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ACRS-1737

Minutes of the April 24, 1980

Subcommittee Meeting on Natural Circulation Decay Heat Removal

Dr. Carbon opened the meeting indicating that the Subcommittee was continuing its review of the information available on natural circulation decay heat removal in reactor systems under various conditions. Subcommittee consultants and members indicated that one area they were particularly interested in was condensation heat removal in the steam generator under conditions when non-condensable gas was present.

Dr. McPherson, NRC Research, indicated that recent experimental data from LOFT tests has provided the starting point for new insights into the performance of reactors under single-phase and two-phase natural circulation. The results of these recent tests and the present understandings were presented by personnel from INEL (EG&G).

Dr. J. Linebarger indicated that the small break LOCA program had a number of objectives that included investigation of phenomena using various parametric studies, experiments in Semiscale and LOFT, code development, and code assessment so that similar accidents in commercial reactors could be evaluated. As a part of the overall program, a number of small break LOCAs have been conducted in LOFT wherein natural circulation has occurred under various conditions. Tests L3-1, and L3-2 conducted in late 1979 and February 1980 both entered periods of natural circulation heat removal. Additional small break tests are scheduled and more information is expected

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from these tests. The data from the tests will be compared to code predictions in an attempt to accurately calculate the phenomena involved. The Semiscale facility, as well as other test facilities in the 3D program serve to extend and complement the LOFT data base. INEL considers natural circulation to be a process whereby heat is removed by flow caused by density grandients in the heat transfer fluid that are induced by heat addition in the reactor core and removal in the steam generator. This can include single phase loop flow, two-phase loop flow, and feflux boiling. Tests have not been done with two components (non-condensable gases).

At the first LOFT small break test, L 3-1, was a cold leg break of 2.5% area (4" dia equivalent) where the break flow was greater than the HPIS flow. The primary system rapidly depressurized and at about 400 seconds into the test the primary side pressure became lower than the secondary side pressure. The reactor coolant pumps were tripped at the beginning of the test. Following pump trip, a period of several (5) seconds of single phase natural circulation was initiated followed rapidly by a transition to two phase natural circulation as the upper plenum and the low plenum became saturated. At about 400 seconds heat removal at the steam generator stopped and the break became the decay heat removal path, in fact, the steam generators began to add heat to the primary system at this period. Through out the transient the break flow itself appeared to have a dominating effect upon the fluid flow and natural circulation process. Single-phase natural circulation really never had a chance to fully develop in the test. The shift to 2-phase circulation also appeared to be smooth and stable. In this test feed and bleed on the secondary side, which was initiated late in the transient, was ineffective in removing primary side heat. Another observation during the L3-1 test concerned the accumulator flow. Some calculations have shown pressure oscillations as the cold fluid enters the primary system; however, in the test the accumulator emptying was smooth and gradual as the primary pressure decreased.

The second small break test, L3-2, is of more interest with regard to natural circulation. This test was a small break .16% cold leg pipe area (1" dia. equivalent) wherein the HPI flow matched the break flow. This allowed the system pressure to stabilize at a point just above the steam generator pressure. The break was small enough in that it could not remove the decay heat and the steam generators were required. In this test an extended period of natural circulation was encountered. Following pump countdown at 40 seconds single phase natural circulation was established and extended to about 180 seconds. At this point saturation pressures were reached and a transistion to 2-phase loop circulation began. At about 800 seconds the system was in a fully saturated state with 2-phase loop flow. As the system continued to depressurize the fluid volumes decreased and at about 1600 seconds a second transition to reflux boiling was observed. By approximately 2300 seconds refluxing was fully established. At about 5500 seconds the primary system began to refill and the refluxing shifted back to a two phase loop flow at 6500 seconds which continued to 8,000 seconds. Finally as the system was completely refilled, the flow shifted back to a single phase fluid at about 8750 seconds. Each of the transitions was smooth and gradual and it appeared that there was no difficulty in removing decay heat. Secondary side feed and bleed was used to remove decay heat and depressurize the system starting at about 4000 seconds and the test was terminated at about 12,000 seconds. Some uncertainty still remains as to the fluid behavior during the refluxing and an additional test should shed new light on the phenomena. A number of difficulties were encountered due to the low flow velocities and the lack of measurement capability under fluid stratification conditions expected in refluxing. Later tests will also include a small LOCA initiated from a loss of feed water where primary side feed and bleed will be used for heat removal.

In response to questions, INEL and the NRC staff indicated that they have no plan to introduce non-condensable gases into LOFT at the present time. LOFT does get some small quantities of non-condensables already due to dissolved gases and the nitrogen from the accumulator when it finally empties all of its water at about 300 psia. The staff indicated that they have no way of tracing where the gas goes if they should inject it. Semiscale will be doing some tests with gas injected.

Dr. K. Condie, EG&G, reviewed the results of the calculations performed for the L3-1, and L3-2 tests. RELAP 4/Mod 7 was used and RELAP5 is being used for tests that are upcoming. The results showed that the code was able to predict the sequence of events in tests L3-1, and L3-2 but the quantitative results of the calculations need improvement. Problems encountered included inadequate boundary conditions due to unidentified flow paths during the test. In some areas the models in RELAP 4/Mod 7 are probably inadequate as it does not simulate thermal non-equilibrium and stratified flow conditions. RELAP 5 includes improved models which take these effects into account. The pretest predictions for test L3-7 which will be run with the break closed off at a point in time indicate that an extended period of reflux boiling will be entered. This will provide additional data on the phenomena.

