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Quarterly Progress Report on Blowdown Heat Transfer Separate-Effects Program for January-March 1980

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QUARTERLY PROGRESS REPORT ON BLOWDOWN HEAT TRANSFER SEPARATE-EFFECTS PROGRAM FOR JANUARY—MARCH 1980

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ABSTRACT

Six additional bundle uncovery/recovery tests were performed in the Thermal-Hydraulic Test Facility during January, bringing the total number of these tests to eight. Data taken during the tests were found to be contaminated by numerous spurious spikes. Work to remove the spurious spikes is under way. Posttest analysis of the tests is ~20% completed. The recovery portion of one of the tests will be analyzed by COBRA/TRAC, currently being developed by Pacific Northwest Laboratories (PNL). Work to debug the code for this application is in progress at PNL. The uncovery/recovery tests apparently caused damage to the O-rings that form part of the loop pressure boundary. Refurbishment of the O-ring seal system is being performed concurrently with scheduled loop modifications that include installation of ten in-bundle differential pressure instruments. Design, procurement, and fabrication of the in-bundle gamma densitometer system are continuing on schedule.

Keywords: Pressurized-water reactor, blowdown heat transfer, separate effects, loss-of-coolant accidents (LOCAs), Thermal-Hydraulic Test Facility (THTF), electrical heater rods, bundle hydraulics, two-phase flow, RELAP4, double-ended break, dynamic response, fuel pin simulator, THTF bundle 3, PINSIM, ORINC, ORTCAL, COBRA, bundle uncovery tests, small-break LOCAs, high-pressure reflood.

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1. ANALYSIS

W. G. Craddick

1.1 Data Management

R. M. Flanders

The Data Reduction Code (DACREP) for the Thermal-Hydraulic Test Facility (THTF) has been debugged and is being used to reduce data from the THTF bundle uncovery/recovery tests. Data from these tests were found to have systematic as well as random spikes. An algorithm has been developed to remove the systematic spikes. Development has begun on an algorithm to handle the random spikes.

A computer code has been developed to process data from a THTF hot test section fill test, which is conducted by flooding the test section with hot water at a controlled rate. Comparisons of the times at which thermocouples indicate the passage of the hot water allow verification of the axial locations of the temperature sensors. By searching bundle thermocouple response, the code will indicate whether any thermocouple appears to be in a different location from where it was designed to be as a result of the thermocouple leads touching at a different location than the original junction.

The THTF process code has been debugged. The code will create an output tape containing the engineering units data as read from the transient file plus additional calculated quantities such as spool piece composite density (as calculated from triple-beam gamma densitometer signals), spool piece "best" momentum flux, and heater rod powers. The code will modify the Instrument Data Base file on the output tape to include plotting information about these quantities.

1.2 Electric Pin Analysis

L. J. Ott

The development of a preprocessing program for ORINC (ORNL Inverse Code) and ORMDIN (ORNL Multidimensional Inverse Code) has been completed.

Most elements of the code have been debugged with an engineering units tape from the aborted December power-drop tests; however, certain sections of the code remain to be debugged because there is no powered transient file on the engineering units tape. This program basically restructures and combines the coefficient data tape (generated by ORTCAL, ORNL Thermocouple Calibration Code) and the engineering units tape for a given THTF test into a single one-pass tape input for ORINC and ORMDIN. With the preprocessed tape, ORINC and ORMDIN would be limited to computational work.

The core and loop heat balance code for THTF-Mod 2 has been started. This code will essentially make a total loop and core heat balance (includes heat losses; core balance; and balances around all exchangers — primary and secondary, pump) for each powered file on the enginneering units tape.

An extensive comparison of the one-dimensional and multidimensional inverse results (ORMDIN) was made for test 79-2-5 of the Forced-Convection Test Facility (FCTF), a single-rod test loop. During test 79-2-5, fuel rod simulator (FRS) axial level D exhibited circumferentially dissimilar surface phenomena in the time period of 5 to 7 s after blowdown. Prior to departure from nucleate boiling (DNB) (5.40 to 5.55 s), the one-dimensional computed surface flux oscillates about the multidemensional flux at each thermocouple location; however, in transition and film boiling, the one-dimensionally-computed surface flux differs by 10 to 30% from the multidimensional results.

The first draft of the ORMDIN documentation and user's manual has been completed.

The development of a "transfer function" for correlating the multidimensional and one-dimensional results of the inverse problem is continuing. Emphasis is currently being placed on selection criteria to determine when one-dimensional computations are adequate and/or when multidimensional computations must be made. This work is slightly behind schedule because of limitations that have been discovered in the multidimensional forward heat conduction software available at ORNL.

