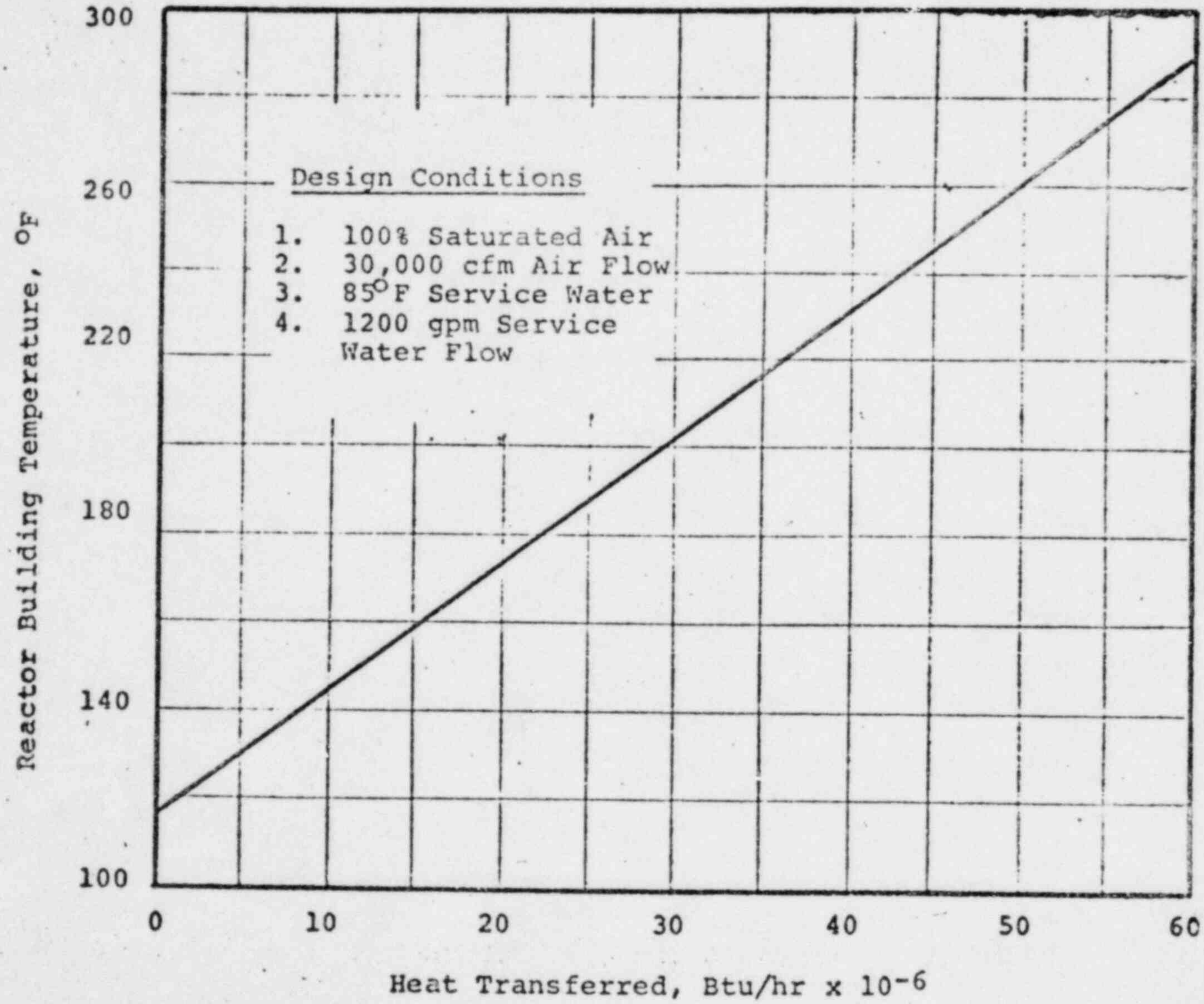


REACTOR BUILDING
COOLING SAFEGUARDS

NOTE: FOR LEGEND & NOMENCLATURE
SEE FIG. 9-1

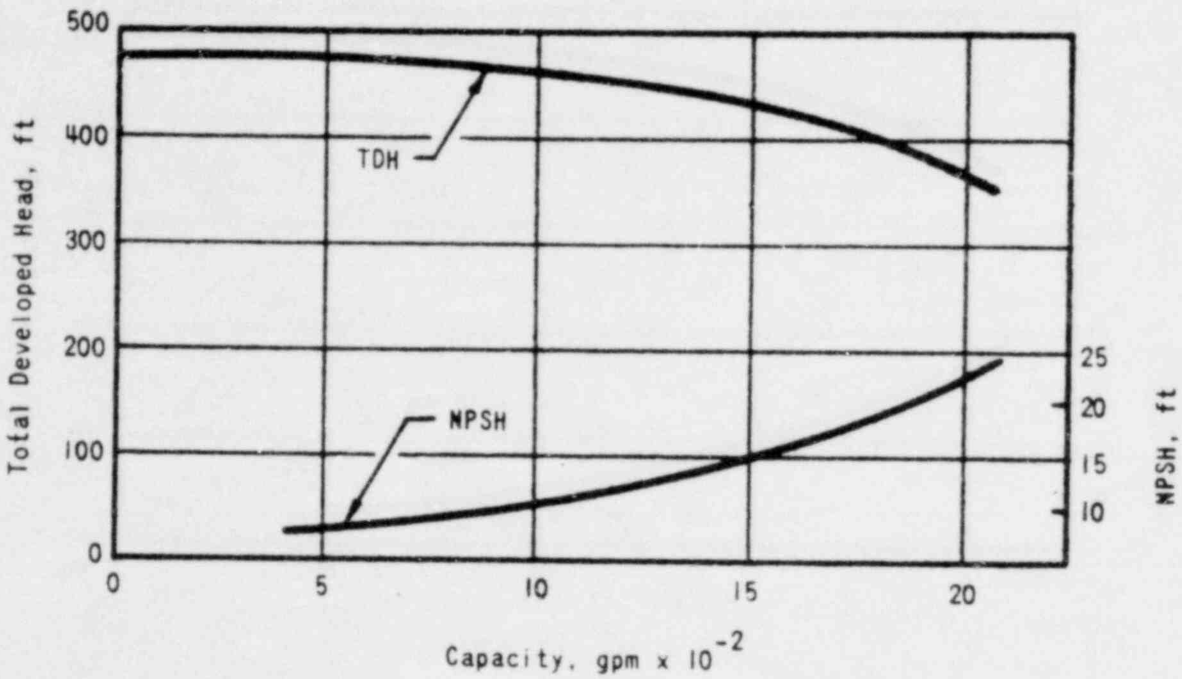
Figure 6-5

Supplement 17



REACTOR BUILDING COOLER CHARACTERISTICS

Figure 6-6
Supplement 17



REACTOR BUILDING SPRAY PUMP CHARACTERISTICS

Figure 6-7