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FFTF COOLANT THERMOCOUPLE DEVELOPMENT*

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MASTERABSTRACT

A group of twenty-four thermocouples was exposed to a fast neutron fluence of approximately 2.7×10^{21} as part of a program to develop sodium coolant thermocouples for the Fast Flux Test Facility (FFTF). Chromel/Alumel[†] is the most promising candidate thermocouple based on a negligible amount of decalibration and other thermal neutron reactor effects on this type of thermocouple. Chromel/Alumel, Geminol-P/Geminol-N^{††}, platinum/10% rhodium-platinum, tungsten/26% rhenium-tungsten, and 5% rhenium-tungsten/26% rhenium-tungsten thermocouples were subjected to a series of laboratory materials verification tests, response time tests, and emf calibration runs. The tests are being repeated after EBR-II fast neutron reactor irradiation to determine the extent of transmutation, or other property changes which would affect their performance in the FFTF. Although these initial thermocouple irradiations were run primarily for the purpose of developing measurement and handling techniques, much useful information is being obtained, which is being used in irradiation testing of additional base metal thermocouples.

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Similar laboratory tests were conducted on a second group of 55 candidate Chromel/Alumel thermocouples to determine their fast neutron reactor performance characteristics. This group of candidate thermocouples was purchased under an existing Hanford specification for thermal reactor coolant thermocouples. A new series of pre and post-irradiation high temperature response time and insulation resistance tests were performed on this group at about 1,000°F to determine these important parameters of interest to reactor operations and safety personnel.

INTRODUCTION

Reliable, accurate thermocouples are needed for application in measuring FFTF sodium coolant temperatures. The past performance record of thermocouples in thermal nuclear reactors and calculations of the transmutation effects occurring in several common types of thermocouples during thermal neutron irradiations indicate that Chromel/Alumel changes calibration less than other types of thermocouples ^(1,2,3,4,5,6,7,8). However, acceptable operation in a thermal neutron environment does not indicate that corresponding success will be achieved during application in the new fast neutron reactors being planned under the Atomic Energy Commission's Liquid Metals Fast Breeder Reactor Program (LMFBR), of which the Fast Flux Test Facility will serve an important function. Both the effects of the high level fast neutron flux and the high gamma flux on thermocouples, along with high temperatures, must be investigated because of the small amount of irradiation test data available.

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DISCUSSION

Some of the environmental parameters and operational goals predicted for the FFTF coolant thermocouples are listed below. These parameters are estimated to be representative of actual operating conditions based on the presently available conceptual and preliminary design information.

Anticipated FFTF Coolant Thermocouple Operating Conditions and Performance Goals

1. Temperature Range: 0°F to $1,200^{\circ}\text{F}$, with transient capability to $1,400^{\circ}\text{F}$. Some of the thermocouples in the recirculating sodium test loops will have ranges of 0°F to $1,400^{\circ}\text{F}$.
2. Radiation and Neutron Fluxes: 10^{16} nv - fast neutron flux density environment at the center of the core.
 10^{11} nv - slow neutron flux density environment 140 cm above the top of the core.
 10^{10} R/hr - gamma radiation environment at the center of the core.
3. Accuracy: $\pm 2^{\circ}\text{F}$ to 530°F and $\pm 3/8\%$ from 530°F to $1,400^{\circ}\text{F}$.
4. Corrosion: The coolant thermocouples must withstand the effects of exposure to liquid sodium at temperatures of 500°F to $1,200^{\circ}\text{F}$ for long periods of time with unimpaired performance.
5. Material: All material in contact with liquid sodium shall be AISI type 304, or type 3/6, stainless steel.

6. Exponential 63% Point Time Constant: 0.8 second or less in response to a step change of temperature near 1,000°F.
7. Thermal Transients: The maximum rate of change of coolant temperatures is expected to be 30°F/sec.

The coolant thermocouple development work for FFTF will result in the issuance of appropriate thermocouple specifications and ordering information at the end of the investigative project.

The assembly and calibration of all laboratory and hot cell test equipment is now essentially complete. Instrumentation for measuring room temperature response time, and thermocouple emf calibration curves was assembled and used to prepare the initial group of 24 candidate thermocouples prior to irradiating them in EBR-II, as shown in Figure 1, a photograph of the laboratory calibration equipment. Calibration was done by comparing the emf of a platinum/platinum-10% rhodium working standard thermocouple with each candidate thermocouple. The working standard thermocouple and each candidate thermocouple emf signal are monitored by the K-4* potentiometer facility, as shown in Figure 1. The thermocouples were connected to the K-4 potentiometer by means of a sixteen point, low-thermal-emf-generating-type thermocouple switch. A comparison calibration was then performed on the candidate thermocouples at 200°F intervals from room temperature to 1,400°F.

