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THE USE OF THE NATIONAL LOW-TEMPERATURE NEUTRON IRRADIATION FACILITY FOR FUSION MATERIALS RESEARCH

R. R. Coltman, Jr., H. R. Kerchner, C. E. Klabunde
and F. W. Young, Jr.

SOLID STATE DIVISION
OAK RIDGE NATIONAL LABORATORY
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R. R. Coltman, Jr., H. R. Kerchner, C. E. Klabunde, and F. W. Young, Jr.

Oak Ridge National Laboratory, Solid State Division
P. O. Box X, Oak Ridge, TN 37831 USA

ABSTRACT

The National Low-Temperature Neutron Irradiation Facility (NLTNIF), now constructed and currently being evaluated, will provide high radiation intensities and special environmental and testing conditions for qualified experiments at no cost to users. The NLTNIF will be of interest for both basic and applied research on fusion reactor materials. A general description and major specifications of the facility are presented along with recent results of the performance tests. In addition, a description is given of the procedure and experimental assemblies needed to perform experiments in the NLTNIF.

Introduction

Since May 1983, when the Division of Materials Sciences, Office of Basic Energy Sciences of the Department of Energy authorized its establishment, work on the design and construction of the National Low-Temperature Neutron Irradiation Facility (NLTNIF) proceeded until it was completed in February of this year. (Work on auxiliary equipment continues.) This facility is located at the Bulk Shielding Reactor (BSR) in the Oak Ridge National Laboratory (ORNL). It is available for qualified experiments at no cost to users.

The NLTNIF provides a combination of high radiation intensities and special environmental and testing conditions that have not previously been attainable in the United States. Irradiations are possible at temperatures between 3.5 K and 800 K. The facility currently provides a large flux of fast neutrons (2×10^{17} n/m^{2}s, $E > 0.1$ MeV) at moderate gamma-ray intensity. Radiation modifiers will be constructed as needed to provide modified fast neutron spectra, thermal neutrons, or gamma rays. This facility is expected to be a valuable resource for evaluating the radiation tolerance of fusion reactor materials as well as for a wide variety of other problems in materials science.

Bulk Shielding Reactor

The core of the BSR is constructed of a rectangular array of square fuel elements suspended from a bridge and carriage assembly. This assembly allows the core to be positioned at almost any location in a 6 x 12 m open pool of demineralized water. The exposed core is fully accessible on three faces. The reactor can be operated for indefinite periods at any power up to 2 MW, and it is dedicated to the operation of the NLTNIF.

Two features of the BSR will be important to NLTNIF experimenters. First, the core fuel loading provides sufficient excess reactivity to permit restarting after any operating history — xenon poisoning is not an operational limitation. This is an asset for experiments that require frequent on-off reactor operations. Second, convenient locations are available in the open pool for ambient-temperature and cryogenic storage and test facilities for radioactive specimens. These facilities are located close to the irradiation cryostat, and they make use of pool water for biological shielding.

Irradiation Cryostat

The irradiation cryostat is shown schematically in Fig. 1 along with typical test and experiment assemblies. It is capable of cooling specimens to temperatures as low as 3.2 K during irradiation and testing (at reduced reactor power). Up to 100 g of metal can be irradiated at 5 K at full reactor power. The irradiation chamber is a 37-mm-diameter tube inside the lower, rectangular parallelepiped section of the cryostat, which occupies the position of a missing fuel element in the reactor core. Just above the irradiation chamber is a 197-mm-diameter test chamber for in-situ testing of irradiated samples. Liquid helium and liquid nitrogen are delivered to the two heat exchangers surrounding the test chamber. Depending upon the desired irradiation temperature, gaseous or liquid (condensed on the helium heat exchanger) helium cools the sample by circulating through the irradiation chamber in a natural convection loop. Because the test chamber is outside the irradiation zone, specimens can be irradiated to high fluences and then tested in the absence of nuclear heating, using unirradiated test devices that may be sensitive to radiation (e.g., a superconducting magnet as is illustrated in the figure).

