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High Temperature Neutron Source
for UHTREX

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**High Temperature Neutron Source
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by

Robert W. Wiesener

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HIGH TEMPERATURE NEUTRON SOURCE FOR UHTREX

by
R. W. Wiesener

ABSTRACT

A $^{238}\text{PuBe}_{13}$ neutron source with an intensity of 1.3×10^7 n/sec has been fabricated and tested for use in the Ultra High Temperature Reactor Experiment (UHTREX).⁽¹⁾ The source is doubly contained in niobium and is designed to operate in the reactor helium environment at 500 psi and 2400°F. It will be used to facilitate hot restart following a scram or shutdown from high temperature power operation.

1. Introduction

Experimental data obtained during critical experiments with the UHTREX core prior to assembly in the reactor vessel indicated that a 10^8 neutrons/sec source mounted external to the reactor vessel at its midplane would produce adequate counting rates in startup detectors located on the opposite side of the reactor vessel. Therefore, this external source-detector geometry was designed and installed. However, experimentation with the external source after assembly of the reactor showed the background interference to be so large that observation of the reactor multiplication was difficult and uncertain. When the external source was removed and a 10^6 neutrons/sec source was installed in the central hole in the reactor core plug, count rate statistics were much improved. Extrapolation of these data led to the conclusion that placing a 10^7 neutrons/sec source in the center of the core would reduce the background and increase the count rate, in comparison with the 10^8 external source, to levels where reactor multiplication could be readily determined and safe startup could be facilitated. However, inquiries revealed that standard or commercially available neutron sources could not withstand the UHTREX core plug environment. Consequently, a high temperature neutron source was

developed at the LASL.

After the feasibility of a high temperature neutron source was demonstrated, the source was mounted on the end of one of the central plug control rods. On a startup, the plug rod position indicator would show the exact location of the source, without the necessity for development of a new source drive system, and, during reactor operations at significant power, the source rod would be completely withdrawn from the core. The rod would not be one of those selected to be dropped into the core by the nuclear safety system on a scram.

2. Description of Source

The 1.3×10^7 n/sec source is doubly contained in niobium and is designed to operate in the reactor helium environment at 500 psia and 2400°F. The source consists of 0.83 g of PuBe_{13} (80% ^{238}Pu - 20% ^{239}Pu). The PuBe_{13} was prepared with a small excess of beryllium present to minimize the presence of free plutonium. The source material is held in a beryllium oxide crucible surrounded by granular beryllium oxide filler material to prevent movement of the source relative to the niobium container. Adequate void volume is provided to prevent excessive pressure buildup from the alpha decay of the

plutonium. The source container configuration is shown in Fig. 1.

Fig. 1 UHTREX High Temperature Source.

Tests have been run to demonstrate the adequacy of the container to withstand the reactor core environment and to demonstrate that the PuBe_{13} is stable and no free plutonium is present. The doubly contained source was subjected to a 100 h proof test in helium at 500 psia and 2000°F before being installed in the reactor.

The source is attached to the end of one of the plug control rods as shown in Fig. 2. The source will be withdrawn from the core during operation at significant power levels. This method of operation will minimize the burnup of the source material and limit high temperature exposure for extended periods of time.

Fig. 2 UHTREX Source - Control Rod Assembly.

3. Fabrication

The sequence of operations and inspections performed to assure that a satisfactory source was obtained are listed in Table I.

TABLE I

$^{238}\text{PuBe}_{13}$ High Temperature Neutron Source Fabrication Sequence

1. Prepare $^{238}\text{PuBe}_{13}$ source.
2. Calibrate source to assure strength of $1.2 - 1.3 \times 10^7$ n/sec.
3. Encapsulate source in primary niobium container.
4. Alpha scan container exterior.
5. Helium mass spectrometer leak test primary container.
6. Radiograph container to check weld.
7. Install source in secondary container and spin plug closure.
8. Seal weld secondary container.
9. Alpha scan container exterior.
10. Helium mass spectrometer leak test secondary container.
11. Radiograph to check weld quality and PuBe_{13} configuration and location.
12. Proof test source (100 h at 500 psia and 2000°F).
13. Alpha scan source.
14. Helium mass spectrometer leak test source container.
15. Radiograph source to determine if the proof test had any detrimental effects on the containers and to check the PuBe_{13} configuration for possible changes.
16. Install the source in the control rod.
17. Install the control rod and source in the reactor.

