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EXAMINATION OF CONTROLLED DEPRESSURIZATION TO ACHIEVE LONG TERM COOLING STATUS IN THREE MILE ISLAND

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I. INTRODUCTION

A subcommittee was formed on 2 April to examine concepts to depressurize, and achieve long term cooling status in the the Three Mile Island Plant. The committee members were: T. Johnson (Chairman, West); J. J. Holman (NRC); R. Muench (West.); J. Hurley (Bechtel) and L. J. Ybarrando (EG&G).

The scope of this assignment was to develop and evaluate conceptually techniques for depressurizing the Three Mile Island (TMI) primary coolant system in a controlled manner considering the effect of dissolved gases on the pressure decrease. After achieving a stable lower pressure at which the residual heat removal system could be used we further evaluated a long term cooling option.

This report contains a tabular summary of the alternate con-rolled depressurization methods evaluated in section II, a discussion of the alternatives in section III and the subcommittee recommendation in section IV.

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IV RECOMMENDATION

This committee recommends case 2A for depressurizing TMI because: (1) very little additional fluid is discharge to the containment (2) it is a near normal ~~operation~~ configuration and (3) it is backed up by case 1.

This committee has a further recommendation for long term cooling

~~[illegible]~~

After achieving a stable lower pressure through case 2, the ~~[illegible]~~ RHR system could be used as alternate long term cooling. However, we believe ~~[illegible]~~ using case 3 would be a better option. Reasons for reverting to case 3 in lieu of using the RHR system are:

(1) Specific ~~[illegible]~~ activity is kept in the reactor bldg.

(2) ~~[illegible]~~ The letdown and make up system can be used for continued degasification

(3) ~~Additional~~ Discharge ~~[illegible]~~ may require ~~use~~ of additional water, and concomment ~~and~~ contamination of ~~[illegible]~~ the water and does not adding to inventory in ~~[illegible]~~ the containment ~~is minimized~~.

~~[illegible]~~ If the pump fails the primary system is basically configured to default to a natural circulation mode

(4) Continued operation of the RC pump will help to sweep H_2 from R.C. into letdown systems.

(5) Forced cooling will help cool ~~whatever~~ configuration the core is in better than natural circulation.

(6)

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Disadvantages

1. Could be slow depending on heat input from pressurizer steel and amount of manual control required.
2. Level control affected by RCS bubble.

(4) Temperature control of RCS provided by steaming the S/G.
(5) RCS being periodically vented to containment; recombiners maintaining containment H_2 concentration.
(6) RCS temperatures and pressure are stable.
(7) Spray valve closed.

Plant Maneuver and Behavior

After achievement of initial conditions, the secondary side cooling is adjusted to maintain RCS temperature approximately constant throughout the depressurization to 300 psia. (Constant T_{ave} is not essential; however, since time is not a factor, it is felt advantageous to concentrate on one operation only.) There is probably a bubble in the RCS; its response to the maneuver is discussed under alternate 1.

At the outset the pressurizer heaters are energized and the vent valve(s) are opened slowly to the position calculated. This position should be such that, with the heaters 50% energized there is measurable rate of pressure increase. The heaters are then deenergized and pressure is seen to drop at the predetermined rate. The heaters are cycled to adjust the rate of pressure decay. Should heater control be lost or the rate become too large the vent valves will be immediately closed. Pressurizer level will be controlled automatically through MUV17; however, level may oscillate mildly as gases trapped in the RCS "slide" into the pressurizer. At about 400 psia one bank of heaters are turned on to case the pressure to stability at 300 psia. Some adjustment of the vent rate may be necessary. Final conditions reached are:

T_{ave} = 280°F
T_{Press} = 415°F
P_{rcs} = 300 psia
1 RCP still operating

Variations

The following variations are also possible:

1. RCS flow by natural circulation. Although heat impact to the RCS is reduced by about 4-5 Mw, the inherent difficulties in RCS temperature control make RCP operation preferable.

2. Pressure in unisolated full Core Flood tanks could lead the RCS manuever. This would provide protection against rapid depressurization. This variation introduced the risk of adding N_2 to the already gas saturated RCS as well as complicating the evolution.

