ATTACHMENT 3

Question:

It is the NRC's position that Reactor Coolant Pump Seals will not last any longer than two hours with no seal cooling.

Response:

In the technical review of a Probabilistic Safety Study it is inappropriate to reach technical conclusions based on regulatory positions.

Northeast Utilities has utilized a methodology to assess RCP seal leak rates and their time of occurrence based on current state of the art knowledge (field experience and limited test data) developed as part of an ongoing Westinghouse Owner's Group effort on seal performance.

Attachment 1 is a proprietary copy of the calculations of RCP seal leak rates vs. time used in the Millstone -3 P.S.S.

ATTACHMENT 1

Designation of Code Letters and the criteria they represent in determining information to be proprietary

a. The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

b. It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

c. Its use by a competitor would reduce his expenditures of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

d. It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

e. It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

f. It contains patentable ideas, for which patent protection may be desirable.

g. It is not the property of Westinghouse, but must be treated as proprietary by Westinghouse according to agreements with the owner.

CALCULATION OF TIME TO CORE UNCOVERY FOR LOSS OF ALL AC POWER EVENT

1. PURPOSE

The purpose of this letter report is to document analysis performed as part of Section 3 of the Millstone Probabilistic Risk Assessment Analysis.

2. SUMMARY OF RESULTS

The analysis presented in the following sections indicates that for a loss of all AC power event in which turbine driven auxiliary feedwater is available, the time until core uncovery resulting from pump seal leakage is in excess of 6 hours. This result is based in large part upon analysis of pump seal behavior presented in Reference 1.

3. ACCIDENT SCENARIO DESCRIPTION

The immediate consequences of a loss of all AC power event, (LOAP), if not accompanied by additional complicating events such as a loss of secondary heat sink, are not severe. The degree of severity, of a LOAP event depends primarily on the duration of the power outage and the response of the reactor coolant pump (RCP) shaft seals to the simultaneous loss of high pressure injection flow to the RCP seals and of component cooling water flow to the RCP thermal barrier. Loss of high pressure seal injection flow from the charging/SI pumps results in out leakage from the reactor coolant system along the RCP shafts. Without power, this leakage cannot be replaced and a continuous loss of RCS coolant occurs with time.

The Millstone Unit 3 RCPs are designed to accommodate the temporary loss of seal injection flow and component cooling water that accompanies a loss of offsite power. This is accomplished by the volume of cool water in the seal area and the time that it takes to leak this water through the RCP seals prior to hot water entering the seal areas. Under best estimate conditions, the RCP design should preclude hot water from entering the seal area for several minutes.

Under the LOAP event, RCP support systems may not be restored prior to the introduction of hot coolant into the seal system. Under this condition the RCP leak rate becomes dependent on RCS temperature as well as RCS pressure. At temperatures in excess of 300°F, RCP seal system sealing capability and sealing life may start to degrade with a consequential increase in seal leakage flow.

Seal performance under high temperature conditions is difficult to analyze due to several interacting considerations. An April 1983 review of RCP seal performance under these conditions conducted by Westinghouse EMD (Ref. 1) suggests an increase in seal leak rate from the nominal 3 gpm/pump at 2235 psig to 15-20 gpm/pump @ 2235 psig due to thermal gradient distortion effects and decreased viscosity from increased temperatures. This review further states that although some softening of the No. 1 seal O-ring is expected, in most cases no O-ring extrusion is expected. In the case that O-ring extrusion might occur, it would not be immediate and lead to an immediate massive leakage.

