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ULTRASONIC THERMOMETRY IN LMFBR SYSTEMS

Progress Report

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Covering **the** Quarter Ending June 30, 1970

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Summary

In this quarterly period progress **has** been made on **two** aspects of the project.

1) Several models of the ORTC-4 composite sensor have been tested in a furnace and a modification of the design has been decided upon.

2) The FFTF centerline sensor simulation design has been finalized, and the parts procured or ordered. The electromagnetic connector-transducer for manipulation under liquid sodium has been built and tested at room temperature. The method for heating the simulated sensor has been decided, and work on the heating apparatus is progressing. Part of this work continues to be the installation of the tungsten tube furnace.

ORTC-4 Test

Our original ORTC-4 composite sensor design (**NYO-3906-9**, Fig. 5) met with only limited success, failing above 1800 C in **two** modes. Above 1800 C the signal deteriorated; one problem is thought to involve pressure contact between the sensor and/or the lead-in wire against the hafnia insulator or the sheath. Differential thermal expansion between the W-3 Re and the W-25 Re thermocouple wires may be the cause. Another possibility is that the end of the sensor may be fusing onto the insulator tube which it is placed into. Photographs taken of the sensor after the test at ORNL indicate this.

Three other approaches were attempted. These are as follows:

1) BeO insulators were supplied by R. L. Shepard and were experimented with as a replacement for the hafnia insulators. The BeO insulators were found to be less restrictive at room temperature than **the** hafnia insulators because of **the** straightness **of** the bore in the BeO.

2) Short sections **of** 2-hole hafnia insulators separated by single bore hafnia insulators were tried in an attempt to reduce the restriction on the lead-in lines. This approach was not successful.

3) The use of a noncomposite ultrasonic line eliminating the insulators and second tc leg was suggested. This approach is known to be good ultrasonically, but the lack **of** thermocouples **is** a drawback.

A noncomposite ultrasonic line (3rd type, above) was sent to R. L. Shepard at ORNL for calibration runs. The line was heated repeatedly to a temperature of 2360 C. During the calibration runs the transit time of the rhenium sensor differed by no more than ± .1 μ s from the rhenium calibration curve established by Panametrics (see NYO-3906-8, October 1969, Appendix A),

In addition, a composite line was sent to R. L. Shepard for testing. This line employed a BeO insulator which had straighter bores than the hafnia insulators previously used, and interfered less with the echoes. However, during testing the BeO insulator* melted prematurely (2000 C) and fused to the T. C. legs causing a loss of signals. Also, the sensor apparently welded to its surroundings. These difficulties, however, are not attributed to the ultrasonic line.

Very recently R. L. Shepard obtained a 3-hole insulator of suitable OD and bore to be used for the ORTC test. With a 3-hole insulator it is possible to use two holes for the thermocouple wires and the third hole for a separate ultrasonic thermometer line. Such a configuration is advantageous because the differential thermal expansion in the two thermocouple wires would have no effect upon the ultrasonic signal. It is thought that the stress due to differential thermal expansion in the composite sensor design has contributed to the malfunctioning of previous models by binding up the acoustic waveguide wire in the insulator hole and pushing the acoustic sensor against its sheath. Hence it has been decided to utilize the 3-hole insulator with the ultrasonic sensor separate from the thermocouple wires for the ORTC-4 test. That is, a noncomposite ultrasonic line is to be run in parallel with an ordinary thermocouple. See Fig. 1. The noncomposite line is the preferred ultrasonic configuration, and will ultimately be used in all FFTF work, As noted above, a noncomposite line worked to 2360 C in a furnace at Oak Ridge.

During June two such noncomposite ultrasonic lines were built, fitted with transducers and delivered to R. L. Shepard. Each line consists of a rhenium lead-in line etched at the end to form a 2 in. sensor. See Fig. 2. The remainder stub and terminator configuration remain identical to that of the previous composite line. (See NYO-3906-9, Fig. 5). It was decided to use an etched rhenium line for two reasons:

* Note added in proof: Chemical analysis showed that the insulators were actually Al_2O_3 .

1. Reliability (no sensor to lead-in line weld).
2. Size restriction (< 0.0125 in. diameter).

One of the **two** lines will be tested by R. L. Shepard prior to the actual test planned for ORTC-4 in late July.

