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NOV 2 1982

MEMORANDUM FOR: Thomas M. Novak, Assistant Director for Licensing, Division of Licensing, NRR

FROM: L. S. Rubenstein, Assistant Director for Core and Plant Systems, Division of Systems Integration, NRR

SUBJECT: DESIGN COMPARISON BETWEEN SNUPPS AND SIZEWELL "B" NUCLEAR PLANTS

In response to the October 25, 1982 letter from H. Denton to Division Directors, the Auxiliary Systems Branch and the Power Systems Branch have reviewed Item 7, "Increased Equipment Redundancy" of Enclosure 1 to the referenced letter.

The results of our review are enclosed and follow the format of Enclosure 2 to the Denton letter. In summary we have identified the differences between the SNUPPS and Sizewell designs for the auxiliary feedwater system, component cooling water system, essential service water system and electrical distribution system. The Power Systems Branch performed the review of the electrical distribution system. Also, for these systems, we described the SNUPPS design, showed how the SNUPPS design meets our criteria, and identified areas for further exploration to help in understanding the design differences.

An analysis of the safety benefit due to the design differences is being performed by the Division of Safety Technology (DST) and will be transmitted under a separate cover letter after we have DST's input.

L S Rubenstein

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B-18
(2)
B-14

7. Increased Equipment Redundancy

a. TITLE

Auxiliary Feedwater System - Design Differences Associated With The Sizewell B Use of Four ASW Pumps Instead Of the SNUPPS Three Pump System

DESCRIPTION

The Sizewell B AFW system consists of four AFW pumps (2 Motor Driven, 2 Turbine Driven) that comprise two independent subsystems of the AFW system, made up of the motor driven subsystem and turbine driven subsystem. Each subsystem normally takes suction from its own condensate storage tank (each of which is the same capacity as the one CST at SNUPPS) during normal operation and as in the case of SNUPPS, each pump is capable of discharging to any combination of 1 to 4 steam generators. However, the Sizewell motor driven pumps discharge to their own dedicated nozzles in the steam generators, while the turbine driven pumps discharge to the main feedwater system piping in the same fashion as all three pumps (2 motor driven, 1 turbine driven) at SNUPPS. Normally, each pump is lined up to feed two steam generators automatically via the same initiating signals as SNUPPS. Each of the pumps at Sizewell is rated at 100 percent while at SNUPPS the motor driven pumps are each 100 percent and the turbine driven pump is 200 percent.

Each condensate storage tank at Sizewell B is protected against natural phenomena including earthquakes, and a backup unprotected long term supply (dedicated to AFW) is available to each pump via manual valving. The SNUPPS design has an unprotected CST with a protected automatic long term supply which is the essential service water system.

Another difference in the two systems is the AFW flow control valves. At Sizewell, the flow control valves are semi-automatic in that after system initiation they will cycle full open or closed using steam generator high and low level setpoints as inputs. This continues until the operator intervenes to take manual control to maintain specified level. At SNUPPS the valves do not cycle open or closed but remain at a preset throttled position until the operator takes control to maintain the specified level.

The final major difference in the two systems is AFW flow following a main steamline break or main feedline break that results in an unisolable steam generator. The Sizewell B includes a feed only good steam generators system similar to the US Babcock and Wilcox designs that automatically terminate AFW flow to the faulted steam generator. The SNUPPS design relies on flow limiting orifices (similar to other W designs) to limit the flow to the faulted steam generator thereby assuring sufficient AFW flow to the intact steam generators. The SNUPPS design requires operator action within 10 minutes to secure flow to the faulted steam generator.

SNUPPS DESCRIPTION

The SNUPPS AFW system consists of three AFW pumps (2 Motor Driven, 1 Turbine Driven) taking suction from one condensate storage tank during normal operations, with each pump capable of discharging

via the main feedwater system piping to any combination of 1 to 4 steam generators. Normally, one motor driven pump is lined up to automatically supply water to two steam generators while the other motor driven pump is lined up to automatically provide water to the remaining two steam generators. The turbine driven pump is normally lined up to automatically supply water to all four steam generators.

U. S. ACCEPTANCE CRITERIA AND HOW THEY WERE MET BY THE SNUPPS DESIGN

1. GDC2 "Design Bases for Protection Against Natural Phenomena"

The entire AFW system, except for the normal water supply from the CST, is designed to seismic Category I requirements, and is located in the seismic Category I, flood-, missile-, and tornado protected auxiliary building. In the event of failure of the CST due to natural phenomena or other causes, the AFW pump suction is automatically transferred to the essential service water (ESW) system which is protected against natural phenomena. Therefore, in the event of any natural phenomena the system would automatically deliver water to the steam generators and the requirements of GDC-2 are met.

2. GDC-4 "Environmental and Missile Design Bases"

Each AFW pump and associatedactive valves are located in separate cubicles such that any flooding, missile, harsh environment or pipe break would only affect the capability of the pump train within a given cubicle which would assumed to be disabled due to the failure. The remaining trains would be available to supply adequate flow even assuming a single failure. Additionally the AFW system is not used for startup, hot standby or shutdown and therefore is not considered a high energy system except for those portions of the steam supply line to the turbine and the portions of piping connected to the main feedwater system that are pressurized during normal plant operations. Also all necessary components within the system will be environmentally qualified to operate under accident conditions, including pipe break and loss of ventilation.

3. GDC-5 "Sharing of Structures, Systems and Components"

The AFW system at SNUPPS is not shared between reactor units.

4. GDC-19 "Control Room"

The AFW system is automatically initiated on receipt of an auxiliary feedwater actuation signal (AFWAS) and delivers flow to the steam generator without operator action. Steam generator water level control is then manually controlled by the operator from the control room or remote shutdown panels. The operator can monitor steam generator pressure, level and AFW flow at either station. The system therefore meets the requirements of GDC-19 regarding prompt initiation of plant shutdown.

5. GDC-44 "Cooling Water" and GDC-34 "Residual Heat Removal"

Adequate isolation of the AFW system from non essential systems is included in the system design. The AFW system connects to the main feedwater system in the safety-related portion of the main feedwater line downstream of the main feedwater line isolation valve. Essential lines connecting to the condensate storage tank are provided with automatic isolation valves to isolate the AFW system from the tank in the event of tank failure. These isolation features meet the isolation requirements of GDC-44.

The AFW system can function automatically in the event of a loss of offsite power. The heat transfer path under this condition is from the steam generators to the atmosphere via the safety related atmospheric dump valves. The turbine-driven pump receives main steam from two of the four steam generators through an air-operated, fail open valve, one on each of the two steam generators. These valves are normally closed, and open automatically on receipt of a turbine-driven pump initiation signal. Each motor-driven pump is powered from a separate diesel generator backed bus. The AFW system discharge valves are air operated and normally open. They also fail open on loss of normal air and are provided with a seismic Category I backup accumulator (backed up by nitrogen). Based on the above, plus the reliability analyses performed by the applicant and reviewed by the staff, the design meets GDC-34 and GDC-44 with respect to its ability to remove decay heat from the reactor under accident conditions.

In accordance with the single-failure criterion of GDC-34 and GDC-44 the SNUPPS AFW system is designed to accommodate a single failure in any active system component without loss of function. The AFW system consists of three trains, supplying all four steam generators. Each train is supplied by one AFW pump. The turbine-driven pump train normally supplies all four steam generators. Each of the two motor-driven pump trains supplies two of the four steam generators. The motor-driven and turbine-driven pump trains are connected together downstream of the AFW valves before the connections to the main feed lines.

The AFW control valves for each train are powered from separate power supplies, such that a power supply failure only affects one train. The valves associated with the turbine-driven pump are all powered from a battery backed source, such that AC power is not required for turbine train operation. A failure modes and effects analysis for the entire AFW system results in the loss of not more than one train. Thus, adequate feedwater is ensured to at least two steam generators in the event of a pipe break or other postulated design basis accident concurrent with a single active failure.

The decay heat removal requirements of GDC-44 are met since each AFW pump is designed to provide 100 percent of the flow necessary for residual heat removal over the entire range of reactor operation, including all postulated design basis accidents.

6. GDC-45 and GDC-46 "Inspection of Cooling Water Systems" and "Testing of Cooling Water Systems"

Each pump is equipped with a recirculation line to the CST which can be used for periodic functional testing. Periodic testing of pumps and valves is performed in accordance with the Westinghouse Standard Technical Specifications. The limiting conditions for operation also follow the Westinghouse Standard Technical Specifications and the recommendations derived as a result of the TMI accident. The safety related portions of the system have also been designed and located in areas that are accessible during normal plant operation to permit periodic inservice inspection.

7. Branch Technical Position ASB 10-1 "Design Guidelines for Auxiliary Feedwater System Pump Drive and Power Supply Diversity for Pressurized Water Reactor Plants"

To meet the diversity requirements the turbine-driven AFW pump train provides a diverse means of ensuring feedwater supply to the steam generators independent of all offsite or onsite AC power sources for at least two hours. The turbine-driven pump bearings do not require cooling from an AC dependent source, and the pump can operate without area-forced ventilation for the 2-hour period. Automatic actuation and control of this train is provided from the vital DC power source.

8. Branch Technical Position RSB 5-1 "Design Requirements for Residual Heat Removal System"

The AFW system has the capability to permit operation at hot shutdown for at least four hours followed by cooldown to the RHR cut-in temperature from the control room using only safety grade equipment and assuming the worst case single active failure. This is assured by virtue of safety grade atmospheric dump valves and a safety-grade long term source of water from the ESW system. Thus the requirements of RSB 5-1 with respect to AFW are met.

9. II.E.1.1 Auxiliary Feedwater System Reliability Evaluation

The SNUPPS AFW system also meets all the recommendations of the TMI Task Action Plan outlined in NUREGS-0660 and 0737. The manner in which these recommendations are met are summarized below.

a. Recommendation GS-1 - The proposed SNUPPS Technical Specifications will be based on NUREG-0452, Revision 3, "Standard Technical Specifications for Westinghouse Pressurized Water Reactors". This meets the outage time limit and subsequent action time with respect to one AFW pump and its associated flow train and essential instrumentation being inoperable.

b. Recommendation GS-2 - The SNUPPS AFW system has an automatic switchover to the ESW system such that the single manual valve from the CST cannot interrupt AFW flow and there are no other single valve closures that could interrupt all AFW system flow.

c. Recommendation GS-3 - Throttling AFW flow will not be used to avoid waterhammer at SNUPPS. Therefore, this recommendation is not applicable.

d. Recommendation GS-4 - Although automatic switchover to the ESW water supply is included in the design, emergency procedures will . be available for transferring the AFW pump suction to backup water supplies, and the single manual valve in the line from the CST to the AFW system will be locked open by physical means such as a chain and padlock.

e. Recommendations GS-5 and GL-3 - Since the turbine-driven pump train is capable of being automatically initiated and controlled independent of any AC power source for at least two hours, these recommendations are met.

f. Recommendation GS-6 - Flow-path availability from the CST to the steam generators via an AFW train will be confirmed as part of functional testing on return from any extended cold shutdown. A second independent operator will also perform valve lineup checks following return to service of a train that has been out for testing or maintenance.

g. Recommendation GS-7 and GL-5 - The AFW system automatic initiation and control circuitry and signals are redundant and meet safety-grade requirements.

h. Recommendation (1) - The condensate storage tank level is monitored by redundant transmitters one of which is AFW pump suction pressure and is powered from redundant Class 1E power sources. Each transmitter provides indication and alarm in the control room. The low level alarm setpoint allows at least 20 minutes for operator action. These alarms are also backed by the safety-related switchover to the ESW system.

i. Recommendation (2) - The applicant has committed to performing a 48-hour endurance test on each pump to assure long term operability. The results of these tests will be reviewed by the staff.

j. Recommendation (3) - Redundant safety-grade flow instrumentation to each steam generator with indication in the control room is provided. The instrument channels are powered from the emergency buses that satisfy the diversity requirements of ASB 10-1.

k. Recommendation (4) - Since two AFW flow paths are available during periodic tests, this recommendation does not apply.

l. Recommendations GL-1 thru GL-5 - These recommendations either do not apply or are met as described under the short term (GS) recommendations.

Analysis - Provided in Separate Section

Areas for Further Evaluation

1. Determine whether decision to add another turbine-driven pump was based on single failure concern during a complete loss of all AC power, or, whether redundancy in diverse power sources was the basic concern without consideration of complete loss of AC power.

2. Determine the rationale for adding separate AFW inlet nozzles on the steam generator for the motor-driven pumps. Noting that it adds four containment penetrations to the design, inquire which safety concern or accident scenario was instrumental in the decision.

3. Was the feed only good steam generators system designed by Westinghouse, Bechtel or by others? At any rate has a detailed failure analysis been performed to assure that no failure modes could result in isolation of more than the one (faulted) steam generator including momentary pressure fluctuations?

b. TITLE

Design differences between the SNUPPS and Sizewell B component cooling water (CCW) systems and essential service water (ESW) systems.

DESCRIPTION

The CCW systems for both plants are basically the same with two-100 percent trains each of which has two-100 percent pumps. The major differences are (1) the Sizewell B CCW design is allocated more loads because the ESW system uses seawater, and (2) there is a forced-air (radiator) heat exchanger that can be used to remove heat from the CCW system as a backup to the ESW system. The backup heat exchanger is necessary since the Sizewell B ESW system is not seismically designed. The SNUPPS CCW system has only one main heat exchanger (cooled by ESW) since it is capable of maintaining CCW temperature within design limits under all conditions. The Sizewell B CCW system has two heat exchangers cooled by ESW because, given the higher heat load of the Sizewell design, the main heat exchanger cannot maintain CCW water temperature low enough to cool containment air coolers, pump room coolers, and pump lube oil heat exchangers. Consequently, an auxiliary heat exchanger automatically supplements CCW cooling under accident conditions. At SNUPPS, the ESW system supplies cooling water for many of these heat loads.

An added feature at the Sizewell B plant is the addition of two reserve ultimate heat sink (RUHS) pumps that have only one function: To provide CCW flow to the containment air coolers in the event that all CCW pumps

are not available. The pumps are manually started and stopped and are not designed to handle full accident loads such as a large LOCA.

The RUHS heat exchangers associated with the CCW system are automatically switched into the system on loss of ESW system flow due to common mode failure of the ESW pumps such as screen blockage or a seismic event. They are not designed to handle the design basis LOCA heat loads since a large LOCA concurrent with a design basis earthquake is considered beyond the design basis. Although a large LOCA concurrent with an SSE is also considered beyond the design basis for SNUPPS, the ESW system and UHS for SNUPPS is designed for the SSE.

The ESW system at Sizewell has four-100 percent pumps while the SNUPPS ESW system has two. However at Sizewell two of the pumps are necessary for normal operation, while SNUPPS ESW pumps are only used during emergencies. During normal operations at SNUPPS, the ESW system heat loads are supplied by two out of three (50 percent capacity each) station service water pumps. At first glance the ESW systems appear to be quite different for Sizewell and SNUPPS but further inspection shows they are very similar since each plant has two-100 percent headers with each header having two pumps capable of supplying water with one of the two pumps normally operating.

