NUCLEAR MATERIALS and PROPULSION OPERATION

FLIGHT PROPULSION LABORATORY DEPARTMENT

FORMERLY

AIRCRAFT NUCLEAR PROPULSION DEPARTMENT

APEX-716

Engineering Capabilities of In-Pile Irradiation Facilities used by GE-ANPD

R.J. Harry

R.C. Fries

GENERAL ELECTRIC

DISCLAIMER

Printed in USA. Price $2.00. Available from the

Office of Technical Services
U.S. Department of Commerce
Washington 25, D.C.

APEX-716
(Informal)
UC-38 Engineering
and Equipment
TID-4500, (16th Ed.)

ENGINEERING CAPABILITIES OF IN-PILE IRRADIATION FACILITIES USED BY GE-ANPD

R. J. Harry
R. C. Fries

UNITED STATES AIR FORCE CONTRACT NO. AF 33(600)-38062
UNITED STATES ATOMIC ENERGY COMMISSION CONTRACT NO. AT(11-1)-171

GENERAL ELECTRIC
NUCLEAR MATERIALS AND PROPULSION OPERATION
(Formerly Aircraft Nuclear Propulsion Department)
Cincinnati 15, Ohio

Published
October 1961

Standard Distribution

Copies	
1	Aerojet-General Corporation
1	Aerojet-General Nucleonics
1	Alco Products, Inc.
1	Argonne National Laboratory
1	Atomic Energy Commission (English)
1	AEC Scientific Representative, France
3	Atomic Energy Commission, Washington
4	Atomic Energy of Canada Limited
2	Atomics International
3	Babcock and Wilcox Company
2	Battelle Memorial Institute
4	Brookhaven National Laboratory
1	Carnegie Institution
1	Chicago Operations Office
1	Chicago Patent Group
1	Defence Research Member
2	duPont Company, Aiken
1	duPont Company, Wilmington
1	General Atomic Division
2	General Electric Company (ANPD)
2	General Electric Company, Richland
1	General Nuclear Engineering Corporation
1	Glasstone, Samuel
1	Goodyear Atomic Corporation
1	Homestake Mining Company
1	Iowa State University
1	Johns Hopkins University (Wolman)
1	Knolls Atomic Power Laboratory
2	Los Alamos Scientific Laboratory
1	Lovelace Clinic
1	Mallinckrodt Chemical Works
1	Martin Company
1	Moran, Proctor, Mueser & Rutledge
1	Mound Laboratory
1	National Academy of Sciences (Bascom)
1	National Lead Company of Ohio
1	New Brunswick Area Office
1	New York Operations Office
1	Nuclear Development Corporation of America
1	Oak Ridge Institute of Nuclear Studies
1	Patent Branch, Washington
2	Phillips Petroleum Company (NRTS)
1	Pratt and Whitney Aircraft Division
1	Sandia Corporation, Albuquerque
1	Space Technology Laboratories, Inc.
1	Sylvania Electric Products, Inc.
1	Tennessee Valley Authority
2	Union Carbide Nuclear Company (ORGDP)
4	Union Carbide Nuclear Company (ORNL)
2	University of California, Berkeley
2	University of California, Livermore
1	University of Puerto Rico
1	University of Rochester (Hempelmann)
1	Westinghouse Bettis Atomic Power Laboratory
1	Westinghouse Electric Corporation
1	Yale University (Sears)
325	Office of Technical Information Extension
75	Office of Technical Services, Washington

SPECIAL DISTRIBUTION

R. J. Harry - MSVD
B. Blumberg
H. C. Brassfield
V. P. Calkins
C. L. Chase (2)
C. G. Collins
E. S. Collins
E. B. Delson
G. G. Leeth
W. H. Long
H. F. Matthiesen
J. A. McGurty
F. W. Mezger
W. E. Niemuth
P. S. Olson
A. J. Rothstein
M. T. Schoenberger
G. W. Pomeroy
G. Thornton
Reports Library (12)
54303

ABSTRACT

GE-ANPD had exclusive use of irradiation testing facilities in four reactors: the Materials Test Reactor (MTR), the Engineering Test Reactor (ETR), the Low Intensity Test Reactor (LITR), and the Oak Ridge Research Reactor (ORR). This document is a compilation of data concerning the GE-ANPD facilities in these reactors. It lists instrumentation capabilities, dimensions of the in-pile tubes, flow characteristics, control capabilities, and detailed design data.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION I-MATERIALS TEST REACTOR

GENERAL DISCUSSION OF THE MTR

General Description

The Materials Test Reactor is located on the National Reactor Testing Station (NRTS) in southeastern Idaho. The reactor is owned by the U. S. Atomic Energy Commission and Phillips Petroleum Company is the operating agency. Personnel do not reside at the NRTS but commute to and from work on AEC-owned busses. The closest major city is Idaho Falls, population 30,000, which is situated 29 miles from the NRTS boundary.

The MTR is a high-flux, heterogeneous, enriched, water-cooled and moderated reactor. The fuel elements are vertical plate assemblies with each plate consisting of aluminum clad uranium-aluminum alloy. The enriched lattice is surrounded by a water-cooled beryllium reflector which in turn is enclosed by the tank system. Outside of the tank a secondary reflector of graphite, a thermal shield, and a biological shield are also provided. The whole reactor is an approximate cube of about 34 feet to a side.

The reactor has approximately 100 experimental holes for test irradiation to users authorized by the AEC. GE-ANP Department had the use of two experimental holes at the MTR. These holes are the A-19 and the HT-1. See Figures 1-1 and 1-2 for their positions in the reactor.

The A-19 hole is essentially a beryllium reflector block that has been modified to take a 2" schedule 40 closed pipe. Into this closed pipe an inner pipe of $1^5/_8$" O. D. is located to provide an inner and outer flow passage. High-pressure, room-temperature air can be passed down the inner pipe and evacuated through the flow passage between pipes. This hole, usually called the "Top Hole" is discussed further on page 10.

The HT-1 facility is a through-loop of 3.688" diameter that passes from the north face into the tank, through the beryllium reflector pieces at a position below the center line of the active lattice, and exits at the south face in the same manner. This hole is discussed further on page 20.

MTR Operating Policy

The reactor is operated on a three-week cycle. Of the three weeks, approximately four days are required to change experiments and conduct pre-irradiation calibration runs, such as irradiations of flux wires to determine flux distribution in the test hole. At the completion of this preliminary work, the reactor is brought to its full power of 40 MW. The initial period following attainment of full power can be a time of unstable operation due to rapid failure of newly-installed tests. For this reason, ANP usually chose to wait several days after startup before inserting a sample. Therefore, only 250 irradiation hours were normally achieved per cycle.

The operating cycle is arranged so that shutdown is usually conducted on Sunday with the job of removing tests starting Monday morning. The samples to be installed during a cycle are required at the MTR building twelve days prior to reactor shutdown. The twelve-day period is needed by the Phillips Petroleum Co. for inspection by their Operations and Safeguards groups.

When the experiments of the various sponsors have been installed, and this could be a substantial number because of over 100 available test holes, instrumentation and facility connections can be made. If flux calibration wires are to be irradiated for an experiment, the connections are temporary for the flux run; permanent connections are made after withdrawal of wires. If no flux wires are needed, permanent connections are made prior to the flux run. The reactor is then brought to 400 KW, often referred to as N_L, for the flux-calibration run.

At the start of the flux run, the A-19 sample is held at the top of the hole. Insertion consists of lowering the sample into the hole until the seated position is reached. The sample, with flux wires attached, remains here during the period of the flux run. The sample is then raised, the flux calibration

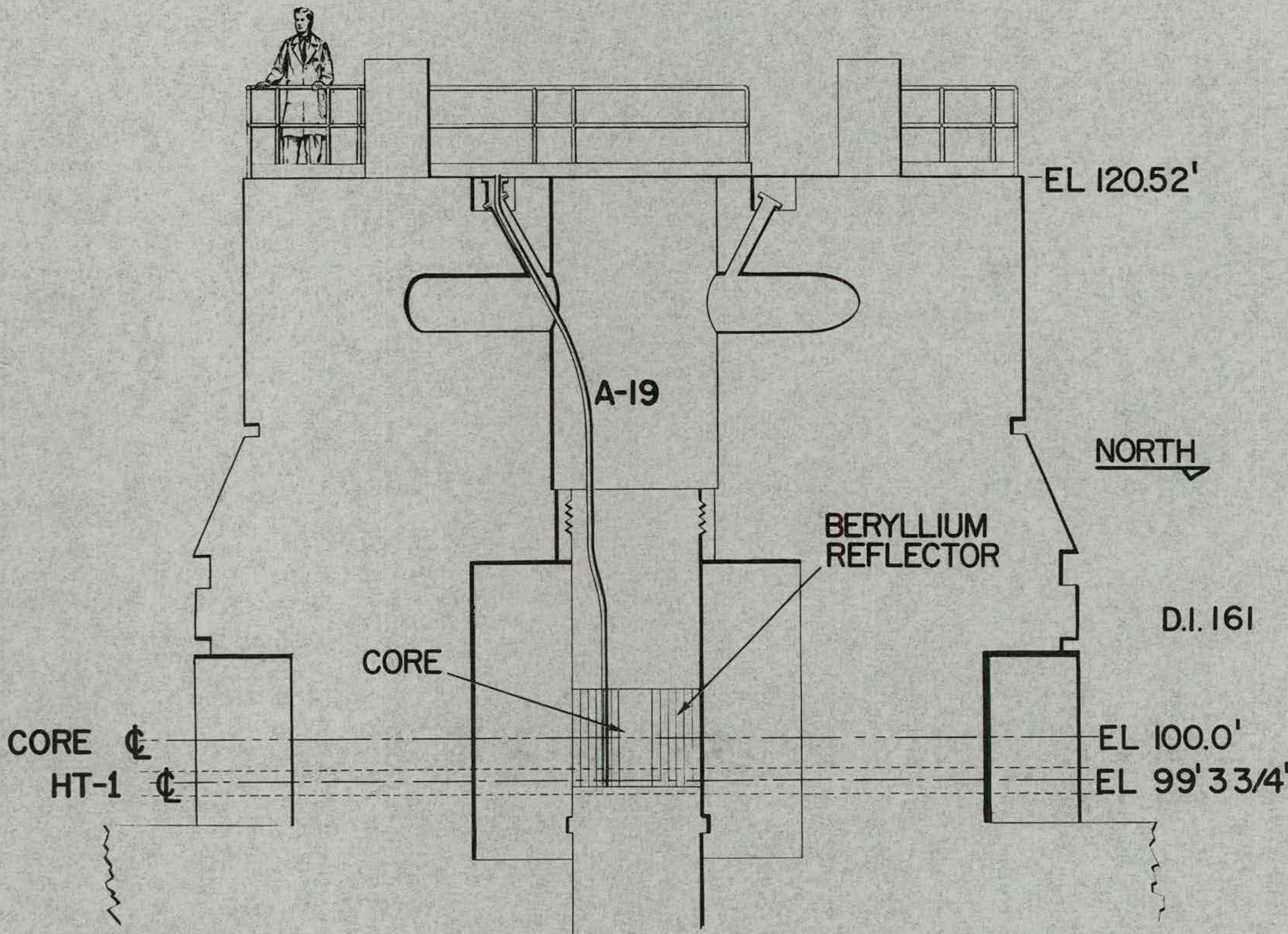


Fig. 1-1 - Vertical Section of MTR Showing A-19 and HT-1 Facilities

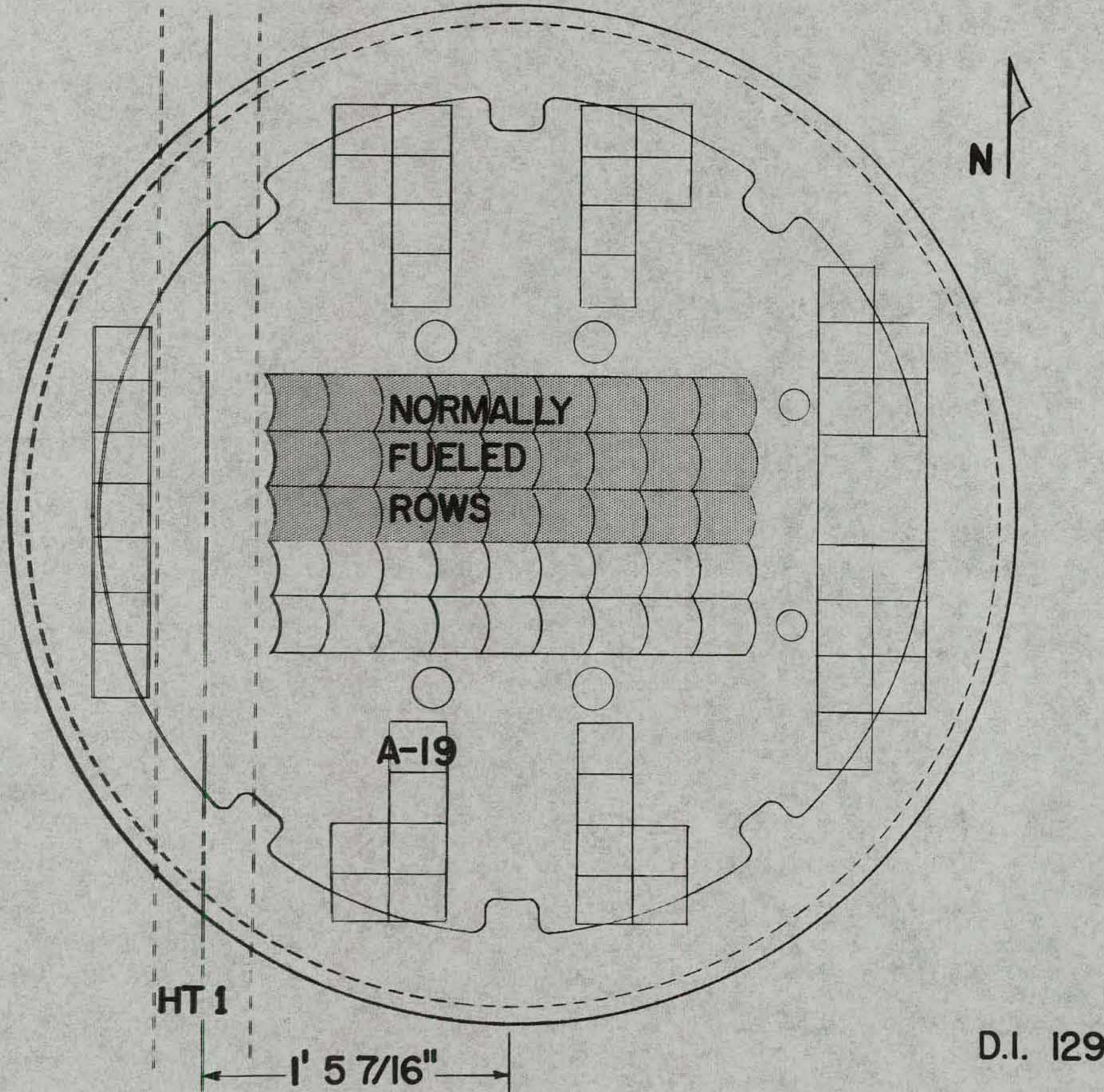


Fig. 1-2 - Plan of Reactor Lattice and Beryllium Reflector wires pulled, and permanent connections made. The same procedure of raising and lowering the sample is used when full-power operation is conducted.

Irradiating the flux wires on the HT-1 sample is significantly different and bears discussion. The HT-1 sample is installed from the north face and rests within the biological shield. Permanent connections are not made prior to the flux run because the withdrawal of flux calibration wires requires access to the shield plug and reactor face. When the reactor is brought to 400 KW, the HT-1 sample is pushed into flux and positioned at a point where flux is maximum. A flux run normally lasts about 30 minutes at which time the reactor is shut down. The sample is pulled back into the shield, flux wires removed, and permanent connections made.

The reactor is then brought to 40 MW for full-power operation. After the reactor has stabilized, the HT-1 sample is moved from the biological shield into flux and brought on-power. The desired test conditions of airflow, temperature, dynamic head, etc., are set by the operator and the test is run for the requested time.

Engineering Description - Top Hole

The A-19 Top Hole loop (see Fig. 1-1) is a compound curve that originates at the top of the reactor and dead-ends in one of the beryllium reflector pieces. Figure 1-1 shows only the outer tube; but to obtain airflow, an inner tube is also used. This concentric-flow configuration is shown in Figure 1-3. Essentially, airflow comes down the inner tube through the sample to the bottom of the loop where it reverses direction. It then flows up the annulus between tubes and exits at the top of the reactor. In this manner, the inner tube, which holds the sample, is cooled on both sides by the flowing air. The outer tube is cooled on its inner surface by the flowing air in the annulus, and on its outside surface by reactor cooling water.

A typical complete sample construction is shown in Figure 1-4. The test assembly is inserted, sample first, into the Top Hole and fed down the curved hole. The assembly can pass the compound curves because the $^3/_8$" diameter aluminum tube bends easily and a short piece of flexible hose is installed at the sample for additional flexibility. The sample is positioned when the shoulder on the sample case seats on the necked-down area at the exit of the inner tube (see Fig. 1-4). In the seated position, the fit between the inner tube necked area and the sample shoulder is practically air-tight and all airflow is driven through the sample. It is not required that the sample be "seated" but if this is not done, not only will the sample be positioned farther from the centerline of the core, but the cooling airflow path will be divided.

It is a design requirement that rings, spiders, or a similar arrangement be provided to guarantee that the test sample not pass the necked-down area.
The type of instrumentation used on a sample is optional and depends on the data desired. In the past, metal-sheathed thermocouples and asbestos-insulated thermocouples have been used successfully.

The problem of a sample located 25 feet from the thermocouple head demands careful fabrication and instrumentation techniques. Figure 1-5 depicts the transition from alumina insulators on a top-hole sample to the asbestos-insulated leads in the drawbar. It is seen that a full-length piece of 0.060" dia. tubing or rod acts as a spine to support the flexible asbestos leads. The critical point occurs where the asbestos leads travel between the ceramic and the rod. Small pieces of varglas socking are eased over the asbestos leads in the transition area and tucked under the larger socking on the rod. In general, asbestos insulation is never allowed to contact steel directly and socking is a convenient means of providing a chafe-resistant coating.

When metal-sheathed thermocouple wire is used, the only precaution necessary is that all leads be anchored securely to the conical transition piece or a similar piece of hardware. This is done because the bowing of the drawbar causes a relative movement of the leads within the drawbar. An expansion loop is provided at the junction box to allow for this movement, but the sample end must be anchored tight to prevent pulling the leads free. It is customary to band the leads with 0.005" stainless steel ribbon at nominal points along their length in the drawbar.

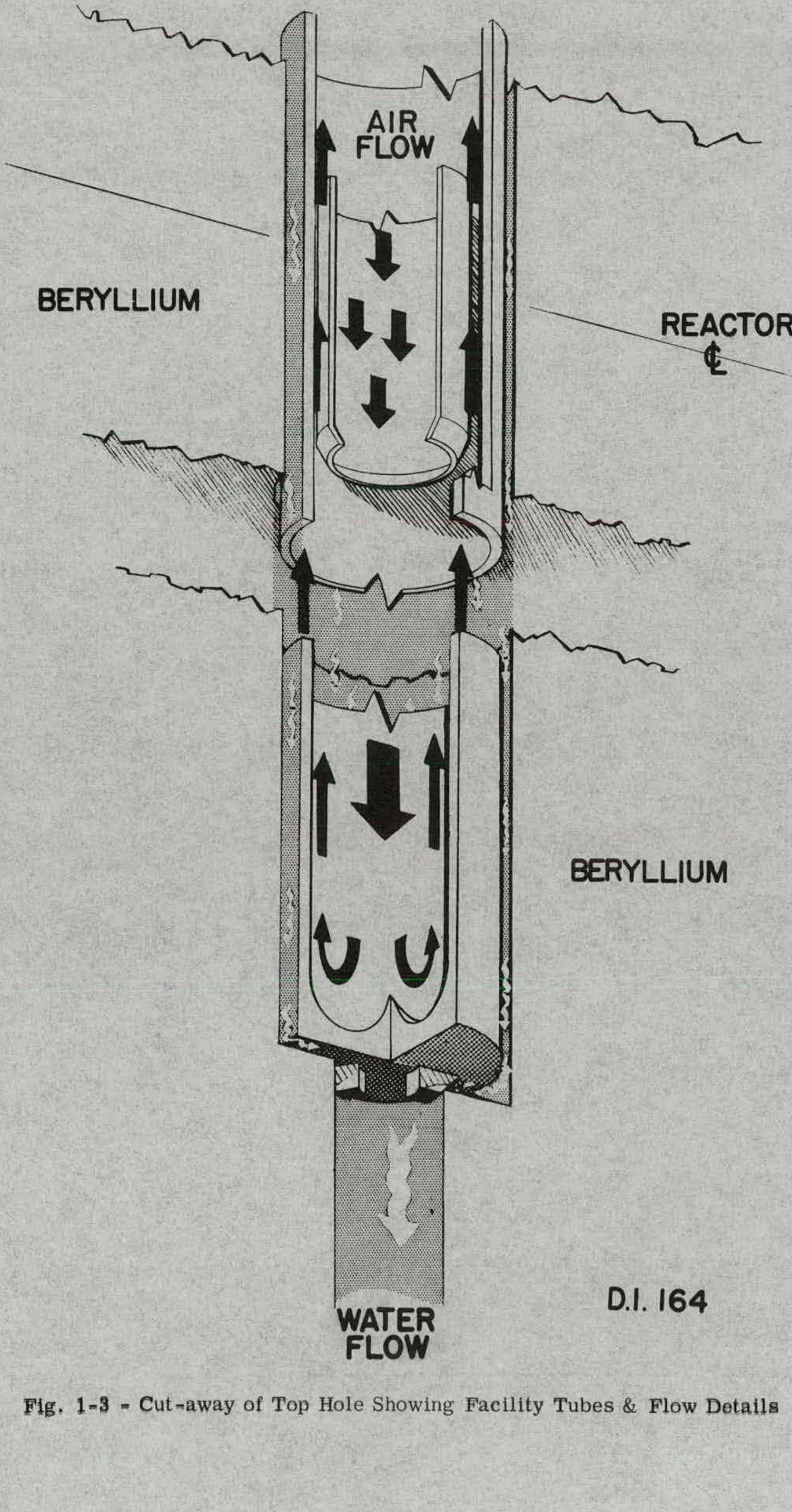


Fig. 1-3 - Cut-away of Top Hole Showing Facility Tubes & Flow Details

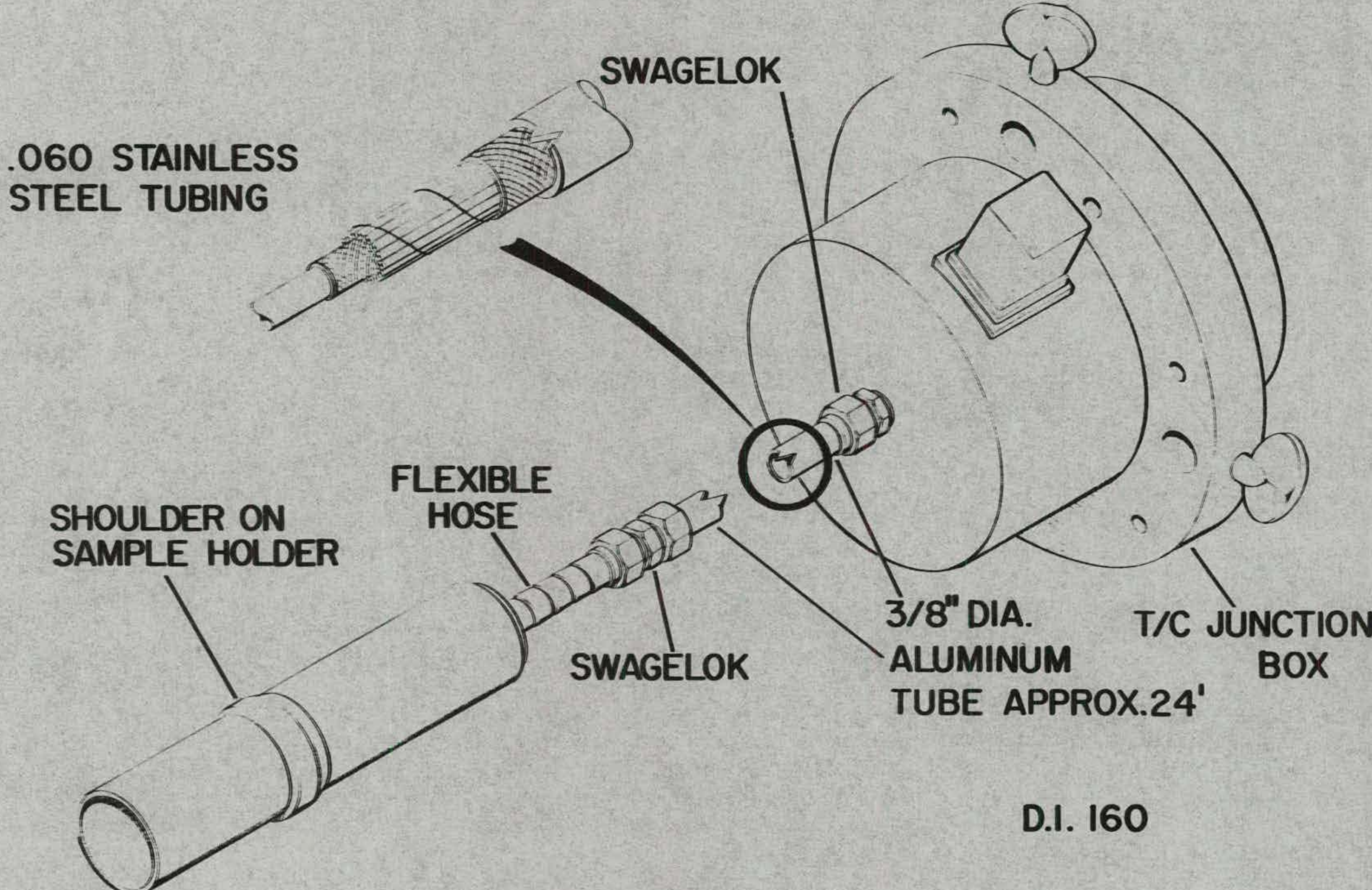


Fig. 1-4 - Typical Top Hole Sample Ready For Installation

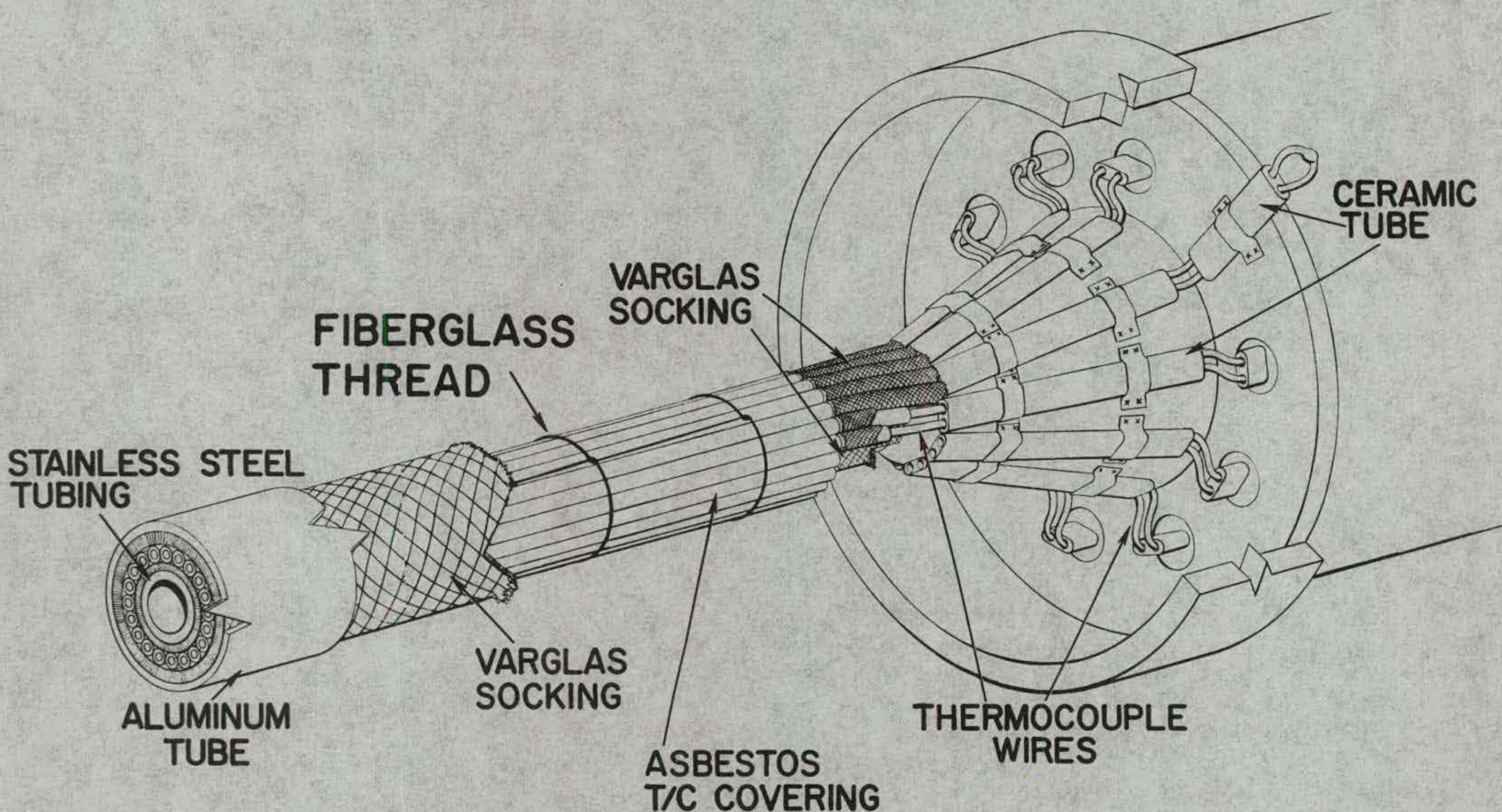


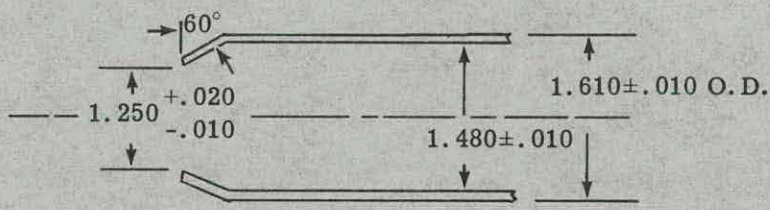
Fig. 1-5 - Typical Sample to Drawbar Transition for Top Hole (D.I. 131)

A completely assembled Top Hole sample is shown in Figure 1-4. It should be noted that the long aluminum drawbar has been cut to fit the illustration, but the dimensions indicate the true length of the assembly.

