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10 EXPERIMENTAL FACILITIES AND SERVICES

The NBSR is at the heart of the NIST Center for Neutron Research (NCNR), the nation's premier neutron source. In the words of a recent report issued by the White House Office of Science and Technology Policy, "The NCNR is the highest performing and most used neutron facility in the United States at this time, and will remain in that position until the Spallation Neutron Source is operational and robustly instrumented" (OSTP, 2002). The NCNR is the only source in the U.S. offering all neutron scattering methods coupled with modern instrumentation that is competitive with the worlds best. The NCNR has developed strong working relations with other Federal agencies, including the National Science Foundation and the National Institutes of Health, as well as with federally funded national laboratories (e.g. Brookhaven National Laboratory). Major universities across the nation, such as the University of California, Penn, Johns Hopkins, SUNY at Stony Brook and international organizations such as ANSTO in Australia, Tsinghua University in Taiwan, and the Institut Laue Langevin in France perform work at the NBSR. The current replacement cost of this facility, including the instrumentation, is estimated to exceed $800M.

More than 2000 participants used the NCNR during 2003, in various scientific fields, including biology, materials science, and theoretical physics. Since these participants come from every regional area within the nation, the NCNR is a truly national resource. The impact this facility has on science is exceptional – more than 8 major awards from national science organizations in the past decade have been based on work done at the NCNR. Additionally, more than 200 graduate students yearly, use the NCNR in their thesis research. Unique and innovative instrumentation, such as the High Flux Back Scattering Spectrometer for high-resolution inelastic scattering, which was developed at NCNR, has been reproduced for use in major facilities worldwide. Although reactors of higher neutron flux than the NBSR are in service, several specialized instruments at the NCNR are clearly the best in the world.

The NCNR is used for various research activities, including:

- Studies involving novel catalyst structures that have led to major chemical processing advances,
- Studies of how both giant (current data storage technology) and colossal (future data storage technology) magnetrostriction works, which is the key phenomenon that enables the increase in computer disk drive capacity, while cost has decreased,
- Studies of the dynamic motion of proteins in solution that provides fundamental knowledge on how biological processes function,
- Studies of the stresses produced during the welding of railway tracks that can lead to premature failure of the weld,
- Studies that provide fundamental property data on quantum, one dimensional magnetic chains, which have very special and unique physical characteristics,
- Studies on neutron lifetime by trapping ultra cold neutrons of energies corresponding to less than 10^{-3} K in temperature, using a magnetic trap,
- Studies of jet engine turbine failures from hydrogen embrittlement,

- Studies of polymer structures used to develop additives that prevent diesel fuel from freezing and clogging in fuel lines,
- Studies of complex fluid motions critical to mixing in chemical processes,
- Development and analysis of Standard Reference Materials.

A key aspect of the NCNR has been, and will continue to be improvement-based change. New thermal neutron spectrometers will provide the most intense triple axis crystal spectrometers ever constructed, allowing a new class of measurements to be performed involving problems of major national importance. A new cold neutron triple axis crystal spectrometer will become the world's most intense cold neutron instrument, once again setting a new standard for the field. Even though 37 years have passed since first criticality of the NBSR, this facility is still a critical component in the nation's research and development infrastructure, and remains at the forefront of neutron research in the United States and the world.

10.1 Summary Description

10.1.1 Introduction

The experimental facilities built into the NBSR can be seen in Figures 10.1 and 10.2. Eleven positions are available within the core structure itself for the insertion of experiments and seven positions are available in the reflector. Nine beam tubes are arranged in a radial pattern within the central plane of the core and see the unfueled gap region neutron flux. Two beam tubes run completely through the reactor on either side of the core just below the radial tubes. The reactor includes a large experimental thimble within which a low temperature liquid hydrogen moderator or cold source is installed. This moderator increases the intensity of long wavelength (i.e. "cold") neutrons available to the beams from this neutron source. Seven neutron guide tubes, which transport cold neutron beams with losses of less than 1 % per meter into an adjacent neutron experimental building or neutron guide hall, and one beam port (which does not go to the guide hall) are served by this source. Five pneumatic tubes make up the "rabbit" system, which operates on CO_2. This system allows the rapid insertion and removal of small samples into various parts of the core, reflector, and thermal column. A large volume of well-thermalized neutrons is also available in the graphite thermal column.

Table 10.1 summarizes the experimental facilities in use or under development.

10.2 Experimental Facilities

10.2.1 Radial Beam Tubes

There are a total of nine radial beam tubes. A typical beam tube is shown in Figure 10.3. Four have an inside diameter of 6" (15cm) from the shutter through the thermal shield with a 6-1/2" (16.5cm) ID experimental thimble tube within the reactor vessel. Similarly there are five tubes with corresponding dimensions of 5" (12.7cm) and 5-1/2" (14cm). With the exception of one beam tube shutter that is modified to avoid mechanical interferences, all nine radial beam tubes are identical from the shutter out to the face of the biological shield. The thermal neutron flux at the core end of the beam holes is slightly less than 2.0 x 10^{14} n/cm^2-sec during 20 MW power operations.

There is an aluminum window bolted to the outer face of the thermal shield plug that seals the region between the reactor vessel and the thermal shield. This region is filled with CO_2 to reduce ^{41}Ar production. The thermal shield plug consists of an aluminum liner, surrounded by lead, set in a steel plug that penetrates the thermal shield. All radial beam tubes have vertical shutters located as close to the thermal shield as possible. With the exception of the one beam tube with the modified shutter mentioned above, all radial beam tube shutters are identical and consist of 14" (36cm) of lead, 1.75" (4.5cm) of hydrogenous material (masonite), 0.25" (0.6cm) borated aluminum, and 2" (5cm) of steel, for a total thickness of 18" (45.7cm). The shutters and shutter cavities are lined with Boral. These shutters are designed to provide sufficient shielding when the reactor is shutdown to facilitate easy removal and insertion of plugs and collimators outside of the shutters. Beyond each shutter is an 8" (20.3cm) I.D. hole followed by a 14" (35.5cm) I.D. hole, with beam tube termination in a 2' x 2' x 6" (61cm x 61cm x 15cm) deep recess in the reactor face. This recess has multiple conduits leading into it to allow access to all the services provided for the beam tube.

