XA04C1606

THE HIGH FLUX BEAM REACTOR INSTRUMENT UPGRADE

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ABSTRACT

A brief overview is given of the current status of the High Flux Beam Reactor, including the ongoing safety review, and of plans for the upgrade of the instruments on the experimental level.

I. INTRODUCTION

Brookhaven's High Flux Beam Reactor (HFBR) is one of the major world centers for neutron scattering investigations in solid state and nuclear physics, chemistry and biology. The first reactor designed expressly for neutron beam research, the HFBR began operation in 1965 at 40 MW thermal power. It has operated since 1982 at 60 MW, providing a maximum thermal flux of 1×10^{15} n/cm^2-sec. It uses 9.8 kilogram of 93% enriched U-235 fuel configured in a compact core consisting of 28 curved plate elements. Heavy water serves as both coolant and moderator and the core is undermoderated to produce the peak thermal flux outside the core region with a minimum contamination by fast neutrons. The HFBR has a 24-day fuel cycle during which one half of the fuel elements are expended. It typically operates 10 cycles annually.

The HFBR is the only research reactor in the U.S. with a liquid hydrogen moderator, and it supports a major program of sub-thermal neutron investigations. Its nine ports serve 15 experimental facilities. Most of these facilities are operated by Participating Research Teams (PRT's) consisting of Brookhaven scientists and regular users of the HFBR from other government laboratories, industrial research laboratories and universities. A 25% fraction of the PRT instrument time is set aside for general users (non-PRT members), who obtain beam time through a peer reviewed proposal system.

The HFBR has been shut down since March 1989 for an extended safety review. The shutdown was initiated as the result of a BNL study of the consequences of a hypothetical major loss of coolant accident (LOCA). The conservative conclusions of this study could not rule out the possibility of some minor (1%) fuel damage at 60 MW operation accompanied by unacceptably high potential radiation exposures for small numbers of reactor personnel. Because no fuel damage was anticipated at 40MW operation, BNL proposed continuing at this reduced power level pending further study of possible problems attending 60 MW operation. DOE rejected this plan. In the months following shutdown several committees have examined and initiated studies of all vital aspects of HFBR operation. These studies have centered principally upon the thermal-hydraulic problems associated with LOCA's, containment vessel embrittlement and management and training of the reactor staff. The investigative phase of these investigations has wound-down and no problems have been identified which would preclude resumption of operation at 40 MW. The present schedule calls for 40 MW operation of the HFBR by August 1990. Although improved analytical calculations no longer suggest the likelihood of fuel damage at 60 MW operation, it appears that some physical modelling will be desirable before higher power operation is resumed.

II. PRESENT AND FUTURE ROLE OF THE HFBR

During its last full year of operation the HFBR had the largest neutron scattering program (263 users) of any U.S. neutron facility. The instruments available at the HFBR have been developed to cover a wide range of scientific studies. Major programs currently exist in protein crystallography and small angle scattering studies including biological assemblies (proteins, viruses and membranes) as well as metallurgical precipitates, micelles, polymer structures, etc. Single crystal structure determinations emphasize precise location of light atoms in carbohydrates and organometallic compounds, and on magnetically ordered structures. Inelastic neutron scattering studies are carried out on thermal excitations of solids and liquids using polarized and unpolarized neutrons. Recent studies have, for example, helped elucidate the structural and magnetic properties of high temperature superconductors. Nuclear physics center on neutron capture reactions and short-lived fission fragment studies using an on-line mass separator. Seven vertical thimbles provide a variety of neutron energies for sample irradiations, and also supports a major positron physics facility through the production of Cu-64 positron sources. Two new instrument (recently completed neutron reflectometer and a high resolution powder diffractometer still under construction) further increase the scope of the program.

Over the years there has been a steady increase in the number of scientists using the HFBR and it is fast approaching the limit of its research capacity. Moreover, in spite of the instrument building activities noted above, many of the existing instruments are 25 years old and are becoming increasingly outmoded.

Especially in view of the cost and complexity associated with building and licensing new reactors, well maintained high performance reactors such as the HFBR must be considered as renewable national resources. As has been noted in several high level reviews, the HFBR, with little modification is capable of supporting a considerably larger and broader-based research program than exists at the present time. The HFBR Upgrade, together with the Advanced Neutron Source, a next generation reactor presently under development, provide a coordinated plan for meeting our national needs for research reactors well into the next century.

The complement of new and refurbished instruments, many of which take advantage of the unique hydrogen cold neutron moderator at the HFBR, are summarized in Figure I, and will be built with very minor interruption of the ongoing HFBR programs. The improved performance of these instruments increase the scope of experiments susceptible to investigation, reduce the time necessary to perform a given experiment and thereby will consequently permit a substantial growth in the number of users that can be accommodated in the HFBR Program. Much necessary development and testing of instrumentation concepts relevant to the success of the ANS project will be performed. Moreover, wherever practical, these activities will be carried out in collaboration with the ANS staff and/or other appropriate neutron scientists in the U.S. Many of the new instruments could be transferred to the ANS in the future, should this prove desirable. Finally, the Upgrade will permit the HFBR to continue to accommodate the growing neutron scattering community until the ANS is in operation.