Engineering Data - A-19 Top Hole

Part 1 - Structural Items

1. Material of Outer Tube = 304 stainless steel
2. Dimensions of Outer Tube = 2" Schedule 40 pipe (2.375" O. D. × 0.154" wall)
3. Material of Inner Tube = 304 stainless steel
4. Dimensions of Inner Tube = $1\frac{5}{8}$" O. D. × 0.065" wall
5. Dimensions of necked area for seating of specimen - See illustration below



Part 2 - Dynamic Parameters

1. Maximum Pressure Obtainable at Sample = 125 psig
2. Approximate Atmospheric Pressure at MTR = 12.2 psi
3. Maximum Flow Obtainable = 400 scfm = 0.512 lb/sec
4. Minimum Preferred Flow = 20 scfm = 0.0256 lb/sec

A lower flow than 20 scfm has been permitted if accompanied by heat transfer data which indicate that no danger to inner or outer facility tube will exist. Heat generation from the sample and gamma-heat generation from the inner-facility tube form the basis for thermodynamic calculations. When desiring a low-flow condition (<20 scfm) it is desirable to have one or more thermocouples installed on the sample hardware adjacent to the necked-down area to confirm analytical calculations.

5. Inlet Air Temperature = No pre-heating of air available at present

   Compressor inlet temperature to facility averages about 90°F

6. Maximum Allowable Temperature of Inner Tube = 1400°F
7. Maximum Allowable Temperature of Outer Tube at Surface Cooled by Water = 200°F

Part 3 - Nuclear Parameters

Only limited neutron flux measurements in the A-19 hole of the MTR are available. Figure 1-6 shows a measurement of neutron flux in A-19 with no experiment present. In general, the test specimen will perturb the magnitude and to some extent the longitudinal distribution shown in Figure 1-6; however, the neutron flux is reasonably constant over approximately 6 inches in the longitudinal distribution. Perturbations caused by the test specimen may yield a circumferential variation in the sample power density with a resultant hot sector facing the reactor core.

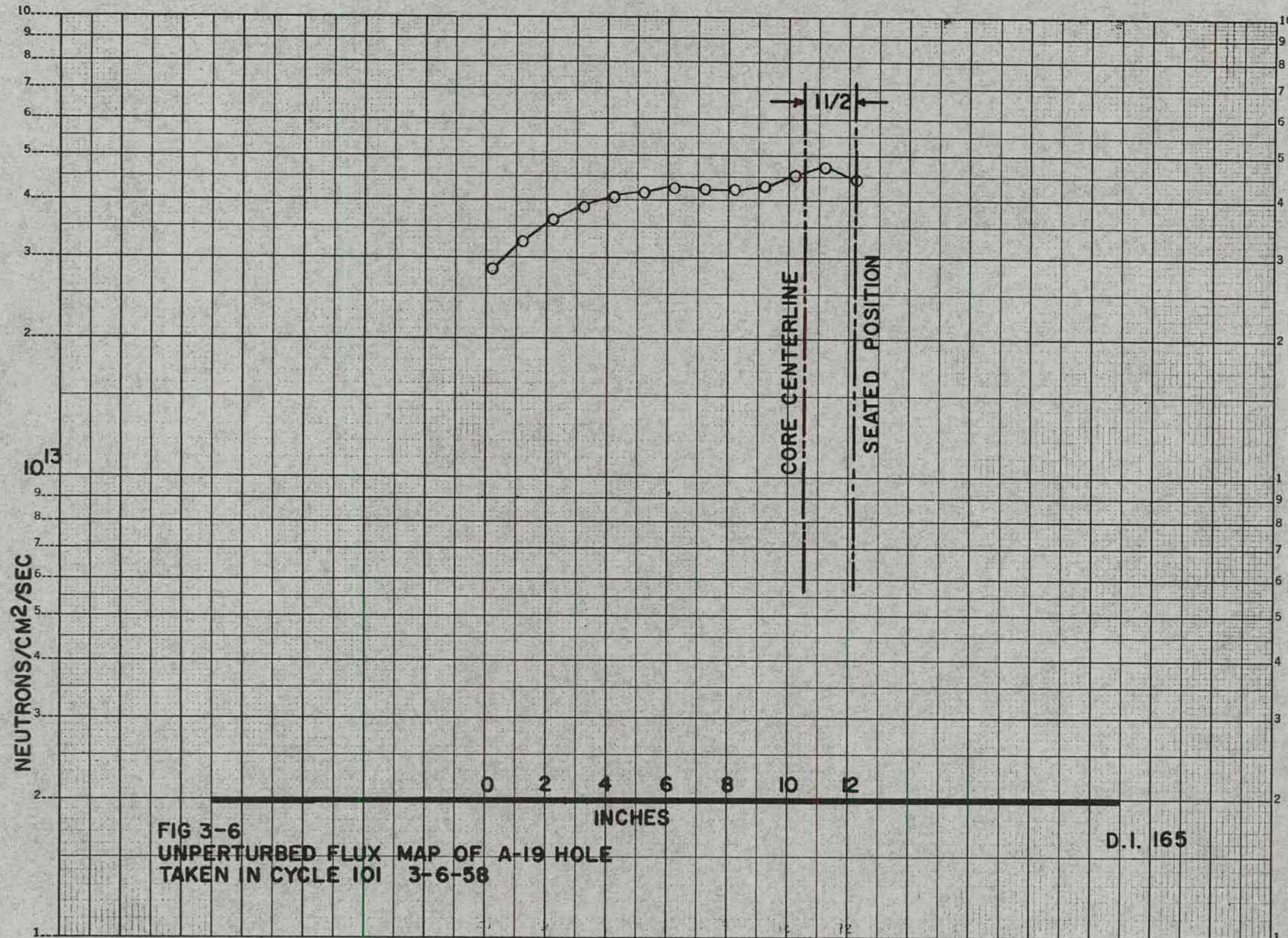
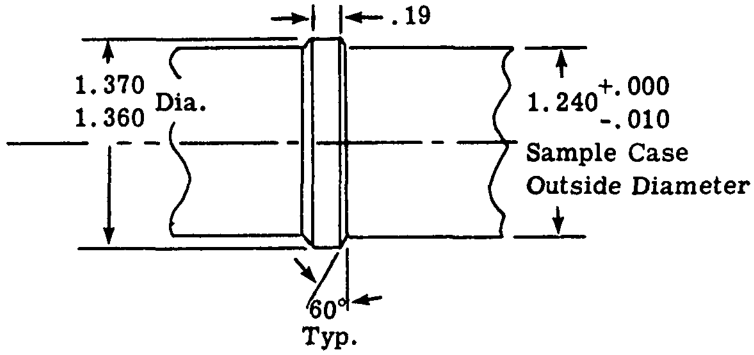


Fig. 1-6 - Unperturbed Flux Map of A-19 Hole Taken in Cycle 101 3-6-58

Part 4 - Sample Parameters

1. Maximum Sample Diameter

The maximum sample diameter is the collar on the sample that matches the necked-down area of the inner tube shown in Part 1. For applications where the sample seats against the necked-area, the following dimensions are recommended:



2. Maximum Sample Length

The present design has a 1¼"-diameter outer shell that is 6" long. However, the 6" dimension was obtained by determining the maximum straight cylinder of 1¼" O. D. that could move around a 4 ft - 0" radius without binding. Obviously, a smaller diameter will permit a longer specimen to pass around the arc. The bend radii can be seen on Phillips Petroleum Drawing MTR-E-3614 obtainable from the Engineered Irradiation Tests Group or through Document Control. The absolute maximum sample length is determined by the cask length and is presently 14½".

3. Maximum Number of Sample Thermocouples

At present the total number of thermocouple outlets at the T/C head (see Fig. 1-4) is ten and both platinum - platinum 10% rhodium and chromel-alumel sensor wires can be used. Samples have never required as many as 10 thermocouples but a T/C head modification could allow more outlets. It is felt that the maximum number of thermocouples will be dictated by the size of the bundle that must pass through a 5/16" I. D. drawbar hole (see Fig. 1-4).

4. Maximum Number of Sample Pressure Tubes

The T/C head can be modified to handle pressure tubes of 0.080 inch O. D. The exact number will depend on the size of the bundle that must pass through a 5/16" I. D. drawbar (see Fig. 1-4).

5. Drawbar Dimensions

The drawbar is a 61ST6 aluminum tube, 3/8" O. D. x 5/16" I. D., approximately 24 feet long. It is connected to the sample by means of a swagelok fitting and is also connected to the T/C head by a swagelok fitting.

6. Flexible Hose

To assure that all samples will seat properly, a 6" length of flexible hose is used as a connecting link between the sample and the downstream swagelok fitting. In this manner, regardless of the drawbar curvature imposed by the compound curves of the tubes, the sample can readily swivel and seat itself. The common dimensions of the flexible hose are 0.480" O. D. × 3/8" I. D. of 0.012-gauge metal. The hose material is 304 stainless steel.

7. Sample Flux Wires

The common flux wires installed on ANP-3 specimens are 0.040" diameter cobalt. There is no stated limit as to the maximum number of wires that can be installed on a sample.

Part 5 - Engineering Data - Facility Instrumentation

The ANP-3 facility instrumentation consists of components to record temperature, pressure, airflow, and fission products. Figure 1-7 shows a simplified flow diagram of the facility. In the figure, the air comes from the Top Hole compressor and enters the inlet filter. The primary purpose of this filter is to clean oil and large particles from the air stream. Leaving this filter, the air passes through the rotometer. Basically this meter controls the sample air flow by means of the flow recorder TRC4A. The hottest thermocouple, called the controlling T. C., is put on TRC-4A to regulate sample airflow. TRC-4A is a single-point, continuous-recorder, 24-hour-chart controller. The air stream leaving the rotometer enters the Top Hole and flows through the facility. The pressure of the air entering the reactor is read on a 0-150 psi pressure gauge. The sample thermocouples are read on two recorders designated as TR-2A and TR-3A. These instruments are 6-point recorders with a range from 0^{o} to 2400^{o}F, set up for Pt/Pt - 10 Rh sensor wires. Twelve thermocouples can be handled here but the T/C head is presently limited to ten outlet pins.

Leaving the facility, the discharge air is monitored by a Jordan radiation monitor. This instrument has a chart speed of 2 inches per hour and is designated as RR1A. This instrument is the primary parameter of sample failure and is allowed to reach a maximum reading of 500 mr/hr before a test is terminated. Beyond the Jordan, the flow dumps into a vertical graphite hole and leaves the reactor.

Engineering Description - HT-1 Hole

The HT-1 facility is a single-pass hole that goes through the reflector from north to south. When viewed from the north looking south, the hole is below and to the right of the core centerline.

This hole, located in the reflector, is a square aluminum tube with approximately $4\frac{3}{4}$" inside dimensions and walls $\frac{1}{2}$" thick. See Figure 1-8. A steel tube, with attached spacers, of 4.25" O. D. with 0.13" walls, is in the hole to form an air-cooled pressure liner. Secondary cooling air is passed between the square hole and circular hole to maintain safe operating conditions. The actual liner that sets the 3.688" test-hole dimension is a second insulated tube that is positioned inside the pressure liner. This inner tube contains the flow, and the cooler outer liner withstands the test pressure. Thus, as shown in Figure 1-8, the HT-1 liner is a double-tube assembly consisting of an inner liner and a pressure liner. The complete assembly is subject to deterioration and has to be replaced about every 16 months.

A trimetric view of the test hole is shown in Figure 1-9. In this view, only the major components are shown. The inlet air enters the hole at the tee piece to the left of the figure. Changing direction, it then flows down the tube, through the sample to the exit tee piece. At this point, the air leaves the facility and passes to the MTR stack.

It will be noticed that the figure includes a downstream probe immediately behind the sample. The use of the probe is optional, but preferred whenever possible. The probe is inserted from the south face and includes a thermocouple-mixer arrangement to act as a mixed-mean gas monitor. The use of the downstream probe has decreased in recent years because most samples provide adequate gas monitoring thermocouples to insure against facility damage.

When it is desired to bring the sample to test, the drawbar is manually pushed toward the south. Thus, the sample slides out of the biological shield and into flux.

The problem of leading instrumentation to and from the sample is again a specialized application. The wrap method for the A-19 hole actually was an adaptation of the successful HT-1 practice. The basic principal of laying the thermocouple wires on a spine to prevent strain loading of the junction is employed. Additional protective measures are evident from Figure 1-10. It is recommended that all MTR HT-1 samples employ this technique when using thermocouples with soft insulation.

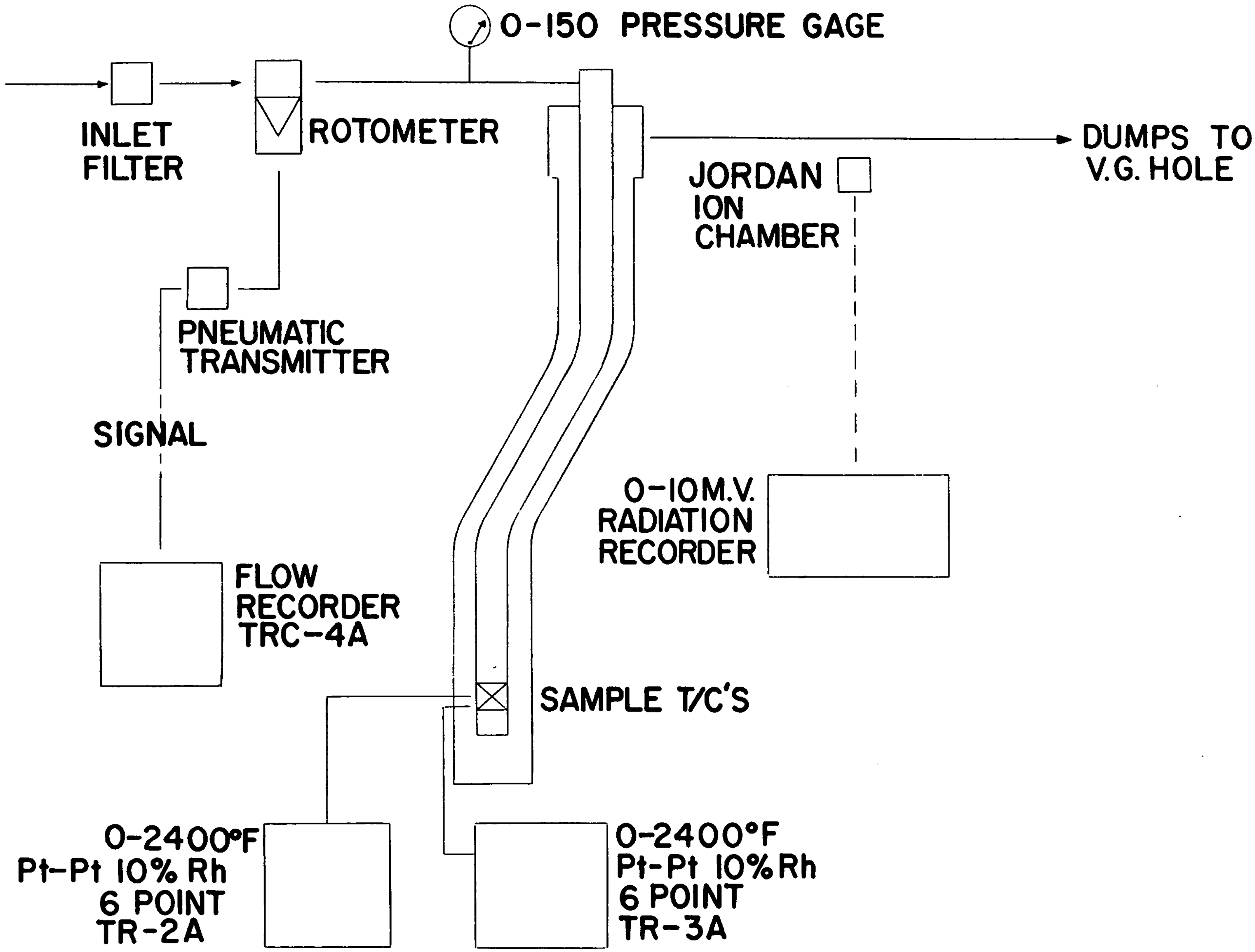
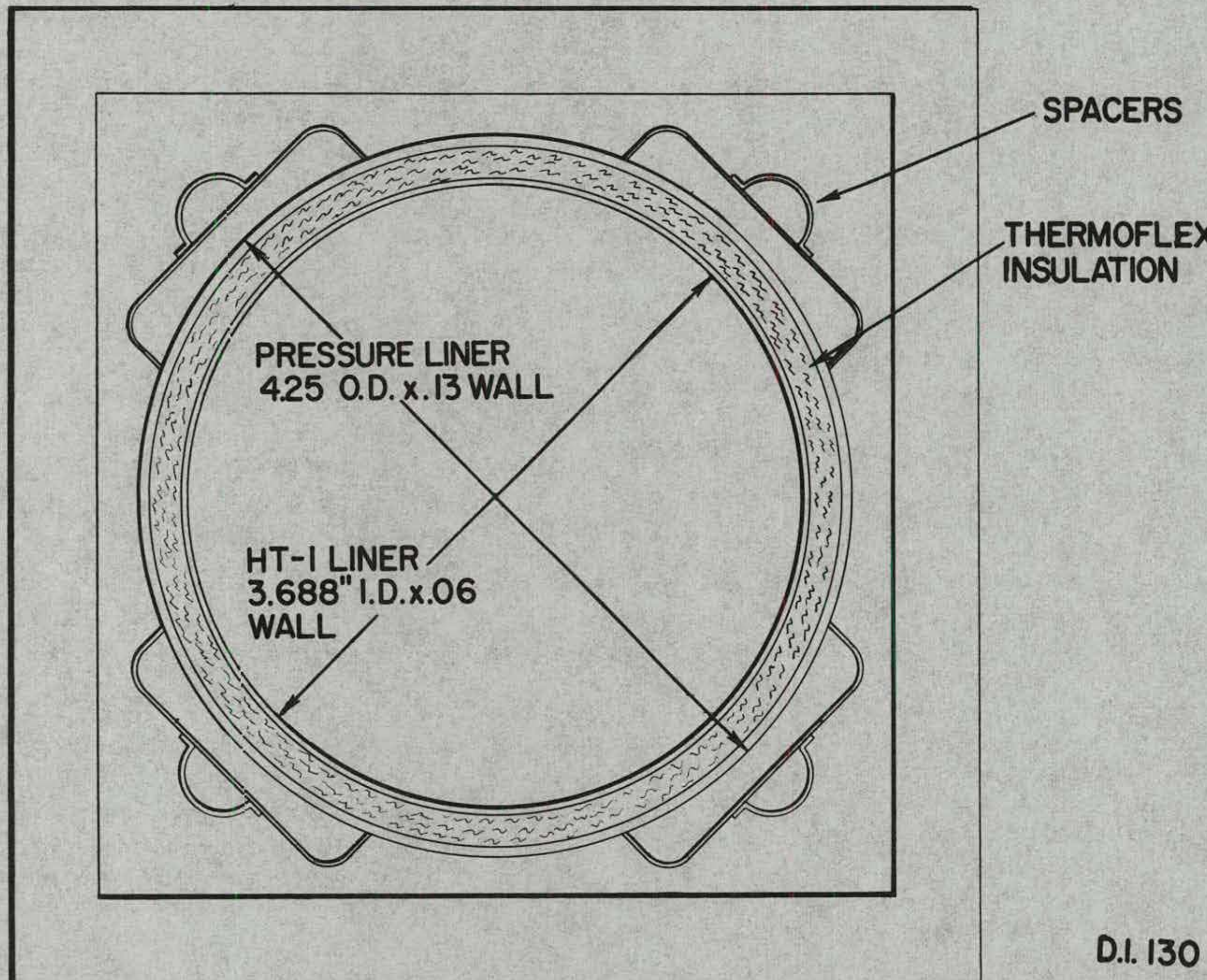
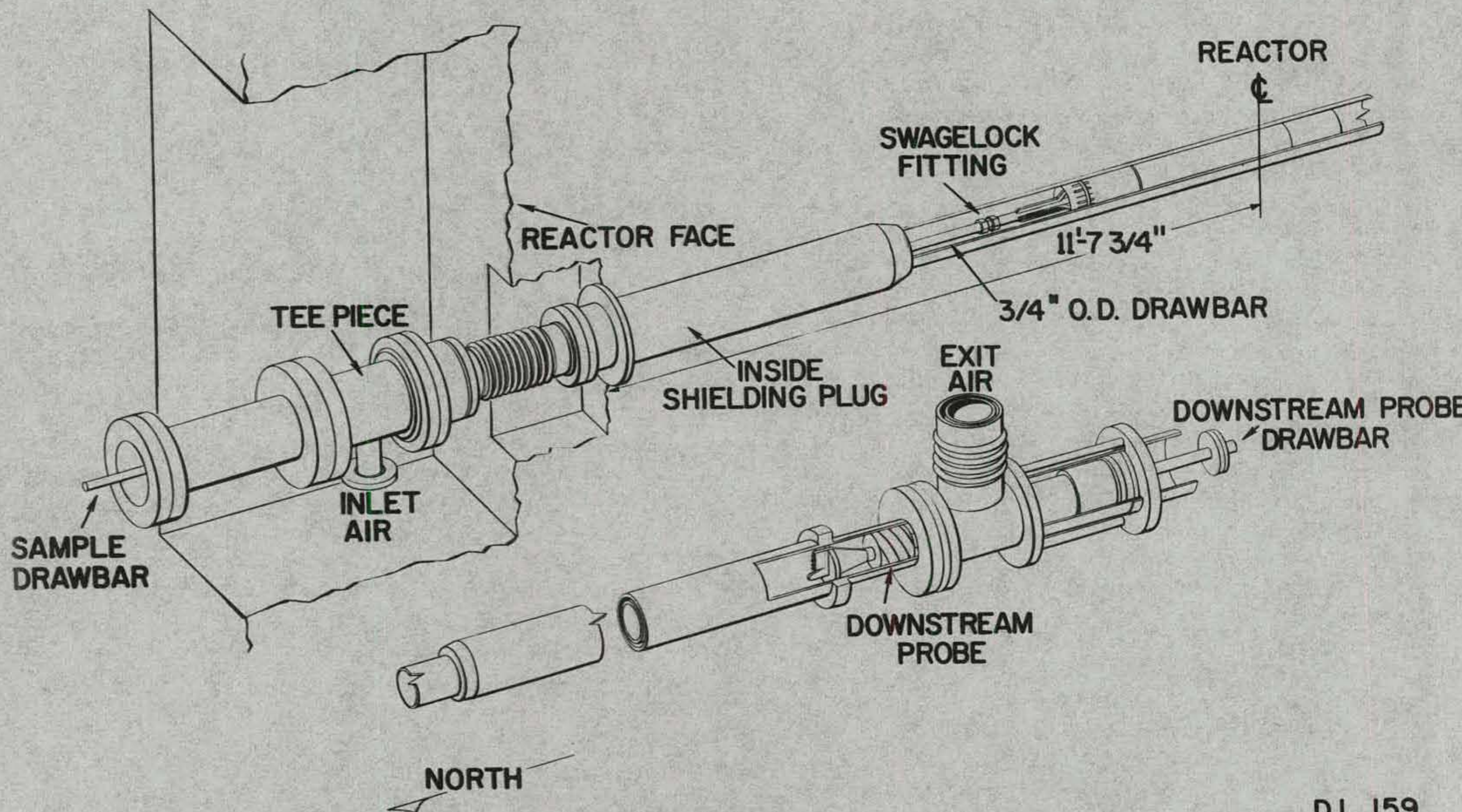


Fig. 1-7 - Simplified Flow Diagram for A-19 Facility (D.I. 162)



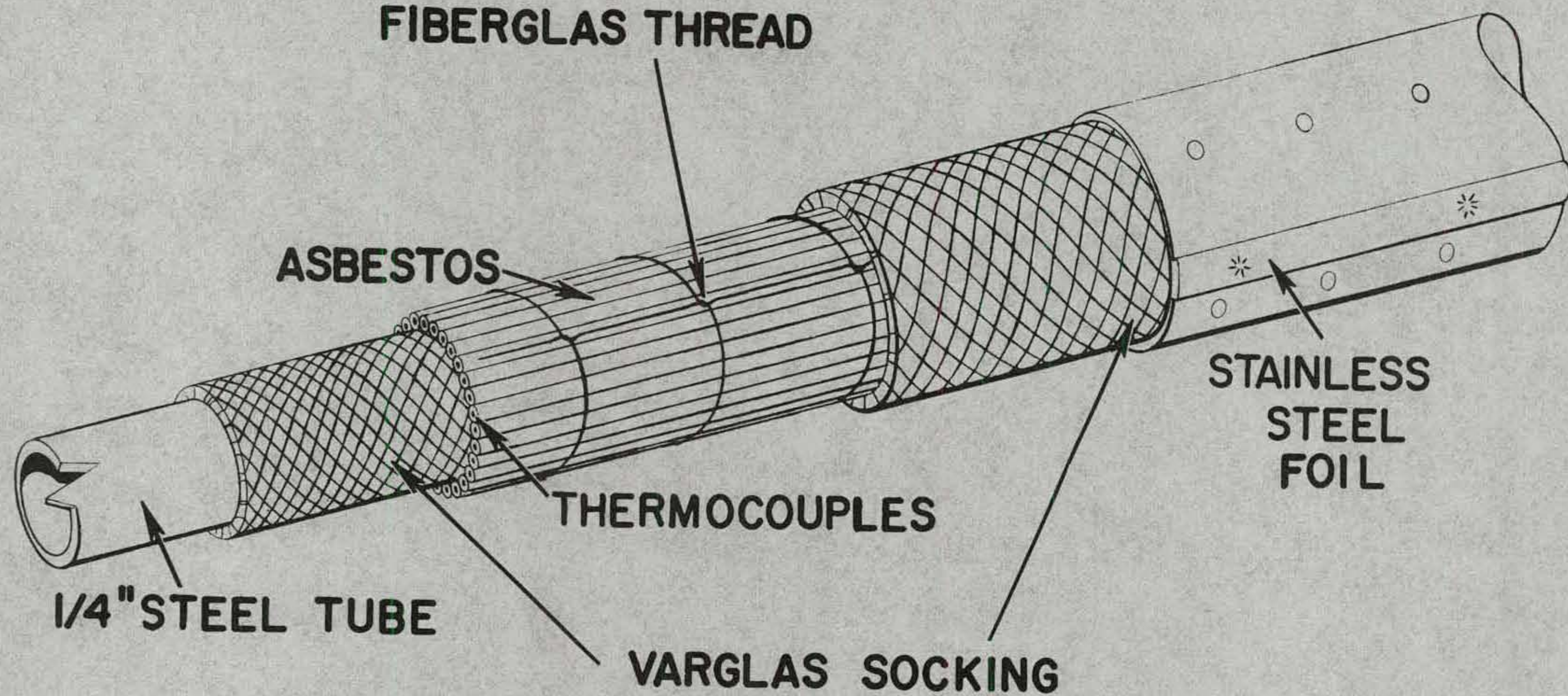
D.I. 130

Fig. 1-8 - HT-1 Hole $5^3/_4 \times 5^3/_4$ Outside Dimensions $\times\, ^1/_2$ Wall Scale $^2/_1$



D.I. 159

Fig. 1-9 - Trimetric View of HT-1 Facility Showing A Metallic Sample & Downstream Probe Installed



D.I. 163

Fig. 1-10 - Method of Protecting Asbestos Insulated Thermocouples Inside of MTR-HT-1 Drawbar

When using metal-sheathed thermocouple wire, the basic principle of anchoring the leads to sample hardware and binding the leads in the drawbar should be followed. All comments pertaining to the use of metal-sheathed thermocouples in the A-19 application apply also to the HT-1.