3. Cooldown coincident with depressurization. Plant staff would be controlling two operations and makeup rate would be increased. This variation is not recommended because there is no need to complicate operation by trying to vary two parameters at once.

Advantages

1. Low makeup requirements
2. Minimizes mass lost from RCS to containment.
3. Positive control of pressure change.
4. Cessation of manuever leaves plant in original operating configuration
5. Forced core cooling without liquid release.
6. Similar to normal operating procedures.

Controlled Depressurization Alternate #2

Depressurization by Steam Venting from the Pressurizer

Description

With a steam bubble in the pressurizer, pressure control is decoupled from temperature control of the reactor coolant system (RCS). Thus RCS pressure can be lowered in a deliberate, controlled manner by venting the pressurizer while cycling the pressurizer heaters. Pressurizer level is maintained through use of the level control feature of the Makeup and Purification System (MU&PS). Venting of the pressurizer may aid degasification of the RCS with declining pressure. RCS temperature control is provided by heat transfer through the steam generator(s).

The alternate can be performed both with or without the reactor coolant pump (RCP) operating. RCS makeup for level control may be obtained either from the makeup tank or the borated water storage tank (BWST). The makeup tank is also available for RCS chemistry control, if appropriate.

Schmatic

Piping, equipment, and instrumentation for this alternate is shown on plant drowning 2024.

Assumptions and Prerequisites

1. Emergency power to valves RC-RV2, RC-V2 and RC-V137 and to the pressurizer heaters. Backup power supplies (not necessarily Class IE) should be available to RCS and MU&PS instrumentation and MU-V17.

2. Control air should be available to operate AOV's in the MU&PS.

3. H_2 recombiners available.

4. Enough instrumentation to maneuver the RCS and MU&PS available including at least RC temperature and pressure pressurizer temperature and level, and steam generator pressure.

5. Either the BWST or Makeup Tank should be selected and lined up as supply of makeup.

6. Calculations are complete to estimate the amount of opening of RC-RV2 and RC-V137 and energy necessary to control depressurization a predetermined rate. Latent heat in the pressurizer should be factored into this calculation.

7. Calculations to estimate amount of water added to containment are complete.

Summary of Operation (with RCP operating)

Initial conditions:
(1) RCS at 1070 psia, T_{ave} 280° - 285°, and 1A RCP in operation
(2) Pressurizer maintaining 1070 psia with steam pressurizer. Heaters are operable, level is at about 200".
(3) MU&PS operational supplying seal water to all RCP's and controlling pressurizer level with MU-V17.

EXAMINATION OF CONTROLLED DEPRESSURIZATION TO ACHIEVE LONG TERM COOLING STATUS

CASE NO.	HEAT SINK	WATER SOURCE	PRESSURIZER STATUS HEATERS	BUBBLE	VENTING	RCP
1A	HPI TO R.B. AND SECOND. STEAM.	BWST	NO	NO	CONTIN.	NO
1B	HPI TO R.B. AND SECOND. STEAM.	BWST	NO	NO	CONTIN.	YES
2A	SECONDARY STEAMING	NORMAL L.D. & M.U.	YES	YES	YES	YES
2B	SECONDARY STEAMING	NORMAL L.D. & M.U.	YES	YES	YES	NO
3*	SECONDARY SOLID	NORMAL L.D. & M.U.	NO	NO	NO	YES OR NO

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* CASE 3 IS NOT IN ITSELF A DEPRESSURIZATION METHOD. RATHER, IT IS ~~THE~~ A RECOMMENDED LONG TERM COOLING MODE TO BE USED IN LIEU OF RHR OPERATION.