10.2.2 Through Tubes

Two 4" (10cm) tubes pass completely through the reactor just below the core. This arrangement is shown in Figure 10.1. The arrangement is very similar to that of the radial beams except there is only one shutter for each tube. One end of each through tube has a shutter and the other end contains a plug. The opening through the thermal shield is 4" (10cm) and the tube through the reactor vessel is 4-1/2" (11.4cm) I.D.

10.2.3 Cold Neutron Source

The energy spectrum of thermal neutrons emerging from the beam tubes at the NBSR is described well by a Maxwellian distribution with a characteristic temperature of 350K. Less than 1.5 % of this thermal distribution is composed of neutrons having energies under 5 meV (.005 eV), or equivalently, with wavelengths greater than 0.4 nm. Such neutrons are commonly referred to as "cold" neutrons, and are essential for many neutron scattering experiments. The cold neutron source utilizes a large 21.25" ID (54 cm) experimental thimble port that allows placement of a large volume of low temperature moderating material close to the core. Placement of this moderating material close to the core increases the flux of cold neutrons, which can then be transported with small losses through guides to instruments 164' to 262' (50 to 80 meters) from the source. By maintaining a volume of liquid hydrogen in the path of the neutrons extracted from the experimental thimble port, neutrons attempt to come into thermal equilibrium with the liquid hydrogen, which increases the low-energy neutron intensity by a factor ranging from 40 to 50.

A schematic diagram of the Liquid Hydrogen Cold Source is shown in Figure 10.4, while a plan view showing its location with respect to the reactor and the neutron guides is shown in Figure 10.5. The moderator chamber contains liquid hydrogen used to moderate and lower the effective temperature of the neutrons. Heat generated by neutrons and gamma rays in the liquid hydrogen and its aluminum container is removed by boiling of the liquid hydrogen. The vapor generated exits from the moderator and returns to the hydrogen condenser by the vapor return line, where it is re-liquified and returned to the moderator chamber by gravity through the liquid supply line. These lines are concentric tubes with the liquid supply in the center. Cooling and heat removal is supplied by a closed cycle helium gas refrigerator that can produce up to 3.5 kW of cooling with a final helium gas temperature of 18 K. A thermosiphon maintains the entire hydrogen system at a constant pressure, so the boiling temperature remains between 19.5 K and 21.7 K for pressures of 0.8 bar to 1.5 bar. The heat load at 20 MW reactor power is 1200 W for this source, which vaporizes hydrogen at a rate of 3 grams per second. Total flow in the thermosiphon is larger, but the resulting two-phase flow (liquid and vapor) in the return provides a higher level of stability in operation over varying operating conditions. A large ballast volume that is maintained at room temperature has sufficient volume to contain the entire hydrogen inventory with the refrigerator stopped, the system temperature at 300 K, and a system pressure of less than 74 psia (500 kPa). Calculations of the loop stability, as well as independent friction calculations, indicate that 20 cm of head is adequate for this circulation, while the actual liquid/vapor separation distance is in excess of 79” (200 cm), leaving ample margin to assure two-phase flow in the vapor return line. There is a phase separator located near the vapor return line in the condenser that returns some of the liquid directly to the source, which also increases stability. All vessels and piping are designed to the ASME code for pressure vessels, using the maximum design stress specified for 6061-T6 aluminum with welded joints, which is 6000 psi (40.8 MPa). This makes the rupture strength for these vessels many times the maximum design working pressure.

The hydrogen loop and ballast volume, once leak-tight and charged with hydrogen, is entirely closed. Charging is only done at installation, and after the system is opened for corrective maintenance. This charging operation is only performed by trained and qualified staff, and is strictly controlled by written procedures. There is no provision for hydrogen venting in this system, as this would create additional failure modes with no safety gain. This non-vented system also eliminates further gas handling, which minimizes the possibility of inadvertent oxygen contamination. If the system must be emptied of hydrogen to allow maintenance on a component, it is accomplished by absorbing the entire inventory into metal hydride storage containers, which facilitate removal from the confinement building. All hydrogen lines are either within the biological shield, encased within heavy steel shields, or routed in existing floor trenches outside the biological shield, which prevents possible accidental rupture during operation. In addition, all hydrogen containing components are completely surrounded by a blanket of helium gas, maintained above atmospheric pressure so that there can be no in-leakage of air into the hydrogen system, and thus no oxygen is available to combine chemically with the hydrogen. Preventing oxygen intrusion into the system precludes any oxygen deflagration concentration formation. The parameter used for control and monitoring of the system is the hydrogen pressure. When in equilibrium, absolute pressure is a measure of the temperature of the hydrogen in the source, which is a direct analogy to a vapor bulb thermometer. This system avoids having an active measuring device installed in a high radiation area. The entire design philosophy relies on simple, passive safety features that minimize the possibility of a system failure or a procedural problem, thus promoting reliable and safe operation.

When the reactor is at power, operation of the hydrogen system is procedurally controlled. The cold source and refrigerator are operated from a control console that is equipped with a programmable controller (PLC) to monitor and display all important system parameters. It is powered from an Uninterruptible Power Supply (UPS) that provides power during short power interruptions. The PLC has its own battery backup, so that the status of the system can be preserved. The PLC interface is via personal computers capable of initiating routine operations, displaying system parameters, and logging data.

There are two conditions associated with the cold neutron source that can cause a reactor run-down: 1) An inability to cool the moderator chamber due to a refrigerator malfunction, and 2) A loss of the heavy water supply. It should be noted that these rundowns occur to protect the cold source, and are not required to protect the reactor. The basic cold source operating parameters, such as temperature and pressure, are constantly monitored, and when these deviate from normal operating ranges, an alarm is annunciated in the control room.

