Status of the High Flux Isotope Reactor and the Reactor Scientific Upgrades Program

Douglas L. Selby
Oak Ridge National Laboratory

1. Introduction

In the 1980's a number of high-level government sponsored committees strongly supported the need for both a new reactor source and a new pulsed neutron source within the USA. Although an upgrade to the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) was proposed during this time as an alternative to a new reactor facility, it was nearly a unanimous opinion within the community that a new facility with a design optimized for neutron beams, rather than isotope production, was what was needed. In the late 1980's a project was formed at ORNL to design and construct a new research reactor that would be called the Advanced Neutron Source (ANS) Reactor. Unfortunately, the project was cancelled in the late 1990's, as a result of a number of factors, including cost and its use of high enriched fuel. Shortly after the cancellation of this project, the idea of upgrading the HFIR scientific capabilities was discussed with the US Department Of Energy. A concept of a number of upgrade projects was presented, and initial funding for the development of a cold source concept was received in 1998.

2. Description of Upgrades and Their Status

Figure 1 shows a layout of the reactor and its four beam tubes. The focus of the Scientific Upgrades Program was to elevate the neutron scattering capabilities to state-of-the-art or better. Therefore, all four neutron beams were examined to see what could be done to enhance performance. A number of modifications were determined to be cost effective and the remainder of this paper will describe the changes that have been made or that are planned.

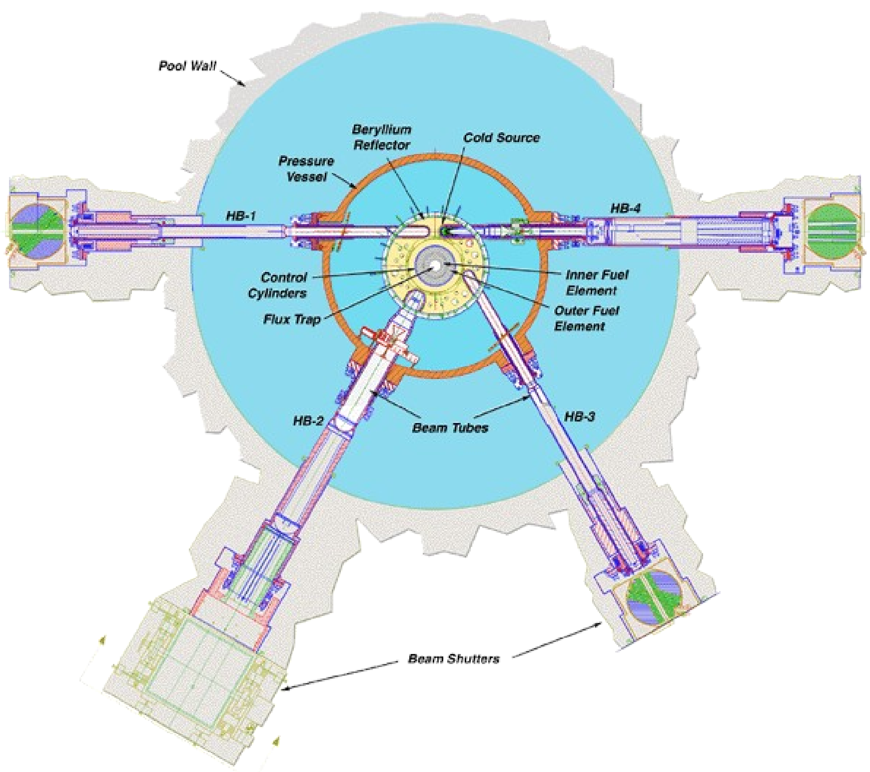

Figure 1: HFIR Beam Tube Layout

2.1 Upgrades at Beam Lines HB-1 and HB-3

At HB-1 and HB-3 a determination was made that the beam tubes could be made larger thus increasing the neutron flux available to experimenters. Therefore, when the reactor beryllium reflector was replaced in 2001 the new beryllium was designed with a larger hole for each beam tube so that the beam tubes could be expanded to the largest sizes permitted by the openings in the pressure vessel. The larger beams required the need for new monochromators that could accommodate the larger beams. The new monochromators at HB-1 and HB-3 were installed in 2002. Figure 2 shows the Triple Axis Spectrometer presently installed at HB-1. Comparison of experiments, prior to and after the upgrades, imply that we have received a factor of 2 to 3 improvement in performance at HB-1 and a factor of 3 to 4 improvement at HB-3. These are consistent with expectations. The HB-1 and HB-3 instruments are now fully operational and are part of the ORNL Center for Neutron Scattering's User Program.

