6.0 ENGINEERED SAFEGUARDS

6.1 DESIGN OBJECTIVES

The design, fabrication, inspection and testing of the various components and systems of this reactor plant have as a prime objective safe and reliable operation under all anticipated conditions. However, several systems have been included in the overall design of this plant which are intended to serve as backup protection in the improbable event of a major accident that might result in potential public exposure to more than normally acceptable radiation levels.

These systems commonly grouped under the heading of "engineered safeguards", have as their prime objective minimizing the consequences of any accident involving the potential uncontrolled release of radioactivity from the containment system. In order to accomplish this prime objective these systems are designed to perform three types of function; (1) elimination of all sources of leakage from the containment vessel, (2) reduction of the airborne fission product inventory in the containment vessel and (3) reduction of the driving force (pressure) for potential leakage from the containment.

In a pressurized water reactor system, the accident which presents the largest potential for public exposure is a loss of reactor coolant and the subsequent events which might lead to the release of some fraction of the core fission product inventory to the containment and its eventual leakage to the environment. The engineered safeguards accordingly are designed to minimize public exposure from this improbable event.

The types of systems to be provided and the design objectives are presented here to outline the philosophy used in the selection and design of engineered safeguards systems for public safety. Design methods and techniques and the results of typical analyses are presented in Chapter 12, SAFETY EVALUATION.

The engineered safeguards systems which will be incorporated in the design of this plant will include systems to eliminate leakage from the containment and separate, redundant systems in the categories of fission product inventory reduction and pressure reduction.

In the first category, the systems provided are the continuously pressurized, double penetrations and liner weld channels and the Isolation Valve

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Seal Water System. These systems eliminate all potential sources of leakage from the containment and limit the off-site doses to the doses allowed by 10CFR20 when averaged over a year. These systems are pneumatically operated from pressurized gas reservoirs and do not require outside electrical power or operation of the station diesels for their proper operation. Station batteries provide ample power for necessary pilot valve operation.

In the second category, the systems provided are the Safety Injection System, the air recirculation filtration provisions of the Containment Ventilation System and the chemically treated containment sprays. The Safety Injection System is designed to reduce the likelyhood of clad damage following loss-of-coolant accidents and to limit fission product releases for break sizes up to the largest pipe connected to the coolant system to no more than that accumulated in the gaps between the fuel and the cladding of the fuel rods. The air recirculation filtration system and the chemically treated containment sprays, each independently and under the conditions of partial operation on emergency diesel power, are designed to limit off-site doses to less than the guidelines of 10CFR100. Thus, the operation of these systems reduces the fission product inventory available for leakage in the improbable event of a temporary malfunction of the leakage preventing systems.

In the third category, the systems are the air recirculation cooling provisions of the Containment Ventilation System and the containment sprays. The Containment Ventilation System fans and ductwork and the containment sprays are common to the latter two categories.

The evaluation of the engineered safeguards systems and the public protection which they provide will be made under sets of various assumptions and conditions to demonstrate their ability to provide more than adequate protection even under combinations of events which are considered incredible. In order to provide a base case with which a comparison can be made, required dose reduction factors needed to meet the exposure limits of 10CFR100 (300 rem to the thyroid in two hours at the exclusion radius and 300 rem to the thyroid over the duration of the accident at the low population zone distance) will be calculated using site meteorology and the fission product release and leakage model outlined in TID 14844 for a major loss-of-coolant accident in a pressurized water reactor. The details of the analytical model for the dispersion of fission products leaking from the containment and the techniques and methods employed in the design and evaluation of the various engineered safeguards systems are presented in Section 12.2.

After the establishment of the base case reduction factors, the individual engineered safeguards systems will then be evaluated under conditions of full and partial effectiveness to determine the dose reduction factors that it alone will provide. This evaluation of the performance of each of the systems under various conditions of performance must be performed using consistent environmental conditions so that only changes in the systems operation or performance will produce a change in the reduction factor calculated for the system.