4. PUMP SEAL EXPERIENCE

The experience data base of RCP pump seals at high pressure and temperature is summarized in Ref. 1. This experience includes 8 incidents at operating nuclear plants in which seal cooling was lost to the seals for times ranging from 2 minutes to 65 minutes. These incidents give 396 pump-minutes or 6.6 pump-hours without seal (O-ring) failure. Since there are 10 O-rings per pump (Ref. 1), this gives 66 O-ring hours of experience without failure. In addition to the pump O-ring experience, Ref. 1 identifies non-pump experience with ethylene propylene O-rings in the temperature range of interest. Two mainloop stop valves, each with two seals (each seal with 3 O-rings) were tested at 550°F and held at 2250 psi for 10 hours without failure, O-ring extrusion, or elastomer hardening. This gives 120 O-ring hours without failure. Including the mainloop stop valve O-ring experience gives a total of 186 O-ring hours without cooling and without failure.

The total of this data, 186 O-ring hours without cooling and no failures, was used in a Chi-Squared test to find probabilities of O-ring failure for 50 percent and 95 percent confidence levels:

$\lambda_{50} = 3.74 \times 10^{-3}$/O-ring hr.
$\lambda_{95} = 1.6 \times 10^{-2}$/O-ring hr.

Each Millstone RCP (Model 93A) has 10 O-rings with 4 of these 10 providing only negligible leakage paths upon failure. The remaining 6 O-ring seals upon failure can allow leakage of 20 to 300 gpm at 2235 psig. A representation of these 6 seal leakage paths from Ref. 1 is given in Figure 1. A maximum RCP leakage rate of 300 gpm at 2235 psig is given by Ref. 1 as an upper bound. As seen in Figure 1, the leakage resulting from certain seal failure is limited by downstream resistances.

To simplify the calculation of the magnitude of leakage resulting from seal failures, the coupling effect of downstream resistances can be ignored as shown in Figure 2. This artificial decoupling of leakage paths has the effect of overestimating maximum leakage for multiple seal failures but in addition allows leakage due to individual O-ring failures to be calculated independent of other O-ring failure. An additional simplifying assumption which will be made is that upon O-ring failure, the leakage resulting from the failure is the maximum potential leakage of 100 or 300 gpm as shown in Figure 2. A 60 gpm (15 gpm/pump @ 2235 psig) nominal leakage is assumed to be present regardless of additional leakage.

The probability of having at time t, a leakage path of magnitude W (gpm) can be expressed as Pw, where Pw is calculated by summing the probabilities of the possible combinations of failures which would result in a maximum leakage of W gpm. For a four pump system, these probabilities can be expressed by a binomial distribution (Ref. 4) to be:

$$P_{x,y}(t) = \frac{20!(1-e^{-\lambda t})^{x}(e^{-\lambda t})^{(20-x)}}{X!(20-x)!} \cdot \frac{4!(1-e^{-\lambda t})^{y}(e^{-\lambda t})^{4-y}}{Y!(4-Y)!} \quad (1)$$

where $P_{x,y}(t)$ = probability of X 100 gpm leakage paths and Y 300 gpm leakage paths existing at time t,

λ = RCP O-ring failure rate,

given 20 initial 100 gpm paths and 4 300 gpm paths.

Thus for leakage rate of 60, 160, 260, and 360 gpm, the associated probabilities are:

$$P_{60} = P_{0,0}$$
$$P_{160} = P_{1,0}$$
$$P_{260} = P_{2,0}$$
$$P_{360} = P_{3,0} + P_{0,1}$$

Using equation 1 with λ = 3.74E-3/O-ring hr., a maximum leakage rate, W_{max}, was determined as a function of time for which P_{max} at time t is greater than 98%, where $P_{max}(t)$ is the cumulative probability of leakage of size W_{max} or less existing at time t. The resulting values of W_{max} and P_{max} as a function of time are given in Table 1.

5. TRANSIENT ANALYSIS

To estimate the time to core uncovery following a LOAP event, use was made of LOFTRAN (Ref. 2) computer calculations. These calculations, which are discussed in Reference 3, were performed for a four loop, 3411 MW_{th} Westinghouse plant. A number of analyses were performed, assuming initial pump seal leakage rates of 5, 50, and 300 gpm/pump in all 4 pumps; with and without operator initiated cooldown of the steam generators. Figure 3 (Ref. 3) shows the time to core uncovery as a function of initial leakage rate. For the smaller leakage rates, the LOFTRAN calculations were terminated prior to core uncovery and the time to core uncovery was estimated by assuming a constant leakage rate after problem termination.