10.2.4 Thermal Column

The thermal column provides the ability to perform irradiations on large and irregular shaped specimens. It can be seen in Figure 10.2. A section of the thermal column is a tank containing circulating D_2O that cools a 7 1/2" (19cm) thick bismuth gamma ray shield. The bismuth reduces the core and capture gamma rays to a level where most of the gamma radiation in the graphite region comes from neutron capture in the graphite itself. The D_2O circulated through the thermal column is a separate flow system from the reactor coolant system, and also includes a plate type heat exchanger to remove the heat produced in the system.

The graphite region is 54" x 52" (137cm x 132cm) in cross section and 37" (94cm) deep. It is made up of blocks of graphite called stringers. Certain groups of stringers are made to be readily removable through a plug in the thermal column shield door. In addition, access is provided to the graphite from the top through a vertical hole approximately one foot on a side. The shielding door can be rolled back to provide access to the whole graphite region if desired. The graphite is surrounded by Boral that is backed by water-cooled lead. There is a Boral curtain the size of the thermal column that can be raised and lowered between the bismuth shield and the graphite that acts as a thermal neutron beam shutter.

10.2.5 Pneumatic Tube System

Four thimbles for pneumatic tubes penetrate the reactor vessel. They are designed to allow the rapid insertion and removal of samples inside the high flux regions of the reactor. The containers that carry the samples, commonly known as “rabbits,” are approximately 1" (2.5cm) inside diameter, and travel at speeds of 30 to 45 ft/sec (914 to 372 cm/sec). Automatic timing and control devices can be set to allow exposures ranging from a few seconds to several days.

Each tube has a send and receiver station in a radiological laboratory located in the reactor basement. All of these stations are located within radiological hoods.

10.2.6 Vertical Thimbles

The position of the in-core and reflector thimbles can be seen in Figure 10.1. In the regular hexagonal arrangement of the core there are seven positions, which are normally used for 3-1/2" (8.9cm) diameter thimbles. Also within the core, there are four smaller 2-1/2" (6.3cm) thimbles located between adjacent fuel elements. Seven more thimble positions up to 4" (10cm) in diameter are available in the reflector.

10.2.6.1 Three and One-Half Inch Experimental Thimbles

Each of the seven 3-1/2" (8.9cm) positions in the core is occupied by a 4" (10cm) O.D. x 3-1/2" (8.9cm) I.D. cylinder that has a bottom end fitting designed to fit the standard grid plate opening. The end fitting largely blocks the normal flow, but contains a small opening that allows approximately 8 gpm (0.5 liter/sec) to flow upwards through the tube to cool it, and any experiment that may be in it. This flow is sufficient to cool most samples that are inserted. If necessary, the experiment can be cooled by auxiliary lines from above. Poison tubes above the reactor core, as depicted in Figure 10.2, hold down these thimble cylinders. To insert an experiment, the shielding plug is removed from the inside top of the hold down tube and the experiment inserted in the core. Only six of the seven positions are available for experiments, since one position is used for the regulating control rod.

These thimbles are actually small volumes of D_2O surrounded by fuel elements with a radius of 7" (17.8cm) to the center of adjacent elements. Consequently, the thermal flux is somewhat enhanced, while the fast flux is depressed. The ratio of thermal to fast flux is estimated to be approximately 2 adjacent to the fuel, and over 4 at the mid-core gap.

10.2.6.2 Two and One-Half Inch Experimental Thimbles

The 2-1/2" (6.3cm) I.D. experimental thimbles are semi-permanent cylinders held in place by the top grid plate. They can only be removed by removing the top grid plate first, and do not fit into a standard fuel element hole in the bottom grid plate. Therefore, special, smaller receivers have been built into the bottom grid plate to accommodate them. These smaller sockets have a small hole at the bottom that allows approximately 10 gpm (0.6 liter/sec) of plenum cooling water to flow up through the experimental thimble.

The cylinders are located between adjacent elements so they are as close as possible to fuel. This proximity to the fuel enhances their fast flux spectrum, and provides a better flux for radiation damage experimentation than is available in the 3-1/2" (8.9cm) thimbles.

Although samples and supporting equipment can have a diameter up to 2-1/2" (6.3cm) in the core, any supporting tubes, leads, or other needed services which project above the top grid plate must not exceed 1-1/2" (3.8cm) diameter. Although there are normally no interferences in this region, this restriction is necessary so that fuel elements being transferred by the transfer arms do not touch the supports of the experiments in the 2-1/2" (6.3cm) thimbles.

10.2.6.3 Reflector Thimbles

The top shield plug has seven ports designed into it to allow insertion of experiments up to 3-1/2" (8.9cm) diameter in the reflector. Location of these ports is depicted in Figure 10.1. They are approximately half way between the core surface and the vessel wall. There are no thimbles constructed in the vessel as part of the reflector facilities. Instead, any sample or experimental device is supported from the top by a tube inserted through the plug. Each experiment requires its own design and construction; only the openings in the top plug are provided initially. No cooling other than free convection is provided in the reflector, but additional cooling can be provided from outside the plug if necessary.

10.2.7 Experimental Facility Services

The utilities that service the NBSR experimental facilities exist on both the first and second floor levels inside and outside confinement. These utilities within confinement are discussed separately in the following sections.

10.2.7.1 First Floor Services

Recesses in the biological shield contain utilities necessary for experimental stations located at the reactor face. Uninterruptible and regular 120 volt power are available, and one three-phase 208 volt outlet is mounted flush with the shielding face, and located approximately every two beam holes. All power supplies are protected by 20 amp circuit breakers.

Demineralized water and compressed air are available within these recesses. Recesses where the beam ports exit from the biological shield are connected to these utility recesses by curved conduit embedded in the concrete. This allows utilities to be supplied to the interior of the shielding system around the beam holes without interfering with the shielding.