The plutonium-beryllium alloy was prepared in a glove box to minimize the hazards of handling the plutonium.⁽²⁾ The required amounts of the two metals were weighed into a beryllium oxide crucible with the heavy plutonium metal on top of the lighter beryllium metal. The crucible and contents were then heated by means of a tantalum susceptor in an induction furnace containing an argon atmosphere. The two elements reacted vigorously as the temperature approached 1150°C. The exothermic reaction yielded a friable mass having the character of coke

which was further heated until it melted at about 1800°C. Upon cooling, a hard, brittle ingot of PuBe_{13} was obtained which has cavities caused by solidification shrinkage. The PuBe_{13} source and the beryllium oxide crucible were doubly contained in polyethylene bottles to facilitate handling prior to encapsulation in the niobium container.

The PuBe_{13} source strength was verified by comparing it with a 1.03×10^6 n/sec source. Two BF_3 detector channels were used to take one minute counts of the two sources in identical geometry. The calibration results are as follows:

	Channel #1	Channel #2
Average background	15	17
1.03×10^6 n/sec (avg. 10 counts)	9,938	11,236
$^{238}\text{PuBe}_{13}$ source (avg. 10 counts)	125,716	138,135
Calculated source strength	1.27×10^7 n/sec	1.30×10^7 n/sec

The source was encapsulated in the primary niobium container by TIG fusion welding. The capsule loading and welding were done remotely in a shielded drybox. The drybox was evacuated and then pressurized with a 90% helium - 10% argon atmosphere. The source, crucible and granular beryllium oxide were placed in the niobium capsule and the capsule cover was pressed into place with the rotary welding fixture. The TIG fusion weld was done automatically. The welding parameters were as follows:

Voltage	11 volts DC
Current	132 amps
Welding time	5 sec upslope - 13 sec weld - 5 sec downslope
Collet speed	12 sec/rev

The encapsulated source was alpha scanned, helium mass spectrometer leak tested and radiographed to assure that the container was sound. The results of this nondestructive testing indicated that the capsule was leak tight and the weld acceptable.

The source was then placed in the secondary container and the end plug spun in place. This operation was done on a standard lathe using special fixturing to minimize personnel exposure. The secondary container was sealed by TIG fusion welding, using the same technique as outlined for the primary container weld.

The doubly contained source was alpha scanned, helium mass spectrometer leak tested and radiographed.

The scanning and leak testing indicated that the container was leak tight. The radiography indicated that the secondary weld was satisfactory and shows the PuBe_{13} configuration and location.

4. Testing

Three tests have been run to demonstrate that the source will withstand the UHTREX environment. The test parameters and inspection techniques used are listed in Table II.

TABLE II

UHTREX Source Testing Outline

	Test I	Test II	Test III
Source Material	None	$^{239}\text{PuBe}_{13}$	$^{238}\text{PuBe}_{13}$
Source Strength	None	2.6×10^5 n/sec	1.3×10^7 n/sec
Container Material	Niobium	Niobium	Niobium + Niobium
Filler	BeO	BeO	BeO
Test Temperature	600°F to 2400°F	200°F to 2000°F	200°F to 2000°F
Test Pressure	0 to 500 psig	0 to 500 psig	0 to 500 psig
Duration	200 hours	200 hours	100 hours
Temperature Cycles	6 5	5	4
Pressure Cycles	6 5	7	5
Number of Samples	1 1	1	1
Inspection:			
Radiography	Before & After	Before & After	Before & After
Alpha Scan	None	Before & After	Before & After
He Leak Test	Before & After	Before & After	Before & After
Dye Penetrant	Before & After	Before & After	None

