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THE REACTOR AND COLD NEUTRON FACILITY AT NIST

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H.J. Prask and J.M. Rowe
Reactor Radiation Division
National Institute of Standards and Technology
Gaithersburg, MD 20899

ABSTRACT

The National Institute of Standards and Technology Reactor (NBSR) is a 20 MW research reactor located at the Gaithersburg, MD site, and has been in operation since 1969. In the reactor hall there are 26 experimental facilities which are used for materials science, chemical analysis, nondestructive evaluation, neutron standards work, and irradiations. The reactor had built into it from the beginning a provision for a large volume cold neutron moderator. Utilizing this capability, the Department of Commerce and NIST have begun a project to develop a major national facility for cold neutron research, the CNRF. This $30M project will, when fully completed, provide fifteen new experimental stations with capabilities currently unavailable in this country. It will be operated as a National User Facility, open to all qualified researchers on the basis of scientific merit. One-third of the experimental stations will be provided by sources outside of NIST.

The NBSR

The reactor is D_2O cooled and moderated; the core is comprised of thirty, enriched-uranium fuel elements of a unique, split-core design, in which beam tubes "look" at a 17 cm gap between fuel-element halves. The reactor operates 24-hours a day on monthly cycles, followed by approximately a week of shutdown for refueling and maintenance. Specifications and reactor capabilities are listed in Table 1.

The experimental facilities in the reactor hall are allocated among the following activities:

- •neutron scattering and diffraction; neutron radiography;
- •trace analysis and depth profiling; nondestructive evaluation;
- •neutron standards development; fundamental neutron physics;
- •long-term irradiations and isotope production.

A plan view of the reactor hall is shown in Figure 1. The NBSR utilizes the flux available in a very efficient manner through the incorporation of relatively short core-to-instrument distances and large-diameter beam tubes. As a reference, the flux on the sample at the BT-4 and BT-9 spectrometers is 10^7 n/cm^2-s, measured at 14 meV incident energy, with 40′ collimation before and after the monochromator. Programs and instrumentation of the thermal beams have been described recently.[1]

The CNRF

Ground breaking for this laboratory took place in November 1987; it was dedicated by Secretary of Commerce C. William Verity in January 1989. The guide hall (30 m wide by 61 m long) and associated office and laboratory space has more than tripled the area available for neutron beam research, much of which is reserved for guest researchers.

This new national user facility utilizes the cold neutron source indicated in Figure 2. This source is a block of D_2O ice (with 8% H_2O added) cooled to 30-40 K by recirculating helium gas. The gas is circulated by a compressor through a refrigerator capable of removing 1 kw of heat at 25 K. The ice block is 36 cm in diameter by 22 cm long, with an 18 cm diameter by 10 cm long reentrant hole to increase the cold neutron flux. Integrated cold neutron flux (λ>3.95Å) is expected to be 1.8×10^8 n/cm^2-s at the entrance to the guide hall. The increase in neutron flux with the present cold source has been measured to be a factor of five, source full to empty, in the 4-8Å range.[2] An advanced liquid hydrogen source is now being designed for future installation.

The cold source will be viewed by eight neutron guide tubes (NG 0-7), one of which ends inside the reactor hall. The neutron guides consist of a thin coating (1000 Å) of Ni deposited on optically flat glass, of 15x6 cm^2 cross-section. The initial three guides will be coated with Ni^{58} to increase the useable solid angle by 30% over normal nickel. There is also a provision for installing supermirror guide elements on subsequent guides to further enhance available flux. The guides are completely evacuated to reduce neutron losses due to air scattering and go through holes in the reactor confinement building wall, with shutters provided at the wall to allow work on the beam lines in the guide hall while the reactor is operating.

On completion in 1993, the CNRF will include up to 15 new cold neutron instruments, the categories of which are listed in Table 2. In Figure 3 is shown the planned layout for the main floor of the new construction, and the first three guides to be instrumented. Also indicated is the neutron depth-profiling instrument which will be on NG-0, the new beam-line in the reactor hall. Installation is staged to minimize reactor down-time. Some features of particular interest are described below for the initial instruments.

Two 30m SANS instruments are under construction: the first to be installed (1990) will be an NIST/Exxon/U. of Minn. instrument on NG-7; the second, on NG-3, will be one of two instruments in the NSF/NIST Center for High Resolution Neutron Scattering (CHRNS). The NIST/Exxon/U. of Minn. SANS instrument will be the first to use a doubly curved mirror as a focal element in a long flight path to provide angular resolution and beam intensities which compare favorably with any SANS instrument in the world. In addition, each instrument will have provision for two large-area position-sensitive detectors to extend the angular range to cover both the small and intermediate angle regions. An optional feature for these instruments will be the ability to utilize a polarized neutron beam to study materials with magnetic constituents.

