Task 4

IA-4-1

BEHAVIOR OF RCS WITH

STEAM GENERATORS IN CONDENSING MODE

INDUSTRY ADVISORY GROUP

THREE MILE ISLAND #2

4/10/79

Agreed to and understood by:

Chuck Solbrig
Rick Muench
*Jim Thiesing
Harry Lawroski
Joe Palladino
Bob Campbell

163 102

Abstract:

This report recommends that the low pressure natural circulation method of core cooling be utilized for long term use (1 year). Three possible primary system fluid configurations can result from this type of cooling. It is recommended that analysis be performed to determine the heat transfer in each of these configurations.

Introduction:

In the long term, it would be desirable to cool the core with a minimum amount of equipment in operation. Natural circulation is a core cooling method which meets this objective. Many people are studying natural circulation with detailed computer analyses, etc. It appears that these studies are being performed at elevated pressures. In the very long term, however, it is also necessary to bring the RCS to atmospheric pressure. In this condition, the RCS is ameneable to another method of cooling.

Using this method, the RCS can be opened to the containment atmosphere by opening the pressurizer relief valve. The core will be allowed to achieve nucleate pool boiling. Theoretically the generated steam will displace RCS water out of the pressurizer vent, and flow to the steam generator. In the steam generator, the steam will ultimately be condensed by a cold, water-solid secondary. After an equilibrium water level is achieved in the hot leg riser and steam generator, only occasional make-up will be needed to replenish the RCS for the small amounts of steam flow vented through the pressurizer vent. Many techniques are available to provide this make-up.

163 103

This method can be used in place of natural circulation. Its real value, however, is as a back-up to natural circulation which may not be sufficient or may break down completely at low pressures. This method is complicated by the possible presence of non-condensibles. Non-condensibles may limit the flow of steam to the steam generator and/or reduce the condensation coefficient significantly. The following description will amplify the effect of non-condensibles.

At the initiation of the tube side condensing mode in the steam generator, the following initial conditions are presumed:

Initial Conditions

1. Secondary side solid -- cold water
2. Pressurizer vented to containment atmosphere, either by relief valve open or through 3/8" sample line re-plumbed to containment.
3. Primary system solid
4. Core flood tanks floating -- either under N_2 head or on head tank
5. Little or no non-condensibles in RCS
6. RC pumps off
7. Assume little or no natural circulation

The behavior of the RCS in this mode is estimated to be as follows:

I. No Non-Condensible Gas In System

1. Heat generation in core will form steam
2. Steam will form bubble in top of vessel
3. Steam bubble will displace water and raise pressurizer level
4. When bubble uncovers top of hot legs, steam will (eventually) slide out hot leg, forming bubble at top of candy cane quite rapidly (roughly 5000 - 10000 cfm).
5. The increasing bubble volume continues to drive water into pressurizer
6. The increasing bubble volume in candy cane uncovers cold tubes in steam generator until such time as the condensing rate in steam generator equals or exceeds the steaming rate in the core.
7. Then,
   a. If the system is heavily damped, a steady state steaming in core/condensing in steam generator condition will result.

   <u>OR</u>

   b. If the system is undamped which is more likely the bubble in the steam generator and candy cane will collapse rapidly, and the process will begin at Step 3 above again and repeat itself, <u>ad infinitum</u>, as long as there is a non-condensible free flow path through the candy cane. The perculation frequency in this mode is estimated to be 0.5 to 0.05 sec -1.

II. Non-Condensibles Present

Non-condensibles formed during this time will be swept to the top of the candy cane where they will form a bubble at the top of the bend.

8. After an undefined period of time, the bubble of non-condensibles may reach a size wherein it "seals" the top of the candy cane (i.e. there is no longer a free steam flow space below the bubble through the candy cane).

163 105

Rough calculations indicate that diffusive action will not be sufficient to transport steam through the non-condensible bubble. The core steaming rate in this mode is about 70 ft.^{3}/sec, at 20 psia and a valve which will rapidly (say in 10 seconds) drive the bubble into the steam generator and disperse it therein. If the non-condensible bubble is not too large, a condition will develop in which heavier steam reaches the top of the candy cane and begins to "fall" into the steam generator displacing non-condensibles to the top of the candy cane.

