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ULTRASONIC THERMOMETRY IN LMFBR SYSTEMS

Third Quarterly Progress Report

Contract AT(30-1)-3906

Covering the Period April 1, 1968 - June 30, 1968

Work performed for

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SUMMARY

The purpose of this contract is to design, develop, construct and test an ultrasonic system to measure temperature in the coolant, cladding and fuel meat of liquid metal cooled fast breeder reactors (LMFBR's).

The progress achieved during the third quarter, April-June, 1968, may be summarized as follows:

- 1) Sodium immersion tests were conducted at the Argonne National Laboratory (ANL) up to 700°F . These tests:
 - a) demonstrated lead-wire transmission through liquid sodium, with ~ 20 ft sections of lead-in wire both directly immersed in liquid sodium and also contained in an immersed sheath.
 - b) determined the feasibility of using the immersed fuel cladding as a temperature sensor.
 - c) determined the feasibility of using sheathed tungsten and/or SS 304 as lead-in wires.
 - d) demonstrated the structural integrity of the ultrasonic thermometer with respect to the liquid sodium environment.
- 2) The system test has been agreed upon and is scheduled for August 15, 1968.
- 3) A relaxation of the operational temperature requirement on the 20 ft lead-in wire from 2000°F to 1060°F has revived the possibility of using higher transmission frequencies, or shorter coils, than had previously been contemplated on the basis of the higher attenuation associated with a lead-in at 2000°F . The coils used at ANL were 3" long. Recent experiments using 0.5" coils have shown the attenuation to be less than 4 db/20 ft at $\sim 1250^{\circ}\text{F}$. The significance of this result lies in the possibility of using shorter sensor lengths, thereby obtaining a more localized temperature reading.

4) A paper on Ultrasonic Thermometry for Nuclear Reactors was accepted for presentation at the 15th Nuclear Science Symposium, Montreal, Canada, October 23-25, 1968.

5) Several types and sizes of commercially available wire were evaluated for the transducer coil. The most satisfactory compromise for a combined transmit/receiver coil from the standpoints of reliability, voltage breakdown, signal amplitude and stability, was found in #40 Niclad wire.

LABORATORY TEST PROGRAM

Sodium immersion tests were conducted at ANL during the period April 29 to May 3, 1968. Figures 1, 2 and 3 illustrate the main features of the test set-up.

Figures 1 and 2 of the flange assembly show the relative positioning of the transducers, the magnetostrictive wires, and the lead-in wires. The bellows valves and needle valves were used for the evacuation and backfilling with argon of all the tubes prior to startup. This precaution was observed to eliminate the possibility of an oxidation reaction in the event of a weld failure.

Four probes were simultaneously immersed in sodium as shown in Fig. 3. Probe #1 consisted of a sheathed 0.063" SS 304 lead-in wire and a 0.047" dia x 14" long SS 304 sensor. Probe #2 consisted of a sheathed 0.050" dia tungsten lead-in wire etched to 0.030" dia along the last 12" of its length to form a sensor. Probe #3 was not completed on time for the experiment; its position was plugged with a SS 304 rod (see Figs. 1 and 2). Probe #4 consisted of a bare 0.063" dia SS 304 wire with a 12" long kinked sensor, and Probe #5 consisted of a 0.063" SS 304 wire heliarc-welded to a 1/8" O. D. x 0.020" wall SS 304 tube through a SS 304 conical transition element. A sheathed chromel-alumel thermocouple was used as a cross-check on the ultrasonic temperature measurement.

As a backup for the immersed chromel-alumel thermocouple and as a further cross-check, diametrically opposed longitudinal probes were attached near the bottom of the tank. The longitudinal probes were used to obtain a through transmission measurement of the time taken for a 3 MHz pulse to traverse a diametric path in the vicinity of the probes (see Fig. 7 in previous quarterly report, NYO-3906-2). (Additionally, two shear probes were intended to measure the time taken for the ultrasonic wave to traverse a diagonal path to the opposite wall of the tank and back. The failure of a glass insulator in one of the shear probes, however, precluded their use in the experiment.) The longitudinal probes operated successfully and yielded temperatures in reasonable agreement with the values obtained from the immersed and wall-mounted thermocouples and the thin wire sensors. (This temperature measurement using the liquid sodium itself as the "sensor" medium was of only minor significance in these tests. In future applications, however, where it may be required to monitor sodium inlet and outlet temperatures for periods up to five years, an ultrasonic transmission measurement similar to the one we demonstrated at ANL may be desirable.)

