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Safety Analysis Report for the
National Low-Temperature Neutron Irradiation Facility (NLTNIF)
at the ORNL Bulk Shielding Reactor (BSR)

R. R. Coltman, Jr.
H. R. Kerchner
C. E. Klabunde
S. A. Richardson

Experimenters

Solid State Division

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Oak Ridge, Tennessee 37831
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EXPERIMENT INFORMATION AND SAFETY ANALYSIS FORM
FOR EXPERIMENTS IN THE ORNL RESEARCH REACTORS

Form Completion Date	June 1986
Experiment Number	NLTNIF
Research Person in Charge	R. R. Coltman, Jr./H. R. Kerchner
Research Division (Sponsoring)	Solid State
Reactor	Bulk Shielding Reactor (BSR)
Experiment Facility Type	National Low-Temperature Neutron Irradiation Facility (NLTNIF)
Experiment Assembly (Type)	
Location in Reactor	Center Position - West Face
Operations Technical Coordinator	S. S. Hurt III/T. P. Hamrick
I&C Lead Designer	W. M. Fletcher
MMES Engineering Lead Designer	D. L. Haynes (C. W. Collins, Ret.)
Quality Assurance Coordinator	J. R. Gibson
Duration of Experiment Program	Indefinite
Date of Planned Insertion	June 1986
Charge Code	3475-0440

BRIEF DESCRIPTION OF THE EXPERIMENT

A National Low-Temperature Neutron Irradiation Facility (NLTNIF) has been constructed at the Bulk Shielding Reactor (BSR) for qualified experiments at no cost to users. The NLTNIF provides a combination of high radiation intensities and special environmental and testing conditions that have not been previously available in the U.S. The capabilities of the NLTNIF include a 7.75 in. diam x 12 in. long test chamber into which specimens can be moved without warmup from a 1.5 in. diam irradiation chamber below. The test chamber can be equipped with devices for property change measurements. Irradiation temperatures from 3.5 to 350 K can be obtained. Provisions are made for the transfer of specimens at 4.2 K into test devices or into vessels for shipment to other laboratories. On-line data acquisition and computer capability are provided.

1. GENERAL INFORMATION

1.0 Introduction

In May 1983 DOE authorized the establishment of a NLTNIF at ORNL's Bulk Shielding Reactor. The facility is to be available for qualified experiments at no cost to users. Funding is provided for operation of the BSR with primary use by NLTNIF. Presently, there is no other low-temperature reactor neutron irradiation facility in the U.S.

Since it was recognized at the outset that the construction of NLTNIF would take about three years, the staff made two interim presentations with handouts (7/15/83 and 11/8/84) to the RERC and others interested in the project. The purposes of the presentation were to familiarize the RERC with the design and operation of the facility during the course of construction and to solicit any comments and discussion prior to the preparation of this Safety Analysis Report (SAR). During the course of construction the basic design of the facility did not change.

The facility can be divided into four main parts constructed by the indicated groups:

1. The Irradiation Cryostat System — Gen. Engrg., ORNL, and outside contractor
 - a. The Irradiation Cryostat
 - b. Interchangeable Gamma-Ray Shield
 - c. Personnel Platform
 - d. Ambient Storage Facilities
 - e. LHe Storage Facilities (SSD)
 - f.

Test Assemblies	}	Future Components
Experiment Assemblies		
Radiation Modifiers		

2. The Interface System - SSD

Cryopiping, a commercial Joule Thomson heat exchanger, and valving connect the refrigeration system to the irradiation cryostat.

3. The Improved Liquid He Refrigeration System — Gen. Engrg., ORNL, and outside contractor

A commercial refrigeration system that has been in service at ANL combined with a commercial heat exchanger and compressors from an earlier ORNL system provides refrigeration to the irradiation cryostat.

4. Instruments and Controls for Cryostat Management and Safety — Gen. Engrg., ORNL, and SSD

This Safety Analysis Report seeks approval of:

The basic cryostat as an "empty facility" and the interface and refrigeration systems.

One interchangeable gamma-ray shield made of zircaloy.

The personnel platform.

The ambient storage tubes.

Approval will be sought later on a timely basis from operations or, as needed, from the RERC for:

Test Assemblies

Experiment Assemblies

Alternative Gamma-Ray Shields

Radiation Modifiers

The LHe storage facility constructed by SSD has been approved by Operations.

1.1 Experiment Personnel

(The order to be contacted in the event of an emergency is variable. It is posted on a board over the main control panel of the NLTNIF Control Room. Operations Personnel are familiar with the board.)

Table 1

Name	*	**	Building	Phone	
				Business	Home
R. R. Coltman, Jr.	x	x	3115	4-6263	7-690-2705
H. R. Kerchner	x	x	3115	4-6270	3-482-1975
C. E. Klabunde	x	x	3115	4-6264	3-483-8055
S. A. Richardson		x	3115	4-4727	7-947-0273

*Persons qualified to make technical decisions regarding the experiment.

**Persons qualified to operate the experiment.

1.2 Manning of the Experiment by Research Personnel

The NLTNIF staff is present during the insertion and removal of all experiment assemblies and at reactor startups and scheduled shutdowns. The experimenters monitor the facility at least every four hours during the day shift on regular work days (reactor ON or OFF), and reactor operations monitors once each shift at all other times.

1.3 Special Assistance Desired from Operations Personnel (Nature and Extent of Assistance Desired)

Overhead crane and traveling bridge operation is required for short periods during experiment insertion and removal. See 1.2 above for needed refrigerator monitoring service. It is required that the NLTNIF "E" panel be unlocked and the Tel-Alarm system checked prior to each reactor startup after insertion of a new experiment assembly

1.4 Special Requirements of the Reactor

1.4.1 During power level changes (startups, shutdowns, power adjustments).

Any power level up to 2 MW may be required. Stepwise startups are often requested. Small power adjustments are sometimes required during irradiation.

1.4.2 During the operating cycle.

The BSR does not operate on a fixed cycle. Reactor schedules are arranged by the NLTNIF staff and Operations personnel.

1.4.3 During shutdowns.

Both normal shutdowns and prearranged scrams originating from the NLTNIF control room are used. Relocation of the reactor at least three feet away from the NLTNIF cryostat (standby position) within one minute after scram is often requested.

1.5 Health Physics Services Required

Personnel monitoring by a health physicist is required during the removal of an experiment from the NLTNIF sample chamber to adjacent proside experiment storage tubes and from the latter to disposal sites. Monitoring is also needed occasionally for the transfer of an experiment from the NLTNIF sample chamber or storage tubes to an adjacent laboratory for adjustment, repair, or further study. Health Physics assistance will also be needed when the NLTNIF is dismantled.

1.6 Utilities Required

Table 2

	Property	A.C.*	D.C.	Emergency**	Other
Electrical Power	Voltst	480/3 ϕ			
	Amps	200 AMP service plus a separate 750 KVA substation			
	Power	~60 % of capacity			
		Process	Demineralized	Reactor	Pool
Water††	Pressure (psig)	60			
	Flow (gpm)	50			
Compressed Air		Plant Supply	Emergency Supply	Other	
	Pressure (psig)	50			
	Flow (scfm)	<1 (instruments only)			
Steam	Pressure (psig)				
	Quantity (lb/min)	Steam is used for building heating			
Drains		Process	Radioactive		
	Flow (gpm)	50			
Cell Ventilation System		Normal	Emergency	Other	
	Negative Pressure (in H ₂ O)	0.03			
	Flow (cfm)	10 intermittent	250 (single puff)		

*Designate whether clean or standard power source is required.

**Designate the source of emergency power.

†From the incoming 480 v/3 ϕ service indicated above, transformers located at NLTNIF also provide 240 v/3 ϕ , 240 v/1 ϕ , and 110 v/1 ϕ .

††Closed circuit cooling for compressors is provided through use of the BSR cooling tower when outside ambient temperatures permit.

1.7 Disposal

1.7.1 The Experiment Facility

A precise description of the disposal procedure for the NLTNIF depends upon the radioactivity of various parts which cannot be accurately predicted. Activity levels will depend upon the unknown factors of lifetime of the facility, amount of irradiation, and the time for decay after the final irradiation. (When the research program is terminated, the existing facility can be allowed to decay in the pool for perhaps a year or more without interference to other operations.) The following general procedure will be used for disposal. First, the upper end of the irradiation cryostat will be disconnected from the cryopiping inside the junction box, and the experiment access tube/heat exchanger assembly will be removed. After raising the cryostat to expose the midpoint flange it will be disconnected and the upper unit sent to salvage after checking for contamination. The cryostat will then be further raised to expose the lower flange which will be disconnected along with the ballast if radiation levels permit. The lower vacuum jacket will be slipped off and the inner tube severed for their removal to the burial ground. If the activity at the lower flange is too great for disassembly the unit will be buried as is. These operations are not expected to differ in difficulty from many other disposal procedures carried out at the BSR.

1.7.2 Experiment Assemblies

Experiment assemblies are removed from the sample chamber of the NLTNIF and first stored in adjacent (about 4 feet away) poolside dry

storage tubes. Sometimes an experiment assembly is reinserted for further study. An assembly is allowed to decay for usually one or more years, after which the lower radioactive end is severed and removed for burial.

2. EXPERIMENT FACILITY INFORMATION

2.1 Objective of Experiment Facility

The goals for the NLTNIF are to provide a combination of high radiation intensities and special environmental and testing conditions for use by U.S. and foreign scientists to study irradiation effects in materials at low temperatures.

2.2 Description of Experiment Facility

2.2.1 Space Requirements

Figure 1 (ORNL-DWG-82-19248R2) shows the layout of NLTNIF in Buildings 3010S and 3010.

2.2.2 Containment Barriers

The principle of double containment has been employed in the design of the NLTNIF cryostat. The barriers are identified in Fig. 14 (ORNL-DWG-86-10364) but a discussion of the containment system is given later in Section 11.

2.2.3 Flow or Functional Diagrams, Drawings, and Specifications

Schematic diagrams showing the four circuit branches of the NLTNIF system are given in:

Fig. 2 (SSD-NLTNIF-6) He Refrigeration System

Fig. 3 (SSD-NLTNIF-3) Cryostat Management System

Fig. 4 (SSD-NLTNIF-7) LN Systems

Fig. 5 (SSD-NLTNIF-8) Insulating Vacuum System

Engineering drawings with specification lists of the system mechanical components are attached in packets as follows:

NLTNIF Cryostat

Installation	X3E-12566-001
Cryostat Assembly	-003
Main Access Box Assembly	-006
Main Access Box Details	-007
Access Tube/Sample Tube and Copper Shield Assembly	-009
Access Tube	-010
Sample Tube Assembly and Detail	-011
Jacket and Tube Detail	-014
Miscellaneous Details	-015
Heat Exchanger and Flange Assembly	-016
Heat Exchanger and Flange Assembly	-017
LN ₂ Heat Exchanger Assembly	-018
LHe Heat Exchanger Assembly	-019
LN ₂ Inner Can Subassembly	-020
Miscellaneous Details	-022
Miscellaneous Details	-023
Irradiation Vacuum Can Assembly	-024
Irradiation Vacuum Can Detail	-025
Vacuum Jacket Assembly	-029
Access Tube Assembly	-030

Gamma-Ray Shield

Zirconium Shield Assembly X3E-12566-026

Biological Shields

Biological Shield Details X3E-12566-027

Shield Assembly and Details -028

Personnel Platform

Platform Installation X3E-12566-002

Work Platform and Details -004

Work Platform Details -005

Ambient Storage Facilities

Platform Installation X3E-12566-002

Work Platform Details -005

Interface System

NLTNIF Interface System X3E-12566-100

2.2.4 Major Mechanical Components and Special Design Features2.2.4.1 Interrelationships Between the Irradiation Cryostat, Shield, and BSR Core

Figure 6 (SSD-NLTNIF-5) shows a broad view of the relationship between the fixed irradiation cryostat and the movable BSR reactor core. NLTNIF irradiations are made with a core location which places the cryostat in a central notch on the west core face. At all other times the core is positioned away from the cryostat (at least 3 ft).

The irradiation cryostat was installed in the BSR pool in early December, 1984. The fitting-up between the cryostat, shield, and

core was carried out from 12/15/84 to 1/15/85, and the process is described in Appendix I. Permanent steel stops were installed to provide for the quick repositioning of the core at the NLTNIF site. The BSR core has been reduced to the smallest size heretofore — 24 elements (5 x 5)-1 — to increase the neutron flux. This core has been operated at full power (2 MW) many times and, according to operations, its stability and other qualities are found to be suitable for continuous service. Interchangeable gamma-ray shields fit into the selected central core face position in the same fashion as a fuel element. The first shield will be of zircaloy.

Figure 7 shows the detailed relationship between the cryostat and the BSR core. When the core is in the NLTNIF position the center of the cryostat's irradiation chamber is at the center of the vacant fuel element position. The location of control rods in next-nearest neighbor positions to NLTNIF minimizes the effect of rod motions on the flux in NLTNIF and, in turn, the effect of experiment materials on reactor control. This configuration is needed to provide clearance between the control rods, and the larger upper portions of the cryostat. To provide additional clearance the cryostat is tilted 2° outboard.

2.2.4.2 The Operating Principle of the Cryostat (Refer to Figure 6)

A metered amount of GHe is charged into the main access tube through a cryostat management circuit (Fig. 3). A portion of this charge is condensed on the outside surface of the LHe heat exchanger

(located in the crescent shaped space between the main and experiment access tubes) through which process LHe flows continuously from a cryopipe leading to the LHe refrigeration system (Fig. 2). The condensed He flows by gravity down the supply tube into the irradiation zone of the sample chamber where it is vaporized by nuclear and radiant heat loads. The vapor rises upward into the experiment access tube, exits through the lower level vent holes, and is recondensed on the LHe heat exchanger to complete a natural convection loop. While the convection loop just described operates with both gas and liquid phases, the loop can also be operated in only the gas phase by reducing the initial GHe charge.

Above the LHe heat exchanger there is an LN heat exchanger fed by another cryopipe through which commercial LN is metered. This heat exchanger, which is jacketed for additional containment (see Section 11), is used to reduce vertical heat leaks into the colder region below. It is also used separately or in conjunction with the LHe heat exchanger to operate a gas phase convection loop which provides irradiation temperatures from 5 K to 350 K. An electric heater (not shown) attached to the bottom of the experiment access tube provides additional temperature controllability.

Cold portions of the cryostat are vacuum insulated, and a shield refrigerated by the LN heat exchanger (although not shown in Fig. 6, it is detailed in X3E-12566-009 and 030) reduces the radiant heat load on the main access tube below the LN heat exchanger.

A main feature of the cryostat design is that all process refrigeration flows lie well outside the irradiation zone, and they

are not contiguous with the cryostat. Any radioactivity is confined to the cryostat which, in turn, is connected to the ORNL cell ventilation system (CVS).

Figure 8 (ORNL-DWG-82-20185R2) shows the component parts of the NLTNIF irradiation cryostat drawn to scale. The design follows the principle of double containment. Further details and a topographical analysis of the containment system are given in Section 11 of the SAR.

The i.d. of the sample chamber is 1.5 in. and the active irradiation zone is considered to be 10 in. long. A test zone in the experiment access tube adjacent to the LHe heat exchanger is 7.75 in. in diameter and 12 in. long, and it is centered 5 ft above the irradiation zone.

It is planned that, by means of pull-rods sealed through the containments at the top of the cryostat, specimens can be moved from the irradiation to the test zone and returned without warmup from 4 K.

Figure 9 (ORNL-DWG-85-18365R), which has been prepared for users to aid in designing experiment and test assemblies gives precise dimensional detail and other layout information. Figure 10 (ORNL-DWG-86-8656) shows the nested relationship between an experiment assembly, a test assembly, and the cryostat. A 12-Tesla magnet test assembly (approval for use to be submitted later) is shown as an example.

2.2.4.3 Interchangeable Gamma-Ray Shield

The main body of the first gamma-ray shield for the NLTNIF is made of zircaloy. The lower end of the shield or solid foot piece

is made of 6061 Al to the same external dimensions as a fuel element (see DWG X3E-12566-026). The inboard arced surface of the slot contains 4 zircaloy weld beads which serve as stops against the rounded nose of the irradiation cryostat and thus ensure the presence of a water cooling gap to remove nuclear heat. Side clearance between the slot wall and the cryostat is 0.056 in. (each side). A storage rack is provided in the pool when the shield is not in use. The thermodynamics of nuclear heating in the shield is given in Section 8.