A third recess is located directly below each hole that is also connected to the recess described above by embedded conduit. This recess contains valved water returns and a valved drain to the reactor liquid waste system. It also contains a junction or pull box for any signal leads, tubes, or wires from which it may be desirable to run from the vicinity of the beam hole to a control station. These pull boxes are connected to the containment building wall by conduits embedded in the concrete floor, with an intermediate access box approximately 10' (3m) from the reactor face.

Chilled water for experiments is available from a header system located at the top of the biological shield. This cooling system loop, made up of circulating pumps, a pressure tank, and a heat exchanger uses site-wide chilled water to maintain the circulating water at a temperature of 70º F (21ºC).

In addition to the utilities in the reactor face, electric power and domestic water are available along the building wall.

10.2.7.2 Second Floor Services.

A utility trench and raceway, approximately 12" (30.5cm) deep by 12" (30.5cm) wide formed by the center plug liner and the top outer doughnut of the reactor, contain services for use on the reactor top. There are holes in the raceway walls that provide direct access to the utility trench. Conduit is installed from the trench to the experimental hole recesses in the upper doughnut and directly from the trench to the center plug region. The experimental hole recesses are connected to the center plug region using short 6" (15.2cm) diameter openings. Conduit from the trench to pull boxes in the floor is routed to the wall, allowing signal cables, and other experiment wiring, to be run between instrumentation at the wall and the center plug region. This system of conduit, trenches, and openings allow configurations necessary to service in-core experiments, while maintaining shielding requirements.

Demineralized water, D_2O, and compressed air outlets are provided in the trench. Each line is valved and also equipped with a quick disconnect fitting. Instrument and regular 120 volt electric power are available both on the outer trench walls and in the raceway. More instrument and regular outlets are mounted on the room walls with 208 volt three-phase outlets.

In addition to the utilities, the trench contains the pneumatic drive system for the shutters. A pneumatic cylinder is mounted above each shutter and the compressed air to move the shutter is supplied from the trench.

All trenches, raceways, and other recesses are fitted with cover plates that fit flush with the floor. The plates are sufficiently strong to match the load bearing capacity of the floor. The floor plate over the center plug is made of 6” (15.2cm) thick steel.

10.2.8 Operating Considerations

10.2.8.1 Experimental Cooling

None of the presently installed experimental facilities on the horizontal beam tubes require cooling water during operation, except for the cold source that was previously described. The plenum water flowing up through the vertical experimental thimbles in the core is adequate to cool most of the in-core irradiations, although some irradiation facilities may require additional cooling, which can be obtained from the D_2O services mentioned earlier. The pneumatic rabbit facilities are cooled by experimental D_2O. Each cooling system for removal of reactor-generated heat is monitored for temperature or flow, and sometimes both.

10.2.8.2 Experimental Interactions with the Core

The emphasis at the NBSR is on neutron beam programs and small sample irradiations. No plans exist for fuel element development studies or the irradiation of other bulk type components, which might introduce large amounts of fissionable materials into the core. The beam tubes, which are used almost exclusively to extract neutron beams from the reactor, have no significant interaction with the core. The differential reactivity of filling the cold neutron source with liquid hydrogen is -$ 0.013 ± 0.04.

The pneumatic tube system does have a limited interaction with the core. Since the rabbits are inserted and removed rapidly, they can introduce sudden, but quite small changes in reactivity. These changes are small compared to the reactivity controlled by the regulating rod and do not impact reactor control.

The vertical thimbles are used primarily for small sample irradiation. Most of the in-core facilities are designed so they can be inserted or removed only during shutdown. Although it is possible to insert and remove a few low reactivity experiments during operation, the reactivity of such experiments is limited to values less than the worth of the regulating rod.

In every case, where it is determined that the failure of any experimental component or physical phenomena could impact the operation of the reactor those effects are monitored. Technical Specification 4.0 requires that the absolute reactivity of any experiment not exceed 0.5% $\Delta\rho$, and the sum of absolute reactivity for all experiments not exceed 2.6% $\Delta\rho$, including a 0.2% $\Delta\rho$ for potential pneumatic irradiations.

The loss-of-coolant analysis in Chapter 13 states that for a total loss of reactor coolant, the integrity of the fuel will be intact. Therefore, even though the experimental facilities described in this chapter penetrate the reactor vessel, and in some cases into the core region, occurrence of a failure in the experimental facilities is bounded by the analysis contained in Chapter 13 of this report.

10.3 Experiment Review

Before any new experimental instrument may be commissioned, an experimental proposal that details the function and design of the instrument must be submitted to the NCNR Safety Evaluation Committee (SEC) in accordance with Technical Specifications 6.2(2) and 6.2(3). This committee reviews and approves all new experimental instruments that make use of the neutron beams provided by the NBSR. The experimental proposals are written with assistance from the NCNR Beam Coordinator, who ensures that each proposal contains all of the requisite information required for a safety review. In addition, a brief summary document, that describes in simple terms, how to shut down the instrument in a safe configuration, must be included in the proposal, must be subsequently posted by the instrument, and is provided to the reactor operations staff.

In order to obtain access to any experimental facility at the NCNR, an applicant must submit a request or proposal for beam time that describes the experiment in detail, the type(s) of sample(s) to be studied, and any potential risks that might exist. The NCNR Safety Representative reviews this information. The Safety Representative determines whether any safety issues merit a more complete review. No hazardous material may be introduced into the confinement building without the review and approval of the Director, NCNR. The Hazard Review Committee is composed of members from the scientific, technical, and reactor operations staff, and includes at least one representative from the Health Physics Group, from the Safety Evaluation Committee, and from Reactor Operations. The Hazard Review Committee is responsible for review of all materials brought into the NCNR, if the Safety Representative determines any materials are outside of existing safety envelopes.

