MEMORANDUM TO: Mel Silberberg, Chief
Accident Evaluation Branch

JUN 17 1988

THROUGH: Jocelyn A. Mitchell, Section Leader
Source Term Analysis Section

FROM: James T. Han

SUBJECT: DETAILED SEVERE ACCIDENT RESEARCH PLAN AND LOGIC DIAGRAMS - NATURAL CIRCULATION IN THE RCS

Enclosed please find my contribution to the Severe Accident Research Plan for the Natural Circulation in the RCS.

James T. Han

distribution: circ; chron; AEB r/f; Han r/f; Han; Wright; Meyer; Mitchell

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NATURAL CIRCULATION IN THE RCS - A Research Plan

1. Total Safety Issue

Natural Circulation in the RCS involves multi-dimensional circulation of superheated steam and other gas including hydrogen in the uncovered region of the core and the rest of the RCS. As a result, the RCS piping and steam generator tubes will rise in temperature because of the continuous energy transfer from the uncovered core, and the RCS structural integrity may be challenged. This activity addresses five technical questions: (1) Will Natural Circulation exist during a severe accident? (2) How effective is Natural Circulation in heating up the RCS piping and steam generator tubes? (3) Will Natural Circulation preclude high-pressure melt ejection (HPME) and direct containment heating (DCH) by causing RCS piping failure and system depressurization? (4) Will Natural Circulation induce steam generator tube rupture (SGTR) and containment bypass of radionuclide fission products? (5) What are the effects of Natural Circulation on the release of radionuclide fission products and hydrogen to the containment? Natural Circulation in the RCS is one of the major areas of uncertainties identified in NUREG-0956.

2. Major Parameters of Uncertainty

There are three major parameters of uncertainty that may have significant impact on accident progression and the consequences. Note that the uncertainty question on the condensation-induced hydrogen and steam separation (stratification) in the vessel upper plenum, as suggested in the Kouts' report (NUREG/CR-4883), is no longer considered to be a "major" one.

1. Time-dependent Structure Temperatures

The time-dependent temperatures of the surge line, hot leg junctions at the vessel, and steam generator tubes are most important in determining whether a RCS structure failure will occur early enough to prevent HPME and DCH. The steam generator tube temperatures are also important in determining the induced SGTR which may lead to containment bypass. These temperatures are calculated by either the MELPROG/TRAC or the SCDAP/RELAP5 code, in which thermal-hydraulics is coupled with core melt progression. The uncertainty in predicting these temperatures is currently not known, but it will be estimated after the codes are validated against data from the Westinghouse 1/7-scale natural circulation experiments, the TMI-2 accident, and the core melt experiments of PBF, LOFT, etc. Furthermore, an explanation for the absence of "high" upper plenum and hot leg piping temperatures in the TMI-2 accident will also be determined.

2. Break Size and Pre-Accident Conditions of Steam Generator Tubes

The consequences of the SGTR induced by the natural circulation flows depend on several factors including not only the tube temperature but also the break size (at the failure temperature determined by the structural failure analysis), any defects or thinning of the tubes prior to the accident, and statistical nature of tube failure (because there are over 3000 tubes in a steam generator). To address this issue requires both deterministic and statistical studies.

3. Effects of the Elevated Structure Temperatures on Fission Product Retention in the RCS

Temperatures of the vessel upper plenum structures, RCS piping, and steam generator tubes are likely to increase due to natural circulation flows. The thermal and chemical effects of the elevated structure temperatures on fission product retention in the RCS are not well understood. Additional analytical model development supported by experiments is needed in conjunction with the "Fission Product Behavior & Chemical Form" activity.

3. Planned Research Activities

To resolve the above major parameters of uncertainty requires interdisciplinary studies of thermal-hydraulics, core melt progression, and structural failure analysis for RCS piping and steam generator tubes. As a result, the research activities cover a wide spectrum of phenomena. The state-of-the-art computer codes such as MELPROG/TRAC and SCDAP/RELAP5 are being used to analyze severe accident progression in the RCS of a PWR in which theraml-hydraulics is dynamically coupled with core melt progression. Structural failure analysis is handled separately using simplified models supported by test data.

Research activities completed include: (1) A state-of-the-art review of RCS Natural Circulation, which has been published in Chapter 2 of NUREG-1265 and also in Appendix J.3 of NUREG-1150, (2) A COMMIX analysis for a TMLB' accident in the Surry plant (a Westinghouse reactor without vessel upper-head injection in a large dry containment) assuming intact geometry, which provides necessary information to SCDAP/RELAP5 and MELPROG/TRAC for modeling the counter-current flows in hot legs and steam generators, and (3) Structural failure analyses for predicting the creep rupture temperatures as a function of RCS pressure and duration in time for the hot leg nozzle, hot leg piping, surge line, and steam generator tubes of the Surry plant.

