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ULTRASONIC THERMOMETRY IN LMFBR SYSTEMS

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SUMMARY

The progress achieved during the seventh quarter, April-June 1969, may be summarized as follows:

1) Attempts were made to use a composite W/Re thermocouple-ultrasonic probe even though the tie-on lines were not at the optimum points for ultrasonic measurements. Signal overlap and interference were again observed at $\sim 3500^{\circ}\text{F}$. In addition, the thermocouple emf was observed to fluctuate erratically, indicating poor contact of the tie-ons. From these results it appears that, in order to successfully conduct tests at ORNL, alternative designs need to be considered.

Several alternative designs were communicated to J. McGurty (GE-NPS). The designs were discussed during a meeting at GE (NPS) on June 25, 1969, and tentative agreement has been reached to schedule in-pile testing for ORR Cycle 89 starting October 17, 1969. The minutes of this meeting are contained in an ORNL intra-laboratory memo by R. L. Shepard dated June 30, 1969.

2) Aluminum coils, anodized at Panametrics, were tested at 500°F for 1030 hours, 800°F for 780 hours, 900°F for 100 hours, and at 1000°F for 230 hours. Coil failures were observed at 800°F and 1000°F , possibly due to gradual diffusion of the parent metal through the anodic layer. A summary of all coil tests to date is shown graphically in Figure 1.

Additionally, samples of anodized aluminum wire were ordered from a vendor for evaluation. These may be usable to 1200°F .

LABORATORY TEST PROGRAM

Anodized aluminum coils were tested at 500°F for 1030 hours, 800°F for 780 hours, 900°F for 100 hours, and at 1000°F for 230 hours. Coil failures were observed at 800°F and 1000°F . These failures may be due to gradual diffusion of the parent metal through the anodic layer. A summary of high temperature coil tests conducted at Panametrics is shown graphically in Figure 1.

A typical test configuration is shown in Figure 1b. The coils were placed in an oven (air-atmosphere) side by side with a type K thermocouple. A Sim-Ply-Trol provided direct readout in $^{\circ}\text{F}$ of the

temperature in the vicinity of the coils. The electronic pulsing equipment consisted of a GR pulser and pulse amplifier types 1398-A and 1397-A, respectively. The coils were coupled to a 0.023" dia x 6" Remendur alloy wire. Where more than one coil was being tested, a multiple-position switch was used to interrogate each coil at random intervals throughout the experiment. Direct oscilloscope displays of the resulting signal patterns are shown in Figure 1 (c) to (h).

The above experimental set-up was designed to test both the anodized aluminum coils and the magnetostrictive Remendur alloy at elevated temperatures. Some increase in signal amplitudes relative to room temperature was observed at all test temperatures up to 1000°F. A similar increase has been reported by Mobsby* in his tests of Permendur to 932°F.

In those cases where the transducer assembly failed, the failure was traced to the coil winding by comparing the dc resistances before and after the test, and by attempting to operate the previously heated coil, at room temperature, in conjunction with an unheated Remendur wire of the same dimension as that used in the test. In all cases of coil failure, it was found that the dc resistances had diminished by a factor of about 2 to 3 or dropped to zero (indicating a short) and little (< 10 mV) or no signals could be obtained from the test wire. No degradation of magnetostriction was observed up to 1000°F. Coil failures were sudden and not accompanied by gradual amplitude degradation.

Independently, after learning of a possible vendor, samples of anodized aluminum wire were ordered from said vendor for evaluation. These were reported to have passed 9000 hours at 1200°F.

Attempts were made to use a composite W/Re thermocouple-ultrasonic probe even though the tie-on lines were not at the optimum points for ultrasonic measurements. Signal overlap and interference were again observed at ~3500°F. In addition, the thermocouple emf was observed to fluctuate erratically, indicating poor contact of the tie-ons. From these results it appears that, in order to successfully conduct tests at ORNL, alternative designs need to be considered. As a result, several alternative designs were communicated to J. McGurty (GE-NPS) in a letter dated May 21, 1969.

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*Ultrasonics 7 (p 39) Jan. 1969.