The reactor pressure vessel, beam tubes and core support structure are made of aluminum alloy that maintains its properties particularly well in high radiation fields. Recent metallurgical studies of samples taken from the highest flux regions indicate that radiation damage effects have not, as yet, become severe. On this basis it is expected that full power operation could continue for more than another decade before replacement of any in-pile components are necessary. And, should such replacement become necessary we have begun an engineering study for removal of the beam tubes by remote cutting, and replacement using a flanged seal. From a structural point of view, all indications are that the HFBR can support a world-class neutron scattering program well into the next century.

III. BRIEF PHYSICAL DESCRIPTION OF THE UPGRADE PROJECT

The HFBR Upgrade proposal is a $22M, four-year plan to build five new neutron scattering instruments at the HFBR and to rebuild six others to current standards. It was developed in response to several high level studies which called attention to the strong neutron instrumentation initiatives in Western Europe and to the aging and saturation of U.S. facilities. A major DOE review of all aspects of design, cost and management was satisfactorily performed in 1988, and the project now awaits funding.

It is proposed to make the following modifications to the reactor's external beam configuration: (i) Two additional thermal neutron beams would be brought out of the reactor. (ii) Existing beams would be enlarged wherever possible and modern focusing techniques applied to take fullest advantage of the flux available. (iii) Instrument shielding would be increased to keep the room background at its current low level. (iv) Neutron guides would be installed so that new instruments operating with sub-thermal neutrons could be placed well back from the reactor shield face where there is more floor space available and the background is lower.

Five new instruments for condensed matter and biological research would be added--one on a new thermal beam and other four on the neutron guides--and six existing instruments used for condensed matter research would be reconfigured to operate with bigger beams. Additionally, an existing neutron reflection spectrometer would be relocated on a neutron guide tube. The positron facility will be rebuilt to state-of-the art standards and minor changes and additions would also be made to operational equipment to support the expanded program.

Instruments Employing Thermal Neutrons. To increase the number of spectrometers operating with thermal neutrons (and improve performance of existing spectrometers) it is proposed that the present H-7 and H-8 single-beam plugs be replaced with double-beam plugs designed to bring out beams of the maximum practical size. Two new instruments would be installed on the satellite beams.

Instruments Using Sub-thermal Neutrons from the HFBR's Liquid-Hydrogen Moderator. For optimum performance of all spectrometers using sub-thermal neutrons it is proposed that the existing H9 beam plug and moderator assembly be replaced with one designed to provide three beams of the maximum practical size and that new shielding be fabricated to accommodate the bigger beams. Additionally, three guides would be installed to conduct neutrons to four new spectrometers within the experimental hall but removed from the reactor shield face.

Instrument Upgrading. Most of the two and three-axis crystal spectrometers presently in use at the HFBR to investigate the structures and excitations of solids (both magnetic and non-magnetic) and liquids were designed and built in the mid-1960's when the reactor first became operational. They are in need of substantial modification to bring their performance up to current standards. New beam plugs will be installed to increase the vertical beam height (so that vertical focusing of the beams can be employed to fullest advantage) and the existing shielding will be replaced with new, thicker shielding to keep the room background at its present low level. There are six instruments which fall in this category.

A plan view of the physical layout of the instruments on the HFBR floor is shown in Figure II. All of the instruments will be accommodated in the existing reactor containment structure.

In spite of our current frustrations associated with the protracted shutdown, as the HFBR nears its 25th anniversary in October of this year, we are convinced that the HFBR not only has a distinguished history, but has an equally important role to play in the future of U.S. neutron scattering.

ACKNOWLEDGEMENTS

This work was supported by the U.S. Department of Energy, Division of Materials Sciences under Contract No. DE-AC02-76-CH00016.

Figure I.

OUTLINE OF HFBR PROPOSAL

BEAM PORT	NEW PLUG	GUIDE TUBES	SPECTROMETER	SHIELDING	SUBTOTAL ($1000)	TOTAL ($1000)
A. ENGINEERING, DESIGN, INSPECTION AND ADMINISTRATION						2162
B. SCIENTIFIC EQUIPMENT, FABRICATION, ASSEMBLY AND TEST						11573
POSITRON FACILITY	NO	NO	BUILD NEW SLOW POSITRON BEAMLINE	NO	396	
H5	YES	NO	REBUILD 3-AXIS SPECTROMETER	NEW	718	
H6 M	YES	NO	REBUILD DIFFRACTOMETER	NEW	721	
H6 S			NEW DIFFRACTOMETER WITH 2D DETECTOR	NEW	878	
H7 M	YES	NO	REBUILD 3-AXIS SPECTROMETER	NEW	874	
H7 S			FUTURE EXPANSION	NEW		
H8 M	YES	NO	REBUILD 3-AXIS SPECTROMETER	NEW	907	
H8 S			NEW BACKSCATTERING SPECTROMETER	NEW	802	
CNM			NEW MODERATOR AND PLUG ASSEMBLY		1211	
H9-A	YES	NO	REBUILD 3-AXIS SPECTROMETER (H9-A1)	NEW	425	
			RELOCATE REFLECTION SPECTROMETER (H9-A2)	NEW	94	
			NEW TIME-OF-FLIGHT SPECTROMETER (H9-A3)	NEW	1950	
H9-B	YES	YES	NEW MEDIUM RESOLUTION SANS (H9-B1)	NEW	609	
			NEW HIGH RESOLUTION SANS (H9-B2)	NEW	1634	
H9-C	YES	YES	NEUTRON INSTRUMENT R&D STATION	NEW	354	
C. GENERAL FACILITIES						1032
D. CONTINGENCY						2796
			GRAND TOTAL		($FY88)	17563
			GRAND TOTAL		($ESCALATED)	20782