Engineering Data - HT-1 Facility

Part 1 - Structural Items

1. Nominal Inside Diameter of HT-1 Liner = 3.688 in.
2. Required Maximum Sample Outside Diameter = 3.630 in.
3. Material of HT-1 Liner = 316 stainless steel
4. Material of Pressure Tube = 316 stainless steel
5. Drawbar Dimensions = $^3/_4$ in. O. D. $\times$ $^5/_8$ in. I. D. 304 stainless steel tubing - approx. 25 ft long
6. Maximum Design Skin Temperature of HT-1 = 1500°F

Part 2 - Dynamic Parameters

1. Maximum Pressure Obtainable = 300 psig
2. Approximate Atmospheric Pressure at MTR = 12.2 psi
3. Maximum Flow Obtainable = 6.0 lb/sec

   The maximum flow has never been required with full preheat of 1200°F. It is expected that the maximum flow at maximum preheat is probably 5.5 lb/sec.

4. Minimum Preferred Flow = 0.5 lb/sec

   This has always been considered an adequate minimum flow for facility safety.

5. Maximum Preheat Temperature = 1200°F
6. Average Temperature of Air Entering HT-1 Liner When No Preheat Being Used = 90°F

Part 3 - Nuclear Parameters

1. Neutron Flux

   Figure 1-11 demonstrates the magnitude and the longitudinal distribution of neutron flux in the HT-1 hole with no test specimen present. The values are determined by the irradiation of 0.040-inch-diameter cobalt wires at approximately 400 kw of reactor power. The counting and processing of these wires is performed by the Phillips Petroleum Co. Similar measurements can be made with a test specimen in position for irradiation so that perturbations in the neutron flux due to the specimen itself can be determined. Due to the limited thermocouple installations available to a test specimen, the irradiation of cobalt wires generally provides the most satisfactory values of relative power density for use in post-test thermodynamic analysis. The value 7.0×10^{13} n/cm^2/sec $\pm$ 20 percent is the maximum neutron flux normally available in the HT-1. The flux level near the peak of the distribution is practically uniform for approximately 9 to 10 inches in the longitudinal direction. The neutron energy spectrum is well thermalized; approximately 98 percent of the neutrons are at thermal energies in the unperturbed state.

   For most samples placed in the HT-1 hole a perturbation of the neutron flux results. The magnitude of the perturbation depends upon the sample blackness, i. e., the fraction of the incident neutrons which are absorbed. For specimens such as metallic fuel cartridges, the average neutron flux as seen by the specimen is reduced and a circumferential variation in the power density is observed. The circumferential variation in power density results in a hot quadrant

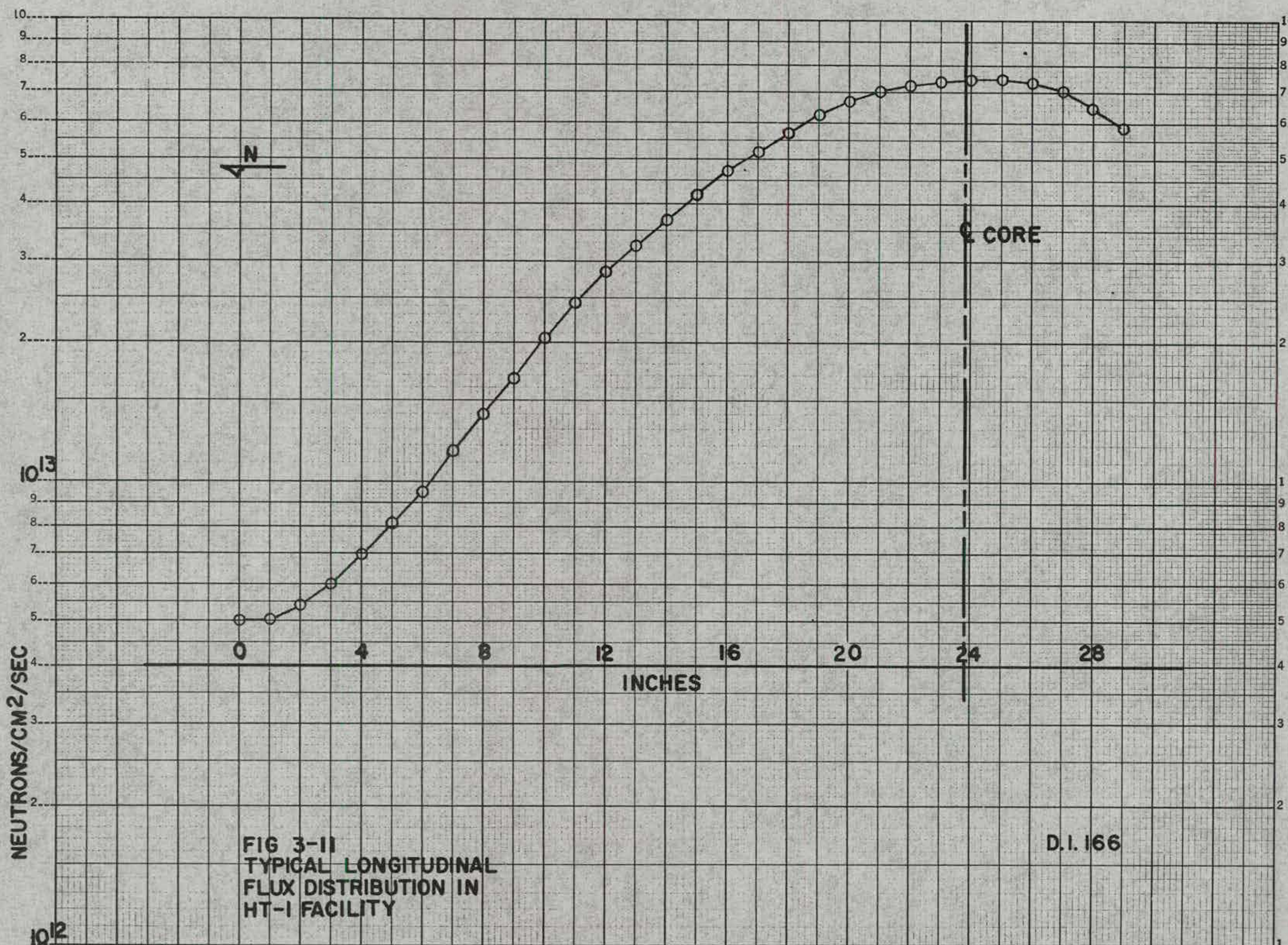


Fig. 1-11 - Typical Longitudinal Flux Distribution in HT-1 Facility on the fuel specimen in the upper left hand portion of the element when looking in the direction of coolant flow. The limiting temperature conditions for the test specimen generally appear in the hot quadrant.

As the reactor cycle and burnout of the MTR core proceed, the control rods are withdrawn to maintain the reactor operating level at 40 MW. The withdrawal of the control rods reduces the neutron flux level and consequently the power generation of specimens in the HT-1 hole. The magnitude of this variation depends upon core loading and cycle duration and cannot be predicted beforehand. Variations as large as 22% have been experienced in HT-1 experiments.

2. Gamma Heating

   The longitudinal distribution of gamma radiation in the HT-1 hole has been assumed to have the same distribution as the neutrons. Although this may be somewhat in error, data from previous measurements have been insufficient to establish the distribution more exactly. From the previous tests in the HT-1 hole, the average gamma heating in specimens 10 - 14 inches long has been approximately 1.1 - 1.3 watts per gram.

Part 4 - Sample Parameters

1. Maximum Sample Diameter = 3.630 in.

   A check gauge consisting of a 42-in. length of machined pipe has been provided to easily check proper fits. All specimens should be gauge checked prior to shipment to ITS.

2. Maximum Sample Length: The withdrawal cask limits the maximum sample length. At present this is 52 inches.

3. Number of Thermocouple Outlets at Thermocouple Head = 30 outlets

   Present equipment provides for use of Pt/Pt - 10 Rh, Pt - 6 Rh/Pt - 30 Rh, and chromel-alumel sensor wires.

4. Number of Pressure Tube Outlets at Thermocouple Head = 6 fittings

   The MTR uses 0.080" O.D. pressure tubing; other sizes should be avoided.

   At the present time, 6 pressure probes have proved adequate. However, should more outlets be desired, modification to the thermocouple head can be arranged and portable gauges or manometers provided for the test.

5. Drawbar Dimensions
   The drawbar is 310 stainless steel tubing, 3/4" O.D. x 5/8" I.D., approximately 25 feet long. It has been the practice on metallic samples to include on all assemblies an 18-inch length of this drawbar stock welded to the front hardware. Upon receiving the sample at ITS, Idaho personnel complete the instrumentation bundle and join the stub length to the 25-foot length by means of a swagelok fitting. In this manner, no welding is required when joining the 25-foot length to the sample. Obviously, welding is undesirable in close proximity to instrumentation leads.

Part 5 - Facility Instrumentation

The HT-1 piping system operates in the following manner.

Air enters the system and passes through a filter that removes dust, grit, and other air-borne contaminants. Leaving the filter it passes to the Clark compressors where it is compressed to 300 psig and stored in the receiver tank. From the receiver tank, it passes through an oil removal filter and then through a metering orifice. The air then passes a pressure control valve to the 9 stage preheaters. The preheaters have a flow capacity of 6 lb/sec and nominally can heat the air to 1200° F. However, at flows less than 1 lb/sec, 1200° F air cannot be delivered to the sample because of heat loss between the preheaters and the sample and over-temperaturing of the heating elements.

Air then enters the reactor, through the specimen, and exits at the south face. Water injection is provided to cool the exit air to 1500°F prior to entering the Buffalo Forge Filter which is intended to catch any large particles that would break from the sample, and thus protect the downstream piping. Leaving the filter, the piping leads into the basement and passes a flow control valve. The air then exits the system via the MTR stack. Radiation monitors, referred to as RR-1 and RR-2 are located ahead of the Buffalo Forge Filter and ahead of the flow control valve respectively.

An itemized description of the HT-1 system limitations is presented below:

1. Piping to Preheaters:
   a. Flow 6 lb/sec
   b. Pressure 300 psig
   c. Temperature ~ 300° F
   d. Six inch, Sch. 40, standard pipe
2. Orifice Assembly:
   a. Orifice plates 1, 2, 3, 4, and 6 lb/sec
      (1) Plates can be changed during operation
   b. Upstream pressure ~ 300 psig
   c. Upstream temperatures 60°~ 120° F
3. Preheaters:
   a. Maximum flow 6 lb/sec
   b. Minimum flow 1 lb/sec with one full stage on
   c. Control ±25° F
   d. Total output 2000 KW
   e. Pressure rating 300 psig
   f. Outlet temperature 1200° F
4. Clark Compressor:
   a. Output pressure 300-320 psig
   b. Outlet temperature 60°~ 120° F
   c. Flow 6 lb/sec with standard cylinders
   d. Flow ~ 5 lb/sec with a 21-inch 2nd-stage cylinder
   e. Three compression stages
   f. Horsepower 1500
   g. Five loading stages
   h. Water cooled
5. Piping from Preheaters to In-Pile Tube:
   a. Pressure 300 psig
   b. Temperature 1200° F
   c. Six-inch, Sch. 40, 347 stainless steel
6. Exit Piping From South Face to Basement Entry
   a. Pressure 300 psig
   b. All piping insulated internally and water jacketed. Air inlet temperature 1500° F
7. Buffalo Forge Filter:
   a. Flow 6 lb/sec
   b. Air temperature 1500° F
   c. Pressure 300 psig

8. Exit Piping to Flow Control Valve:

   a. Pressure 300 psig
   b. Temperature 750°F

9. Radiation Monitors:

   a. Jordan head located upstream of the Buffalo Forge Filter - Recorder designation RR-1
   b. Jordan head located in basement, just upstream of flow control valve - Recorder designation is RR-2
   c. Jordan heads (4) located around the south face area - recorder RR-3, points 1, 2, 3, and 4
   d. Charcoal trap sampler at discharge probe T/C head - a total of 12 traps are shared with ANP-3

10. Radiation Control Limits:

    To prevent hazardous health and safety conditions, the following radiation controls have been specified.

    a. If RR-2 reads 200 mr/hr + background or if basement aisleway reads 7½ mr/hr at chest line, the sample is withdrawn.
    b. Operation of a test, when RR-2 reads less than 30 mr/hr + background, will be without weather restrictions.
    c. If RR-2 reads between 30 and 200 mr/hr and the aisleway radiation is below 7½ mr/hr, the test is discontinued when the following weather conditions exist:
       (1) Wind velocity less than 2 MPH
       (2) Wind direction from South, Southeast, East, or Northeast
       (3) Fumigation conditions or approach thereof
       (4) Rain or other precipitation
       (5) Thunderstorms in vicinity
    d. The reactor is scrammed if RR-2 reaches 500 mr/hr + background
    e. If filter inlet activity RR-1 reaches 10R the reactor is scrammed

11. Sample Thermocouple Facility Leads:

    a. Types and numbers:
       (1) Thirty Pt - 6 Rh/Pt - 30 Rh
       (2) Forty Pt/Pt - 10 Rh - Note this is 10 greater than presently provided on the thermocouple Head
       (3) Thirty Chromel-Alumel

12. Sample Thermocouple Recorders:

    a. TR-1 two-point continuous type, chart speeds 2 in./hr and 2 in./min
    b. TR-2 twelve-point printout type, chart speed 6 in./hr
    c. TR-3 twelve-point printout type, chart speed 4 in./hr
    d. TR-4 twelve-point printout type, chart speed 4 in./hr
    e. TR-5 single-point continuous type, chart speed 2 in./hr
    f. TRC-1 single-point continuous type, circular 24-hour chart. Range-change kits for 6-30 PT-RH and CR-AL are available for the above recorders.

13. Sample Pressure Instruments:

    a. Pressure recorders:
       (1) PR-1, Foxboro, 6-point intermittent type, 24-hour chart. Only one point reserved for sample pressure.
    b. Pressure transmitters:
       (1) Two transaire transmitters are used to cover the range from 50-180 psi.

14. Sample ΔP Instruments:
   a. Recorders:
      (1) PR-2, Foxboro, consotrol, two-point, continuous type, chart speed 2 in. /hr
   b. ΔP Cells
      (1) Two, 0-25 psi, Foxboro 3A
      (2) One, 0-50 psi, Barton

MTR Test Terminology and Nomenclature

The operation of a test reactor gives birth to expressions and terms unique to the reactor. Likewise, a test facility within a reactor frequently has features that result in defining names or terms. The MTR and the GE facilities at the MTR are not exceptions to this statement.

Because the reactor operation directly affects HT-1 and A-19 performance, a knowledge of terms frequently used in correspondence is worthwhile. It is with this thought in mind that the following discussion of reactor and facility terms is presented. Although not intended to be complete for all reactor terms, the nomenclature most frequently seen in MTR reports and data are presented.

Reactor Terminology

The most frequent reactor condition affecting the GE facilities is power reduction. Five rates of automatic power reductions are common. These rates are defined as follows and presented in Figures 1-12 and 1-13.

scram: The release of all seven shim-safety rods which are driven into the lattice by gravity and water pressure

junior scram: The release of shim-safety rods 6 and 7 which are driven into the lattice by gravity and water pressure

reverse: A motor-driven insertion of all shim-safety rods

fast setback: A logarithmic reduction of 1 percent of full power in 90 seconds

slow setback: A logarithmic reduction of 1 percent of full power in 420 seconds

The above conditions are the automatic power reductions. The reactor operator can manually reduce power at almost any rate.

Another condition that results in reduced test time is "mid-cycle shutdown" or sometimes called "mid-cycle refueling." Depending on the amount of fuel added during the shutdown period, the reactor may or may not be able to operate for a full three-week cycle. Many times, the reactor conduct and reactivity margin is better controlled if a planned shutdown midway through the three weeks is performed. At this time, new fuel is added and test changeouts are conducted much the same as at the start of a three-week cycle. Hence, the name "mid-cycle shutdown" or "mid-cycle refueling." When Phillips Petroleum Co. plans mid-cycle operation, it is possible to conduct two irradiations in a facility within a three-week period. However, recent Phillips Petroleum Co. practice has been to fuel the reactor "heavy" to eliminate the mid-cycle shutdown.

Facility Terminology

The most frequent question arising during the conduct of an HT-1 test is, "Where is the sample relative to peak flux?" This question, of course, arises for tests that are conducted with samples not positioned at peak flux. The daily test telegrams and the Operating Report cover this question by giving a dimension in inches "north of brass plate." A typical report might say, "sample position 16. 7 inches north of brass plate." To explain this term, reference is made to figure 1-14.

In the figure, "N" is the dimension "north of brass plate" and is measured from a plumb bob to the permanent brass plate. The plumb bob is always placed 24 feet from the leaking edge of the sample and to determine the distance between the leading edge of sample and peak flux (Z), the following relationship holds:

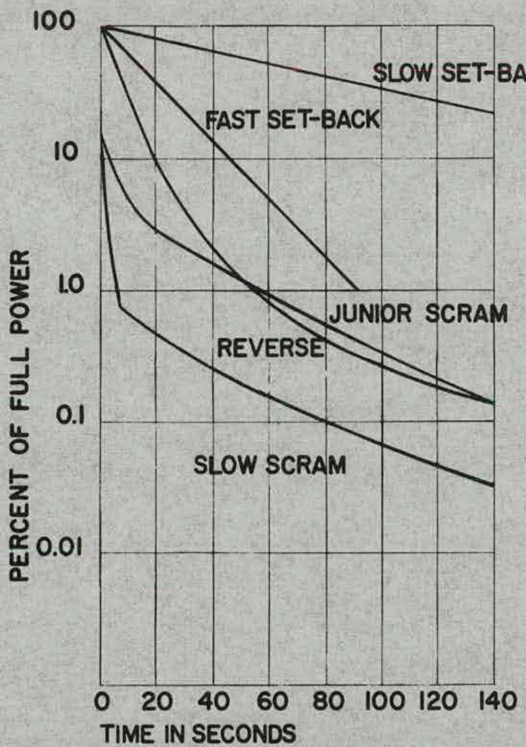


Fig. 1-12

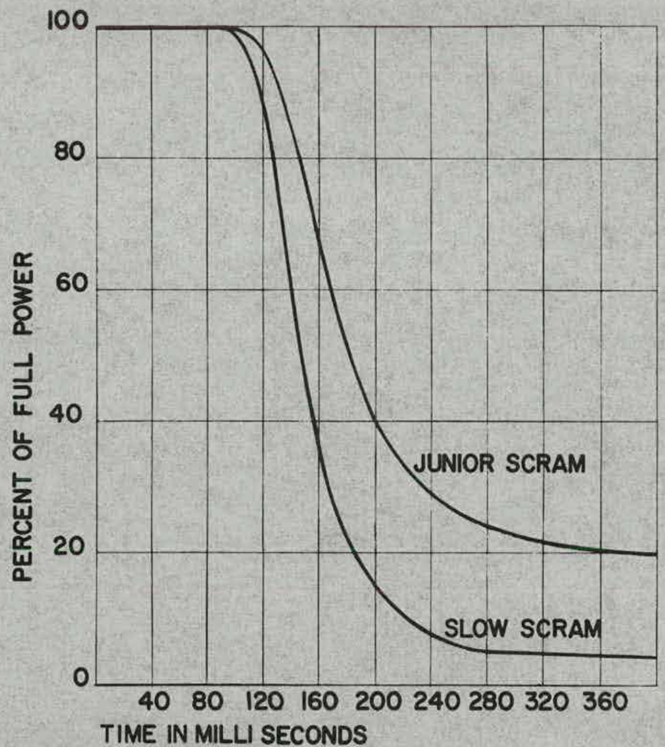


Fig. 1-13

GRAPHS OF AUTOMATIC POWER REDUCTIONS D.I. 367

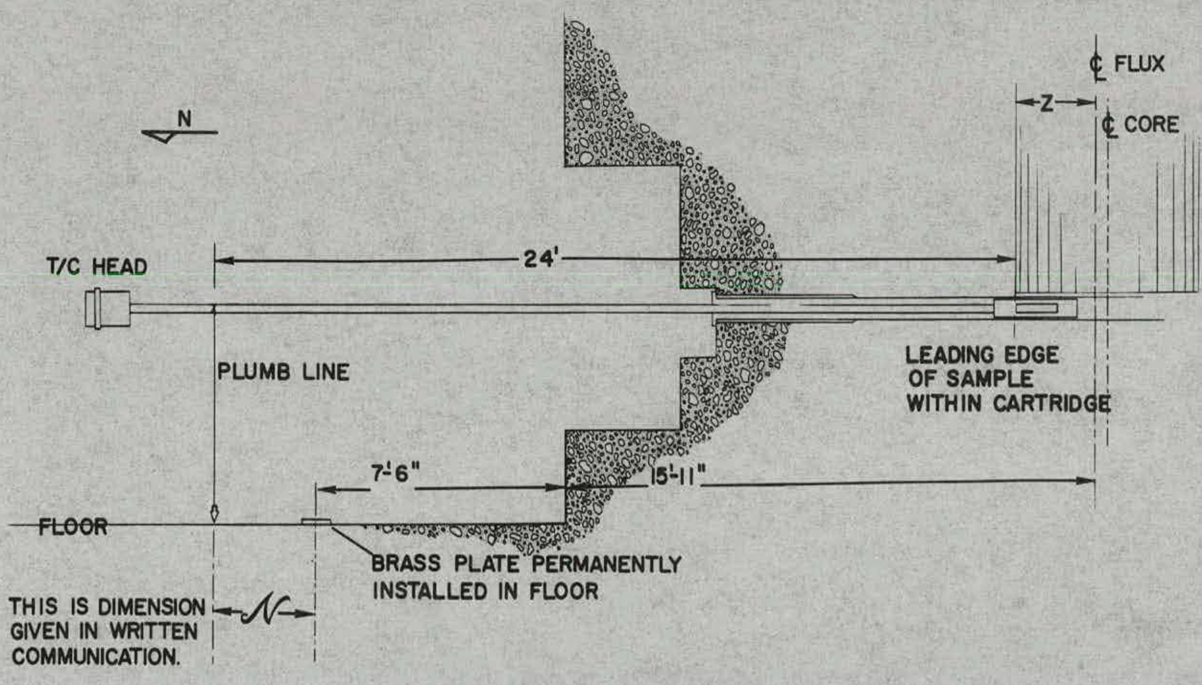


Fig. 1-14

SAMPLE POSITION RELATIONSHIP D.I. 368

$$24'0'' + Z + (\text{thermal expansion of drawbar}) = N + 7'6'' + 15'11''$$

For an inlet air temperature of 1000° F, the thermal expansion equals about $1\frac{1}{2}$."

The relationship then simplifies to: $Z = N - 8\frac{1}{2}''$

Obviously, the above equation changes for significantly different inlet air temperatures. The reader is referred to reference 7 for a detailed discussion of the sample location relationships.

Notation - Abbreviations

E. I. T.	-	Engineered Irradiation Tests
ETR	-	Engineering Test Reactor
HT-1	-	Horizontal Through Hole No. 1
IDO	-	Idaho Operations
ITO	-	Idaho Test Operations
ITS	-	Idaho Test Site - G. E.
kw	-	kilowatt
m/sec	-	meters per second
mev	-	millielectron volt
MTR	-	Materials Test Reactor
MW	-	megawatts
NRTS	-	National Reactor Test Site
PM Material	-	Precious Metal Material
PP Co.	-	Phillips Petroleum Co.
RML	-	Radioactive Materials Lab
SS Material	-	Special Source Material
V. G. Hole	-	Vertical Graphite Hole

BIBLIOGRAPHY

1. Kircher, J. F., "Survey of Irradiation Facilities," REIC Report No. 7, Radiation Effects Information Center, Battelle Memorial Institute

2. Leyse, C. F., "Facilities for Irradiation Within the MTR Reactor Tank," Phillips Petroleum Company, IDO 16048, June 5, 1953

3. Wilder, L. D., "Assembly of GE-ANP Experiments for the Materials Testing Reactor," Procedure P24C-YA-524, November 2, 1959

4. Argonne National Laboratory and Oak Ridge National Laboratory, Materials Testing Reactor Project Handbook, ORNL 963, May 7, 1951, Technical Information Service, Oak Ridge, Tennessee

5. Atomic Energy Commission, "Research Reactors", TID 5275

6. Atomic Energy Commission, "Thumbnail Sketch of National Reactor Testing Station", March 2, 1959

7. Sims, F. L., "Sample Location in the HT-1 Facility of the MTR," DC 60-5-715, May 6, 1960

SECTION II - ENGINEERING TEST REACTOR

GENERAL DISCUSSION OF THE ETR

General Discription

The Engineering Test Reactor (ETR) is a complete nuclear engineering test facility located near the Materials Test Reactor on the National Reactor Testing Station some 50 miles west of Idaho Falls, Idaho. It was constructed under the control and ownership of the Atomic Energy Commission and is presently operated by the Phillips Petroleum Company. This test reactor is designed to perform engineering tests on reactor core materials and components for nuclear power plants. Its main purpose is to provide large experimental test facilities with very high neutron fluxes, thus supplementing research reactors now in use.

The design concepts for the ETR were initiated in 1954 and evolved from studies of future requirements for satisfying nuclear experimental programs for industry. In 1957, the ETR became an operating research reactor thus providing more than twice the high flux space available for tests of reactor components. At this time, the test facilities within the reactor gradually became a reality to conduct tests under environmental conditions of temperature, pressure and nuclear environments that could simulate those to be encountered in the end use.

The ETR is a 175 megawatt (MW), heterogeneous, light-water moderated and beryllium-reflected reactor. It is, at present, the highest-powered test reactor available to industry for performing large engineering experiments. As such, the reactor was designed as a fixed-fuel-loading configuration with the test facilities housed vertically within the core and reflector regions. No experimental test facility penetrates the shield; thus horizontal test facilities are not available.

The ETR has an asymmetrical core containing 49 3-inch-square fuel elements, 12 gray control rods, 4 black control rods, 2 regulating rods and 17 major experimental penetrations. The fuel elements are flat-plate MTR type aluminum-uranium assemblies, having an active length of 36 inches. The control rods are driven from the bottom of the reactor so as not to interfere with experimental test loops. The enriched lattice is surrounded by a beryllium reflector (4.5 inches thick), additional thicknesses of aluminum and beryllium (reflector region) and then various thicknesses of 304 stainless steel to protect the concrete biological shield and vessel walls from excessive temperature. The entire configuration is enclosed in a stainless steel vessel designed for pressure of 250 psig. The reactor, reflector and internal thermal shields are cooled by high-purity demineralized water circulated at a rate of 44,000 gallons per minute. The water enters at 110 °F and 200 psia and is discharged at ~140 °F and ~150 psia. A T-shaped canal connects with the reactor to provide underwater shielding for safe handling of fuel elements, experimental facilities, and experimental tests where applicable. The whole reactor is approximately 35 feet in length and 7 feet in diameter.

The reactor contains 17 major engineering test facilities of the closed-loop design and some 125-150 locations for smaller capsule tests primarily for open-type irradiations at reactor water ambient temperatures. Of the 17 major test facilities provided in the ETR, 9 of these penetrate the core region and 8 penetrate the reflector region. These facilities vary in size from a 3x3 inch to 9x9 inch penetration. The GE-ANP Department had the use of three test facilities all of which are located within the active lattice region. These are designated as the 33, 66, and 99, derived from 3x3-inch, 6x6-inch, and 9x9-inch core penetrations, respectively. See Figures 2-1 and 2-2 for orientation and position through the core region.

