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CHARACTERIZATION OF THE NATIONAL LOW-TEMPERATURE NEUTRON IRRADIATION FACILITY

H. R. Kerchner, R. R. Coltman, Jr., C. E. Klabunde,

and F. W. Young, Jr.

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

Solid State Division, Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

Abstract

The National Low-Temperature Neutron Irradiation Facility (NLTNIF) is now operating at Oak Ridge National Laboratory. The facility provides high radiation intensities and special environmental and testing conditions for qualified experiments at no cost to users. A general description and major specifications of the NLTNIF are presented along with the results of performance tests. In addition, the hardware and other considerations required to perform experiments in the NLTNIF are described.

Keywords: radiation effects, neutron irradiation, nuclear reactors, cryogenics, user facility

Introduction

In May 1983 the Division of Materials Sciences, Office of Basic Energy Sciences of the Department of Energy authorized the establishment of the National Low-Temperature Neutron Irradiation Facility (NLTNIF) at the Bulk Shielding Reactor (BSR) in the Oak Ridge National Laboratory (ORNL). Work on the design and construction of the facility proceeded from that time until it was completed in February of this year. (Work on auxiliary equipment continues.) This facility 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 has been optimized initially for 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 used for a wide variety of experiments on radiation effects in materials.

Bulk Shielding Reactor

The core of the BSR is a rectangular array of square fuel elements resting upon a grid plate, which is supported by 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. Primary control of the BSR is available for the operation of the NLTNIF.

Two features of the BSR will aid 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, the open pool provides convenient locations 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. A layout of the NLTNIF is shown in Fig. 1.

Irradiation Cryostat

The irradiation cryostat sketched in Fig. 2 is capable of cooling specimens to temperatures as low as 3.5 K during irradiation and testing. At 5 K, 30 W of nuclear heating (generated in about 100 g of metal at full reactor power) can be removed from experiment assemblies during irradiations. The irradiation chamber is a 37-mm-diameter tube inside the lower, rectangular parallelepiped section of the cryostat, which nests inside a U-shaped gamma-ray shield in place of a missing fuel element. 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 by the refrigeration system to 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).

The configuration described above optimizes the fast neutron flux at moderate gamma and thermal-neutron flux. Preliminary measurements of the radiation characteristics are listed in Table I. It is expected that irradiations with highly thermalized neutrons and other modified spectra will be of interest to experimenters. A useful aspect of the open-pool construction of the BSR is the ability to move the core and insert radiation modifiers easily into and out of position between the fixed cryostat and a core face.

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. Short term storage is often essential to allow decay of short lived radioactive isotopes that may be present. A 12 T superconducting magnet is on hand 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. 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.

Requirememts 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. Consultation with the NLTNIF staff will 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^2s [a]
thermal neutrons	1.5×10^{17} n/m^2s [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.

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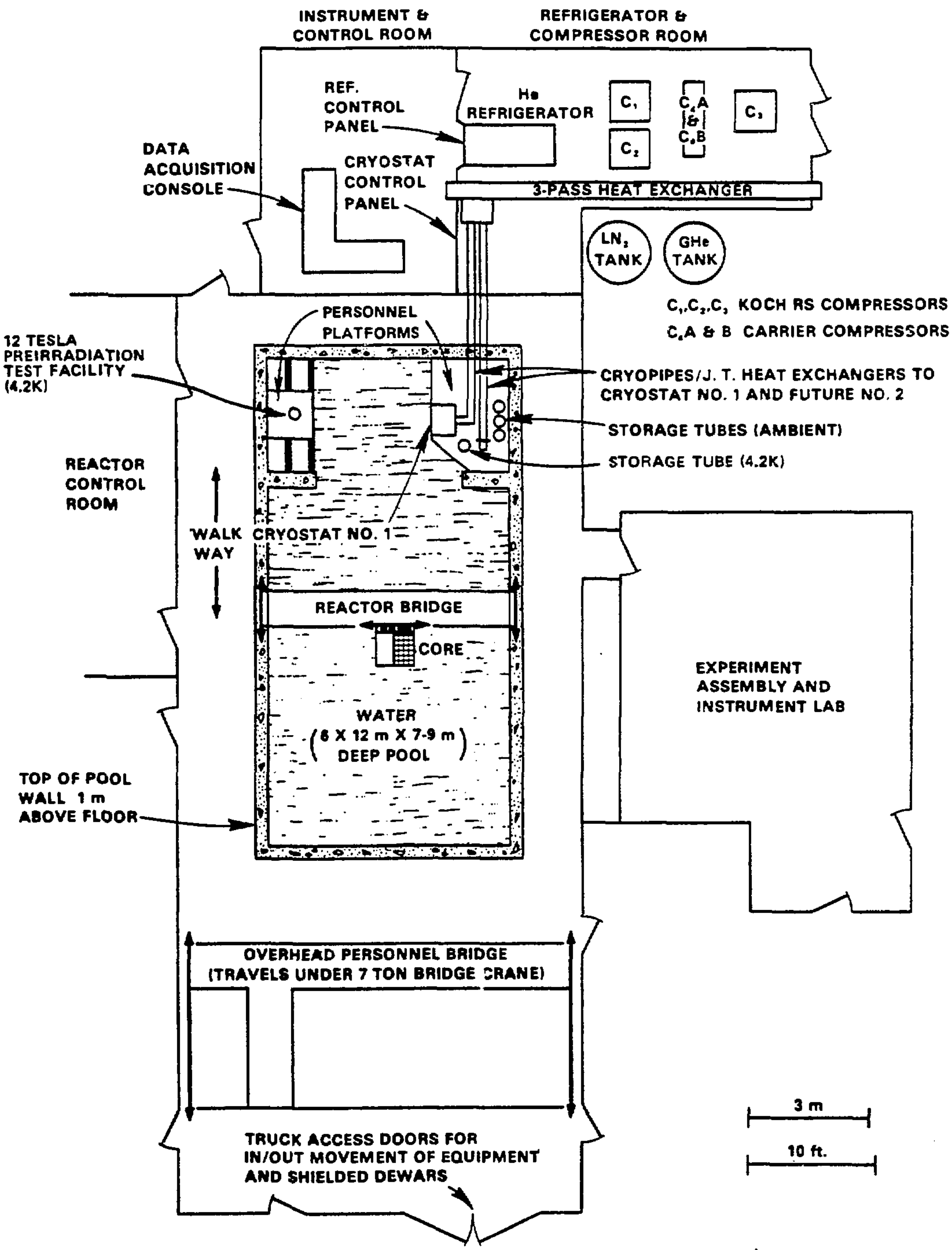