2.2.4.4 Personnel Platform

The personnel platform (DWGS. X3E-12566-002, 004, and 005) provides access to the cryostat junction box for experimenters to load, unload, and manipulate test and experiment assemblies. The load limit posted adjacent to the platform (500#) is somewhat less than that allowed by QA&I. The platform also provides anchor points for the top of the irradiation cryostat, although the cryostat does not provide support for the platform.

2.2.4.5 Ambient Temperature Storage Facilities

Poolside tubes (DWGS. X3E-12566-002 and 005) located 3 1/2 feet from the access plug flange of the cryostat provide for the safe dry storage of radioactive experiment assemblies by using the pool water as a biological shield.

2.2.4.6 Interface System: Two Main Components (See DWG-X3E-12566-100)

The Interface Junction Box is an aluminum vacuum vessel with removable cover plates which attaches in turn to the vacuum jacket

which houses the three pass heat exchanger (see 2.2.4.7 below). Other cryogenic connections to the junction box are: two commercial cryopipes from the Cold Box (see 2.2.3.7 below), a commercial LN cryopipe from the LN storage vessel, and the Interface Cryopipe System which connects the junction box to the cryostat. In addition the junction box houses cold valves and many refrigerant line interconnections, which are part of the refrigeration system. Two vacuum jacket pressure safety valves, vacuum sensors, electrical feedthrus, and the vacuum pumping system are attached to this vessel. A nesting LN refrigerated shell inside the vessel serves to reduce the radiant heat load on the colder piping within.

The Interface Cryopiping System consists of an aluminum tubular vacuum jacket which houses the final stage cold heat exchanger (a commercial device) in the refrigeration system and both the LN and LHe supply and return lines to the cryostat. All LHe lines and the heat exchanger are located inside a concentric LN refrigerated shield. The insulating vacuum is derived from that in the junction box described above.

2.2.4.7 The Improved LHe Refrigeration System

The refrigeration system consists of the following main commercial components:

1. The Cold Box — A vacuum vessel containing heat exchangers, charcoal traps, reciprocating expansion engines, and cold valving (Koch).
2. Two RS screw compressors (Koch).

3. Two reciprocating compressors (Carrier).

4. A three-pass heat exchanger (Joy).

These components have been interconnected with appropriate valving and pressure regulators, and water cooling, electrical, and plant air services have been supplied to produce a system package which supplies sufficient refrigeration to meet the operational needs of the NLTNIF. It is important to note that NONE of the property sensors and instrumentation of this commercial equipment are utilized in the dedicated safety system which protects the reactor, the cryostat, and experimental data. This safety system is described in Sections 4 and 11. Some nonsafety related instrumentation has been constructed by ORNL forces to provide additional diagnostics for the refrigerator operation.

2.2.5 Operating Design and Test Limits

Table 3. Experiment Facility

The components listed here are those which comprise the in-pool/in-core irradiation cryostat. During the course of operation these components are subjected to alternate external (E) and internal (I) pressures which may differ from the usual range of operating pressures. For example, the evacuation and charging procedure which prepares the cryostat for irradiation applies net external pressures to some components and net internal pressures to others not encountered in normal operation. Failure modes produce similar effects. For these reasons the table lists MAX Oper. E and I values, and it is expanded to include NORM Oper. values for the sake of completeness. For the sake of clarification, a written description of each MAX Oper. condition is given below.

Component or Material	Temperature (K)			Net Pressure Difference (PSI)							
				External (E)				Internal (I)			
	Design	Test	Oper.	Design	Test	MAX Oper.	NORM Oper.	Design	Test never positive	MAX Oper. never positive	NORM Oper.
1. Cryostat Vacuum Jacket	307	307	307	23	23	23	23	0 Abs.	positive	positive	0 Abs.
2. Main Access/sample chamber/supply tube	0-350	2.6-350	2.6-350	57	57*	14.7	never positive	50	50 (warm)	33	5-25
3. LHe Heat Exchanger (LHX)	0-350	3.2-307	3.2-307	37	37	29	3-20 never positive	37	37	20.2	0-20.2
4. LN Heat Exchanger (LNX)	0-307	73-307	73-307	37	37	7	positive	37	37	30	20-23 never positive
5. LN Heat Exchanger Jacket	0-307	73-307	73-307	37	37	29	1-25	37	37	14.7	never positive
6. Interface Vacuum Jacket (IVJ)	10-350	10-307	10-307	33	33	33	5-25	14.7	14.7	14.7	0 Abs.
7. Secondary Containment	300	300	300	14.7	14.7	14.7	14.7	7.0	7.0	2.8	1.0

Notes for Table 3

1. MAX Oper. E = $8.3 + 14.7 - 0$ (water + atm. outside - vac. inside) safety relief into interface vacuum is at $I = 5.8$ PSIA through HV-CRY. E values refer to lower AI section. Values for the stronger upper stainless steel section are less.
2. MAX Oper. E: applied rarely during tests or maintenance when component 1 is vented to atm. and component 2 is evacuated. MAX Oper. I results from LHe boil off "puff" during loss of vacuum (LOV) accident (see Section 11).
*External pressure collapse test results made on identical model of sample chamber. All listed values refer to the lower AI sample chamber and supply tube section. Values for the stronger upper stainless steel sections are 3.1 PSIA greater for E (water pressure) and 14.7 less for I (atm. pressure).
3. MAX Oper. E: applied rarely during tests or maintenance when LHX is evacuated and cryostat is at normal relief pressure (29 PSIA). MAX Oper. I: applied during shutdown when cryostat is evacuated and LHX is at normal relief pressure (20.2 PSIA).
4. MAX Oper. E: applied rarely during tests or maintenance when LNX is evacuated and LNX Jacket is at maximum charged pressure (7 PSIA). MAX Oper. I: applied rarely during tests or maintenance when LNX is normal LN tank pressure (30 PSIA) and LNX Jacket is evacuated.
5. MAX Oper. E: applied during maintenance when LNX Jacket is evacuated and cryostat is at normal relief pressure (29 PSIA). MAX Oper. I: applied during maintenance when LNX Jacket is at one atmosphere and cryostat is evacuated.
6. MAX Oper. E: applied when IVJ is under normal vacuum and cryostat is in LOV accident mode (see No. 2 above). MAX Oper. I: applied rarely during test and maintenance when IVJ is vented to atm. and cryostat is evacuated.
7. MAX Oper. E: applied when the Secondary Containment is purged in preparation for irradiation. MAX Oper. I: applied when "puff" occurs during LOV accident (see No. 2 above).

3. EXPERIMENT ASSEMBLY INFORMATION

3.1 Test Assemblies

These devices are used to test irradiated samples, and they extend only to the test section of the cryostat—they do not extend into the irradiation zone (see Fig. 10). It is expected that the lower biological shield (see Section 6) will provide sufficient protection against neutron activation that, after use, these assemblies may be adjusted or modified at poolside or in the laboratory with little or no need for radiation shielding.

Approval for test assemblies will be requested on a timely basis for each unit. Examples are a 12-Tesla superconducting magnet and mechanical strength testing devices.

3.2 Experiment Assemblies

These devices are used for support, encapsulation, or in situ tests of specimens, and they extend into the irradiation zone (see Fig. 10). Some will be designed for manual retraction (~5 ft) into the test section for interim or postirradiation testing. Such retractions are made with the reactor off. While the upper section (~16 ft) of these assemblies may be reused, the lower end will become radioactive, and only some may be reusable. Approval for experiment assemblies will be requested on a timely basis for each unit.

4. INSTRUMENTATION AND CONTROLS

4.1 Instrumentation Space Requirements

The NLTNIF control console is located in the south addition to Bldg. 3010 along with the refrigeration equipment. Figure 1 (ORNL-DWG-19248R2) shows the I&C location with respect to the overall arrangement of the facility. Photographs 1 and 2 (ORNL PHOTOS 2013-86 and 2015-86) show the arrangement of cryostat control panels with labels which designate the Instrumentation Readouts and/or Controls listed in Table 5. Other instrumentation seen in these photos is related only to the operation/diagnostics of the refrigeration system.

4.2 Functional or Flow Diagram

The diagrams listed in Section 2.2 are also appropriate for this section. These diagrams (Figs. 2, 3, 4, and 5) are also referred to in the body of Table 5.

4.3 Wiring Diagrams and Specifications

Instrument Application Diagram	I3E20309 A001
Safety Circuit M.E.D.	I3E20309 A006

4.4 Instrumentation Identification

See Table 5.

4.5 Spare Sensing Elements

All spare sensing elements have been listed in Table 5, and they are designated by the suffix B (Backup). P denotes the primary elements. It is pointed out that the use of certain experiment assemblies will provide further redundancy over that indicated in Table 5.

LEGEND - See also SSD-NLTNIF-9

CM = Containment Monitor
LOV = Loss of Vacuum
LOC = Loss of Cooling
LOE = Loss of Exchange
P = Primary Sensor
B = Backup Sensor

TABLE 5 INSTRUMENTS AND CONTROLS IDENTIFICATION*

ALARM AND REACTOR ACTIONS

Note 1: Signal Conditioner/Readout/
HI-LO Setpoint Controller
Note 2: Process Controller
Note 3: HI-LO Meter Face Setpoint
Controller

PROTECTIVE FUNCTION	PROPERTY OR CONDITION BEING MONITORED	SENSING ELEMENT			TYPE OF MONITOR	ACTION REQUIRED			CONDITION FOR ACTION
		DESIG- NATION	TYPE	LOCATION		ALARM	CONTROLLED SHUTDOWN	REACTOR SCRAM	
CM-He(2)-P	PRESSURE	PE 1SC	TRANSDUCER	CRY. JUNC. BOX SSD-NLTNIF-3	NOTE 1			X	>1.1 HI <0.9 LO PSIG
CM-He(2)-B	"	PE 2SC	"	CRY. MGT. CIR. SSD-NLTNIF-3	"			X	"
CM-He(3)-P	"	PE MHS	"	"	"	X	X		< 12 PSIG ALARM < 5 PSIG SHUTDOWN
CM-He(3)-B	"	PE GHS	"	"	"	X	X		"
CM-He(4)-P	"	PE 1NXJ	"	INSIDE 2nd CONT. SSD-NLTNIF-7	"			X	> 4 PSIA HI
CM-He(4)-B	"	PE 2NXJ	"	"	"			X	"
CM-V(2)-P	PRESSURE (VACUUM)	PE 2IVJ	Cold Cathode (Varian)	INTERF. JUNC. BOX SSD-NLTNIF-8	NOTE 3	X		X	>1 x 10 ⁻⁴ TORR
CM-V(2)-B	"	PE 1IVJ	TC Gauge (Convectron)	"	"			X	>20 m Torr
CM-V(1)/V(2) [#]	VALVE POSITION	nv CRY	Micro switch	INSIDE CRY. JUNC. BOX SSD-NLTNIF-8	MICRO SW. IND. LIGHTS	X			VALVE OPEN
CM	BSR POOL WATER LEVEL					X			
LOV-V(1)-P	PRESSURE (VACUUM)	PE 2CVJ	Cold Cathode (Varian)	INSIDE CRY. JUNC BOX SSD-NLTNIF-8	NOTE 3		X		>1 x 10 ⁻⁴ TORR
LOV-V(1)-B	"	PE 1CVJ	TC Gauge (Convectron)	"	"		X		> 20 m TORR
LOC-He(1)-P	TEMPERATURE	TE 1LHX	Carbon Glass Resistor	TOP LHe HEAT EXCHANGER	NOTE 2	X	X		> 50 K
LOE-He(1)-B	PRESSURE	PE 1CRY	TRANSDUCER	INSIDE CRY. JUNC. BOX SSD-NLTNIF-3	NOTE 1		X		>25 PSIA HI
LOE-He(1)-P									< 4 PSIA LO
LOE-He(1)-B	"	PE 2CRY	"	"	"		X		< 4 PSIA LO
LOE-He(5)-P	"	PE 1CAP	"	"	"		X		"
LOE-He(5)-B	"	PE 2CAP	"	"	"		X		"
AIR EXCLUSION	OXYGEN IMPURITY	TOA	Trace O ₂ Ana- lyzer	CRY. MGT. CIR. SSD-NLTNIF-3	SELF CONTAINED UNIT	X			O ₂ > 10 ppm
"	PROCEDURE CERTIFICATION	PROCESS CONT'R.	PROCESS CONTROLLER	NLTNIF OPERATING CONSOLE	NOTE 2	X			IMPROPER LOADING PROCEDURE

* When no experiment assembly is present in the facility, the reactor is neither operated nor stationed at the facility.

Dual Purpose - see Table 5 - Mechanical Actions

6-5-86

LEGEND - See also SSD-NLTNIF-9

CM = Containment Monitor
LOV = Loss of Vacuum
LOC = Loss of Cooling
P = Primary Sensor
B = Backup Sensor

TABLE 5 INSTRUMENTS AND CONTROLS IDENTIFICATION*

MECHANICAL ACTIONS

Note 1: Signal Conditioner/Readout/
HI-LO Setpoint Controller

Note 2: Process Controller

Note 3: HI-LO Meter Face Setpoint
Controller

PROTECTIVE FUNCTION	PROPERTY OR CONDITION BEING MONITORED	SENSING ELEMENT			TYPE OF MONITOR	ACTION REQUIRED	CONDITION FOR ACTION
		DESIG- NATION	TYPE	LOCATION			
CM-He(2)-P,B	PRESSURE RELIEF	PSV SCR	3 Valve Cluster (Special)	Cry.Mgt.Cir. SSD-NLTNIF-3	NONE	Relieve excess He(2) Press. into Cell Vent. System	2.00, 2.08, 2.16 PSIG
CM-V(2)-P	" "	PSV 11VJ	VALVE (SPECIAL)	Interf. Junc. Box SSD-NLTNIF-8	"	Relieve Excess Internal V(2) Press. to Atm.	About 0.1 PSIG
CM-V(2)-B	" "	PSV 21VJ	"	"	"	"	"
LOV-V(1)-P #	" "	HV CRY	"	Inside Cry.Junc. Box SSD-NLTNIF-8	"	Relieve Excess V(1) Press. into V(2)	5.9 PSIA
LOC-He(1)-P	" "	PSV 1CRY	Valve (Circleseal)	Inside Cry.Junc. Box SSD-NLTNIF-3	"	Relieve Excess He(1) Press. into He(2)	28.75 PSIA
LOC-He(1)-B	" "	PSV 2CRY	"	"	"	"	28.08 PSIA
LOC-He(5)-P	" "	PSV 1CAP	"	"	"	Relieve Excess He(5) Press. into He(2)	28.8 PSIA
LOC-He(5)-B	" "	PSV 2CAP	"	"	"	"	29.9 PSIA
LOC-V(2)-P	" "	PE 11VJ EPV 1VJ	TC Gauge (Convectron)	Interf.Pump Sys- tem SSD-NLTNIF-8	NOTE 3	Close EPV 1VJ-Excludes Atm. From V(2) On Pump Failure	150 m TORR
OVERPRESSURE	PRESSURE RELIEF	PSV LNX	Valve (Rego)	LNX Exit Line SSD-NLTNIF-7	NONE	Relieve Excess LNX Press. To Atm.	17.5 PSIG
		Note 1: All valves in this table are programmed for annual recalibration and test- ing by ORNL Inspection Engineering. In addition PSV 11VJ and PSV 21VJ are tested on each occasion that the interface vacuum jacket is vented for maintenance purposes. Further, PSV 1CRY, PSV 2CRY, PSV 1CAP, PSV 2CAP, and PSV SCR are tested after the installation of each new or repeat experi- ment assembly before reactor startup (see Section 10.2).					
		Note 2: PSV SCR, HV CRY, PSV 11VJ, and PSV 21VJ designated as "special" are of SSD design and construction, and they have been inspected and approved for use by ORNL Inspection Engineering.					

* When no experiment assembly is present in the facility, the reactor is neither operated nor stationed at the facility.