A neutron reflectometer to probe surfaces and interfaces in a wide variety of materials will be installed in early 1991. The low background and high intensity of cold neutrons in the new guide hall will permit the measurements of reflectivities down to levels of $\approx 5 \times 10^{-7}$. The proposed instrument will have the capability to produce polarized neutrons to study magnetic and superconducting materials. The sample geometry will be horizontal to facilitate the study of liquid samples. There will also be provisions to do grazing-angle surface neutron diffraction experiments, the feasibility of which was recently demonstrated at NIST.

Two experimental stations for chemical analysis are planned. A neutron depth profiling (NDP) instrument is being designed to take advantage of the factor of twenty or more increase in signal intensity expected over the existing thermal neutron beam facility. The new instrument will include several new features.

Neutron capture prompt-gamma-ray activation analysis has been developed at NIST and elsewhere as a reliable, often uniquely sensitive, method of elemental analysis with wide application in materials science, geochemistry, and environmental monitoring. Through a combination of greater neutron intensity, lower gamma-ray background, and advanced detectors and coincidence-counting instrumentation, the new instrument on NG-7 will provide 100 times more sensitivity for this method than at any thermal neutron instrument in the world.

Two of the stations will be devoted to fundamental neutron physics, including neutron interferometry. A variety of interferometer geometries will be investigated for several different experiments. The anticipated experimental investigations will include long baseline neutron interferometry with separated crystals, delayed choice experiments and, possibly, a neutron Michelson-Morley experiment. The other experimental station will provide an intense cold neutron beam for basic investigations in nuclear and particle physics. Anticipated experiments on this beam include studies involving neutron decay, nucleon-nucleon weak interactions and tests of basic symmetry principles.

Not shown in Figure 3 is the new cold neutron triple-axis spectrometer to be installed on NG-5. It is expected to be operational early in 1991.

Development of NG-1, 2, 3 and 4 will proceed as quickly as possible and will include the NSF/NIST 30m SANS and the NSF/NIST spin-polarized inelastic neutron scattering spectrometer (SPINS). The latter will be a triple-axis type instrument, but with high resolution and high intensity achieved through the use of supermirror polarizers and an energy-dependent flipper. Other instruments are listed in Table 3, among which will be a conceptually-new, very high-resolution multichopper time-of-flight spectrometer and a state-of-the-art back-reflection spectrometer.

The National-User Facility

Administratively, this facility is located within NIST's Materials Science and Engineering Laboratory, which is comprised of the Polymers, Ceramics, Metallurgy, Fracture and Deformation Divisions, and the

Center for Nondestructive Evaluation, as well as the Reactor Radiation Division. As indicated in Figure 3, office and laboratory space for users of the facility is provided in an addition to an existing office/lab wing of the reactor building. This space provides 36 additional offices for users and staff, and 12 laboratories for sample preparation and equipment maintenance.

CNRF facilities are divided into two classes: CNRF instruments and Participating Research Team (PRT) instruments. For CNRF instruments, 2/3 of available time will be scheduled by the Program Advisory Committee (PAC) and 1/3 reserved for NIST use (out of which proprietary research is allocated). For PRT instruments, 1/4 of available time will be scheduled by the PAC and 3/4 reserved for PRT members. As mentioned above, two of the instruments at the CNRF are being funded by the NSF as a Center for High Resolution Neutron Scattering (CHRNS). The NSF-funded portion of CHRNS will be scheduled entirely by the PAC, aside from some time for instrument improvement, "breakthrough" experiments, and a small allotment of time for instrument-responsible scientists. Other PRT members include Exxon Research and Engineering, Eastman Kodak, AT&T Bell Labs, Sandia Labs, and the University of Minnesota.

Full cost recovery will be required for all proprietary research, whether performed on a CNRF instrument or by a PRT member during PRT-reserved time. No fees will be charged for non-proprietary research. Unless formally described as proprietary research, all research is required to be published in the open literature or made accessible in the public domain.