DEFINITIONS CASE 1: RCS CONTROLLED DEPRESSURIZATION WITH A WATER SOLID PRESSURI

CASE 2: RCS CONTROLLED DEPRESSURIZATION WITH A STEAM BUBBLE IN PRESSURIZE

ALTERNATE 1

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4/3/79

TITLE: RCS CONTROLLED DEPRESSURIZATION WITH WATER SOLID PRESSURIZER. [redacted]

I. SCOPE/OBJECTIVE

THE OBJECTIVE OF THIS PROCEDURE IS TO BRIEFLY OUTLINE A MEANS FOR ACCOMPLISHING A GRADUAL AND CONTROLLED DEPRESSURIZATION OF THE RCS BY USING HHSI PUMPS AND PRESSURIZER VENTS. THE SCOPE OF THIS DOCUMENT IS LIMITED TO ONLY THE MEANS FOR DEPRESSURIZATION THE RCS DOWN TO PRESSURE COMPATIBLE WITH PLACING THE PLANT IN A NORMAL COOLDOWN MODE OF OPERATION. DURING THIS OPERATION THE [redacted] FLOW INJECTED INTO THE RCS BY THE HHSI PUMP(S) WOULD BE SUFFICIENT TO REMOVE ALL CORE DECAY WITH SENSIBLE HEAT ONLY THUS NO BOILING WOULD OCCUR WITH IN THE CORE.

II DESCRIPTION

1) SUMMARY

THIS CONTROLLED DEPRESSURIZATION OF THE RCS WOULD BE PERFORMED WITH OR WITHOUT THE REACTOR COOLANT PUMP OPERATING. THE PRESSURE LETDOWN WOULD BE ACCOMPLISHED BY SLOWLY INCREASING THE PRESSURIZER VENT AREA AND/OR DECREASING THE HHSI INJECTION FLOW. SHOULD A GAS BUBBLE EXIST IN THE RV HEAD, IT WOULD BE PERMIT TO EXPAND OUT OF THE HEAD INTO THE STEAM GENERATORS. DURING THIS OPERATION, THE HHSI PUMP(S) WOULD BE INJECTING FLOW INTO THE RCS COLD LEG(S), DOWN THE DOWNCOMER, THRU THE CORE, DOWN LOOP B HOT LEG, INTO THE PRESSURIZER SURGE LINE AND OUT ONE OF TWO AVAILABLE PRESSURIZER VENT PATHS. SUBCOOLED FLOW WOULD BE MAINTAINED THRU THE CORE.

FT Jcharda
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2) SUGGESTED PROCEDURE (PHASE A)

THE FOLLOWING PROCEDURE IS RECOMMEND FOR OBTAINING A WATER SOLID PRESSURIZER AND ESTABLISHING MAXIMUM FLOW FROM ONE HHSI PUMP(S) THRU THE CORE AND OUT THE PRESSURIZER VENT(S). DURING THIS PHASE A, THE RCP 1A WOULD CONTINUE TO OPERATE AND THE RCB WOULD BE MAINTAINED AT 1000 PSI.

THE PURPOSE OF ESTABLISHING MAXIMUM FLOW IS TO PROVIDE A MEANS OF SWEEPING ANY EXISTING OR NEWLY CREATED BUBBLES OUT OF THE RCS AS THE RCS PRESSURE IS REDUCED AS DESCRIBED IN SUGGESTED PROCEDURE PHASE (B).

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9/3/79

2) SUGGESTED PROCEDURE (PHASE A ONLY)

a) TURN OFF PRESSURIZER HEATER

b) INCREASE MAKE UP FLOW TO RCS BY OPENING CONTROL VALVE MU V17 AS REQ'D TO MAINTAIN RCS PRESSURE AT ≅1000 PSI.

c) SLOWLY OPEN PRESSURIZER VENT VALVE RC-V137 AND SIMULTANEOUS INCREASE MAKE UP FLOW TO MAINTAIN RCS PRESSURE AT ≅1000 PSI

d) ALLOW PRESSURIZER TO BECOME WATER SOLID AND STABLE

e) CONTINUE TO OPEN PRESSURIZER VENT VALVE RC-V137 AND INCREASE MAKE UP FLOW UNTIL THE MAKE UP CONTROL VALVE MU-V17 IS OPEN 100% AND THE RCS PRESSURE IS ≅1000 PSI.

