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August 1,2001

MEMORANDUM TO: Stephen Dinsmore
Probabilistic Safety Assessment Branch
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FROM: Walton Jensen */RA/*
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SUBJECT: CRDM THIMBLE RUPTURE SENSITIVITY STUDY

You requested evaluations of potential CRDM thimble ruptures in operating PWRs to help assess applicability of existing PRA evaluations for hot leg breaks. Leaks and cracks in the CRDM thimbles were recently observed at Oconee and have subsequently been observed at other operating PWRs. The failure of a CRDM thimble would produce the equivalent of a small break LOCA. Small break LOCA is traditionally evaluated for piping ruptures in primary coolant piping and in connected smaller piping. The rupture of a CRDM thimble would cause a leak directly in the reactor vessel upper head. There is concern that the event would evolve in a different manner than that expected by plant operators and cause confusion.

We preformed the following series of calculations for Oconee using the RELAP5 computer code using an input model prepared by INEEL. Both loops of the reactor system and portions of the steam and feedwater systems are described in the RELAP model of the plant.

1. The rupture of a single CRDM thimble with AFW and minimum HPI flow.

2. The rupture of two CRDM thimbles with AFW and minimum HPI flow.

3. The rupture of three CRDM thimbles with AFW and minimum HPI flow.

4. A leak in the upper reactor vessel head equivalent to one half the area of a CRDM thimble with AFW and minimum HPI flow.

5. The rupture of a single CRDM thimble without AFW, HPI or steam dump capability to the condenser.

6. A hot leg leak equivalent in area to a CRDM thimble. AFW, HPI and steam dump capability to the condenser were assumed to be unavailable.

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In these analyses the reactor coolant pumps were assumed to trip at the same time the break opened. Actually operators are instructed to trip the coolant pumps manually on loss of subcooling as indicated on a monitor in the control room. Operator action was assumed to raise the steam generator level to 95% on the operating range as required by procedures on loss of forced flow and subcooling. This action was assumed to occur 600 seconds after the break opened.

Cases 1 through 4 approximate the assumptions made in the plant's design basis. No unusual phenomena were calculated to occur. The reactor system did not repressurize significantly from loss of natural circulation and the reactor core remained covered. Figure 1 is a plot of system pressure in the reactor and steam generators for the single CRDM thimble case. The steam generators are cooled and depressurized by the addition of auxiliary feedwater until the required level of 95% on the operating range is reached at 1452 seconds. After that time steam generator cooling is temporarily interrupted. The primarily system water level continued to decrease to a level corresponding to that in the steam generators. This occurs at approximately 2000 seconds. At that time rapid depressurization occurred. The 95 percent steam generator level is well above the core and provides an adequate heat sink before core uncovery can occur. See NUREG-0565, "Generic Evaluation of Small Break Loss-of-Coolant Accident Behavior in Babcock & Wilcox Designed 177-FA Operating Plants," January 1980. The reactor system eventually reached an equilibration pressure of approximately 500 psi corresponding to a balance of heat removed by the break and added by the reactor core. Other break sizes exhibited a similar response with the larger breaks reaching a lower equilibrium pressure and the smaller break reaching a higher equilibrium pressure.

The borated water storage tank (BWST) at Oconee contains a minimum inventory of 415,200 gallons, approximately 14 hours of injection water would be available (one HPI pump) before operators would be required to recirculate containment sump water for continued ECCS cooling. This could be accomplished by the low pressure injection system (LPIS) injecting directly into the reactor vessel if operators depressurized the plant. Alternately the HPI could continue to be operated during the recirculation period taking suction from the LPIS pump discharge.

The analysis in case 5 with no HPI or AFW flow was made for the purpose of determining the time available for manual restoration of safeguards equipment and comparison to the similar analysis of a hot leg break of the same size. The result of this comparison is shown in Figure 2. A much longer time was required for beginning of core uncovery for a break in the top of the reactor vessel than for an equivalent break in a hot leg. The Oconee design with once through steam generators includes hot leg piping that extends 43 feet above the core. A break at the top of the reactor vessel permits this liquid to flow into the core before uncovery can occur. The hot leg break was located close to the reactor vessel in the horizontal section. Much of the liquid in the vertical hot leg sections was lost out the break before it could reach the core. These results indicate that PRA conclusions for hot leg break close to the reactor vessel would be conservative if applied to a potential CRDM break.

So that the effect of break location could be assessed for other PWR designs, we preformed the following additional RELAP5 analyses.

6. The rupture of a single CRDM thimble without AFW, HPI or steam dump capability to the condenser for a four loop Westinghouse plant (Seabrook).

7. The rupture of a single CRDM thimble without AFW, HPI or steam dump capability to the condenser at a Combustion Engineering plant (ANO-2).

These analyses were compared to the equivalent break size in a hot leg. The conclusions for Seabrook are the opposite of those for Oconee. For Seabrook a CRDM thimble break at the top of the vessel caused core dryout to begin earlier than for a hot leg break (Fig. 3). The reason for the difference in results lies in the design of the reactor vessel internals. In both designs the upper head is separated from the upper plenum by a plenum cover plate. In the Oconee design the plenum cover plate is porous providing an open path for coolant to flow up through the control rod guide tubes and down through the plenum cover plate into the upper plenum. The upper head at Oconee is heated to the temperature of the core outlet during operation. For the Seabrook design flow within the upper head is restricted. During operation leakage flow is permitted from the reactor vessel downcomer into the upper head. Flow then passes downward through the control rod guide tubes to the top of the core. During operation the upper head at Seabrook is approximately at the core inlet temperature.

For a postulated CRDM break at Oconee flow from the core to the break is primarily though the upper plenum where the large flow area permits steam/water separation so that steam can flow out the break and water can remain above the core. For a CRDM thimble break at Seabrook, flow from the core to the break is primarily through the control rod guide tubes which have a small hydraulic diameter and permit little steam/water separation. Water from the core is sucked up to the break through the control rod guide tubes in a process similar to drinking through straw. The reactor vessel internal design for a typical Westinghouse plant is shown in Figure 4.

The upper head flow design at ANO-2 is less restrictive than that for Seabrook but more restricted than Oconee. During operation the upper head temperature is between that of the core inlet and that of the core outlet. The time for the beginning of core dryout was found to be approximately the same whether the break was in the upper head or in a hot leg. See Figure 5.

In summary the conclusions from this study are that a break in a CRDM thimble produces the effect of a small break LOCA. No new phenomena were identified from those which have already been evaluated.

In investigating the effect of break location, use of hot leg break analyses appear to be conservative in describing a CRDM thimble break for Oconee and slightly conservative for ANO2. Use of hot leg break analyses to describe a CRDM thimble break at Seabrook does not appear to not be conservative.

Attachment:
As stated

cc: Rlandry
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