Figure 2a illustrates a probe configuration similar to the earlier designs but with slightly different relative dimensions of transducer: lead-in:sensor. This modification is intended to prevent any interference before the third sensor end echo rather than the second, as the earlier design provided. This does not guarantee, however, that echoes from mode converted waves in the cold junction tie-on will not jeopardize the measurement. For this reason, it is proposed that a smaller diameter tie-on be used (0.003" to 0.005") inasmuch as the tungsten transport problem is not expected to be severe at that point. This smaller diameter cold tie-on is a common feature to all the alternative designs. The second and third alternatives introduce the 2" long Re sensor in the thermocouple circuit. There, the hot junction tie-on is placed either at the end of a sharp right angle extension of the sensor (Figure 2b) or at a massive termination (Figure 2c). It appears that the introduction of the sensor in the T/C circuit may not influence the T/C operation, especially if the region is essentially uniform in temperature.

A fourth alternative which McGurty suggested involves the butt brazing of the hot junction tie-on to a larger diameter sensor as shown in Figure 3a. The geometry in Figure 3a was tested in the laboratory and yielded a satisfactory echo configuration (Figure 3b). However, the diameters in the actual test probe could be modified to give an echo ratio of 2:1 to 3:1.

The above probe designs were discussed in a meeting held at GE (NPS, Evendale, Ohio) on June 25, 1969. It was agreed that the composite sensor design shall proceed on the basis of a preferred and two alternative designs.

For the preferred design, a three-hole thoria or hafnia insulator 0.062" OD with 0.012" holes is needed. If it can be fabricated, separate W/Re thermocouple and Re ultrasonic sensors will be used. This approach eliminates acoustic interference in the ultrasonic sensor due to thermocouple wire tie-on, allows each sensor to be designed for maximum reliability, and allows the thermocouple junction to be placed at the midpoint of the ultrasonic sensor's active portion.

If three-hole material cannot be made, we would proceed with either of two options:

(a) Using two-hole hafnia insulator material on hand, 0.047" OD with 0.012" holes, a composite thermocouple-ultrasonic sensor will be tested for use as the best alternative. Two 0.009" W/Re thermocouple

wires are to be joined to one end of a 2" length of rhenium wire, using a Mo50Re refractory braze. Kuhlman (GE) will assemble a test unit for testing by Panametrics by July 25th. If this option is chosen, a sensor will be tested at ORNL to 2300° C in the lab furnace before incorporation in the ORR capsule.

(b) If neither the three-hole separate sensor, nor the brazed composite sensor in a two-hole insulator prove feasible, two-hole insulators will be used with an ultrasonic line of tungsten attached to rhenium occupying one hole, and a W26Re wire occupying the other hole. A light bridge of 0.001" W/Re wire or foil will provide low temperature thermocouple circuit completion and the lowered resistance of the insulator will provide a thermocouple connecting path at high temperatures.

A design decision is to be made between the various sensor options by August 1st.

A minimum of four (and preferably five) complete sensors are to be made for use in the capsule and the various pre- and post-irradiation tests at ORNL. These tests have been discussed previously.

At this point, the earliest time that the complete capsule could be inserted in the ORR appears to be the beginning of ORR Cycle 89, starting October 17th.

ACKNOWLEDGMENTS

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Fig. 1a. High temperature anodized aluminum coil tests - progress to date. Symbol (F) indicates coil failure.

(b) Sketch of high temperature experimental set-up

Room temperature

1 V/cm, 20 μ sec/cm

(c) 500 $^{\circ}$ F

(d) 600 $^{\circ}$ F

Fig. 1. (continued) Same scale in all scope photos.

(e) 700°F

(f) 800°F

(g) 900°F

(h) 1000°F

Fig. 1. (continued)

Fig. 2. Sketches of alternative designs for composite T/C-ultrasonic probe.

Fig. 3a. Configuration tested in the laboratory. Hot junction butt welded to sensor (suggested by J. McGurty, GE - Evendale).

(b)

Fig. 3. Oscilloscope display, 1V/cm, 0.1 msec/cm. First pulse train due to transmission through lead-in.