For a postulated major loss-of-coolant accident, the continuously pressurized penetrations and weld channels and the isolation valve seal water system operating as expected will provide sufficient protection so that off-site exposures will not exceed the limits of 10CFR20 averaged over a year. The above condition of operation can be achieved with station batteries and requires no power from outside sources or the on-site diesel generators. For the postulated condition of a loss-of-coolant accident, failure to maintain pressurization of the welds and penetrations and failure of the isolation valve seal water system to prevent leakage of the containment atmosphere to the environment, partial operation of the remaining engineered safeguards systems using the diesel generators will keep the off-site exposures below the levels at which the Federal Radiation Council recommends that protective action be taken. The recommendation is that protective action should be initiated if the possible exposures due to the release of I-131 exceed 1/10 of the limits of 10CFR100. For a third condition which is similar to the second except that no credit is taken for the Safety Injection in limiting the amount of core meltdown and subsequent fission product release, the resulting off-site exposures will be below the limits specified in 10CFR100.

Table 6-1 presents an outline of the various accident conditions, analyses and criteria which will be studied in the evaluation of the performance of the engineered safeguards systems. The details of the evaluations are presented in Section 12.2.

6.2 GENERAL DESCRIPTION

Five types of engineered safeguards are included in the design of this facility. These are:

a) A steel-lined, reinforced concrete reactor containment vessel with continuously pressurized double penetrations, and weld channels and an isolation valve seal water system, which form a virtually leak-tight barrier to

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the escape of fission products should a loss of coolant occur. Refer to Chapter 5 for a detailed description of the containment system.

b) The safety injection system which injects water into the hot leg and the cold leg of each reactor coolant loop. This system limits damage to the core and limits the energy released into the containment following a loss of coolant accident.

c) The air recirculation coolers which reduce containment pressure following the loss of coolant accident. Air is recirculated through these coolers by the same fans which circulate air through the air recirculation filters.

d) The containment spray equipment in the safety injection system, which is used to reduce containment pressure and remove elemental iodine from the containment atmosphere.

e) The air recirculation filters which provide for rapid removal of particulate and halogen activity from the containment atmosphere if fission products are released from the reactor.

Although the engineered safeguards loads are arranged to operate from electrical buses supplied from normal outside AC power which should not fail as a result of reactor trip, reliable on-site emergency power is provided. Thus, if normal AC power to the station is lost concurrent with a loss-of-coolant accident, power is available for the engineered safeguards.

In the event that one of the three diesel generators fails to start immediately, any of the engineered safeguards equipment normally supplied by that diesel is automatically transferred, if required, to one of the other two diesel supplied buses. In this manner, any engineered safeguard component can be used to meet the minimum starting requirements listed below. The minimum safeguards load started under these conditions is:

1 Residual Heat Removal Pump (Hot Leg Injection)

1 High Head Safety Injection Pump (Cold Leg Injection)

4 Containment Fan-Cooler-Filter Units

1 Containment Spray Pump

1 Service Water Pump

The additional containment spray pump can be manually started in place of a containment fan if a motor should fail or be out of service or to achieve a more rapid pressure reduction. Also, for long-term recirculation cooling of the core by circulation from the containment sump, one of the fan motors will be shut down to permit substitution of a component cooling pump on the diesel for cooling of the recirculated sump water.

Routine periodic testing of the engineered safeguards components is intended.

6.2.1 CONTAINMENT SYSTEM

A detailed description of the containment system and the pressurized penetrations and liner weld channels and the isolation valve seal water system is given in Chapter 5.

6.2.2 SAFETY INJECTION SYSTEM

6.2.2.1 Design Bases

The primary purpose of the safety injection system is to supply borated water to the reactor coolant system to limit fuel rod cladding temperatures in the unlikely event of a loss-of-reactor coolant. The system also provides a means of introducing a spray of borated water into the containment as an additional dynamic heat sink.

The conditions which the safety injection system is designed to protect against and the analysis of the system performance are given in Chapter 12.

With normal AC power available, operation of all components of the safety injection system prevents any melting of fuel cladding and limits the metal-water reaction to a negligible amount for reactor coolant piping ruptures up to and including the diameter of the largest pipe connected to the reactor coolant loops (the pressurizer surge line). The Safety Injection System branch lines are sized so that a break of a branch line will not result in a violation of the system design criteria.

6.2.2.2 System Design

The safety injection system arrangement is shown on Figure 6-1.

The principal components of the safety injection system which provide emergency core cooling are three high head safety injection pumps, the two charging pumps of the chemical and volume control system, and the two low head residual heat removal pumps of the auxiliary coolant system. These pumps are all located in the auxiliary building and take suction directly from the refueling water storage tank located in the auxiliary building.