Figure 2: HB-1 Triple Axis Spectrometer Instrument

2.2 Upgrades at Beam Line HB-2

As with HB-1 and HB-3, the size of the HB-2 beam tube was increased making it the largest HFIR beam tube with a diameter of approximately 9 inches (23 cm). It was also determined that an increase in neutron current down the beam tube could be obtained by placing a beryllium insert in the nose of the beam tube giving it a tapered beam tube appearance. In addition to increasing the magnitude of the beam, our desire was to increase the number of instruments that could be supported by the beam. Thus, we designed a shield tunnel arrangement that allowed us to bring the beam out into the middle of the beam room and place multiple instruments around it. The difficulty with the shield tunnel was that since the HB-2 beam tube was a radial beam tube with a large diameter, the radiation source that we had to shield against was large and on the order of 10^9 mrem. Considering there was only limited space for shielding and we needed to get the dose at the outside surface of the shield down to less than 5 mrem, the shield design was a challenge. A liquid nitrogen cooled sapphire filter was installed upstream of the main shutter as a fast neutron filter to reduce the high energy neutron source at the shield. With this fast neutron filter in place it was found that using steel encasements filled with a certain ratio of steel shot and paraffin, the desired dose reduction could be achieved. The shield tunnel was fabricated and assembled in late 2003 as shown in Figure 3. Included as part of the assembly was the installation of an M = 3 neutron guide that was installed inside the tunnel to support the HB-2 instrument position at the end of the tunnel. Radiological surveys performed as part of the commissioning of the tunnel indicated that the shielding met its requirements with typical dose measurements on contact of 1 to 4 mrem.

Figure 3: West and South Faces of the HB-2 Shield Tunnel

With the shield tunnel in place, the installation of instruments could begin. Figure 4 shows the layout of instruments in the beam room. The HB-2 tunnel is shown in the central portion of the layout with four instruments around it. The HB-2B instrument (Residual Stress) was installed first and was given permission to open its instrument shutter and receive beam in December of 2003. Similar experiments performed before and after the upgrades indicate that the HB-2B port provided a beam to the Residual Stress Instrument with a beam strength approximately 8 to 10 times greater than had previously been available to this instrument. Since December of 2003 the Wide Angle Neutron Diffractometer (WAND) at the HB-2C port and the (Mirror) Reflectometer at the HB-2D port have been installed. In addition, a small station using the top 1 cm of the HB-2D beam was installed to provide a detector test station for the Spallation Neutron Source (SNS) facility. A Powder Diffractometer located at the HB-2A port will finish the initial complement of instruments at HB-2, but this instrument will most likely not be installed until the later part of 2006. At this time all indications are that the HB-2 modifications have and will meet or exceed our expectations.

