APR 20 1968

NYO-3906-2

MASTER

ULTRASONIC THERMOMETRY IN LMFBR SYSTEMS

Second Quarterly Progress Report

Contract AT(30-1)-3906

Covering the Period January 1, 1968 - March 31, 1968

Work performed for

Development Contracts Division
U. S. Atomic Energy Commission
New York Operations Office
New York, New York

April 1968

by

S. Fam
L. C. Lynnworth
E. H. Carnevale

PANAMETRICS, INC.
221 Crescent Street
Waltham, Massachusetts 02154

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

This document is

PUBLICLY RELEASABLE

Larry E. Williams
Authorizing Official

Date: 05/30/2007

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

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 second quarter may be summarized as follows:

- (1) The feasibility of using the spacing wire or the cladding as ultrasonic temperature sensors has been demonstrated.
- (2) Ultrasonic isolation of the lead-in wire from the sheath has been achieved. Spacing wires were helically wound around 25 ft lengths of 0.063" SS 304 and 0.050" W lead-in wires. In general, the resulting attenuation was found to be negligible if the ratio of spacing wire diameter to lead-in wire diameter was less than $\sim 1/10$. Some increase in attenuation was observed when the spiral-clad wire was placed inside a SS 304 protective sheath. Subsequent heating to 1200°F produced no significant increase in attenuation.
- (3) Attempts to wet wind transducer coils with a zirconia base cement (Sacreisen No. 29) were unsuccessful. This type of cement was being considered for transducer operation in the temperature range 1000°F to 2000°F . Other cement bases, viz. Al_2O_3 , SiO_2 , Na_2O are being considered for this purpose, as well as the possibility of using anodized tantalum. For the lower temperature range ($< 1200^{\circ}\text{F}$) a 0.5" long anodized aluminum coil

was found to give good signals. No degradation of the signals was observed when the coil was heated with a torch to about 800° F. Longer coils, using both copper and aluminum wire, (3.0") are being wound for field tests at ANL. The longer coils correspond to the lower frequencies necessary to minimize attenuation.

- (4) In preparation for the sodium-immersion tests in the oscillator rod facility at ANL, a special 16" SS 304 top flange and most of the spiral wound lead-in wires, sensors and transducers have been fabricated. The SS 304 sheaths will either be of one-piece construction, or be welded and helium leak-checked. Ultrasonic testing will be conducted at Panametrics before shipment to ANL. At ANL, the field tests are scheduled for the week of April 29th.
- (5) A preliminary measurement has been made of the speed of sound in tungsten at its melting point (6170° F).
- (6) A summary of a proposed technical report entitled "Ultrasonic Thermometry for Nuclear Reactors" has been prepared, and, if approved by the AEC and NASA, will be submitted for presentation at the 15th Nuclear Science Symposium, Montreal, Canada, October 23-25, 1968.

LABORATORY TEST PROGRAM

The feasibility of using the spacing wire or the cladding as ultrasonic temperature sensors has been demonstrated with a 0.056" Remendur magnetostrictive wire, a 0.063" SS 304 lead-in wire, and, more recently, with a 0.050" W lead-in wire.

In order to obtain acoustic isolation of the lead-in wire from the sheath, spacing wires were helically wound about 25 ft lengths of 0.063" SS 304 and 0.050" W lead-in wires. In general, the resulting attenuation was found to be negligible if the ratio of spacing wire diameter to lead-in wire diameter is kept below $\sim 1/10$ (Figs. 1 and 2). Some increase in attenuation was observed when the spiral-clad wire was placed inside a SS 304 protective sheath (Fig. 3). Subsequent heating to 1200°F (Fig. 4) produced no significant increase in attenuation.

The velocity of sound in W at its melting point has been measured for the first time by the self-heating technique in the setup shown in Fig. 5. The preliminary measurement yielded a value of approximately 3500 m/sec $\pm$ 500 m/sec. More work is required to determine the dependence of this value on tungsten purity, history, time at temperature, hysteresis effects, etc.

