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QUARTERLY TECHNICAL PROGRESS REPORT
LMFBR TASK 25, TRANSIT TIME FLOWMETER
JANUARY-MARCH 1970

AEC Research and Development Report

Atoms International
North American Rockwell

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Program: LMFBR Component Development
AEC Task: No. 25, Transit Time Flowmeter
Project Manager: C. W. Wheelock

Reporting Period: January-March 1970

General Order: 7757

Subaccount: 53100

AEC Category: 04-40-03-01.1

Principal Investigator: R. L. Randall

I. PROGRAM OBJECTIVES

The objective of the program is the demonstration of the feasibility of liquid-metal flowrate measurement by use of cross-correlation techniques, and development of an operating instrument for use in calibration of, and as an alternative to, other flow-measurement methods. The technique involves detection of small temperature variations (thermal eddies) at two points in the flow stream. The two signals are cross-correlated with a variable delay time. The delay time which gives maximum correlation is the transit time of the fluid between the sensors. The Transit Time Flowmeter (TTF) operates on this principle.

Water-loop tests and analytical studies in Part 1 of the development program indicated that the TTF method, which is based on the detection and correlation of temperature patterns at two axial positions in a flow channel, would perform satisfactorily in sodium at flowrates above 1 fps.

The objectives of the second part of the program were to demonstrate the TTF technique for flow measurements in Na at temperatures up to 1200°F, to obtain comparative performance data of a 2-in. -diam TTF of fixed design in Na and in H₂O, and to investigate the effects on potential accuracy of the TTF variables such as the number and configuration of in-stream sensors, amount and type of heat injection, operating conditions, and measurement techniques.

II. MAJOR ACCOMPLISHMENTS DURING FISCAL YEAR 1970

Demonstration tests of a 2-in. -diam TTF in water at flowrates to 15 fps and in sodium at operating temperatures of 1200°F were completed. A topical

report describing the test results* has been prepared and a draft submitted for AEC review.

Plans for the Part 3 program for the period February 1970 through January 1971 were prepared. This part includes tests of a 6-in. -diam TTF in 1050°F Na at flowrates to 30 fps, assembly and test of a prototype transit time flow analyzer, and the fabrication and testing in 1200°F sodium of a small-diameter TTF to measure sodium flow from individual fuel elements in reactors of the Fast Flux Test Facility (FFTF) and EBR-II (Experimental Breeder Reactor) types. This program will establish the performance characteristics of large-diameter TTF's for use as a flow-measurement standard in the Sodium Pump Test Facility (SPTF), and an evaluation of the performance characteristics of small-diameter TTF's for use in monitoring flow from reactor fuel assemblies.

III. PROGRESS DURING REPORT PERIOD

A. TESTS AND CALIBRATION OF 2-in. -DIAM TRANSIT TIME FLOWMETER

A topical report describing the tests of a 2-in. -diam TTF (AI-AEC-12941) was completed and submitted for AEC review. The water-loop tests were made at flow velocities up to 15 fps, to check the accuracy of the TTF flow measurements for various sensor configurations against volumetric/time measurements. Sodium-loop tests were made at 500, 900, and 1200°F and flow velocities up to 10 fps. The report describes development and fabrication of sensors and flow section for use in sodium, flow-test facilities and test apparatus, test methods, test results, comparison with electromagnetic (EM) flowmeters, and recommendation for the design and operation of future TTF's.

Results of Na tests at 500 and 900°F did not differ significantly from the 1200°F tests or from the H₂O-loop tests; therefore, the major emphasis on analysis and evaluation was given to data from the 1200°F tests and comparisons with H₂O-loop results.

*R. T. Randall, "Transit Time Flowmeters Employing Noise-Analysis Techniques, Part 2 - 2-in. Sodium Loop Tests," AI-AEC-12941 (to be published)

The studies of the propagation and decay of temperature patterns in Na show results strikingly similar to those from the H₂O tests. Empirical models were developed which relate amplitude, bandwidth and measurement velocity of temperature patterns in H₂O and Na to injection temperature, geometrical factors, sensor position, and flow conditions. Measurements mapping the acceleration of temperature patterns to average stream velocity were used to compute second-order correction factors relating measured transit times for the various sensor configurations to average flowrate. Results from water tests show that velocity measurements made with the two sets of "reference" sensors and the axial average of all sensor combinations are consistent within 1% with the average flow determined using the volume/time method for flowrates above 2.5 fps. Results from the sodium tests show that the velocity measurements made with the two sets of reference sensors are consistent within 1% with the axial average of all sensor combinations for all temperature conditions, all flow conditions above 2.5 fps, and all combinations (2, 4, 6, 8, 10, 12, or 14) of thermocouples on each sensor.

Sodium-velocity measurements by the transit-time method were compared with velocity indications from two EM flowmeters. These results show the expected linear proportionality relationship; however, 15 to 17.5% discrepancies were observed between the two EM flowmeters in the loop. The measured velocities using the transit-time method were consistent within 5% with the computed flow velocities measured by one of the EM flowmeters. The computed flow velocities from this EM flowmeter were based on post-test room-temperature measurements of the field strength of the permanent magnet. The prediction of actual field strength at temperature is expected to be within 5% of the values predicted from the measurements at room temperature. Post-test flux measurements were not obtained for the second EM flowmeter.