ETR Operating Policy - General

The ETR is operated on a six-week cycle. This period of time includes both the reactor operating time and shutdown time and has been established to provide a firm guide for test sponsors in planning and executing desired test programs. Of the six-week period, some ten to fourteen days are normally required to change experiments, conduct necessary maintenance and to perform pre-irradiation calibrations of necessary test parameters. Upon completion of the above work, the reactor is brought to

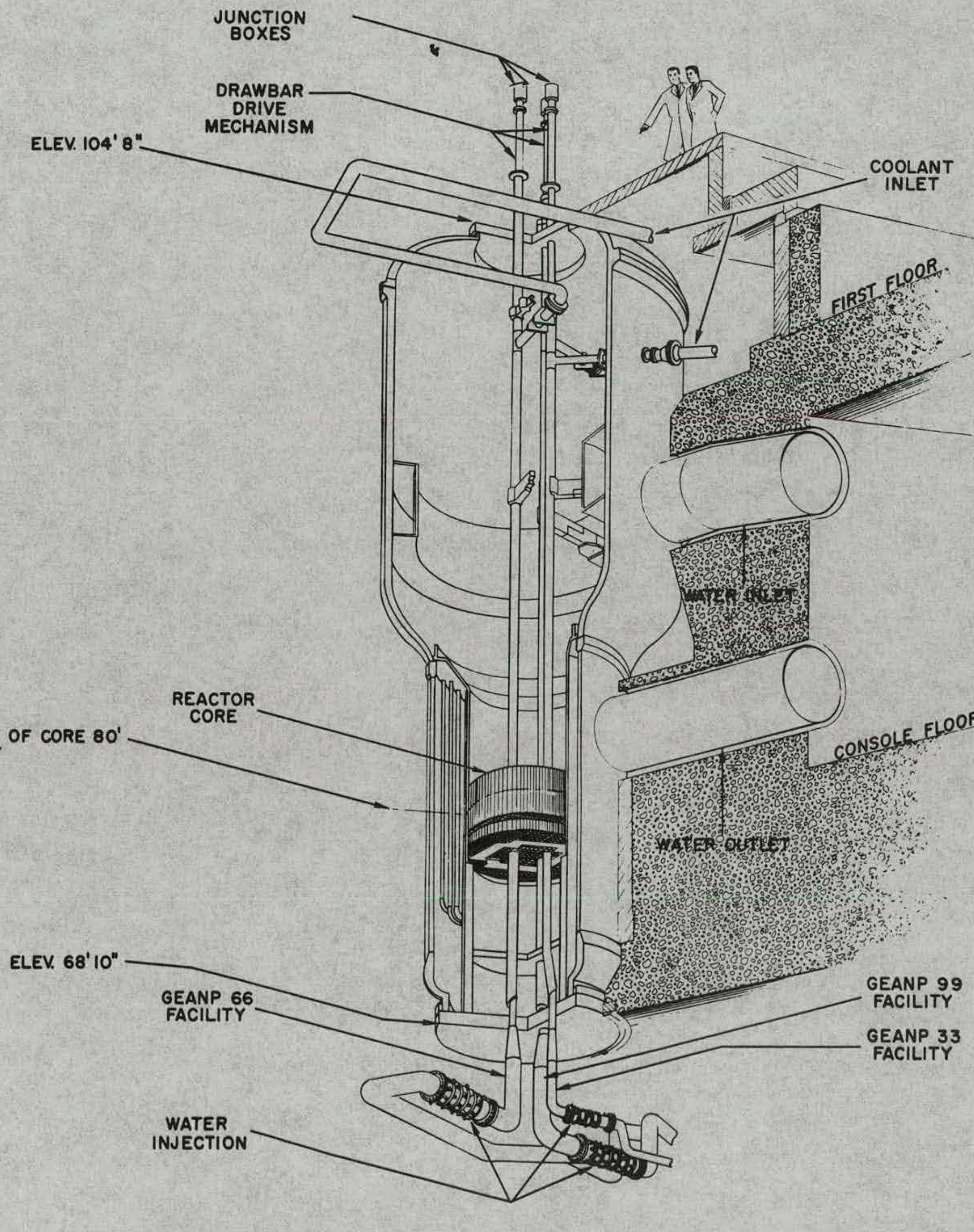


Fig. 2-1 - Engineering Test Reactor (D.I. 351)

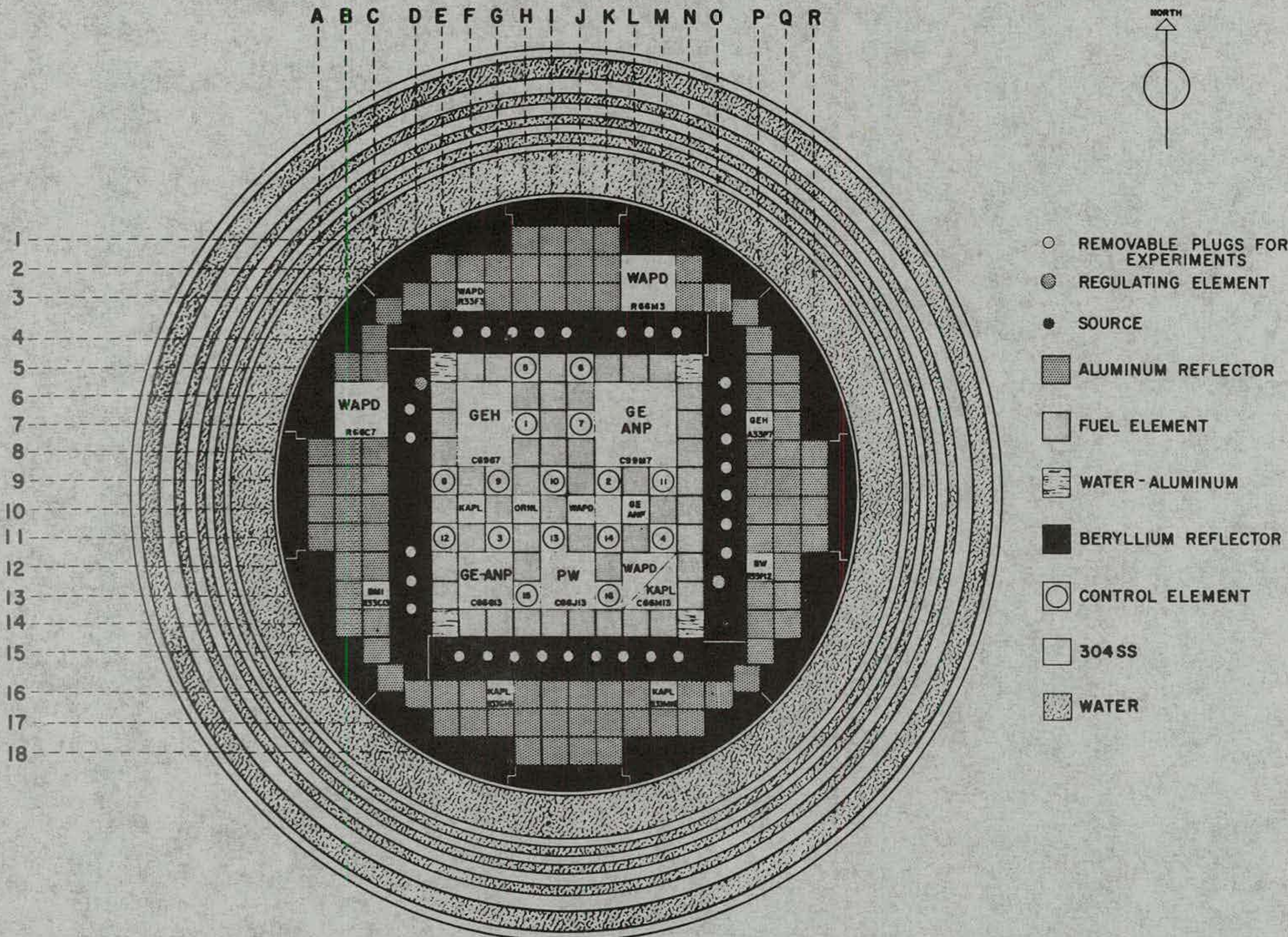


Fig. 2-2 - Plan View of ETR Core (D.I. 327) full operating power of 175 MW in proper rate sequence as preferred by the reactor operations and test sponsors. With the occurrence of further shutdown times due to scrams, refueling, specific test requirements, approximately 500 irradiation hours are normally achieved per test cycle.

The operating cycle is arranged so that reactor shutdown occurs on Sunday at midnight with the immediate commencement of work to be performed including necessary maintenance and change out of experiments. The test assemblies to be installed during a cycle are required at the ETR building twelve days prior to reactor shutdown. This twelve-day period has been established by Phillips Petroleum Company for inspections by their Operations and Safeguards personnel and also to assure the achievement of fixed schedules.

After the installation of experiments from test sponsors, instrumentation and facility connections can be made. In the case where flux-monitoring wires or packets are required prior to full-power operation of the reactor, temporary connections are made where necessary and the reactor is brought to N_L or 1 percent of full power (1.75 MW) to activate the flux monitors, which generally requires only 5 to 20 minutes of operation. Permanent connections are made after removal of flux monitors. Following this, time is then available to conduct other calibration tests, such as coolant flow, to obtain a check on instrumentation accuracy. Thermocouple checks are also performed during this period by passing preheated coolant on the order of 600°F (or as required) to establish both their accuracy and proper connections of the numerous temperature sensors prior to irradiation.

In all cases, the test assemblies are positioned below the core region (44 inches from C_L of sample to C_L core) prior to the conduction of any calibration or endurance test. Upon bringing the sample to test conditions, the sample is raised into the core by an established procedure between test sponsor and reactor operations to assure the safety of the test from undesirable temperature excursions or other limiting parameters. After completion of the specified on-test procedure, the desired test conditions of airflow, temperature, pressure, preheat, etc. are set by the operator and the test is operated for the requested time.

ETR Policy and Procedure - Phillips Petroleum Company

Phillips Petroleum Company, as designated operators of the Engineering Test Reactor, have established policies and procedures applicable to sponsors for the conduct of experimental tests in the ETR. Complete details are available on request from:

Phillips Petroleum Company
Operations Engineering Branch
P.O. Box 1259
Idaho Falls, Idaho

Since these procedures are lengthy and pertain to any potential reactor test program, excerpts of these procedures which are most applicable to individuals planning an irradiation test in the Engineering Test Reactor are listed in the following.

Phillips Petroleum Company as operator of the Engineering Test Reactor under contract with the Atomic Energy Commission has the responsibility of seeing that this operation is conducted safely, efficiently, and in the best interests of the Commission program objectives.

In order that there may be a clear understanding with regard to the conditions under which service irradiation requests are accepted and carried out at the ETR, the following statement of procedure and policy is issued for the information and guidance of all organizations sponsoring such programs.

A. Design, Fabrication, Shipment, and Installation

1. It is the responsibility of the organization sponsoring a given irradiation project to design and fabricate all equipment required to carry out the project and to ship the equipment to the ETR in a ready-to-install condition.

2. Shop facilities are available at the ETR to do a limited amount of fabrication of parts which cannot be supplied by sponsors and for emergency service during reactor shutdown periods. The ETR shop cannot undertake any fabrication work that should properly be done by the sponsor.

3. Phillips has the exclusive responsibility for the installation of experimental equipment, all service lines and instrument connections, and the insertion of all experimental tests in the reactor.

4. The sponsor is responsible for supplying the shipping casks required to transport any radioactive materials involved in his experimental program. He is also responsible for securing governmental approvals on such casks.

B. Project Engineering

In order to assure that experimental equipment being designed and constructed for installation in the ETR conforms fully to all applicable engineering and safety requirements, a staff of Project Engineers is available at the ETR for consultation with sponsors' representatives during all phases of this work. Where any significant amount of engineering effort is involved, one member of the project engineering staff will usually be assigned to follow a specific project and subsequent contacts can be made directly with him.

C. Acceptance Requirements on Reactor Installations

1. The ETR Program Committee, which is comprised of senior qualified men from both technical and operations activities, has the responsibility for the review and approval of all proposed irradiation projects from the viewpoint of technical and operational feasibility as well as suitable space in the reactor.

2. The ETR Safeguard Committee has the exclusive responsibility of reviewing and passing on all safety aspects of proposed experimental installations and irradiation programs as well as operation of the reactor. Sponsors are responsible for procuring and supplying to the Safeguard Committee the details of experiments and calculations by which the safety of an experiment is judged.

3. The Project Engineering Staff, in consultation with Operations personnel and technical representatives of the sponsoring organization, has the responsibility for inspection and approval of all equipment proposed for installation in the reactor. This inspection will be carried out after the equipment arrives at the ETR but prior to its installation. Tests which are required to establish that the equipment, as fabricated, meets all essential specifications will be carried out at this stage.

D. Responsibility of ETR Operations

The operation of the Engineering Test Reactor and its associated experimental program is the exclusive responsibility of the Phillips ETR Operations Branch. No one outside this organization, whether Phillips employee or sponsors' representative, is permitted to perform any manipulations in or around the reactor, including the instrument consoles of experimental equipment, without direct authorization from the Operations shift supervisor.

E. Sponsors' Representatives

Technical representatives of organizations sponsoring irradiation experiments at the ETR will be granted extended visits at the reactor site for the purpose of observing and facilitating the conduct of their experimental project. Representatives of sponsors' organizations are granted operational approval to visit the ETR purely in an observational or engineering liaison capacity.

ETR Test Procedure - GE-ANP

Within the GE-ANP Department, the Irradiations subsection had the responsibility for assigning facility space and scheduling of experiments in all reactor test facilities available to the Department. In order to assure the normal accomplishment of experimental programs desired by various engineering and development functions within the Department, together with the most advantageous use of reactor test facilities, time schedules were established for completing an irradiation test. The time schedules were developed to include the normal completion of work by the GE-ANP Idaho Test Station and those established by Phillips Petroleum Company. These were usually referred to as minimum times in order to minimize any overload in the ITS shops that could easily occur depending on the number of tests planned for any one reactor test cycle. The developed irradiation time schedules are listed below and are a guide for the normal accomplishment of an inpile irradiation experiment.

Item	Days Prior to Reactor Shutdown
Test Request from Evendale	28
Insertion Package to P. P. Co.	21
Sample in ITS Shops	19
P. P. Co. Safeguards Approval	14
All hardware to P. P. Co.	12
P. P. Co. Schedules Installation	10
Reactor Shutdown	0

ENGINEERING DESCRIPTION - GE-ANP ETR FACILITIES

General

The three GE-ANP test facilities are similar in design with the exception of size and test parameter capability. All of the facilities are vertical through loops penetrating both the top plate and the bottom plate of the reactor. The inpile sections are approximately 35 feet in length and consist of a liner covered with insulation and then enclosed in an outer pressure tube. Each of the test loops is surrounded by fuel elements whose longitudinal axes are parallel to the experimental holes. The active lattice has a vertical height of 36 inches, thus the test facilities through this region will have a corresponding length of high neutron flux exposure. Each inpile test loop represents a completely separate experiment with respect to piping, coolant flow, pressurization, and data gathering. High pressure, variable preheated air can be passed independently through each experimental loop to obtain desired operation of respective experiments.

Coolant and Purification System

The coolant air is furnished by two compressors (two-piston, 3-stage), each capable of delivering 15 lbs/sec at 320 psig. The air from the compressors passes through two receivers and onward to three oil-fired heaters. From the heaters it enters the reactor building and penetrating the reactor pressure vessel, enters the vertical inpile tube. It then flows downward past the test sample in the active lattice region of the core. The hot coolant piping exits the pressure vessel passing through the sub-pile room where its temperature is reduced to 800°F maximum by passing through a water injection system. For the 99, maximum air temperature exiting the water injection is 500°F. From the sub-pile room, the air is piped through an underground tunnel through high-temperature filters and then finally discharged to atmosphere through the ETR exhaust stack.

The coolant air is purified, initially by passing through the compressor intake filter for dust removal; moisture and oil are condensed out between each stage of the compressors by passing through intercoolers and finally after exiting the last compressor stage through an aftercooler. It then passes through a separator before entering the receivers. From the receivers, the air passes through an oil-absorption filter and finally a pipe line filter before passage through the preheaters.

Within the preheaters, oil-laden air can be reduced to combustion products provided preheat temperature is maintained at 900 °F. Figure 2-3 is a trimetric view of the ETR experimental coolant piping as it presently exists.

The air-flow system is shown for the G-E test loops in block-diagram form in Figure 2-4. This sketch also presents the flow capabilities of the system together with respective locations of temperature control valves, flow control valves, orifice assembly, pressure control valves, and emergency air supply.

In addition to the above, the ETR 99 loop only has been equipped with a second air-piping system for the testing of ceramic fuel samples.

Briefly, it consists of the inclusion of two large tanks, inlet and exit air filters, and necessary piping all of which is located beneath ground level. The tanks were sized to delay a maximum of 10 lbs/sec of hot exit coolant for a period of three minutes prior to being exhausted to the atmosphere through the ETR stack. The three minute delay period allows for decay of greater than 90 percent of fission products released in the air stream during test operation. This flow system is described on drawing 6445D540(ANP-ITS).

Test Assembly Description

Each test assembly for the GE-ANP ETR test facilities consists of test sample, X-drawbar, upper neutron scatterer, tubular drawbar, shield plug, stuffing box, gear drive mechanism, and junction box.

The test sample is designed to fit the facility and may be of any shape provided maximum tolerances of the facility dimensions are adhered to. The test sample is suspended from a drawbar that extends outside the reactor thus providing a means for sample orientation and vertical location, and provides a means for routing instrumentation. A typical ETR sample positioned in the ETR is shown in Figure 2-5. Attached to the X-drawbar is an upper neutron scatterer, consisting essentially of a bullet-nose steel structure sized to fit each inpile loop. Near the upper end of the drawbar, a shield plug is attached that fastens to the top of inpile pressure tube. To provide a pressure-tight seal of the drawbar as it passes through the top plate of the reactor, a stuffing box with appropriate seals is provided. The upper-most part of the drawbar is threaded to mesh with a motor-driven gear assembly for rotational and longitudinal position of the test sample within the facility. The drawbar terminates in a junction box for the instrumentation from the sample, thus also providing a pressure-tight system for the entire test assembly. A sketch of the drawbar junction box is shown in Figure 2-6.

Instrumentation cables are attached to the junction box by means of amphenol connectors and are routed to the console from which the sample parameters are controlled.

ENGINEERING DATA - 33 FACILITY *

Part 1 - Structural Items

1. Nominal Inside Diameter of 33 Liner	= 2.114 in.
2. Required Maximum Sample Outside Diameter	= $2.02^{+.011}_{-.000}$ in.
3. Material of Liner	= Inco 702
4. Insulation Material (between liner and pressure tube)	= Thermoflex
5. Material of Pressure Tube	= 347SS
6. Drawbar Dimensions	
X-drawbar (core region)	= 1.5 in. x 48 in.
Tubular drawbar (above core region)	= .750 in. x .065 in. wall

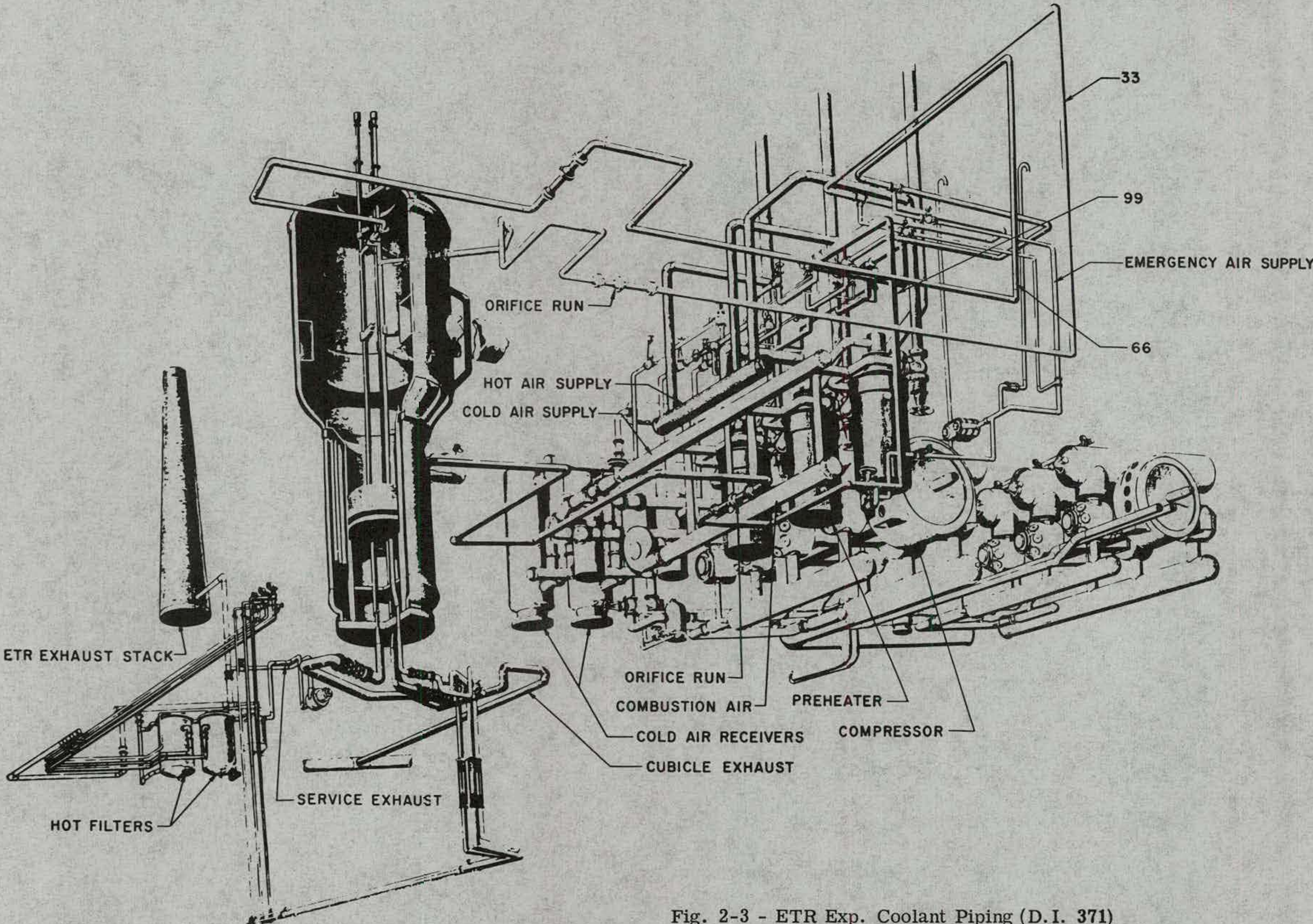


Fig. 2-3 - ETR Exp. Coolant Piping (D.I. 371)

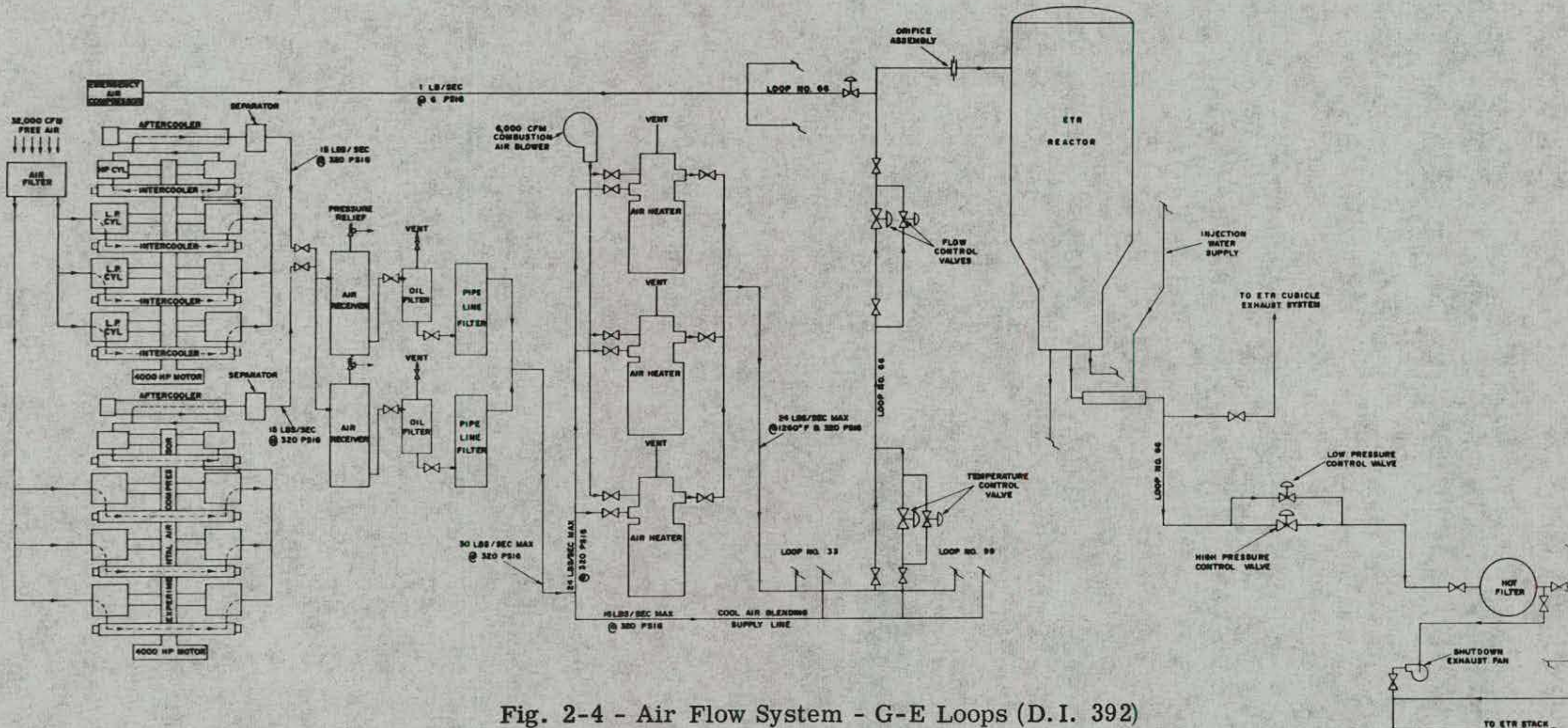


Fig. 2-4 - Air Flow System - G-E Loops (D.I. 392)

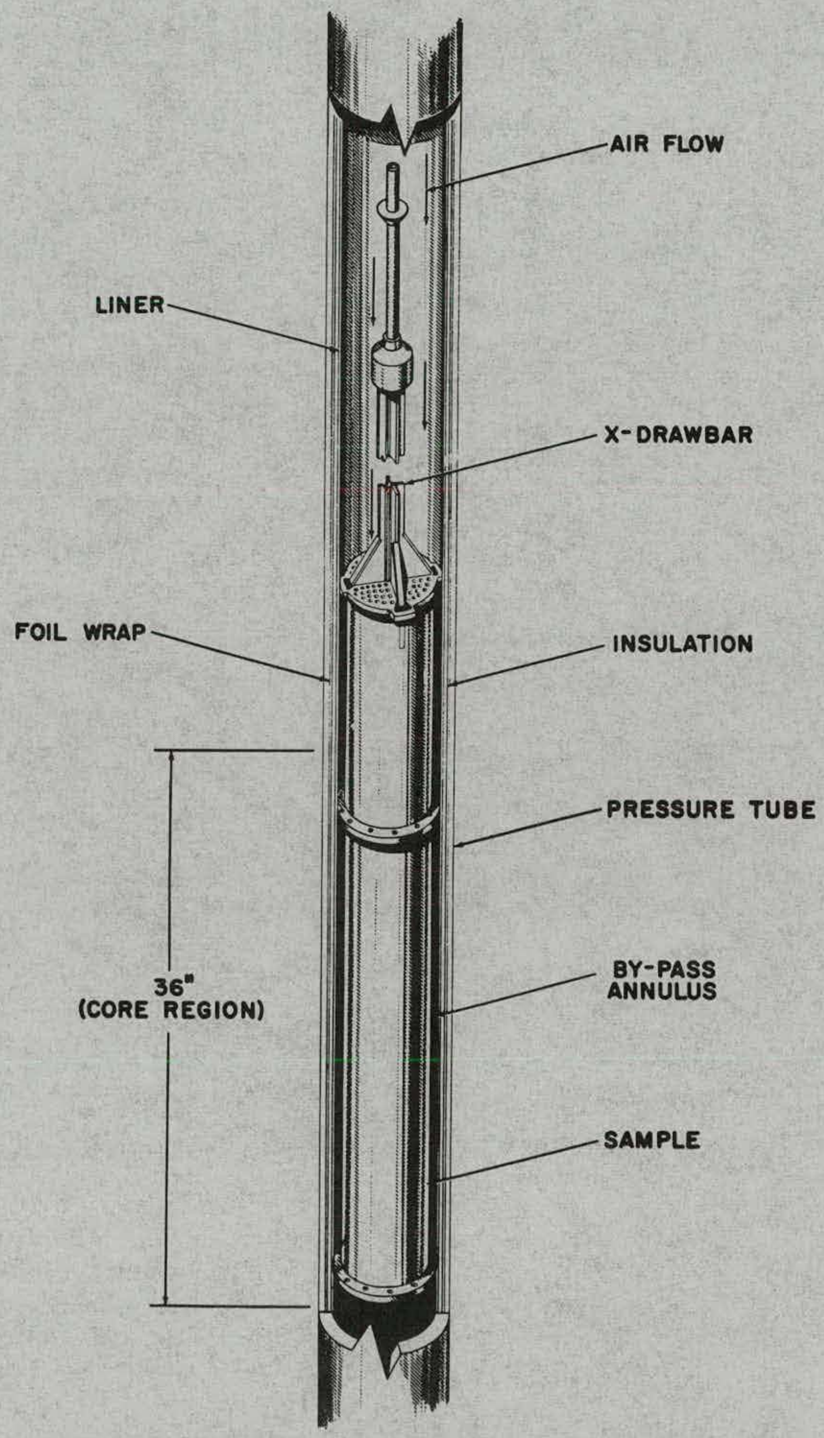


Fig. 2-5 - ETR Sample Positioned in Core (D.I. 343)

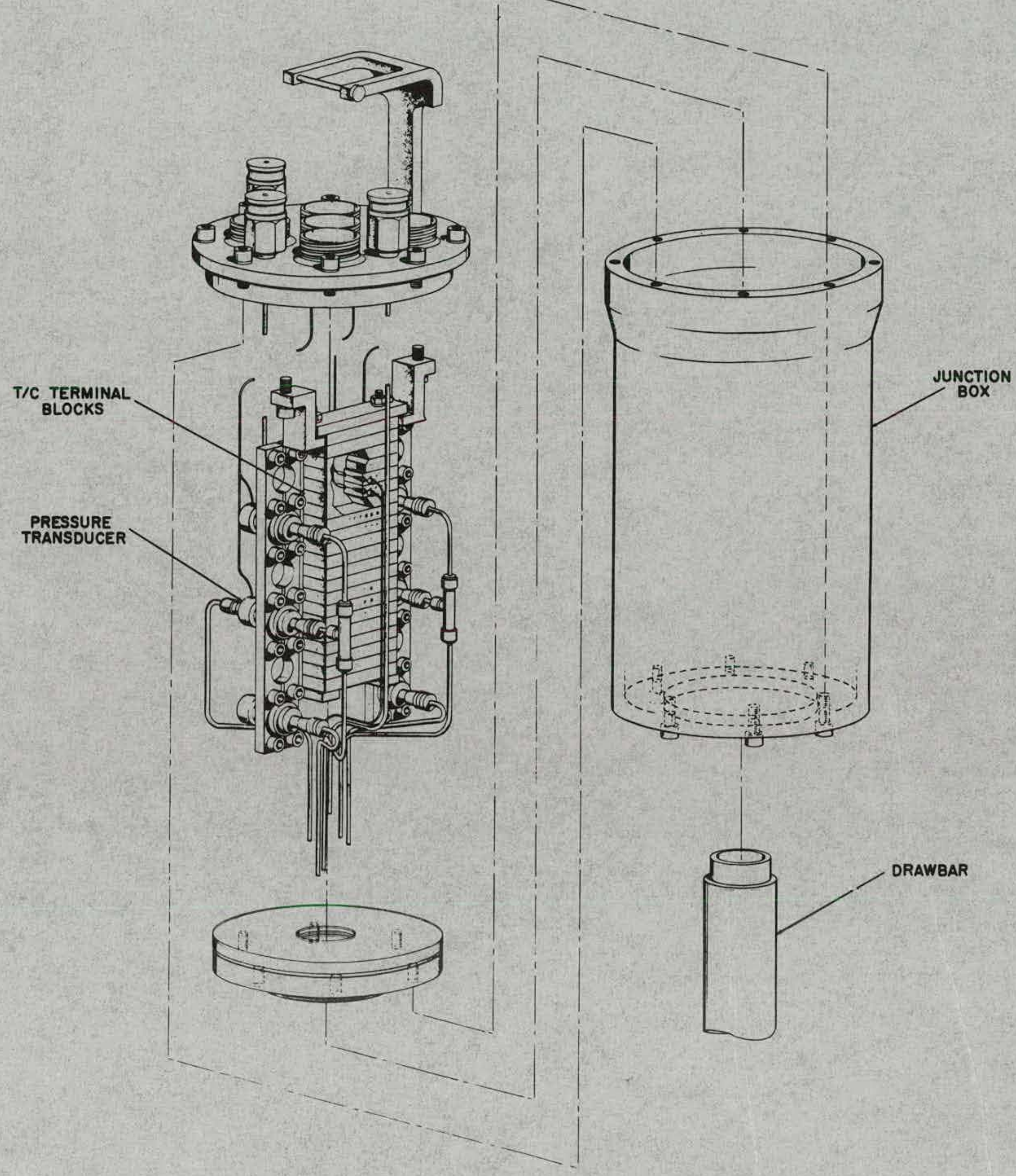


Fig. 2-6 - ETR Drawbar Junction Box (D.I. 382)

7. Drawbar Material = 304SS

8. Maximum Design Liner Temperature = 2000°F

*A section of the 33 Facility through the core region is shown on Figure 2-7.