Attempts to wet wind transducer coils with a zirconia base cement (Saureisen No. 29) were unsuccessful. This type of cement was being considered for transducer operation in the temperature range 1000°F to 2000°F. Other cement bases, viz. Al_2O_3 , SiO_2 , Na_2O are being considered for this purpose, as well as the possibility of using anodized tantalum. For the lower temperature range ($< 1200^\circ F$) a 0.5" long anodized aluminum coil was found to give good signals. No degradation of the signals was observed when the coil was heated with a torch to about 800°F. Longer coils, using both copper and aluminum wire, (3.0"), are being wound for use in the field tests at ANL. The longer coils correspond to the lower frequencies necessary to minimize attenuation.

It may also be possible to take advantage of the high temperature, radiation resistant coils which Atomics International developed

in connection with the SNAP program. These coils were wet-wound using various inorganic encapsulants and have been successfully tested to 1100°F in a radiation environment of 1.16×10^{19} nvt ($E > 0.1$ MeV) and 3.9×10^{10} R, gamma. However, the potential advantages of anodized aluminum or tantalum coils over the insulation encapsulated type lie in a greater ease of fabrication, greater turns density (higher ampere-turns at less current), and with the tantalum wire, higher maximum operating temperature, so far as the coil is concerned.

A considerable amount of time was spent in planning, fabricating, and testing the necessary hardware for the sodium-immersion tests at ANL. These tests are intended to achieve one or more of the following objectives (No. 1 being of paramount importance):

1. Demonstrate lead-in wire transmission through liquid sodium, with a ~ 25 ft path of the lead-in wire either directly immersed in liquid sodium, and/or contained in an immersed sheath. Tests will be conducted up to the maximum temperature capability of this ANL facility.
2. Determine the feasibility of using the immersed fuel cladding as a temperature sensor.
3. Determine the feasibility of using tungsten and/or SS 304 as lead-in wires. The tungsten wire would be sheathed in a SS 304 tube.
4. Demonstrate the structural integrity of the ultrasonic thermometer with respect to the liquid sodium environment.
5. Evaluate an arrangement consisting of a 50 ft lead-in wire with two 2" radius loops. The wire would pierce the cover with a Conax fitting and terminate in a fuel element tube. The transducer assembly in this case would be located above the cover flange.

6. Establish the feasibility of operating the transducer assembly in a sodium vapor environment. This may eliminate the necessity of having a 50 ft lead-in wire containing bends with a 2" radius of curvature, which would be necessary if the transducer unit were limited to operation outside the primary tank of the EBR II reactor.

To meet the above objectives, it is planned to simultaneously immerse five (5) probes in the liquid sodium as shown in Fig. 6. Each probe will have its own transducer assembly. Probes 1, 2 and 5 will be fitted with two sheathed SS 304 lead-in wires and a sheathed tungsten lead-in wire, respectively. Probe #4 will have a bare SS 304 lead wire. The sheaths will pierce the cover through a Conax fitting.

As a cross-check on the ultrasonic temperature measurement we propose to use one or more chromel-alumel thermocouples and/or a measurement of the speed of sound in liquid sodium, across a diametrical path in the vicinity of the probes. The latter method (Fig. 7) will involve coring two ~ 1" diameter holes through the insulation only (a minor operation; the holes in the insulation can easily be plugged afterwards) and temporarily coupling two ultrasonic buffer rods to the exterior of the pipe envelope.

At ANL, the field tests are scheduled for the week of April 29th.

Fig. 1. Experimental arrangement

Fig. 2. Scope display before winding 0.003" spiral spacing wire; room temperature

Fig. 3. Scope display at room temperature after winding spacing wire and sheathing in 0.019" dia x 0.012" W SS 304 tube.

Fig. 4. Scope display at 1200°F; isolated in heated SS 304 tube.

0.5 msec/cm

50 mV/cm

Fig. 5. Photograph of lab set up for ultrasonically testing self-heated wires. This experiment simplifies the acquisition of data up to the specimen's melting point.

Fig. 6. Sketch of Probe Cluster for tests in sodium at Argonne National Laboratory

SOUND VELOCITY,
FT/SEC

10,000

9000

8000

7000

6000

5000