The configuration described above optimizes the fast neutron flux at moderate gamma and thermal-neutron flux. In Table I are listed preliminary measurements of the radiation characteristics. It is expected that irradiations with highly thermalized neutrons and other modified spectra will also be of interest to some experimenters. Insertion of radiation modifiers into and out of position between the fixed cryostat and a core face will be accomplished easily in the open pool. Construction of such modifiers will be carried out as the needs arise.

Other Features of the NLTNIF

Although the design and construction of experiments are primarily the responsibility of the user, certain auxiliary equipment is on hand and available for experimenters' use. A computer-based, on-line data acquisition system is provided with hard-wired electrical terminals available at the cryostat top. Data can be tabulated, plotted, or transmitted to a distant computer over telephone lines for later analysis. Provisions are available for transfer of irradiated specimens at 4.2 K into the user's test device or into vessels for shipment to other laboratories. Temporary storage at 4.2 K or 308 K of radioactive samples or experiment assemblies is available in the BSR pool. Many times, short term storage will be needed to allow decay of short lived radioactive isotopes that may be present. A 12 T superconducting solenoidal magnet has been procured and will soon be mounted for use either in a poolside experiment dewar or in the test section of the irradiation cryostat. An ambient temperature irradiation facility (ATNIF) is available for irradiation at temperatures from ambient up to a maximum of about 800 K (using a furnace constructed by the experimenter). A 200 kV electron microscope is being procured, and a liquid helium stage and transfer device to move specimens from the irradiation cryostat to the microscope without warmup is under design. After completion of this microscope facility it will be possible to obtain direct microscopic structural information about radiation-induced defects and their thermal annealing as it occurs in the microscope.

Requirements for Experiments

The difficulty of carrying out experiments will vary greatly depending upon their complexity. The first experiments should be as simple as reasonable; for example, cryogenic irradiation with the specimens being tested at room temperature in the user's laboratory. The NLTNIF staff will suspend the user's specimens in an aluminum wire basket for the irradiation, remove them and store them for the user in such experiments. When in situ testing is desired, the user will need to construct a test assembly that can be suspended in the test chamber and a coaxial nesting specimen holder that can be lowered to the irradiation zone for irradiation and raised to the test chamber for testing. Examples shown in Fig. 1 are the 12 T solenoid and helically mounted wire specimens to be irradiated and tested electrically in a high magnetic field. Consultation with the NLTNIF staff will usually be required for proper design of experiment and test assemblies. The NLTNIF staff will also assist users in planning for low temperature transfer to cryostats in other major facilities (e.g., for characterization of irradiated samples by neutron diffraction).

All experiment proposals must be reviewed both for scientific merit (by a user's committee) and for reactor safety (by ORNL staff members). A proposal must include a brief description of the basis for the experiment and certain crucial technical details. Proposal forms are available on request. Prospective users should contact one of the authors.

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Table 1. Preliminary radiation characteristics at the full BSR power of 2 MW.