The safety injection pumps refill the reactor vessel by way of the reactor-inlet piping, assuring core cooling by restoring water level to a point above the top of the core. The safety injection pumps discharge into the cold legs of the reactor coolant piping. Flow from these pumps is augmented by the charging pumps which discharge into one of the loops.

The residual heat removal pumps deliver borated water directly to the reactor vessel hot legs. This arrangement results in immediate cooling of the reactor core through a deluge action of the borated water on top of the core.

The residual heat removal pumps are aligned to take suction directly from the containment sump after the water has been expended from the refueling water tank. The safety injection and charging pumps can take suction from the containment sump via a bypass line from the discharge of the residual heat removal pumps.

The refueling water storage tank contains approximately 320,000 gallons of borated water for injection into the reactor coolant system. The water in the tank is borated to the refueling concentration which assures that, with all RCC assemblies inserted, the reactor will be subcritical when cooled down for refueling. The volume of water in the tank is based upon the requirement for filling the refueling canal and is more than 2.5 times the minimum volume which must be injected prior to initiating recirculation of spilled water from the containment sump. That minimum amount of water to be injected must be sufficient to refill the reactor vessel above the nozzles, to increase the boron concentration of spilled water to a point assuring no return to criticality with the reactor at cold shutdown and all control rods inserted with the exception of the most reactive RCC assembly.

Safety injection (emergency core cooling) is actuated by coincidence of low pressurizer pressure and low pressurizer water level. This signal opens the safety injection system isolation valves and starts the high head safety injection pumps and low head residual heat removal pumps. Under conditions of low pressurizer pressure and water level, both charging pumps would already be running. In addition to opening the isolation valves and starting pumps, the safety injection signal shifts the suction of the charging pumps and the residual heat removal pumps to the refueling water storage tank. Suction for the safety injection pumps is always aligned to the refueling water storage tank when the reactor is in operation.

After the reactor coolant system has been cooled and depressurized through secondary steam dump and safety injection operation, coolant spilled from the break is cooled and returned to the reactor coolant system by the auxiliary coolant system. In this mode of operation, the residual heat removal pumps take suction from the reactor containment sump, circulate the spilled coolant through the residual heat exchangers and return the coolant to the reactor. The safety injection pumps may be used to augment the head capacity of the residual heat removal pumps in returning the spilled coolant to the reactor.

The emergency core cooling portion of the safety injection system may be tested for proper operation at shut-off head any time when the reactor is hot and pressurized. Lines connecting each of the safety injection branch lines to the refueling water storage tank are used periodically to recirculate the safety injection piping contents to ensure that water in the safety injection piping contains the same boron concentration as the water in the refueling water storage tank.

6.2.2.3 Components

a) Safety Injection Pumps

Three high-head safety injection pumps supply borated water to the Reactor Coolant System. The pumps are horizontal centrifugal type, driven by electric motors. Parts of the pump in contact with borated water are stainless steel or equivalent corrosion resistant material. A minimum flow bypass line is provided on each pump discharge to recirculate flow to the refueling water storage tank in the event the pumps are started with the normal flow paths blocked by closed valves. The safety injection pumps are sized to meet the design criteria outlined in Section 6.2.1.

b) Residual Heat Removal Pumps

The two residual heat removal pumps, described in the section on Auxiliary Coolant System, are utilized as the low head (core deluge) subsystem.

c) Valves

All parts of safety injection valves in contact with borated water are austenitic stainless steel or equivalent corrosion resistant material. The motor operators on the injection isolation valves are capable of rapid operation in opening the valves.

All throttling control valves and remotely operated stop valves, regardless of size, are either provided with double-packed stuffing boxes with stem leakoff connections or are totally enclosed. Special provisions to prevent valve stem leakage are not required for some Safety Injection System valves, since the refueling water storage tank and the Safety Injection System are normally filled with cold, borated water. Leakoff connections are provided on the motor-operated isolation valves and control valves on lines which contain reactor coolant.

The check valves which isolate the Safety Injection System from the Reactor Coolant System are installed as close as practical to the reactor coolant piping to reduce the probability of a safety injection line rupture causing a loss-of-coolant accident.