Five of the new group of 55 candidate thermocouples are shown in Figure 2.

Hot cell equipment is assembled in a small area of a large hot cell. After irradiation to a fast neutron fluence of 2.7×10^{21} , the first group of 24 thermocouples was shipped to Battelle Northwest from NRTS at Idaho Falls in a shielded cask. The cask was opened inside the hot cell (Figure 3 -

* Leeds and Northrup Co. Type K-4 Potentiometer

hot cell instrumentation and work area) and lead wires are being attached to the candidate thermocouples by capacitance-discharge welding or crimping techniques. Remote measurements are made of the thermocouple emf output versus temperature and other electrical parameters in a work area similar to that in Figure 3.

Figure 4 shows a schematic of the calibration method. The working standard is switched for monitoring by the same potentiometer as is used for the candidate thermocouples. This provides an accurate comparison check between the candidate thermocouple emf and the working standard emf. Note that all switching is done in the copper wires after the cold junction compensator.

Of the eight metallic-sheathed thermocouples in the first group of 24 thermocouples, six were 304 L stainless steel-sheathed and two were Inconel-sheathed. All 24 thermocouples, including 16 without cladding, were insulated with loose-fitting vitrified alumina or magnesia insulators. At the time of removal from EBR-II, the six 304 L-sheathed thermocouples measured about five Rads/hr of combined beta particle and gamma radiation at a distance of one foot. The inconel-sheathed thermocouples, mainly because of their higher nickel content, yielded the higher beta gamma exposure rate of about five Rads/hr at three feet. Due to unavoidable transportation and hot cell equipment installation delays, the thermocouple post-irradiation electrical testing began about one month after capsule disassembly. During this time, the short half life radioisotopes had decayed to beta gamma exposure rates of about three Rads/hr at one foot for 304 L-sheathed stainless steel and about 0.6 Rads/hr at three feet for the Inconel-sheathed thermocouples. This

lower exposure rate permitted more of the work than originally anticipated to be done using partial or "shadow shielding" techniques. Shadow shielding techniques greatly reduce the labor required to measure such parameters as radioactive thermocouple 63% point time constants. Special purpose tongs and localized shielding were utilized to advantage in connecting 0.020 in o.d. thermocouple extension lead wires to the 0.010 in o.d. candidate thermocouple leads and in conducting the other post irradiation electrical tests.

Figure 5 shows the Inconel-X temperature equalizing block and a group of test thermocouples. The candidate thermocouples and the working standard are wired together and the complete test assembly is inserted into the 0.75-in ID Inconel tube for calibration.

Figure 6 shows the sequence of steps in the development program. The laboratory tests and EBR-II irradiation are now complete on the first group of 24 thermocouples and the second group of 55 thermocouples awaits insertion in EBR-II. Irradiation information is now being obtained for the first group of thermocouples by means of a series of post-irradiation electrical tests.

The second group of 55 candidate nuclear thermocouples was purchased under an existing Hanford thermal reactor thermocouple specification. These thermocouples have performed reliably in many thermal neutron reactor capsule tests and in monitoring water temperatures in the Hanford production reactors. They are Chromel-P Alumel with compacted magnesia insulation and an AISI type 304 L stainless steel sheath. About half of this group was fabricated with grounded thermal junctions and the other half with insulated junctions. The second group of 55 candidate thermocouples is being tested

in a manner similar to that employed for the first group of 24 thermocouples with the exception that the response time and insulation resistance are measured at 1,000°F instead of at room temperature and thermocouple wire loop resistance is measured at 0°C in an ice bath. Irradiation information should be available for this group of thermocouples in the fall or winter of 1968.

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FIGURE 4
Thermocouple Calibration Facility Schematic

FIGURE 6
Block Diagram of one FFTF Thermocouple Development Cycle

FIGURE 1
Laboratory Calibration Facility for Candidate Thermocouples

FIGURE 2
Candidate Nuclear Thermocouples

FIGURE 3
Hot Cell Instrumentation and Work Area

FIGURE 4
Thermocouple Calibration Facility Schematic

FIGURE 5
Candidate Thermocouple Test Assembly

FIGURE 6
Block Diagram of one FFTF Thermocouple Development Cycle