The ESW system at Sizewell B is not designed to remain functional following a seismic event since it is backed up by the seismically qualified RUHS. At SNUPPS the ESW system is designed to remain functional following a seismic event.

SNUPPS CCW System Description

The CCW system at SNUPPS consists of two separate 100 percent trains each capable of being supplied by two-100 percent pumps (4 pumps total). Each train has one surge tank and one CCW heat exchanger cooled by the ESW system.

A common nonseismic header is used to supply nonsafety-related loads during normal operation. This common loop is connected to both essential trains via automatically operated safety-grade isolation valves that close upon receipt of a safety injection signal, surge tank low level or high flow indicative of a pipe failure.

Redundant safety related components cooled by the CCW system are the RHR heat exchangers, RHR pump seal coolers, centrifugal charging pump bearing oil coolers, SIS pump bearing oil coolers, and the fuel pool heat exchangers.

During normal operation one pump in one of the safety-related loops is operated with the redundant safety-related train isolated from the system. If the pump should fail the remaining pump in the same operating loop automatically starts.

Upon loss of offsite power one pump in each of the safety-related loops automatically starts when sequenced onto the diesel generator buses. The remaining pumps stay in auto-standby.

SNUPPS ESW System Description

The ESW system at SNUPPS consists of two independent 100 percent trains, with one 100 percent pump per train which are in standby during normal plant operation. During normal operation the ESW loads are supplied cooling water by the nonsafety grade station service water system consisting of three 50 percent capacity pumps. The ESW pumps take suction from the seismic Category I UHS retention pond. Locked closed isolation valves separate the two ESW trains.

Although each train of the ESW system is interconnected with the non-safety-related station service water (SSW) system, after a SIS, AFW low suction pressure, or loss of offsite power the ESW system is automatically isolated from the SSW system.

The ESW system heat loads are all safety related except for the air compressors and include the diesel generators, safety-related air conditioning systems, all safety-related pump room coolers, and the containment air coolers. The nonseismic air compressors have seismic Category I isolation valves separating the essential and nonessential portions of the ESW system.

U. S. ACCEPTANCE CRITERIA

1. GDC2 "Design Bases for Protection Against Natural Phenomena"

Both the CCW and ESW systems at SNUPPS are protected against natural phenomena. The systems are designed to seismic Category I requirements and are located in seismic Category I, wind and tornado missile protected structures which also provide protection against the design basis flood. All connections to nonessential portions of the systems are isolable by seismic Category I, automatically operated isolation valves such that a single failure following any natural phenomena will not prevent either system from performing its safety function. Regulatory Guides 1.26, "Quality Group Classification," 1.29, "Seismic Design Classification," 1.102, "Flood Protection for Nuclear Power Plants," and 1.117, "Tornado Design Classification," were followed in meeting GDC2.

2. GDC4 "Environmental and Missile Design Bases"

Each CCW pump and ESW pump and all necessary piping and valving are located in separate rooms or cubicles such that flooding, environmental conditions, pipe whip and jet impingement due to a pipe break, or internally generated missiles could only affect components in that particular room or cubicle. Since both the CCW and ESW systems are classified as moderate energy, dual-purpose (used during normal operations and emergency conditions) systems, single active failures following a pipe break (crack) in a seismic Category I portion of the system are not postulated in accordance with ASB 3-1. Following a pipe break in a nonseismic Category I portion of the systems, no single active failure will result in the loss of more than one ESW or CCW train. Both systems are adequately separated from high energy piping systems such that pipe whip, jet impingement or missiles generated from high energy piping system are not a concern.

3. GDC5 "Sharing of Structures, Systems and Components"

There is no sharing of the CCW system or ESW system between units, so this GDC is not applicable.

4. GDC44 "Cooling W[illegible]

For both the CCW system and the ESW system component redundancy is such that their safety function can be performed following a loss of offsite power coincident with any single active failure. Automatic isolation valves are provided to isolate nonessential portions of the system from essential portions of the system. The combination of the CCW and ESW systems have adequate capacity to transfer heat loads, including decay heat, from safety-related structures, systems and components under both normal operating and accident conditions.

5. GDCs 44 and 45 "Inspection of Cooling Water System" and "Testing of Cooling Water System"

The ESW and CCW systems are inspected and tested periodically in accordance with plant Technical Specifications. The systems are capable of being tested through the entire sequence of operations that brings them into service including the sequencing of the components onto the emergency buses. Limiting conditions for operation are provided that are consistent with the Westinghouse Standard Technical Specifications.

The systems are designed and located in accessible areas to allow periodic inservice inspection of the components and piping.

. Analysis - This topic is covered in a separate section.

. Areas for Further Exploration

1. Identify which specific safety concern led to the addition of special pumps in the CCW system to supply only the containment air coolers upon loss of all normal CCW pumps. Determine whether consideration was also given to providing this capability for other components cooled by the CCW system.
2. Ascertain whether the primary reason for adding the reserve ultimate heat sink was based on common mode ESW pump failure such as clogged screens, or whether it was based on the problems of designing the ESW system to seismic requirements.

7.C Title: Plant Auxiliary Electrical Systems

Description:

The Sizewell "B" vital ac electrical system consists of four essential buses, each of which feeds one of the four emergency load groups. The four essential buses receive offsite or station power through the nonessential station buses. A normally-open bus tie between essential buses 1 & 4 and 2 & 3 is used to provide an alternate source of offsite power to an essential bus. The standby power sources to the four essential buses are four independent diesel generators, each of which is rated 5500 kw and supplies only one of the essential buses.

The Sizewell "B" vital dc electrical system consists of eight independent batteries, each with its own battery charger, distribution boards and inverter. Four of the batteries provide power through the inverters to the primary protection and instrumentation system while the other four power the secondary protection and instrumentation system. The batteries also provide power to other essential equipment such as the steam driven auxiliary feedwater pumps, the diesel driven emergency charging pump, main and emergency control room lighting, and control and switching power for essential equipment. Section 15.5.2.1 of the preconstruction safety report indicates the batteries have capacity to power the steam driven feedwater pumps and charging pump for 12 hours.

The four dc power trains which supply primary instrumentation and the four which supply secondary instrumentation are each electrically independent. The four ac power trains are electrically independent except for the common source of offsite power to the buses and the crossties

between buses which are only enabled when on offsite power. The four ac and dc electrical trains are physically separated for fire protection purposes either four ways or two ways. Where there is two way separation, the equipment associated with trains 1 and 3 is separated from equipment on trains 2 and 4. Within these pairs of safety trains it appears the physical separation generally follows that of IEEE 384. The primary and secondary reactor protection system batteries are located in separate buildings, however within the auxiliary building and reactor building, primary and secondary cables of the same channel will be run together.

SNUPPS Description:

The SNUPPS vital ac electrical system consists of two essential buses, each of which feeds one of the two completely redundant emergency load groups. The two essential buses receive both the normal and alternate source of offsite power directly from the offsite power supplies. No bus tie exist between the essential buses. The standby power sources to the two essential buses are two independent diesel generators, each of which is rated 6200 kw and supplies only one of the essential buses.

The SNUPPS vital dc electrical system consists of four independent batteries, each with its own battery charger, distribution boards and inverter. The batteries provide power through the inverters to the four channels of the reactor protection and engineered safety features systems. The batteries also provide power to other essential loads such as the steam driven auxiliary feedwater pump train, main control room

emergency lighting and switching power for essential equipment. The batteries have sufficient capacity to power their loads for 3 hours and 20 minutes.

The four dc power trains are electrically independent. The two ac power trains are electrically independent except for the common sources of offsite power to the buses. The dc and ac power trains maintain physical separation between redundant divisions in accordance with the criteria contained in IEEE 384.

U.S. Acceptance Criteria

The U.S. acceptance criteria used by the staff for the vital onsite ac and dc distribution systems is contained in Table 8-1 of the SRP and is primarily based on the General Design Criteria. The criteria requires that the onsite power systems have redundancy, meet the single failure criterion, be testable and have the capacity, capability and reliability to supply power to all the required safety loads.

The onsite ac power system at SNUPPS meets the redundancy and single failure criterion by utilizing two independent, 100% distribution system divisions, each of which is powered by an independent diesel generator or by one of two offsite circuits. The diesel generators and offsite circuits meet the capacity and capability requirements by having sufficient capacity to sequentially start and operate all of the safety loads connected to them. The diesel generator in addition has demonstrated the required reliability and capability by meeting the requirements of IEEE 387 and RG 1.9 for automatic sequential loading, load rejection, light loading, reliability qualification

testing, margin test, and load capability qualification tests.

The onsite dc power system at SNUPPS meets the redundancy and single failure criterion by utilizing four independent distribution system divisions, each of which is powered by an independent battery and battery charger. Each division meets the capacity and capability requirements by utilizing battery chargers sized with sufficient capacity to supply the largest combined demand of all the steady state loads connected to it. Although no specific criteria exists for battery endurance (following completion of Station Blackout, USI A-44, specific criteria will be developed) it is required that the turbine-driven AFW pump train be available for 2 hours assuming a total loss of ac power. The SNUPPS batteries, which support the turbine driven AFW pump train, have a 3 hour and 20 minutes endurance which meets this requirement.

The redundancy and reliability requirements are further met by the ac and dc vital onsite systems at SNUPPS by physically separating the power supplies to the redundant divisions in separate rooms in a Seismic Category I building and physically separating switchgear and cabling of redundant divisions according to IEEE 384 and RG 1.75 requirements.

Analysis

Provided separately

Area for Further Exploration

(1) It is not clear whether those cable runs which have only two way separation for fire segregation purposes still in fact maintain four way separation for electrical segregation purposes as defined in Section 8.4.2.3.(b) of the Pre-Construction Report. Determine whether there is four way electrical segregation in these areas and if this results in four way electrical segregation for all the safety equipment.

(2) Chapter 15 of the Pre-Construction Report indicates that the essential batteries have capacity to power the steam driven AFW pumps and charging pump for 12 hours, and Chapter 8 of the report indicates that the battery rating has not been finally established. Determine whether the 12 hour endurance quoted for the batteries which support the AFW pump trains include all other safety loads connected to the batteries and whether the batteries not associated with the AFW and charging pumps also have 12 hours endurance.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 2 1 1983

MEMORANDUM FOR: B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing

FROM: G. E. Edison, Project Manager
Licensing Branch No. 1
Division of Licensing

SUBJECT: SUMMARY OF MEETING WITH WESTINGHOUSE ON REACTOR COOLANT PUMP SEAL PERFORMANCE (GENERIC)

The subject meeting was held in Bethesda on January 19, 1983. The purpose of the meeting was to gather information on the performance of Westinghouse Reactor Coolant Pump (RCP) Seals. This information was needed to assist in the evaluation of the probability of certain accident scenarios involving RCP seal leakage.

Westinghouse made an impressive presentation in which they described the RCP and seals, the seal support functions and systems, seal performances and operating experience, and systems reliability and accident scenario probabilities. They indicated that the RCP was designed to operate without damage to the seals for at least 24 hours, and probably much longer, if seal injection water was lost while component cooling water to the seal thermal barriers was maintained, or vice-versa. Test results were presented for valve seal "O" rings which showed essentially no damage (slight feathering) after 10 hours at 550 F; the "O" rings were stated to be identical in material, thickness and include the range of clearances that exist in RCP applications. The tests were stated by Westinghouse to be extrapolable to RCP application. Further RCP seal tests and analyses are planned.

Using seal failure rates based on the valve seal "O" ring test data as well as reactor operating data, Westinghouse presented analyses which were stated to conservatively predict a 10 gpm leak rate for as long as 10 hours if all cooling water to the RCP seals (component cooling water to seal thermal barriers, plus CVCS seal injection flow) were shut off. The analyses assumed the RCP was tripped and the seal "O" rings did not fail.

Westinghouse stated that they had done a bounding analysis earlier for Indian Point in which they assumed that all three seals were totally missing from the RCP; for that case they calculated a maximum leak rate of 300 gpm per RCP. They stated this was the largest leak possible which could result from a loss of all seal cooling water. They noted that an earlier Westinghouse calculation for the large leak at the H. B. Robinson plant had estimated a leak rate of about 400 gpm; however, they indicated they had little faith in that calculation, that they could not find it now, and the individual who had performed it is no longer with Westinghouse. The Robinson event did not involve a loss of all seal cooling water.

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For the loss of all AC power (which would shut off all seal cooling water, a nationwide average probability of $\sim 2 \times 10^{-4}$/R-yr. was estimated, resulting in a probability of core uncovery (after RCP seal LOCA) of $\sim 3 \times 10^{-6}$/R-yr. The analyses used EPRI data for recovery of AC power, and showed the loss of all AC power to be the strongly dominant mode of losing all seal cooling water. Pipe break was not considered to cause a loss of all seal cooling water; it was noted that in the SNUPPS design, no single pipe break in the CCW system would cause a loss of CCW function because of the redundant flow trains. It was also noted that in the SNUPPS design, d.c. battery endurance was 200 minutes fully loaded, and 8 to 12 hours with load shedding; also, the turbine-driven auxiliary feedwater train could be manually operated without batteries.

Westinghouse concluded that:

(1) The design of the RCP seal system and plant seal support systems meet the licensing design basis criteria.

(2) Available data and operating experience show that the probability of significant seal leakage (from loss of seal cooling water) is low.

(3) Loss of all a.c. power is judged to be the dominant cause of failure of all seal cooling.

(4) The probability of core uncovery after loss of all a.c. power (due to RCP seal leakage) is $\sim 3.5 \times 10^{-6}$/R-yr.

The Westinghouse presentation is attached, as well as a meeting agenda and a list of attendees.

G E Edison

G. E. Edison, Project Manager
Licensing Branch No. 1
Division of Licensing

Attachments:
As Stated

ATTENDANCE AT WESTINGHOUSE/NRC

MEETING HELD JANUARY 19, 1983

ON REACTOR COOLANT PUMP SEAL PERFORMANCE

NRC Participants

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A. Thadani, DST
R. Riggs, DST
L. Marsh, DSI
A. Buslik, DST
A. Singh, DSI
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J. Wermeil, DSI
R. Anand, DSI
C. Liang, DSI
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Westinghouse

D. Rawlins
W. Poulson
R. Etling
D. Salak
D. Paddleford
J. Crane
W. Brown
G. Harkness
J. Swogger

Union Electric

A. Passwater
S. Miltenberger
D. Capone

Kansas Gas & Electric

G. Rathbun
M. Stewart
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Bechtel

P. Ward
J. Prebula
D. Quattrociocchi

SNUPPS

F. Schwoerer

CONCLUSIONS

1. DESIGN OF RCP SEAL SYSTEM AND PLANT SEAL SUPPORT SYSTEMS MEET THE LICENSING BASIS DESIGN CRITERIA.

2. EXPERIENCE AND AVAILABLE DATA SHOW THAT THE PROBABILITY OF SIGNIFICANT SEAL LEAKAGE IS LOW. (CURRENT STUDIES ARE EXPECTED TO CONFIRM THIS CONCLUSION.)