Part 2 - Dynamic Parameters

1. Maximum Pressure Obtainable = 320 psig
2. Approximate Atmospheric Pressure at ETR = 12.2 psi
3. Maximum Flow Obtainable = 6.0 lb/sec
4. Minimum Preferred Flow = 0.5 lb/sec
5. Maximum Preheat Temperature = 1200°F
6. Average Temperature of Air Entering 33 Liner when no preheat being used = 100°F

Part 3 - Sample Parameters

1. Maximum Sample Diameter $= 2.020 \begin{smallmatrix} +.011 \\ -.000 \end{smallmatrix}$ inches

   A check gauge consisting of 48-inch length of machined pipe has been provided to easily check proper fits. All test assemblies should be gauge checked prior to shipment to ITS.

2. Maximum Sample Length = 53.5 inches

   The withdrawal cask limits the maximum sample length. Also the diameter of the section at 53.5" from bottom-most part of sample is limited to 1.50" O.D. since this is the maximum cut obtainable with the cask shears.

3. Number of Thermocouple Outlets at Drawbar Junction Box = 31

   Present equipment provides for use of Pt/Pt - 10 Rh, Pt - 6 Rh/Pt - 30 Rh, and chromel-alumel sensor wires.

4. Number of Pressure Probe Outlets at Junction Box = 4

   At present, these probes are pneumatic instruments and provide the following range of pressure measurements, 2 each at 0-350 psig, 1 each at 0-50 psid, and 1 each at 0-250 inches of water. Accuracy = 1 to 2 percent

   Future redesign will consist of strain gauge transducers (located inside drawbar junction box). Probe capacity will be 6 with following range of pressure measurements, 0-350 psia, 0-100 psid, 0-10 psid, and 0-2.5 psid. Any combination of these can be used.

   Pressure tubing 0.080" O.D., is used at the ETR site, and other sizes should be avoided.

5. Drawbar Dimensions

   The ETR 33 drawbar consists of two parts, the "X" configuration for location in the core region and the round tube configuration. Adjacent to the upper end of the test assembly, the "X"-shaped drawbar is used to permit ample cooling of drawbar and instrumentation while sample is stored below the core; thus this portion of the drawbar is subjected to the high gamma heating rates (~ 15 watts/gram) in the core region while the reactor is at full power. The dimensions of the "X" drawbar (Hastelloy X) are 1.5" wide x 0.063" thick x 48" long. The "X" drawbar is attached, at the upper neutron scatterer, to a round tubular drawbar (304SS) 0.750" O.D. x 0.065" wall x approximately 25' long. The tubular drawbar carries the instrumentation and extends vertically outside the reactor and terminates in the drawbar junction box.

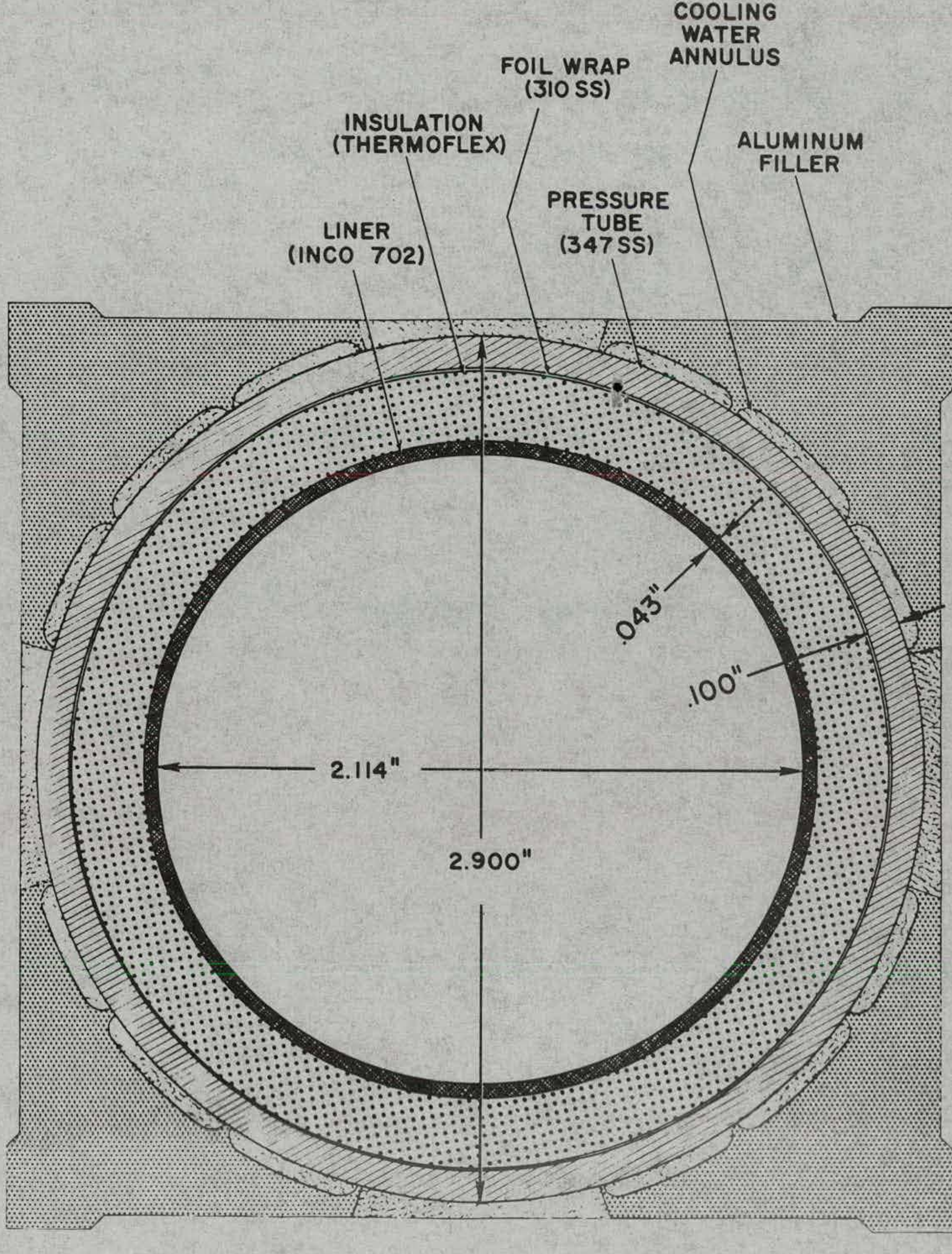


Fig. 2-7 - ETR 33 Facility Section Through Core (D.I. 339)

ENGINEERING DATA - 66 FACILITY*

Part 1 - Structural Items

1. Nominal Inside Diameter of 66 Liner	= 4.584 in.
2. Required Maximum Sample Outside Diameter	= 4.460 ± .010 in.
3. Material of Liner	= Inco 702
4. Insulation Material	= Thermoflex
5. Material of Pressure Tube	= 347SS
6. Drawbar Dimensions	
X-drawbar (core region)	= 1.5 in. x 48 in.
Tubular drawbar (above core region)	= 1.250 in. ODX .125 in. wall
7. Drawbar Material	= 304SS
8. Maximum Design Liner Temperature	= 2000 °F

Note: A design modification for the removal of the liner and insulation in the ETR 66 facility was completed to eliminate possible mechanical buckling of the liner due to large pressure differentials across the test assembly. With this modification, items 1 and 2 and 8 under Part 1 above will become 5.170 in. and 5.160 ± .010 in., and 1800 °F, respectively.

*A section of the 66 facility through the core region is shown on Figure 2-8.

Part 2 - Dynamic Parameters

1. Maximum Pressure Obtainable	= 283 psig at sample
2. Approximate Atmospheric Pressure at ETR	= 12.2 psi
3. Maximum Flow Obtainable	= 14.0 lbs/sec
4. Minimum Preferred Flow	= 1.0 lb/sec
5. Maximum Preheat Temperature	= 1100 °F †
6. Average Temperature of Air Entering 66 Liner when no preheat being used	= 100 °F

† The design modification of the ETR 66 facility noted above in which the insulation liner is removed is expected to limit the maximum preheat to the test sample to approximately 1000 °F.

Part 3 - Sample Parameters

1. Maximum Sample Diameter = 4.460 ± .010 in.

   A check gauge consisting of 48-inch length of machined pipe has been provided to easily check proper fits. All test assemblies should be gauge checked prior to shipment to ITS.

2. Maximum Sample Length

   The withdrawal cask limits the maximum sample length. Also the diameter of the section at 53.5" from bottom-most part of sample is limited to 1.50" O.D. since this is the maximum cut obtainable with the cask shears.

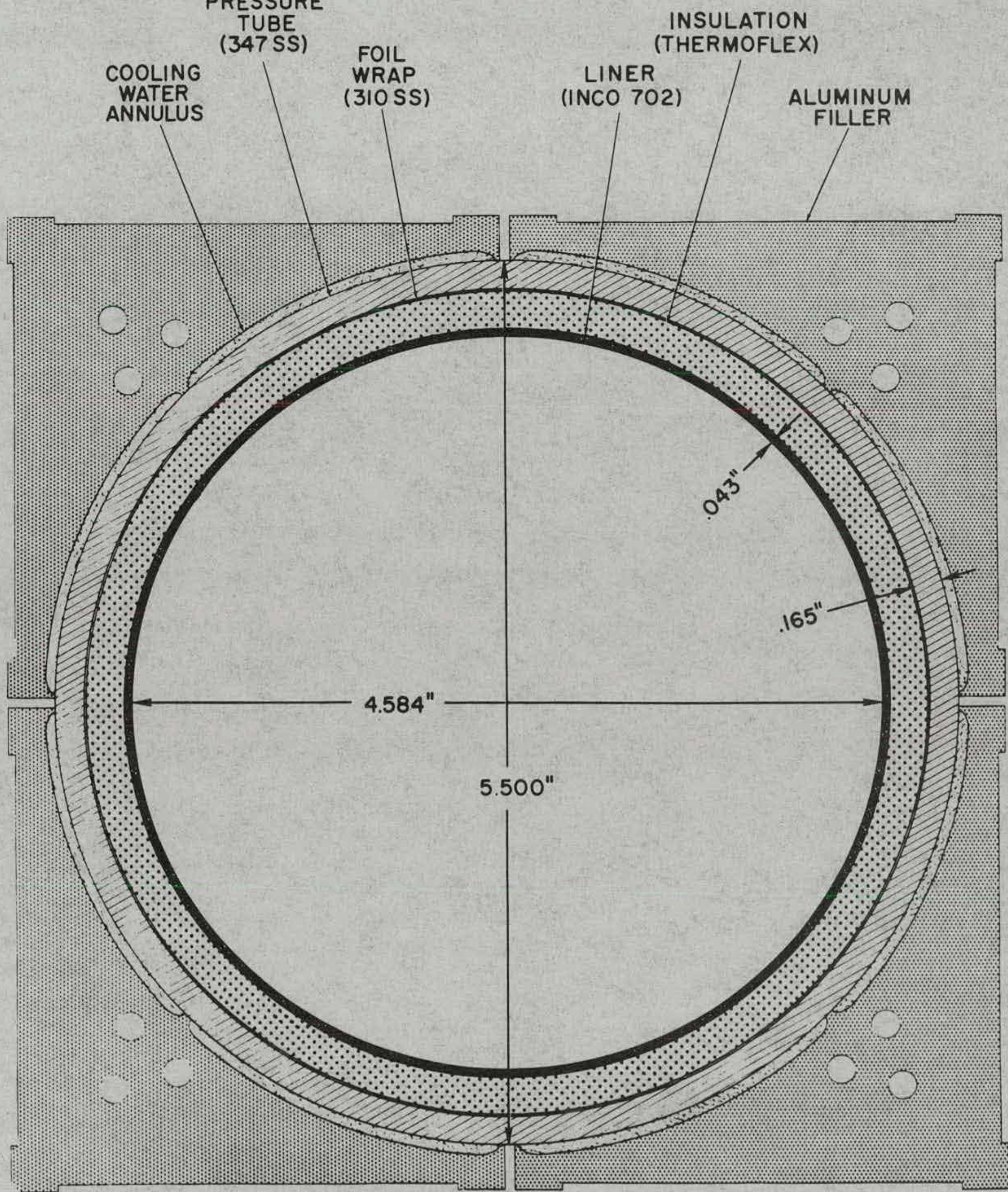


Fig. 2-8 - ETR 66 Facility Section Through Core (D.I. 340)

3. Number of Thermocouple Outlets at Drawbar Junction Box = 51

Present equipment provides for use of Pt/Pt - 10 Rh, Pt - 6 Rh/Pt - 30 Rh, Chromel-Alumel and Hoskins .875 - Chromel A sensor wires.

4. Number of Pressure Probe Outlets at Junction Box = 12

At present, pneumatic probes and straingauge transducers (latter located inside the drawbar junction box) are available. The following range of pressure measurements are provided:

Strain Gauge Transducers: 0-350 psig, 0-100 psid, 0-10 psid, and 0-2.5 psid. Any combination of these can be used.

Pneumatic: 2 each at 0-350 psig, 1 each at 0-50 psid, and 1 each at 0-250" of water.

Pressure tubing, .080" O.D., is used at the ETR and other sizes should be avoided.

5. Drawbar Dimensions

The ETR 66 drawbar consists of two parts, the "X" configuration for location in the core region and the round tubular configuration. Adjacent to the upper end of the test assembly, the "X" shaped drawbar is used to permit ample cooling of drawbar and instrumentation when sample is stored below the core; thus this portion of the drawbar is subjected to the high gamma heating rates (7 watts/gram) in the core region while the reactor is at full power. The dimensions of the "X" drawbar (Hastelloy X) are 1.5" wide x 0.063" thick x 48" long. The "X" drawbar is attached, at the upper neutron scatterer, to a round tubular drawbar (340SS) 1.250" O.D. x 0.125" wall x approximately 25' long. The tubular drawbar carries the instrumentation and extends vertically outside the reactor and terminates in the drawbar junction box.

ENGINEERING DATA - 99 FACILITY*

Part 1 - Structural Items

1. Nominal Inside Diameter of 99 Liner	= 7.454 in.
2. Required Maximum Sample Outside Diameter	= 7.263 ± .010 in.
3. Material of Liner	= Inco 702
4. Insulation Material (between liner and pressure tube)	= Thermoflex
5. Material of Pressure Tube	= Inconel X
6. Drawbar Dimensions	= 1.5" w x 48" 1
X-drawbar (core region)	= 1.250" ODX
Tubular drawbar (above core region)	0.125" wall
7. Drawbar Material	= 304SS
8. Maximum Design Liner Temperature	= 1800°F

*A section of the 99 facility through the core region is shown on Figure 2-9.

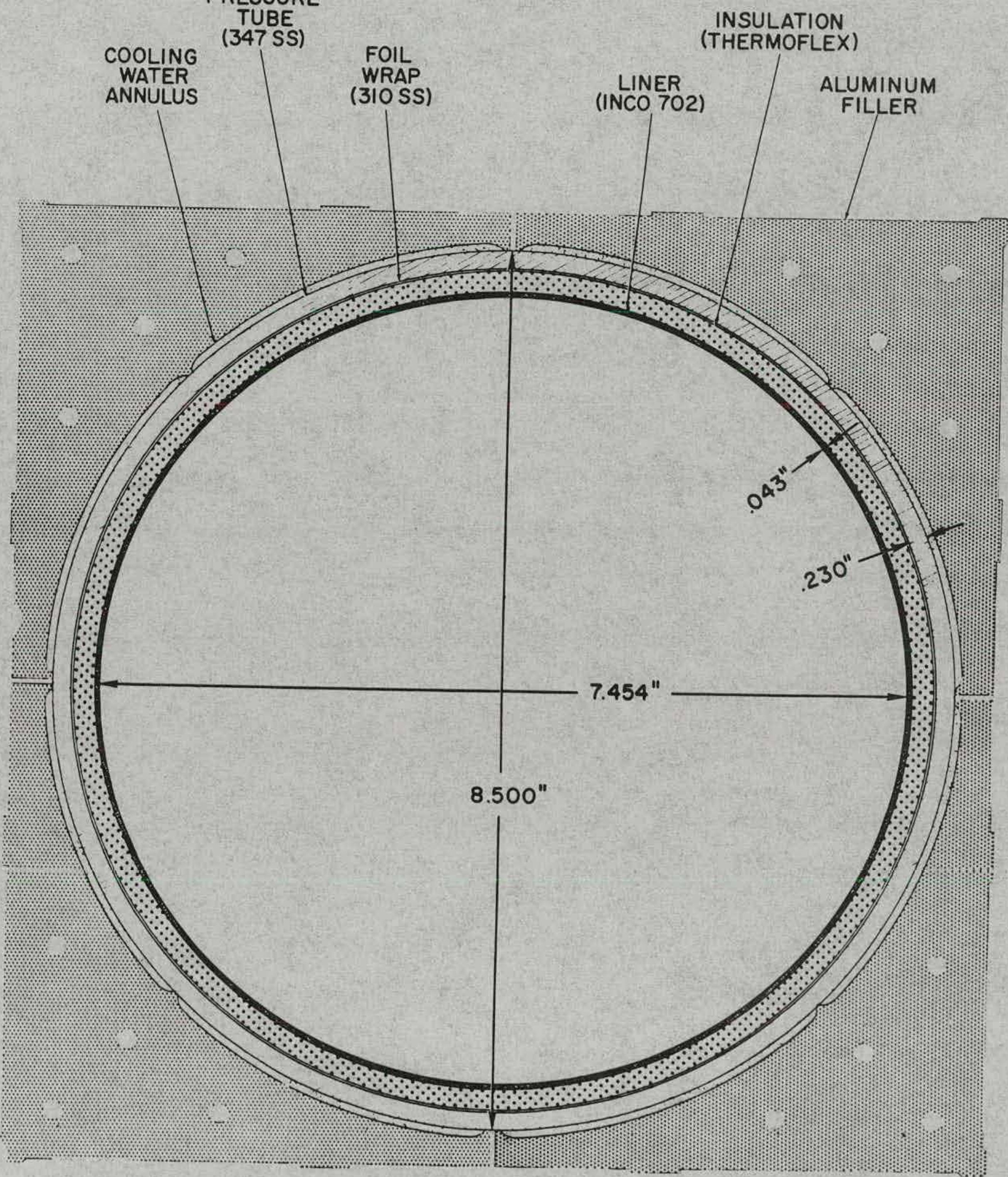


Fig. 2-9 - ETR 99 Facility Section Through Core (D.I. 341)

Part 2 - Dynamic Parameters

	Other Tests	Ceramic Fuel Tests
1. Maximum Pressure Obtainable	= 300 psig	300 psig
2. Approximate Atmospheric Pressure at ETR	= 12.2 psi	12.2 psi
3. Maximum Flow Obtainable	= 20 lb/sec	10 lb/sec
4. Minimum Preferred Flow	= 3.0 lbs/sec	3 lb/sec
5. Maximum Preheat Temperature	= 1120°F	1120°F
6. Average Temperature of Air Entering 99 Liner when no preheat being used	= 100°F	100°F

Part 3 - Sample Parameters

1. Maximum Sample Diameter = 7.263 ± .005 in.

   A check gauge consisting of 48-inch length of machined pipe has been provided to easily check proper fits. All test assemblies should be gauge checked prior to shipment to ITS.

2. Maximum Sample Length = 53.5 in.

   The withdrawal cask limits the maximum sample length. Also the diameter of the section at 53.5" from the bottom-most part of the sample is limited to 1.5" O. D. since this is the maximum cut obtainable with the cask shears.

3. Number of Thermocouple Outlets at Drawbar Junction Box = 90

   Present equipment provides for use of Pt/Pt - 10 Rh, Pt - 6 Rh/Pt - 30 Rh, and Chromel-Alumel sensor wires.

4. Number of Pressure Probes Outlets at Junction Box = 12

   At present, pneumatic probes and strain gauge transducers (latter located in drawbar junction box) are available. The following ranges of pressure measurements are provided:

   Strain Gauge Transducers: 0-350 psig, 0-100 psid, 0-10 psid and 0-2.5 psid. Any combination of these can be used.

   Pneumatic: 2 each at 350 psig, 1 each at 0-50 psid, and 1 each at 0-250" of water.

   Pressure tubing, 0.80" O.D., is used at the ETR and other sizes should be avoided.

5. Drawbar Dimensions

   The ETR 99 drawbar consists of two parts, the "X" configuration for location in the core region and the round tubular configuration. Adjacent to the upper end of the test assembly, the "X"-shaped drawbar is used to permit ample cooling of drawbar and instrumentation when sample is stored below the core; thus this portion of the drawbar is subjected to the high gamma heating rates (~ 7-10 watts gram) in the core region while the reactor is at full power. The dimensions of the "X" drawbar (Hastelloy X) are 1.5" wide x 0.063" thick x 48" long. The "X" drawbar is attached, at the upper neutron scatterer, to a round tubular drawbar (304SS) 1.250" O. D. x 0.125" wall x approximately 25' long. The tubular drawbar carries the instrumentation and extends vertically outside the reactor and terminates in the drawbar junction box.

ENGINEERING TEST REACTOR CRITICAL FACILITY

General Description

The Engineering Test Reactor Critical Facility, commonly designated as the ETRC, is an exact nuclear mockup of the core region of the ETR. It is located inside the MTR building at the National Reactor Testing Station. It was constructed to evaluate the flux variations that are to be expected in each ETR test cycle resulting from complexities of the various ETR experiments. Its prime objective is to provide long megawatt-day operation per core loading together with minimizing the flux variation throughout the core region. Factors that provide this are selection of most advantageous core fuel loading and program for reactor control rod motion.

Briefly, the ETR Critical is comprised of the ETR core mockup, located in a water pool, eleven feet deep. The reflector region is not an exact mockup of the ETR, since flux variations in this region do not substantially affect the flux within the core region. All sponsor facilities are an exact mockup of those contained in the ETR to duplicate the affect of flux perturbations.

ETR Critical Operating Policy

To evaluate the flux variations for each ETR test cycle, Phillips Petroleum Company requires a nuclear "mockup" of each experiment planned for the ETR core. (Those experiments planned for exposure in the reflector region do not require a nuclear "mockup.") The nuclear evaluation is performed by exposing the nuclear "mockup" in the sponsor's respective ETR Critical Test Facility. Phillips personnel conducted these experiments one to two weeks prior to each reactor test cycle starting date. Sponsors are required to provide the nuclear "mockup" assembly three weeks prior to each reactor cycle starting date together with the nuclear computations that compare the "mockup" to the experiment.

In order to compare the "mockup" to the experiment, it is necessary to homogenize the materials to obtain over-all absorption and scattering cross-sections. For purposes of illustration, the over-all cross-section is a summation of the volume fraction times the microscopic cross-section for the individual materials.

ETR CAPSULE-TYPE FACILITIES

General Discussion

As shown in Figure 2-2, the ETR lattice and reflector regions are composed of 3-inch x 3-inch grid work for housing fuel elements, control rods, and major loop type facilities. In addition to these, there are some 125-150 locations that house aluminum filler pieces for the conduction of capsule type experiments. Although there are many variations of capsule test facilities, a four-hole aluminum filler piece that houses an X-basket is the most commonly used for capsule irradiations. The capsule type irradiations may consist of three types, namely, 1) open-type capsules, 2) sealed-type capsules, and 3) instrumented capsules. A typical four-hole reactor filler piece showing X-basket and open-type test capsule is shown on Figure 2-10. Although a complete description of the capsule irradiation facilities is contained in IDO-16428, engineering data on the types commonly used by GE-ANP are presented.

Engineering Data - Four-Hole Filler Piece

Part 1 - Structural Items

An aluminum filler piece, containing four 1.312-inch I.D. x 37 inch long holes, is most commonly used in the ETR lattice and reflector region. Within each hole, a thin-walled aluminum sleeve (designated as an X-basket) is positioned and holds up to 36 inches of experimental capsules. The X-basket is 1.129-inch O.D. x 20 mils thick and contains four vertical grooves. These grooves are designed to center the capsules and thus insure water flow along the entire surface of the capsules. Capsules for this type of basket are limited to a maximum of 1.125-inch O.D. Capsules of lesser diameter will not be centered by the grooves and may rest against the wall of the basket thus minimizing the uniformity of cooling.

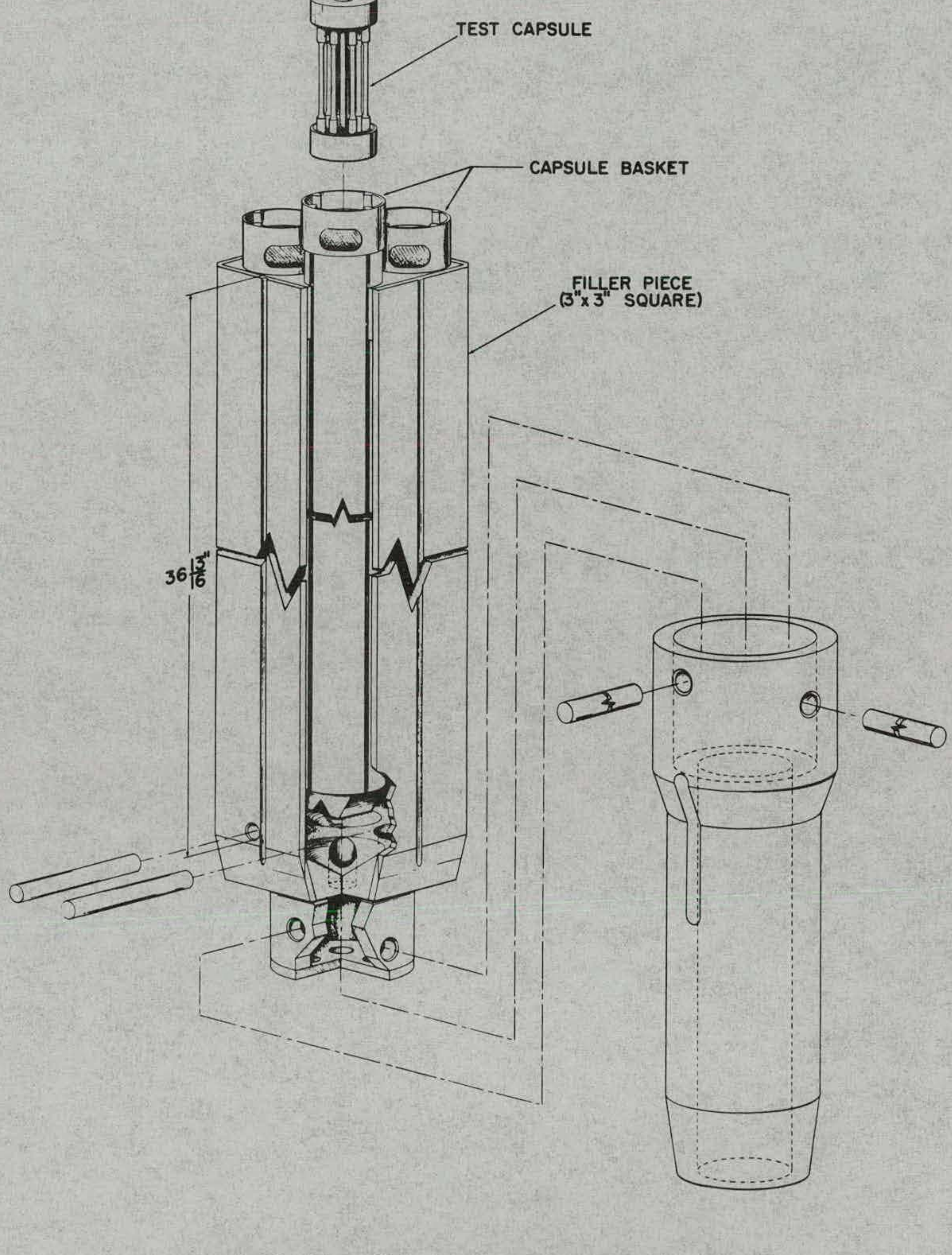


Fig. 2-10 - Four-Hole Reactor Filler Piece (D.I. 379)

Part 2 - ETR Dynamic Parameters

1. Nominal ETR Water Pressure, core in	= 200 psia
2. Nominal ETR Water Pressure, core out	= 145 psia
3. Nominal Coolant Water Pressure Drop	= 55 psia
4. Nominal Coolant Water Temperature, core in	= 110°F
5. Nominal Coolant Water Temperature, core out	= 140°F

Part 3 - X-Basket Dynamic Parameters

1. Nominal Coolant Water Flow between X-basket and 1.125" O.D. Capsule	= 17.2 gpm = 2.37 lbs/sec
2. Nominal Coolant Velocity between X-basket and 1.125" O.D. Capsule	= 22.6 ft/sec

Part 4 - Sample Parameters

1. Maximum Outside Diameter	= 1.125 in.
2. Maximum Length	= 36 in.
3. Length of Lead Tube (when used)	= 20 ft
4. Maximum O.D. of Lead Tube (when used)	= 0.75 in.
5. Maximum Thermocouple Leads	= 10

BIBLIOGRAPHY

1. "Design Summary and Status Report, GE-ANPD Irradiation Facilities, Engineering Test Reactor," E. F. Thurston, J. D. Provost.
2. "GEEL Facilities Description Report," L. Ghan, J. D. Provost, 1959 (DC 59-11-706).
3. "Operations Manual for General Electric Experimental Loops in the Engineering Test Reactor," M. Johnson, J. D. Provost, 1960.