FFTF Simulation

A. Design and Construction

The design for the FFTF fuel centerline sensor simulation has been finalized. The design is based upon the following three conditions:

- 1) The sensor must survive and function in an environment of UO_2 outside its protective sheath at a temperature of 5000 F.
- 2) The transducer must survive and work at the liquid sodium outlet temperature, designed to be no higher than 1050 F.
- 3) The heat for the sensor must be supplied from the outside since the UO_2 will be supplying no heat in the simulation.

The resulting design is shown in Fig. 3. The sensor is a 4-in. piece of rhenium wire of 0.015 in. diameter. The lead-in wire is tungsten of 0.020 in. diameter. Surrounding these is a tungsten **26** rhenium sheath of 0.062 in. OD and 0.009 in. wall to protect the wires in the region of the fuel. In the gas-filled plenum above the fuel, the **W-26 Re** sheath is replaced by a 316 stainless steel sheath of 0.050 in. OD and 0.006 in. wall which goes through and is welded to a stainless cap to make a gas-tight joint. The stainless steel sheath continues to the transducer. Outside the sheath is the depleted UO_2 fuel in tube form with an ID of 0.063 in. and an OD of 0.148 in. (actually pellets with a center hole). The simulated cladding is a tantalum tube of 0.250 in. OD and 0.020 in. wall. This Ta tube can serve as an electrical resistance heater or as a tube to withstand the requisite temperature within another furnace. The Ta tube is welded shut with a Ta cap at the bottom and the above mentioned stainless steel cap at the top.

The length of the simulated fuel pin is shorter than the length of a real fuel pin (P.N.L. DWG. NO. SK-3-14583/1/1, 5th issue) because of the limited length of the available furnaces. The length has been

foreshortened at the bottom because material below the sensor is extraneous to the experiment. It **has** been foreshortened in the relatively cool plenum region also because the temperatures below about 2000 F will have a negligible effect upon the tungsten lead-in line.

Materials have been ordered, and much has been received. Significant items still outstanding are as follows:

1) UO_2 fuel pellets. R. L. Shepard has begun work on having them bored to 1/16 in. ID to surround the sheath.

2) **W-Re** sheath. The first order for this material has been canceled because of late and indeterminate delivery by the vendor. **A** second order has been placed with a new vendor, with delivery promised by **24 July**.

B. Heating Method

A modification has been made to the preferred configuration for heating the FFTF sensor simulation model. See Fig. 4. In the modification, an auxiliary heater will be mounted in a gas plenum above the G. E. furnace to heat the upper portion of the simulated cladding to about 2000 F. See Fig. 4 for the configuration of the furnace and heater, and Fig. 3 for an indication of the region to be heated to 2000 F. The auxiliary heating was agreed upon by S. N. Ceja as a reasonable method to achieve the temperatures to be expected in the fuel pins above the fuel meat itself. Heating this region **is** important for simulating thermal cycling of the weld between the W-Re lower sheath and the stainless steel upper sheath around the lead-in **wire**.

C. Electromagnetic Connector

An electromagnetic connector **as** in Fig. 5 was built tested. Its design will permit connecting and disconnecting in liquid sodium or other environments, and isolates the electrical drive element from the magnetostrictive driven element in separate, stainless-steel-enclosed chambers. The connector was found to reduce the amplitude of the signals only by 2 dB due to the shielding effect of the stainless steel tubes between the transducer and remendur stub. The connector had no adverse effect on signal shape. Operation of the electromagnetic connector was successfully demonstrated to S. N. Ceja during **his** visit on **23 June**. This type of connector will be used in the FFTF centerline sensor simulation test and **is** proposed for subsequent **FFTF tests** and for use in instrumenting operating reactors.

D. Tungsten Tube Furnace Installation

The installation of the tungsten tube furnace received from G. E. -Evendale *is* progressing steadily. Not yet obtained are replacements for a pair of large thoria insulators which are badly cracked.

The designs for the interior baffles and exterior auxilliary heater and **gas** plenum are almost complete and will be finished soon. See Fig. 4. Construction of these units will begin immediately thereafter.

APPENDIX A

The following report on the Acoustical Thermometers subcommittee meeting at the June ASTM meeting in Toronto is included in this report.

Acoustical Thermometry was discussed at an Evening Workshop Session of the American Society for Testing and Materials (ASTM Committee E-20, Sub VI) on June 25 in Toronto, Canada, as part of the 1970 Annual Meeting and North American Materials Exposition. ASTM's E-20 Subcommittee VI on Acoustical Thermometers was formed in April 1969 at the Society's Philadelphia headquarters (see ULTRASONICS Oct. 1969).

