SCIENTIFIC UPGRADES AT THE HIGH FLUX ISOTOPE REACTOR AT OAK RIDGE NATIONAL LABORATORY

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1. Introduction

The United States Department of Energy is sponsoring a number of projects that will provide scientific upgrades to the neutron science facilities associated with the High Flux Isotope Reactor (HFIR) located at Oak Ridge National Laboratory. Funding for the first upgrade project was initiated in 1996 and all presently identified upgrade projects are expected to be completed by the end of 2003. The upgrade projects include: 1) larger beam tubes, 2) a new monochromator drum for the HB-1 beam line, 3) a new HB-2 beam line system that includes one thermal guide and a new monochromator drum, 4) new instruments for the HB-2 beamline, 5) a new monochromator drum for the HB-3 beam line, 6) a supercritical hydrogen cold source system to be retrofitted into the HB-4 beam tube, 7) a 3.5 kW refrigeration system at 20 K to support the cold source and a new building to house it, 8) a new HB-4 beam line system composed of four cold neutron guides with various mirror coatings and associated shielding, 9) a number of new instruments for the cold beams including two new SANS instruments, and 10) construction of support buildings. This paper provides a short summary of these projects including their present status and schedule.

2. New Larger Beam Tubes at HFIR

The planned replacement of the reactor beryllium reflector has given us the opportunity to increase the size of the four neutron beam tubes in the reactor. The new HB-1 and HB-3 beam tubes could not be enlarged inside the pressure vessel due to constraints on the respective holes in the pressure vessel. However, these two beam tubes have been expanded external to the pressure vessel to provide a ID beam tube cross sectional area that is 89% larger. The new HB-2 beam tube provides a beam tube with an increased cross sectional area that is approximately 200% larger inside the beryllium reflector and 420% larger in the space between the reflector and pressure vessel wall. This new beam tube will also contain beryllium inserts inside the nose of the beam tube to provide performance enhancement. The new HB-4 beam tube will contain the new hydrogen cold source and will have increased cross sectional areas of about 50% in the reflector and 100% larger in the space between the reflector and pressure vessel wall. These increases provide a substantial performance increase for the users.

The new HB-1, HB-2, and HB-3 beam tubes have been fabricated and their installation will be completed during the present reactor shutdown that will extend until approximately the end of September. The new HB-4 beam tube is in fabrication and will be available for testing with the cold source in the winter/spring of 2002 and will be installed in the reactor with the cold source in the spring/summer 2002 time frame.

3. New Monochromator Drums for HB-1 and HB-3 beam tubes

New monochromator drums to support triple axis spectrometer instruments have been designed and are being fabricated to make use of the increased size of the beams generated by the new HB-1 and HB-3 beam tubes. When fully loaded with paraffin and steel shot shielding, these drums will weight approximately 60 ton each. The HB-1 monochromator drum is nearly completed and is expected to be delivered to ORNL in June of this year followed closely by the delivery of the HB-3 monochromator drum in July. Installation of the upgraded triple axis spectrometers utilizing the new monochromator drums is expected to be completed in the fall of this year. With the new drum and new beam tube we expect to see about a factor of 2.5 performance gain for the triple axis instrument on HB-1 and about a factor of 2 increase in performance for the triple axis instrument on HB-3.

4. A New HB-2 Beam System with Thermal Guide that Will Support Four Instruments

Fabrication of the new HB-2 beam system, as shown in Fig. 1, is well underway. The thermal guide for the HB-2 beam has also been delivered to the HFIR site but will not be installed until next year. The fabrication of a shield tunnel around the thermal guide is also underway and expected to be completed this Fall. A new monochromator drum to support the triple axis machine on the HB-2 system is in fabrication and should be delivered to the site in October of this year. Installation of the HB-2 beam system is expected to begin in January with the installation of a new crane system and is expected to be operational in the summer of 2002. The new system should provide performance improvements of a factor of 2 for the residual stress instrument, a factor of 3.5 for the HB-2 triple axis instrument, and factors of 10 for the WAND and Powder Diffractometer instruments.

