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ULTRASONIC THERMOMETRY IN LMFBR SYSTEMS

Progress Report

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Covering the Quarter Ending September 30, 1970

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Progress

During the quarterly reporting period July 1 through September 30, 1970, work has continued on the FFTF simulation oven. Several models of the ORTC-4 noncomposite line have been fabricated at Panametrics and tested by R. L. Shepard at Oak Ridge. The calibration of rhenium as an ultrasonic thermometer sensor was confirmed in these tests. A calibration curve for W-25 Re sensor, fabricated at Panametrics, was also obtained by Shepard. In a separate experiment carried on under the direction of Panametrics, more calibration data were obtained on Re and W-25 Re. Materials needed for the FFTF simulation tests are now in-house, and fabrication methods are under test.

FFTF Simulation Oven

The simulation oven has been assembled and augmented with an extension heater designed to operate at 1100C. This will provide a close simulation to the expected FFTF temperature conditions near the inside top portion of the fuel pin. Figure 1 shows the oven with the extension in cross-section. Figure 2 is a photograph of the structure.

Several safety features and monitoring devices not supplied with the oven have been installed. These include temperature monitors for the cooling water outlet temperature, an inlet supply monitor, a pressure release device for the oven in the eventuality of steam generation due to a water leak, and an inert atmosphere gas flowmeter to prevent gallium spills in the lower electrode due to gas overpressure. Inlet and outlet gas moisture content will also be measured using two Panametrics aluminum oxide hygrometer probes.

The oven has been partially tested with temperature held to 800C. The extension heater has been tested to 700C. With the addition of an insulating tube outside the coil, it is expected that the temperature within the extension tube upon which the coil is wound will rise to 1100C as desired. See Fig. 3. Possibly only the lower portion of the extension will be double-walled for the high temperature. See comments under Fabrication. The entire oven assembly will be tested next quarter with thermocouples and a rhenium sensor for independent temperature determinations.

ORTC-4 Noncomposite Lines

Several noncomposite lines as in Fig. 4 were sent to R. L. Shepard for testing during this quarterly period. Designs were modified on a continuing basis in conformity with his findings. The specifications of the lines are listed in Table I.

TABLE I

Specifications of Noncomposite Lines

No.	Lead-In		Sensor		
	Material	Diameter	Material	Diameter	Attachment
1	Rhenium	0.010"	Rhenium	0.007"	Continuous, Etched down
2	W-25 Re	0.009"	W-25 Re	0.006"	Continuous, Etched down
3	W-25 Re	0.009"	Rhenium	0.006"	Welded*
4	W-3 Re	0.009"	Rhenium	0.006"	Welded*
5	W-3 Re	0.009"	Rhenium	0.006"	Welded*

*Welded at a diam. of 0.010" and etched to 0.006" subsequently.

Results were as follows: #1 lost amplitude above 2200C and became unreadable above 2400C. It is probable that the attenuation in the rhenium lead-in line became prohibitive at the high temperatures. Other data indicate that the attenuation begins to rise steeply above 1500-1600C. #2 worked well at temperatures at and above 2400C because the W-25 Re is less attenuating. However, Shepard's results on delay time versus temperature indicate W-25 Re is less sensitive than Re as a thermometer element. The preliminary W-25 Re results to date are not in close agreement with Arave's data, but further testing and analysis is required before definitive comparisons can be made. #3 was built to combine the preferred features of the first two. R. L. Shepard reported satisfactory operation but found a discrepancy between his time-vs-temperature plot and the earlier calibration work. He is checking the possibility of chemical contaminants or other problems.

Sensor Calibration

Using our ultrasonic system, a rhenium sensor and two W-25 Re sensors were independently calibrated at the thermocouple calibration facility of Englehard Industries, Newark, N. J. Plots of these data,

normalized to room temperature, are shown in Figs. 5, 6, and 7. Between 1750 and 2250C, the rhenium sensor had a slope of -0.020% change in transit time per degree C increase in temperature while the W-25 Re sensors had a slope of $-0.013\%/^{\circ}\text{C}$. These results show the W-25 Re to be about 2/3 as sensitive as Re, in reasonable agreement with Arave's results. The new result in rhenium, $-0.020\%/^{\circ}\text{C}$, compares favorably with the earlier slope of $-0.019\%/^{\circ}\text{C}$.