6. DETERMINATION OF TIME TO CORE UNCOVERY

To determine the time to core uncovery for a system in which the leakage size is not constant, average inventory loss rates were determined as a function of leakage size. Table 2 gives these results as a function of leakage size in terms of fraction of core inventory above the core which is lost on average per hour.

Combining the results from Table 1 and Table 2, a cumulative fraction of core inventory above the core which is lost to time t ($F_{cum}(t)$) was determined at one half hour increments. During the time interval between t-.5 to t, a leakage rate of $W_{max}(t)$ was used. These calculations show that F_{cum} becomes 1.0 in the time interval between 6 and 6.5 hours.

7. CONCLUSION

Based on the methodology shown above, it was established that the time for which the probability of core uncovery occurring prior to that time is less than 2 percent is 6.0 hours. This result was used in the degraded core cooling recovery analysis in Section 3 of the Millstone PRA.

8. REFERENCES

1. Reactor Coolant Pump Seal Performance, Westinghouse Electric Corporation, April 1983.

2. WCAP 7878 Rev. 3, LOFTRAN Code Description, L. A. Campbell, January 1977, Proprietary Class 2.

3. Westinghouse Emergency Response Guidelines, ECA-2," Loss of All AC Power," Basic Revision, September 1, 1981.

4. "Probability and Statistics," Morris H. DeGroot, Section 5.2.

TABLE 1

Leakage Size (W_{max}) for which the probability of seal leakage being less than or equal to W_{max} (P_{max}) is greater than 98 percent.

Time (Hrs)	W_{max} (gpm @ 2235 psig)	P_{max}

(a,c)

TABLE 2

TIME TO CORE UNCOVERY AND AVERAGE INVENTORY LOSS RATE AS A : FUNCTION OF LEAKAGE SIZE

Leakage Size (gpm @ 2235 psig)	Time to Core Uncovery (Hrs)	Fraction of Inventory above Core Lost/Hr
[		] (a,c)