A relief valve is installed on the safety injection pump discharge header discharging to the refueling water storage tank to prevent overpressure in the lines which have a lower design pressure than the Reactor Coolant System. The relief valve is set at the design pressure of the Safety Injection System discharge piping.

d) Piping

All Safety Injection System piping in contact with borated water is austenitic stainless steel. Piping joints are welded except for the flanged connections at the safety injection pumps.

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

The high-pressure injection branch lines are designed for high pressure losses to limit the flow rate out of the branch line which may have ruptured at the connection to the reactor coolant loop. The branch lines are sized so that such a break will not result in a violation of the design criteria for the Safety Injection System.

6.2.3 AIR RECIRCULATION COOLING

A description of the Air Recirculation Cooling equipment and its design basis are given in Chapter 5.

6.2.4 AIR RECIRCULATION FILTRATION

A description of the Air Recirculation Filtration equipment and its design basis are given in Chapter 5.

6.2.5 CONTAINMENT SPRAY

6.2.5.1 Design Bases

The containment spray is designed to reduce containment pressure and to remove elemental iodine from the containment atmosphere. The heat removal capacity of the spray, with either pump operating, is at least equivalent to the heat removal capability of four fan-coolers.

6.2.5.2 System Design

The containment spray arrangement is shown on Figure 6-1.

Two separate pumps, automatically actuated, are provided for containment spray. These pumps are located in the auxiliary building and can take their suction directly from the refueling water storage tank or from the containment sump by way of the residual heat removal pumps and residual heat exchanger.

The two containment spray pumps are of the horizontal centrifugal type driven by electric motors. Parts of the pump in contact with borated water are stainless steel or equivalent corrosion resistant material.

A minimum flow bypass line is provided on each pump discharge to recirculate flow to the refueling water storage tank to allow the pumps to be tested periodically.

In order to provide a second independent means for cleaning the containment atmosphere of iodine, sodium thiosulfate ($Na_2S_2O_3$) is mixed with the borated spray to form a solution of approximately 1 weight percent sodium thiosulfate. The thiosulfate will react chemically with the elemental-iodine either in the containment atmosphere or on surfaces, eliminating it as a leakage source. A portion of the water discharged by each spray pump is used to sweep the contents of the thiosulfate solution tank into the spray pump suction header. The thiosulfate solution mixes with the borated refueling water and is discharged into the spray header.