Dual purpose - see Table 5 - Alarm And Reactor Actions

4.6 Recovery From Instrumentation Failure

Should a sensing element fail during an irradiation an assessment would be made to determine if, for that particular experiment, additional redundancy is in place. If the needed redundancy existed, a request would be made to operations for permission to continue the irradiation. If the needed redundancy did not exist, the reactor would be shut down until repairs could be made. It is pointed out that such a shutdown does not result in a conflict since the NLTNIF has primary use of the BSR.

5. MATERIALS

5.1 Hazardous Materials

[In Table 6, list all materials (such as acid, caustic, highly flammable, toxic, or otherwise potentially hazardous materials) to be used in conjunction with the experiment. Clearly indicate units.]

Table 6. Hazardous Materials

There are no hazardous materials used in conjunction with the NLTNIF. Any impact of the use of such materials in an experiment assembly will be assessed for each assembly, although no such use is foreseen.

5.2 Materials To Be Irradiated

Table 7. Materials Within Reactor Core or Reflector

Facility		Experiment Assembly	
Material and Type (e.g., 304L SST)	Quantity (Mass)	Material and Type (e.g., 304L SST)	Quantity (Mass)
Zircaloy Gamma-Ray Shield: Zircaloy 6061 Al	15.6 kg 4.5 kg	The inventory of materials for experiment assemblies will be assessed on an individual basis prior to their insertion into the cryostat.	
Cryostat Vacuum Jacket - 6061 Al	3.4 kg		
Sample Chamber and LHe Supply Tube 1100 Al	83 g		
4 ea 0-80 SS spacer screws	0.88 g		

6. RADIOACTIVITY

6.1 The Quantity and Types of Radioactive Materials Which Might Be Distributed Throughout the Experiment Facility or Assembly

The only radioactive material which emerges from the facility (cryostat) is tritium, H^3 , which is directed into the ORNL Cell Ventilation System. Any effects of radioactive materials in an experiment assembly will be assessed on a per unit basis prior to their insertion into the cryostat.

The natural He which must be charged into the cryostat for every irradiation contains a trace isotopic abundance, a , of He^3 which produces H^3 via an n,p reaction. The maximum expected radioactivity is:

$$Ci = \frac{Ama\sigma_p\phi t\lambda}{MHe \ 3.7 \times 10^{10}} = 1.92 \text{ Curies}$$

where A = Avagadro's nubmer = 6.02×10^{23} atoms/mole

m = max LHe inventory in the core = 105.6 g

a = He^3 isotopic abundance = 1.4×10^{-6} atomic fraction

σ_p = n,p reaction cross section = 5.33×10^3 b

ϕ = central thermal n cryostat flux = 1.5×10^{13} n/cm²s

t = max irradiation time = 1.81×10^6 s = 3 weeks

λ = H^3 decay constant = 2.20×10^{-8} /s

MHe = atomic weight of He = 4

3.7×10^{10} = disintegrations/s = Ci definition

Although the irradiation time and LHe inventory will vary for each experiment, it is estimated that the average accumulated H^3 inventory will be 10 to 20% of the maximum calculated above.

6.2 The Radioactive Source Which Must Be Provided With External Biological Shielding

The decay of H^3 produces a soft beta particle (18.6 keV) which cannot penetrate the piping between the irradiation cryostat and the cell ventilation system.

6.3 The Radioactive Source Strength To Be Shielded During Removal of the Experiment Components From the Reactor

The removal and storage of the zircaloy shield is an under-water operation performed by the reactor operators, and it requires no additional shielding.

The eventual removal of the irradiation cryostat is discussed in Section 1.7.1.

The removal of radioactive experiment assemblies is discussed in Section 7.2.

6.4 The Radioactive Materials To Be Removed By Any Cleanup Systems Such As Charcoal Traps

Any effluents from the irradiation cryostat as well as experiment assemblies including H^3 are piped directly to the cell ventilation system without any intervening traps (see Fig. 3, SSD-NLTNIF-3).

6.5 Personnel Exposure (direct and ingested dose) Resulting From Complete Rupture of the Containment System

The maximum inventory of any dispersable radioactivity expected in the NLTNIF cryostat is 1.9 Ci of tritium, H^3 (see section 6.1). During warmups, after an irradiation, the H^3 inventory along with the He charge in the cryostat is routed into the cell ventilation system (CVS) through pump HS SCP or by normal thermal expansion through pressure relief valves PSV CRY and PSV SCR (see Fig. 3 - SSD-NLTNIF-3). In the cases of warmup due to loss of cooling (LOC) or loss of vacuum (LOV) the second route applies.

A rupture of the containment accompanied by a warmup of the cryostat could allow an escape of the H^3 inventory into either the BSR reactor bay or into the refrigerator and compressor room of the NLTNIF facility (see Fig. 1 - ORNL-DWG 82-19248R2). An analysis of the second case given below shows that, because of the much larger volume of the bay compared to the compressor room (12 x), the resulting greater volume dispersal-dilution places the "worst case" scenario in the compressor room.

If a rupture and warmup occurred with the reactor on so as to activate the NLTNIF safety system, corrective measures could be taken to reduce personnel exposure. The "worst case" scenario, however, occurs if the branch of the CVS system in the compressor room ruptures and allows the H^3 inventory to enter the room without notice during a postirradiation warmup. For the analysis which follows, it is assumed that the H^3 inventory enters the compressor room in the early AM where a worker remains undisturbed for 8 hours with the doors closed. Dispersal of the inventory into the volume of the room is assumed but no credit is taken for a reduction of the concentration by any type of air exchange. This greatly exaggerates the exposure since no credit is taken for trapping of the lighter than air H^3 against the ceiling of the room especially in a high bay (19 1/2 feet) area. In the exposure calculations which follow use was made of: Report to J. A. Setaro from D. W. Ramey, RCO Operations Division report on "Calculation and Consequences of Credible Accidents, Bldg. 3038," July 21, 1983. This report deals with a 1000 Ci release of H^3 .

Compressor room volume, including high-bay and compressor area:

$$\begin{aligned} V &= 6863 \text{ ft}^3 \\ &= 194 \text{ m}^3 \end{aligned}$$

Concentration of tritium (T) with uniform mixing throughout V:

$$\begin{aligned} C_T &= (1.92 \text{ Ci}) / (194 \text{ m}^3) \\ &= 0.99 \times 10^{-2} \text{ Ci/m}^3 \end{aligned}$$

- A. Skin Dose in the center of an infinite Beta Cloud is given (per Ramey's report, p 3) by:

$$D_T(\text{rads}) = 0.457 \cdot \bar{E} \cdot C_T \cdot t$$

where: .457 = collected constants for units used below

$$\bar{E} = 6 \times 10^{-3} \text{ MeV, average Beta energy for T}$$

$$C_T = 0.99 \times 10^{-2} \text{ Ci/m}^3, \text{ as given above}$$

$$t = 2.88 \times 10^4 \text{ s, exposure time (8 hrs)}$$

$$\boxed{D_T = 0.79 \text{ rad}}$$

- B. Internal Dose from HTO or T₂O

Quoting Ramey's report, p 4: "Experiments have shown that approximately 0.2% of T₂ gas is HTO or T₂O. 0.4% is assumed for the following calculation."

$$\text{Quantity Inhaled: } QI = C_T \cdot f_w \cdot BR \cdot t$$

where: C_T = total tritium concentration, as above in A

$$= 0.99 \times 10^{-2} \text{ Ci/m}^3 \text{ or } \mu\text{Ci/cm}^3$$

f_w = fraction of T₂ gas as HTO or T₂O

$$= 0.004$$

BR = Breathing Rate

$$= 333.3 \text{ cm}^3/\text{s} \quad (\text{per Ramey, p 4})$$

t = exposure time

$$= 2.88 \times 10^4 \text{ s} \quad (8 \text{ hrs})$$

$$\text{then: } QI = 380 \mu\text{Ci}$$

The effect of this Quantity Inhaled is interpreted by continuing with p 4 & 5 of Ramey's report to derive 50-year dose commitments to various organs:

"From the Inhalation Dose Conversion Factors (IDCF) which assumes that for every μCi inhaled, $0.5 \mu\text{Ci}$ are absorbed thru the skin."

<u>Organ</u>	<u>IDCF₅₀ (rem/μCi Inhaled)</u>	<u>50-y Dose Commitment (rem)</u>
Res. Lymph	2.48×10^{-4}	.095
Lungs	1.25×10^{-4}	.048
Liver	1.24×10^{-4}	.048
Skeleton	5.57×10^{-5}	.021
Thyroid	1.24×10^{-4}	.048

6.6 Radioactive Effluents

Table 8. Radioactive Effluents To Be Discharged

Nuclei	Mass No.	Discharge Rates (Curies/Puff*)		Disposal System
		Normal	Emergency (Max)	
H	3	0.2 - 0.4		Cell Ventilation (CVS)

*The standard purge procedure following an irradiation will produce a single puff into the CVS. It is roughly estimated that there may be 50 puffs per year.

NOTE: The cryopiping and all other umbilicals to the cryostat pass in a tight bundle from the reactor bay into the NLTNIF compressor room (see Fig. 1). A radiation MONITRON under assignment for programed calibration and maintenance by Health Physics personnel is located in the compressor room at the point of entry to detect any radioactivity traveling to the CVS.

7. SHIELDING

7.1 External Biological Shielding

7.1.0 Introduction

Shielding for the NLTNIF irradiation cryostat is arranged in two sections: the Upper Biological Shield and the Lower Biological Shield. Since the operation of the BSR at the NLTNIF position is available to meet the needs of any experiment or test, surveys of radiation leakage can be made by Health Physics personnel at any time and at any reactor power. Through such surveys the biological shielding for any NLTNIF experiment can be iteratively adjusted to reduce leakage to acceptable levels. Values of acceptable leakage will depend upon any particular needs for personnel to manipulate an experiment at the top of the cryostat. When manipulations are required, surveys will be used to determine if they can be safely performed with the reactor on, at reduced power, or off. To implement the adjustment of shielding to provide safe operating levels, "touch up" shield materials may sometimes be laid atop the cryostat junction box.

7.1.1 Layout Sketch Showing the Location and Space to Be Occupied By the External Biological Shielding

Lower Biological Shield: Dwg. X3E-12566-003

Upper Biological Shield: see Figs. 9 (ORNL-DWG 85-18365R) and 10 (ORNL-DWG 86-8656) and dwg. X3E-12566-003.

7.1.2 Sketch of the Installation Showing the Effective Shield Thickness and Geometry

Lower Biological Shield: for the gamma-ray shield/ballast see dwg.

X3E-12566-15, for the gamma-ray shield block see dwg. X35-12566-24 and for thermal neutron shield see dwg. X35-12566-27.

Upper Biological Shield: see fig. 10 (ORNL-DWG 86-8656) and dwg. X3E-12566-028.

7.1.3 Description of the Material, Design, and Constructional Features, Including Absorption Coefficients and Other Pertinent Data for Special or New Materials

Lower Biological Shield. Stainless steel plates attached to the underside of the lower end of the large outer vacuum tube serve to reduce the already low gamma-ray intensity at this point (~4 ft above the core). Their main purpose, however, is to serve as ballast to prevent bottom-end-up floatation of the cryostat under any circumstance.

A small Pb block attached to the bottom end of the main access tube between the sample chamber and the supply tube reduces gamma-ray streaming along that unoccupied path to the core region.

An Al-clad Cd shield surrounds the ballast and the lower 1 ft of the large outer vacuum tube to reduce thermal neutron streaming up the tube, but more importantly, to minimize activation of test assemblies within.

Upper Biological Shield. This is a multiple section shield located about 4 ft below the surface of the pool water to prevent streaming up the main access tube. The outermost section is permanently fixed in the crescent shaped space between the main and experiment access tubes. It consists, from the bottom-to-top, of 6 in. of high density polyethylene, .060 in. of Cd and 4 in. of Pb. The thickness of additional nested shield sections constructed of the same materials for use at the same level on test assemblies and experiment assemblies will be determined from the results of radiation streaming surveys made by Health Physics personnel.

It is planned that certain complex test and experiment assemblies which have "one-of-a-kind" penetrations through the upper shield region

will carry permanent shields. Other demountable shields will be used to accommodate assemblies having similar penetrations through the shield region.

7.2 Removal and Transport Shields

Sections 7.2.1, 7.2.2, 7.2.3, and 7.2.4 are deleted since, presently, there are no large removal or transport shields associated with NLTNIF. All transfers of radioactive assemblies from the cryostat into ambient or LHe poolside storage facilities (or between storage facilities) are made by reactor operations and Health Physics personnel according to established BSR procedures which utilize the BSR personnel bridge (mobile catwalk).

Past experience with dry poolside storage tubes (dwg. X35-12566-005), which can accommodate the full length of an experiment assembly (18.5 ft), has shown that activity at the mouth of a tube is almost nil. Shielding in the neck of the subsurface LHe storage vessel uses 4 in. of Pb 2 ft below the water surface. The unlikely need for any additional shielding will be determined at the time of first use.

The transfer of irradiated samples supervised by Health Physics personnel will be made from time to time from storage facilities to test devices using small hand-carried Pb shields and under the supervision of Health Physics personnel.

At the present time NLTNIF has received no requests for the transfer of irradiated specimens to another laboratory at either ambient or LHe temperatures. While such transfers may be requested, the design of the transfer devices is delayed until precise needs can be identified.

Summary of the Development of Typical Biological Shields for the LTNIF

1. As a result of a series of "reactor on" surveys by health physics personnel the biological shielding for LTNIF has been iteratively adjusted to reduce leakage to acceptable levels as described in the attached survey results. This is in keeping with the plan outlined in section 7.1.0 of the SAR for the LTNIF.
2. The removable internal shield assembly (SSD-LTNIF-13) nests with the permanent upper biological shield of the irradiation cryostat (X3E-12566-028 and ORNL-DWG-86-8656).
3. The Test Assembly Piece (total weight = 55 lbs.) is supported from the Plug Flange by three 3/8" diam. stainless steel rods. The Experiment Assembly Piece is supported by a 1/2" diam. stainless steel rod from the experiment support flange (total weight 5 lbs.)
4. The removable shield (assembled weight = 200 lbs) sits captured in a supporting cradle which, in turn, is supported by four legs pegged into matching platform holes. There is 1/8" clearance between the shield and the lid of the cryostat junction box. The shield does not bear on the cryostat.
5. Survey #1 gives the results for the fully shielded facility. Survey #2 shows that a significant fraction of the gamma ray intensities are present if the facility is absent. Survey #3 shows that intensities shortly after reactor scram are suitable for the manipulation of experiments by operators under health physics supervision.
6. In the company of the LTNIF staff, H. M. Butler and J. H. Pemberton, Environmental Safety Division, inspected the LTNIF and reviewed the operating procedures and the attached survey reports on 9-8-86. The LTNIF staff agreed to implement their recommendations as follows:
 - a. Waist high gates with signs warning of elevated radiation levels will be installed in the south and west aisles.
 - b. All visitors will be escorted by the LTNIF staff and warned of any elevated radiation levels.
 - c. A Health Physics survey will be requested for manipulations of experiment assemblies from the irradiation to the test zones of the cryostat when the reactor-off time is short.
 - d. The LTNIF staff members will be issued neutron badges.

Pb = Lead HDPE = High Density Polyethylene (as 1" plate) Cd = Cadmium

TYPICAL INTERNAL SHIELD ASSEMBLY
(scale: 1/2" to 1")

ANGLED SLOTS AND CHORD CUTAWAYS SERVE AS NO-SHINE GAS PASSAGES

EXTERNAL SHIELD
(scale: 1/8" to 1")

LTNIF SURVEY #1

DATE 8-7-86

NOTES

TEST ASSY., EXPT. ASSY.
AND EXTERIOR SHIELDS
IN PLACE.

1" BRASS CENTER FLANGE

ALL MEASUREMENTS AT
PLATFORM LEVEL EXCEPT
OVER EXTERIOR SHIELD.