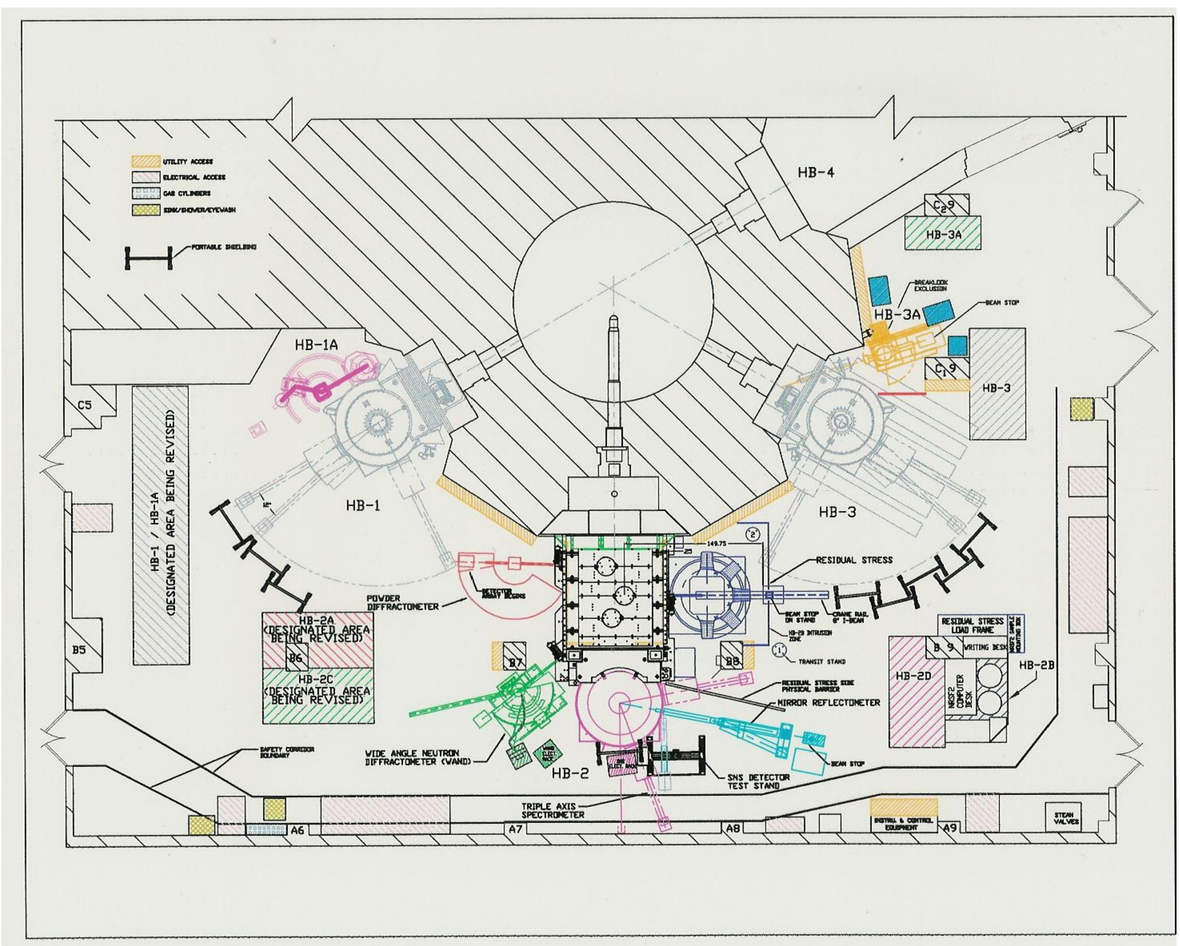

Figure 4: Beam Room Instrument Layout

2.3 Upgrades at Beam Line HB-4

The most significant changes have been made at the HB-4 position. The focus of the changes at HB-4 is a new supercritical hydrogen cold source. A separate paper by David Cook of the ORNL Research Reactor Division is presented at the conference and thus, the details of the cold source will not be discussed in this paper. The cold source will support four curved or off-set neutron guides that will transport neutrons to a new guide hall. A new shield tunnel has been constructed through the beam room that will provide shielding around the neutron guides. Figure 5 provides a layout of the HB-4 guides and instruments. As seen from this figure, the four guides will support seven instruments. A new triple-axis spectrometer is planned for the CG-1 guide. CG-2 and CG-3 will support two new small angle neutron scattering (SANS) instruments. Four instruments will be fed by the CG-4 guide including a reflectometer and a US/Japan Program triple axis instrument that was formerly located at Brookhaven National Laboratory.