REFERENCES

1. H. Prask, reported in Neutron News 1, 9-13 (1990).

2. C.J. Glinka, T.J. Udovic, J.M. Rowe, J.J. Rush, D.M. Gilliam, and G.P. Lamaze, NIST Tech. Note 1257, 134-6 (1989).

Table 1. NBSR Specifications

Power	20 MW
Peak Thermal Neutron Flux	4×10^{14} n/cm^2-sec
Peak Fast Neutron Flux	10^{14} n/cm^2-sec
Core:	
Radius	55 cm
Height	74 cm
Loading	6 kg U^{235}
Life	30-35 weeks
Moderator/Coolant	5×10^4 L D_2O
Fuel Elements:	
Type	Split MTR curved plate
Enrichment	93% in U^{235}
Shielding:	
Thermal	5 cm lead and 20 cm iron
Biological	1.8 m magnetite concrete
Neutron Ports	
Beam tubes:	
Radial	4 with 15 cm diam.
Radial	3 with 13 cm diam.
Radial (truncated)	2 with 13 cm diam.
Tangential	2 with 10 cm diam.
Vertical	1 with 10 cm diam.
Cryogenic Facility	8 15x6 cm^2 guides viewing cold source
Thermal Column	137x132x94 cm^3 graphite
Vertical Thimbles:	
In-core	6 with 9 cm diam.
In-core	4 with 6 cm diam.
In reflector	7 with 9 cm diam.
Rabbit tubes (2.5cm IDx7.5cm long):	
Near-core	3 at $(3\text{-}10) \times 10^{13}$ n/cm^2-s
Thermal column	1 at 3×10^{11} n/cm^2-s

Table 2. CNRF Instrumentation

Materials Structure
- SANS
- Reflectometer
- Grazing-Incidence Diffractometer

Materials Dynamics
- Triple-Axis Spectrometer
- Spin-Polarized Inelastic Neutron Spectrometer (SPINS)
- Time-of-Flight Spectrometer
- Back-Reflection Spectrometer
- Spin-Echo Spectrometer