THE HIGHEST THERMAL
NEUTRON COUNT WAS LESS
THAN 300 n/cm²sec OVER
THE CENTER OF THE
EXTERIOR SHIELD
(267 n/cm²sec → 1 mR/hr)

8 ②

AISLE

NUMBERS ARE mR/hr
UNCIRCLED = GAMMA RAYS
CIRCLED = FAST NEUTRONS

RADIATION PATTERN AT 2 MW FOR THE BSR CORE
AT THE NLTRIF POSITION:

LTNIF SURVEY #2

DATE 8-4-86

NOTES

BSR CORE POSITIONED
13 FEET NORTH AND
2 FEET EAST OF THE
LTNIF POSITION.

MEASUREMENTS WERE MADE
AT POSITIONS CORRES-
PONDING TO THE LTNIF
LAYOUT.

3

aisle

NUMBERS ARE mR/hr
UNCIRCLED = GAMMA RAYS
CIRCLED = FAST NEUTRONS

RADIATION PATTERN AT 2 MW FOR THE BSR CORE
AT THE LTNIF POSITION

LTNIF SURVEY #3

DATE 5-23-86

NOTES

SURVEY MADE 2 MIN.
AFTER SCRAM FOLLOWING
A 6 HOUR RUN AT FULL
POWER.

THE EXTERNAL SHIELD IS
REMOVED

0 (nominal)

AISLE

NUMBERS ARE mR/hr
UNCIRCLED = GAMMA RAYS
CIRCLED = FAST NEUTRONS

RADIATION PATTERN AT 0 MW FOR THE BSR CORE
AT THE LTNIF POSITION

8. THERMODYNAMICS

8.0 Introduction

There are two NLTNIF components for which thermodynamic analyses are a necessary part of the related safety analysis: the zircaloy gamma-ray shield and the in-core portion of the irradiation cryostat (see Fig. 6).

When the gamma-ray shield is located in its assigned center core face position (see Fig. 7) the reactor may be operated with the "U" shaped shield slot occupied by the cryostat or with the slot vacant as when the core is positioned away from the cryostat. In the first case nuclear heating within the slot region is removed by convection-driven water flow through a narrow gap compared to the unrestricted access by water in the second case. Since the results given below show that cooling in the first case with the narrow gap is suitable, a safety analysis for the second case is moot.

The SAR form asks for an analysis of the case when the reactor is ON, but the facility (cryostat) does not contain an experiment assembly. This case is NOT applicable for the NLTNIF.

In the analysis which follows the gamma-ray shield and the irradiation cryostat will be discussed in turn for each item in this section.

8.1 Coolant Flow Paths

Shield. Nuclear heat generated in the shield flows directly into the pool water.

Cryostat. Nuclear heat generated in the vacuum jacket of the cryostat flows directly into the pool water. Nuclear heat generated in the sample chamber and delivery tube walls and in any experiment assembly flows into the convection-driven He stream which is cooled, in turn, by the process LHe flowing through the LHX (see Fig. 6).

8.2 Calculations and Measurements

8.2.1 Heat Generation Rates

Shield. During the design stage of the NLTNIF project, nuclear heat generation rates were calculated by M. Siman Tov, ORNL for Pb, Zr, and Al shields to determine if the pool water would boil at full reactor power (safety regulations do not permit boiling). Zircaloy was chosen as the shield material since boiling was predicted for Pb while the shielding efficiency for Al was too small. The accuracy of the calculations was limited by uncertainties in determining heat removal rates in the convection-driven water flow through the narrow slots between the shield and the adjacent fuel elements. To remove any uncertainty, a performance test was made on the completed zircaloy shield using a mockup of the cryostat located in the shield slot. The mockup was an accurate reproduction of the cryostat in terms of materials, dimensions and configuration. NO boiling could be detected during a test carried out by operations personnel up to full reactor power. The instrumentation, test method, and detailed results are given in Appendix II.

Cryostat. The need for a thermodynamic analysis of heat generation in the walls of the vacuum jacket of the cryostat is eliminated by the results of the performance test given above; i.e., no boiling of the pool water was found at full reactor power. The remainder of this section, then, deals with components inside the vacuum jacket.

To determine heat generation rates, use is made of the detailed computer calculations made by R. A. Lillie for the BSR/zircaloy shield/cryostat configuration (see Appendix III). The nuclear heating rates in the NLTNIF components given in Section 8.3 are based on the key specific

nuclear heating values found by Lillie for the center of the irradiation chamber (0.34 W/g in Al and 0.92 W/g in LHe).

It is appropriate in this section to discuss certain questions posed in the SAR about normal and off normal response and other thermodynamic related failure conditions peculiar to the NLTNIF. In these discussions use is made of results obtained from extensive performance tests made using an assembly with two temperature sensors mounted at the upper and lower ends of an electrical heater located in the center of the irradiation chamber. Electrical heat was used to simulate nuclear heat. Of course, extensive use was made of the permanent temperature and pressure sensors in the cryostat system (see Figs. 2, 3, and 6).

Normal Design Operating Conditions With the Reactor at Full Power.

After purging according to procedure (see Section 10) the cryostat is charged at ambient temperature with 250 std. (STP) liters of He gas. Refrigerant flow is started, in turn, in the LNX and LHX, and He is added during the ensuing cool-down period. Performance test results showed that an inventory of 2500 std. liters provides suitable irradiation temperatures for the full range of nuclear heat loads to be expected (see Fig. 11 - SSD-NLTNIF-11). As the nuclear heat load increases, more of the liquid inventory is vaporized to increase the pressure in the cryostat. At higher values of nuclear heat load the liquid inventory in the irradiation zone

†The reliability of these values is considered to be high since Lillie's computational program gave excellent agreement with SSD experimental results for a hollow fuel element facility in the same core position; i.e., 0.61 W/g - experimental value and 0.59 W/g - calculated value.

is reduced (noted by a liquid level indicator located in the supply tube) thereby reducing, in turn, the contribution to the total nuclear heat load by the LHe (see Table 9 in this section). It should be noted that the pressure in the cryostat is always equal to the vapor pressure of the warmest LHe (if any LHe present), and the liquid temperature/vapor pressure dependence is well known.

Larger LHe inventories are used only when the reactor is off for postirradiation studies made in the test chamber or for the transfer of irradiation specimens into the LHe storage dewar.

Performance tests for operation at elevated temperatures (up to 350 K) using only the gas phase will be carried out later when firm requests for this mode are received from experimenters.

Reactor Power Constant at the Maximum Level Allowed by Its Power-Level Protection System (110% of Nominal Power). If the reactor should surge to 110% of nominal power, the temperature for the maximum nuclear heat load would increase from 4.55 to 5.20 K and remain in control (see Fig. 11).

Loss of Experiment Coolant Flow and the Reactor Continues to Operate at Full Power. Loss of cooling (LOC) performance tests were made in which electrical heating was used to simulate nuclear heat. When the LOC occurs the LHe inventory in the cryostat soon vaporizes, and the resulting gas in the irradiation zone makes virtually no contribution to the nuclear heating, especially above ~20 K. The remaining total nuclear heat load for the maximum allowed experiment mass is 64 W (see Table 9 in Section 8.3). For test purposes an electrical heat load of 70 W (109.4% of the maximum allowed) was applied. The resulting warmup curves for a complete LOC are shown in the lower part of Fig. 12 (SSD-NLTNIF-12).

Along with the relatively slow temperature rise seen in Fig. 12, the cryostat pressure (PE-1CRY) rose, in contrast, in only about 2 minutes from the initial value of 22 to 28 PSIA (pressure relief values of PSV 1CRY and PSV 2CRY) where it remained throughout the test. To examine the longer term effect at higher temperatures of a LOC a second test run was made with a starting temperature of 301 K compared to 4.6 K in the first case. The result is shown in the upper portion of Fig. 12. Note that the rate of temperature rise has increased markedly over that found at the end of the low temperature run. The run was terminated to avoid damage to the test assembly.

For a LOC in the LNX and LHX under the maximum nuclear heat load it is concluded from these results that, after several hours, the sample chamber and an experiment assembly within may be damaged. To provide protection against such a failure PE 1CRY and TE 1LHX are utilized in the NLTNIF safety system to provide primary and backup scram action (see Table 5, Section 4). These sensors also provide protection for the cases of partial LOC. A LOC in the LNX alone transfers to the LHX the conductive and radiant heat loads always present in the cryostat. This added heat load may exceed the capacity of the LHX which results, in turn, in a LOC in the LHX which initiates the scenario described above. For the case of a LOC in the LHX alone both PE 1CRY and TE 1LHX increase to the values set for scram action in much the same manner as that for complete LOC.

Loss of Experiment Coolant Flow and the Reactor is Shut Down as Prescribed by the Experiment Safety Circuit Tie-Ins to the Reactor Controls. This scenario results in a loss of data which can be recovered. No other harmful effects are foreseen. Many hours would be required for the cryostat

to warm to ambient pool temperature during which time any residual nuclear heating would decay to a negligible value.

The Reactor Power is Brought From Zero to the Maximum Level Allowed by Its Power-Level Protection System in 90 Seconds. Performance tests using electrical heat in the sample chamber to simulate nuclear heat showed that a 90 second approach to 110% of the maximum expected heat load has no adverse effect on cryostat response. Startup in power steps is often preferred for the NLTNIF operation, however, since they provide for finer tuning of the refrigerator power to match the nuclear heat load which, in turn, results in lower irradiation temperatures sometimes requested by experimenters.

Loss of Vacuum in the Irradiation Cryostat [LOV(1)]. A loss of the insulating vacuum in the irradiation cryostat (see Figs. 6 and 14) results in an increased thermal heat load on the LNX and the LHX. The LOV(1) may occur as a result of an underwater leak or a He leak in the primary cryostat containment located inside the cryostat junction box. If the leak is relatively small so as not to produce an abrupt increase in thermal heat load, the loss of cooling scenario described above will ensue when the cooling capacity of the LHX is exceeded.

If the LOV(1) results from a major breach of the containment so as to impose a large-abrupt heat load on the system, any LHe inventory will rapidly flash into gas and the warming of the cold gas will result in a rapid pressure rise in the cryostat. Performance tests were made to study the pressure response in the primary and secondary containments to a simulated LOV(1). To avoid contamination that would occur in a performance test made by injection of water or He into the cryostat vacuum space, the

LOV(1) heat load was simulated by large electrical heat loads applied in the irradiation (130 W) and test (270 W) chambers. (Note for reference: 400 W vaporizes LHe at 4.2 K at the rate of 5.3 liters/min.) The test was carried out with a large He inventory (6000 std. liters) that may be used only when the reactor is off for postirradiation studies made in the test chamber. The LHe inventory at the start of the test was 6.5 liters. The time dependence of the cryostat and secondary containment pressures are shown in Fig. 13 (SSD-NLTNIF-10).

From the results in Fig. 13 it can be seen that the peak pressure in the cryostat (33 PSIA) and the secondary containment (2.7 PSIG) stay well below the test pressures (50 PSIA and 7 PSIG respectively (see Table 3, Section 2) of these vessels indicating that larger heat loads can be accommodated. For the reactor-on case the LHe inventory is only 2500 std. liters which reduces the peak pressures according to test results.

In the case of LOV(1) reactor scram action is initiated by PE 2CVJ and backup is by PE 1CVJ. Pressure relief from the cryostat into the secondary as provided by PSV 1CRY and PSV 2CRY and from the secondary into the CVS by the special redundant valve assembly PSV SCR (see Table 5, Section 4). Any pressure that may develop in the cryostat vacuum space is relieved into the interface vacuum through the dual function valve HV CRY (see Fig. 5, Table 5, and Section 11).

Loss of Exchange (LOE). Nuclear heat generated in the irradiation chamber wall and any experiment assembly within is transferred to the LHX by convection of the He in the cryostat. The accidental loss of this He heat exchange medium from the cryostat with the reactor ON could result in damage from the ensuing excessive temperatures. The loss of He exchange gas from the cryostat could occur if the process controller fails

to give its programmed alarm when an operator errs in making a He inventory adjustment to the cryostat. For further protection against this or the loss of cryostat pressure from any other cause, PE 1CRY and PE 2CRY are utilized as primary and secondary sensors respectively (see Table 5, Section 4) for initiating a reactor scram if the cryostat pressure falls below 4 PSIA. This value is lower than the minimum cryostat pressure expected for any irradiation experiment. To insure that the chosen value maintains safe sample chamber conditions, the chamber temperature was measured as a function of decreasing cryostat pressure under a full equivalent nuclear heat load (70 W electrical) during a performance test. At 4 PSIA the temperature of the warmest sensor rose to only 46 K from a starting value at 16 PSIA of 4.3 K. It is concluded that, in the case of the maximum nuclear heat load, the chosen value of 4 PSIA limits the LOE scenario to a minor loss of recoverable data.

8.2.2 Fluid Temperatures, Pressures, and Velocities

See Table 10.

8.2.3 Temperatures of Heat Transfer Surfaces

See Table 9, Section 8.3.

8.2.4 Heat Fluxes Through Heat Transfer Surfaces

See Table 9, Section 8.3.

8.2.5 Heat to be Dissipated by or Discharged to the Reactor Water, Pool Water, and Off-Gas System

See Table 11, Section 8.3.

8.3 Tabulation of Calculated and Measured Results

(The following tables are included for use in tabulating the requested information. Clearly indicate units for values listed.)

Table 9. Heat Generation Rates and Operating Temperatures

Heat Generating Element (See Fig. 6)	Surface		Heat Generation*			
	Temp.	Heat Flux* Watts/cm ²	Fission	Gamma	Fast Neutron	Total
Irradiation chamber and supply tube (90 grams Al)	4.6 K	0.33		28	2	30 W
LHe (est. inventory = 6.5 grams)	4.6 K	not applicable		2	4	6 W
Maximum experiment mass (100 grams)	4.6 K	variable		31	3	<u>34 W</u> 70 W
Vacuum Jacket	307 K	0.8 maximum 0.26 average		0.56	0.06	0.62 KW
Gamma-Ray Shield	307 K	2.7 maximum 1.1 average		5.0	0.5	5.5 KW

*Calculations based on Lillie's nuclear heating values given in Appendix 3.

Table 10. Fluid Conditions*

Fluid	Point Reference (Fig. 6)	Physical Form	Temperature (K)	Pressure (PSIA)	Velocity	
					Std. Liters per min.	ft/min.
He	Sample chamber and supply tube	Gas and liquid	4.1 to 4.7 (see Fig. 11)	13 to 23	300 to 1000	Linear velocities uncertain due to percolation in the gas-liquid mixture
He	LHX	Gas and liquid	3.5 to 4.4	7 to 17	800 to 2500	"
N ₂	LNK	Gas and liquid	86 K	27 to 30	25 to 35	"
	See Fig. 6 for all of above					

*The values cited above are for the full range of nuclear heat loads.

Table 11. Heat Disposal

Heat Receiver		Heat Received (kW)
Reactor Water		None
Pool Water		6.12
Drains	Process	250 (est.) - compressor cooling
	Warm	None
	Hot	None
Off-Gas System		None

9. ESTIMATED OR MEASURED REACTIVITY EFFECTS

9.1 The Experiment Facility (Exclusive of the Experiment Assembly and/or Test Materials)

9.1.1 Installation of the In-Reactor (Core or Reflector) Facility Components

Reactor operations personnel have measured the effect on the reactivity† ($\% \Delta K/K$) of BSR core 102 by the zircaloy gamma-ray shield and the shield plus the cryostat:

Zircaloy Shield	+0.22
Zircaloy Shield + Cryostat	0.00
Net Change Due to Cryostat	-0.22

After approval has been obtained for operation at LHe temperatures any moderating effect of LHe in the radiation zone on core reactivity will be checked, although the effect is expected to be small.

9.1.2 Displacement of Gases by Accidental Water In-Leakage

The results given above show that the leakage of water into the cryostat would have a small effect on reactivity.

9.1.3 Other Causes

As indicated above the sudden loss of LHe during a LOV(1) is expected to have a small effect on core reactivity.

9.2 Installation of the Experiment Assembly and/or Test Materials into the Facility

The effect of experiment assemblies on core reactivity will be assessed and/or measured on a timely basis for each unit prior to its use.

†Reactivity measurements June 12, 1986, NLTNIF: BSR Log Book No. 86, p. 143.

9.3 Intentional Repositioning of Any In-Reactor Materials and/or Components During Reactor Operation

Although there is no present need for this type of operation, the future possibility is recognized. The effect of these motions upon reactivity and control will be measured prior to their use.