The first two parts of the ORTCAL calibration package have been modified for the bundle 3 FRSs. Debugging of the code has been completed (primarily due to the availability of the December power-drop engineering units tape). Part 1 of ORTCAL accumulates on a "history" tape the in-bundle conditions for each steady-state scan taken when the bundle is at power. Part 2 of ORTCAL reads the "history" tape generated by Part 1 and determines the in situ thermal conductivity of the annular BN insulator at each sheath/middle thermocouple position in the bundle.

1.3 Thermal-Hydraulic Analysis

C. R. Hyman M. D. White
C. B. Mullins R. H. Greene
T. M. Anklam D. F. Hunt

Posttest analysis is under way for THTF bundle uncovery/recovery tests 3.02.10A through H. The work is on schedule and is 20% completed. This analysis consists mainly of steady-state calculations of local heat transfer coefficients based on experimental data and the comparisons of those heat transfer coefficients with vendor correlations for steam cooling. Data reduction required to provide best estimate values of local fluid conditions include mass balances, energy balances, and radiation corrections on fluid thermocouple signals. The physics underlying the behavior observed in test series 10 was studied, and preliminary analysis for tests 3.02.10A, B, C, E, and F was presented in quick-look reports distributed in January and February.

At the present time, backup analysis is being undertaken for tests 3.02.10C through H so that independent verification of selected parameters computed in the previously described analysis is performed. Among parameters selected are bundle mass flux, inlet subcooling, test section mass inventory, two-phase liquid level, liquid carryover, equilibrium quality as a function of axial position, steam velocity above the froth front, and local heat transfer coefficients. This analysis is being provided for the uncovery phase of the tests.

Work was initiated to enable COBRA/TRAC to be used as the tool for analysis of the transient recovery phase of tests 3.02.10A through H. COBRA/TRAC, an advanced thermal-hydraulics code being developed at Pacific Northwest Laboratories (PNL), is intended to be used as both a blowdown and reflood transient code.

Since the code is still under development, proper documentation for code input does not exist. As a result, a description of THTF geometry was assembled and sent to PNL in January. In February, a work session was conducted at PNL to develop a model of the THTF-Mod 2 test section. Test 3.02.10E was selected as the first test to undergo analysis. As can be expected with a code still under development, problems have arisen that have impeded progress in performing analysis with the code. COBRA/TRAC had never been used to calculate a high-pressure reflood like that in THTF test 3.02.10E. As a result, performance of this calculation has required further debugging of the code. J. M. Kelly of PNL is currently working on a COBRA/TRAC calculation of initial conditions for test 3.02.10E. He will freeze a version of the code which works for this test so that subsequent analysis can be performed for other tests in the series.

In March, a meeting was held at PNL to discuss modification of COBRA/TRAC so that externally calculated FRS surface heat fluxes can be supplied as boundary conditions to the calculation of local fluid conditions. Also, modifications to provide for output of variables of interest to Blowdown Heat Transfer (BDHT) staff were discussed. This will allow plotting and heat transfer correlation evaluation. A remote job entry terminal for the CDC 7600 computer at Brookhaven National Laboratory (BNL) has been installed and is operational. The COBRA/TRAC code has been developed on the BNL computers. BDHT staff are learning commands necessary for input and output processing between the Oak Ridge and Brookhaven facilities.

Pretest planning and analysis have been carried out for the upflow film boiling test. To accommodate possible changes in the test conditions that can be achieved in the THTF, analysis of different options to meet the test's objectives is continuing.

1.4 Nuclear Pin Simulation Analysis

R. C. Hagar

The report describing the nuclear pin simulation of THTF test 105 is undergoing final review prior to submission for publication; it will be distributed early in the next quarter. The report describing PINSIM-MOD1[1] has been distributed.

The PINSIM-MOD2 code has been completed and has replaced PINSIM-MOD1 as our principal analytical tool. A study to verify PINSIM's heat conduction modules (which solve the forward, inverse, and back-calculational formulations of the conduction equation) is 50% completed. This study, which uses for comparison and as boundary conditions data gathered during a power-drop test on a bundle 3 FRS in the FCTF, will be finished and documented early in the next quarter.

Pretest analysis for the first THTF bundle 3 double-ended blowndown test (3.05.5B) has begun. This analysis utilizes RELAP4/MOD5 to predict (1) how well THTF hydraulic conditions can be made to match predicted conditions in a pressurized-water reactor core during an LOCA and (2) how nuclear fuel pins would respond to the THTF's conditions. PINSIM-MOD2 will be used to determine an appropriate FRS power program. A report will be issued which describes the methods and models used and the results obtained in this analysis. The work is on schedule.