Chemical Analysis
- Depth-Profiling Facility
- Prompt-Gamma Facility

Neutron Physics
- Neutron Interferometer
- Fundamental Physics Station

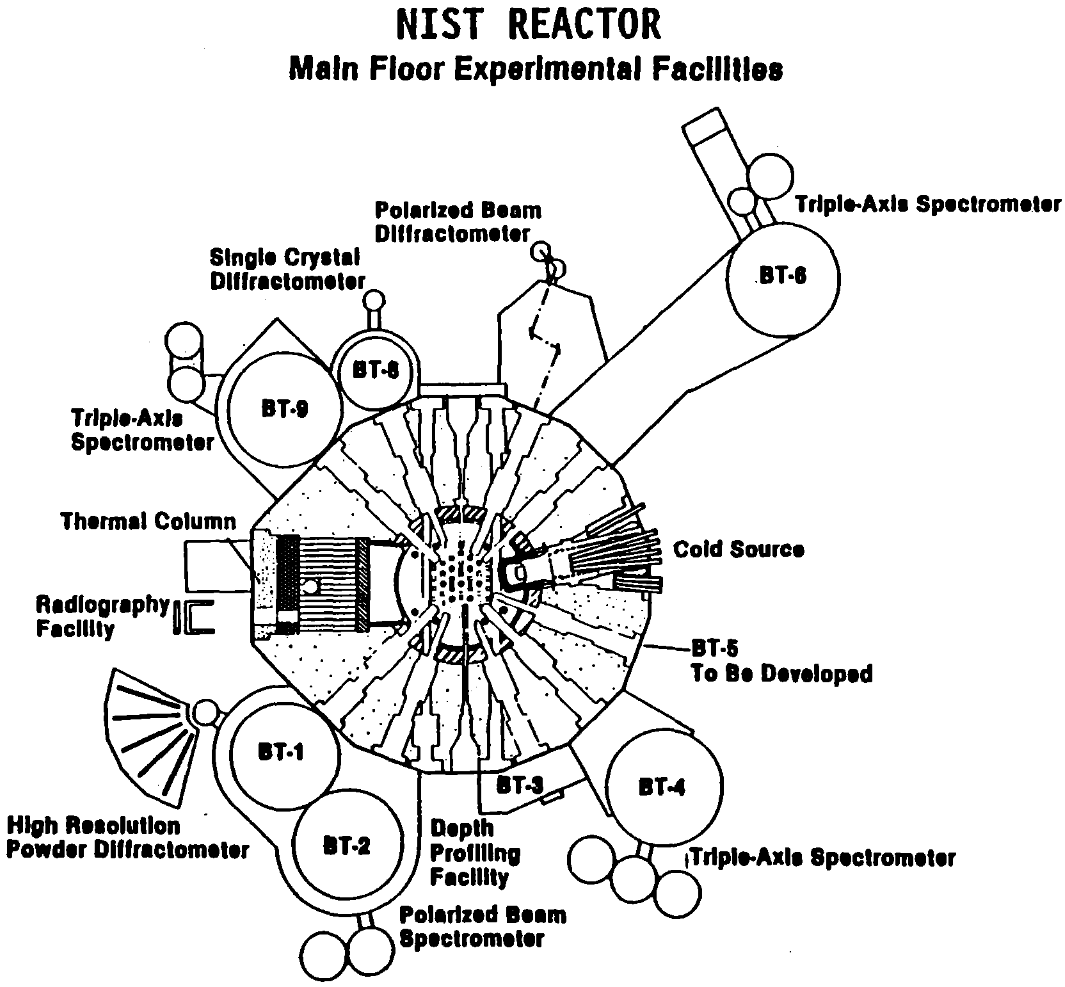

Fig. 1. The floor plan of the NIST Reactor hall.