The movement of specimens between the irradiation and the test chamber will be made frequently for some experiment assemblies to measure property change in specimens as a function of neutron fluence. Such movements will be made with the reactor at near zero power rather than OFF so that full power operation can be restored quickly after the specimens have been returned to the irradiation zone.

10. PROCEDURES

10.1 Installation and Removal of the Experiment Facility In-Reactor Components

Gamma-Ray Shield. The shield is moved, underwater, into and out of the core by reactor operations personnel with a standard pole-type tool having a special end piece. A special underwater rack is provided to store the shield when it is not in the core.

Cryostat. The irradiation cryostat is fixed in the pool and the BSR core is moved into the NLTNIF position (determined by permanent stops) by reactor operations personnel according to an established operations procedure. The relocation of the core to the "standby" position (one meter east of the cryostat) is required immediately after the reactor shutdown which terminates the planned irradiation dose.

10.2 Installation and Removal of the Experiment Assembly and/or Test Materials

TEST AND EXPERIMENT ASSEMBLY INSTALLATION PROCEDURE*

1. All diametral and length requirements are within prescribed limits. _____
2. Biological shield meets specifications. _____
3. All parts are securely fastened. _____
4. No teflon parts or teflon insulated wire is present. _____
5. No unplanned amounts of high neutron cross section material (B, Cd, Gd, Au) are present. _____
6. All internal and external surfaces are free of grease and dirt obtained by wiping with acetone or freon using clean cloth or tissue. Final wipe-down made in lab just prior to insertion or during insertion into cryostat. _____
7. Any encapsulation is leak checked OK. _____

*This procedure is to be initialed stepwise by the NLTNIF operator and a copy delivered to the BSR reactor engineer prior to reactor startup after any venting to the atmosphere of the primary and/or secondary containment of the NLTNIF cryostat.

8. All electrical and thermocouple circuits are checked for continuity and freedom from grounding. _____
9. Test and experiment assemblies and any related biological shields are installed by the NLTNIF staff. Any electrical or mechanical checks and any tie-in to the data acquisition system have been checked by the experimenter with staff assistance. _____
10. The secondary containment lid (close vent valve) and exterior shield are installed, and all loose materials are removed from the platform. _____
11. An Experiment Information and Safety Analysis form has been submitted to Reactor Operations and reactivity tests have been scheduled if needed. _____

TEST AND EXPERIMENT ASSEMBLY REMOVAL PROCEDURE

1. The cryostat is warmed to ambient temperature.
2. The secondary containment is vented and the lid is removed.
3. The cryostat is vented.
4. All electrical, mechanical, and flanged connections to the cryostat are disconnected.
- 5.† The experiment assembly is removed and transferred to a poolside storage tube for the decay of radioactivity.
6. The test assembly is removed and placed in storage.

It is expected that transfers of radioactive specimens from the cryostat to the adjacent LHe storage vessel will be made at 4.2 K. The procedure for such transfers will be established and presented for review following the construction and performance testing of the transfer devices.

10.3 Sampling, Experiment Position Adjustments, Etc.

Normally, the movement of an experiment assembly between the irradiation and test chambers will be carried out with the reactor OFF or at near zero power. For exceptional cases, notification will be given to the reactor

†The removal of radioactive experiment assemblies is carried out by reactor operations personnel under the supervision of a health physicist and with NLTNIF staff assistance. A long standing reactor operations procedure which utilizes the BSR overhead personnel bridge is followed for making these and other transfers in the BSR bay area.

operator of any movements to be made with the reactor ON (see Section 9.3).

The staff member executing the movement with the pull rod device at the top of the cryostat will be monitored by a health physicist.

10.4 Instrumentation and Pre-Start or Checkout Operations

10.4.1

RELIEF VALVE TEST PROCEDURE*

The cryostat, capsule (if in use), and the secondary relief valves are tested according to the following steps:

1. PCV CRY } opened
PCV 2SCS } closed position indicator lights are red
PCV MHS } opened
2. HV MHS is adjusted to give a He filling rate into the cryostat of a few PSIA/min as seen on PE 1CRY. The proper operation of PSV 1CRY and/or PSV 2CRY is observed when the rise in PE 1CRY stops at the relief valve setting of PSV 1CRY and/or PSV 2CRY while the He flow continues as seen on FE MHS.
3. The proper operation of PSV SCR is observed when PE 1SC rises and then holds fast at its adjusted relief valve setting while the He flow continues as in step 2.
4. HV MHS is closed and all valves used in step 1. are returned to their normal positions (position lights are green). Note, if a sealed experiment capsule is in use, steps 1. and 2. are repeated with PCV CAP substituted for PCV CRY.

10.4.2

TOA SAFETY CIRCUIT AND CALIBRATION TEST PROCEDURE*

(Performed Prior to Every Preirradiation Loading of the Cryostat and Secondary Containment)

1. Move TOA selector valve from RUN to TEST. (Adjust TOA flow rate to 0.7 SCFH if needed.)
2. Observe TOA to give alarm response at 8 PPM O₂ and equilibrate at 10 PPM O₂ (adjust span if needed).
3. Return TOA selector valve to RUN.

*This procedure is to be initialed stepwise by the NLTNIF operator and a copy delivered to the BSR reactor engineer prior to reactor startup after any venting to the atmosphere of the primary and/or secondary containment of the NLTNIF cryostat.

10.4.3 CRYOSTAT PURGING AND He LOADING PROCEDURE FOR IRRADIATION*

(Relates to Section 11)

<u>STEP</u>	<u>MONITORED ELEMENT</u>
1. Call up the program on the Process Controller (PCON). The PCON sends an alarm to the Tel-Alarm unit.	PCON _____
2. Pump out the cryostat to less than 100 mTorr.	PE 1MVP _____
3. Charge the cryostat to greater than 15 PSIA.	PE 1CRY _____
4. Pump out the cryostat to less than 100 mTorr.	PE 1MVP _____
5. Charge the cryostat to between 5-7 PSIA.	PE 1CRY _____
6. Pump out the capsule to less than 100 mTorr.	PE 1MVP _____
7. Charge the capsule to greater than 15 PSIA.	PE 1CAP _____
8. Pump out the capsule to less than 100 mTorr.	PE 1MVP _____
9. Charge the capsule to between 5-7 PSIA.	PE 1CAP _____
10. Pump out the secondary to less than 500 mTorr.	PE SCP _____
11. Charge the secondary to greater than 0.9 PSIG.	PE 1SC _____
12. Pump out the secondary to less than 500 mTorr.	PE SCP _____
13. Charge the secondary to greater than 0.9 PSIG.	PE 1SC _____
14. Return all PCV's to the "Green Condition." The PCON now clears the alarm signal to the Tel-Alarm unit.	
(Monitored Elements) PCV MVP, MHS, 2SCS, 1SCS, SCP, CRY, CAP _____	

*This procedure is to be initialed stepwise by the NLTNIF operator and a copy delivered to the BSR reactor engineer prior to reactor startup after any venting to the atmosphere of the primary and/or secondary containment of the NLTNIF cryostat.

10.4.4 FINAL PREIRRADIATION SCRAM CIRCUIT CHECK PROCEDURE

The final procedure is carried out after completion of the foregoing procedures and the cryostat is cooled down to the operating temperature and properly charged, the reactor is placed in the NLTNIF position, and all safety monitors are checked to be in their operating ranges.

1. The NLTNIF operator requests the reactor operator to unlock the NLTNIF "E" panel and requests the Health Physicist (4-6523) for survey service if a new biological shield configuration has been installed.
2. The reactor power is raised to 100 kW, and the reactor operator requests alarm and scram signals from the NLTNIF operator.
3. The NLTNIF operator closes PCV 1SCS and opens PCV SCP momentarily to reduce the secondary containment pressure (PE 1SC) below the alarm and scram value.
4. When the reactor operator confirms that proper scram action has occurred, the NLTNIF operator restores the secondary containment to the normal operating condition.

10.4.5 PROCEDURE FOR CHANGING THE He INVENTORY DURING IRRADIATION

(Relates to Section 8.2.1 - LOE)

1. Close PCV 2SCS. PCON starts internal clock. If PCV 2SCS is not opened within 5 minutes, the PCON sends an alarm to the Tel-Alarm unit.
2. Open PCV CRY.
3. Add or remove He as needed and return all PCV's to the "Green Condition" within 5 minutes.

10.4.6 PROCEDURE FOR PERIODIC INSTRUMENT CALIBRATIONS AND CIRCUIT CHECKS

The instruments listed in Table 5 will be calibrated and the indicated reactor actions verified on a quarterly schedule by the NLTNIF operator and I&C personnel. Except for TE 1LHX, this maintenance will be scheduled while the refrigerator system and the reactor are off at the times of the quarterly reactor checks.

TE 1LHX cannot be calibrated. The NLTNIF operator will record readings of all low temperature sensors under various conditions during every experiment. Any discrepancies from one experiment to another or other indications of inaccuracy will be brought to the attention of the NLTNIF director. TE 1LHX will be replaced if its accuracy becomes suspect. At the end of the last experiment before the quarterly check, SCRAM action will be verified when TE 1LHX rises above 50 K as the cryostat warms.

The calibration of the pressure sensors relies on PI CM, which is a stable and accurate aneroid manometer. The accuracy of PI CM is verified on an annual schedule by comparison with a secondary standard maintained by ORNL Inspection Engineering.

1. With the cryostat closed, the secondary containment in place, and the managment circuit valves in "Green Condition," HV SCB is opened and PCV 1SCS closed to bleed the He(2) pressure (initially 1 PSIG) down until SCRAM action is observed at PIY 1SC and PIY 2SC readings of $0.90 \pm .05$ PSIG.
2. Bleed down is continued until PIY 1SC and PIY 2SC stabilize at 0 PSIG. The zeroes of PIY 1SC and PIY 2SC are reset if necessary, and the absolute atmospheric pressure is read on PI CM. PIY 1MVP should read

750 $\pm$ 50 Torr. Failure to do so or to read less than 20 mTorr in step 8 indicate a need for repair.

3. HV SCB is closed, PCV 1SCS opened, and HV SCS is opened to raise the regulated He(2) pressure until SCRAM action is observed at 1.10 $\pm$.05 PSIG on PIY 1SC and PIY 2SC.
4. Close HV SCS. PIY 1SC and PIY 2SC span settings are adjusted to agree with PI CM if necessary.
5. If zero or span adjustments have been made, steps 1-3 are repeated as necessary until specified SCRAM actions are observed.
6. The secondary containment is removed after closing PCV 1SCS and bleeding He(2) down to 0 PSIG through HV SCB.
7. A temporary hose connection is made between the service ports at HV NXJ and HV CM.
8. HS 1MVP and HS 2MVP are started, PCV 2SCS is closed and PCV 1MVP, PCV 2MVP, and HV MVP are opened. PIY 1MVP should fall below 20 mTorr. HV NXJ and HV CM are opened. The He(4) region is evacuated to less than 100 mTorr as read at PIY 1MVP.
9. Adjustments of PIY 1NXJ and PIY 2NXJ are made if necessary to obtain readings of 0 PSIA.
10. PCV 1MVP, PCV 2MVP are closed and PCV MHS and HV MHS are opened to raise the He(4) pressure until SCRAM actions are observed at 4.0 $\pm$ 0.1 PSIA on PIY 1NXJ and PIY 2NXJ.
11. PCV MHS is closed and span adjustments of PIY 1NXJ and PIY 2NXJ are made if necessary to bring their readings into agreement with PICM.
12. If zero or span adjustments have been made, steps 8-11 are repeated as necessary until specified SCRAM action is observed.

13. The pressure of He(4) is raised to the standard warm condition (6.6 PSIA) by opening PCV MHS.
14. HV NXJ and HV CM are closed and the temporary hose is removed.
15. PCV 1MVP, PCV 2MVP, PCV CRY, and PCV CAP are opened. Regions He(1) and HE(5) are evacuated to less than 100 mTorr as read at PIY 1MVP.
16. Adjustments of PIY 1CRY, PIY 2CRY, PIY 1CAP, and PIY 2CAP are made if necessary to read 0 PSIA.
17. PCV 1MVP and PCV 2MVP are closed and PCV MHS is opened to raise He(1) and He(5) pressures. The SCRAM action indicated at low pressure should be removed as pressure rises above 4.0 ± 0.1 PSIA on PIY 1CRY, PIY 2CRY, PIY 1CAP, and PIY 2CAP. SCRAM action should be observed again when PIY 1CRY reads 25.0 ± 0.1 PSIA.
18. PCV MHS is closed and span adjustments of PIY 1CRY, PIY 2CRY, PIY 1CAP, and PIY 2CAP are made if necessary to bring their readings into agreement with PI CM.
19. If zero or span adjustments have been made, steps 15-18 are repeated as necessary until specified SCRAM actions are observed.
20. PCV CRY, PCV CAP, and HV 1ET are closed; PCV MHS is opened; and metering valve HV TOA is opened to a high flow rate. ALARM action should be observed when PIY MHS and PIY GHS fall below 12.0 ± 0.5 PSIG, and SCRAM action should be observed when PIY MHS and PIY GHS fall below 5.0 ± 0.5 PSIG.
21. HV TOA is closed. TOA ALARM action should be observed within 5 minutes.
22. Span adjustments of PIY MHS and PIY GHS are made if necessary to bring their readings into agreement with PI CM (remembering to add the atmospheric reading observed in step 2 to PIY MHS and PIY GHS for comparison with PI CM).

23. HV TOA is opened and PE MHS and PE GHS pressures are allowed to drop to atmosphere.
24. Zero adjustments of PIY MHS and PIY GHS are made if necessary.
25. HV IET is opened to return the management circuit to normal pressures.
26. If zero or span adjustments have been made, steps 20-25 are repeated as necessary until specified SCRAM and ALARM actions are observed.
27. HV TOA is closed, and the He gas line is disconnected from the TOA.
28. Every second quarterly check (twice yearly) the TOA sensing cell is replaced.

11. HAZARDS

The following is a list of all perceived potential hazards to the reactor, the facility, and personnel. The protective responses incorporated in the NLTNIF design or applied through the use of safety equipment (monitors and protective action devices) are discussed below for each item in turn.

- 11.1 All thermodynamically related hazards are discussed in Section 8. They include:

Reactor Power Surge to 110% of Normal
Loss of Cooling (LOC)
Loss of Vacuum [LOV(1)]
Loss of Exchange (LOE)

- 11.2 Protection of BSR fuel elements during positioning at NLTNIF.
11.3 Accidental bottom-end-up floatation.
11.4 Breach of internal refrigeration piping.
11.5 Radiation damage to the cryostat.
11.6 Stored energy release in the sample chamber.
11.7 Cryogenic irradiation hazard.

11.2 Protection of BSR Fuel Elements During Positioning at NLTNIF

The lower end of the gamma-ray shield is constructed precisely like that of a fuel element. When inserted into the NLTNIF core position it provides a rigid stall which will not yield to the small forces exerted on it by the cryostat during entry into the shield. (See also Appendix I.)

11.3 Accidental Bottom-End-Up Floatation

If for any reason the irradiation cryostat should become loose from its mooring to the personnel platform, stainless steel ballast weights attached to the underside of the lower end of the outer vacuum jacket tube are designed to keep the in-core (radioactive) end of the cryostat downward during any ensuing tipping or falling accident.

11.4 Breach of the Internal Refrigeration Piping

To prevent excessive pressure build-up in the vacuum jacket of the interface system due to a rupture of any internal cold piping, two 2" diam — specially designed — relief valves (the design is approved by ORNL Inspection Engineering) are located on the interface junction box, PSV 1IVJ and PSV 2IVJ. (See also Table 5, Section 4).