SECTION III - LOW INTENSITY TEST REACTOR

GENERAL DISCUSSION OF THE LITR

General Description

The Low Intensity Test Reactor is located at the X-10 area of the Oak Ridge National Laboratory (ORNL). The reactor is owned by the U. S. Atomic Energy Commission and the Union Carbide Corporation is the authorized operator. The Laboratory is situated in eastern Tennessee and is approximately 28 miles from Knoxville and 12 miles from the town of Oak Ridge. Visitors to the LITR reside at either of the cities. Figures 3-1 and 3-2 present a general layout of the ORNL site.

The LITR was intended originally as a mockup for the MTR and early literature makes reference to the "MTR Mockup" rather than LITR. However, after the mockup had served its original purpose, it was apparent that a great deal of additional information could be obtained from the reactor. Accordingly, it was decided to operate the reactor as a research tool. The LITR operated at 1500 kw for several years and was then increased to its present level of 3000 kw on September 2, 1953.

The LITR is similar to the MTR in that it is a light-water moderated, heterogeneous, enriched reactor. The fuel elements are vertical plate assemblies with each plate composed of aluminum-clad, uranium-aluminum alloy. The fuel plates are spaced to allow the passage of cooling water which also serves as a moderator.

Figure 3-3 is a simplified plan view of the reactor core. The enriched lattice is surrounded by a water-cooled beryllium reflector which, in turn, is enclosed by the tank system. Outside the tank, the shielding is composed of a 4" layer of sand backed up by high-density concrete blocks. A side view of the reactor is shown in Figure 3-4 to illustrate the core, shield, and tank system.

The reactor can operate with 20 fuel elements of approximately 200 grams of U^{235} per element. Control is effected by 3 safety-shim rods and 1 regulating rod. In addition to the facilities within the core, 12 experimental facilities are provided which consist of 6 horizontal beam holes having internal neutron fluxes ranging from 8×10^{12} to 3×10^{13} n/cm^2/sec, 2 pneumatic tubes, and 4 low-flux slant holes.

General Electric occupied core position 4-8, commonly called C-48. See Figures 3-3, 3-4, and 3-8. The C-48 facility, being a low-flux, small-diameter hole, has been used primarily for evaluation of new materials or fabrication techniques. Because of a one-week operating cycle, many tests can be screened. However, the LITR is not suitable for tests where extended exposure or flux levels greater than 2×10^{13} n/cm^2/sec is desired.

LITR Operating Policy

The reactor operates on a nominal 7-day cycle with six days at power and one day to handle experiment change-outs, insertions, etc. The reactor is shut down on Monday evening with Tuesday as the change-out day. Usually the reactor is operating at full power by Tuesday evening.

Samples to be tested in the C-48 facility of the LITR were handled by the G-E Radiation Testing Unit at Oak Ridge. The test capsule design, instrumentation, and fabrication were handled at Oak Ridge by the Radiation Testing Unit with the test requestor supplying the sample.

In general, a test requestor should supply his sample at least one week prior to the scheduled test date.

The test objectives and planned test procedures were presented to the LITR Reactor Safeguards Committee for approval by the G-E Radiation Testing Unit at Oak Ridge. The test requestor should be in a position to supply, upon request, all available back-up data pertinent to the sample.

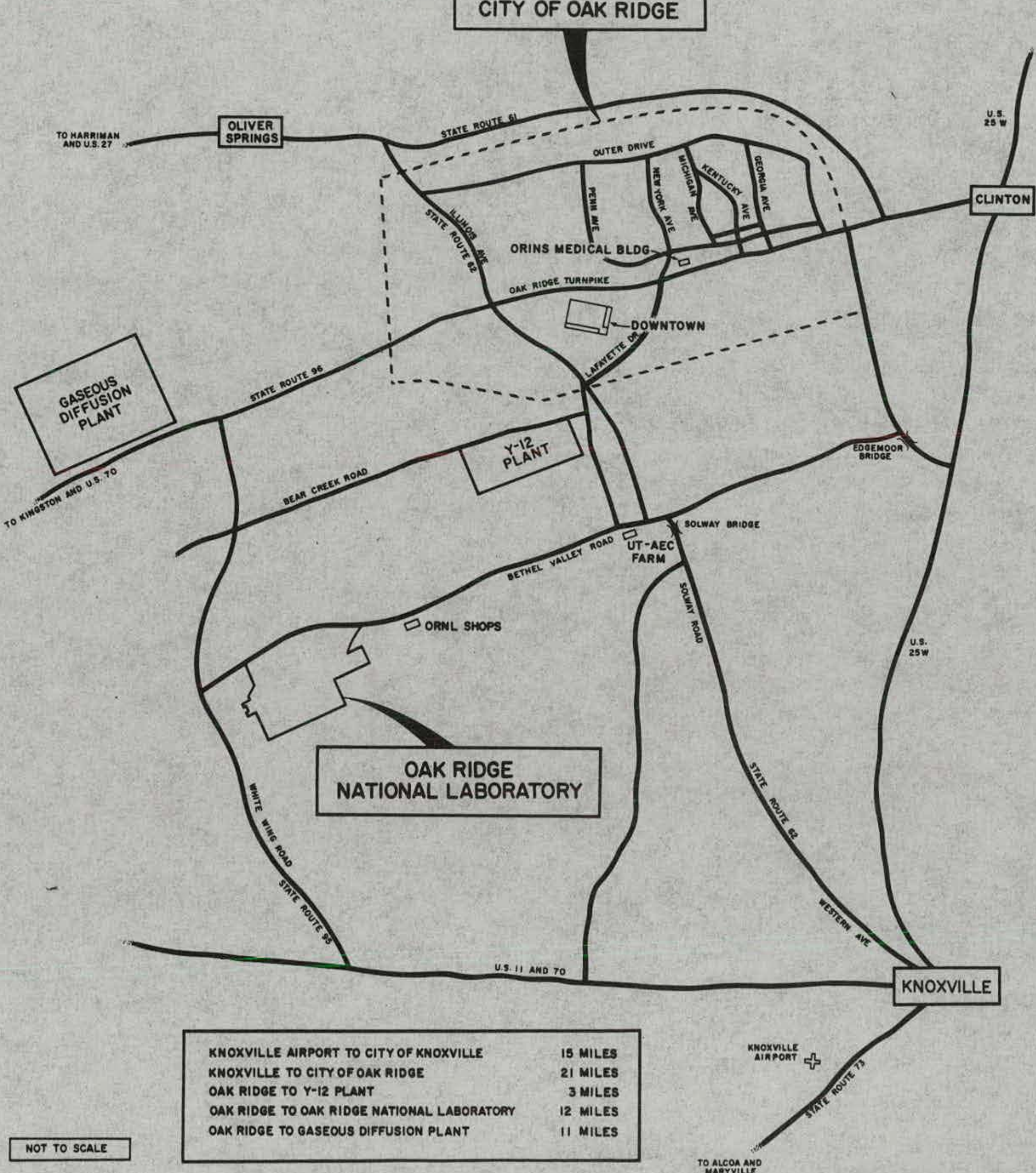


Fig. 3-1 - Map of Oak Ridge and Vicinity (D.I. 231)

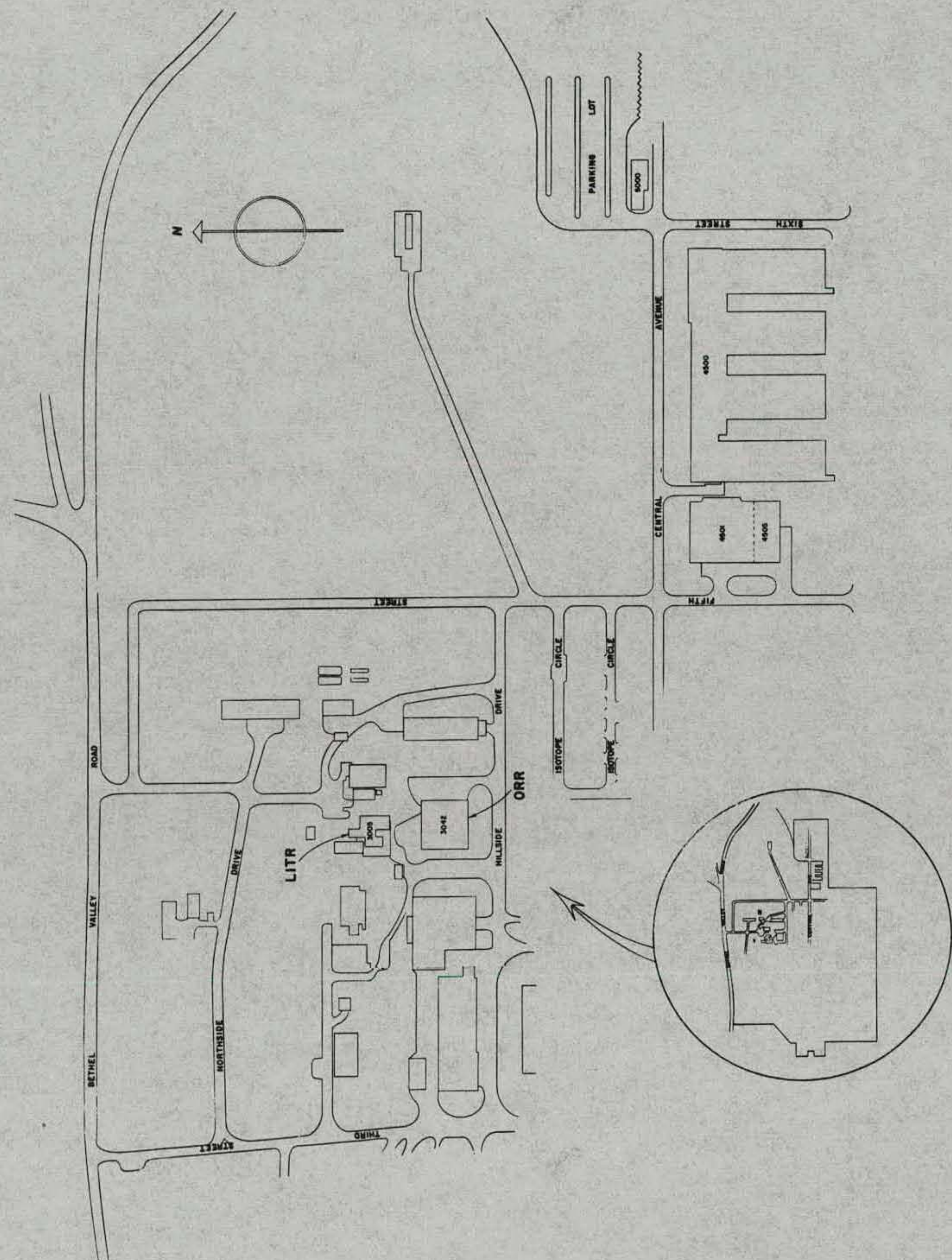


Fig. 3-2 - Map of Oak Ridge National Laboratory (D.I. 232)

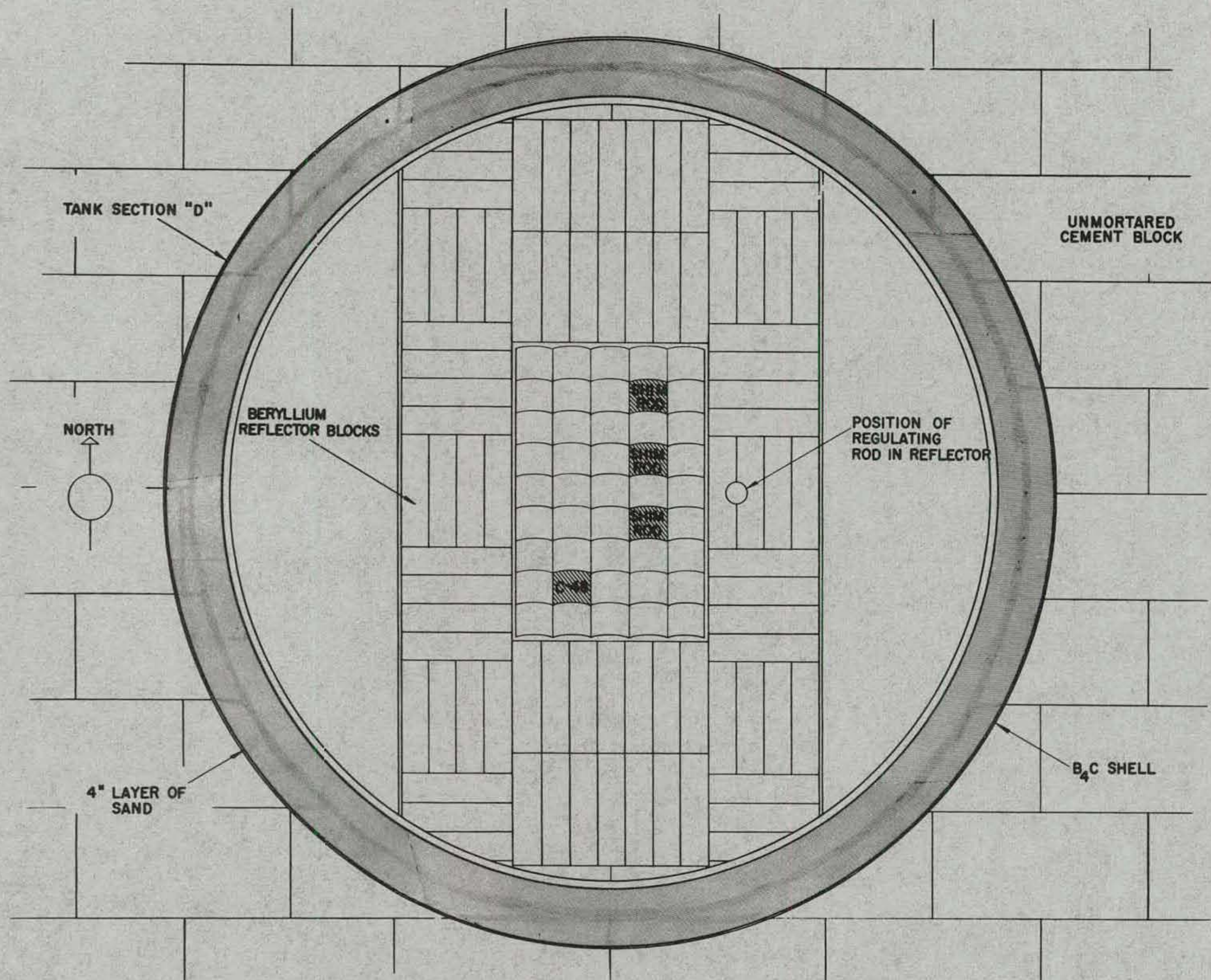


Fig. 3-3 - Plan View of Reactor Core and Tank Section (D.I. 294)

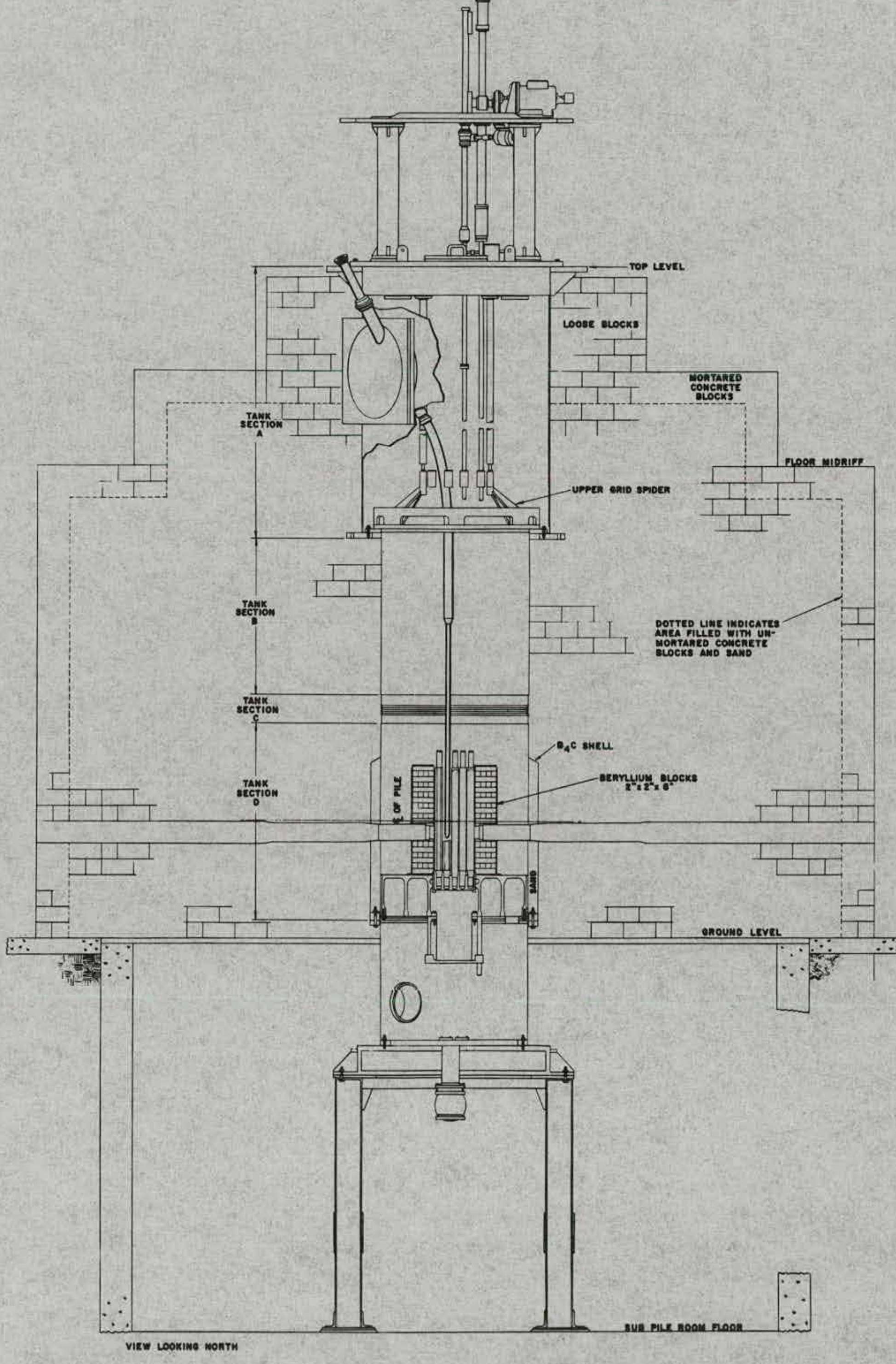


Fig. 3-4 - Section of LITR Showing ANP C-48 Test Facility (D.I. 244)

Engineering Description - C-48 Facility

The LITR C-48 loop is a double-curvature tube that enters the side of the tank at the top of the reactor. It then "snakes" through the upper spider and dead-ends in the reactor core at the C-48 position. Figures 3-3 and 3-4 illustrate a plan view and a side view of the LITR. Figure 3-4 clearly shows the C-48 facility tube to be a stepped assembly. The tube is a welded assembly consisting of a piece of 4.5-inch O.D. aluminum tubing reducing to a 2.75-inch O.D. aluminum length that rests in the core. As can be seen in Figure 3-4, the transition occurs in the "B" section of the reactor tank. The dead-ended bottom of the tube ends nominally 5.5 inches below the centerline of the core.

Figure 3-5 depicts a current LITR capsule assembly. The capsule is provided with two full-length pieces of flexible hose to lead sample air in and out of the assembly. The hoses must be flexible to allow the assembly to pass the compound curves in the facility tube. The capsule is inserted in the tube, fed down the passage till the top flange mates with the reactor tank manhole lateral. By use of a marmon clamp, a seal is effected at this point and the assembly is ready for test.

With the assembly in position, the capsule rests in the hole as shown in Figure 3-6, for a typical capsule design. Briefly, sample air is piped down the inlet bellows to the capsule can. Entering the can, the air passes down the concentric annulus to the bottom inlet holes. Thus the flowing air cools the outer steel can and prevents facility tube damage. From the bottom holes, the air flows upwards through the sample and exits through the flexible exhaust bellows.

Many innovations can be used to modify this basic design, such as the addition of air preheaters to increase sample operating temperatures.

In addition, it is not necessary that the sample capsule design utilize the double-flexible-hose concept. Some capsules have employed a single-hose technique whereby the facility tube was pressurized and inlet holes at the bottom of the capsule permitted air to flow through the sample and leave through the exhaust hose.

Engineering Data - LITR

Part 1 - Structural Items

1. Material of C-48 Facility Tube

   The material is 2S aluminum GE B12B3A.

2. Dimensions of Facility Tube

   Figure 3-7 depicts a simplified view of the tube. It is seen that the tube consists of a six-foot length of 2.75 in. O.D. × .125 in. wall tube joined to a 4.50-in. O.D. × 0.25-in. wall tube by means of a conical transition piece. The 2.75-in. O.D. tube is straight and fits into the core piece. The 4.50-in. O.D. tube has two 96-in.-bend radii stepping the facility tube centerline from the C-48 position closer to the reactor tank. A 79-in.-bend radius in a plane at 45° to the 96-in. radii plus the use of a 17-in. bellows section allows the facility tube to exit at the reactor manhole lateral.

3. Dimensions of Active Core

   The minimum critical dimensions are 9 in. wide × 24 in. high × 24 in. long. These dimensions correspond to 20 fuel elements and 3 rods in the 5 × 9 lattice array. However, in the present core the number and spacing of fuel, beryllium, etc., is arranged to accommodate LITR users. A recent core loading is shown in Figure 3-8.

4. Reflector

   The reflector consists of beryllium blocks, 2 in. × 2 in. × 8 in. long, stacked around periphery, with water on top and bottom.

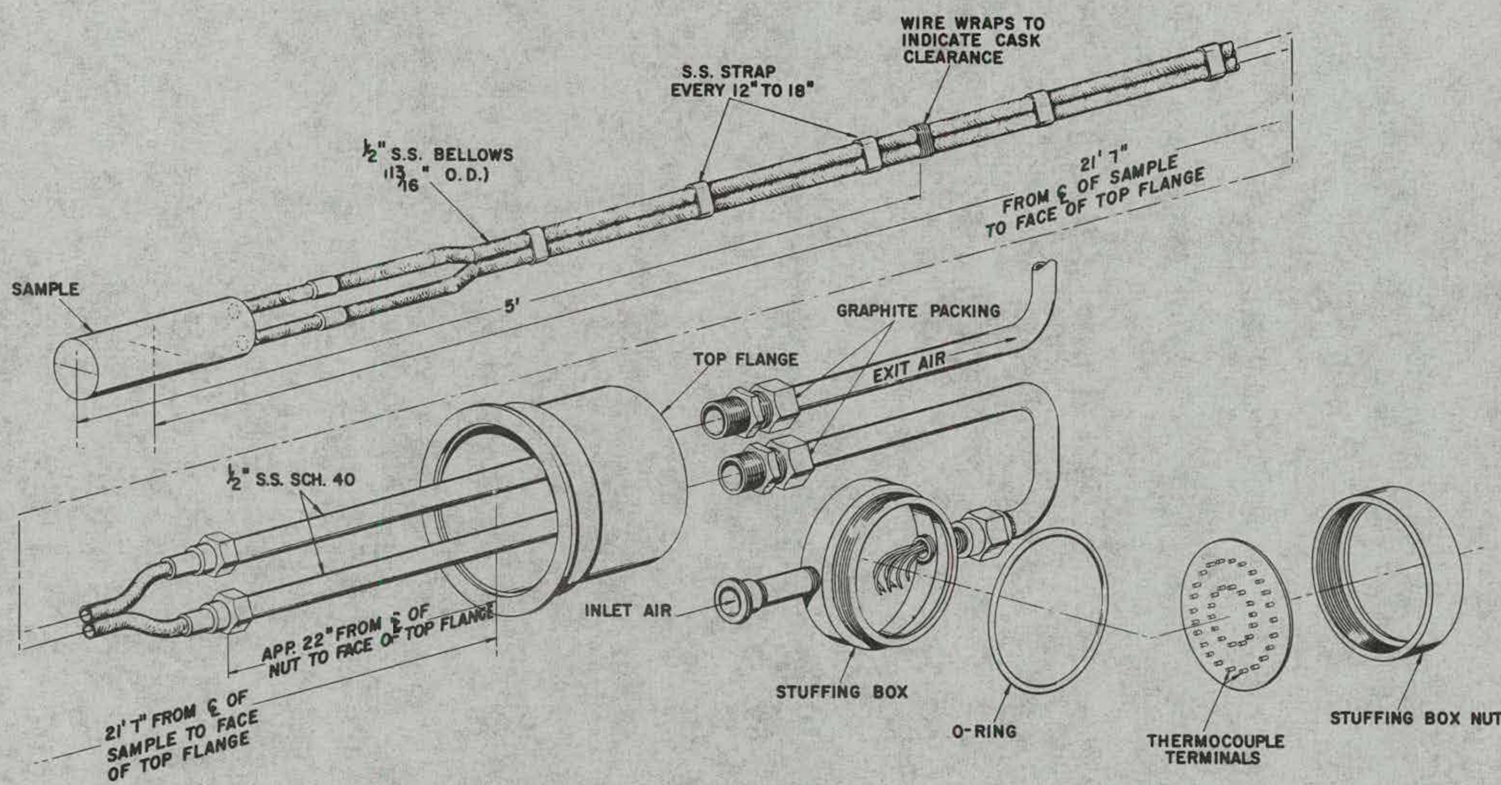


Fig. 3-5 - Typical LITR Capsule Assembly (D.I. 235)