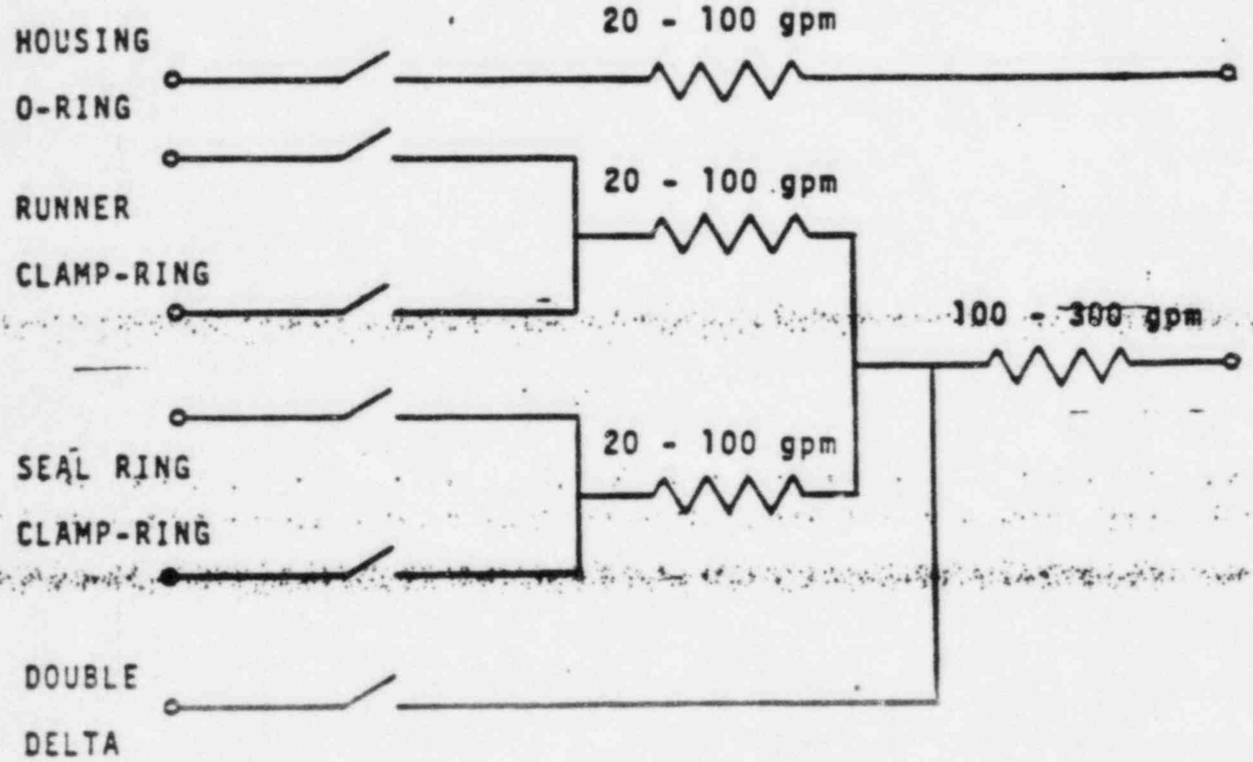

FIGURE 1 SCHEMATIC OF SIGNIFICANT SEAL LEAK PATHS PER PUMP (REF. 1)