11.5 Radiation Damage to the Cryostat

There are no data on radiation effects in 1100 Al (sample chamber material) or 6061-T6 Al (supply tube material) for the cyclic irradiation (4 K) and annealing (307 K) to which the cryostat will be subjected over its lifetime. Data for these materials irradiated near 300 K shows that an onset for loss-of-ductility occurs at a neutron fluence at least two orders of magnitude greater than the expected lifetime fluence of NLTNIF.[†] It is our judgment that the low temperature cycling in NLTNIF will not reduce the radiation tolerance of these materials to the lifetime fluence level of NLTNIF. Nevertheless, we consider the risk of the worst imaginable case (replacement, probably due to cracking, of the sample chamber/supply tube assembly) to be acceptable, and we note that any resulting hazard has already been accounted for. The use of Al alloys for these components is, because of the lower nuclear heating compared to more dense materials, absolutely essential to the design of the cryostat. Based on the radiation tolerance of 6061 Al at 300 K[†] we foresee no difficulty from radiation damage to the vacuum jacket of the cryostat.

[†]K. Farrell, Response of Aluminum and Its Alloys to Exposure in the High Flux Isotope Reactor, "Dimensional Stability and Mechanical Behavior of Irradiated Metals and Alloys," British Nuclear Energy Society, London, 1983.

11.6 Stored Energy Release

Energy is stored by defects produced during irradiation at low temperatures in most solids. During subsequent annealing the stored energy can be released as a result of the thermal migration and recombination of the defects. The release can produce spontaneous temperature increases from a few to hundreds of degrees depending upon the irradiation history. The temperatures at which the energy releases occur depend upon the material. This phenomenon has been studied for a few elements, including Al.

It is calculated that nearly saturated damage can be reached in Al in about 10 days irradiation time in NLTNIF. From stored energy data it is estimated that during warmup after such an irradiation near 4 K, a catastrophic energy release will begin between 60—100 K which will result in a rapid temperature rise in the irradiated section of the sample chamber to about 310—330 K. The accompanying sudden thermal expansion of the chamber (est. ~ 2 mm) can easily be accommodated by the loop of flexible metal hose at the top of the supply tube. This hose also accommodates transient differential contraction between legs of the "U" tube assembly during cooldown of the cryostat (see Fig. 6). No other effects of stored energy release on the cryostat are foreseen.

To provide needed information to all NLTNIF experimenters a subcontract has been let between ORNL and Prof. R. L. Chaplin, Clemson University, to study stored energy release in small test specimens of sample and structural materials to be irradiated to high fluences at low temperatures in NLTNIF. After approval by the RERC for reactor operation, the first experiment will be the study of stored energy release in copper to successively higher fluences. The stored energy assembly will also be used to study the stored energy release in the cryostat. The results of this "bootstrap" performance testing will be forwarded to the RERC for evaluation. The release of stored energy will be assessed in seeking approval for all experiment assemblies planned for high fluence increments.

11.7 The Cryogenic Irradiation Hazard

The "cryogenic irradiation hazard" has been known for many years. The hazard occurs when air condenses or freezes (possibly insidiously without detection) on cold surfaces located in zones of high radiation intensity. While the exact details are uncertain, O_2 in the air is converted by the radiation to O_3 . Under suitable conditions (often during a subsequent warmup) the O_3 decomposes or reacts with other agents explosively. Since the cryostat is to be located in the core of the reactor it is essential that the probability of an explosion shall be reduced to the lowest possible value. For this reason the NLTNIF design employs double containment over the entirety of the paths between the atmosphere and the irradiation zone. Above the surface of the BSR pool water the secondary containment is metal. Below the surface, the pool water becomes the secondary containment. The primary containment is metal.

There is an important distinction between the cryogenic irradiation hazard and hazards associated with most other reactor experiments which require double containment. In all cases the hazard derives from the sudden release of energy which can damage the facility and/or the reactor. In most such reactor experiments the energy (chemical, thermal, mechanical) preexists within the experiment or facility and the containments provide protection against its outward release. In the case of the cryogenic irradiation hazard, however, no energy preexists in the facility and the containments provide protection against the entry of the atmosphere which only then produces potentially hazardous energy.

The topography of the NLTNIF containment system is complicated by various penetrations needed for operation of the cryostat. Figure 14 shows in schematic fashion the topography of the NLTNIF containment system. The system is characterized by its parallel branches and bulkheads. In the case of the latter we note that although a breach of a bulkhead is not a breach of a containment, it,

nevertheless, may lead to another hazard such as LOV(1) which would be detected. All sensors, protective devices and the resulting remedial actions needed to meet the principles of double containment are identified in Table 5, Section 4.

In the sections which follow discussions are given of the energy of the ozone reaction, other O₂ sources, and special features of the containment system.

11.7.1 Energy of the Ozone Reaction

It is generally believed that the explosive reaction responsible for the cryogenic irradiation hazard is the decomposition of O₃ back to O₂, i.e.:

From these equations one calculates that 1 std. cc of O₂, if converted to O₃ by radiation with 100% efficiency, can release 1.03 calorie upon decomposition. If the rate of decomposition equals that of TNT, which releases 1050 cal/gm, then the maximum explosive potential of 1 std. cc of O₂ is very nearly 1 mg of TNT.

It is very difficult to make a realistic estimate of the amount of O₂ that might be accumulated in the irradiation zone as the result of undetected simultaneous breaches of the primary and secondary containments. For example, the freezing-out of the entering air on cold surfaces well above the radiation zone could greatly reduce the amount or prevent air from reaching the radiation zone. Nevertheless, an unrealistic upper limit is the O₂ in the amount of solid or liquid air which can fill the sample chamber and supply tube in the radiation zone. This limiting amount is calculated to be 1.06×10^5 std. cc of O₂ having an equivalent explosive potential of 106 grams of TNT. While the unrealistic upper limit may be

10 times higher than a realistic value there remains, nevertheless, ample justification for the use of double containment in the NLTNIF design.

11.7.2 Purging the Cryostat

As a result of installing an experiment the cryostat contains air which must be purged prior to cooldown and irradiation. This is accomplished by an operator directed procedure (see Section 10.4) which is monitored by the Process Controller (PCON). Any failure to properly complete the procedure results in a continuing reactor safety circuit alarm which is intended to delay a reactor start until the procedure is completed correctly, clearing the alarm.

The double purging procedure provides a dilution of the air with He by a factor of 5.6×10^7 . The resulting O_2 residue in the 250 liter cryostat is a little less than 10^{-3} std. cc, which has a negligible explosive potential.

11.7.3 He Purity

The possibility is recognized that O_2 may enter the cryostat during the charging procedure as an impurity in the helium supply. The O_2 impurity could originate from residue air remaining in the refrigeration system as a result of improper purging following maintenance, or it may result from an impure cylinder of commercial He used to charge the NLTNIF system. Protection against O_2 impurity is provided by a continuously operating Trace Oxygen Analyzer (TOA) situated in the cryostat management circuit (see Fig. 3). The TOA is adjusted to produce an alarm if the O_2 impurity exceeds 10 PPM or if the input He sampling stream is cut off. For the standard He inventory for irradiation (2500 std. liters) the O_2

limit set on the TOA corresponds to 25 std. cc of O_2 or an explosive potential of 25 mg of TNT; which we consider acceptable.

11.7.4 O_2 Impurity in LN — The LNX Jacket

It is well known that commercial LN as used in the LNX contains variable amounts of O_2 impurity. For this reason the LN supply is treated as air which requires double containment of the LN system. This is accomplished by placing a copper jacket around the LNX and charging the resulting interspace with He [space He(4) in Fig. 14]. Some bonding by braze material between the LNX and the jacket occurred during construction. Vacuum jacketing needed for insulation provides double containment for the LN piping enroute to the LNX (see Figs. 4, 5, and 14). The jacketed space is connected to a ballast can (located inside the secondary containment at room temperature) which reduces pressure variations between warm (6.3 PSIA-LNX OFF) and cold (3.7 PSIA-LNX ON) cryostat conditions. Pressure sensors PE 1NXJ (Primary) and PE 2NXJ (Backup) are set to give alarm and scram actions if the pressure rises above 4 PSIA which can result from a breach in the LNX jacket (minimum operating cryostat pressure outside is 5 PSIA) or the LNX wall (operating range of the LN flow inside is 12-15 PSIG).

11.7.5 The V(1) — V(2) Containment Barrier

The possibility of pumping the cryostat insulating vacuum space, V(1), directly (see Fig. 14) with conventional pump components was rejected since the principle of double containment would require the components to be housed in a He pressurized container. The expense of such a containment and the back-diffusion through the pumps of He which cannot be cryotrapped,

led to the present design. Fig. 5 shows that the cryostat vacuum space, V(1), is pumped through HV CRY by the interface vacuum system, V(2). When a suitable low pressure is reached in V(1), HV CRY is closed and V(1) remains static during subsequent cold operations. As a result, HV CRY is part of the primary containment for V(1). During normal operation the pressures in V(1) and V(2) are virtually identical with the result that a failure of HV CRY to close cannot be detected by the sensors, PE 1CVJ and PE 2CVJ on V(1) and PE 1IVJ and PE 2IVJ on V(2) (see Table 5, Section 4.1). To meet this need a special design was used for HV CRY which requires finite stem motion (approx. 1/8") before opening occurs. After a travel of approx. 1/16" a related microswitch initiates a reactor alarm action. While an alarm may be produced over a narrow motion with the valve still closed (nuisance) the valve cannot be opened without producing an alarm (necessity). This valve has been inspected and approved for use by ORNL Inspection Engineering.

11.7.6 A Containment Ambiguity

The range of cryostat pressures [region He(1) in Fig. 14] needed to accommodate the full range of nuclear heat loads encountered in all experiments is 5 to 25 PSIA, while the regulated pressure in the secondary containment is 1 PSIG $\approx$ 15.7 PSIA [region He(2)]. It is possible that the cryostat pressure in a particular experiment could equal the secondary containment pressure with the result that a breach of the cryostat primary containment would go undetected. To minimize this possibility, the HI-LO trip-point span of the secondary pressure (see Table 5, Section 4.1) has been squeezed down to the smallest practical interval, 0.9 to 1.1 PSIG. This interval corresponds to a LHe vapor-temperature range of

4.265 to 4.284 K. To eliminate this ambiguity in containment integrity, adjustments to the LHe refrigeration system will be made to avoid, in turn, this corresponding narrow irradiation temperature range.

12. QUALITY ASSURANCE

A Quality Assurance Program was formulated for the construction of the cryostat, personnel platform, and zircaloy shield, and it is attached hereto as Appendix IV. All documentation related to the execution of this program is available for audit.

Separately, the Vacuum Jacket Assembly (Eng. Dwg. X3E-12566-029) and the Access Tube Assembly (Eng. Dwg. X3E-12566-030) were fabricated by an outside contractor according to the ASTM Pressure Vessel Code specifications and certified by the attachment of a Pressure Vessel Code stamped plate applied to each assembly.

APPENDIX I

Notes on Fitting-Up of the Cryostat, Shield, and Core

(Between December 15, 1984 and January 15, 1985)

Shield in the Core

After removing a small burr from the ID of the $\frac{1}{4}$ " diam "key hole" in the welded tab near the bottom of the shield, it was found that the shield could easily be inserted into its "home" position including proper keying into the grid-plate pin which determines angular position. Visual observation indicated no angular misorientation, but the top of the south face of the shield was closer to the adjacent fuel element than the north face. It could not be determined if actual contact was made at the top. At the bottom of the shield the spacing looked equal. The reactor engineer (E. D. Lance) lifted each of the 3 adjacent fuel elements up and down several times to "feel" for any interference with the shield. Only a slight contact "may" have been felt with the south element, but the engineer considered there to be ample freedom for all reactor operations. Between 12/15/84 and 1/15/85 the shield was reinserted three times without any difficulty.

Cryostat in the Shield

The cryostat was mounted in the pool with the prescribed 2° west tilt and a "best guess" value for the height, and the shield was inserted into the core. While moving the core south, the closest approach between the reactor bridge and cryostat junction box was found to be only $\frac{3}{32}$ " (too close). With the core in the correct (eyeball accuracy) south position, it was then moved west to within about one foot of the cryostat. Using a depth gauge, the difference in height between the bottom of the cryostat (east nose) and the bottom of the shield (east trough) was between $\frac{7}{8}$ " and 1" (more than that needed for safe clearance and freedom of water flow). After retracting the reactor east, the cryostat was lifted out of the pool and the support leg was shortened by $\frac{3}{7}$ " (3 turns of the 1"-7 NC threaded adjusting screw). The cryostat was remounted in the pool. A recheck of the clearance between the bridge and the junction box gave a minimum value near $\frac{1}{2}$ " (see tabulation on Page 2 for details), equal to that used for many years with the old LTNIF. The clearance at the bottom of the cryostat is now between $\frac{1}{2}$ "- $\frac{5}{8}$ ".

After considerable study with the underwater perioscope, the N-S position of the core was established as accurately as possible. The mounting bolts between the junction box and the personnel platform were then loosened to provide N-S rocking ($\sim 1\frac{1}{2}''$), E-W rocking ($\sim \frac{1}{4}''$) and angular rotation ($\sim 1^\circ$). The core was then slowly moved west to engage the cryostat while the top of the junction box was constantly "jiggled" to check for any loss of freedom. Visual sightings midway during the engagement indicated the core should be moved about $\frac{1}{8}''$ south. After making this adjustment the fitting process was continued. The fitting method was based on the argument that, if any vertical non-parallelism existed between the shield and the cryostat, the angular freedom would be lost as a result of binding. During the engagement process no loss of this freedom was observed. The establishment of the E-W core position was easily found with considerable accuracy by noting the loss of E-W rocking freedom.

After establishing the core position for NLTNIF, scribe marks were made on the E and W bridge rails and on the carriage position locator plate. Permanent steel stops were then fabricated and appropriately attached.

The following positional values were obtained during and after the fitting-up procedure:

1. Clearances between the bridge (lower face of N I-beam) and positions indicated on top of the junction box.

SE Corner	0.426"
Center of East Edge	0.484"
NE Corner	0.502"
NW Hinge	0.696"
Center of Circular Access Flange	0.735"
2. Clearance between bottom of cryostat and bottom of shield (east extremities) = $\frac{1}{2}''$ to $\frac{5}{8}''$.
3. E-W position of junction box: distance between W face of box (center) and flange edge of adjacent (W) A1 I-beam = $4\frac{1}{32}''$ (10.24 cm). Corresponding distances at N and S end of west face are 10.28 and 10.17 cm respectively.
4. N-S position of junction box: distances between the junction box and edges of adjacent tread plate are N- $2\frac{1}{8}''$; S- $1\frac{11}{16}''$.

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

March 19, 1985

To: J. A. Setaro

From: T. P. Hamrick (4-7078)

T. P. Hamrick

Subject: Thermal Check of NLTNIF

Reference: Letter on the same subject from T. P. Hamrick to J. A. Setaro dated February 27, 1985

The experiment referred to in the reference was performed the morning of March 15, 1985.

Prior to the experiment, two thermocouples were installed as follows:

- 1) TC#1 was attached to the east side of the NLTNIF shield in the region of highest thermal neutron flux. This was between the shield and the fuel element in the BSR core.
- 2) TC#3 was attached to the east side of the NLTNIF dummy cryostat in the region of highest thermal neutron flux. This was between the shield and the dummy cryostat. (On the opposite side of the shield from TC#1).

The experiment went according to plans until the reactor power reached 1300 KUS at which time TC#1 became erratic and began reading around $41 \pm 5^\circ\text{C}$ indicating probably TC#1 had developed a short above the original juncture. TC#2 performed throughout the experiment. Table 1 shows the results of the experiment.

TABLE 1

<u>Reactor Power</u> (KW)	<u>Temperatures</u> ($^\circ\text{C}$)	
	TC#1	TC#3
Shutdown	35.0	35.0
500	42.8	41.1
1000	50.7	45.0
1100	52.6	46.6
1200	53.6	46.5
1300	----	48.2
1400	----	48.8
1500	----	49.2
1600	----	49.4
1700	----	50.6
1800	----	50.9
1900	----	52.2
2000	----	52.0

J.A. Setaro

-2-

March 19, 1985

The results clearly indicate that the temperatures at these points are well below the boiling point. At the same time, I&C personnel had installed a chamber in the D₂O tank to detect neutron noise and no unusual noise was detected. Servo action indicated that no unusual perturbations were present at any power level. From all the evidence, I conclude that the heat transfer calculations made on the experiment are correct and no boiling will take place during 2 Megawatt operations.