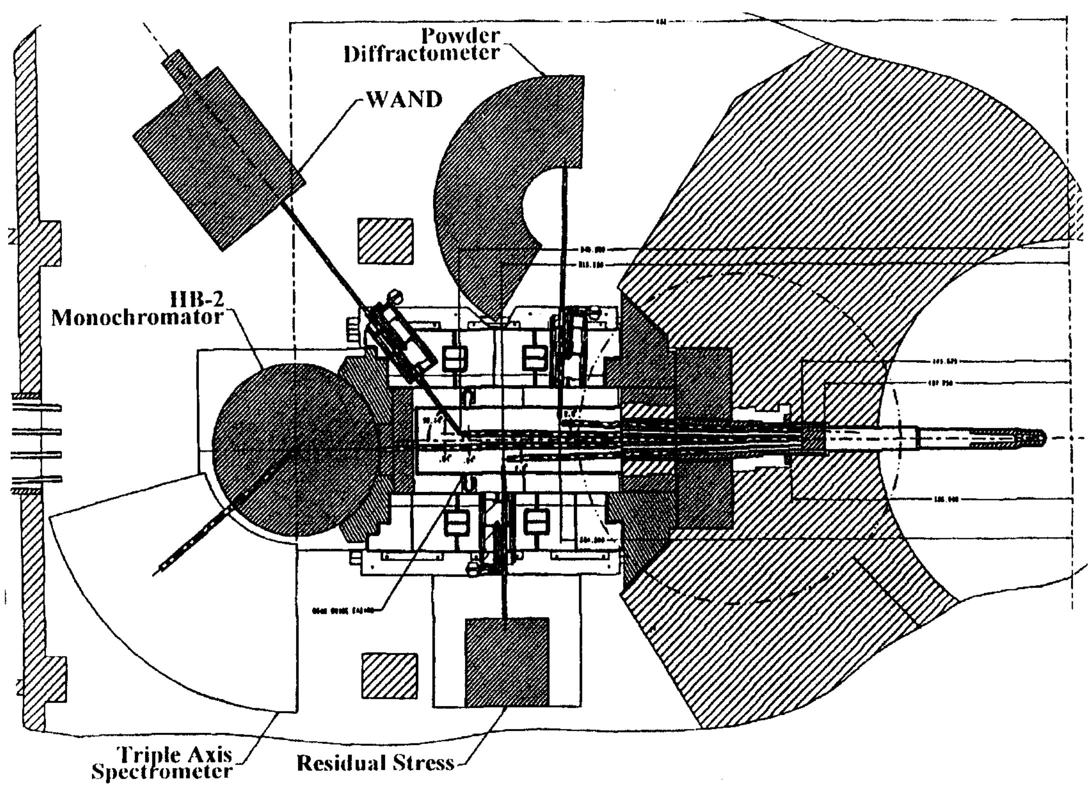

Figure 1: High Flux Isotope Reactor New HB-2 System

5. Supercritical Hydrogen Cold Source

The heart of the new scientific capabilities to be achieved on the HB-4 beamline is the supercritical hydrogen cold source. The design of this system is essentially complete and most of the components have either been delivered or are in the process of being fabricated. The key components of the system are the moderator vessel, the refrigerator system, the hydrogen circulators, and the hydrogen transfer lines.

The moderator vessel fabrication is nearly complete. At the time of this paper all of the moderator vessel pieces have been fabricated as shown in Fig. 2 and only the single circumferential weld is needed to complete the assembly of the vessel. However, this weld is very important and we are performing a series of test welds before the actual weld is performed. The moderator vessel will be assembled into the new HB-4 beam tube sometime during this calender year and flow tested before insertion into the reactor.

A refrigeration system designed to provide 3.5 kW of heat removal at 20 K to support the cold source has been built, installed on site, and successfully tested. At full capacity the refrigerator system removed approximately 4 kW of heat at 20K. The refrigeration system uses a once through LN_2 flow to provide helium precooling. In the event of a refrigerator failure, opening and closing of valves creates a new helium flow path that bypasses the refrigerator expanders. This new path uses the liquid nitrogen to create a passively cooled standby mode of operation that maintains the moderator vessel at safe temperatures without having to shutdown the reactor.

