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ULTRASONIC THERMOMETRY IN LMFBR SYSTEMS

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Progress Report

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PROGRESS

During the first quarterly period of 1970 the BSR test was successfully concluded. Two composite lines with instrumentation for the ORTC-4 test were delivered to R. L. Shepard at **ORNL**. Materials for the FFTF ultrasonic thermometry test have been ordered.

BULK SHIELDING REACTOR (BSR)

The purpose of the BSR test was to determine what effect, if any, gamma radiation would have on a magnetostrictive transducer at high temperature. In preparation for the **BSR** test, an anodized aluminum coil was operated over 1100 deg F for over an hour, and briefly, up to 1200 deg F. Other high temperature coils ~~of~~ this type construction were heated to 1000 deg F for 1000 hours with no coil degradation. Both of these tests were conducted in a conventional muffle type oven.

In planning for the BSR test, electrical methods of heating the coil to 1000 deg F were studied as alternatives to gamma heating.

An added heater coil wrapped around the transducer coil worked well; however, the added lead wires were undesirable and it was not a good simulation for the conditions of the **ORTC** test. Another method tried was pulse self-heating which suffered from local overheating.

It **was** decided to use a heavy walled stainless steel tube as a gamma susceptor into which the coil slid.

Because the coil's BSR operating temperature was expected to reach 1000 deg F and its melting point **is** 1220 deg F, it **was** necessary to monitor the temperature. This was accomplished by using the coil itself as a resistance thermometer. At room temperature the coil's resistance was about 8 ohms, and at 1000 deg F the resistance was about 25 ohms. Tested and calibrated coils were supplied for incorporation into the **BSR** test rig at Oak Ridge.

The transducer coil supplied by Panametrics operated successfully at ~1000 deg F in the Bulk Shielding Reactor at Oak Ridge. The coil was installed on February **18** by R. L. Shepard, and worked as planned. The coil surrounded the end of a length of remendur wire which acted both as a magnetostrictive transduction medium and as a transmission medium. Short electrical pulses fed to the coil produced acoustic pulses which echo back and forth between the ends of the wire

and are detected once per round trip, Oscillograms of the echoes are shown in Fig. 1, kindly supplied by R. L. Shepard. The temperature in the test capsule was monitored by a thermocouple. Concurrently, the resistance ~~of~~ the transducer coil was being monitored for **two** purposes: (1) to detect future possible failure due to open-circuit or short-circuit conditions, and (2) to determine the feasibility of using the coil itself as a resistance thermometer. The resistance curves versus temperature for three coils are shown in Fig. 2.

Results are as follows: (1) the coil operated as an ultrasonic transducer with no degradation of signal. It underwent electrical pulsing for 665 hours at a repetition rate of 100 pulses per second, a voltage of 60 volts, and a pulse width of 5 microseconds. Of this time, 646 hours were at **2MW** of reactor power at a flux of about $2.5 \times 10^{13} \text{ n/cm}^{-2} \text{ sec}^{-1}$ (thermal) for a dose of $5 \times 10^{19} \text{ n/cm}^2$. During 621 hours of this time, the temperature in the test capsule was above 900 deg F. At steady-state, the temperature varied between 1010 deg F and 1040 deg F; (2) small fluctuations in coil resistance have not correlated perfectly with small temperature excursions as measured by the thermocouple, although the resistance of the coil **is** proper for the temperature range to which it is subjected. The coil, **as** a resistance thermometer, read 15 to 18 deg F low.

OAK RIDGE THERMOCOUPLE (ORTC) **TEST**

Design Options

Previous design options, Fig. 3, were limited by the echo at the ~~remendur-tungsten~~/rhenium joint. Line configurations had to be constructed **so** that this echo, and **its** multiple, would not interfere with the echo from the beginning or end of the sensor. Consequently, lines had to be designed with strict proportions.

In separate transducer experiments, we explored the possibility of using a short remendur "**stub**" under the coil only, up to 1000 deg F. The stub transducer, developed and used **by** Fanametrics for a commercial installation about one year ago,* can substantially reduce the number of echoes in the line, if it is matched to the refractory metal wire lead-in,

*K. A. Fowler and L. C. Lynnworth, Proc, 5th **TMS**, pp 191-208, Fig. 8, Hawthorne, Calif. (April 1969). A. Arave recently and independently suggested the use of a stub transducer to avoid lead-in echoes.

over the entire transducer temperature range of interest. Figure 4 illustrates results with this design. Echoes are easier to interpret than obtained previously with longer remendur lengths (see, for example, October monthly, Figs. 3 and 4).

By employing the stub transducer, the major line length restrictions were overcome, making available new design options.

Figure 5 is the final **ORTC** test configuration; it offers several attractive advantages which were not present in previous designs:

- 1) symmetrical for vertical hanging
- 2) choice of coils at beginning of test
- 3) transducer and resistance temperature detector (RTD) redundancy; if one coil should fail prematurely, the second may be used
- 4) two resistance thermometers (**RTD**)
- 5) fabrication easier than previous designs.