TPH/kwl

Distribution: R. Coltman
B. L. Corbett
S. S. Hurt
E. D. Lance
F. E. Muggridge

INTRA-LABORATORY CORRESPONDENCE

OAK RIDGE NATIONAL LABORATORY

January 30, 1984

TO: C. E. Klabunde
FROM: R. A. Lillie *RAL*
SUBJECT: Nuclear Heating Rates in the NLTNIF

The neutron and gamma heating rates at several spatial positions in the NLTNIF with and without either Pb or Zr gamma shielding are enclosed. The spatial positions are denoted in Fig. 1 and the heating rates are given in Tables I through IV. The x coordinate of points 1 and 2 and the y coordinate of points 3 and 4 are slightly different in Tables III and IV from those in Tables I and II because of a slight change in mesh spacing which was required to model the reduced gamma shield configurations.

The neutron heating rates in Pb and Zr are not given. In Pb these heating rates were less than 10^{-3} watts/gm and are thus insignificant. In Zr the neutron heating rates are not given because Zr neutron kerma factors were not available. However, since Zr has a minimal neutron capture cross section like Pb, the neutron heating rates in Zr should also be small compared to the gamma heating rates.

As a final note, the units on the heating rates are watts/gm of the respective element.

RAL:c2
Enclosure
cc:w/enclosures: R. R. Coltman, Jr.
F. W. Young, Jr.

NOTE: Tables I, II, and III have been deleted from Lillie's report since they are not pertinent to NLTNIF Safety Analysis Report.

Table IV. Nuclear Heating Rates at Several Positions
in the NLTNIF (Reduced Zr Gamma Shield)

Point #	Position* (cm)		Nuclear Heating (watts/gm)			
	x	y	Zr Gam.	Al Neut. Gam.	LHe Neut. Gam.	LHe Gam.
1	0.4452	3.8545	0.592			
2	1.3356	3.8545	0.417			
3	4.0500	0.7927	0.388			
4	4.0500	6.9164	0.394			
5	4.0500	3.8545		0.027 0.310	0.606	0.313
6	16.7500	3.8545		0.016 0.105	0.209	0.106

* The axial position, z, of all heating rates is 30.554 cm below the top of the active core. This position represents the location of the maximum axial heating rates.

Fig. 1. Plan View of NLTNIF Calculational Model with Reduced Gamma Shield.

Point	Position
1	0.4452 cm. from center of east fuel face
2	1.3356 cm. from center of east fuel face
3	0.7927 cm. from center of south fuel face
4	0.7927 cm. from center of north fuel face
5	center of cryostat
6	center of LHe feed tube

APPENDIX IV

QUALITY ASSURANCE ASSESSMENT/PLAN

MARTIN MARIETTA ENERGY SYSTEMS, INC.

TM-15008
6-83

PLANT ORNL	DIVISION/FACILITY	ASSESSMENT/PLAN NO. X-QAA-3731	ORIGINAL ISSUE DATE Feb. 7, 1984	REV. (NO.) DATE Rev. 1, Aug. 30, '84
PROJECT TITLE - BUILDING OR ACTIVITY National Low Temperature Neutron Irradiation			PROJECT NO. (ENGRG.) 83-ORNL-35	ESO NO. (ENGRG.) K-3731
JOB (Subproject, Subsystem, Program, Facility, etc.) TITLE - BUILDING Cryostat			WBS NO. (ENGRG.)	PAGE 1 of 15
PROJECT PHASE: ☒ DESIGN/CONSTRUCTION ☐ MANUFACTURE ☐ OPERATION				REF. Engineering QAA No.

I. PROJECT (SUBPROJECT) DESCRIPTION

A liquid helium cooled cryostat will be designed and fabricated for low temperature irradiation experiments to be conducted at the Bulk Shielding Reactor Facility, Bldg. 3010. The cryostat will be supported from the floor of the reactor pool and will slip fit into a vacant fuel element position when the reactor core is moved to the cryostat.

In addition to the cryostat, work will include cryostat supports, piping to a point above the reactor pool, a small work platform above the reactor pool, instrumentation and installation and testing.

ASSESSMENT STATUS

☒ INITIAL ☐ INTERIM ☒ FINAL

III. ASSESSMENT CONCLUSION (See Worksheets UCN-15007)

QA PLAN REQUIRED? ☒ YES ☐ NOQA PLAN REVISION REQUIRED? ☐ YES ☐ NO

IV. INDIVIDUALS RESPONSIBLE FOR PERFORMING THIS ASSESSMENT

CHAIRPERSON			
J. A. Murray	F. H. Neill	F. W. Young	C. E. Klabunde
J. R. McGuffey	E. R. Carpenter	R. R. Coltman	W. M. Fletcher
D. L. Haynes	K. H. Poteet	D. B. Poker	C. S. Meadors

V. APPROVALS (NAME AND DATE)

SITE	ENGINEERING	DOE OR OTHER
PLANT DIVISION REPRESENTATIVE F. W. Young <i>F. W. Young</i>	PROJECT (MANAGER) ENGINEER J. A. Murray <i>J. A. Murray</i>	DOE-ORO
DIVISION QA COORDINATOR D. B. Poker <i>D. B. Poker</i>	PROJECT QA ENGINEER E. R. Carpenter <i>E. R. Carpenter</i>	
PLANT QA COORDINATOR F. H. Neill <i>F. H. Neill</i>	PRINCIPAL ENGINEER C. W. Collins <i>C. W. Collins</i>	

VI. ASSESSMENT REVIEW

#/REV	SCHEDULED REVIEW DATE	DATE REVIEWED	REASSESSMENT REQUIRED		APPROVAL SIGNATURES			
			NO	YES	CHAIRPERSON	QAC		
1	90% Design	8/24/84	X		<i>F. W. Young</i>	<i>E. R. Carpenter</i>	<i>C. W. Collins</i>	<i>J. R. McGuffey</i>
2								
3								
4								

QUALITY ASSURANCE ASSESSMENT AND PLAN

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(2 5 83)

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DOCUMENT NUMBER			
ISSUE/REV. (INC.) DATE			

JOB ELEMENTS OR ACTION PLAN STEPS		POTENTIAL PROBLEMS OR FAILURE MODES	EFFECT(S)	CONSEQUENCE ¹
NO.	DESCRIPTION			
1.0	Work Platform	Structural Failure	Loss of intended use, loss of use of cryostat and reactor during repair.	S
2.0	Gamma Shield, Biological Shield and Ballast	2.1 Constructed of unsuitable materials.	2.1 Failure to perform as required or rapid failure in service.	S

¹Evaluate the consequence of each potential problem in terms of its effect on mortality; programmatic loss and delay; and health, safety, and environmental injuries and insults. Classify each potential problem as I-Insignificant or S-Significant. If the consequence is insignificant, include a rationale statement and designate the result as A-Acceptable in column on reverse side of form. If the consequence is significant, list the results column in the

**QUALITY ASSURANCE ASSESSMENT AND PLAN
(CONTINUED)**

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DOCUMENT NUMBER			
ISSUE/REV. (NO.) DATE			

NO. ²	POSSIBLE CAUSES	PROBABILITY ³	RISK ⁴	PREVENTATIVE ACTION ⁵ OR RATIONALE STATEMENT (ACTION ITEMS)	RESPONSIBILITY (Organization and Person)	SCHEDULE
1.0	Defective Design, Materials or Workmanship	U	U	1.1 Specify accepted codes for design and inspection. 1.2 A design review will be performed by Solid State Division. 1.3 The work platform will be shop and field inspected.	XMD D.L. Haynes SSD QA&I P.B. Burn	
2.0	2.1a Improper Materials Selected During Design	U	U	2.1a(1) Select Gamma Shield, Biol. Shield and Ballast materials after careful review with persons knowledgeable in design, reactor experiments and reactor opns. 2.1a(2) A design review for Gamma and Biol. Shield and Ballast materials will be performed by Solid State Div. 2.1a(3) A design review for Gamma and Biol. Shield and Ballast materials will be performed by Reactor Operations.	XMD C.W. Collins SSD Coltman OPN Hurt	
	2.1b Incorrect Materials Substituted During Fabrication	U	U	2.1b Verify Gamma Shield, Biological Shield and Ballast materials during fabrication.	QA&I P.B. Burn	

²Repeat Job Element or Action Plan Step number from reverse side.

³Evaluate the probability of each possible cause occurring as H-High, L-Low, or U-Unknown. If the probability is Low, include a rationale statement and designate the risk as A-Acceptable. (Note: The consequence of some problems may be extremely severe, requiring preventative action, even though probability is low.) If the probability is high or unknown, designate the risk as U-Unacceptable and include preventative actions in the next column.

⁴Risk is the combination of consequence and probability and should be designated as A-Acceptable or U-Unacceptable, in accordance with the above instructions.

⁵For each preventative action, include responsibility designation and person and schedule for completion.

QUALITY ASSURANCE ASSESSMENT AND PLAN

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DOCUMENT NUMBER			
ISSUE/REV. (NO.) DATE			

JOB ELEMENTS OR ACTION PLAN STEPS		POTENTIAL PROBLEMS OR FAILURE MODES	EFFECT(S)	CONSEQUENCE ¹
NO.	DESCRIPTION			
2. (Cont)	Gamma Shield, Biological Shield and Ballast	2.2 Shape (dimensional error)	2.2 Failure to fit up during assembly.	S
		2.3 Failure to perform in service	2.3 Loss of intended use	S

¹Evaluate the consequence of each potential problem in terms of its effect on monetary loss; programmatic loss and delay; and health, safety, and environmental injuries and results. Designate each potential problem as I-Insignificant or S-Significant. If the consequence is insignificant, include a rationale statement and designate the result as A-Acceptable.

**QUALITY ASSURANCE ASSESSMENT AND PLAN
(CONTINUED)**

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DOCUMENT NUMBER			
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NO. ²	POSSIBLE CAUSES	PROBABILITY ³	RISK ⁴	PREVENTATIVE ACTION ⁵ OR RATIONALE STATEMENT (ACTION ITEMS)	RESPONSIBILITY (Organization and Person)	SCHEDULE
2. Cont)	2.2a Design Error	U	U	2.2a Perform design review and dimensional checking.	XMD C.W. Collins	
	2.2b Fabrication Error			2.2b Perform dimensional inspection during fabrication and assembly.	QA&I P.B. Burn	
	2.3 Excessive Nuclear Heating	U	U	2.3a Perform nuclear heating calculations and have reviewed and approved. 2.3b Perform nuclear heating calculations and have reviewed and approved. 2.3c Perform heat transfer calculations and have reviewed and approved.	SSD Coltman OPNS Hurt XMD C.W. Collins	

²Repeat Job Element or Action Plan Step number from reverse side.

³Evaluate the probability of each possible cause occurring as H-High, L-Low, or U-Unknown. If the probability is Low, include a rationale statement and designate the risk as A-Acceptable. (Note: The consequence of some problems may be extremely severe, requiring preventative action, even though probability is low.) If the probability is high or unknown, designate the risk as U-Unacceptable and include preventative actions in the next column.

⁴Risk is the combination of consequence and probability and should be designated as A-Acceptable or U-Unacceptable, in accordance with the above instructions.

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DOCUMENT NUMBER			
ISSUE/REV. (NO.) DATE			

JOB ELEMENTS OR ACTION PLAN STEPS		POTENTIAL PROBLEMS OR FAILURE MODES	EFFECT(S)	CONSEQUENCE ¹
NO.	DESCRIPTION			
3.0	Cryostat	3.1 Improper materials	3.1 Failure to perform as required or rapid failure in service.	S
		3.2 Improper shape configuration	3.2 Failure to perform as required	S

¹Evaluate the consequence of each potential problem in terms of its effect on monetary loss; programmatic loss and delay; and health, safety, and environmental injuries and insults. Designate each potential problem as I-Insignificant or S-Significant. If the consequence is insignificant, include a rationale statement and designate the result as A-Acceptable.

**QUALITY ASSURANCE ASSESSMENT AND PLAN
(CONTINUED)**

PAGE	7	of	15
DOCUMENT NUMBER			
ISSUE/REV. (NO.) DATE	Rev. 1, August 30, 1984		

NO. ²	POSSIBLE CAUSES	PROBABILITY ³	RISK ⁴	PREVENTATIVE ACTION ⁵ OR RATIONALE STATEMENT	RESPONSIBILITY (Organization and Person)	SCHEDULE
3. (Cont)	3.1a Improper Materials Selected During Design	U	U	3.1a(1) Select cryostat material after careful review with and approval by persons knowledgeable in design, reactor experiments and reactor operations. 3.1a(2) Perform cryostat material review for input to XDE. 3.1a(3) Perform cryostat material review for input to XDE.	XMD C. W. Collins SSD Coltman OPNS Hurt	Fab.
	3.1b Improper Materials Substituted During Fabrication	U	U	3.1b(1) Assure no cryostat material substituted without proper approvals. 3.1b(2) Controlled Manufacturing Plan to address (1) above.	QA&I P. B. Burn P&E S. G. Cortelyou	
	3.2 Deficient Criteria and/or Design Re: Shape and Materials	U	U	3.2a(1) Review and approve cryostat design, verifying that design meets the criteria. 3.2b(2) Confirm cryostat configura- tion and materials by Heat Transfer Calculations. 3.2b(3) Perform stress analysis to confirm configuration and ma- terials.	SSD Coltman SSD Coltman	

²Repeat Job Element or Action Plan Step number from reverse side.

³Evaluate the probability of each possible cause occurring as H-High, L-Low, or U-Unknown. If the probability is Low, include a rationale statement and designate the risk as A-Acceptable. (Note: The consequence of some problems may be extremely severe, requiring preventative action, even though probability is low.) If the probability is high or unknown, designate the risk as U-Unacceptable and include preventative actions in the next column.

⁴Risk is the combination of consequence and probability and should be designated as A-Acceptable or U-Unacceptable, in accordance with the above instructions.

⁵For each preventative action, include responsibility (organization and person) and schedule (month and year).

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JOB ELEMENTS OR ACTION PLAN STEPS		POTENTIAL PROBLEMS OR FAILURE MODES	EFFECT(S)	CONSEQUENCE
NO.	DESCRIPTION			
3. Cont	Cryostat	3.3 Joint failure	3.3 Failure to perform as required	S

Evaluate the consequence of each potential problem in terms of its effect on monetary loss; programmatic loss and delay; and health, safety, and environmental impacts. Designate each potential problem as I-Insignificant or S-Significant. If the consequence is insignificant, include a rationale statement and designate the risk as A-Acceptable.

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NO. ²	POSSIBLE CAUSES	PROBABILITY ³	RISK ⁴	PREVENTATIVE ACTION ⁵ OR RATIONALE STATEMENT	RESPONSIBILITY (Organization and Person)	SCHEDULE
3. (Cont)	3.3a Improper Weld or Braze Detail Specified	U	U	3.3a(1) Review and approve cryostat weld and brazing specification and drawing requirement. 3.3a(2) Review and approve cryostat welding and brazing specification and drawing requirement. 3.3a(3) Review and approve cryostat welding and brazing specification and drawing requirement.	XMD C. W. Collins SSD Coltman QA&I P. B. Burn	
	3.3b Improper Weld or Braze During Fabrication	U	U	3.3b(1) Specify cryostat weld and braze inspection/requirements in design documents. 3.3b(2) Inspect cryostat fabrication and assembly in accordance with drawing and specification requirements. 3.3b(3) Controlled Manufacturing Plan to address (1) and (2) above.	XMD D. L. Haynes QA&I P. B. Burn P&E S. G. Cortelyou	Fab.

²Repeat Job Element or Action Plan Step number from reverse side.

³Evaluate the probability of each possible cause occurring as H-High, L-Low, or U-Unknown. If the probability is Low, include a rationale statement and designate the risk as A-Acceptable. (Note: The consequence of some problems may be extremely severe, requiring preventative action, even though probability is low.) If the probability is high or unknown, designate the risk as U-Unacceptable and include preventative actions in the next column.

⁴Risk is the combination of consequence and probability and should be designated as A-Acceptable or U-Unacceptable, in accordance with the above instructions.

⁵For each preventative action, include responsibility (organization and person) and schedule (month and year).