3. THE OCCURENCE OF LOSS-OF-ALL-AC POWER IS JUDGED TO BE THE DOMINANT CONTRIBUTOR LEADING TO FAILURE OF ALL SEAL COOLING.

4. THE CALCULATED FREQUENCY OF CORE UNCOVERY FROM THE LOSS-OF-AC-ACCIDENT DUE TO RCP SEAL LEAKAGE IS APPROXIMATELY 3.5×10^{-6}/YR.

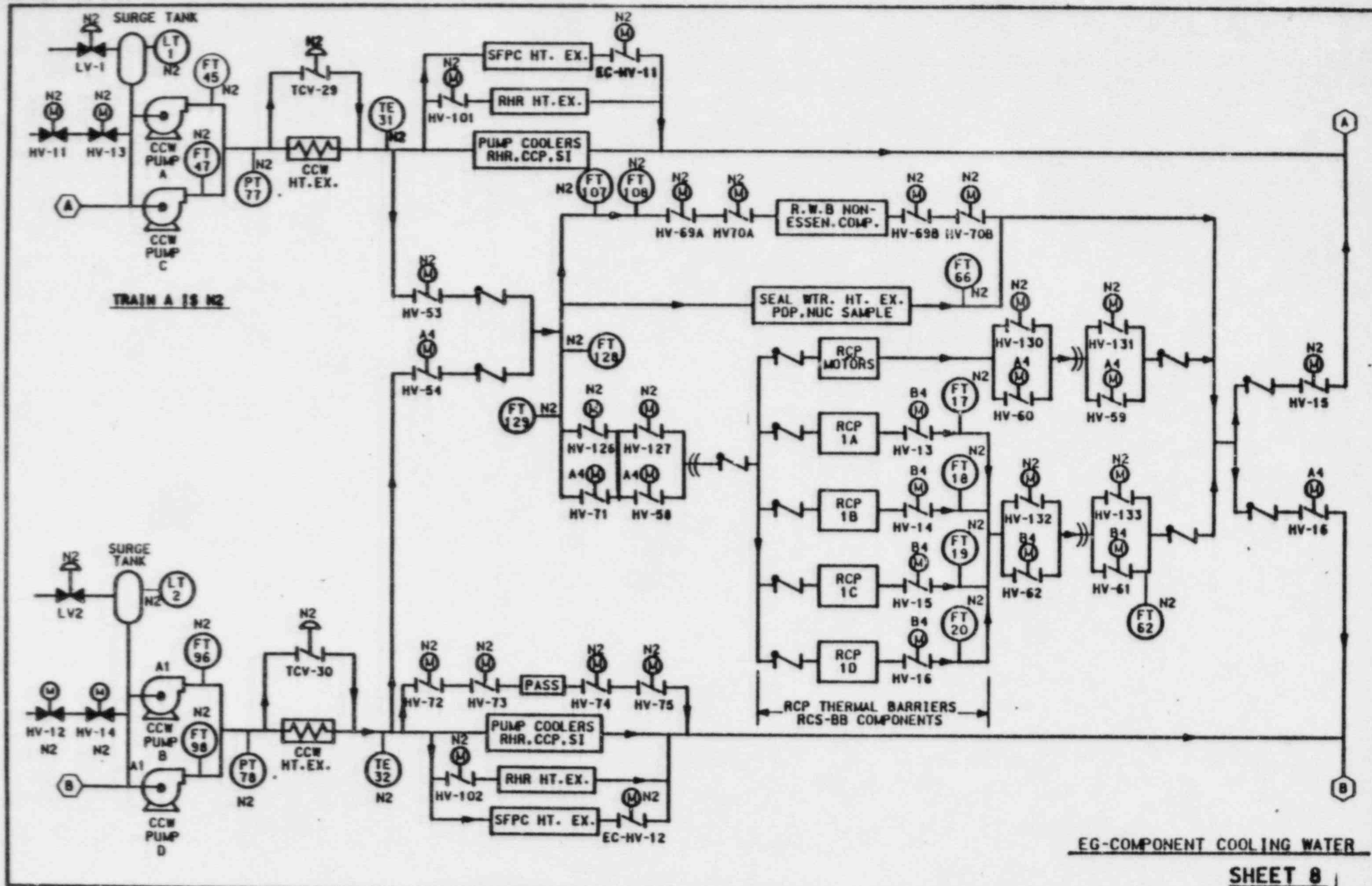
AGENDA

Westinghouse/NRC Meeting
January 19, 1983, 9AM
P110 Phillips Bldg
Reactor Coolant Pump Seal Performance

	Presentor	Approximate Presentation Time
1. Introduction	W NTD	5 Min.
2. RCP - Function and Features	W EMD	20 Min.
a. Pump		
b. Seals		
3. Seal Support Functions	W NTD	15 Min.
a. Seal Injection		
b. Thermal Barrier		
4. Seal Performance and Experience	W EMD	60 Min.
a. Operating History		
b. O Ring Test Data		
c. Projected Seal Performance During Upset Modes		
d. WOG Test and Analysis		
5. Seal Support Systems	W NTD/SNUPPS	20 Min.
a. CVCS		
b. CCW		
6. Systems Reliability	W NTD/SNUPPS	40 Min.
a. Scenarios Including Full Loss of AC Power		
b. Support Systems		
c. Seal		
d. NSSS Effects		
e. Recovery/Mitigation Actions		
7. Conclusions		10 Min.

JOC/nld

STDB REV. 10-7-81



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2. RCP - FUNCTION AND FEATURES

WEMD
D. W. SALAK

REACTOR COOLANT PUMP

GENERAL DESCRIPTION

THE CONTROLLED LEAKAGE SEAL REACTOR COOLANT PUMP IS A VERTICAL, SINGLE-STAGE, CENTRIFUGAL PUMP DESIGNED TO MOVE LARGE VOLUMES OF REACTOR COOLANT WATER AT ELEVATED TEMPERATURES AND PRESSURES.

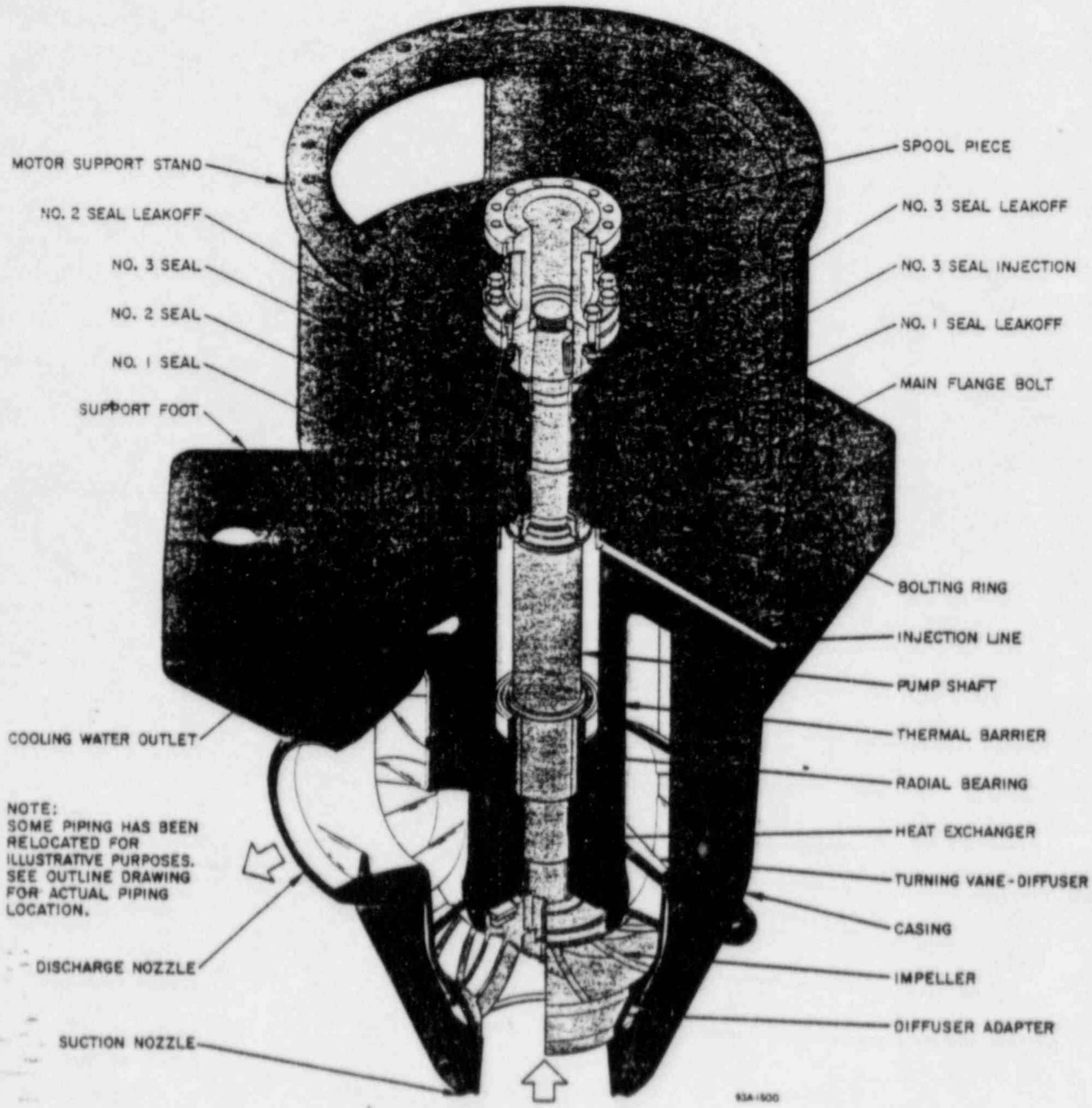


FIGURE 1-1 Cutaway View of Pump

RCP SEALS

GENERAL DESCRIPTION

- THREE (3) SEALS IN SERIES
- REDUCE INJECTION WATER PRESSURE TO CONTAINMENT ATMOSPHERE
- EACH SEAL CONSISTS OF A RING FREE TO MOVE AXIALLY AND A RUNNER THAT ROTATES WITH THE PUMP SHAFT

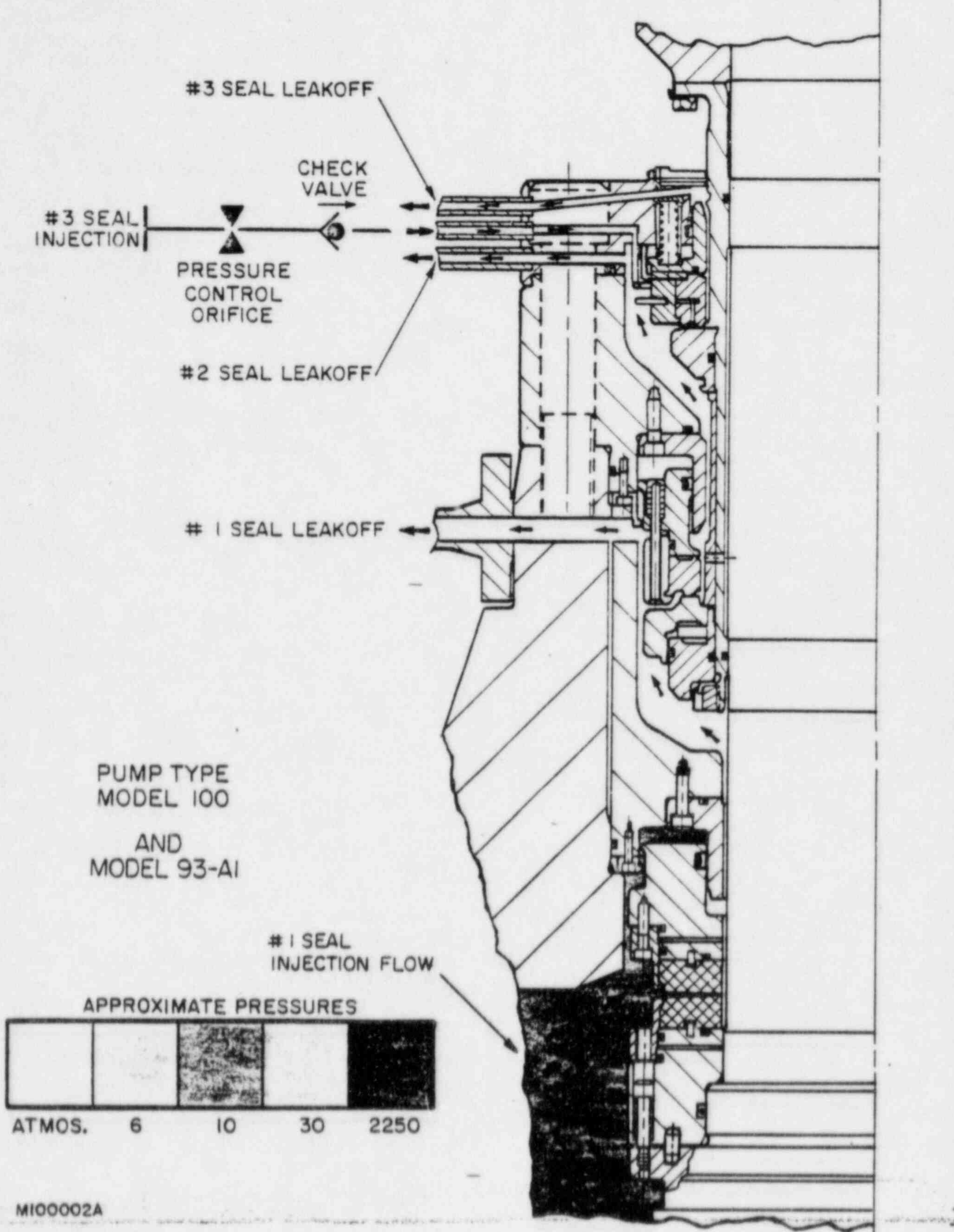


FIGURE 1-8 Seal Flow Diagram

REACTOR COOLANT PUMP SEAL FLOW

- SEAL PACKAGE CONSISTS OF THREE SEALS
- SEAL INJECTION WATER SUPPLIED AT 8 GPM AND $\leq$ 130°F
- SPLIT OF SEAL INJECTION WATER DETERMINED BY NO. 1 SEAL LEAKAGE.
- MAJORITY OF PRESSURE DROP OCCURS ACROSS NO. 1 SEAL
- NO. 2 SEAL DIVERTS MAJORITY OF NO. 1 SEAL LEAKAGE TO THE NO. 1 SEAL LEAK-OFF CONNECTION.
- NO. 2 SEAL CAPABLE OF SEALING FULL SYSTEM PRESSURE
- NO. 3 SEAL DIVERTS NO. 2 SEAL LEAKAGE TO THE NO. 2 SEAL LEAK-OFF CONNECTION.