9. The steam generator and hot leg riser will seek a level which provides adequate tube area for condensation. This area will increase as non-condensibles enter the steam generator and reduce available condensing heat transfer coefficients, and the sweeping action of the steam flow will tend to concentrate non-condensibles in the steam generator.

10. As the level in the steam generator drops to provide adequate tube condensing area, the pressurizer surge line may become uncovered, the pressure will build and drive the water leg out of the surge line perculating steam and non-condensibles through the pressurizer.

11. Eventually, as the steam/non-condensible ratio in the generator approaches zero, the pressurizer surge line will become the primary steam relief path, with the end point being steady perculation of steam through the pressurizer at a rate sufficient to remove the decay heat load. In this mode, RCS pressure will be elevated to 100 - 200 psig to provide adequate steam flow capacity through the pressurizer relief valve. It would be undesireable if the non-condensibles forced the system to this state since we are back to a high RCS pressure and venting considerable RCS fluid to containment.

In evaluating the desirability of this mode of long-term cooling, and to determine the likelihood of its ultimate utilization as a matter of necessity, a number of calculations need be performed.

a. Natural circulation at atmospheric pressure (or near atmospheric pressure) cold primary system -- maximum core head loss to achieve natural circulation.

b. Calculation of RCS behavior in steaming/condensing mode, in the absence of non-condensibles.

c. Analytic quantification of RCS behavior as non-condensibles build up in system. (Steps 8 through 11 above).

Recommendation:

163 106

The IAG recommends that the mode of core cooling discussed above be seriously considered as the long term cooling mode. Analyses (a) and (b) mentioned above are logical extensions of the natural circulation calculations being performed by many people for the Technical Support Group. The output of analysis (b) can be used to construct a simple model to evaluate the possible effects of non-condensibles analysis (c). These analyses should be performed as soon as practical so further evaluation can be performed by the IAG.

163 107

JW Thiesing

To: Milt Levenson | Date: April 9, 1979

Subject: RCS Behavior | From: J. W. Thiesing

Copies: J. C. Judd | Of: TMI - IAG

The following is an assessment of RCS behavior in the "perculating" mode <u>before</u> large amounts of noncondensibles build up:

<u>Initial Conditions</u>

1. Secondary side solid -- cold water
2. Pressurizer vented to containment atmosphere, either by relief valve open or through 3/8" sample line re-plumbed to containment.
3. Primary system solid
4. Core flood tanks floating -- either under N_2 head or on head tank
5. Little or no non-condensibles
6. RC pumps off
7. Assume little or no natural circulation

<u>Behavior</u>

1. Heat generation in core will form steam
2. Steam will form bubble in top of vessel
3. Steam bubble will displace water and raise pressurizer level (~~and head tank level if in place.)~~
4. When bubble uncovers top of hot legs, steam will (eventually) slide out hot leg, forming bubble at top of candy cane quite rapidly (roughly 5000 - 10000 cfm).
5. The increasing bubble volume continues to drive water into pressurizer ~~(and core flood, if on head tank).~~
6. The increasing bubble volume in candy cane uncovers cold tubes in steam generator until such time as the condensing rate in steam generator equals or exceeds the steaming rate in the core.
7. Then,
   a. If the system is heavily damped, a steady state steaming in core/condensing in steam generator condition will result.

<u>Or</u>

   b. If the system is undamped which is more likely the bubble in the steam generator and candy cane will collapse rapidly, and the process will begin at Step 3 above again and repeat itself, <u>ad infinitum.</u>

In this mode before significant non-condensibles build up, I do not believe there will be any perculating through the pressurizer, only a rising and falling of water level in the pressurizer.

Non-condensibles formed during this time will be swept to the top of the candy cane where they will form a bubble at the top of the bend.

163 108

7905230065

P

To: Milt Levenson

Subject: RCS Behavior in Percolating Mode

Date: 4-9-79

From: J.W. Thiesing

Of: TMI-IAG

Reference my previous memo this date on the same subject. The percolation frequency is estimated to be 0.5 to 0.05 sec^{-1}

163 109

7905230069 P