2. THERMAL-HYDRAULIC TEST FACILITY OPERATIONS

G. S. Mailen

Bundle uncovery tests 3.02.10C through H were completed January 9, 1980. Tests were run at three operating pressures [2.76, 4.14, and 6.89 MN/m^2 (400, 600, and 1000 psig)] and at two rod power levels (3 and 6 kW/rod). At least one bundle thermocouple level was uncovered for a total of 187 min during this series of tests. Thus, in combination with bundle uncovery tests performed during December 1979, the heater rod bundle (bundle 3) has been uncovered for a total of 226 min.

On completion of the bundle uncovery tests, severe leakage problems were encountered in the inner and outer seal plate areas at the top of the bundle. The extreme operating conditions [steam temperatures near 865 K (1006°F)] attained during these tests may have caused damage to the O-rings, although pretest calculations had indicated that the O-rings would not experience adverse conditions sufficient to cause failure. The THTF operations staff is currently in the process of replacing the damaged O-ring seals in preparation for continued testing of bundle 3. The next experiment is scheduled for May 15, 1980.

During the time necessary for replacing seals, modifications are being made for installation of ten in-bundle differential pressure measurement instruments (dPs). The locations of the pressure taps are shown in Fig. 1. This modification will permit measurement of pressure differentials at various levels inside the heater rod bundle, providing information important to the analysis of test results from future experiments. Designs are also being completed for an in-bundle densitometer modification, explained in detail in another section of this report. Preparations are being made for making these modifications. This work is on schedule.

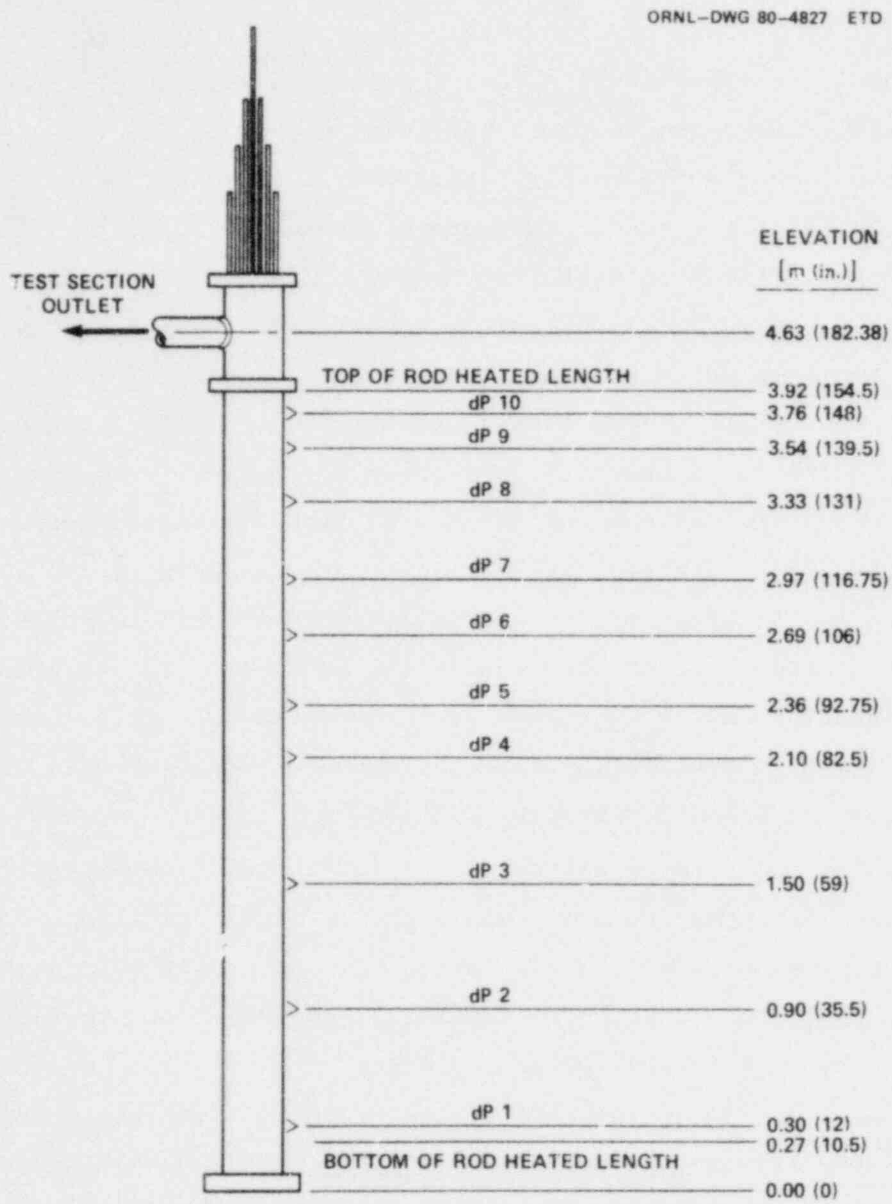

Fig. 1. Diagram of dP installation locations.