4.1 Test Number I. The primary source container design was verified by testing two niobium containers filled with granular beryllium oxide. The containers were exposed to temperature and pressure cycles in the corrosion test loop which simulated the carbon and helium environment to which the source will be exposed to in the reactor. Each of the dummy sources was exposed for two hundred hours in separate tests to sudden pressure drops, between 500 psig and 100 psig, and rapid temperature changes, from about 2400°F to 400°F in two hours. In the first test, the dummy source was exposed to six pressure and temperature cycles with a lower than planned maximum test temperature of 2000°F. In the second test the maximum temperature was higher than

intended, 2600°F. The second sample was exposed to five temperature and pressure cycles.

The capsules were helium mass spectrometer leak tested, radiographed, and fluorescent penetrant inspected before and after environmental exposure. The nondestructive testing showed no discernable change. Figure 3 is a photograph of one of the capsules after testing at 2600°F.

Fig. 3 Capsule After Testing at 2600°F.

4.2 Test Number II. A PuBe_{13} source using approximately two grams of plutonium-239 was fabricated to check out the handling and fabrication technique, efficiency of the α - n reaction in this configuration and for use in environmental Test Number II. This test was run to demonstrate that the PuBe_{13} was stable (no "free" plutonium present) and to assure that the source material would not attack the niobium primary container.

The test was run in an electric resistance furnace 1-1/2 inch i.d. x 3 inches long which is contained in an internally insulated stainless steel pressure vessel. The furnace temperatures were monitored by nine thermocouples and recorded on a multipoint recorder. Helium was supplied from a standard "H" cylinder equipped with a pressure regulator. The helium was vented through a filter

which was alpha scanned after each pressure cycle.

The source was exposed in the furnace for 200 h to a helium environment at 500 psig and 2000°F. During the test period the furnace was pressure cycled seven times (500 - 0 - 500 psig) with a total cycle time of five minutes while the furnace temperature was held at 2000°F. The furnace was thermal cycled five times. A typical thermal cycle is shown in Fig. 4.

Fig. 4 Typical Furnace Thermal Cycle.

The nondestructive testing performed before and after testing showed no changes in the source container. Radiography indicated that the PuBe_{13} configuration was not altered and no "free" plutonium was present. Radiographs of the source before and after testing are shown in Fig. 5.

4.3 Test Number III. The doubly contained source was subjected to a 100 h proof test before being installed in the reactor. The source was tested in a helium environment at 500 psig and 2000°F. During the test period the furnace was pressure cycled five

After Testing

Before Testing

Fig. 5 $^{239}\text{PuBe}_{13}$ Source Radiographs Before and After Environmental Testing.

times 500 - 0 - 500 psig with a total cycle time of five minutes while the furnace was held at 2000°F. The furnace was thermal cycled four times during the test. The same furnace was used as in Test Number II and a typical thermal cycle is shown in Fig. 4.

The results of the nondestructive testing performed before and after the proof test showed no changes in the containers or PuBe_{13} configuration. A photograph of the source after completion of the test is shown in Fig. 6. Radiographs of the source before and after testing are shown in Fig. 7.

Fig. 6 Source After Proof Test.

After Testing (Orientation Rotated 180°)

Before Testing

Fig. 7 Radiographs of the Source Before and After Proof Testing.

5. Conclusions

Environmental testing and inspection has verified the source design to be satisfactory for use in the UHTREX core environment. Results of the proof testing have demonstrated the ability of the doubly contained source to withstand the temperature and pressure conditions to which it will be exposed to in UHTREX. The results of the inspections performed before and after proof testing showed no

changes in the container or PuBe_{13} configuration.

The source will be used internally in the reactor to facilitate hot restart following reactor scram or shutdown from high temperature operation.

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