NO. 1 SEAL

- HYDROSTATIC, FILM-RIDING RADIAL TAPER FACE
- PRIMARY SEAL:

TYPICAL P	2200 PSI
TYPICAL TEMPERATURE	155°F

- PRESSURE ACTUATED, DOES NOT NECESSARILY REQUIRE SHAFT ROTATION
- MATERIALS:

  410 SST BASE RING

  410 SST CLAMP RING

  ALUMINUM OXIDE FACEPLATE

NO. 2 AND NO. 3 SEALS

- RUBBING FACE TYPE
- CARBON-GRAPHITE RING AGAINST CHROME-CARBIDE RUNNER
- NO. 2 SEAL CAN WITHSTAND FULL SYSTEM PRESSURE
- TYPICAL ΔP - 50 PSI (NO. 2 SEAL)

  - 2 - 6 PSI (NO. 3 SEAL)

REACTOR COOLANT PUMP
SEAL SUPPORT FUNCTIONS

WESTINGHOUSE

JANUARY 1983

REACTOR COOLANT PUMP
SEAL SUPPORT

- O REQUIRED TO MAINTAIN RCP SEALS COOL AND CLEAN TO EXTEND OPERATING LIFE.

- O PROVIDED BY THE NSSS AUXILIARY SYSTEMS.

- O IN SERVICE DURING ALL MODES OF PLANT OPERATION (EXCEPT REFUELING).

RCP SEAL SUPPORT FUNCTIONS

O SEAL INJECTION

- PROVIDES COOLING TO THE RCP SEALS
- PREVENTS REACTOR COOLANT FROM ENTERING THE PUMP INTERNALS
- ENSURES SEAL LEAKAGE IS CLEAN AND FILTERED TO PREVENT BLOCKAGE OF SEAL PASSAGES

O THERMAL BARRIER COOLING

- LIMITS THE HEAT TRANSFER FROM THE REACTOR COOLANT TO THE PUMP LOWER INTERNALS
- COOLS REACTOR COOLANT PRIOR TO ENTERING THE PUMP RADIAL BEARING AND SEALS WHEN NORMAL SEAL INJECTION IS NOT AVAILABLE

O SEAL LEAKOFF

- ENSURES SEAL FACES MAINTAIN PROPER SEPARATION
- PROVIDES A CLOSED LOOP PROCESSING FOR ALL PUMP LEAKOFF'S

RCP SEAL INJECTION

- REQUIRED WHEN REACTOR COOLANT SYSTEM IS FILLED OR ABOVE ATMOSPHERIC PRESSURE

- TYPICALLY FILTERED TO 5 MICRONS TO ENSURE A CLEAN FLUSHING OF SEALS

- SUPPLY CHARACTERISTICS

  - TEMPERATURE BETWEEN 60°F AND 130°F

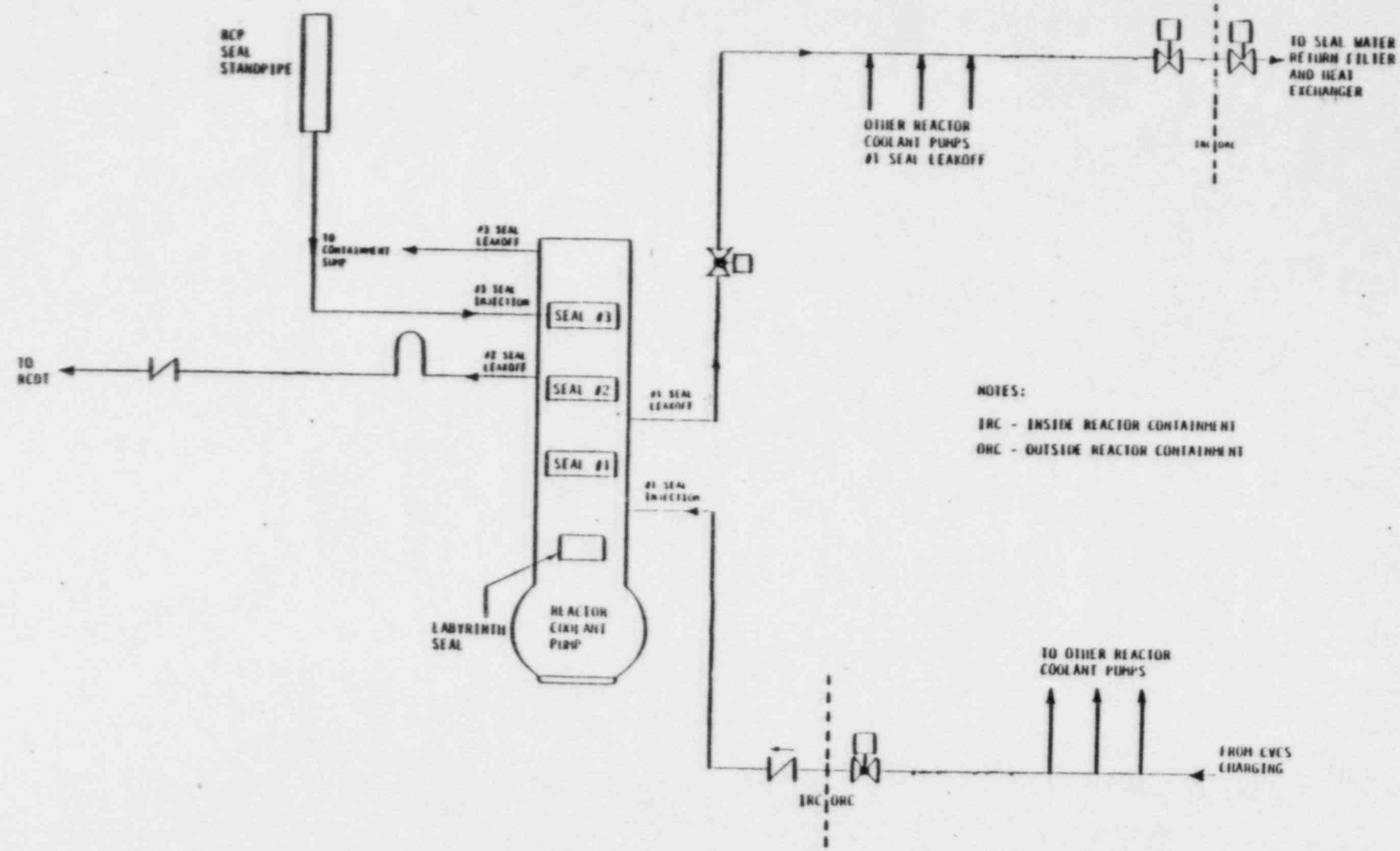
  - FLOWRATE BETWEEN 6 GPM AND 13 GPM

  - PRESSURE SUFFICIENT TO ENSURE REQUIRED FLOWRATES (GREATER THAN RCS PRESSURE)

- PROVIDED BY THE CHEMICAL AND VOLUME CONTROL SYSTEM CHARGING PUMPS

RCP NO. 1 SEAL LEAKOFF

- o REQUIRED TO ENSURE PROPER SEPARATION OF NO. 1 SEAL FACES
- o PROVIDES A CLOSED LOOP COLLECTION OF ALL PROCESS FLUIDS FROM THE NO. 1 SEAL LEAKOFF
- o LEAKOFF CHARACTERISTICS
  - TEMPERATURE BETWEEN 60°F AND 170°F
  - FLOWRATE BETWEEN 1 GPM AND 6 GPM
  - NORMAL BACKPRESSURE IS 30 PSIG
- o ISOLATION OF NO. 1 SEAL LEAKOFF PLACES THE NO. 2 SEAL IN A PRESSURE RETENTION MODE
- o NO. 2 SEAL CAN MAINTAIN THE PRESSURE RETENTION FOR 24 HOURS WITH THE RCP STOPPED



RCP SEAL INJECTION

RCP THERMAL BARRIER COOLING

- O REQUIRED DURING NORMAL RCP OPERATION

- O PROVIDES REDUNDANT SEAL COOLING WHEN REACTOR COOLANT TEMPERATURE IS ABOVE 150°F

- O LIMITS THE HEAT TRANSFER FROM THE REACTOR COOLANT TO THE LOWER PUMP INTERNAL COMPONENTS

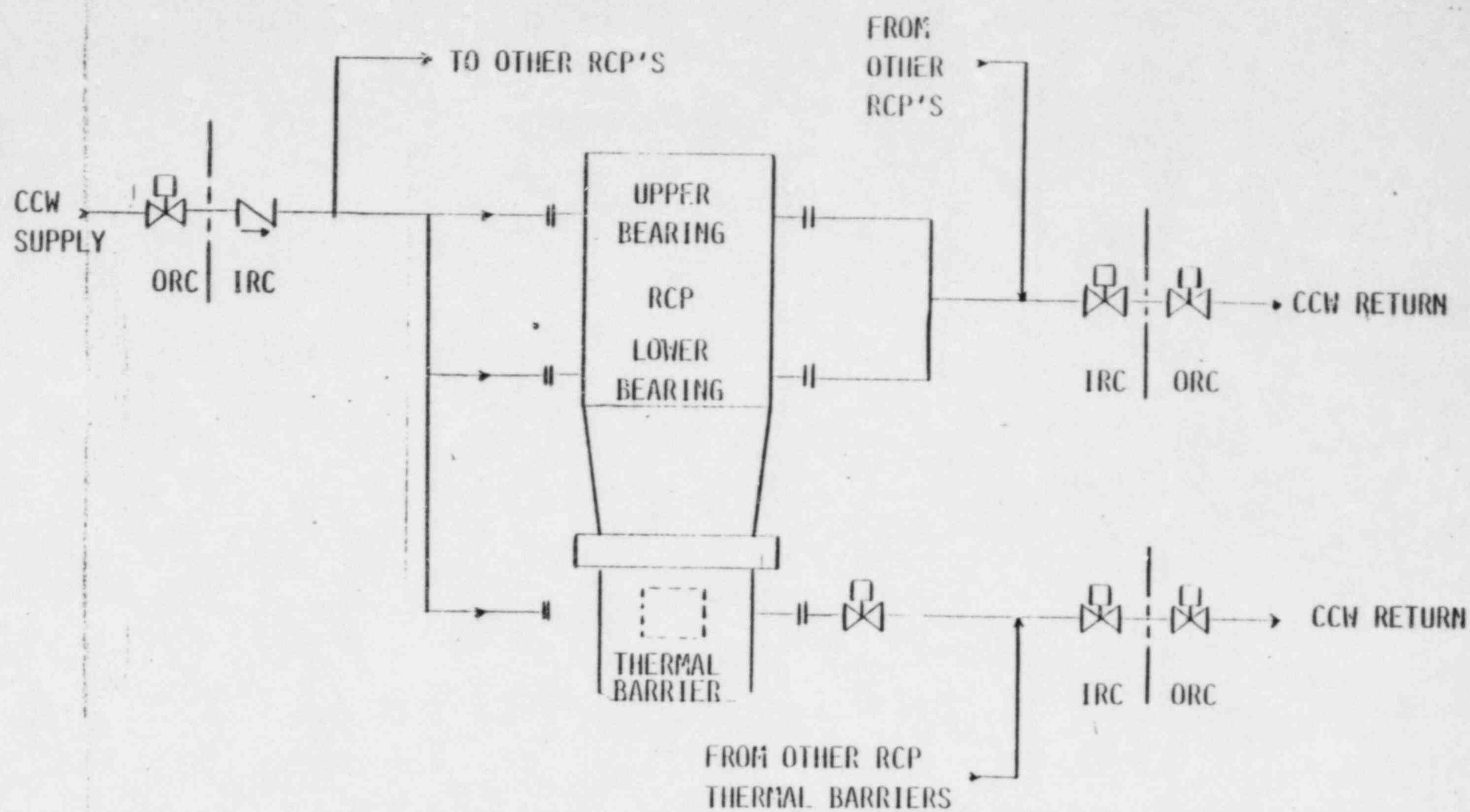
- O SUPPLY CHARACTERISTICS

    - COOLING WATER TEMPERATURE BETWEEN 80°F AND 105°F

    - NOMINAL FLOWRATE OF 40 GPM

    - LOW PRESSURE SOURCE

- O THERMAL BARRIER COOLING IS PROVIDED BY THE COMPONENT COOLING WATER SYSTEM



TYPICAL COMPONENT COOLING SUPPLY

SEAL SUPPORT FUNCTIONS
REQUIRED FOR RCP OPERATION

- O SEAL INJECTION AND THERMAL BARRIER COOLING ARE NORMALLY IN SERVICE DURING RCP OPERATION

- O THE RCP SEAL DESIGN UTILIZES EITHER AN INJECTION OR COOLING METHOD OF SUPPORT

- O RCP CAN OPERATE FOR 24 HOURS WITH EITHER SEAL INJECTION OR THERMAL BARRIER COOLING ISOLATED

- O FOR EQUIPMENT PROTECTION, THE RCP IS TRIPPED FOLLOWING THE LOSS OF BOTH SEAL INJECTION AND THERMAL BARRIER COOLING

- O CONTINUOUS ON-LINE RCP OPERATION IS SUPPORTED BY REDUNDANT SEAL SUPPORT SYSTEM DESIGNS

CHEMICAL AND VOLUME CONTROL SYSTEM

WESTINGHOUSE

JANUARY 1983

CHEMICAL AND VOLUME CONTROL SYSTEMS

FUNCTIONS

- o WESTINGHOUSE NSSS DESIGN PROVIDES THE FOLLOWING FUNCTIONS:

  - MAINTAINS REACTOR COOLANT INVENTORY

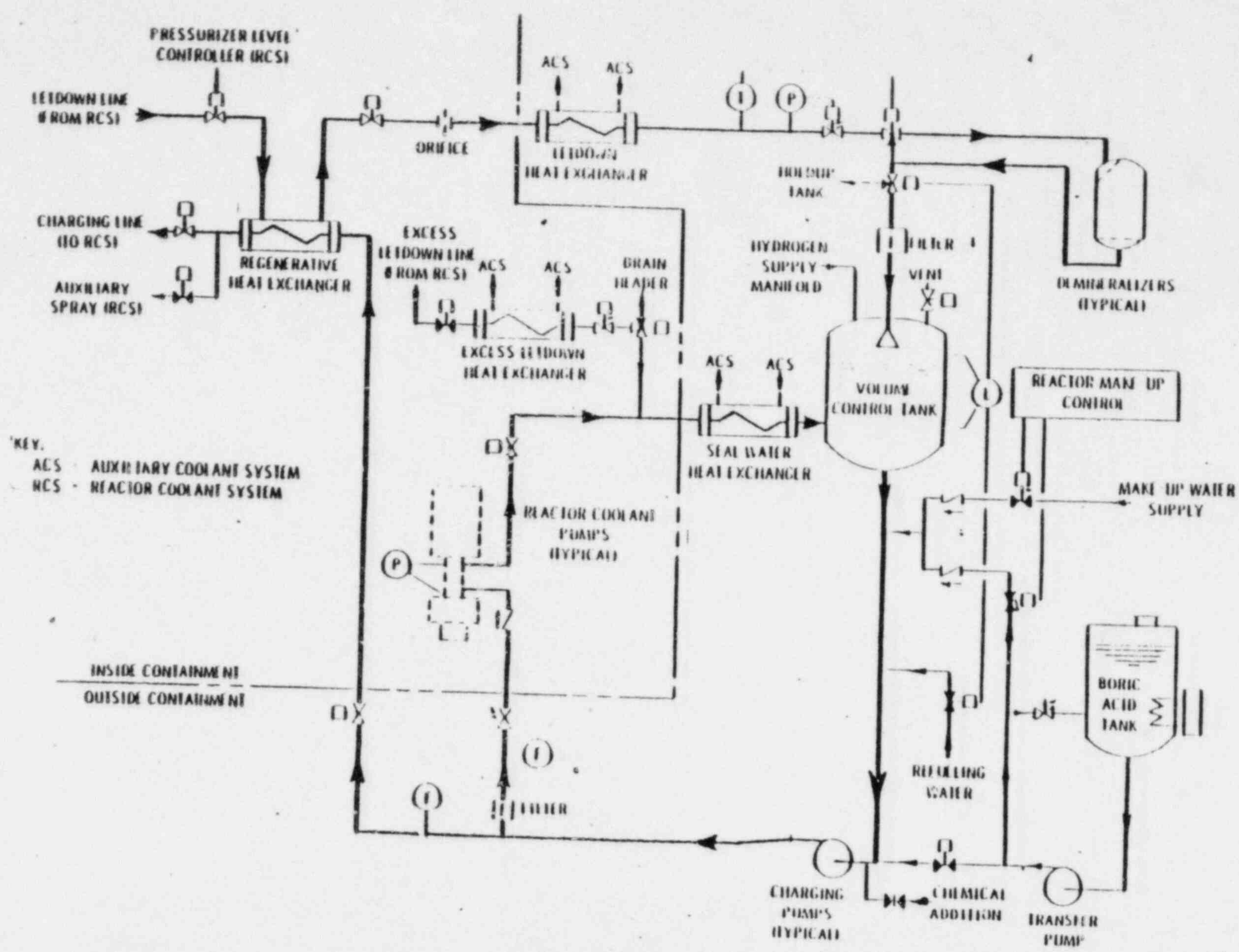
  - USED FOR FILLING, DRAINING, AND PRESSURE TESTING RCS

  - RCS CHEMISTRY CONTROL

  - REACTIVITY CONTROL

  - PORTIONS USED FOR SAFETY INJECTION

  - REACTOR COOLANT PUMP SEAL SUPPORT

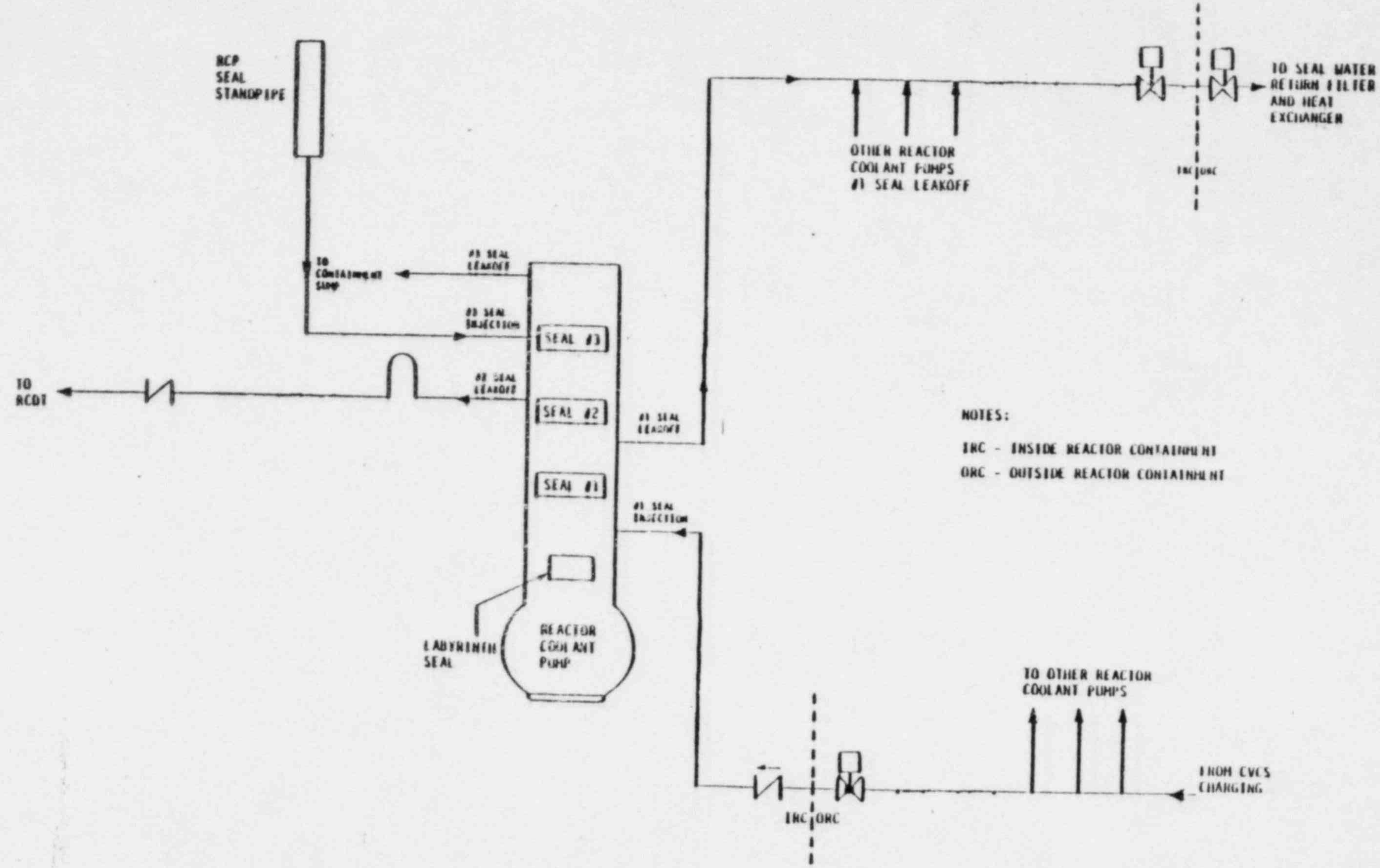


CVCS FLOWPATHS AND COMPONENTS

CHEMICAL AND VOLUME CONTROL SYSTEMS

SEAL SUPPORT

- SEAL INJECTION
  - 8 GPM INJECTION NO. 1 SEAL
  - HEAD TANK FOR NO. 3 SEAL
- SEAL LEAKOFF
  - FILTERS, COOLS, AND RECIRCULATES NO. 1 SEAL LEAKOFF BACK TO CVCS
  - DIRECTS NO. 2 SEAL LEAKAGE TO RCDT



NOTES:

IRC - INSIDE REACTOR CONTAINMENT

ORC - OUTSIDE REACTOR CONTAINMENT

RCP SEAL INJECTION

1.

CHARGING/SEAL INJECTION ARRANGEMENTS

O A VARIETY OF SYSTEM ARRANGEMENTS, EACH INCORPORATING 3 CHARGING PUMPS

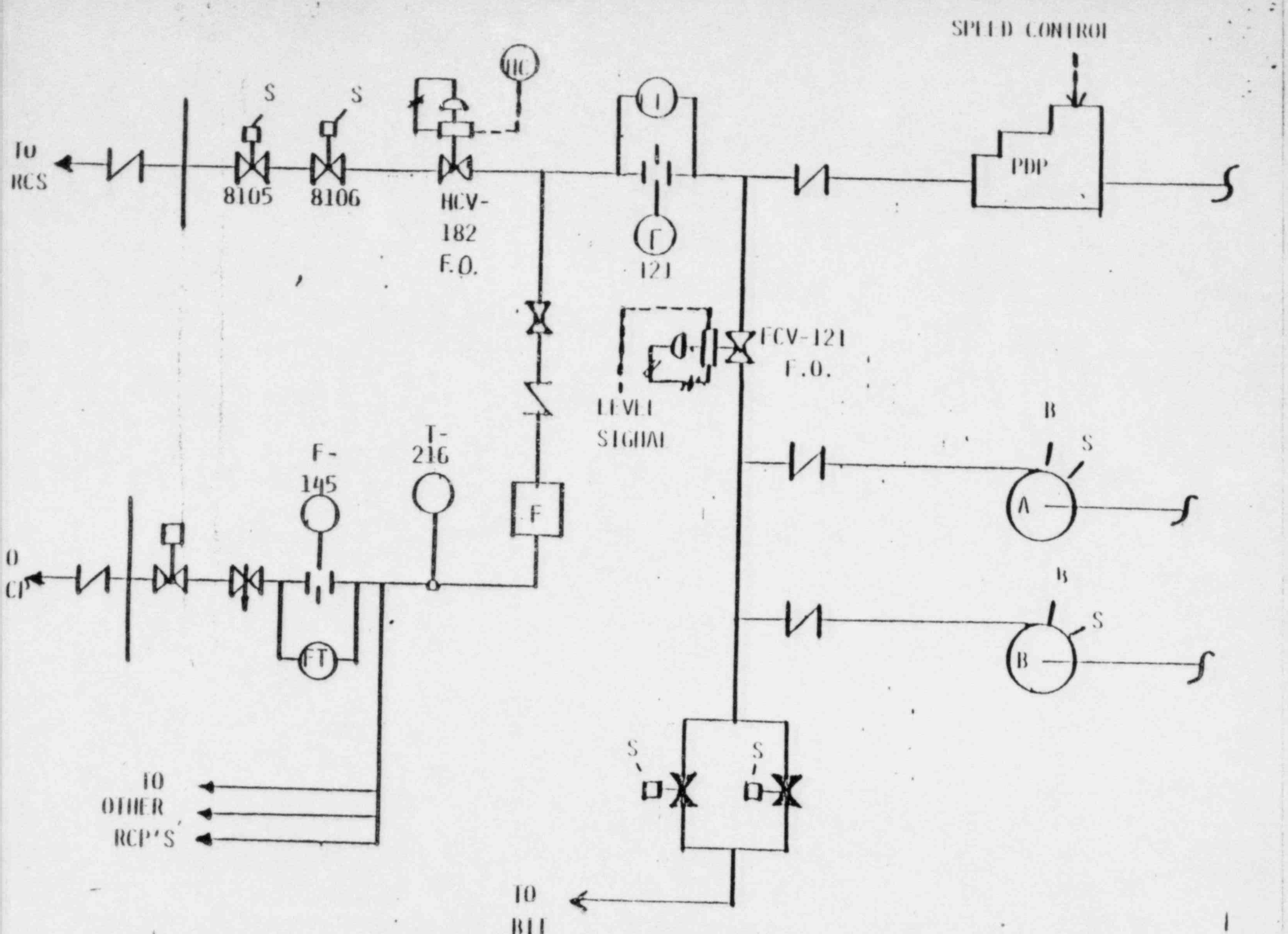
- 3 CENTRIFUGAL PUMPS (3-LOOP PLANTS)

- 3 RECIPROCATING PUMPS (OLDER PLANTS)

- 2 CENTRIFUGAL AND ONE RECIPROCATING (4-LOOP PLANTS)

O SOME PLANTS USE 2 OF THE 3 PUMPS FOR SAFETY INJECTION

O REDUNDANT PUMPS AVAILABLE FOR CHARGING/SEAL INJECTION, OR SAFETY INJECTION


SPEED CONTROL
PDP
TO RCS
S
S
8105
8106
HCV-
182
F.O.
121
FCV-121
F.O.
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S
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F
T-
216
F-
145
FT
TO
OTHER
RCP'S
S
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TO

OPERATING MODES - 4-LOOP CVCS

A. RECIPROCATING PUMP

- O USED FOR NORMAL CHARGING/SEAL INJECTION
- O VARY PUMP SPEED TO CONTROL CHARGING FLOW
- O COMPONENT COOLING WATER USED FOR OIL COOLER IN FLUID DRIVE SPEED CONTROL SYSTEM
- O MANUALLY ACCESSIBLE TO EMERGENCY DIESEL GENERATOR