10.3.1 Technical Specifications

The following Technical Specification applies to the review, approval and implementation of experiments to be performed at the NBSR.

Technical Specification 3.12 Experiments

This specification applies to any experiments to be installed within the NBSR.
Any experiment installed in the reactor shall meet the following criteria:

(1) The absolute reactivity of any experiment shall not exceed 0.5% $\Delta\rho$

(2) The sum of the absolute values of reactivity of all experiments in the reactor and experimental facilities shall not exceed 2.6% $\Delta\rho$

(3) No experiment malfunction shall affect any other experiment so as to cause its failure. Similarly, no reactor transient shall cause an experiment to fail in such a way as to contribute to an accident

(4) Explosive or metastable materials capable of significant energy releases shall be irradiated in double walled containers that have been satisfactorily prototype tested with at least twice the amount of the material to be irradiated

(5) Each experiment containing materials corrosive to reactor components or highly reactive with reactor or experimental coolants shall be doubly contained.

Basis:

The individual experiment reactivity limit is chosen so that the failure of an experimental installation or component shall not cause a reactivity increase greater than can be controlled by the regulating rod. Because the failure of individual experiments cannot be discounted during the operating life of the NBSR, failure should be within the control capability of the reactor. This limit does not include such semi-permanent structural materials as brackets, supports, and tubes that are occasionally removed or modified, but which are positively attached to reactor structures. When these components are installed, they are considered structural members rather than part of an experiment.

The combined reactivity allowance for experiments was chosen to allow sufficient reactivity for contemplated experiments while limiting neutron flux depressions to less than 10 %. Included within the specified 2.6% $\Delta\rho$ is a 0.2% $\Delta\rho$ allowance for the pneumatic irradiation system, 1.3% $\Delta\rho$ for experiments that can be removed during reactor operation, and the remainder for semi-permanent experiments that can only be removed during reactor shutdown. Even if it were assumed that all of the 1.3%Δρ for removable experiments was inserted in 0.5 seconds, analysis shows that this ramp insertion into the NBSR operating at 20 MW would not result in any fuel failure leading to the release of fission products (SAR, NBSR 14, Chapter 13). The 0.2% Δρ for the combined pneumatic irradiation systems is well below this referenced accident as well as being within the 0.5% Δρ capability of the regulating rod.

In addition to all reactor experiments being designed not to fail from internal overheating or gas buildup, they shall also be designed to be compatible with their environment in the reactor. Specifically, their failures shall not lead to failures of the core structure or fuel, or to the failure of other experiments. Also, reactor experiments shall be able to withstand, without failure, the same transients that the reactor itself can withstand without failure (i.e., loss of reactor cooling flows, startup accident, and others where the reactor's safety system provides the ultimate protection).

The detonation of explosive or metastable materials within the reactor is not an intended part of the experimental procedure for the NBSR however; the possibility of a rapid energy release shall be considered when these materials are present. Because the analytical methods used for designing containers for very rapid energy releases are not well developed, full prototype testing of the containment design is specified. The requirement for testing twice the amount of material to actually be irradiated provides a safety margin of a least a factor of two (2) to allow for possible experimental uncertainties.

Experiments containing materials corrosive to reactor components or highly reactive with reactor or experimental coolants, although limited by item three (3) of this specification, provides the potential for reducing the integrity of the fuel elements. For this reason, an added margin of safety shall be required to prevent the release of these materials to the reactor coolant system. This margin of safety is provided by the double encapsulation, each container being capable of containing the materials to be irradiated.

10.4 References

Office of Science and Technology Policy (OSTP), (June 2002). *Report on the Status and Needs of Major Neutron Scattering Facilities and Instruments in the United States*.

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Table 10.1: Experimental Facilities

Description	Number of Units
11 Beam Tubes	
6” (15.2cm) I.D. radial tubes	4
5” (12.7cm) I.D. radial tubes	3
5” (12.7cm) I.D. truncated radial tubes	2
4” (10cm) I.D. through beam tubes	2
Cryogenic Facility	
Large rolling plug for insertion/support of low temperature moderator	1
6” (15.2cm) beam tubes viewing cold moderator	2
Cold Neutron Guides	7
Thermal Column, 54” (137cm) x 52” (132cm) x 37” (94cm) deep graphite	1
18 Vertical Thimbles	
3-1/2” (8.9cm) I.D. in core	7
2-1/2” (6.4cm) I.D. in core	4
4” (10cm) in reflector	7
Pneumatic Tube Penetrations (For accepting 1” (2.5cm) I.D Rabbits)	5