The echoes originating from the beginning and end of the bare SS 304 sensor and the sheathed SS 304 sensor are shown in Figs. 4 and 5, before and after immersion in liquid sodium.

Figure 6 is a plot of the normalized ultrasonic velocity versus the immersed thermocouple temperature for the bare and sheathed SS 304 sensors. Since thermal equilibrium was not maintained during the test,* and because the bare sensor apparently was close to the heated pipe wall, the temperature of the bare wire was at all times slightly higher than that of the sheathed sensor. A laboratory calibration curve is included

*Temperatures measured with thermocouples mounted along the wall of the 10" pipe containing the sodium varied from one another and from the immersed thermocouple by as much as 100°F during the test.

also in the figure. This curve was obtained by heating in an oven a section of the same batch of SS 304 wire as that used in the sodium tests, and monitoring the temperature with two chromel-alumel thermocouples brazed onto both ends of the sensor. Figure 7 is a schematic of the oven calibration test. The two temperatures remained within 2°F of each other throughout the test. Garofalo's data¹ are also included for comparison, but these data were obtained by static tests using bars in which Young's modulus may be expected to be different from drawn wire. That is to say, texturing may account for the small difference between our calibration on a wire and Garofalo's results in a bar.

Construction of the Pana-Therm Model 5010 is proceeding, and the system test is scheduled for August 15, 1968. The test set-up is shown in Fig. 8. The Pana-Therm Model 5010 (special AEC unit) drives the magnetostrictive transducer. This transducer is sealed and is capable of containing sodium vapor pressures up to 100 psi. The lead wire will contain bends with a 2" radius of curvature.

A SS 304 sheath, preferably 1/16" O. D. but possibly up to 1/8" O. D., protects the lead-in from undesired contacts with the flange, and any other items that might be located between the flange and the fuel pin. Twenty feet of the lead-in will be heated to a maximum temperature of 1060°F by electrical heating. If it is convenient in the lab to test with a 50 ft lead-in, this will be done; otherwise the attenuation of the 30 ft portion will be introduced based on separate measurements and calculations. Likewise, any attenuation due to sheathing or liquid sodium not included in the demonstration will be similarly introduced or compensated for.

The bottom 6" simulates the temperature measurement in the fuel pin. The rhenium sensor will also be heated to a maximum temperature of 5000°F . The AEC Pana-Therm Model 5010 should measure the transit time in the sensor to $0.1 \mu\text{sec}$.

Recent tests with 0.5" coils have shown the attenuation to be less than 4 db/20 ft at $\sim 1250^{\circ}\text{F}$. Recent tests have also indicated that lead-in wires which are simply placed within the sheath in a loose fitting arrangement, may be sufficiently isolated acoustically.

PROJECTED GOALS

Our goal for the next reporting period is to work towards the completion of the system test.

Reference

¹Garofalo, F., "Temperature dependence of the elastic moduli of several stainless steels," ASTM Preprint #81. Paper presented at the Sixty-Third Annual Meeting of the Society (June 25-July 1, 1960).

Figure 1. Overall view of flange assembly

Figure 2. Top view of flange assembly - closeup

Fig. 8. Sketch of Probe Cluster for tests in sodium at Argonne National Laboratory

(a) Room temperature, before immersion.
 $20 \mu\text{sec/cm}$, 50 mV/cm .

(b) Immersed in liquid sodium at $\sim 700^\circ \text{F}$.
 $20 \mu\text{sec/cm}$, 20 mV/cm .

Figure 4. Echoes from kink and end of SS 304 bare wire before and after immersion in liquid sodium.

(a) Room temperature, before immersion.
 $20 \mu\text{sec/cm}$, 20 mV/cm

(b) After immersion $\sim 700^\circ\text{F}$
 $20 \mu\text{sec/cm}$, 50 mV/cm

Figure 5. Echoes from sheathed 14" SS 304 sensor before and after immersion in liquid sodium.

Reduced data of sodium immersion tests at ANL
May 2 and 3, 1968

Fig. 6. Ultrasonic velocity vs thermocouple temperature

Figure 7. Schematic of oven calibration.

Figure 8. Schematic of System Test