OPERATING MODES - 4-LOOP CVCS

B. CENTRIFUGAL CHARGING PUMPS

- O TWO PUMPS USED FOR CHARGING, SEAL INJECTION, SAFETY INJECTION

- O TRAIN SEPARATED, SEISMIC, ACTIVE PUMPS

- O FLOW CONTROL VALVE - ADJUSTS CHARGING FLOW

- O COMPONENT COOLING WATER USED FOR LUBE OIL COOLING

- O AUTOMATICALLY ACTUATED BY SAFETY INJECTION/BLACKOUT SIGNALS

- O AUTOMATICALLY LOADED ON EMERGENCY DIESEL GENERATORS

OPERATING MODES - 4-LOOP CVCS

C. SEAL INJECTION FLOW CONTROL

- O LINE RESISTANCE SET BY L.I.P. THROTTLE VALVES DURING STARTUP

- O CHARGING HAND CONTROL VALVE CONTROLS CHARGING/ SEAL INJECTION FLOW SPLIT

SUMMARY OF CHEMICAL AND VOLUME CONTROL SYSTEMS FEATURES

- O REDUNDANCY

- O SAFETY CLASS 2

- O SEISMICALLY QUALIFIED ACTIVE PUMPS

- O EMERGENCY POWER

COMPONENT COOLING WATER SYSTEM
FUNCTIONAL REQUIREMENTS

WESTINGHOUSE
JANUARY 1983

COMPONENT COOLING WATER

- O A SYSTEM PROVIDING A CONTINUOUS SUPPLY OF COOLING WATER TO PLANT COMPONENTS HANDLING POTENTIALLY RADIOACTIVE FLUIDS

- O FORMS AN INTERMEDIATE BARRIER BETWEEN THE ULTIMATE HEAT SINK AND POTENTIALLY RADIOACTIVE SYSTEMS

FUNCTIONS OF COMPONENT COOLING WATER SYSTEMS

1. REMOVAL OF RESIDUAL AND SENSIBLE HEAT FROM THE REACTOR COOLANT SYSTEM THROUGH THE RESIDUAL HEAT SYSTEM

2. COOLING OF SAFEGUARDS EQUIPMENT AND HEAT LOADS FOLLOWING DESIGN BASES EVENTS.

3. HEAT REMOVAL FROM VARIOUS NSSS AND BOP COMPONENTS DURING NORMAL PLANT OPERATIONS

INDUSTRY DESIGN CRITERIA/RECOMMENDATIONS

COMPONENT COOLING WATER SYSTEMS

1. COMPONENT COOLING WATER IS NUCLEAR SAFETY RELATED

2. SAFETY RELATED COMPONENTS MUST HAVE SEISMIC SUPPORT

3. SYSTEMS MUST INCLUDE REDUNDANCY FOR SINGLE FAILURE PROTECTION

4. CCW PUMPS MUST HAVE AUTOMATIC ACCESS TO EMERGENCY POWER SUPPLYS

5. A SAFETY RELATED MAKE-UP SOURCE MUST BE AVAILABLE FOR PASSIVE FAILURE LEAKAGES

6. SUBSYSTEMS WITH PHYSICAL SEPARATION FOR RECIRCULATION SHOULD BE INCLUDED

7. SUFFICIENT REDUNDANCY SHOULD BE INSTALLED FOR ON-LINE MAINTENANCE CAPABILITY

NSSS COMPONENTS TYPICALLY SERVICED BY COMPONENT COOLING

1. REACTOR COOLANT PUMPS

2. RESIDUAL HEAT EXCHANGERS

3. EMERGENCY CORE COOLING SYSTEM PUMPS

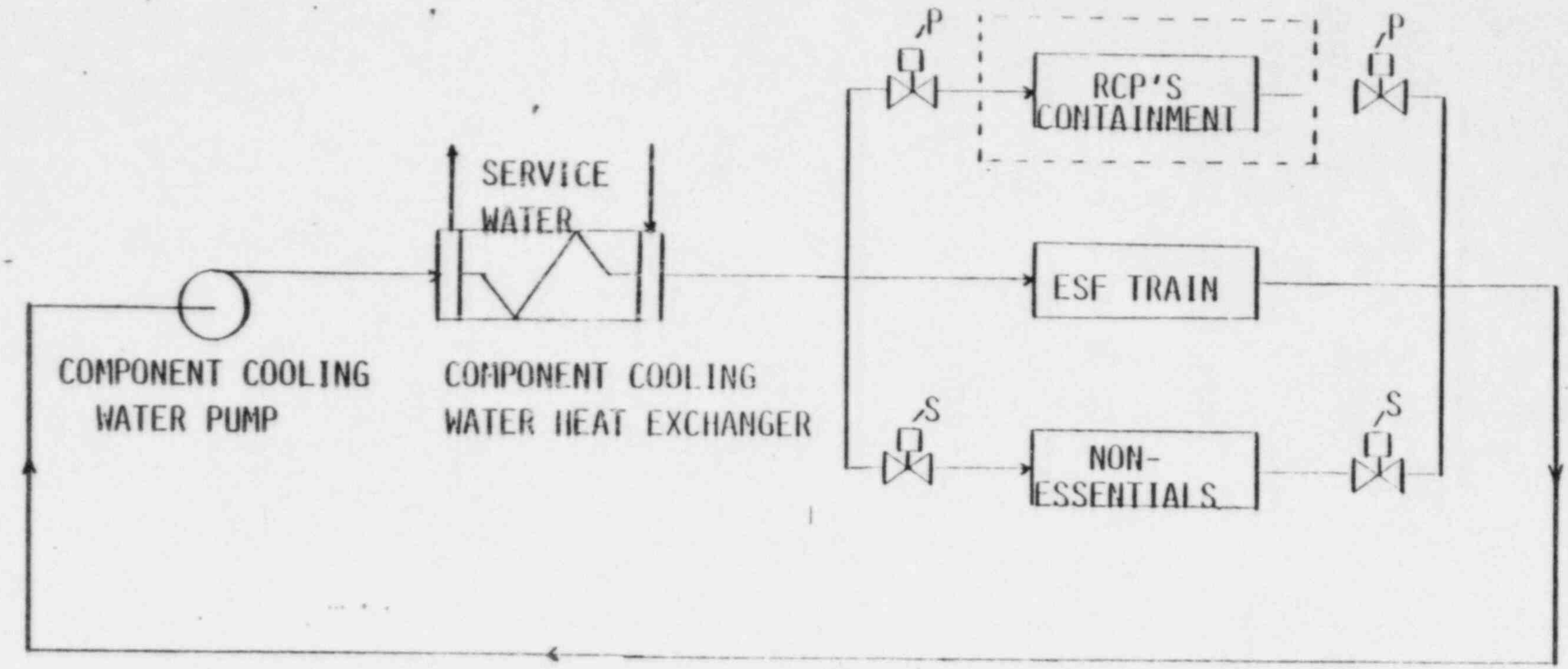
4. CHEMICAL AND VOLUME CONTROL SYSTEM COMPONENTS

5. WASTE DISPOSAL COMPONENTS

6. SPENT FUEL COOLING SYSTEMS

7. CONTAINMENT FAN COOLERS

8. AUXILIARY EQUIPMENT



TYPICAL COMPONENT COOLING WATER SUBSYSTEM

RESPONSIBILITY FOR DESIGN

- COMPONENT COOLING WATER SYSTEMS ARE INCLUDED IN THE OPTIONAL SCOPE FOR WESTINGHOUSE NSSS DESIGNS

- DESIGN CRITERIA AND GUIDELINES ARE PROVIDED TO THE CUSTOMER/AE WHEN THE COMPONENT COOLING WATER DESIGN IS NOT WITHIN THE WESTINGHOUSE SCOPE OF SUPPLY

GENERAL INTERFACE REQUIREMENTS

1. COMPONENT COOLING WATER FUNCTIONS

2. COMPONENT DESIGN REQUIREMENTS

3. SYSTEM DESIGN REQUIREMENTS

4. WATER CHEMISTRY CRITERIA

5. INSTRUMENTATION AND CONTROL REQUIREMENTS

6. EMERGENCY ELECTRICAL POWER SUPPLY

7. HEAT LOAD REQUIREMENTS

COMPONENT COOLING WATER

- O SYSTEM PROVIDES COOLING TO NSSS AND BOP COMPONENTS DURING ALL MODES OF OPERATION

- O SYSTEM DESIGN COMPLIES WITH ALL CRITERIA REQUIRED OF ENGINEERED SAFETY FEATURES

- O RESPONSIBILITY FOR DESIGN HAS TRADITIONALLY BEEN PROVIDED BY BOTH WESTINGHOUSE AND THE CUSTOMER/AE

- O GENERAL INTERFACE REQUIREMENTS ARE PROVIDED WHEN DESIGN IS WITHIN THE CUSTOMER/AE SCOPE

4. SEAL PERFORMANCE AND EXPERIENCE

WEMD

D. W. SALAK

CONTROLLED LEAKAGE SEAL REACTOR COOLANT PUMP ACCUMULATED EXPERIENCE

- Over 5 million operating hours
- Over 131 pumps in commercial operation
- Over 43 plants in commercial operation with Westinghouse reactor coolant pumps
- First commercial operation in 1968

REACTOR COOLANT PUMP MODELS

WESTINGHOUSE REACTOR COOLANT SHAFT SEAL PUMPS

CURRENTLY IN OPERATION OR ON ORDER

MODEL NUMBER	NUMBER OF UNITS	APPROXIMATE FLOW (GPM)	INITIAL MODEL STARTUP DATE
63	9	63,000	1967
70	5	70,000	1968
93	23	90,000	1969
93A	150	100,000	1971
93D	27	95,000	1974
93A-1	62	100,000	1984
100	17	106,000	1980
TOTAL	293		

EVENT

- LOSS OF A/C POWER
- SEAL INJECTION AND CCW LOST
- RCP STATIC
- RCS AT FULL TEMPERATURE AND PRESSURE

LOSS OF SEAL SUPPORT HISTORY

EVENT	DATE	TIME (MIN.)	PUMPS	PUMP (MIN.)
A	4/27/68	10	4	40
B	5/17/69	30	2	60
C	7/15/69	2	4	8
D	1/28/71	65	2	130
D	1/28/71	45	2	90
E	3/14/71	SEVERAL	3	9
F	9/1/77	8	4	32
G	1/12/82	>9	3	27
			24	396

LOSS OF SEAL SUPPORT HISTORY SUMMARY

- 3 INSTANCES WITH CORE LOADED
- TOTAL OF 57 PUMP-MINUTES WITH CORE LOADED
- NO INSTANCES AFTER 1971 WITH CORE LOADED
- 4 PUMPS WERE OPERATED AFTER INCIDENT
- NO. 1 SEALS REUSED AT 4 SITES (OTHER SITES, NO RECORD)
- NO. 2 SEALS ALL REUSED AT 4 SITES EXCEPT WARPED RUNNER ON ONE PUMP, HEAT CHECKED RUNNER ON ONE PUMP (OTHER SITES, NO RECORD)
- NO. 3 SEALS HAD NO DAMAGE REPORTED

O-RING EXPERIENCE DURING VALVE TESTS

. Seal 29-Inch End Plugs

. 4 Tests (2 End Plugs on 2 Valves)

. 10 hours/550°F./2250 psi)

. Same Material (80 IRHD Ethylene Propylene)

. Extrusion Gaps Larger Than Those for Seals

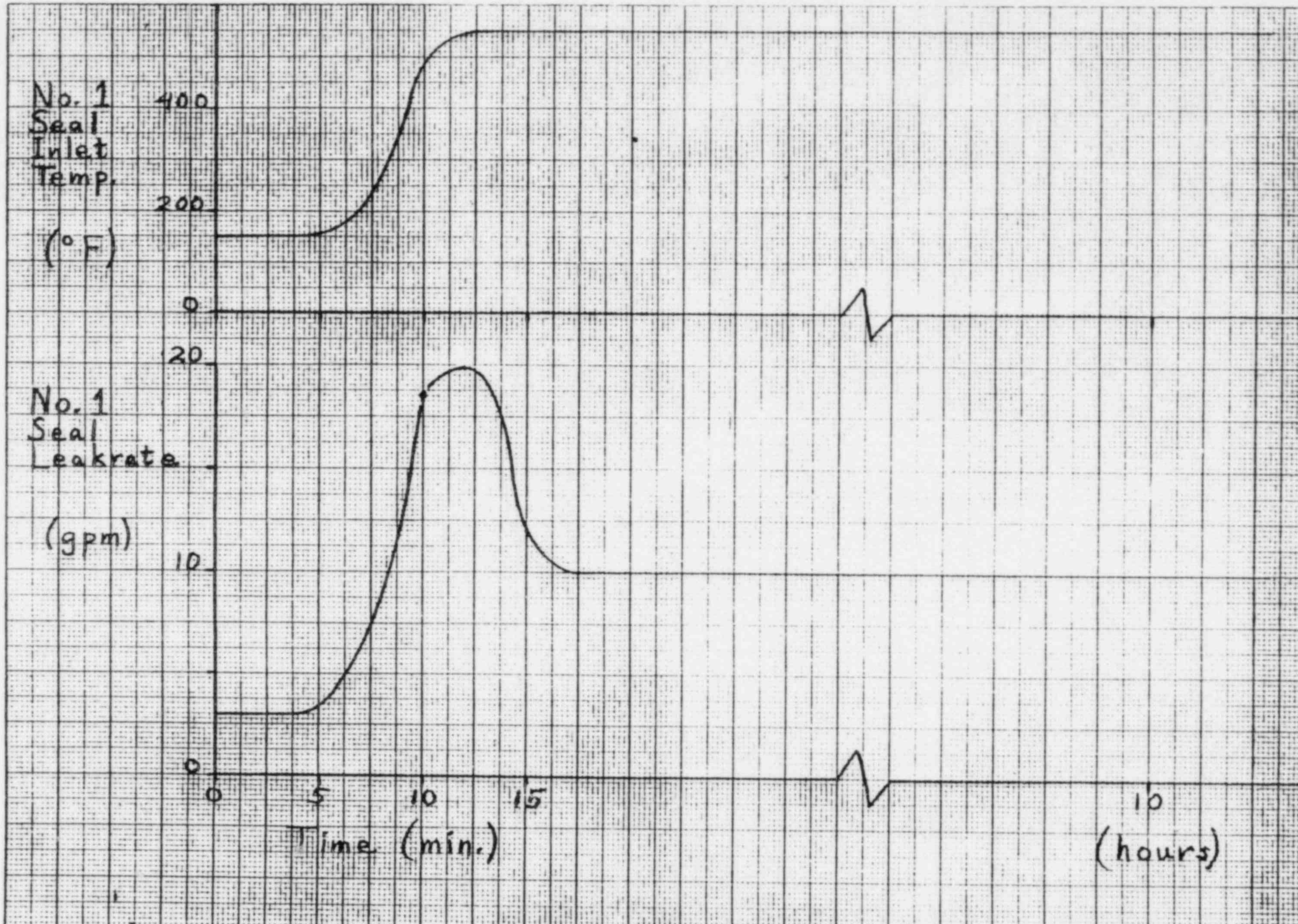
. No O-Ring Blowouts

. No Major Extrusion (Feathered Edge Only)

UPSET MODE FACTORS AFFECTING SEAL LEAKAGE

FACTOR	EFFECT ON LEAKAGE	COMMENT
VISCOSITY	INCREASE	RELATED TO SEAL WATER TEMPERATURE
TURBULENCE	INCREASE	RELATED TO SEAL WATER TEMPERATURE
THERMAL GRADIENT	INCREASE	SHORT-TERM CONDITION
TWO-PHASE FLOW BETWEEN FACEPLATES	DECREASE	OCCURS ABOVE 365°F