B. LARGE-DIAMETER TRANSIT TIME FLOWMETER

Work on the Part 3 program began with preparations for testing a 6-in. - diam TTF in the Sodium Components Test Installation (SCTI) at the Liquid Metal Engineering Center. Present plans call for installation of the test section in SCTI in July 1970 in preparation for tests in Na at temperatures to 1050°F and flowrates to 30 fps.

The test section to be installed in the SCTI will be 6 in. in diameter and approximately 20-ft long. Eight TTF sensors and an EM flowmeter will be located on this test section. This arrangement will provide accurate EM-flowmeter data for comparison with the TTF results, and widely spaced TTF sensors will increase the capability of the test setup for studying diffusion of thermal patterns. Designs for the flow section, sensors, and the thermal-source assembly have been completed and a system design description was drafted.

A "thermal source" was devised in the form of a fin-shaped eductor-injector about 0.9-in. wide by 6-in. long which extends vertically from above into the 6-in. -diam flow section. About 5% of the sodium stream is diverted through an air cooler (a 4-in. -diam pipe with fins, about 5-ft long) where it is cooled before it returns to the flow stream. The heat loss from the cooler is relatively independent of the velocity of the flow stream. By use of this type of thermal source, separate piping connections to the SCTI sodium system are avoided. The thermal and hydraulic analyses of this heat source were completed.

Analyses of a 0.3- by 1.3-in. airfoil-shaped sensor have indicated that these dimensions will provide a wide margin of safety for both strength and vibration resistance for a fin designed as a cantilever long enough to extend across the 6-in. -diam pipe. The fin will be made from a 7/8-in. -diam hollow tubing with either a 0.035- or 0.049-in. wall thickness formed into an airfoil shape with integral transition to the round cross-section. A test specimen of the desired configuration was bent from available 1-1/8-in. -diam by 0.035-in. -wall tubing.

IV. EVALUATION OF EFFORT TO DATE

The sodium tests of the 2-in. TTF demonstrated that inherent or induced temperature patterns are readily detectable at two or more axially spaced in-stream sensors and that these signals are suitable for measuring flow velocity. Random temperature patterns, generated by injection of a thermal tracer, were detected at all four in-stream sensor positions, and transit-time measurements were obtained relating the six sensor-pair combinations for all flow and temperature conditions. Typical signal levels ranged from 0.01 to 1.0°F peak-to-peak, depending on heater power, flowrate, and sensor position. Test results

for flow velocities from ~ 1.4 to 10 fps indicate temperature patterns decay at approximately the same rates in sodium and water. This is in agreement with earlier studies^{*} which indicated that hydrodynamic effects, not thermal diffusion, dominate the deterioration of temperature patterns. However, because of the lower density and heat capacity of sodium, temperature patterns of detectable magnitude are more readily generated in Na than in H_2O . Of particular interest to future applications are the results of the 1200°F 2-in. -loop tests which show that inherent temperature fluctuations created by heat loss at the first in-stream sensor provide temperature signals for flow measurements between the second and fourth sensors, 12 and 60 in. downstream respectively. Results without heat injection appear to be consistent within 1% of those with heat injection.

The TTF sensors and flow section were successfully operated over the temperature range from room temperature (water tests) to 1200°F (sodium tests), which demonstrated one of the unique advantages of the TTF over other methods. The useful temperature range is limited only by the temperature limitations of the sensor materials and the thermocouples. Except for changes in the distance between sensors by thermal expansion (on the order of a few tenths of a percent), flow-velocity measurements by the transit-time method are unaffected by temperature. These factors continue to indicate that the TTF will be valuable for use in calibration measurements of flow velocity in large sodium loops, where volume/time calibration methods are not practical.

The continued recent improvement and reduction in cost of commercially available cross-correlation measurement equipment indicates that such equipment will soon be competitive for widespread industrial application of the transit-time flow-measurement method. Correlation systems which required several racks of equipment a few years ago now require a single-rack module. By the time LMFBR's are placed in operation the electronics package for a TTF with a 0.1% accuracy should require no more than three or four circuit cards. Simpler versions with 1% accuracy are also foreseen for use as in-core flowmeters.

The sensors and signal source for the TTF require pipe penetration for installation in the flowstream. However, the cantilever design for the sensors

*R. T. Randall, "Transit Time Flowmeter Employing Noise-Analysis Techniques, Part 1 - Water Loop Tests," AI-AEC-12802 (1969)

and signal source to be used in the 6-in. TTF is directly applicable to an 18-in. TTF for the SPTF. In an 18-in. pipe the 6-in. cantilevered sensors would be installed at two or more angular positions in planes normal to the pipe axis.

V. NEXT REPORT PERIOD ACTIVITIES

Work will continue on preparations for testing of a large-diameter transit-time flowmeter in the SCTI. Sensors, thermal source, and test section will be fabricated and installed in the Rocketdyne High-Flow Facility for testing and calibration in water. Test instrumentation will be repaired and calibrated for use in the H_2O and Na-loop tests.

Modifications will be made to improve the accuracy and performance of the existing transit-time computer system for use in the water-loop calibration tests. These changes will be evaluated for incorporation in the design of a prototype transit-time flow analyzer.

Thermal analysis will be carried out for optimization of the design of the thermal-flowmeter section of the small-diameter TTF.