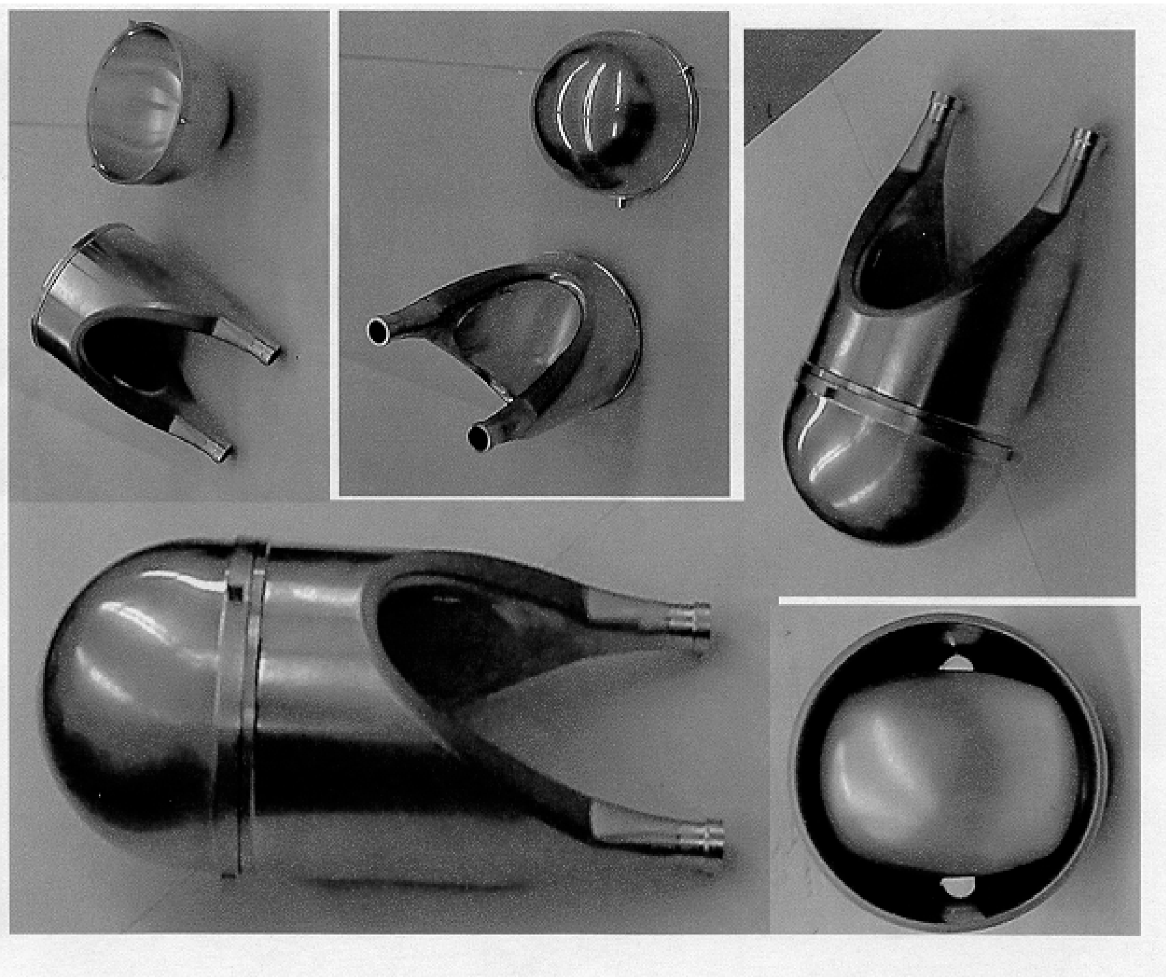

Fig. 2: HFIR Cold Source Moderator Vessel Fabricated Pieces

A new concept in cryogenic circulators has been developed for this cold source that can adjust its volumetric flow to suit the prevailing density of the fluid in circulation. This provides tight control of the fluid, especially during cooldown, by compensating for changes in its thermophysical properties. It also helps control loop perturbations, particularly during fault induced transients or transitions between normal and standby modes that would otherwise give rise to major pressure and temperature spikes. Although operation of the system only requires one functioning circulator, three circulators are being installed to enhance availability. These circulators are expected to be delivered to the HFIR site by the end of September 2001.

Multiple hydrogen lines are used to interconnect the various cold source components. All cold tranferlines are vacuum insulated and further surrounded by an inert gas boundary. Most of the transferlines have the hydrogen feed, hydrogen return, vacuum, and inert gas lines nested one inside the other so that the full tranferline system appears as one line. Even with the nesting, there is still enough flexibility in the line to allow bending for installation. These Cryoflex® transferlines are being fabricated by Alcatel Kabel. We expect all transferlines to be delivered by the end of the calender year 2001.

Testing of the cold source will begin during the Fall of this year when we will operate the system with a shortened hydrogen loop to perform acceptance testing of the circulators. This will be followed by testing with a near prototypic system with a heater assembly to represent the reactor heat load. In the Spring of 2002 flow testing will be performed with the actual moderator vessel installed in the new HB-4 beam tube before the vessel/beam tube assembly is installed in the reactor.

6. HB-4 Cold Neutron Guides and Guide Hall

In order to make the most use out of the cold neutron beam generated by the new cold source a series of four neutron guides (CG-1, CG-2, CG-3, and CG-4) have been designed to feed two modest guide halls. This layout is shown in Fig. 3. As seen from this drawing, we have designed a shielding tunnel that houses the guides out to the first guide hall where shielding of each individual guide will be initiated.