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JOB ELEMENTS OR ACTION PLAN STEPS		POTENTIAL PROBLEMS OR FAILURE MODES	EFFECT(S)	CONSEQUENCE
NO.	DESCRIPTION			
3. Cont	Cryostat	3.4 Pressure boundary integrity not adequate.	3.4a Failure to perform as required 3.4b Explosion	S S

Evaluate the consequence of each potential problem in terms of its effect on monetary loss, programmatic loss and delay; and health, safety, and environmental impacts and quality. Designate each potential problem as I-Insignificant or S-Significant. If the consequence is insignificant, include a rationale statement and designate the risk as A-Acceptable.

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NO. ²	POSSIBLE CAUSES	PROBABILITY ³	RISK ⁴	PREVENTATIVE ACTION ⁵ OR RATIONALE STATEMENT	RESPONSIBILITY (Organization and Person)	SCHEDULE
3. (Cont)	3.4a Improper Design, Materials, or Fabrication	U	U	3.4a(1) Specify pressure, leak, and vacuum testing on design documents 3.4a(2) Review and approve design and testing for cryostat pressure boundary integrity. 3.4a(3) Review and approve design and testing for cryostat pressure boundary integrity. 3.4a(4) Perform pressure, leak and vacuum testing. 3.4a(5) Controlled Manufacturing Plan to address (1) and (4) above.	XMD D. L. Haynes XMD C. W. Collins SSD Coltman QA&I P. B. Burn P&E S. G. Cortelyou	Fab.
	3.4b(1) Leak of ambient air into Liquid Helium Cooling System	U	U	3.4b(1a) Same as 3.4a(1), 3.4a(2), 3.4a(3), 3.4a(4), and 3.4a(5).		
		U	U			

²Repeat Job Element or Action Plan Step number from reverse side.

³Evaluate the probability of each possible cause occurring as H-High, L-Low, or U-Unknown. If the probability is Low, include a rationale statement and designate the risk as A-Acceptable. (Note: The consequence of some problems may be extremely severe, requiring preventative action, even though probability is low.) If the probability is high or unknown, designate the risk as U-Unacceptable and include preventative actions in the next column.

⁴Risk is the combination of consequence and probability and should be designated as A-Acceptable or U-Unacceptable, in accordance with the above instructions.

⁵For each preventative action, include responsibility (organization and person) and schedule (month and year).

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JOB ELEMENTS OR ACTION PLAN STEPS		POTENTIAL PROBLEMS OR FAILURE MODES	EFFECT(S)	CONSEQUENCE
NO.	DESCRIPTION			
3. Cont)	Cryostat	3.5 Contaminated or unclean surfaces	3.5 Failure to perform in service, radioactive contamination	S

Evaluate the consequence of each potential problem in terms of its effect on monetary loss; programmatic loss and delay; and health, safety, and environmental impacts and insults. Designate each potential problem as I-Insignificant or S-Significant. If the consequence is insignificant, include a rationale statement and designate the risk as A-Acceptable

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NO. ²	POSSIBLE CAUSES	PROBABILITY ³	RISK ⁴	PREVENTATIVE ACTION ⁵ OR RATIONALE STATEMENT	RESPONSIBILITY (Organization and Person)	SCHEDULE
3. (Cont.)	3.5 Improper or Incomplete Cleaning After Fabrication, Assembly and Installation	U	U	3.5a(1) Specify adequate cleaning procedures in the design documentation for cleaning contaminated or unclean surfaces of the cryostat. 3.5a(2) Review and approve cleaning procedures developed for cryostat. 3.5a(3) Review and approve cleaning procedures developed for cryostat. 3.5a(4) Witness inspect actual cleaning operations to assure proper cleaning. 3.5a(5) Witness inspect actual cleaning operations to assure proper cleaning. 3.5a(6) Controlled Manufacturing Plan to address (1), (4), and (5) above.	XMD D. L. Haynes SSD Coltman QA&I P. B. Burn QA&I P. B. Burn SSD Coltman P&E S. G. Cortelyou	Fab.

²Repeat Job Element or Action Plan Step number from reverse side.

³Evaluate the probability of each possible cause occurring as H-High, L-Low, or U-Unknown. If the probability is Low, include a rationale statement and designate the risk as A-Acceptable. (Note: The consequence of some problems may be extremely severe, requiring preventative action, even though probability is low.) If the probability is high or unknown, designate the risk as U-Unacceptable and include preventative actions in the next column.

⁴Risk is the combination of consequence and probability and should be designated as A-Acceptable or U-Unacceptable, in accordance with the above instructions.

⁵For each preventative action, include responsibility (organization and person) and schedule (month and year).

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JOB ELEMENTS OR ACTION PLAN STEPS		POTENTIAL PROBLEMS OR FAILURE MODES	EFFECT(S)	CONSEQUENCE ¹
NO.	DESCRIPTION			
4.0	Instrumentation	4.0 Improper sensor selection or installation	4.0 Failure to obtain required data and control information.	S

¹Evaluate the consequence of each potential problem in terms of its effect on monetary loss; programmatic loss and delay; and health, safety, and environmental impacts and results. Designate each potential problem as I-Insignificant or S-Significant. If the consequence is insignificant, include a rationale statement and designate the risk as A-Acceptable.

**QUALITY ASSURANCE ASSESSMENT AND PLAN
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NO. ²	POSSIBLE CAUSES	PROBABILITY ³	RISK ⁴	PREVENTATIVE ACTION ⁵ OR RATIONALE STATEMENT (ACTION ITEMS)	RESPONSIBILITY (Organization and Person)	SCHEDULE
4. (Cont)	Sensors Mounted Rigid to Leads Causing Stress, Improper Heat Sinking	U	U	4.1 Review and approve instrument selection details with particular concern for sensor application in cryostat.	XIE Fletcher	DES
				4.2 Review and approve instrument selection details with particular concern for sensor application in cryostat.	SSD Coltman	DES
				4.3 Inspect and approve cryostat sensor instrumentation installation.	XIE Fletcher	FAB
				4.4 Inspect and approve cryostat sensor instrumentation installation.	SSD Coltman	FAB

² Repeat Job Element or Action Plan Step number from reverse side.

³ Evaluate the probability of each possible cause occurring as H-High, L-Low, or U-Unknown. If the probability is Low, include a rationale statement and designate the risk as A-Acceptable. (Note: The consequence of some problems may be extremely severe, requiring preventative action, even though probability is low.) If the probability is high or unknown, designate the risk as U-Unacceptable and include preventative actions in the next column.

⁴ Risk is the combination of consequence and probability, and should be designated as A-Acceptable or U-Unacceptable, in accordance with the above instructions.

LAYOUT PLAN FOR NLTNIF AT ORNL'S BULK SHIELDING REACTOR

FIGURE 1

LEGEND

Figure 2 SSD-NLTNIF-6
 Figure 3 SSD-NLTNIF-3
 Figure 4 SSD-NLTNIF-7
 Figure 5 SSD-NLTNIF-8

= normally open
= normally closed

BV = Bypass Valve	LNRW = Liquid Helium Return Warm
CAP = (Experiment) Capsule	LNS = Liquid Nitrogen System
CM = Containment Monitor	LNH = Liquid Nitrogen Heat Exchanger
CP = Cryopipe	LP = Low Pressure (Branch)
CRY = Cryostat	MHS = Manifold Helium Supply
CRYB = Cryostat Bleed	MVP = Manifold Vacuum Pump
CVJ = Cryostat Vacuum Jacket	NXJ = Nitrogen (Heat) Exchanger Jacket
CVS = Cell Ventilation System	OCB = Oilless Compressor Bleed
DRF = Diverted Refrigerator Flow	PC = Precool Circuit
EPV = Electropneumatic Valve	PCV = Pressure Control Valve
ET = Expansion Tank	PE = Pressure Element
FE = Flow Element	PI = Pressure Indicator
FI = Flow Indicator	PSV = Pressure Safety Valve
GHS = Gaseous Helium Supply	SA = Subatmospheric (Branch)
GN = Gaseous Nitrogen	SC = Secondary Containment
GNX = Gaseous Nitrogen Exchanger	SCB = Secondary Containment Bleed
HP = High Pressure (Branch)	SCP = Secondary Containment Pump
HS = Hand Switch	SCR = Secondary Containment Relief
HV = Hand Valve	SCS = Secondary Containment Supply
IVJ = Interface Vacuum Jacket	SH = Refrigerated Shield
JB = Junction Box	SV = Solenoid Valve
JT = Joule Thomson	TE = Temperature Element
JTIN = Joule Thomson (Valve) Inlet	TOA = Trace O ₂ Analyser
JTV = Joule Thomson Valve	TPX = Three Pass Heat Exchanger
JVS = Jacket Vacuum (Pumping) System	VP = Vacuum Pump
LHRC = Liquid Helium Return Cold	VPB = Vacuum Pump Bleed
LHX = Liquid Helium Heat Exchanger

FIGURE 2. He REFRIGERATION SYSTEM

FIGURE 3. CRYOSTAT MANAGEMENT SYSTEM

He JACKET (NXJ)
FOR THE LNX

LIQUID NITROGEN (LN) CIRCUIT

FIGURE 4. LN SYSTEMS

INTERFACE & CRYOSTAT VACUUM SYSTEMS

FIGURE 5. INSULATING VACUUM SYSTEM

FIGURE 6. THE IRRADIATION CRYOSTAT, THE GAMMA-RAY SHIELD AND THE BSR CORE

BSR CORE CONFIGURATION
FOR USE WITH
NLTNIF

FIGURE 7

FIGURE 8. CRYOSTAT COMPONENTS

REDUCED IRRADIATION IS LIMITED TO 50 HOURS
 FREE AREA AROUND OR THROUGH THE ASSEMBLY IS NEEDED FOR OPERATION OF THE CONVECTION COOLING LOOP.

A BIOLOGICAL SHIELD IS REQUIRED (SEE ABOVE)

NLTNIF WILL PROVIDE: PLUG FLANGE FOR ASSEMBLY SUPPORT
 DEMOUNTABLE BIOLOGICAL SHIELD
 SIMPLE GUIDE TUBE FOR IN-OUT SAMPLE IRRADIATIONS
 INSULATED FURNACE FOR POSTIRRADIATION ANNEALING
 4.2 K SPECIMEN TRANSFER FROM IRRADIATION CRYOSTAT
 12 T MAGNET FOR USE IN IRRADIATION CRYOSTAT

USER WILL PROVIDE: ANY TEST ASSEMBLY NOT IN THE NLTNIF COLLECTION
 ANY SPECIALIZED BIOLOGICAL SHIELDS

CONSIDERATIONS FOR EXPERIMENT ASSEMBLY DESIGN

USED TO SUPPORT AND MONITOR SAMPLES IN THE IRRADIATION ZONE.
 IT MAY BE INTEGRATED OR NESTED WITH A TEST ASSEMBLY.

UPPER SECTION (4 m LONG)

A BIOLOGICAL SHIELD IS REQUIRED (SEE ABOVE).
 DESIGN AND MATERIALS SELECTION IS BASED ON MINIMIZING HEAT CONDUCTION INTO THE COLD ZONE.
 INDUCED RADIOACTIVITY IS EXPECTED TO BE NEGLIGIBLE.

LOWER SECTION (11.5 m LONG)

FREE AREA THROUGH THE SAMPLE ASSEMBLY IS VITAL FOR SAMPLE COOLING AND OPERATION OF THE CONVECTION COOLING LOOP.
 SIGNIFICANT RADIOACTIVITY IS EXPECTED. REUSE MAY BE POSSIBLE AFTER A LONG STORAGE PERIOD.
 MINIMAL MASS AND PROUENT MATERIAL SELECTION ARE ESSENTIAL TO MINIMIZE NUCLEAR HEATING, NEUTRON ACTIVATION, AND POSSIBLE STORED ENERGY.

NLTNIF WILL PROVIDE: WIRE, BASKETS, AND CAPSULES FOR IN-OUT IRRADIATIONS.
 UPPER SECTIONS FROM THE NLTNIF COLLECTION
 TOP FLANGE AND PULL ROD SEAL ASSEMBLIES
 "STANDARD DESIGN" BIOLOGICAL SHIELDS
 REMOVAL AND STORAGE OF SAMPLES AT 4.2 K OR 300 K.
USER WILL PROVIDE: ANY SPECIAL LOWER SECTION OR WHOLE EXPERIMENT ASSEMBLY NOT IN THE NLTNIF COLLECTION

IRRADIATION CHAMBER - MAINTAINED AT 4 TO 5 K
 BY UPWARD FLOW OF LH_2 CONDENSED ON HEAT EXCHANGER
 ABOVE AND DELIVERED DOWN THROUGH SUPPLY TUBE
 IRRADIATION AT HIGHER TEMPERATURES IS POSSIBLE
 WITH GHe - MAXIMUM ALLOWABLE DIAMETER = 37.47 mm (1.475 in.)

NEUTRON FLUX PEAK IS ESTIMATED TO BE 100 mm
 ABOVE THE BOTTOM. EXACT LOCATION TO BE
 DETERMINED BY LATER PERFORMANCE TESTING.

BIOLOGICAL SHIELD - THIS LAMINATED DEVICE CAN BE DESIGNED TO ACCOMMODATE ALMOST ANY TEST ASSEMBLY. THE REQUIRED THICKNESS OF THE COMPONENT MATERIALS WILL BE DETERMINED BY LATER PERFORMANCE TESTING (TOTAL = 250 mm (10 in.) MAX.)

AMBIENT TEMPERATURE ABOVE - COLD ZONE BELOW

CONSIDERATIONS FOR TEST ASSEMBLY DESIGN

USED FOR INTERMITTANT TESTING DURING IRRADIATION AND FOR POST IRRADIATION TESTING. SAMPLES ARE MOVED FROM THE IRRADIATION ZONE INTO A TEST ASSEMBLY BY A SEALED PULL ROD

DESIGN AND MATERIALS SELECTION IS BASED ON MINIMIZING HEAT CONDUCTION INTO THE COLD ZONE

MASS IN THE COLD ZONE SHOULD BE MINIMIZED TO REDUCE COOLDOWN TIME.

INDUCED RADIOACTIVITY IS EXPECTED TO BE NEGLIGIBLE.

FREE AREA AROUND OR THROUGH THE ASSEMBLY IS NEEDED FOR OPERATION OF THE CONVECTION COOLING LOOP.

A BIOLOGICAL SHIELD IS REQUIRED (SEE ABOVE)

NLTNI'S WILL PROVIDE: PLUG FLANGE FOR ASSEMBLY SUPPORT
DEMOUNTABLE BIOLOGICAL SHIELD
SIMPLE GUIDE TUBE FOR IN-OUT SAMPLE IRRADIATIONS
INSULATED FURNACE FOR POSTIRRADIATION ANNEALING
4.2 K SPECIMEN TRANSFER FROM IRRADIATION CRYOSTAT
12 T MAGNET FOR USE IN IRRADIATION CRYOSTAT

DO NOT PLACE ASSEMBLY IN THE NLTNI COLLECTION

SCHEMATIC LAYOUT OF THE NLNIF CRYOSTAT FOR DESIGN AND DIMENSIONING OF TEST AND EXPERIMENT ASSEMBLIES

(THE OUTER REFRIGERATED SHIELD AND VACUUM JACKET ARE NOT SHOWN)

FIGURE 9

FIGURE 10. THE RELATIONSHIP BETWEEN AN EXPERIMENT ASSEMBLY, A TEST ASSEMBLY AND THE CRYOSTAT.

FIG. 11 Performance test results showing steady-state temperatures (K) at simulated full reactor power versus experiment mass (grams). The LHe refrigeration system was operated at full capacity. Nuclear heat in the chamber and supply tube walls and in the LHe inventory in the irradiation zone is taken as 40 W. Operation at 110% of full reactor power with the maximum allowed 100 gram experiment mass raises the irradiation temperature from 4.55 to 5.20 K. Operation with masses greater than 100 grams will be considered onlv at reduced reactor power so as to produce no more than 74 W total nuclear heat generation.

FIG. 12 Response to the simultaneous loss of cooling in the LN and LHe heat exchangers (LNX and LHX) under the maximum nuclear heat load.

FIGURE 13. SIMULATED LOSS OF VACUUM TEST RESULTS

SCHEMATIC DIAGRAM OF THE NLNIF CONTAINMENT SYSTEM

PHOTOGRAPH #1