Figure 1. Layout plan for the NLTNIF at ORNL's Bulk Shielding Reactor

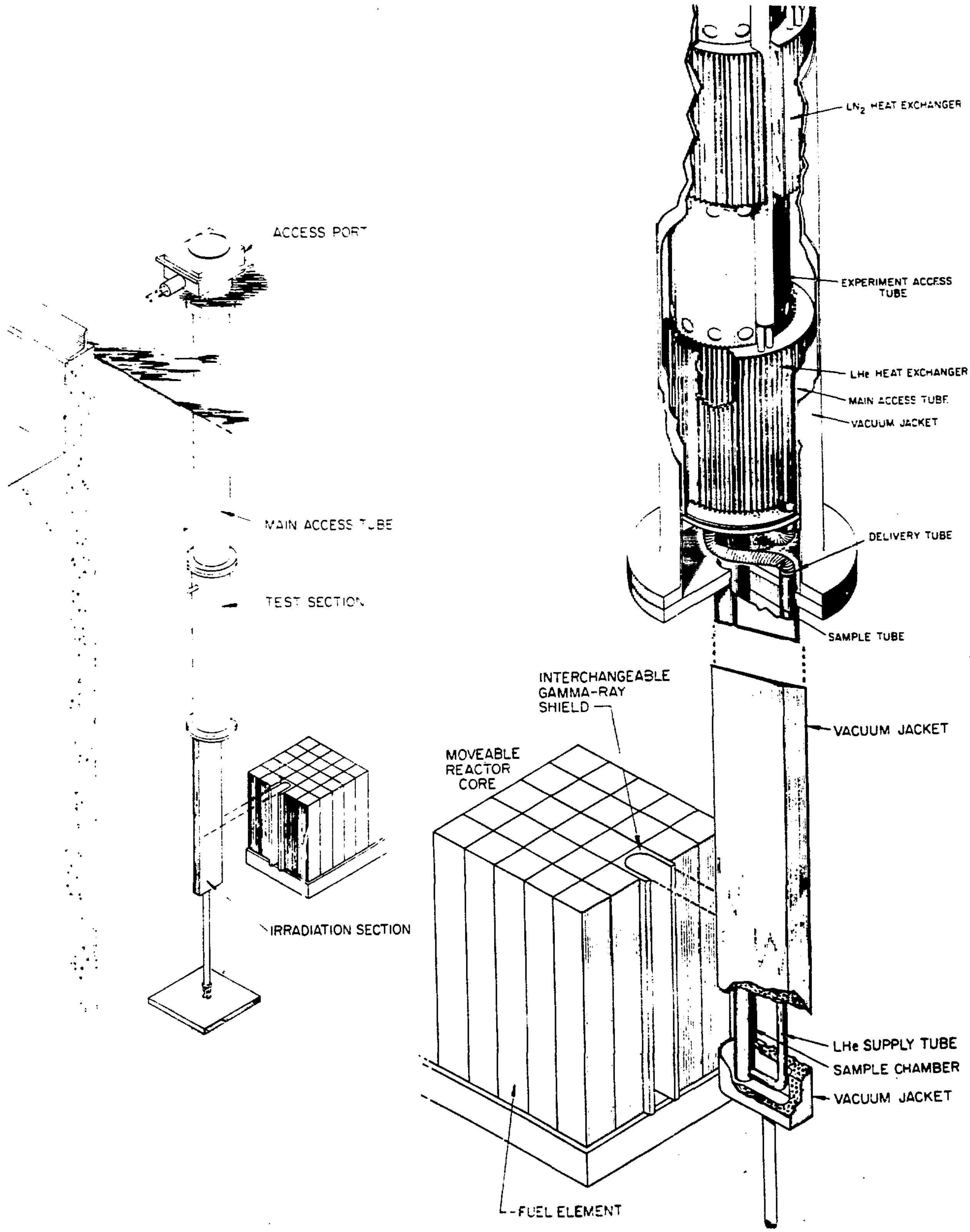

Figure 2. Irradiation cryostat