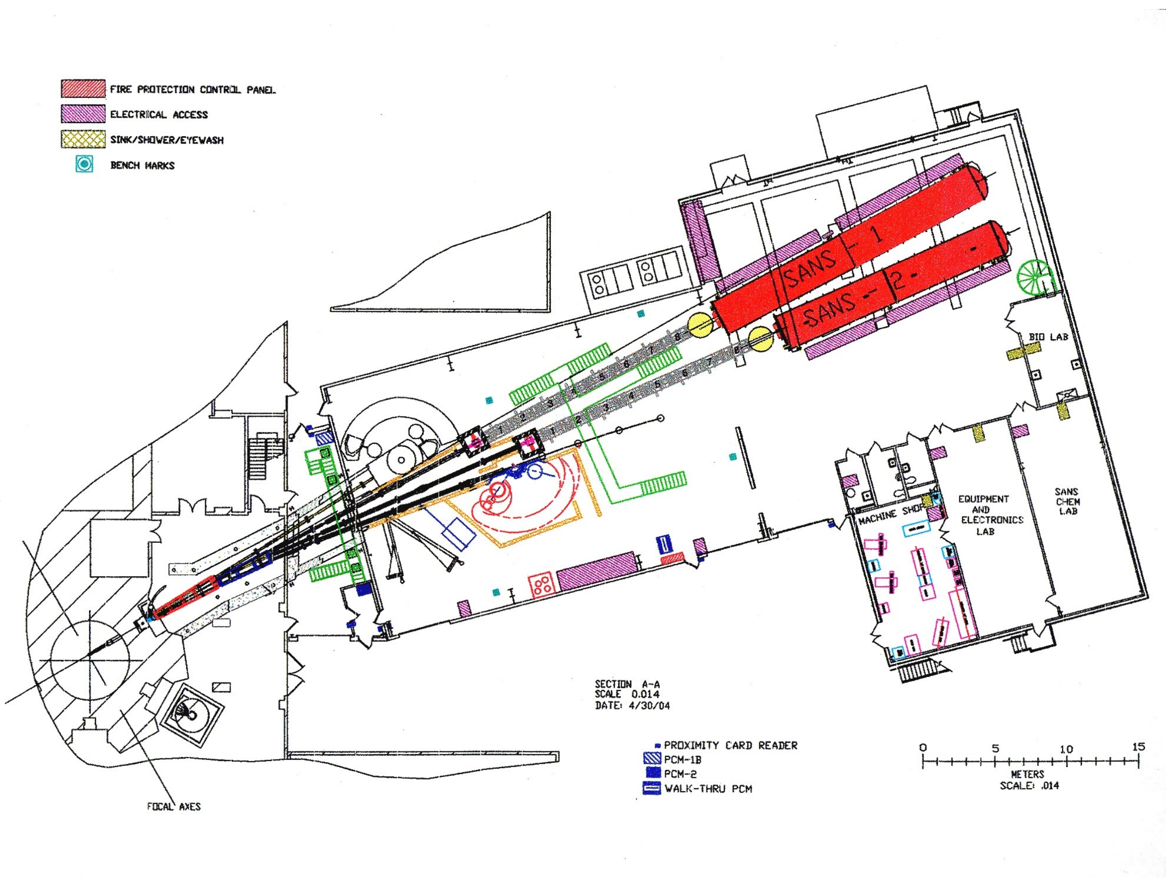

Figure 5: HB-4 Neutron Guide and Instrument Layout

The installation of the guides was initiated in January of this year and at the end of April the CG-1 and CG-2 guide installation was completed. Guide installation is expected to resume in September of this year and be completed by the end of the calendar year. Although a couple of problems have surfaced during the guide installation, our intent is to resolve these problems within the next 9 months. The design of mobile shield sections that will be used to provide shielding around the guides in the Guidehall is nearly completed, and this shielding should be installed in the spring of calendar year 2006. Figure 6 shows the installed CG-1 and CG-2 guides as they exit the presently installed shield tunnel and enter the Guidehall. All supports for the guides have been taken to bedrock.

Figure 6: Installed CG-1 and CG-2 Guides at the Entrance to the Guidehall

As previously indicated, the CG-1 and CG-2 guides feed two new SANS instruments. The flight tubes for both instruments have been fabricated and delivered to ORNL. Their installation is proceeding and they are on schedule to be ready for beam in the summer of 2006. The SANS-1 and SANS-2 flight tubes are 8 feet (2.44 m) in diameter with a length of approximately 67 and 55 feet (21 m and 17 m) respectively. A 1 m by 1 m neutron detector with resolution of 0.5 cm has been procured for each of the SANS instruments. Shield boxes to house the velocity selector assemblies have been installed on both CG-2 and CG-3. The velocity selectors themselves have been undergoing testing for about a year and we expect to proceed with their installation inside their shield boxes by the end of 2005. The flight tubes placed on the Guidehall floor are shown in Figure 7.

Figure 7: SANS-1 and SANS-2 Flight Tubes

3. Summary

Planned upgrades at HB-1 and HB-3 have been completed. The upgrades at HB-2 are nearly completed with three of the four beam ports in operation. Where instruments have been installed at HB-1, HB-2, and HB-3 measurements have indicated that performance improvements have met or exceeded expectations. Although there is still a lot of work to be done to complete the HB-4 upgrades, the HB-4 instrument area is starting to look like a Guidehall, as shown in Figure 8. At present we are on schedule to perform initial testing with the main HB-4 shutter open in the summer of 2006. At that time, both SANS instruments are expected to be ready for commissioning. The reflectometer on CG-4 and the triple-axis instrument on CG-4 should be the next instruments to be installed and commissioned on the HB-4 cold guide lines. The remaining three instrument locations will be filled at a later date.

Figure 8: HB-4 Guidehall Interior