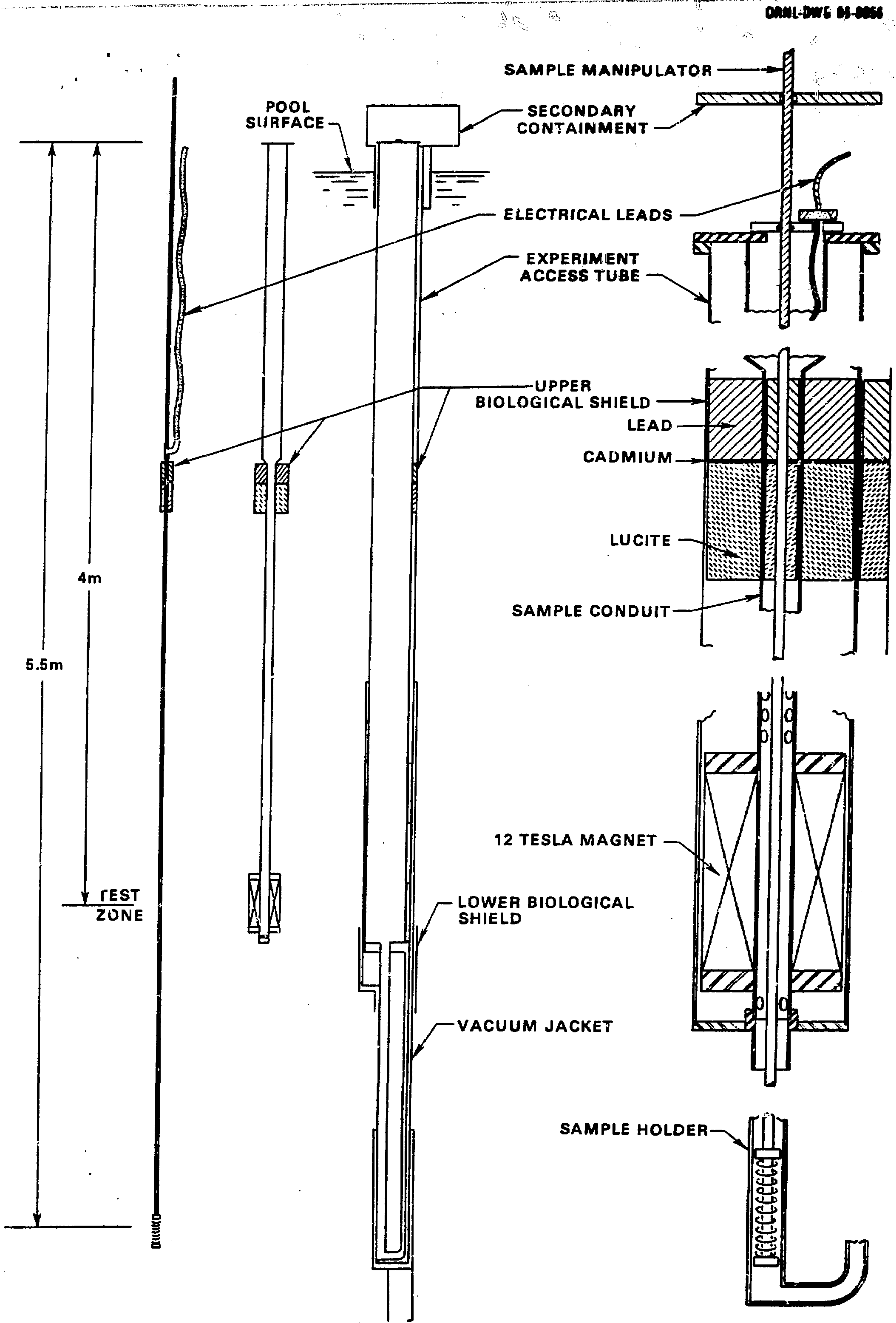
Radiation	Intensity
fast neutrons ($E > 0.1$ MeV)	1.8×10^{17} n/m^{2}s[a]
thermal neutrons	1.5×10^{17} n/m^{2}s[b]
gamma rays (in Al)	0.32 W/g[b]

[a] Determined by scaling more detailed neutronics measurements made in a hollow fuel element device to the results of measurements employing a Ni activation detector in a mockup of the cryostat.

[b] Determined by computer calculations and neutronics/nuclear heating measurements made in a hollow fuel element device.

Figure Caption

Fig. 1. Schematic cross sectional diagram of the NLTNIF irradiation cryostat along with a test assembly and experiment assembly. The test and experiment assemblies are to be nested coaxially in the cryostat. Enlarged views of portions of the nested assemblies are shown on the right.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SAMPLE MANIPULATOR
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CADMIUM
LUCITE
SAMPLE CONDUIT
5.5m
4m
TEST ZONE
12 TESLA MAGNET
LOWER BIOLOGICAL SHIELD
VACUUM JACKET
SAMPLE HOLDER