The planned research activities are listed below:

1. Two-dimensional MELPROG/TRAC and SCDAP/RELAP5 analyses are being performed for the TMLB' accident with or without pump seal LOCA in Surry to determine: (1) Whether an early RCS piping failure will occur so that the RCS is depressurized to preclude high-pressure melt ejection and direct containment heating, (2) Whether SGTR will occur assuming no tube thinning or other defects and will result in containment bypass of radionuclide fission products, (3) The physical and chemical states of the core melt materials that enter the containment (as the initial conditions for core-concrete interactions study and/or direct containment heating study), and (4) The release of radionuclide fission products and hydrogen to the containment (as the initial conditions for assessing source term and hydrogen combustion in the containment).

2. Similar analyses will be performed for the Sequoyah plant, which has a Westinghouse reactor with vessel upper-head injection and an ice condenser containment.

3. Similar analyses will also be performed for a CE plant and a B&W plant.

4. Two-dimensional and three-dimensional analyses using either the COMMIX or TRAC code are being performed to determine the reasons for the relatively low upper plenum temperatures in the TMI-2 vessel (compared with what is expected from natural circulation heating in the TMLB' accident).

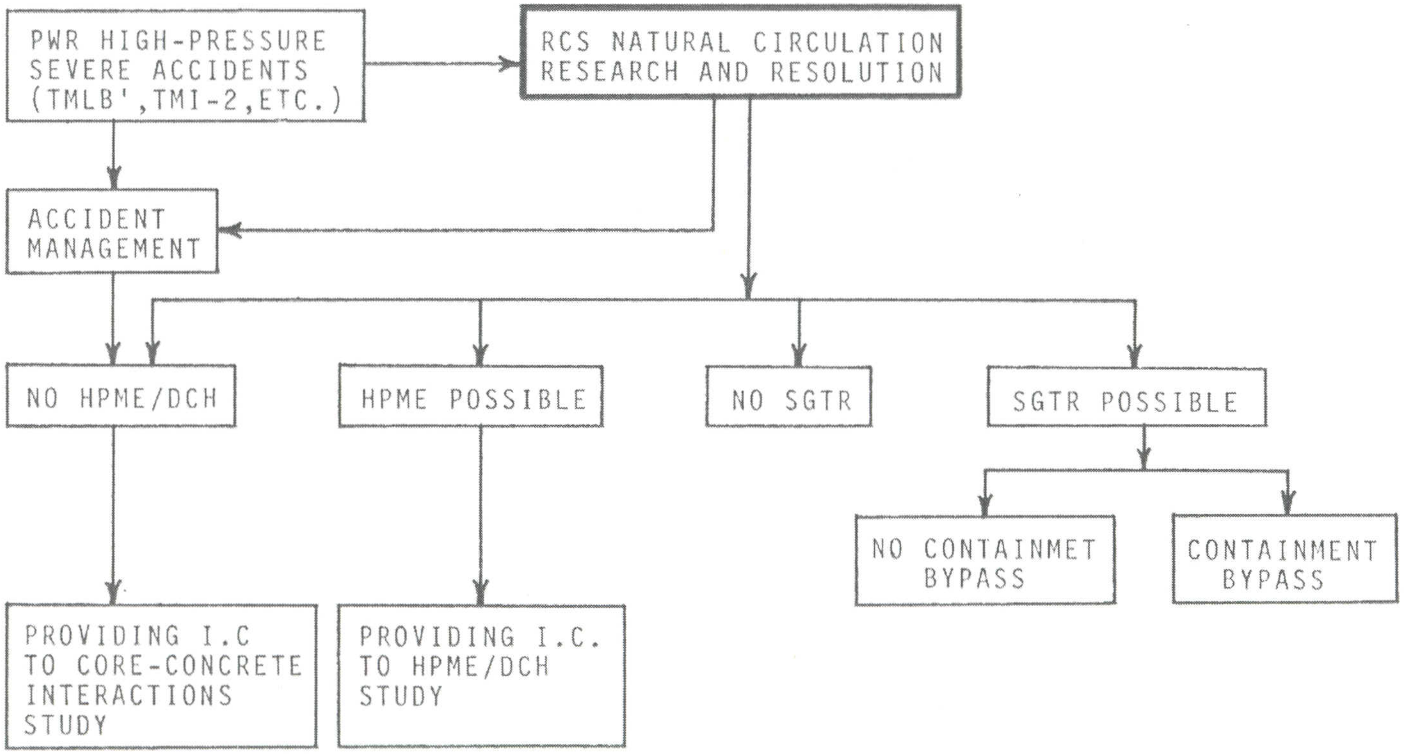
5. Additional tests will be performed in the Westinghouse 1/7-scale natural circulation facility in a cooperative program between EPRI and NRC. Results will be used to validate and improve the codes for modeling natural circulation.

6. Analyses for severe accidents in PWRs and BWRs will be performed as the needs arise.

4. Flow Charts

Two flow charts are provided; the first chart shows the role of RCS Natural Circulation in nuclear plant safety, and the second chart shows the research activities and resolution for RCS Natural Circulation.

ROLE OF RCS NATURAL CIRCULATION IN NUCLEAR PLANT SAFETY



I.C. = INITIAL CONDITIONS

RESEARCH ACTIVITIES AND RESOLUTION FOR RCS NATURAL CIRCULATION (NC)