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MASTER

ULTRASONIC THERMOMETRY IN LMFBR SYSTEMS

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Progress Report

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PROGRESS

During the last quarterly period of 1969 most details of the BSR test were finalized. The ORTC test configuration was nearly completed, with some detail work remaining. The FFTF-type sensor and transducer configurations have been advanced. Fabrication of the FFTF fuel pin prototype simulation, for laboratory testing, should begin next quarter.

BULK SHIELDING REACTOR (BSR)

The purpose of the BSR test is to determine what effect, if any, gamma radiation will have on a magnetostrictive transducer at high temperature. In preparation for the BSR test, an anodized aluminum coil has been operated over 1100 deg F for over an hour, and briefly, up to 1200 deg F. Other high temperature coils of this type construction have been 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 have been studied as alternatives to gamma heating.

To self-heat the coil, two approaches were attempted: dc heating, and pulse heating. In dc heating we had to avoid short-circuiting the coil by the low impedance of the available power supply (voltage source). This could be accomplished by placing a $3/4$ hy choke coil between the power supply and the transducer coil. However, the only $3/4$ hy choke immediately available had a dc resistance of 32 ohms which meant it would have had to dissipate more power than the transducer coil. A second, preferable method, was then tried - simply switching off the power during the moment one wanted to monitor the transducer. Coils tested in this manner burned out at 400, 700, 800 and 1000 deg F, at up to $\sim 1/2$ amperes self-heating current. The basic problem in self-heating the coils, then, was local overheating beyond the 1220 deg F m. pt. of the aluminum wire used in these coils.

The pulse self-heating approach, which also suffers from local overheating, would have used a prf of ~ 60 pps, and a duty cycle of up to $\sim 50\%$. The end of the rectangular, nondrooping pulse would generate echoes which could be observed during the off period.

The local overheating difficulties associated with coil self-heating were avoided by using a separate heating coil, Fig. 1. Oscillograms

Schematic of waveform anticipated in pulse self-heating arrangement. Trailing edge of drive pulse would yield sensor echoes which could be observed during pulse "off" interval.

demonstrating the satisfactory operation of this arrangement to ~1000 deg F are shown in Fig. 2. This arrangement ran for 172 hours before the transducer coil failed. This approach later was abandoned because the added heater coil apparently would not closely simulate the configuration for the future ORTC test. Also, the additional lead wires would be undesirable in the BSR test.

It has now been decided to use a heavy walled stainless steel tube as a gamma susceptor into which the coil will slide.

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

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 Panametrics 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, 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 restriction has been overcome, making available new design options.

Figure 5 is the latest 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 RTD redundancy; if one coil should fail prematurely, the second may be used
- 4) two resistance thermometers (RTD)
- 5) fabrication easier than previous designs.

Some work is still required on the design of Fig. 5. As the lead-in wires become hot there is a tendency for the insulators (not shown) to spread the two wires apart near the sensor joint. If this does happen it will distort or interfere with the echo at the beginning of the sensor by introducing a spurious echo very near it. Various methods of overcoming this problem are now being investigated.

Another possible problem still being considered is the sensor bending in the test furnace at GE-NSP, Evendale, Ohio. If it is determined that bending was caused by differential thermal expansion, a spring type arrangement may be employed above the coil to take up this expansion.

*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.

Regarding ORTC materials for the ultrasonic line, it appears that W/26Re for the lead-in, and possibly for the sensor too, offers several promising advantages:

- 1) compatibility with preferred sheath material
- 2) less brittle than pure W lead-in
- 3) avoids weld in hot zone.

Preliminary attenuation data previously had been obtained by Panametrics in a NASA program on W/Re alloys to about 4000 deg F.^{1*} Following A. Arave's cyclic tests on W/26Re to ~4500 deg F at Idaho Nuclear Corporation, plus a definitive statement on the latest preferred sheath material (W/Re), it was decided to increase the temperature range over which we had previously^{1*} measured attenuation in W/Re. Measurements with a 1/2" coil (~5 μ sec pulse width) indicate an attenuation of ~1 db/inch at 4500 deg F. Preliminary measurements were also obtained with 1" and 2" coils. So far it appears that the attenuation is low enough not to be troublesome. Additional calibration is required, however, to justify switching from pure Re to W/26Re for the ORTC tests, and subsequently, for FFTF sensors.

In preparation for the ORTC test of early April a line such as Fig. 5 will be heated to the temperature expected in the ORTC test.

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

*¹L. C. Lynnworth and E. H. Carnevale, NASA CR-72339 (Aug. 1967).

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 hr, 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.

Fig. 1 Experimental configuration to simulate BSR and test heating coil.

Room temp.
 $.5\text{V/cm}$
 $20\ \mu\text{s/cm}$

600°F
 $.2\text{V/cm}$
 $20\ \mu\text{s/cm}$

1000°F
 $.2\text{V/cm}$
 $20\ \mu\text{s/cm}$

Fig. 2 Oscillograms obtained with setup of Fig. 1.

ultrasonic
transducer
terminals

10" max
0" min

15" max
6" min

2"

Remendur

W/Re TC

.009

.009

.020 Re

butt
brazed

OPTION I

W/Re TC

Re or W/Re

flexible joint
allows for differential
expansion of tc legs

OPTION II

TC not connected to
ultrasonic line

W-Re

Re or W/Re

weld, or
continuous member
with dia change

OPTION III

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

TRANSDUCER TEMPERATURE

Room temperature

5V/cm
20 μ s/cm
 $R_{\text{coil}} = 7.4$ ohms

500 deg F

$R_{\text{coil}} = 13$ ohms

1000 deg F

$R_{\text{coil}} = 21$ ohms
2V/cm

1060 deg F

$R_{\text{coil}} = 22.5$ 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. For better fitting inside 3/8" OD SS tubing, coils may be offset axially. Smaller diameter coil lead wire extensions may also be used, instead of the 0.020" now envisioned.