Expected Seal Responce to Upset Mode Factors



RCP SEAL CONSIDERATIONS

O-RINGS

- EXTRUSION
- MATERIAL PROPERTIES AT HIGH TEMPERATURE

FLUID FLOW AT HIGH TEMPERATURE

- VISCOSITY
- REYNOLDS' NUMBER

THERMAL GRADIENTS

- FACEPLATE TAPERS
- CLEARANCES/INTERFERENCE
- AXIAL SHAFT EXPANSION
- GRAPHITAR SHRINK FITS

CRUD EFFECTS

- BLOCK NO. 1 SEAL
- SEAL RING AXIAL MOTION

#1 LEAK-OFF LINE PRESSURE

- RELIEF VALVE OPERATION AT 150 PSIG
- 2-PHASE FLOW AT NO. 2 SEAL

HIGH PRESSURE - HIGH TEMPERATURE PARAMETRIC SURVIVAL TEST

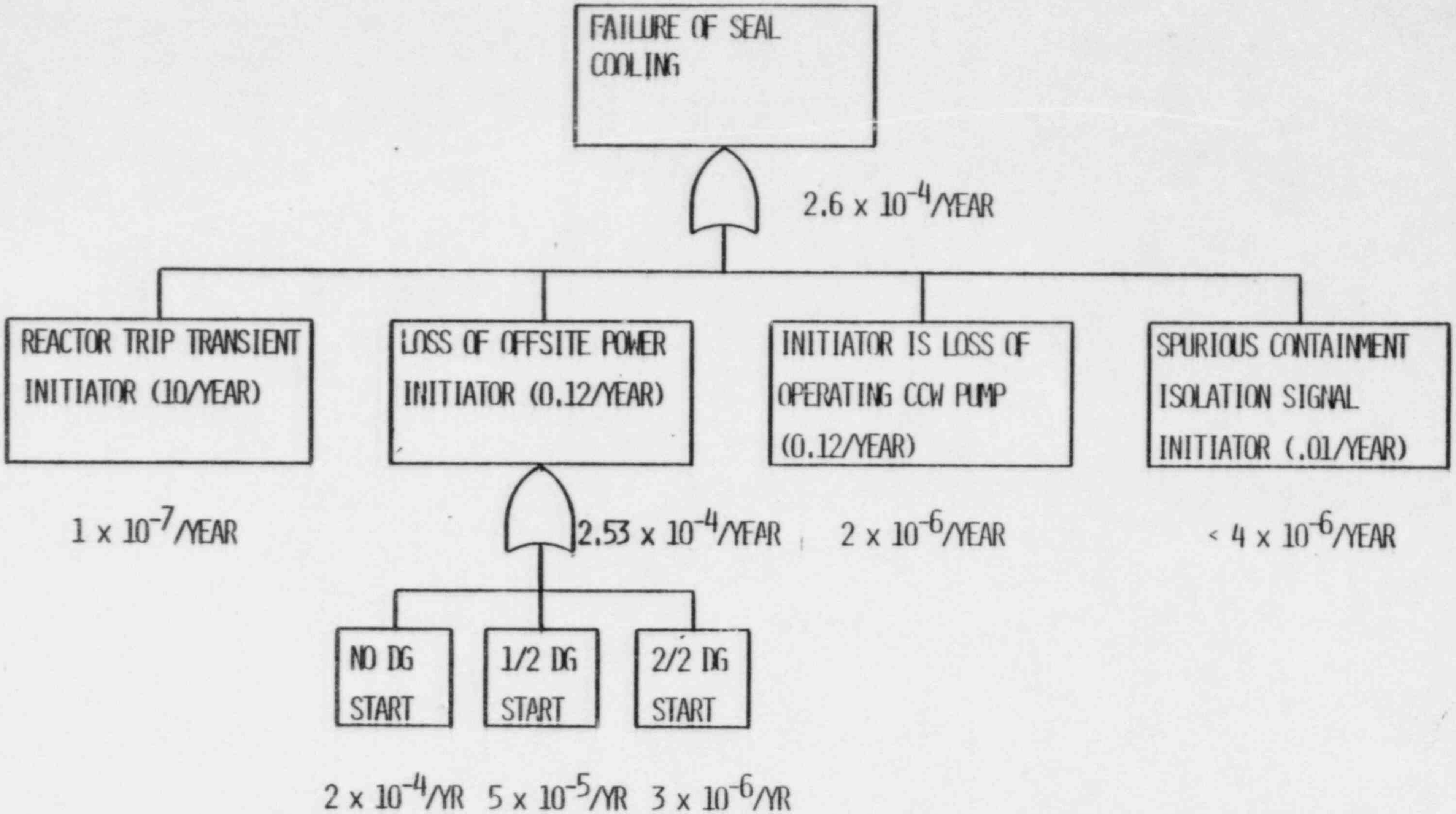
- 2250 PSIG @ 550°F
- 10-HOUR DURATION
- ETHYLENE PROPYLENE SEALS
- TEFLON SEALS
- EXTRUSION GAPS WITHIN DESIGN RANGE
- EXTRUSION GAPS EXCEEDING DESIGN RANGE
- QUANTIFY DEGREE OF PARTIAL EXTRUSION
- DETERMINE CRITICAL EXTRUSION GAP FOR LOSS OF SEAL
- MEASURE BEFORE AND AFTER ELASTOMER HARDNESS
- PERFORM ON FULL SCALE TEST FACILITY

SUMMARY

- With over 300 million pump-minutes of operating experience, only 396 pump-minutes were accumulated with loss of both seal injection and CCW.
  - 339 pump-minutes before core was loaded
  - Longest event was 65 minutes
  - No damage to No. 1 seals
  - O-ring survival for 10 hours in valve tests
- Expected seal leakrate during loss of both seal injection and CCW is less than 20 gpm/RCP.
  - Based on O-ring functional survival
  - Based on experience
  - Based on analysis
- High pressure-high temperature parametric survival test will determine O-ring functional survivability for various durations and extrusion gaps.
  - Confirmatory test
  - Extrusion gaps beyond design range
  - Comparison of elastomer properties before and after tests
  - Quantification of extrusion and related leakrate

SYSTEMS RELIABILITY

- SEQUENCES LEADING TO LOSS OF SEAL COOLING
- SEAL LEAK PROBABILITIES WITH TIME
- PROBABILITY OF SEAL LEAKS AND CORE UNCOVERY IN LOSS OF ALL AC SEQUENCES



98% OF RCP SEAL COOLING FAILURE IS ATTRIBUTED TO LOSP INITIATOR

EXPERIENCE WITH 80 DUROMETER O-RINGS AT P AND T

ON RCP DURING PLANT INCIDENTS

8 INCIDENTS VARYING FROM 2 MINUTES TO 65 MINUTES WITHOUT SEAL COOLING — GIVE 396 PUMP MIN. (6.6 PUMP HRS.)
— GIVE 66 O-RING HRS. SINCE 10 O-RINGS/PUMP

MAINLOOP STOP VALVE TESTS

2 MAINLOOP STOP VALVES EACH WITH 2 SEALS WITH 3 O-RINGS EACH WERE TESTED AT 2250 PSIG, 550°F FOR 10 HOURS GIVES 120 O-RING HOURS. ALTHOUGH THESE O-RINGS HAVE ~ 3 x DIAMETER (PERIMETER) OF RCP O-RINGS, SINCE 3 O-RINGS ACTED IN SERIES, THIS IS CONSIDERED A TRADEOFF.

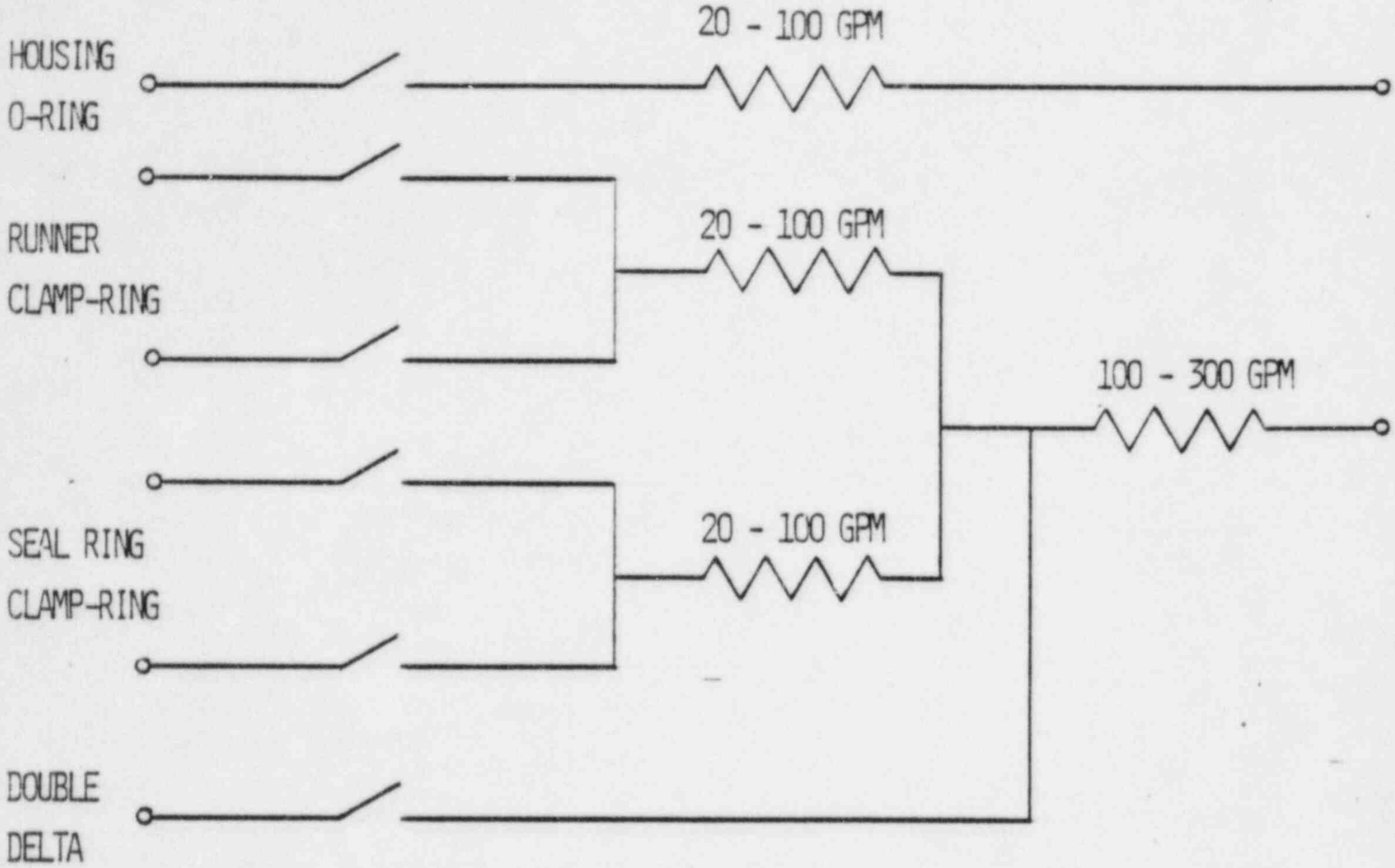
O-RING FAILURE RATE AT P AND T

186 O-RING HOURS WITHOUT COOLING - NO FAILURES

$\lambda_{50} = 3.74 \times 10^{-3}$/O-RING HR.

$\lambda_{95} = 1.6 \times 10^{-2}$/O-RING HR.

SIGNIFICANT SEAL LEAK PATHS



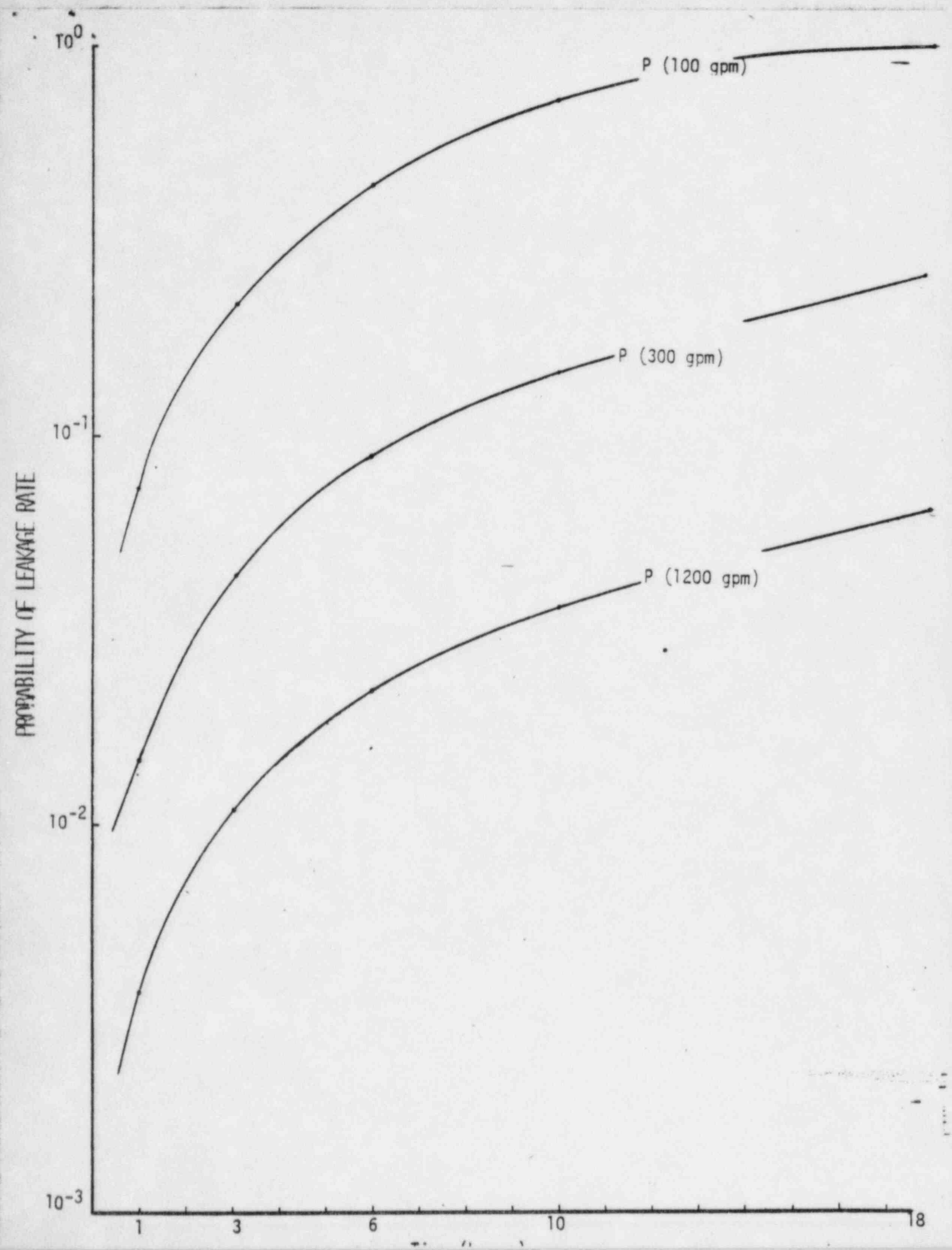
LET $P = \lambda T$ = PROB. OF AN O-RING FAILING IN TIME T

LEAK RATE FOR ONE RCP	PROB EXPRESSION	1 HR	3 HR	6 HR	10 HR
0 GPM	1 - 6 P	.978	.934	.868	.778
100	5P	1.85×10^{-2}	5.5×10^{-2}	1.1×10^{-1}	1.85×10^{-1}
200	$8P^2$		NEGLIGIBLE		
300	P	3.7×10^{-3}	1.1×10^{-2}	2.2×10^{-2}	3.7×10^{-2}.
400	P^2		NEGLIGIBLE		

FOUR PUMP LEAKS

LEAK RATE	PROB.	1 HR	3 HR	6 HR	10 HR
0	1 - 25P	.9085	.725	.45	.075
100	20P	7.4×10^{-2}	2.2×10^{-1}	4.4×10^{-1}	7.4×10^{-1}
300	4P	1.48×10^{-2}	4.4×10^{-2}	8.8×10^{-2}	1.48×10^{-1}
1200	P*	3.7×10^{-3}	1.1×10^{-2}	2.2×10^{-2}	3.7×10^{-2}

* ASSUMED COMPLETE COUPLING ACROSS PUMPS FOR 1200 GPM CASE.