2) SUGGESTED PROCEDURE (PHASE A CON'T)

f) DETERMINE HHSI FLOW RATE INJECTING INTO RCS.

g) IF FLOW IS LESS THAN 400 GPM CONSIDERATION SHOULD BE GIVEN TO OBTAINING ADDITIONAL FLOW BY SLOWLY OPENING AN ADDITIONAL MAKEUP FLOW PATH VIA ONE OF THE 4 HHSI INJECTION LINES WHILE MAINTAINING RCS PRESSURE AT 1000 PSI

h) CONTINUE TO INCREASE HHSI FLOW ~~[illegible]~~ AND OPENING PRESSURIZER VENT VALVE UNTIL EITHER RC-V137 IS 100% OPEN OR THE HHSI FLOW IS 450 TO 500 GPM.

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(3) PHASE B SUGGESTED PROCEDURE

AT THIS POINT of THE OPERATION EITHER THE PRESSURIZER VENT IS 100% OPEN OR THE HHSI FLOW IS 450-500 GPM. THE RCS IS WATER SOLID. SUBCOOLED FLOW CAPABLE of REMOVING ALL THE CORE DECAY HEAT IS PASS THRU THE CORE. DURING THIS PHASE B, THE RCP 1A MAY OR MAY NOT BE STOPPED AND THE RCS PRESSURE DECREASED BY SLOWLY OPENING THE PRESSURIZER VENT PATHS.

a) IF THE DECISION HAS BEEN MADE TO DEPRESSURIZE WITHOUT RCP OPERATION, STOP RCP 1A AND ALLOW THE RCS TO STABALIZE.

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b) CONTINUE TO SLOW OPEN PRESSURIZE VENT PATHS TO START DEPRESSURIZATION. CAUTION: HHSI PUMP FLOW WILL INCREASE. AS RCS PRESSURE DECREASE

(1)

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[redacted] PHASE B

(3 b) CONT)

[redacted]

MAINTAIN HHSI FLOW BETWEEN 430-500 GPM

C) PRESSURIZE VALVE RCV-2 SHOULD BE CLOSED AND THE POWER OPERATED RELIEF VALVE OPENED PRIOR TO USING THIS PATH TO FUTHER REDUCE RCS PRESSURE. SLOWLY JOG RC-V-2 OPEN AS REQ'D TO REDUCE RCS PRESSURE. MAINTAIN HHSI PUMP FLOW BETWEEN 430-500 GPM.

D) CONTINUE THE ABOVE PROCEDURE UNTIL THE RCS PRESSURE IS BELOW THE NORMAL DECAY HEAT SYSTEM CUT IN PRESSURE ($\leq$ 400 PSI).

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2) GAS BUBBLE BEHAVIOR (ASSUMING RCPs NOT OPERATING)

SINCE IT IS ASSUMED THAT A GAS BUBBLE WOULD EXIST OR MAY FORM IN THE REACTOR VESSEL HEAD A DESCRIPTION OF THE BUBBLE BEHAVIOR IS IMPORTANT IN ORDER FOR THE OPERATOR TO ANTICIPATE THE PHENOMENON WHICH COULD WITH IN THE PRESSURIZER.

AS THE RCS PRESSURE IS REDUCED, THE GAS BUBBLE, WHICH IS ASSUMED TO BE LOCATED IN THE REACTOR VESSEL HEAD, WOULD GRADUALLY EXPAND FROM THE TOP OF THE REACTOR VESSEL HEAD INTO THE TOP OF THE HOT LEGS LOOP A AND B. [illegible] FUTHER REDUCTION IN RCS PRESSURE WOULD RESULT IN PART OF THE EXPANDING BUBBLE TO SLIP INTO THE TOP OF BOTH STEAM GENERATORS A AND B. THREE SEPARATE GAS BUBBLES

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SHOULD NOW EXIST.

AS THE PRESSURE IS FUTHER REDUCED, THE BUBBLE IN THE TOP OF THE TWO STEAM GENERATORS WOULD INCREASE IN SIZE AS THEY CONTINUE TO EXPAND AND COLLECT GAS EXPANDING FROM THE REACTOR VESSEL HEAD. THE SIZE OF THE GAS BUBBLE IN THE RV HEAD WOULD NOT EXTENT BELOW THE TOP OF THE RCS HOT LEG LOOPS. THIS BUBBLE WOULD NOT EXPAND DOWN INTO THE UPPER PLENUM AND THEREFORE ITS EXPANSION COULD NOT LEAD TO A CORE UNCOVERY.