However, one problem was encountered during fabrication. The hafnia insulators, when put on the lead-in lines, caused spurious echoes in the line. The reason for this **is** that the holes do not go straight through the insulator but rather spiral through. Different pieces of hafnia have varying degrees of spiral. In the best case the amount of spurious echo caused should not be troublesome.

On March 19 **two** composite lines such as in Fig. 5 were delivered to R. L. Shepard at ORNL with instrumentation.

FAST FLUX TEST FACILITY (FFTF) **SENSOR**

Plans are progressing for the fabrication and testing of an ultrasonic temperature sensor for a liquid-metal-cooled fast breeder reactor fuel pin. This test **is** intended to essentially duplicate actual environmental (temperature) conditions, other than nuclear and sodium, anticipated in a liquid metal-cooled fast test reactor fuel pin, of the FFTF type (see, for example, PNL drawing No. **SK-3-14583**).

While the actual cladding will probably be stainless steel, in order to easily heat depleted uranium oxide and sensor to **-5000 deg F**, a refractory metal (e, **g.**, **Ta**) tube will be substituted for at least a portion of

the cladding, for these tests. The tests will include thermal cycling from ambient up to -5000 deg F. The prototype will be fabricated to withstand fission pressures expected at the end of burnup and will safeguard against escape of fission gas. The transducer will be located a distance from the prototype pin on the order of 3 to 10 feet, dependent on the temperature and nuclear environment which the transducer may be expected to withstand in an actual installation.

Maximum temperatures ordinarily expected in the sodium 3 to 10 feet above the core, are presently estimated not to exceed 1050 deg F. Since our transducer has been tested to over 1100 deg F for over 1 hour, and briefly to 1200 deg F, the 1050 deg F requirement should be met without difficulty.

The centerline sensor sheath will have a maximum OD of 1/16". Inside this sheath, we plan to use the same type stub transducer as in the ORTC test. The ultrasonic line configuration for the FFTF-type fuel pin will be basically simpler than for ORTC; there will be a single (not dual) coil and only a single lead-in line. The reliability of this single line will be better than the dual-line, composite sensor (ORTC) experiment, since ultrasonic design variables will not have to be compromised in favor of thermocouple requirements.

Test design should be finalized next quarter, following a design freeze on the FFTF fuel pin concept. Materials such as W/Re tubing have already been ordered.

The GE furnace has been delivered to our facilities. Currently plans are being made to install it for testing the FFTF sensor models.

- (a) Electrical pulse applied to the coil.
 $5\mu\text{s}/\text{cm}$ abscissa, $20\text{v}/\text{cm}$ ordinate.

545°C 2mw H $5\mu\text{s}/\text{cm}$ 1637 2/24/70

- (b) Echoes in about 5 inches of
 Remendur wire with the 1/2 inch
 coil on one end. Reactor under
 power 6 days. $20\mu\text{s}/\text{cm}$ abscissa,
 $100\text{mv}/\text{cm}$ ordinate.

545°C 2mw H $20\mu\text{s}/\text{cm}$ 1637 2/24/70

- (c) Echoes in wire as seen at
 $200\mu\text{s}/\text{cm}$ on the abscissa.

545°C 2mw H $100\mu\text{s}/\text{cm}$ 1637 2/24/70

FIG. 1

ULTRASONIC TEMPERATURE TRANSDUCER COILS

(Anodized Aluminum Wire & Ceramic Cement)

As prepared and calibrated by Panametrics
for the BSR Irradiation Experiment

1-13-70

Coil Resistance (ohms)

● COIL 1
▲ COIL 2
■ COIL 3

Coil Temperature

°F

FIG. 2

Room temp 7.5 Ω

C

KEE 20 X 20 TO THE INCH 46 1240
MADE IN U.S.A.
KEUFFEL & ESSER CO.

ultrasonic
transducer
terminals

Remendur

10" max
0"

15" max
6" min

2"

.020 Re

.009

OPTION I

OPTION II

OPTION III

Fig. 3 ORTC options, schematic. Not to scale. W/Re alloys include W/3, 5, 26% Re.

TRANSDUCER TEMPERATURE

Room temperature

5V/cm

20 μ s/cm

$R_{coil} = 7.4$ ohms

500 deg F

$R_{coil} = 13$ ohms

1000 deg F

$R_{coil} = 21$ ohms

2V/cm

1060 deg F

$R_{coil} = 22.5$ ohms

2V/cm

Fig. 4. Oscillograms for test of stub transducer. Echoes are for 2 inch long rhenium sensor at approximately room temperature. Temperatures shown next to oscillograms are the temperatures of the transducer. Results show that the **stub** transducer gives much clearer echo pattern than long remendur lines used previously, even for transducer temperatures as high as 1060 deg F.

NOT TO SCALE

Fig. 5 ORTC Ultrasonic Line Configuration - schematic.