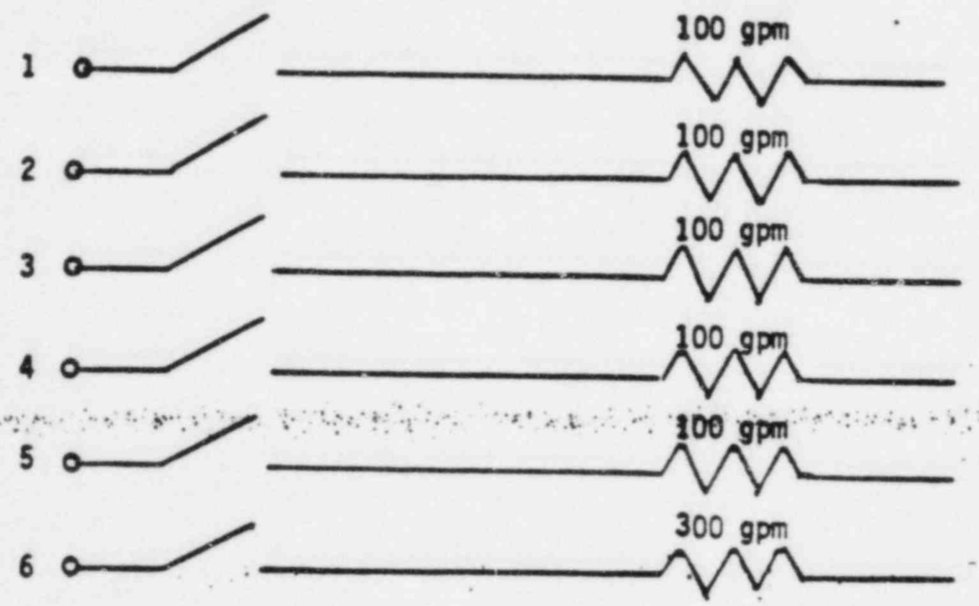

FIGURE 2 SIMPLIFIED SCHEMATIC OF SIGNIFICANT SEAL LEAK PATHS PER PUMP

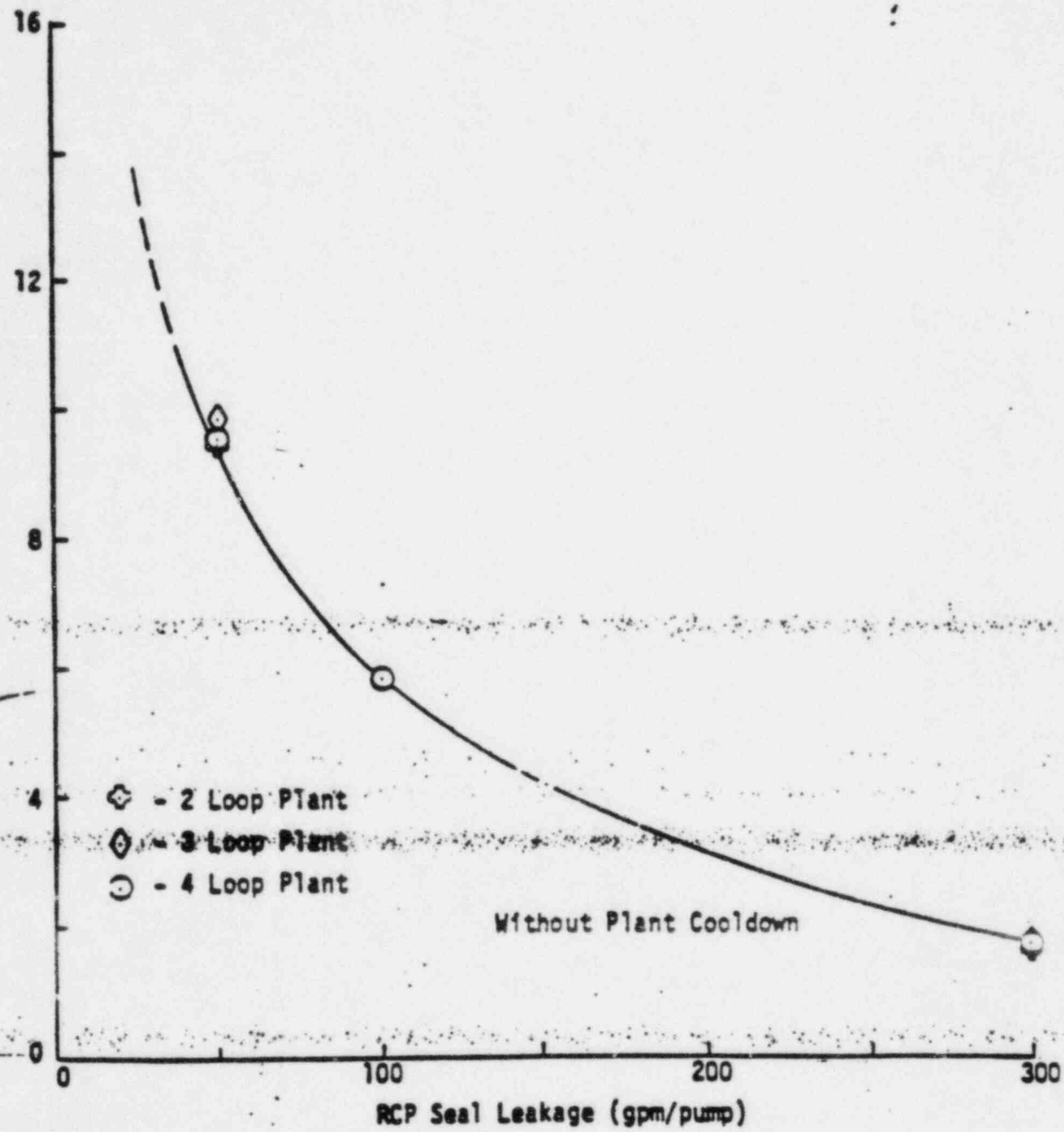

Figure 3 Estimated* Time to Core Uncovery Following Loss of All AC Power (Ref. 3)

*Estimates based on leak rates and total mass loss at approximately 2 hours.

ENCLOSURE

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