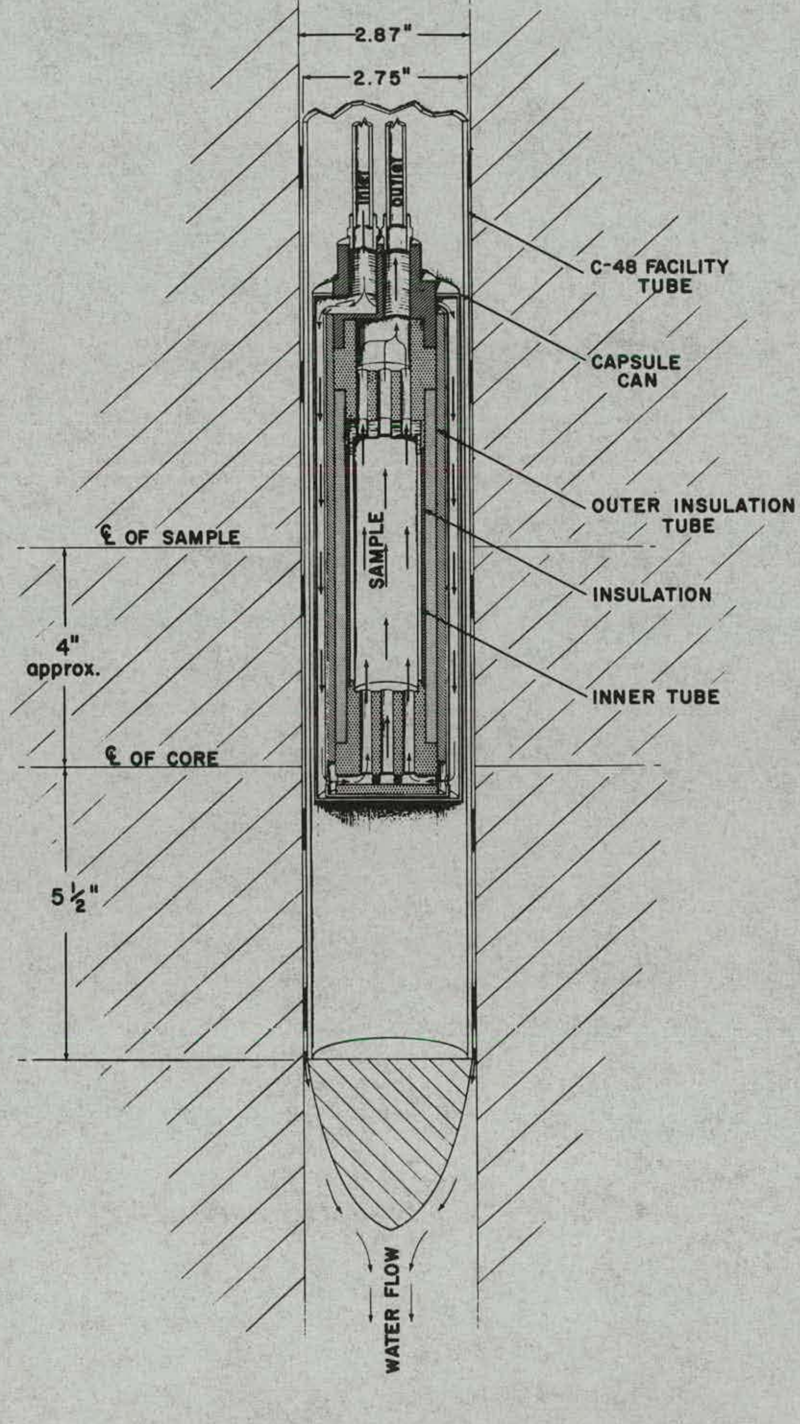


Fig. 3-6 - LITR Capsule Positioned in Facility (D.I. 308)

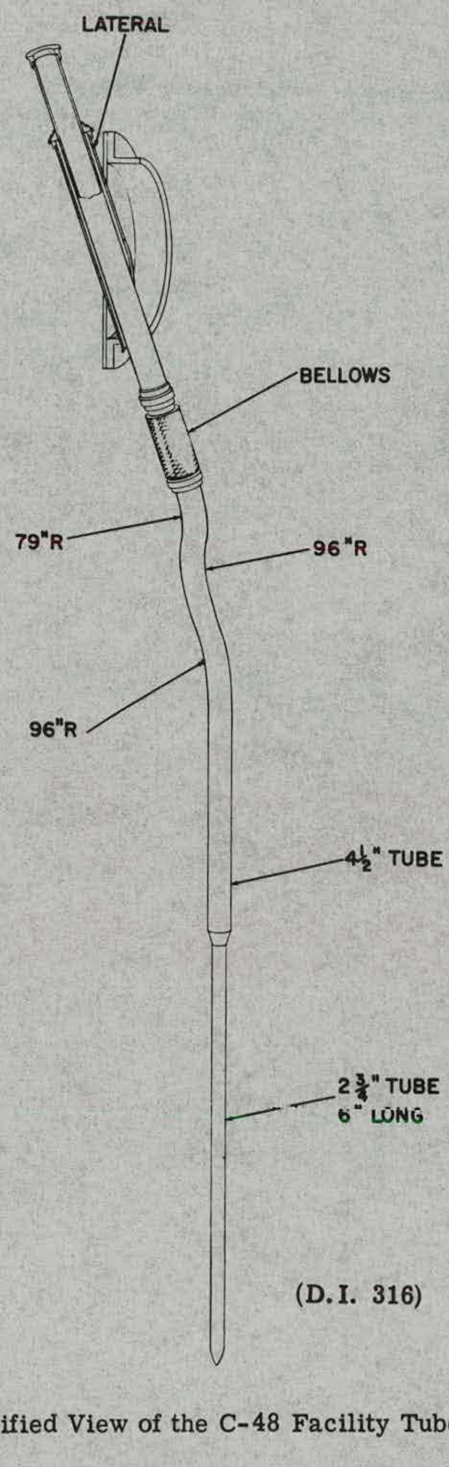


Fig. 3.7 - Simplified View of the C-48 Facility Tube (D. I. 316)

	5	4	3	2	1
1	B	FX	F	F	F
2	B	SP	F	S	F
3	ISO	SP	F	F	F
4	B	SP	F	S	F
5	F	SP	F	F	F
6	F	SP	F	S	F
7	SP	B	F	F	F
8	SP	C-48	FX	B	FX
9	F	B	ISO	ISO	F

CORE LOADING AS OF DECEMBER 1959

NORTH

B - BERYLLIUM
F - FUEL
FX - EXPERIMENTAL PARTIAL FUEL
FD - DEPLETED FUEL
ISO - ISOTOPE STRINGER
SP - SPECIAL PIECE
SC - STORAGE CAN
S - SHIM SAFETY, WHICH IN ADDITION TO CD CONTAINS FUEL.

Fig. 3-8 - Reactor Core Loading as of April 1960 (D.I. 277A)

5. Shield

The shield consists of high-density concrete blocks and sand. The 4-in. layer of sand is directly adjacent to the reactor tank and is held in place by a boron carbide shell. Outside of the boron carbide, the concrete blocks are stacked. Minimum thickness of the shield is 10.5 ft.

6. Reactor Tank

The tank is assembled, as shown in Figure 3-4, in six sections referred to as "A," "B," "C," "D," "E," and "F." Sections A and B are supported from above by structure while "D," "E," and "F," are supported from below. The "C" section is a stainless steel bellows expansion section. The dimensions of the sections are:

"A" section = 70.0 in. I.D. × 11 ft - $6\frac{7}{8}$ in. high
"B" section = 55.0 in. I.D. × 5 ft - $3\frac{1}{4}$ in. high
"C" section = 55.0 in. I.D. × 11.0 in. high
"D" section = 54.25 in. I.D. × 6 ft high
"E" section = 54.25 in. I.D. × 3 ft - $11\frac{1}{4}$ in. high
"F" section = 55.25 in. I.D. × $11\frac{1}{8}$ in. high

Part 2 - Dynamic Parameters

1. Maximum Pressure Obtainable at Sample = 100 psig
2. Approximate Atmospheric Pressure at ORNL = 14.6 psi
3. Maximum Flow Obtainable = 100 scfm = 0.128 lb/sec
4. Maximum Allowable Temperature of Facility Tube at Surface Cooled by Water = 200°F
5. Inlet Air Temperature = No preheating of air available at present.

However, air heaters have been used with samples with very satisfactory performance.

Part 3 - Nuclear Parameters

Past flux determinations in the C-48 facility, with and without a test sample, have indicated little, if any, variation in the flux profile or magnitude. Because of this, flux determinations prior to conducting a test are not usually made. Figures 3-9 and 3-10 indicate recent flux results in the facility. Figure 3-8 shows the results from a flux wire irradiated in the C-48 facility with no test sample in place. It is seen that the flux is generally above 1.6×10^{13} from tube bottom to 8 inches above the bottom, and then decreases. In Figure 3-10 is shown a second flux map taken by positioning a wire on the outside of a typical LITR sample. The wire agrees well with Figure 3-9 and presents an expanded scale in the area of the sample.

In reference 10, a nuclear heating value of 0.51 watts/g has been given for lattice position C-44 and it is reasonable to assume that the C-48 facility would be quite similar. However, for design purposes a value of 1.0 watt/g has been extensively used.

Part 4 - Sample Parameters

1. Maximum Sample Diameter

The maximum diameter is controlled by the ability of the sample to negotiate the 79 in. bends. Most recent samples were 2.375/2.385 in. O.D.

2. Maximum Sample Length

Sample length can be varied depending on the "O.D. - length" combination that can negotiate the facility tube bends. However, the maximum length is usually determined by the pattern of the flux zone in the hole which is considered fairly flat for 12 inches.

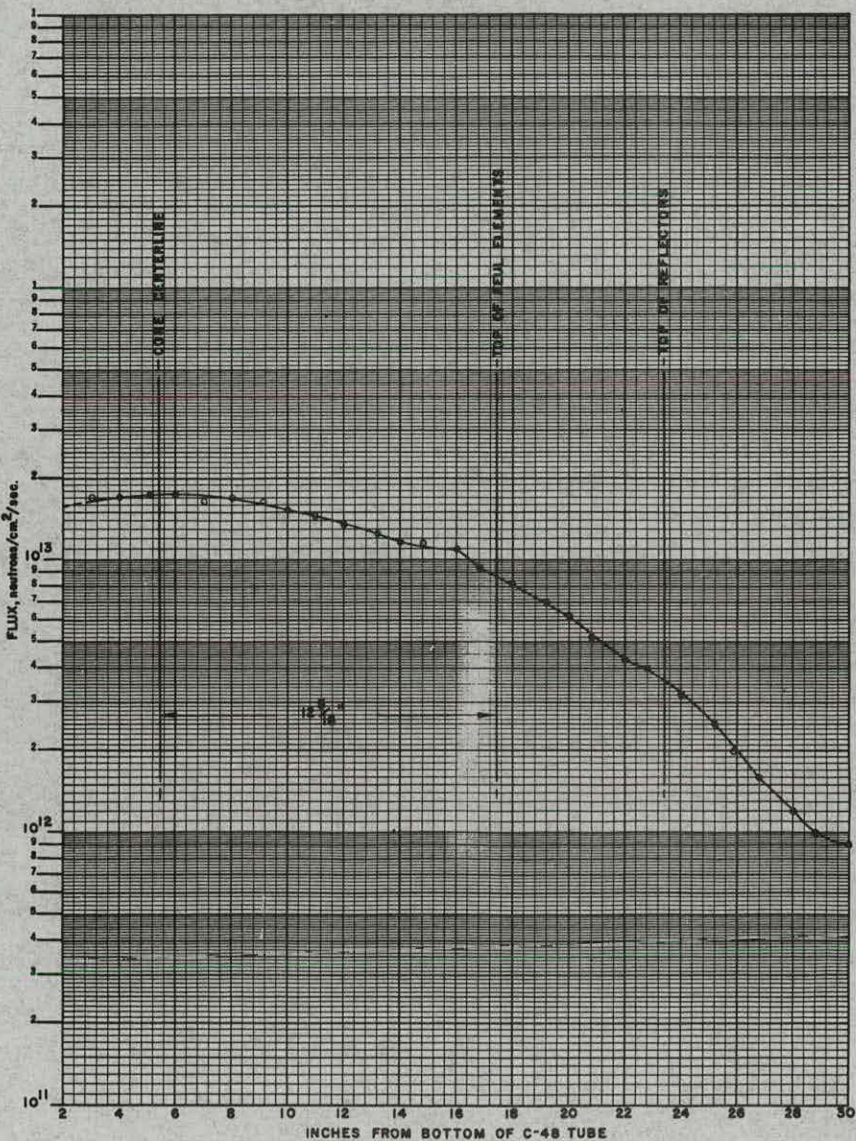


Fig. 3-9 - Unperturbed Flux Map of C-48 Facility (D.I. 250)

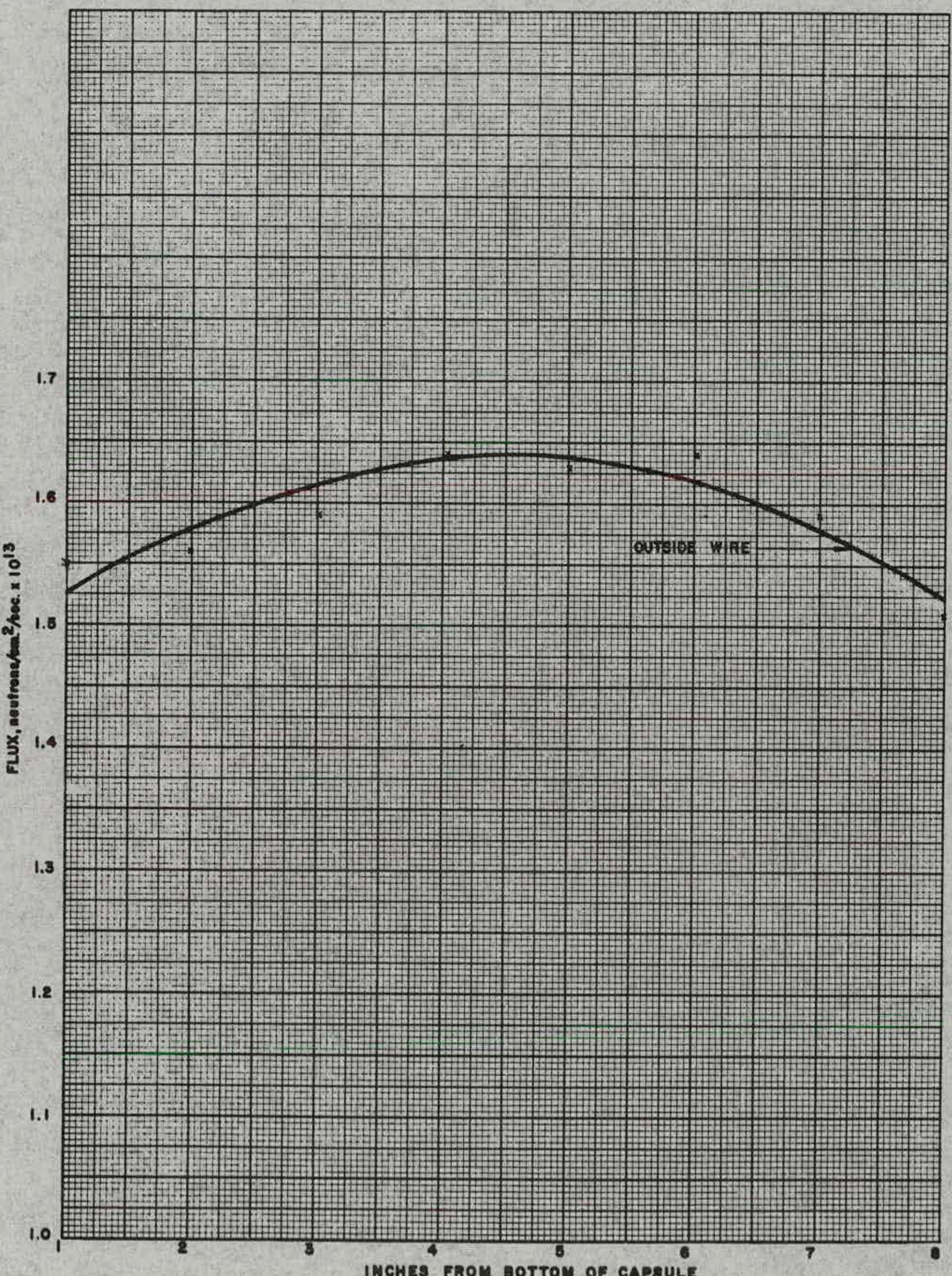


Fig. 3-10 - C-48 Flux Profile as Obtained from Wire on Outside of Sample Capsule (D.I. 279)

3. Sample Thermocouples

There is no specific limit to the maximum number of thermocouples that can be monitored because recorders are available for samples requiring numerous points. For example, 19 Pt/Pt 10 Rh or 19 chromel-alumel thermocouples are easily handled.

4. Sample Pressure Tubes

At present no specific provision exists for a specified size or type of sample pressure-probe tubing. A specific sample instrumentation request would have to be evaluated to determine if the size of hoses, thermocouple bundle, and pressure probes are limited by spatial restrictions. However, a number such as 4 - 0.080-in.-O.D. pressure-tubing leads (a common size) is not excessive.

5. Sample Flexible Hose

On applications where a single hose is used as an exit duct, a 3/4-in. metal braided flexible hose is commonly used.

On applications where an inlet and an exit hose are used, a 1/2-in. metal braided flexible hose is commonly used for both ducts.

6. Sample Flux Wires

Several techniques can be employed to measure flux in the LITR. Wires, such as 0.020-in.-diameter cobalt, can be installed, irradiated and withdrawn prior to the start of the regular cycle. For tests requiring a value for nvt, foils of various materials can be attached to the sample and counted after test.

Part 5 - Facility Instrumentation

The C-48 facility has instruments to measure pressure, temperature, flow, and fission products. A simplified diagram of the instrumentation layout is shown in Figure 3-11.

Referring to the figure, plant supply air is available at 100 psig and is piped to a 35 cubic foot storage tank. The tank dampens compressor surges and provides flow for minutes after a power supply failure. A small stand-by compressor is hooked to the tank and starts automatically in case of plant air supply pressure loss. Leaving the storage tank, air is led through a water trap and passed through alumina-filled air dryers. The dryers are piped in parallel and, while one is in operation, the other can be reactivated by electric heaters.

Leaving the dryers, the air's pressure is controlled by a pressure regulator valve prior to entering the flowmeters. The pressure can be controlled from 2 to 100 psig. Depending on the amount of air required, the air will be routed through a 0.5 to 5 scfm Fischer and Porter flowmeter or through a 5 to 50 scfm Fischer and Porter flowmeter. The test supply pressure is read beyond the flowmeters. The air then enters the C-48 facility tube and passes through the sample.

Leaving the sample, the air exits the reactor through a flexible hose connected to a 3/4-in. stainless steel pipe which runs down the side of the reactor into the off-gas system. In the off-gas system, the exhaust air is monitored by an ionization chamber (designated No. 1 in the figure) for gross activity. Downstream of the chamber, taps are installed for air sampling points and use of a fission gas detector. The theory and operation of this detector are explained in reference numbers 1 and 2. Beyond the sampling points, the flow is again monitored by an ionization chamber and is controlled by a flow control valve. Depending on the contamination of the exhaust air, the flow may be diverted either through double charcoal filters or through a bypass loop around the filters. Beyond the filter-bypass loop, a Chemical Warfare Service filter No. 6 screens the total flow and a third ionization chamber scans the flow prior to leaving the LITR system.

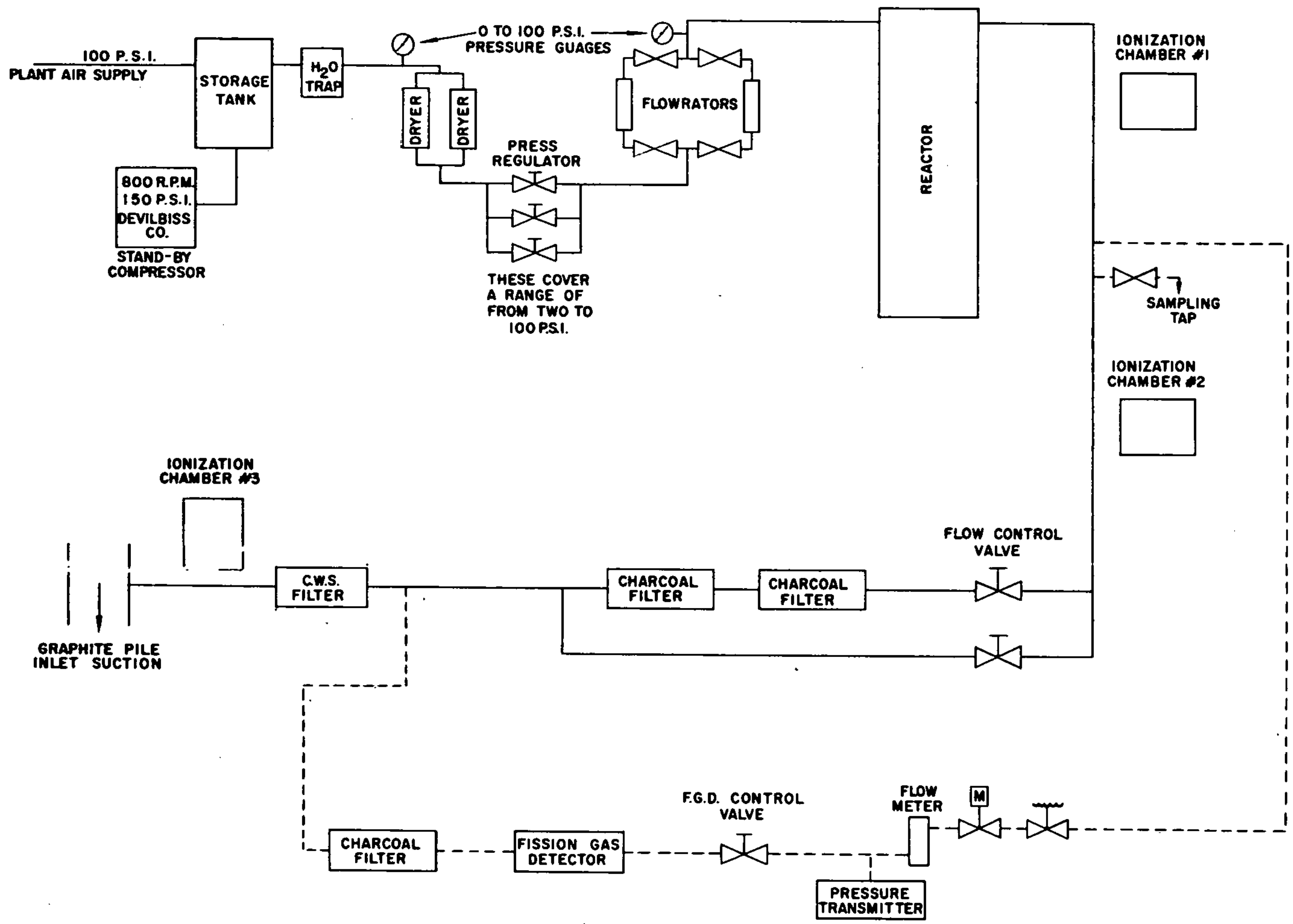


Fig. 3-11 - Instrumentation Diagram of C-48 Facility (D.I. 287)

Beyond the LITR system, the exhaust flow enters the inlet suction duct of the Graphite Pile Reactor which is located nearby. Here the LITR flow is mixed with the large volume cooling flow of the Graphite Pile Reactor. Passing through the Graphite Pile, the exhaust flow exits to the atmosphere from the tall Graphite Pile chimney.

Notation - Abbreviations

℄	-	centerline
kw	-	kilowatt
LITR	-	Low Intensity Test Reactor
MTR	-	Materials Test Reactor
ORNL	-	Oak Ridge National Laboratory
ORR	-	Oak Ridge Research Reactor
$n/cm^2/sec$	-	neutrons per square centimeter per second
nvt	-	neutrons per square centimeter
scfm	-	standard cubic feet per minute
sch 40	-	schedule 40 pipe designation
ss	-	stainless steel
X-10	-	Area designation at Oak Ridge National Laboratory
Y-12	-	Plant designation at Oak Ridge National Laboratory

BIBLIOGRAPHY

1. Collins, E. S., Conn, P. K., and Trice, J. B., "Fission Product Monitoring Techniques in Gas Cooled Reactors," General Electric Aircraft Nuclear Propulsion Department, June 17, 1959.

2. Stevenson, D. B., "Radiation Testing of an Intentionally Defective Fuel Element LT-6-6," Oak Ridge National Laboratory, ORNL 57-2-111, February 25, 1957.

3. Argonne National Laboratory and Oak Ridge National Laboratory, Materials Testing Reactor Project Handbook, ORNL 963, May 7, 1951, Technical Information.

4. Glasstone, Samuel, "Principles of Nuclear Reactor Engineering," D. Van Nostrand Co., 1955

5. Weills, J. T., "Research Pile Experimental Facilities," Oak Ridge National Lab., CF 47-4-34.

6. Beall, S. E., Breazal, W. M. Briggs, R. B., Callikan, A. D. and Jordan, W. H., "Interim Report of Neutron and Gamma Experiments on the MTR Mockup," Oak Ridge National Lab., CF 50-5-140.

7. Cole, T. E., "Proposal for Operation of LITR at Higher Power Levels," Oak Ridge National Lab., CF 53-2-115

8. Beloga, M. W., Mulvihill, R. J., and Zonis, I. S., "Determination of Power Level for LITR at Oak Ridge," Massachusetts Inst. of Tech., Engineering Practice School, K-864

9. Rupp, A. F., and Cox, J. A., "Operation of the ORNL Graphite Reactor and the LITR 1954," Oak Ridge National Lab., ORNL 1866

10. Rupp, A. F. and Cox, J. A., "Operation of the ORNL Graphite Reactor and the LITR 1955," Oak Ridge National Lab., ORNL 2071

SECTION IV-OAK RIDGE RESEARCH REACTOR

GENERAL DISCUSSION OF THE ORR

General Description

The Oak Ridge Research Reactor (commonly referred to as ORR) is adjacent to the LITR at the Oak Ridge National Laboratory (ORNL). The reactor is owned by the U. S. Atomic Energy Commission with the Union Carbide Nuclear Company as the duly authorized operator. Oak Ridge National Laboratory is located in eastern Tennessee approximately 28 miles from Knoxville and 12 miles from the town of Oak Ridge. Visitors to the ORR reside at either of the cities. Figures 4-1 and 4-2 show the general layout of the ORNL site.

The reactor employs a heterogeneous core utilizing enriched uranium MTR type fuel elements. Ordinary water acts as both coolant and moderator with beryllium and water as a reflector. The reactor core is housed near the bottom of a 15-foot high by five-foot diameter aluminum tank. The tank is located in a pool of demineralized water (approximately 21' long x 10' wide x 28' 8" deep) with the tank top 14 feet below the pool surface. The water depth above the tank provides the main shielding during operation and during the removal of fuel, experiments, control rods, etc. Figure 4-3 shows a cut of the reactor within the pool. The G-E facility tube is shown along with a portion of the off-gas piping. The F-2 facility is one of approximately 15 core positions presently available for experiments. Because the control rod drive mechanism is located below the reactor, it is possible to consider experiments in any one of the 63 (7x9 lattice) possible fuel or reflector spaces. Rabbit tubes, beam holes, and pool side facilities are also available to experimenters.

The reactor was initially intended to operate at 20 MW but has now increased to 30 MW. Criticality was obtained on March 21, 1958, and operation at 20 MW attained on April 29, 1958. A typical 20-MW core is shown in Figure 4-4. The core is a 7 x 9 lattice with numerous holes for experiments. Positions in the lattice are identified by a letter-number designation. When viewing the core, as pictured in Figure 4-4, numbers indicate positions along the abscissa and letters refer to positions along an ordinate axis.

The loop used by GE-ANPD is located at core position F-2 and is seen to be surrounded by fuel, beryllium, and other experimental holes. The neutron thermal flux is stated as 8.0×10^{13} n/cm^2/sec for a 20 MW core with greater flux anticipated with 30-MW operation.

ORR Operating Policy

Prior to August 1960 the reactor had been operating at 20 MW on a regular 4-week schedule. The reactor was on-power for three weeks with one week down for refueling, change-outs, and maintenance. Shutdown of the reactor occurred late Sunday evening with the start of change-outs and refueling on Monday morning. Depending on the extent of the work required during a shutdown, start-up could be attained as early as Thursday of the shutdown week. From the 4-week cycle, 500 hours was about the maximum attainable time a sample could be tested.

Operation at 30 MW began in August 1960 and the cycle duration was increased to eight weeks. As a result of the increased power and longer cycle life, generally, two or more refueling shutdowns are required during the cycle. Irradiation tests are not removed from the reactor during the refueling shutdowns.

When all of the experiments have been installed, the reactor is brought to an operating level of 5 to 10 kw. The purpose of this low-level start-up is to determine core criticality and is not a flux run. Flux runs for calibrating flux wires are not conducted on a routine basis, but may be requested.

After the 10-kw level, which usually lasts about 30 minutes, the reactor is run for 30-45 minutes at about 50% power. Heat-power measurements for instrument calibration are made during this time. The reactor is then brought to the 30-MW level and operates for the rest of the cycle.