Fabrication of the FFTF Simulated Fuel Pin and Centerline Sensor

The materials and small parts for the fabrication of the FFTF Simulated Fuel Pin and Centerline Sensor are in-house. See Fig. 8. Fabrication tests have been carried out as planned on the sheath joint between W-25 Re tubing and 316 SST tubing. Electron-beam welding shows promise. Work is continuing on this method.

In the event that it is not successful, there are two other methods which hold promise. Certain applicable brazes are available for use to nearly 1000C. For example, investigators at Argonne National Laboratory suggested copper which melts at 1080C. Use of such a braze would necessitate the use of a longer W-25 Re sheath extending to the fuel pin cap. Then the simulated cladding would have to be brazed to the cap with a yet lower-temperature braze. That end of the simulated fuel pin could be tested up to about 900C maximum. This would be consistent, however, with FFTF operation where the cladding and cap reach only the sodium temperature of 575C.

Future Work

In the next quarter the primary objective is to complete the fabrication, testing and thermal cycling of the FFTF Simulated Fuel Pin and Centerline Sensor. Fabrication tests are now under way, and final fabrication will commence upon their successful completion. Testing will include both ultrasonic testing of the transducer lead-in/sensor to assure good echo quality and sheath leak-testing to assure integrity of the structure with respect to simulated fission gas pressure. Before-and-After tests with an SF_6 leak detector (Panatek [®]) and in-process tests with krypton 85 are planned for the thermal cycling. Thermal cycling will run several times from room temperature to the vicinity of 1100C (2000F) for the lead-in and to the vicinity of 2750C (5000F) simultaneously for the sensor and fuel region. The exact temperatures

will depend upon the sheath joints (welded or brazed) and upon the operating characteristics of the tungsten tube furnace.

A second objective for the next quarter is the annealing and calibration of the Re-Os alloys to 1000C or higher. The purpose is to detect any differences among alloys containing 0, 5, 10 and 15% Os which would predict changes in Re sensor calibration during transmutation under irradiation. If time permits, the measurements will be extended in the tungsten tube furnace to temperatures in excess of 1000C.

A third objective for the next quarter is further work on the calibration and thermal cycling of Re and W-Re sensors above 2000C.

Fig. 1. FFTF simulation oven and heater extension.

Fig. 2. Photograph of oven and extension with cooling water tubes, monitoring thermocouple wires, and bus bars to power supply.

Fig. 3. Proposed outer insulator in extension to raise temperature in test zone by retarding heat loss to water jacket.

Fig. 4. ORTC-4 sensor systems supplied to R. L. Shepard.

Fig. 5. Third Re sensor calibrated

Fig. 6. Second W-25 Re sensor calibrated

Fig. 7. Third W-25 Re sensor calibrated

Fig. 8. Exploded view of the FFTF Simulated Fuel Pin and Sensor Assembly. The rhenium sensor (1) is welded to the lower end of the tungsten lead-in wire (2A). This component is inserted into a W-25 Re sheath (4) which is welded to a 316 SST sheath extension (5A) at location (2B). The lead-in shown continuing at (2B) extends to the magnetostrictive Remendur stub transducer (3) to which it is welded. The SST sheath extension is welded to the 316 SST fuel pin cap (6) and extends into the sodium region (5B) far enough to cover the transducer stub at (5C). Another 316 SST tube (7) contains the transmit/receive coil (8) and slips over the sheath extension (5C). To simulate the environment, depleted UO_2 pellets (3) surround the W-25 Re sheath (4) and fit inside a tantalum cladding simulator (10) which is welded shut at the bottom and brazed to the fuel pin cap (6) at the top.