PROBABILITY OF LEAKAGE RATE
P (100 gpm)
P (300 gpm)
P (1200 gpm)
10^0
10^{-1}
10^{-2}
10^{-3}
1
3
6
10
18

LOSS OF OFFSITE POWER

FREQUENCY = 0.122/YEAR (EPRI NP-2301)

TIME AT END OF INTERVAL	PROB. RESTORED IN INTERVAL	PROB. NOT RESTORED BY T
1/2 HR.	.48	.52
1	.14	.38
2	.1	.28
4	.05	.23
8	.14	.09
24	.05	.05
>24	.05	

DIESEL GENERATOR FAILURE

ATWOOD-STEVERSON MODEL NUREG/CR-2099

$$P = (\lambda T)^2 + R_2 T$$

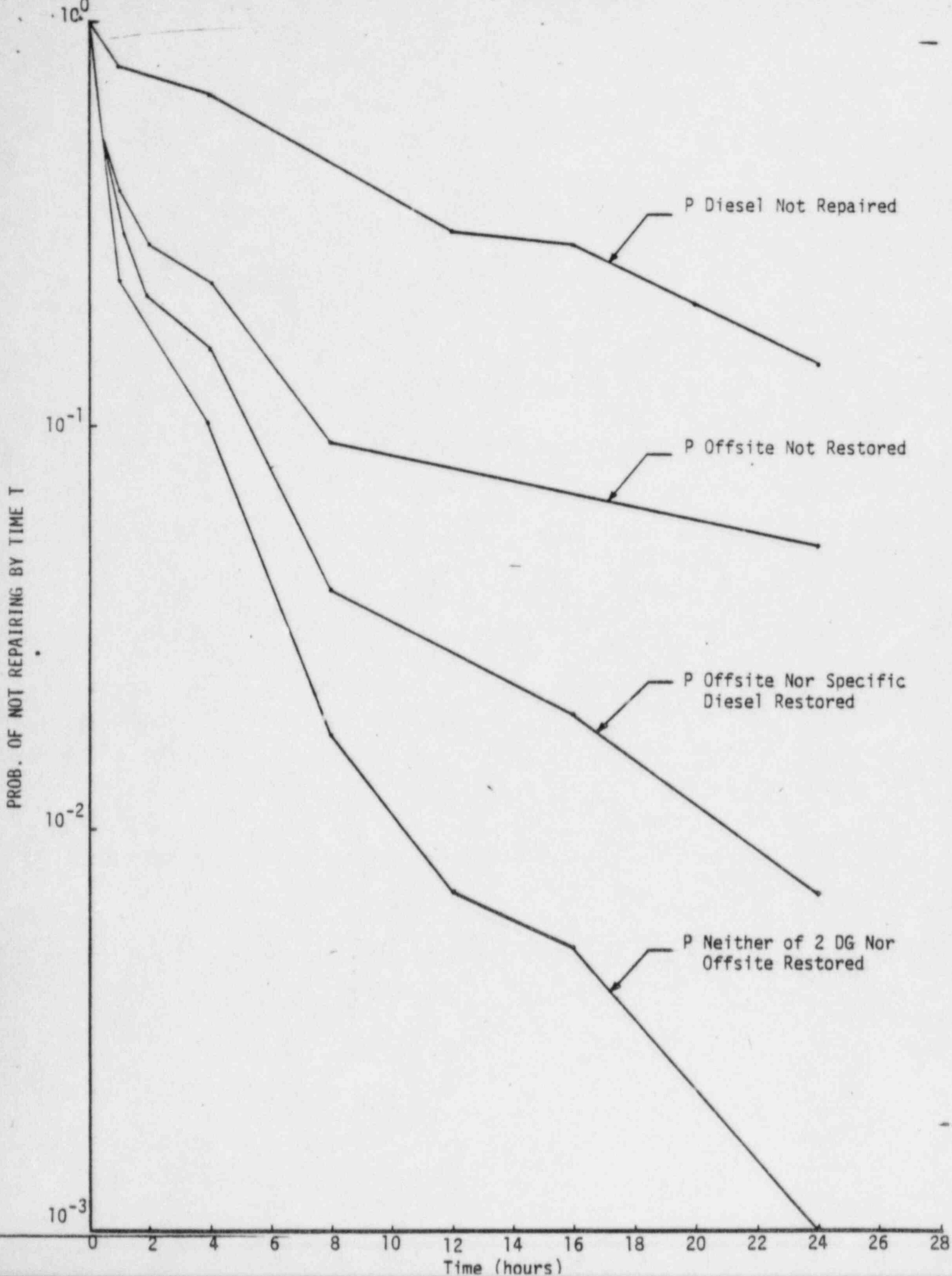
$$\left.\begin{aligned} \lambda &= 7.5 \times 10^{-5}/\text{HR.} \\ R_2 &= 2 \times 10^{-6}/\text{HR.} \end{aligned}\right\} \text{TABLE 2}$$

$$\bar{P} = 1/3(\lambda T)^2 + 1/2 R_2 T$$

T	P
180 HOURS	2.4×10^{-4}
360 HOURS	6.03×10^{-4}
720 HOURS	$\boxed{1.7 \times 10^{-3}}$

DIESEL GENERATOR REPAIR EPRI NP-2433

TIME	PR REPAIRED IN INTERVAL	PR NOT REPAIRED BY TMAX
0 - 1 HOUR	.23	.77
1 - 4	.11	.66
4 - 8	.23	.43
8 - 12	.13	.30
12 - 16	.02	.28
16 - 20	.08	.20
20 - 24	.06	.14
>24	.15	



10^0
10^{-1}
10^{-2}
10^{-3}
PROB. OF NOT REPAIRING BY TIME T
P Diesel Not Repaired
P Offsite Not Restored
P Offsite Nor Specific Diesel Restored
P Neither of 2 DG Nor Offsite Restored
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Time (hours)

CHANCE OF LEAK TYPE

$$P_L = \int_0^T (\lambda e^{-\lambda T} dT)\,(P_{NR}(T))$$

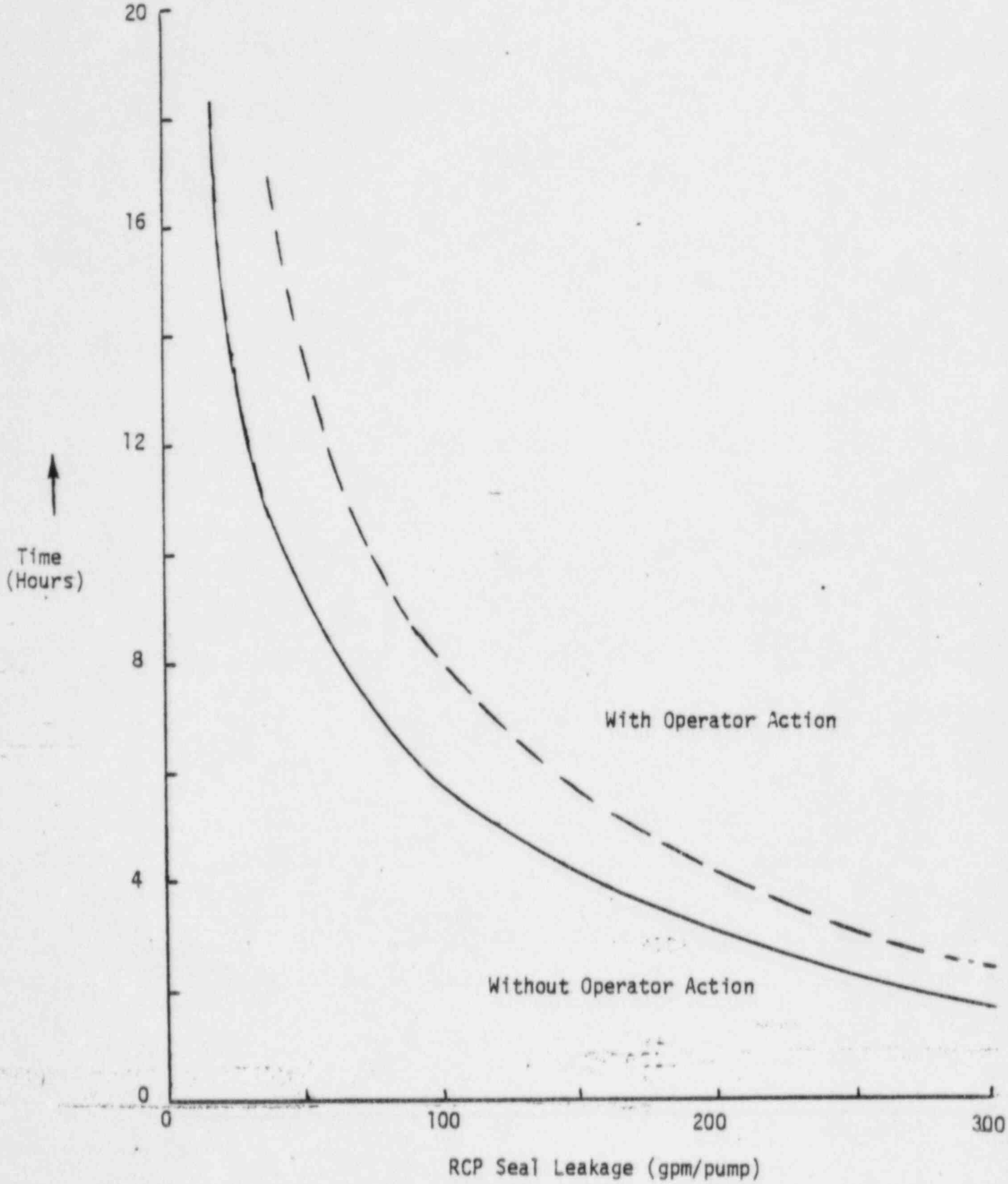
$$\cong \lambda \int_0^{24} P_{NR}(T)\, dT = 2.32\lambda$$

WHERE $P_{NR}(T)$ BASED ON OFFSITE POWER OR SINGLE DG RESTORATION

$\therefore$ $P_{100GPM} = 0.17$

$P_{300GPM} = 0.034$

$P_{1200GPM} = 0.0085$



Estimated Time to Core Uncovery Following Loss of All AC Power

CHANCE CORE UNCOVERY AS

RESULT OF SEAL LEAKS

LEAK RATE	P_{LR}	T = TIME TO UNCOVER CORE TOP	$P_{NR}(T)$	P (UNCOVERY) = $P_{LR} \times P_{NR}$
60 GPM	.788	18.5	1.25×10^{-2}	9.8×10^{-3}
100	.17	14.0	2.3×10^{-2}	3.9×10^{-3}
300	.034	7.0	5.2×10^{-2}	1.8×10^{-3}
1200	.0085	2.0	.21	1.8×10^{-3}
			TOTAL	1.7×10^{-2}

FREQ. CORE UNCOVERY = F(ALL AC) X $P_{UNCOVERY}$

$= 2.1 \times 10^{-4} \times 1.7 \times 10^{-2} = 3.5 \times 10^{-6}$/YR.

INITIATING EVENTS LEADING TO A LOSS OF SEAL COOLING

1. LOSS OF OPERATING COMPONENT COOLING WATER PUMP
   FREQUENCY = 1.2×10^{-1}/YEAR

2. SPURIOUS HIGH-HIGH CONTAINMENT PRESSURE SIGNAL
   FREQUENCY = 5.0×10^{-3}/YEAR

3. NON-LOSS OF OFFSITE POWER TRANSIENTS
   FREQUENCY = 1.0×10^{1}/YEAR

4. LOSS OF OFFSITE AC POWER, FOUR POWER STATES ANALYZED:
   FREQUENCY = 1.2×10^{-1}/YEAR

   A. LOSS OF ALL AC POWER, FREQUENCY = 2.1×10^{-4}/YEAR

   B. LOSS OF ONE (EITHER) TRAIN DIESEL GENERATOR, FREQUENCY = 8.4×10^{-3}/YEAR

   C. LOSS OF NEITHER DIESEL GENERATOR SET, FREQUENCY = 1.1×10^{-1}/YEAR

LOSS OF OPERATING COMPONENT COOLING WATER PUMP

- BACK-UP AUTO-START PUMP IN SAME TRAIN:

  PROBABILITY OF FAILURE TO START = 3×10^{-3}
  PROBABILITY OF PUMP IN MAINTENANCE = 2×10^{-3}

- OPERATOR CAN ALIGN REDUNDANT CCW TRAIN:

  PROBABILITY OF OPERATOR FAILURE = 1×10^{-3}
  SINGLE VALVE FAULTS = 2×10^{-3}

  INDICATIONS AVAILABLE:

  - FLOW ALARMS, CCW
  - PRESSURE ALARMS, CCW
  - POSITION LIGHTS, CCW
  - TEMPERATURE ALARMS, REACTOR COOLANT PUMPS
  - COMPUTER MONITORED INTERLOCKS

- FREQUENCY OF LOSS OF SEAL COOLING IS 2×10^{-6}

SPURIOUS CIS-B SIGNAL

- CENTRIFUGAL CHARGING PUMPS START, AVAILABLE IF POSITIVE DISPLACEMENT PUMP FAILS, NO INTERRUPTION OF SEAL INJECTION FLOW. (4.5×10^{-4}/DEMAND)

- OPERATOR HAS CAPABILITY TO BYPASS CIS-B AND ALIGN CCW TO THERMAL BARRIER COOLERS.

- FREQUENCY OF LOSS OF SEAL COOLING IS 4.5×10^{-6}/YEAR.

NON-LOSS OF OFFSITE POWER TRANSIENTS

- BOTH COMPONENT COOLING WATER AND CHARGING SYSTEMS OPERATE IN NORMAL MODE. NO EXCESSIVE DEMANDS ON SYSTEMS.

- FREQUENCY OF LOSS OF SEAL COOLING IS 1.2×10^{-7}.

OPERATING CCW PUMP MUST FAIL	1.2×10^{-4}
BACKUP CCW PUMP FAIL TO AUTO-START	6×10^{-3}
ALTERNATE TRAIN NOT STARTED BY OPERATOR	3.1×10^{-3}

LOSS OF OFFSITE AC POWER

- LOSS OF ALL AC POWER - SYSTEMS UNAVAILABILITY DETERMINED BY POWER RECOVERY

- LOSS OF ONE TRAIN DIESEL GENERATOR - LOSS OF SEAL COOLING DOMINATED BY FAILURE OF ESSENTIAL SERVICE WATER PUMP, OR FAILURE OF POWERED COMPONENT COOLING WATER PUMP TRAIN

  PROBABILITY OF FAILURE TO START = 3×10^{-3}
  PROBABILITY OF PUMP(S) IN MAINTENANCE = 2.0×10^{-3}

- LOSS OF NEITHER DIESEL GENERATOR - ALL SYSTEMS AVAILABLE, CCW PUMPS AUTO-START ON LOOP.