The purpose of the Toronto session was to review Government, industrial and research requirements on acoustical thermometers, to report on applications in the nuclear, jet engine, steel and glass industries, calibration, temperature profile determinations, remote sensing, cryogenic and high temperature applications, etc.

The group heard progress reports on the Resonant Sensor Thermometer developed by Prof. J. F. W. Bell, now at the University of Aston in Birmingham, England; on A. Arave's in and out-of-pile reactor tests using W/Re sensors to ~2500 C at the Idaho Nuclear Corporation; on R. L. Shepard's 600 hour transducer tests at 500 C at 2 Mw in the Oak Ridge National Laboratory bulk shielding reactor (BSR), as well as design details and Shepard's preliminary results on a composite thermocouple/ultrasonic sensor; and on multiple echo techniques developed by E. P. Papadakis, L. C. Lynnworth and K. A. Fowler of Fanametrics. Brief reports on dual measurements such as temperature plus flow, temperature plus pressure, temperature plus viscosity, etc., and reference to the jet engine work of S. S. Fam, et al, of Panametrics conducted for a jet engine manufacturer, and also Solar's work for the Navy, were included. K. A. Fowler's temperature measurements on steel at 1000 C were also cited. Cryogenic calibration work is proceeding in the USA and Great Britain, but progress reports were unavailable from the laboratories performing this work.

Further details are available from the investigators mentioned above, or from the Chairman of the Acoustical Thermometers subcommittee, L. C. Lynnworth, Fanametrics, Inc. , 221 Crescent Street, Waltham, Mass, 02154 USA.

APPENDIX B

The following is a summary of a paper submitted for presentation at the IEEE Nuclear Science Symposium: Nuclear Instrumentation for R&D, Statler-Hilton Hotel, New York City, November 4-6, 1970.

APPLICATIONS OF NEW ULTRASONIC TRANSDUCERS TO MEASURING FUEL TEMPERATURE, SODIUM TEMPERATURE PROFILE AND BOILING

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New magnetostrictive and piezoelectric transducers have been developed, which expand the scope and improve the accuracy and reliability of ultrasonic measurements in LMFBR-type applications.

A magnetostrictive transducer assembly consisting of a coil of anodized aluminum wound around a remanent magnetostrictive wire was tested in-core at ORNL for over 600 hours above 500°C and was found not to degrade. Fluence was $2.5 \times 10^{13} \text{ n cm}^{-2} \text{ sec}^{-1}$ for a dose of about $5 \times 10^{19} \text{ n cm}^{-2}$. The coil as a resistance thermometer registered within 10°C of adjacent thermocouples. This type coil can be housed in a stainless steel tubular container, separate from the remanent transducer per se to which it is magnetically coupled. Therefore the electro-acoustic system can be disconnected and reconnected literally at the hyphen, even while under sodium. The application of this transducer to ultrasonic measurement of fuel centerline temperature, and its use in a composite ultrasonic (Re sensor)/thermocouple (W/Re) calibration experiment, are described. Ultrasonic measurement of up to ten temperatures in sodium using only one stainless steel wire is also indicated. The same thin wire and associated transducer has also been used passively in the acoustic emission mode to monitor stressed specimens heated to -500°C, and, separately, to listen for boiling of water.

Piezoelectric transducer assemblies have been developed, to provide video pulses or rf bursts over a ~10:1 frequency range. Such transducers can resolve echoes from closely spaced targets, at an optimized

pulse width or operating frequency. Accordingly, they are useful in identifying the presence and location of bubbles in a liquid. Experiments conducted in water demonstrate that 5 to 10 regions (channels) can be monitored continuously using only a single transducer located remote from the region of interest.

These new magnetostrictive and piezoelectric transducers **may also** be applied to measuring liquid level, measuring flow in a nonpenetrating (nondisruptive) manner, measuring pressure, nondestructive testing and surveillance, and in **some** cases, determining **two** independent variables simultaneously.

Fig. 1. Separate ultrasonic thermometer and thermocouple in 3-hole insulator. This configuration will be used in the ORTC - 4 test in July.

Fig. 2. ORTC - 4 ultrasonic thermometer details.

Fig. 3. FFTF simulation design configuration showing simulated fuel pin with centerline sensor, sheath, and transducer.

Fig. 4. Configuration for two-zone heating of the simulated fuel pin in the FFTF simulation test.

Fig 5 Detail f d

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