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EVENTUALLY THE GAS BUBBLE IN ~~THE~~ THE STEAM GENERATOR A WOULD EXPAND IN SIZE UNTIL IT REACHED THE PRESSURIZER SURGE LINE CONNECTION. FUTHER EXPANSION WOULD RESULT IN THE BUBBLE BEING SWEPT INTO (AND OUT THE OPEN VENTS) THE PRESSURIZER. BY THE CONTINUOUS HIGH

FLOW RATE PASSING THRU THE PRESSURIZER SURGE LINE. THE GAS BUBBLE IN STEAM GENERATOR B COULD EXPAND IN SIZE UNTIL IT REACHED THE TOP OF THE RCS HOT LEG LOOP B. FUTHER EXPANSION OF THIS BUBBLE WOULD RESULT IN THE BUBBLE MOVING ALONG THE TOP OF THE LOOP B HOT LEG, BACK INTO THE REACTOR VESSEL UPPER PLENUM WHERE IT WOULD BE SWEPT TOWARD THE PRESSURIZER SURGE LINE ALONG WITH THE EXPAND RV HEAD BUBBLE, BY THE CONTINUOUS HHSI FLOW RATE.

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4/3/79

III ASSUMPTIONS

1) INITIAL CONDITIONS

a) RCS PRESSURE 1000 PSI

b) RCS TEMPERATURE 270°F

c) SG LEVELS AT 95%

d) STEAM DUMP TO CONDENSOR

e) ~~HHSI~~ PUMP SUCTION ALIGNED TO BWST, (SEE ALTERNATE ALIGNMENT PROCEDURE __) AND DELIVERING TO RCP SEALS.

f) CORE FLOOD TANK STATUS, SEE ALTERNATIVE PROCEDURE __)

g) PRESSURIZER LEVEL ON SCALE

h) RCP PUMP 1A OPERATING

i) LPI PUMP SUCTION ALIGNED TO BWST

j) H_2 RECOMBINERS OPERATING

k) GAS BUBBLE EXIST OR CAN FORM IN

L) PRESSURIZER HEATERS ARE ON

M) PRESSURIZER VENT VALVE RC V137 IS
CRACKED OPEN.

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IV INSTRUMENTATION

1) RCS

a) PRESSURIZER LEVEL

b) PRESSURE

c) HOT + COLD LEG TEMP

d) PRESSURIZER VENT VALVE POSITIONS

2) CORE FLOOD TANK

a) PRESSURE

b) LEVEL

c) ISOLATED VALVE POSITION

3) HHSI (MAKEUP)

a) FLOW INTO 4 INJECTION LINES AND INST IN MAKE UP LINE

b) VALVE POSITIONS MU-V 16A, B, C, D
MU-V153

4) BWST

a) LEVEL

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V ADVANTAGES

1) PROVIDE SUBCOOLED FLOW THRU CORE TO REMOVE ALL DECAY HEAT

2) POSITIVE CONTROL OF BUBBLE GROWTH OR THE DISSIPATION OF ANY BUBBLE(S).

3) BORON CONCENTATION KNOWN

4) DILUTION OF H_2 IN REACTOR COOLANT

VI DISADVANTAGE

1) ADDS ADDITIONAL WATER TO CONTAINMENT WHICH COULD PLACE A MAXIMIUM DEPRESSURIZATION TIME CONSTRAINT ON THIS PROCESS.

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4/3/79

#2) PRE REQUISITES

a) THE FOLLOWING PRESSURIZER VENT VALVES MUST BE CONNECTED TO THE EMERGENCY SAFEGUARDS BUSS. RC-V2, RC-R2 and RC V-137.

b) BWST at 40' FT LEVEL

c) LHI AND HHSI LINE (FILLED AND VENTED) WATER SOLID

d) ALL LHI (DECAY HEAT REMOVAL) (PUMPS, VALVES, EQUIPMENT IS OPERABLE

e) AUX BLDG [illegible] ACCESSIBILITY IS ASSURED

d) ALL HHSI (MAKEUP) EQUIPMENT IS OPERABLE

e) CORE FLOOD TANK ISOLATION VALVES ARE OPERABLE

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