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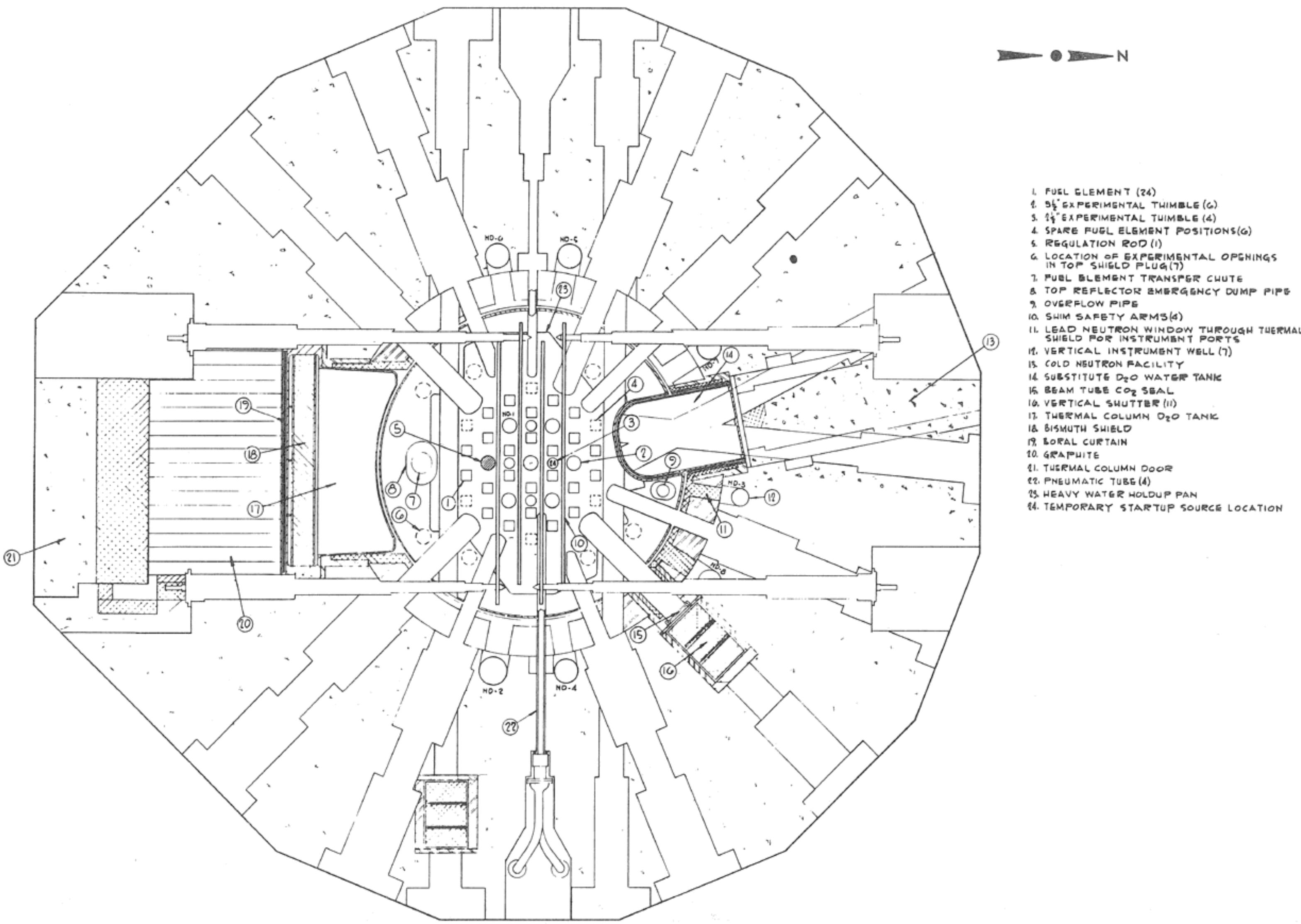