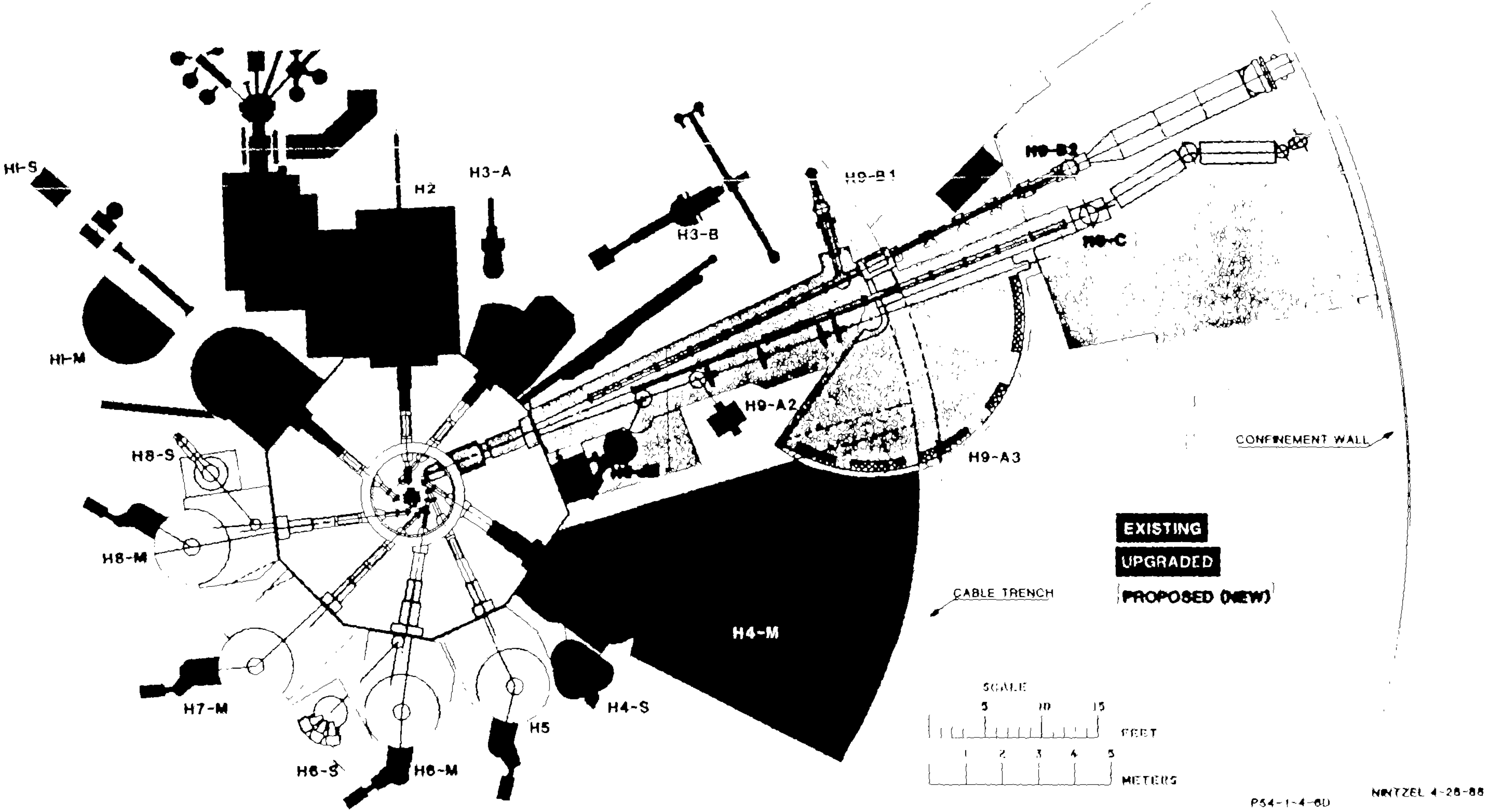

FIG. II

REACTOR FLOOR PLAN (PROPOSED)