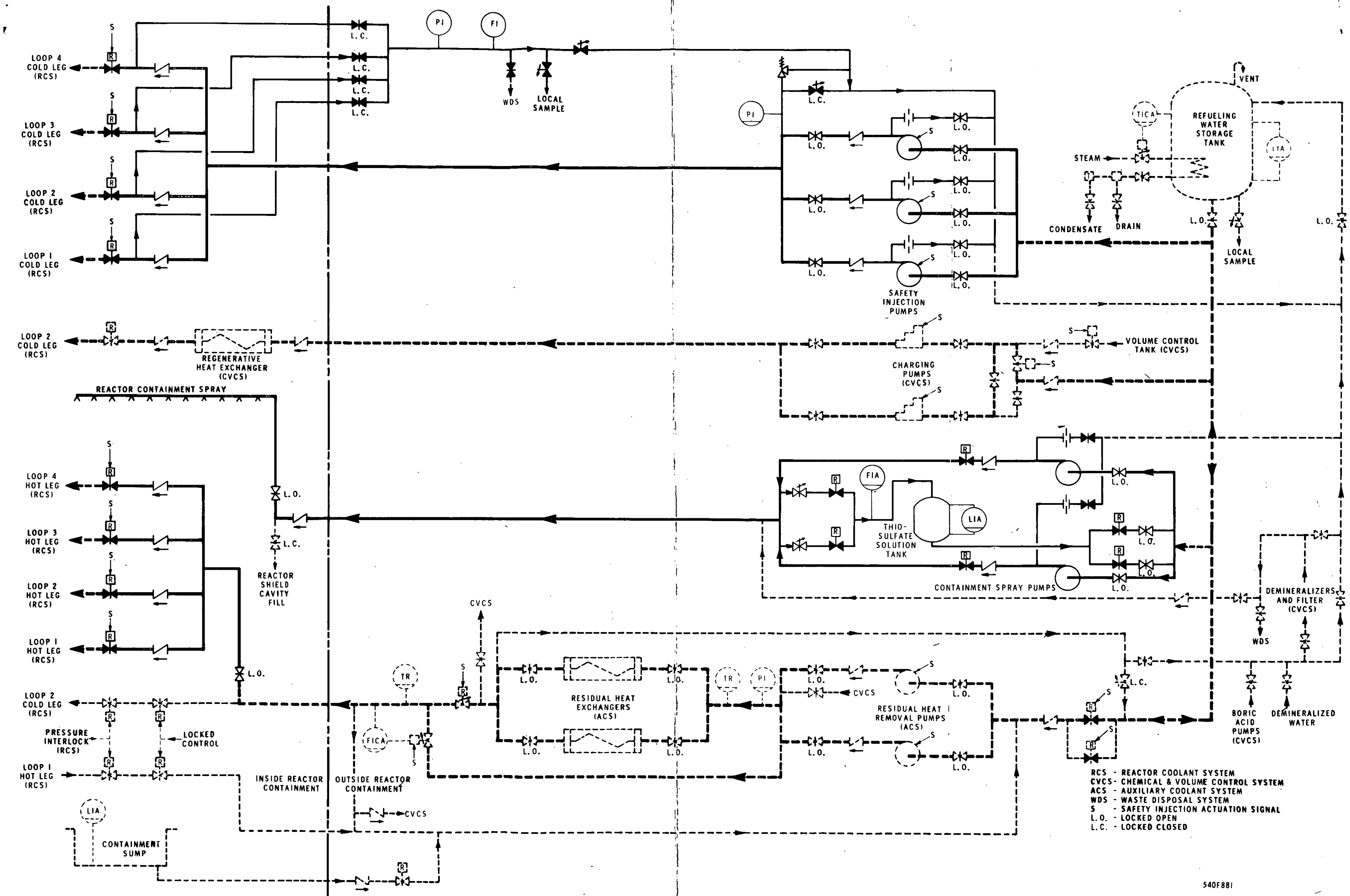
The spray header is located inside the containment outside the polar crane support wall where it is protected from missiles. Branch lines then distribute flow throughout the containment, both in the space above the refueling floor and in the reactor coolant loop compartments. Spray nozzles are oriented to provide effective coverage of the containment free volume and to wash down surfaces where elemental iodine may be deposited. Spray nozzles are of an open throat design not subject to clogging and will be designed to produce the total surface of spray drops per gallon of spray necessary for iodine removal.

The thiosulfate solution tank is isolated from the refueling water line and spray header during normal plant operation. Thiosulfate injection is initiated manually following initiation of spray flow by opening of the two valves at the thiosulfate solution tank inlet and the two valves at the tank outlet. Enough thiosulfate solution will be delivered even though only one inlet valve, one outlet valve, and either containment spray pump operating. The thiosulfate solution tank contains sufficient solution to yield approximately one percent solution when mixed with the entire contents of the refueling water storage tank. This assures the continued iodine removal effectiveness of the containment spray during the recirculation phase of operation after the supply of borated water in the refueling water storage tank has been exhausted.

The thiosulfate solution tank valves can be opened periodically for testing.

TABLE 6-1
ENGINEERED SAFEGUARDS PERFORMANCE EVALUATIONS

Accident Condition	Electrical Power	Pressurized Penetrations and Weld Channels	Isolation Valve Seal Water System	SIS Components	Air Coolers	Air Filters	Containment Sprays	Objectives to be Met
(1) Loss of coolant Main pipe rupture	2 of 3 diesels	Available	Operation completed within 1 minute.	1 high head pump, 1 low head pump.	4 units	4 units	1 spray pump	Containment integrity maintained for energy calculated. Doses kept equivalent to 10CFR20 averaged over a year.
(2) Loss of coolant Main pipe rupture	2 of 3 diesels	Not available	Not available	1 high head pump, 1 low head pump.	4 units	4 units	1 spray pump	Containment integrity maintained for energy releases calculated. Doses kept below 1/10 10CFR100 limits.
(3) Loss of coolant Main pipe rupture	2 of 3 diesels	Not available	Not available	1 high head pump, 1 low head pump.	4 units	4 units	1 spray pump	Containment integrity maintained for energy releases calculated. Doses kept below 10CFR100 limits. Fission product release assumed per TID 14844.



SAFETY INJECTION SYSTEM
FIG. 6-1