Dr. D. Hanson, EG&G, reviewed the capability of the LOFT instrumentation to measure natural circulation. Each of the modes of natural circulation require some different measurement capabilities. Under water solid conditions low flow velocities need to be measured. Under two phase conditions void fractions at various locations and relative fluid (steam liquid) velocities are of interest. Under reflux conditions measurements of fluid under stratified flow conditions at low velocity are necessary. Information available at the present time is based upon instrumentation developed for large break LOCAs and is not ideal for small break LOCAs where fluid velocities are much lower. Improvements are needed on energy balances, low flow turbine meters, and shielded gamma densitometers. Development is under way on low flow measurements using neutron activation, temperature transit time flow meters and a turbine meter rake (small turbine meters located at various elevations in the pipe). Radioisotope tracers, Pitot tubes, drag discs, ultrasonics, and conductivity probes are all under development and have been tried out on a limited bases. At the present time the staff has not identified any way to measure where an injected non-condensable gas might go if they put it into LOFT.

Dr. Harvego, EG&G, reviewed the tests on natural circulation that were conducted on Semiscale as LOFT counterpart tests and the plans for future tests in Semiscale on natural circulation. Several tests have been run to date with a 2.5% break area. A number of difficulties have been encountered in the Semiscale tests. The pump cast down period is larger which delays natural circulation and the system heat losses are large - equivalent to the decay heat - so core power has to be augmented in order to have any natural irculation at all. Thus far Semiscale tests have not entered into natural circulation regimes. Modifications to Semiscale are planned and it is believed that later tests will demonstrate natural circulation. Feed and bleed as well as non-condensable gases will be used in various experiments. The facility upgrade will provide electrical trace heating of the piping and better insulation to eleminate heat loses. The planned test program will explore a variety of parameters that have been considered important to natural circulation and reflux boiling.

Dr. L. S. Tong, NRC RES, reviewed the results of initial tests on natural circulation conducted in Germany on the PKL facility. PKL is an electrically heated PWR model with 340 full length rods and a full elevation steam generator. The steam generator has 30 full size U-tubes and is very well instrumented to determine heat transfer conditions. A series of 12 single component tests have been run with subcooled, saturated, two phase, and reflux heat removal. In each case, heat was effectively removed from the reactor core and carried to the steam generator. Additional tests are planned in the near future with non-condensable gas in the system.

Dr. B. Sheron, NRR, presented the NRC staff position on bleed and feed heat removal. The staff recognizes bleed and feed as a potential heat removal method but no regulatory requirements exist at this time. A number of plants (B&W and some W) have high head HPI pumps which could provide sufficient makeup water for feed and bleed. Other plants, (CE and remaining W) have low head HPI pumps that would require system depressurization in order to use feed and bleed as a heat removal process. In some cases the low head pump plants may not be able to depressurize fast enough to provide adequate makeup water prior core recovery. Tests of the feed and bleed process will take place in the future in various experimental facilities. The staff plans additional studies to review the desirability of requiring feed and bleed, or improved secondary side emergency feedwater, or high pressure RHR systems. This will be included in the NRC Action Plan.

The Subcommittee reviewed a draft of Regulatory Guide 1.139 on decay heat removal systems with the Standards Development Staff. The Regulatory Guide was referred to the Subcommittee from the Regulatory Guides Subcommittee, and Mr. Etherington and Mr. Ebersole provided the staff with comments on the guide. The NRC staff indicated that they made a number of changes to the guide in response to the comments and explained that the intent of the guide was to improve presently existing decay heat removal designs rather than specify any new heat removal systems such as high pressure RHR. That may come in the future. The Subcommittee agreed that the guide could be issued for public comment.

The Subcommittee members and consultants provided a number of comments on the day's presentation and recommendations for future action. Dr. Theofanous indicated that he felt more thought and planning was needed to determine the important effects that need to be modeled in the codes and tested in the experiments. Too much of the present program was plunging ahead without adequate attention to deciding before hand what is important. Mr. Ebersole indicated that since the feed and bleed heat removal process can't be guaranteed, we should concentrate efforts on assuring that we have adequate secondary side heat removal. Dr. Zudans indicated that he had difficulties with the planned upgrading of semiscale. He believes that the system will become so complex that it will be difficult to do an experiment with known boundary conditions.

The members and consultants felt that testing with non-condensable gases was very important to determine their effects on reflux boiling and natural circulation.

Dr. Carbon adjourned the meeting at 5:00 p.m. Additional detail is available in the meeting transcript on file in the NRC Public Document Room at 1717 H Street, N. W., Washington, D. C. 20555.

A complete set of slides used is on file with the second copy of the minutes in the ACRS files.

TION: 10?? (Pan)
8:30 am

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. Linebarger	EG&G
. Lyon	NRC/RES
. D. McPherson	NRC/RES
. E. Marley	NRC/RES
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...ON: 1046 (Rm)

8:30 am

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