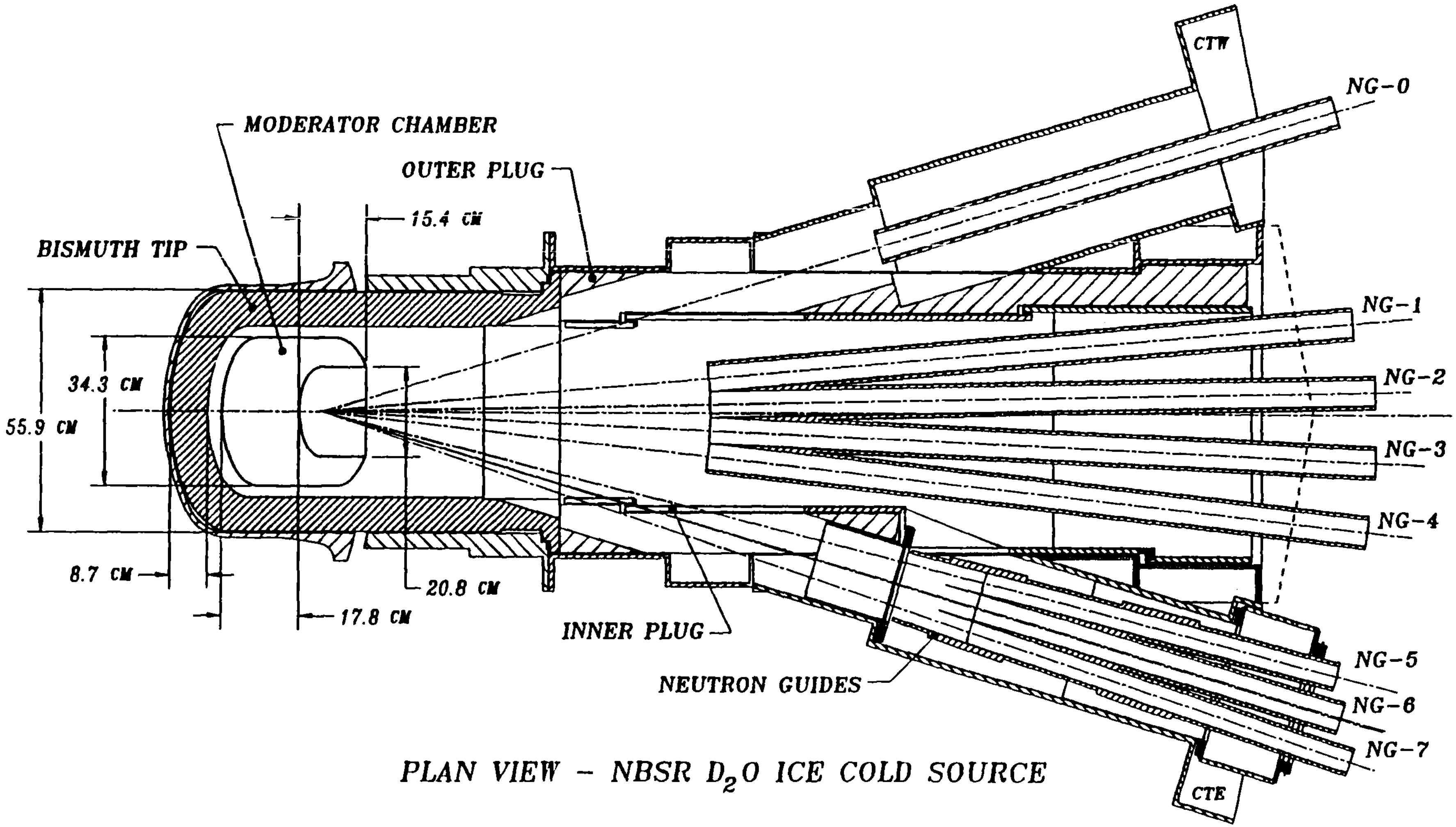

Fig. 2. The NBSR cold source.

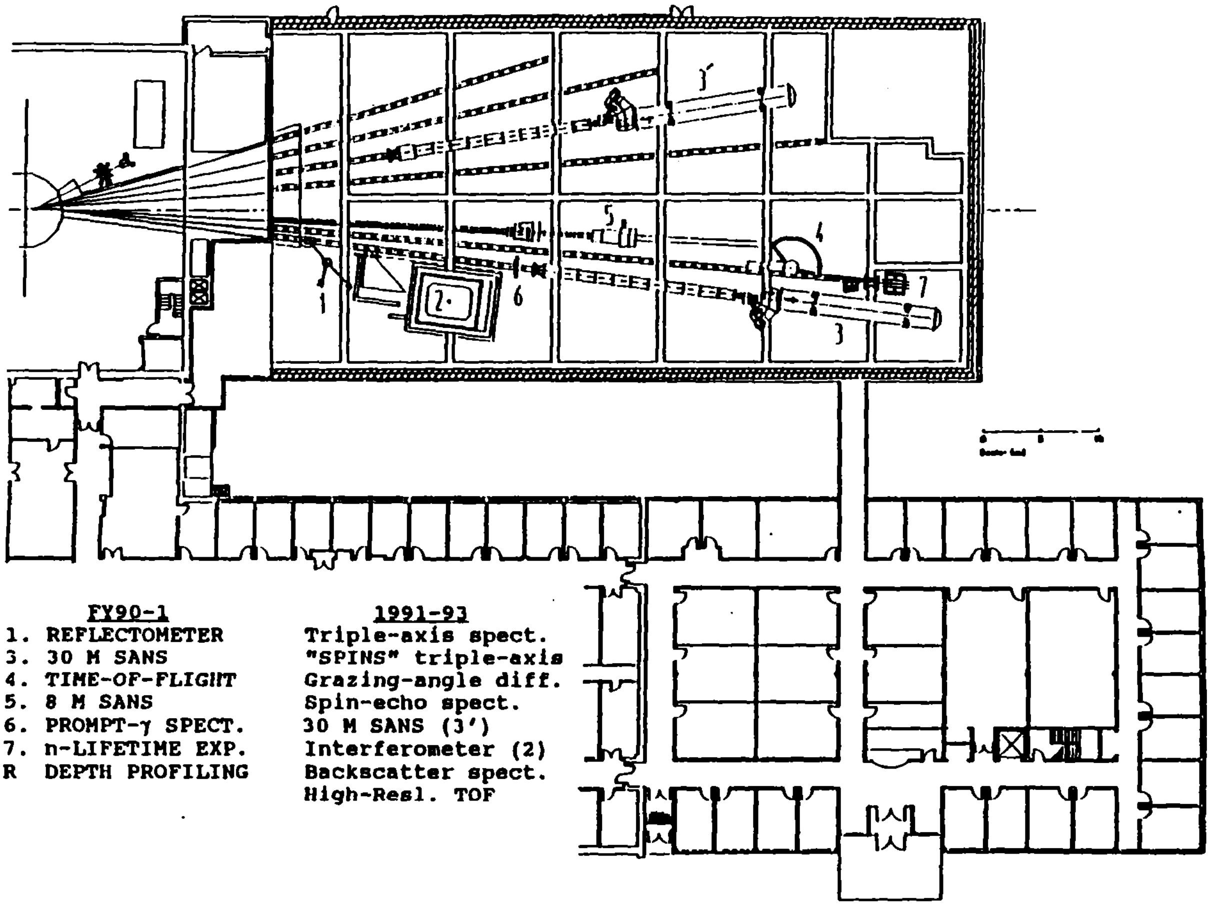

Fig. 3. The floor plan of the CNRF with instrumentation indicated for the initial three guides.