3. TWO-PHASE INSTRUMENT DEVELOPMENT

D. K. Felde

Design, procurement, and fabrication of the THTF in-bundle gamma densitometer system is continuing on schedule. The in-bundle densitometer utilizes low-energy gamma sources and high-temperature ion chambers positioned in two of the instrumented rods of bundle 3. A line-of-sight path which crosses two subchannels exists between unheated instrument rod positions 36 and 46. The design concept, then, is the determination of in-bundle void fraction by measurement of the variation in the attenuation of the source across the subchannel path length. A detail of the source-detector radial geometry is shown in Fig. 2. The annular source design was chosen to allow placement of two source-detector systems using only two instrument rod positions. For the instrument rod where the source is located above the detector, the detector cable passes through

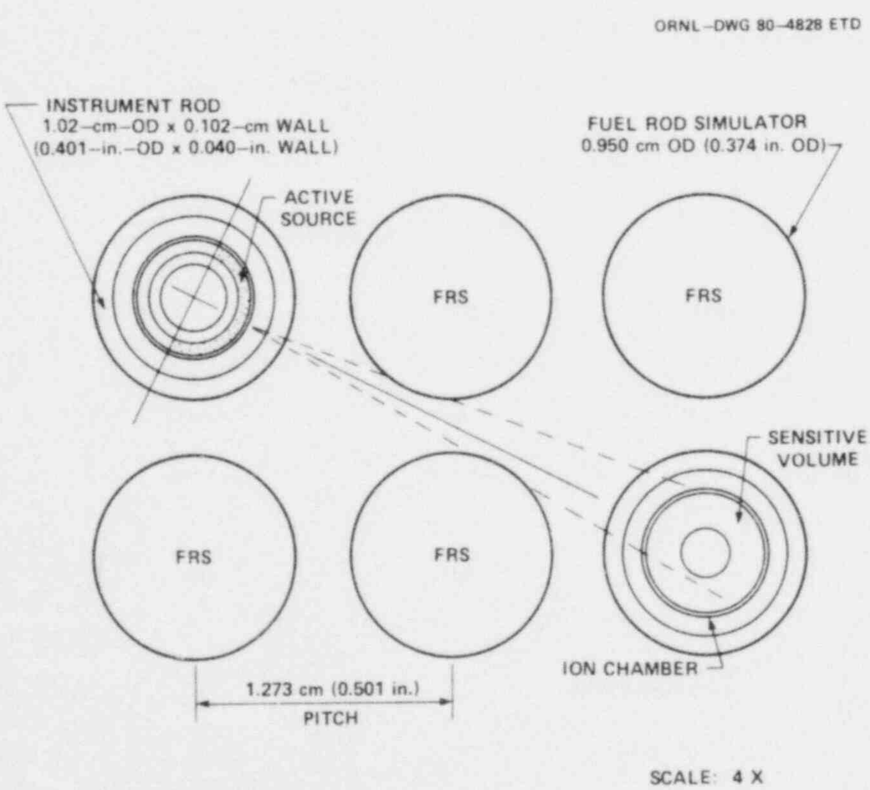

Fig. 2. In-bundle densitometer geometry.

the source annulus and out of the instrument rod tube. The source and detector assemblies in each of the rods will be attached to a motor drive system for axial positioning. The two measurement sites will be fixed with respect to each other; however, variation of the axial position of the two measurement sites over the heated length of the bundle will be made possible with the aid of the positioning motor drive.

A "low-flow" spool piece has been designed and installed for the upflow film boiling test in the THTF. A 1.43-m-long (72-in.), 5-cm (2-in.) spool piece will replace the two 8.89-cm (3.5-in.) spool pieces on the external inlet downcomer. The new spool piece will consist of two 5-cm (2-in.) turbine meters, two drag disks with full-flow three-bladed targets, a single-beam gamma densitometer, a pressure tap, and a thermocouple. The smaller-diameter spool piece will improve measurements for the expected low inlet flows.

The design for placement of differential pressure cells along the axial length of the THTF test section has been completed. The differential pressure cells are spaced 59.7 cm apart in the lower portion of the heated length with closer spacing (25 to 40 cm) in the upper portion of the heated length to facilitate measurements in bundle uncovery tests.

REFERENCE

1. R. C. Hagar and R. A. Hedrick, *PINSIM-MOD1: A Nuclear Fuel Pin/Electric Fuel Pin Simulator Transient Analysis Code*, ORNL/NUREG/TM-291 (January 1980)

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