Figure 10.1: NBSR Experimental Facilities

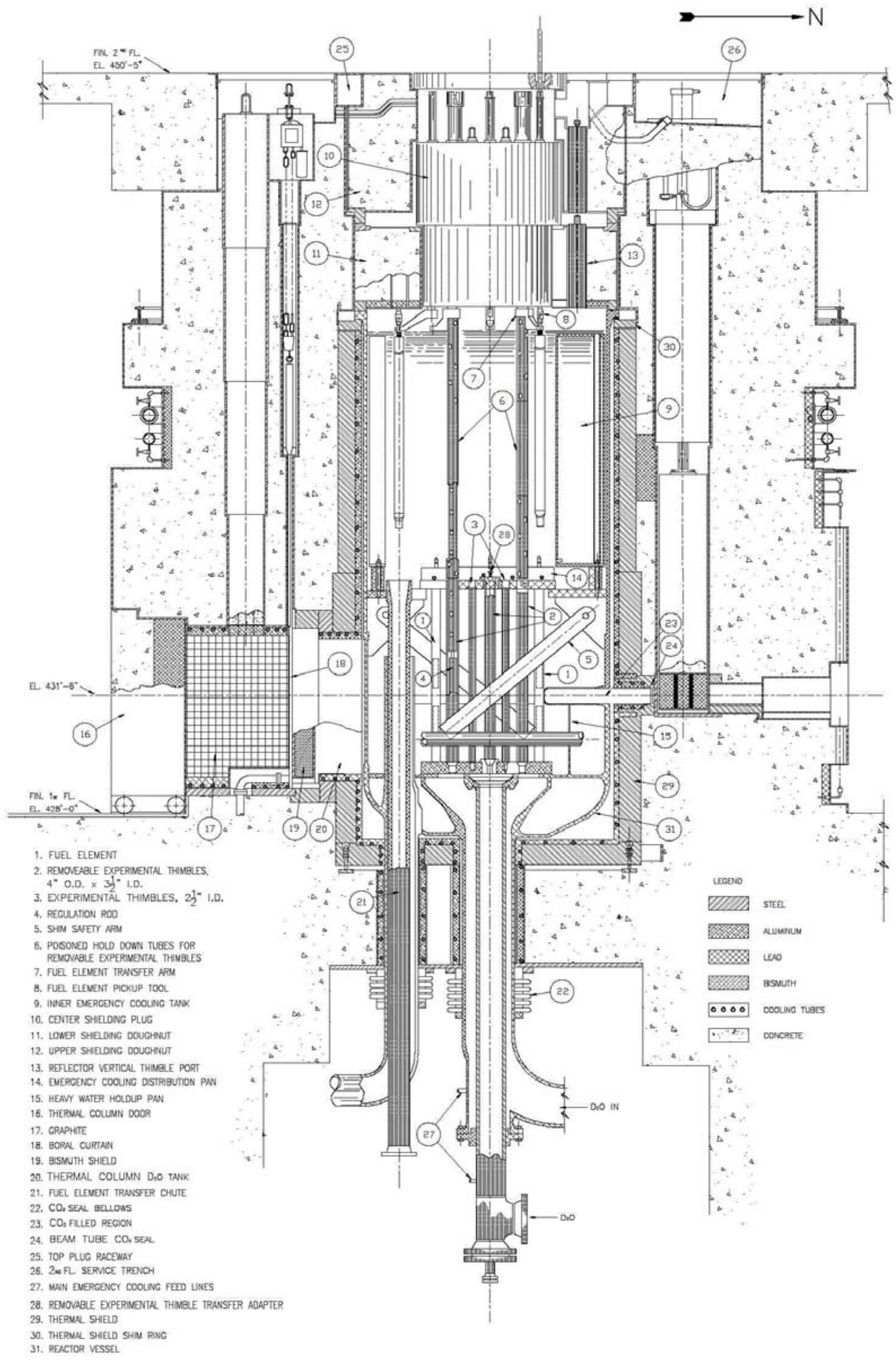

Figure 10.2: NBSR Experimental Facilities 2

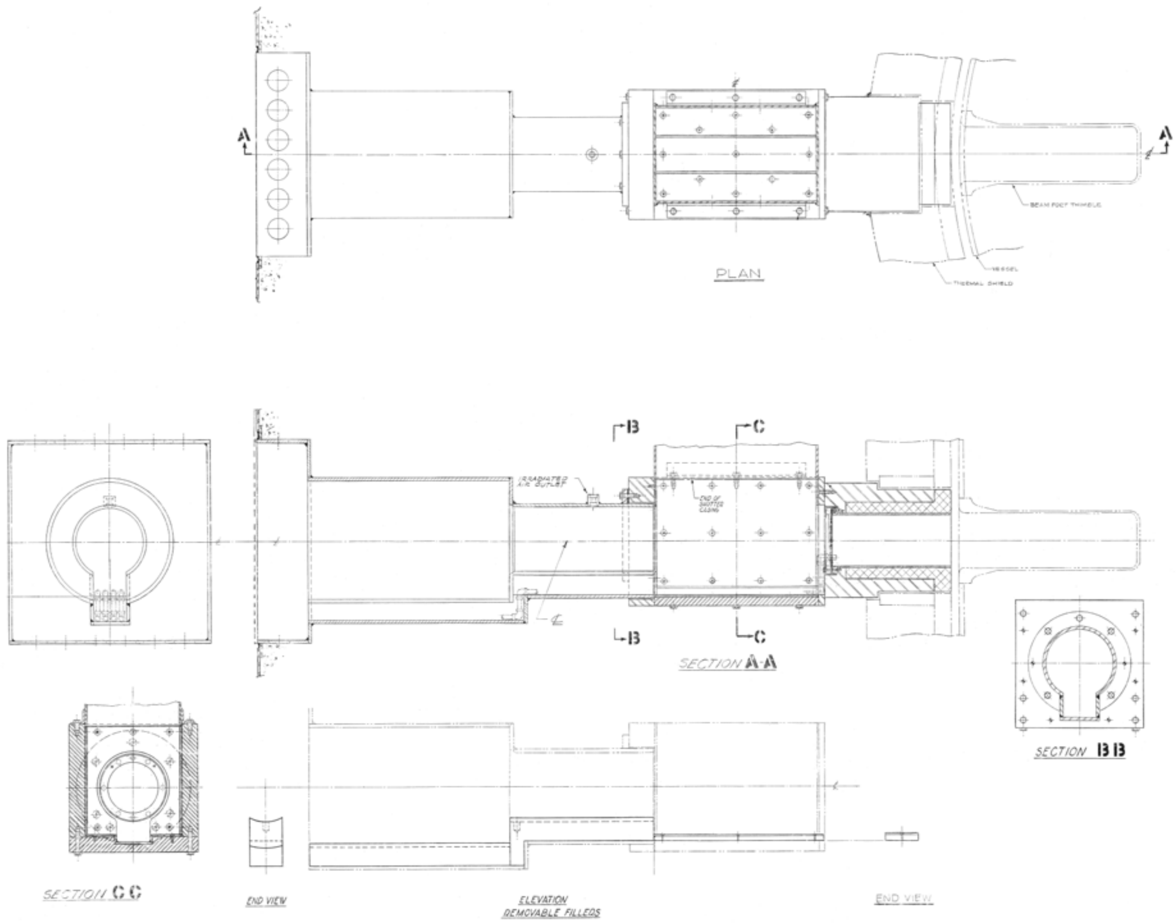

Figure 10.3: Typical Beam Tube