The cold neutron guides are being fabricated by CILAS and have varying degrees of reflectivity up to 3 x nickel reflectivity. The application of the super mirror coatings on the guides was initiated by CILAS in January, but will take almost a full year to complete. Installation of the guides is expected to begin in the Spring of 2002 and be completed by the end of the Summer of 2002.

The cold guides and instruments will be installed in two new buildings. The Neutron Science Support Building (NSSB) has been completed and is presently being used as a storage facility for the existing neutron scattering instruments that had to be removed from the reactor building, during the beryllium reflector and beam tube replacement. A SANS guide-hall is being added to support two new Small Angle Neutron Scattering (SANS) instruments that will be designed and fabricated over the next 12-15 months. Construction of the new guide-hall is expected to begin in the Fall of 2001 and be completed in the Summer of 2002.

In addition to the two new SANS instruments we expect to have two triple axis instruments, a reflectometer, and a cold neutron test station located in the two new buildings. We are in the process of finalizing the instrument layouts and hope to publish this information this summer. The expectations are that all facilities associated with the new HB-4 beam line, including the new instruments, will be operational in the year 2003.

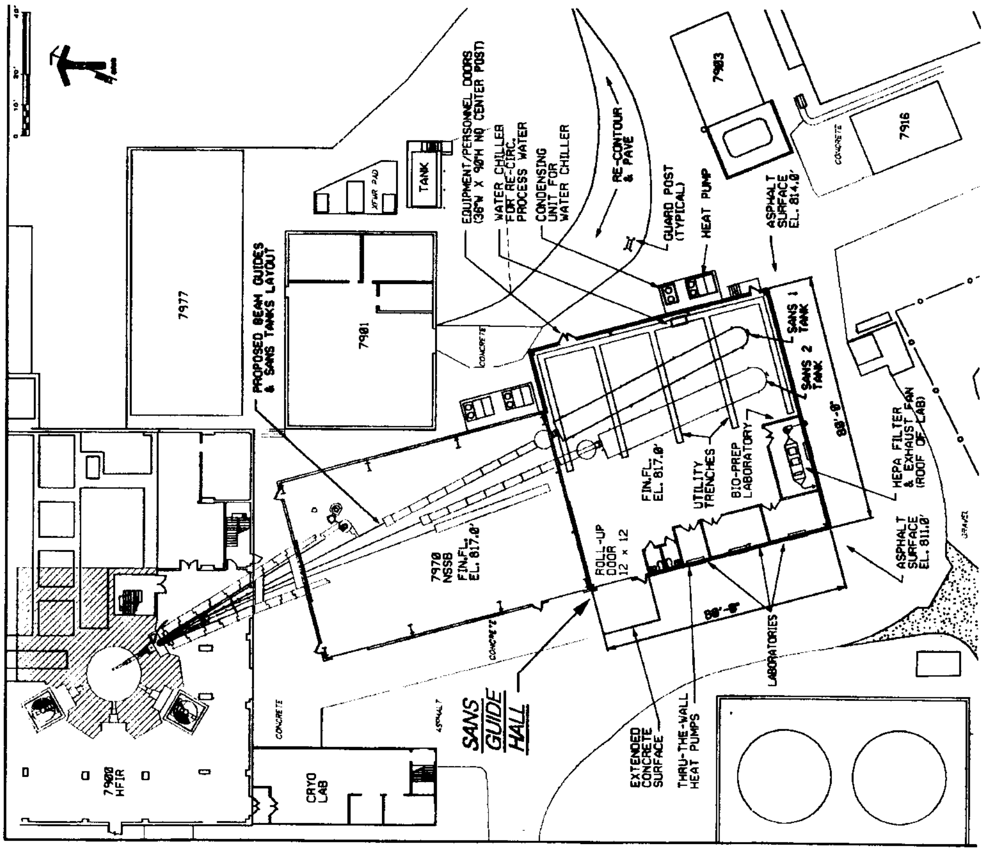

Fig. 3: HB-4 Cold Neutron Guide and Guide Hall Arrangement

The instruments located in the new buildings will be a mixture of new and existing instruments. There should be considerable gain in the performance of the existing instruments based on our present estimates of the neutron flux at the sample locations for the various instruments. For the existing reflectometer instrument that will be moved to the CG-4 location it is anticipated that performance will be improved by about a factor of 10.

7. Closing

When all of the upgrade projects are completed there should be significant improvements in the neutron science capabilities at the HFIR. Coupling the reactor neutron science facility improvements with the completion of the 1 MW Spallation Neutron Source at ORNL a few years later, the Oak Ridge National Laboratory will be a significant center for neutron science research for several decades to come.