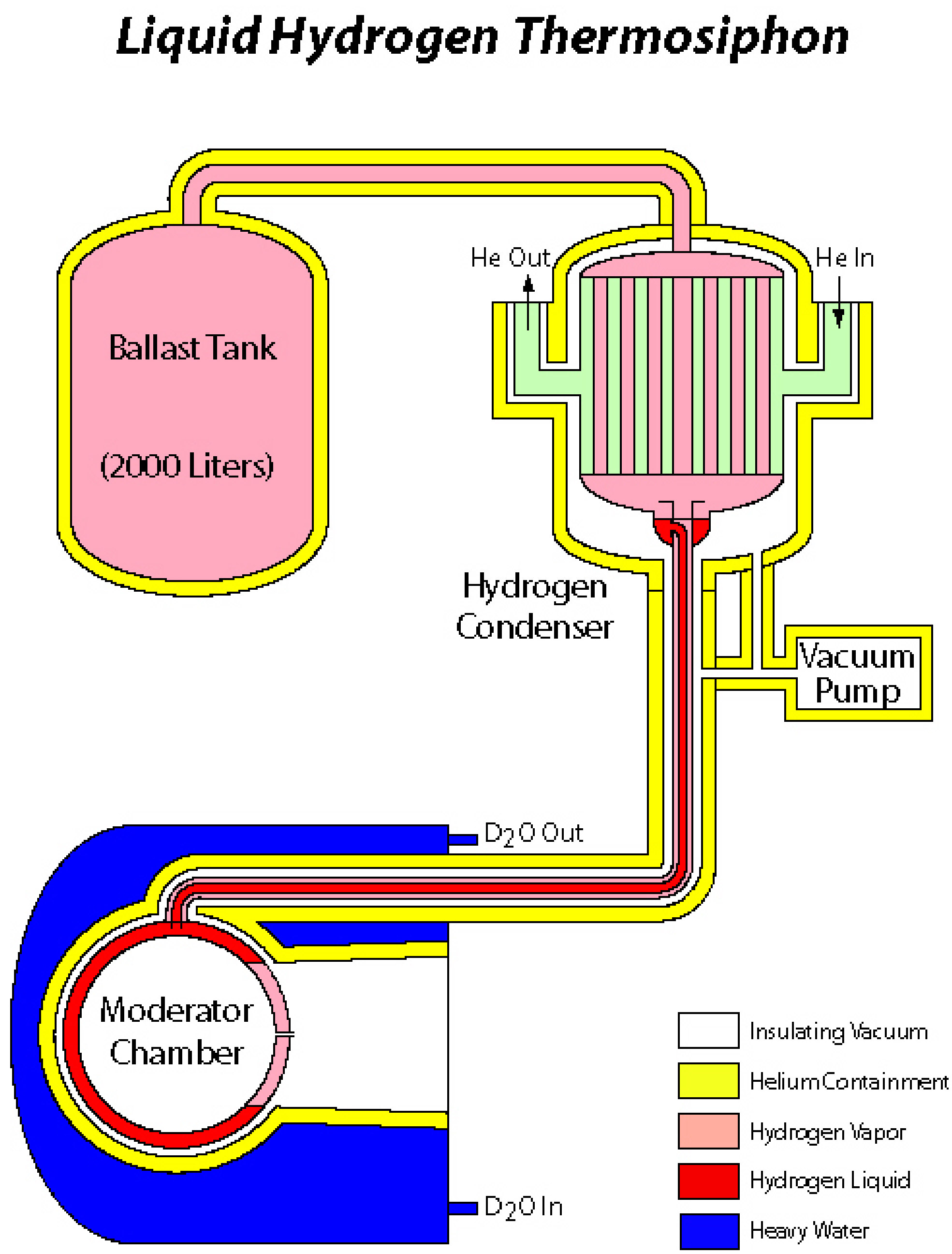

Figure 10.4: Schematic of the Liquid Hydrogen Cold Neutron Source

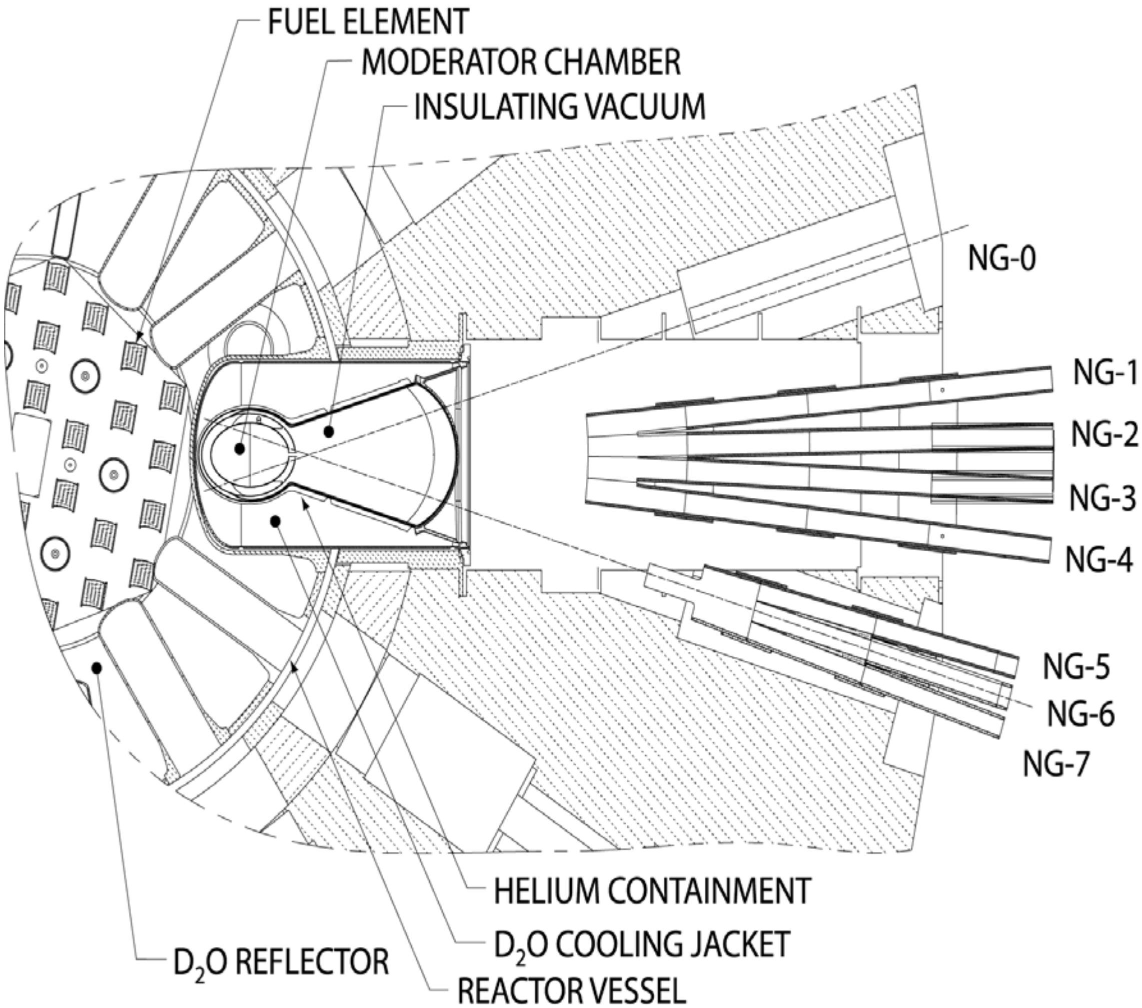

Figure 10.5: Plan View of the Liquid Hydrogen Cold Source