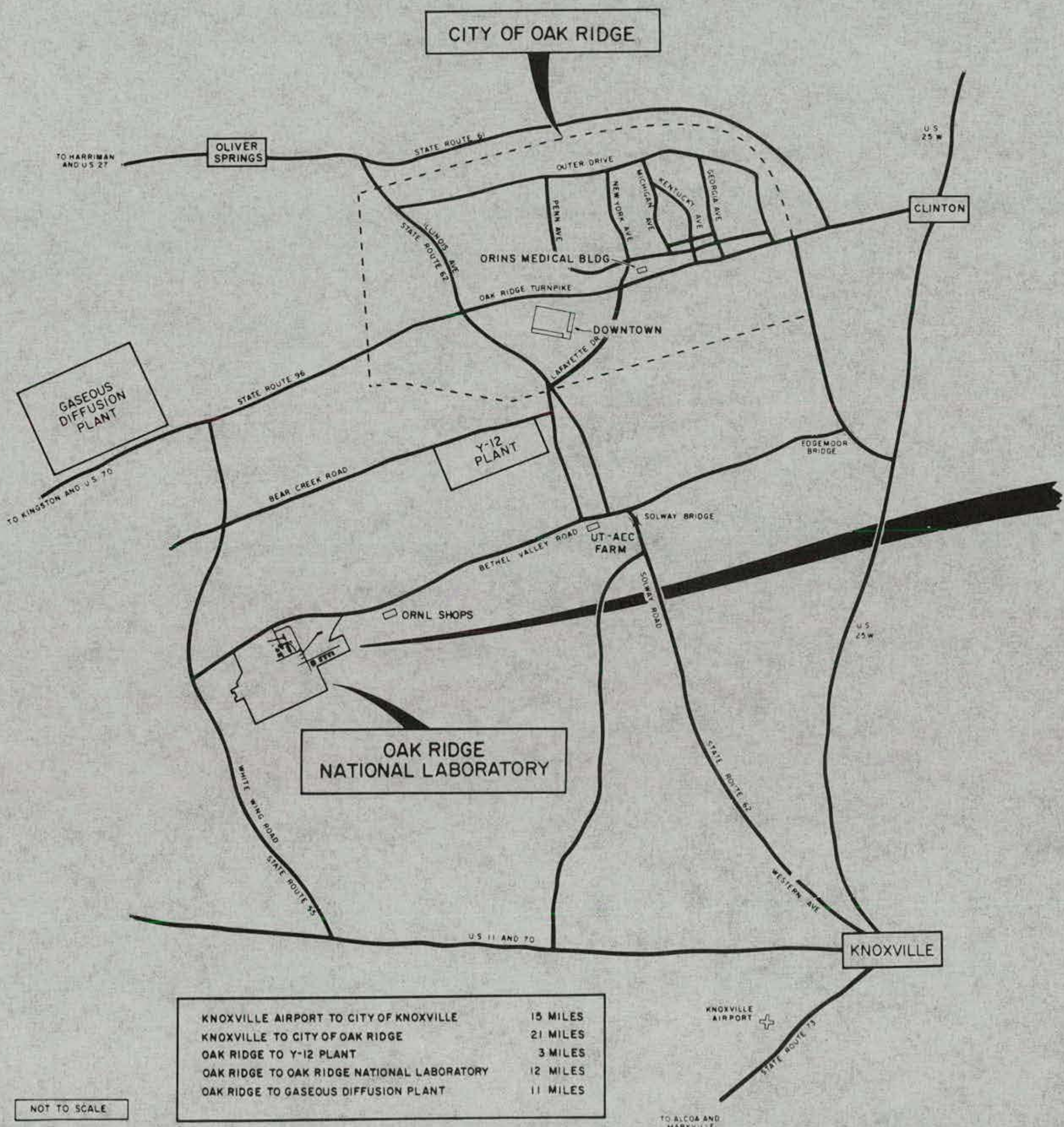


Fig. 4-1 - Map of Oak Ridge and Vicinity (D. I. 231A)

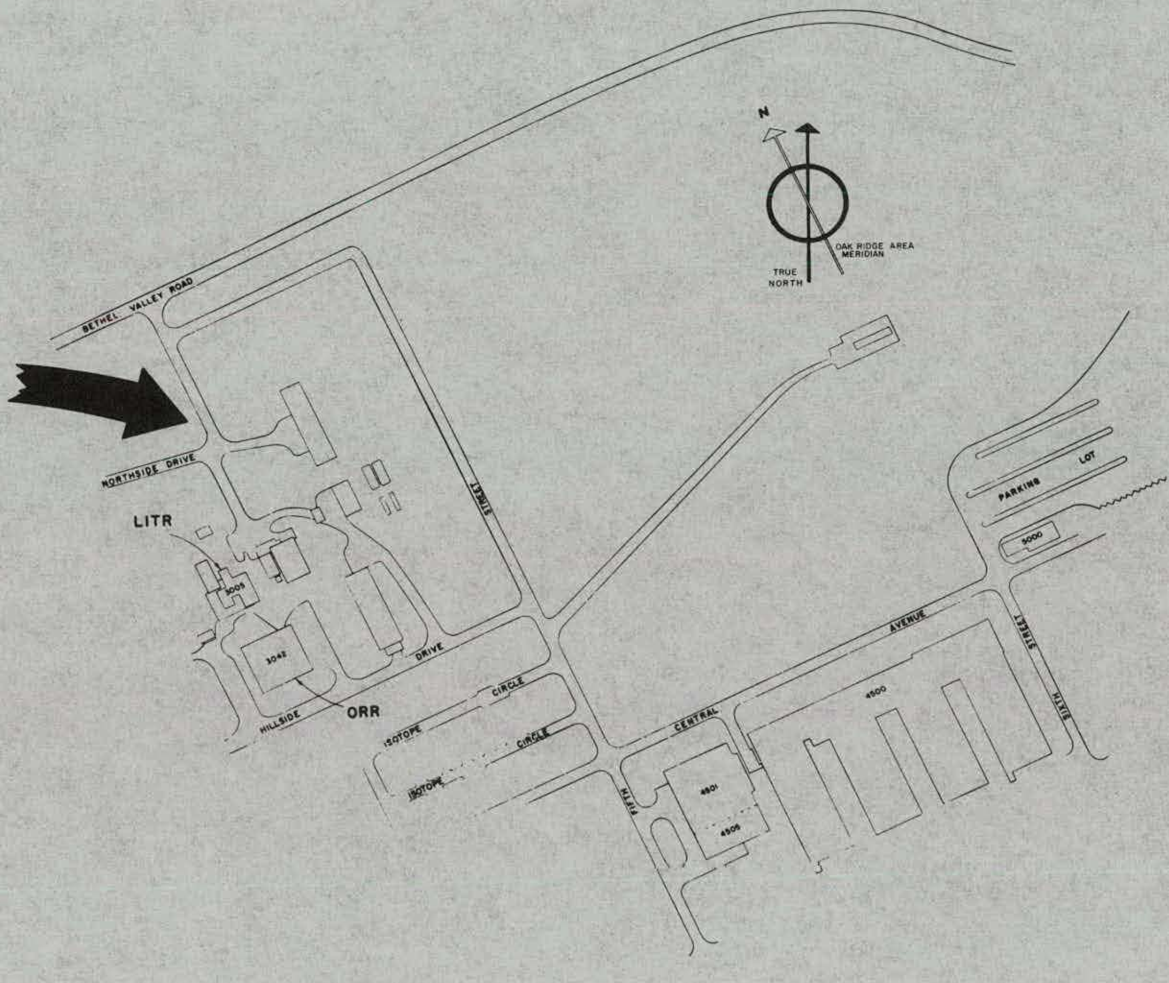


Fig. 4-2 - Map of Oak Ridge National Laboratory (D. I. 232A)

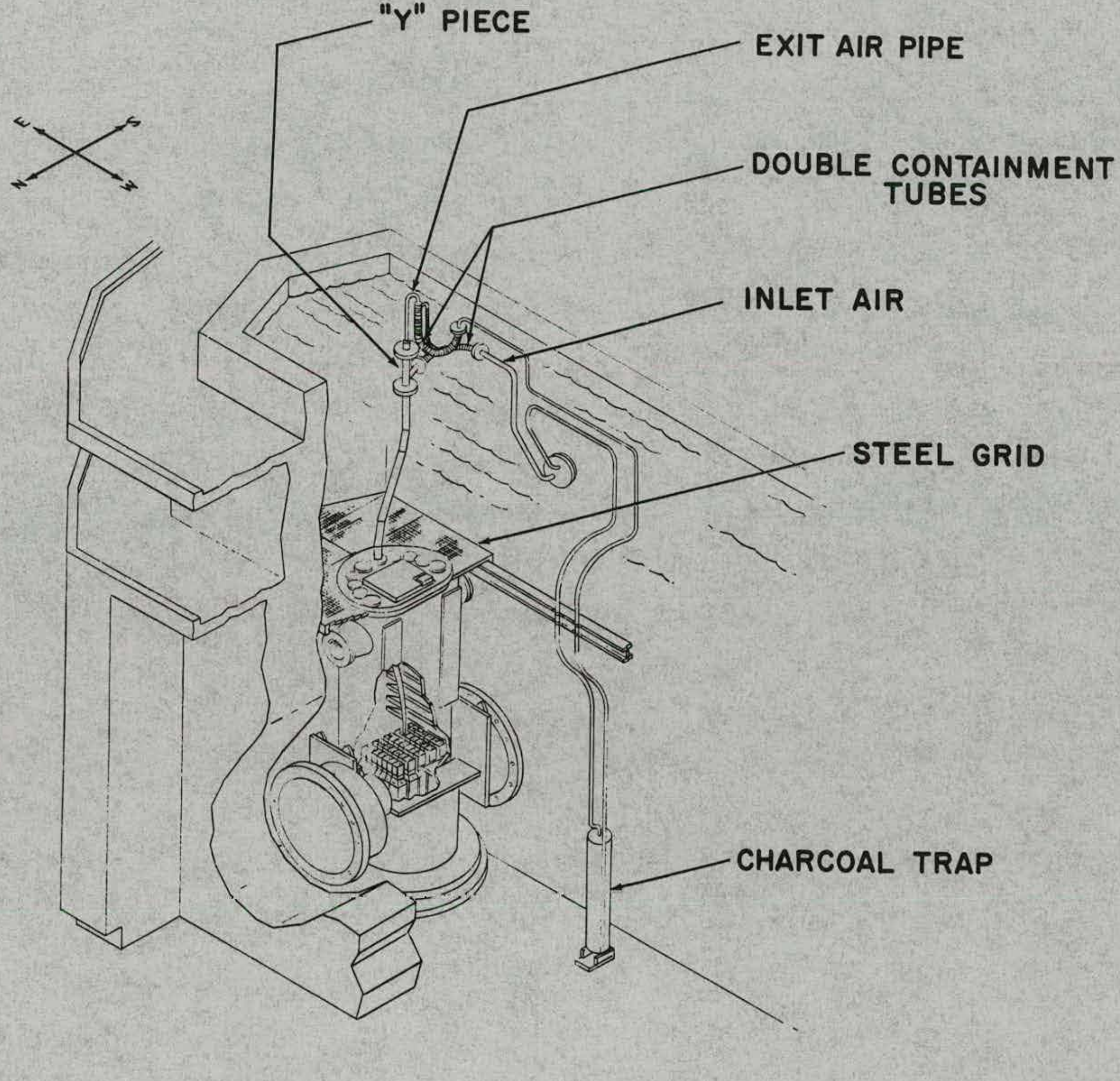


Fig. 4-3 - Oak Ridge Research Reactor showing F-2 Facility (D. I. 350 A)

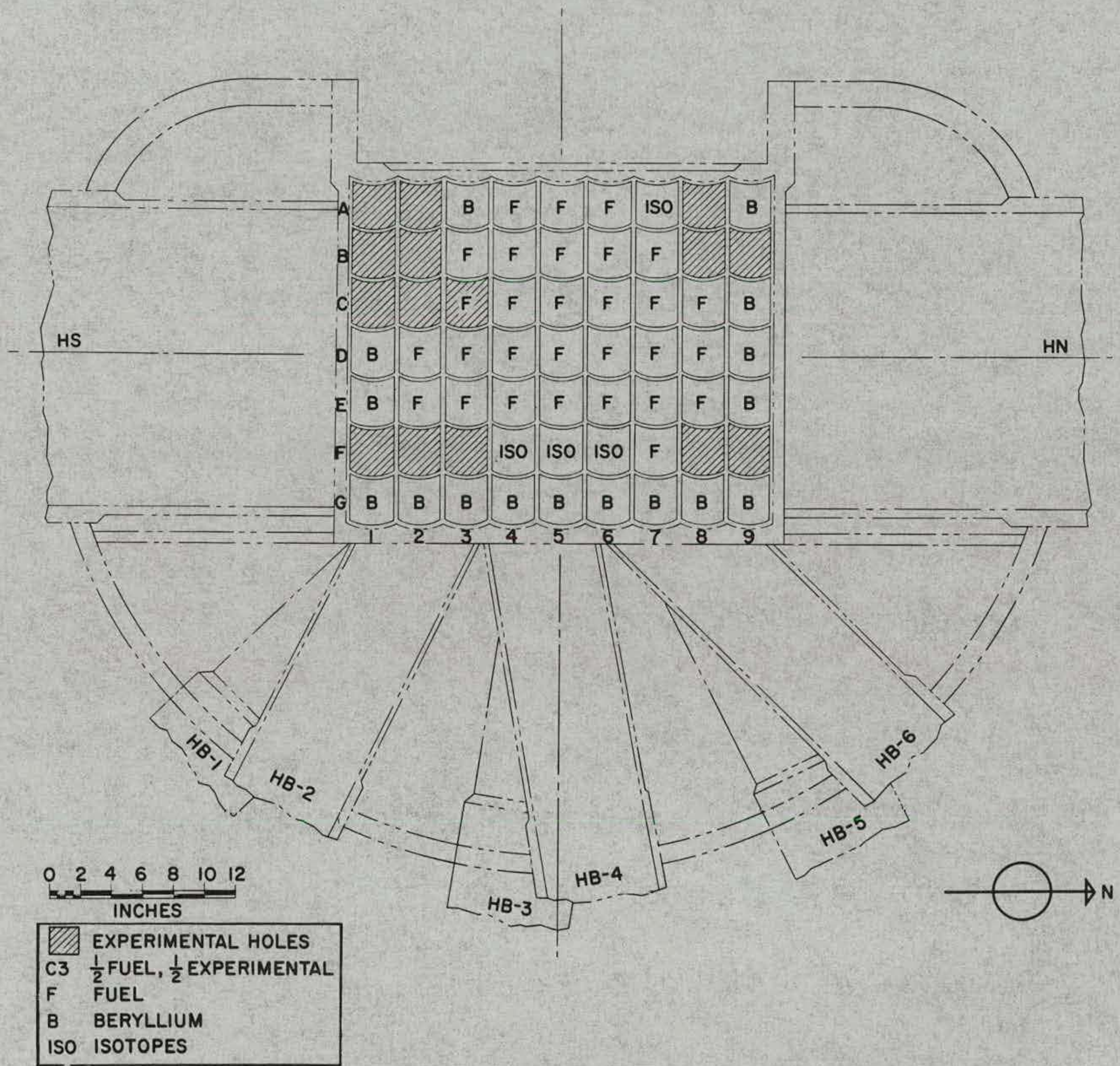


Fig. 4-4 - Typical ORR Core - 20 MW (D.I. 373)

Engineering Description - F-2 Facility

The F-2 facility loop is similar to many reactor core facility loops in that it is constructed with several bends to prevent neutron streaming. The facility tube which had a useable diameter of 2-9/16 inches, is actually 14 separate pieces welded together to form a complexly-bent duct. However, for simple representation, the tube might be pictured as shown in Figure 4-5. The inlet end of the tube lies under approximately 6 feet of water while the sealed end terminates in the F-2 lattice position approximately 11 inches below the core centerline. The tube is completely surrounded by water which prohibits pre-heated air being piped down the facility tube. The portion of the facility tube within the core is also water cooled, see Figure 4-6; and sample design has to prevent excessive heat transfer through the tube to reactor water.

Sample insertion is accomplished by lowering the pool water level to the top of the reactor vessel. This exposes the steel grid as a working floor and also prevents water from entering the facility tube. The "Y" piece is then disconnected and swung aside to allow sample insertion. The capsule assembly (see Figure 4-6) is then inserted, sample-end first, into the facility tube and lowered to the approximate operating position. Now it will be noted that the thermocouples are tied on the outside of the exhaust bellows. The thermocouples now have to be led out the inlet leg of the "Y" connection. In order to do this, a tie wire is fed from the balcony instrument cubicle through the in-pool leads to the "Y" piece. By connecting the capsule assembly thermocouples to the tie wire and pulling the tie wire back through the in-pool piping, the thermocouples are led out to the stuffing box on the balcony instrument cubicle.

With the thermocouples properly routed, the capsule exhaust bellows is screwed into the exit air pipe and made airtight. The "Y" piece is then lowered (which lowers the capsule assembly to its final position) and mated with the flange on the facility tube. The flanges are tightened and the experiment is water tight and ready for test. Approximately 30 inches of vertical positioning is possible by lowering or raising the exit air pipe during or prior to test. Facility tube pressure is always greater than pool hydrostatic pressure and any leak around the flanges or exit air pipe produces an outward emission of clean (uncontaminated) air and prevents water entering the facility tube.

At the end of the testing period, sample withdrawal is practically the reverse of sample insertion. Pool water is lowered several inches below the flange on the "Y" piece. Workmen place a ladder into the water, rest it on the steel grid, see Figure 4-3 and descend to loosen the "Y". By not completely lowering the water, workmen are shielded from the radioactive sample in the facility tube. The "Y" is loosened and raised, exposing the 1" exhaust bellows fitting and the thermocouple leads.

The thermocouples are cut and the capsule assembly disconnected from the exit air pipe. The "Y" piece is swung away from the facility tube and tied to the pool side. An overhead crane positions the withdrawal cask over the open end of the facility tube and a withdrawal tool is used to pull the capsule assembly into the withdrawal cask. No workmen are near the mouth of the facility tube at this time and a radiation instrument (cutie pie) is lowered down to the mouth of tube to signal when the capsule passes from tube to cask. In this manner minimum exposure is experienced by workmen.

In addition to the facility details shown in Figure 4-6, a typical ORR sample is illustrated. A brief discussion of a sample and the air flow pattern may be advantageous. Experiment air enters the reactor tank from the balcony cubicle area. Flowing through the submerged piping, it passes through the flexible hose and enters into the "Y" piece. Thus the facility tube is pressurized at all times and capsules are proveded with the exit duct to lead flow through a specimen. The pressure level, as previously mentioned, is always maintained greater than pool hydrostatic pressure to guarantee no water entry to the facility.

Obviously the heat generation of the test specimen will dictate details of the capsule design. However, for discussion purposes, the illustrated capsule would be used with a test sample of appreciable heat generation. The flow enters the top of the capsule and travels downward via two-flow annuli. The

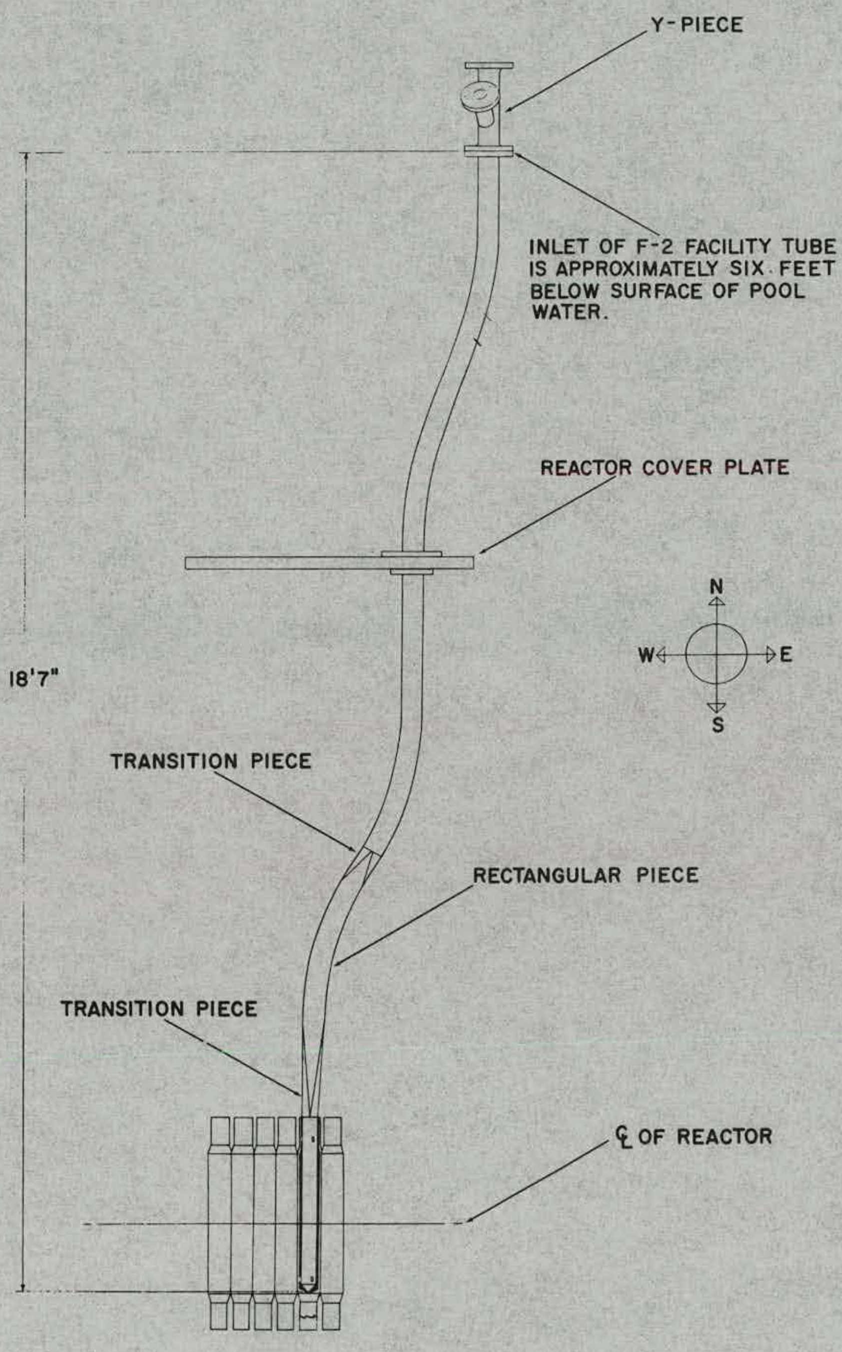


Fig. 4-5 - Simple Representation of F-2 Facility Tube (D. I. 358)

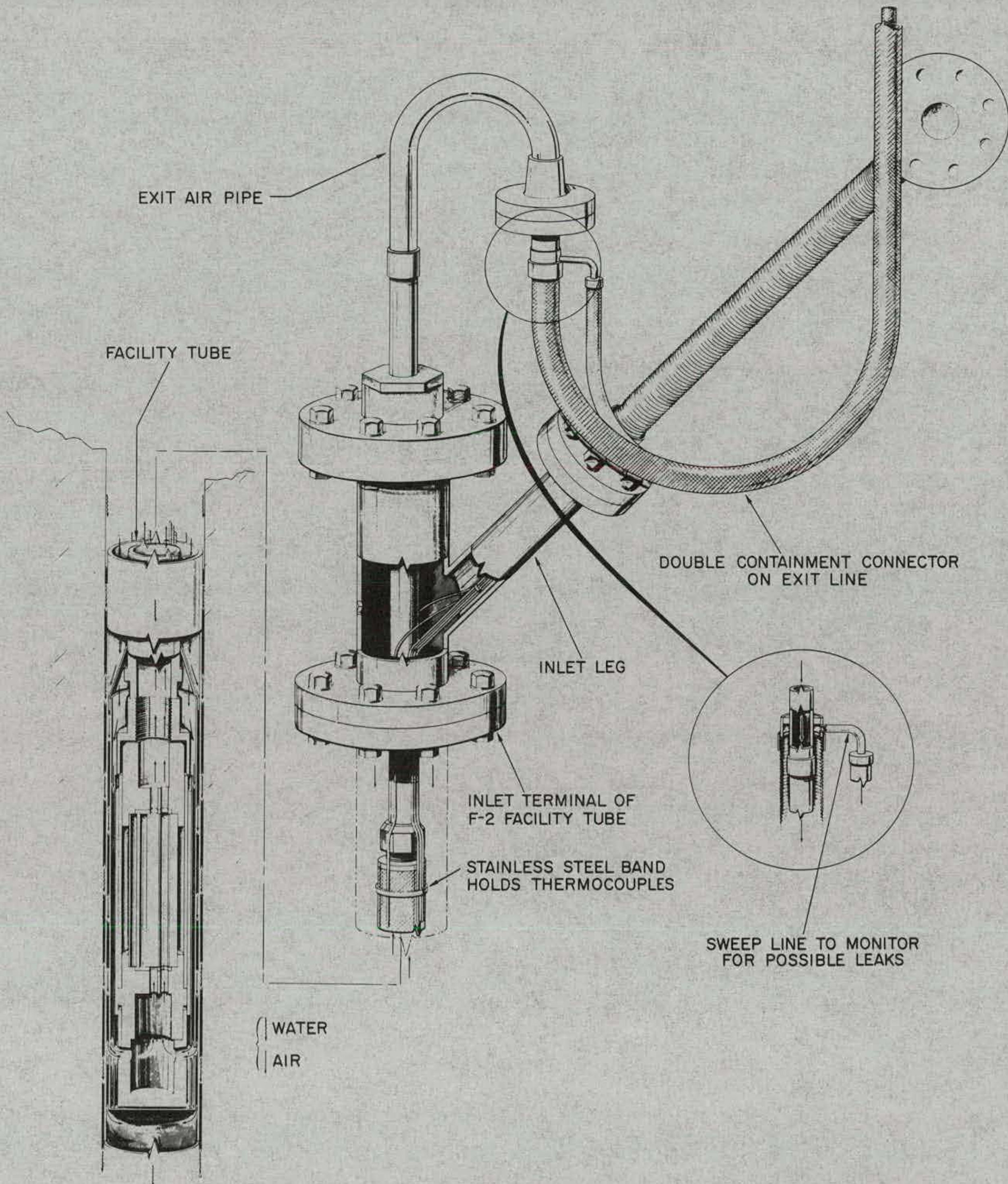


Fig. 4-6 - Typical ORR Capsule Located in F-2 Facility (D. I. 369A) outermost flow passage functions to cool the outer steel can. This is necessary to prevent water boiling at the facility tube surface. The innermost inlet flow passage cools internal hardware and also acts as a heat exchanger to pre-heat a portion of the inlet air. The division of flow between the two passages is a function of the path resistance and is controlled by capsule design.

The air enters the flow manifold at the bottom of the capsule and travels upward through the sample. Specimen thermocouples provide temperature indication with the flow rate being varied, by a pneumatic controller, to maintain the desired specimen temperature. The contaminated air then enters the flexible exit bellows, to the exit air pipe and into the double containment connector. It will be recalled that this connection is moved aside to accomplish sample insertion or withdrawal and therefore, over a period of time, may be subject to leaks. The sweep lines shown in Figure 4-6 constantly monitor the dead space between the inner and outer hoses and assure leak detection before serious contamination could result.

The flow passes the double containment connector and through the system as previously explained.

Engineering Data - F-2 Facility

Part 1 - Structural Items

1. Nominal Inside Diameter of F-2 Facility Tube = 2.625 in.
2. Material of F-2 Facility Tube = 316 ss
3. Outer Double Containment Tube = 2 in. N.P.S. flexible braided stainless steel
4. Inner Double Containment Tube = 1 in. N.P.S. flexible braided stainless steel

Part 2 - Dynamic Parameters

1. Maximum Pressure Obtainable = 100 psig
2. Approximate atmospheric Pressure at ORR = 14.2 psi
3. Maximum Flow Obtainable = The largest single compressor is rated at 130 scfm. It may be possible to exceed this rate by piping both compressors in parallel.
4. Inlet Air Temperature = No preheating of air available. Preheaters installed on capsule assembly.
5. Maximum Allowable Temperature of Facility Tube at Surface Cooled by Water = 200° F
6. Moisture Content of Facility Air
   The air as received from the kemp dryers has a -30° F dewpoint. Moisture can be added to approximately a +70° F dewpoint.

Part 3 - Nuclear Parameters

This section to be added at a later date. Core revisions due for 30-MW operation.

Part 4 - Sample Parameters

1. Maximum Sample Diameter = 2.375 in.
2. Maximum Capsule Length = 18 in.
   The dimension is determined by the length that can pass around the curves of the facility tube.

3. Maximum Number of Thermocouples
   Provisions have been made to accommodate a maximum of 24 platinum - platinum 10% rhodium or 24 chromel-alumel. Samples employing both chromel-alumel and platinum - platinum 10% rhodium can use any combination suitable to the 10 console recorders. The recorders are set up in the following manner:

   16 thermocouples reserved for Pt/Pt - 10 Rh
   16 thermocouples reserved for chromel-alumel
   8 thermocouples that can be switched to either chromel alumel or Pt/Pt - 10 Rh

4. Pressure Probes
   No specific provisions are made to record sample pressures on each test. However, instrumentation is available to handle a definite requirement.

Part 5 - Facility Instrumentation

A simplified drawing of the F-2 piping system is shown in Figure 4-7. Referring to the figure, the main system components operate in the following manner.

The facility loop can be fed on either plant air supply (95 psig and unlimited flow) or from the loop compressors. The number 1 compressor is a 40-HP Joy capable of delivering 130 scfm at 125 psig with a 30-HP Joy provided for emergency use. Tracing the air flow from the Joy compressors, we see the discharge dumping to the receiver tank. In the receiver tank, line surges and condensate are removed. The flow then passes to the Kemp dryers.

The dryers are piped in tandem so that one dryer can be electrically reactivated while the other is in service. Dryer nameplate data states an 8-hour dry cycle for each dryer. From the dryers a smaller surge tank is provided in the system. System flow then passes into the reactor building to the console room.

At the console room, the flow can take a straight-through path or, if moisture addition is required, be split. The straight path is simply routed through a pressure control valve and then to the #2 mix tank. However, when moisture is to be added, the flow splits at the junction of the two paths. Part of the flow travels the upper path previously described while the part to receive moisture follows the lower path. The lower path is channeled through a pressure control valve and then receives moisture from steam injection. The mixed steam and air is allowed to settle in the #1 mix tank and is then joined with the dry air of the upper path and "settled" again in the #2 mix tank. The flowrator in the lower circuit was purposely neglected in the discussion because it serves more for complementary information rather than system-control data.

The thoroughly-mixed air leaves the #2 mix tank, passes through the Fischer and Porter flowrator and flows to the experiment. To assure that cooling or minor flow restrictions do not force any water from the controlled stream, the piping to the reactor is steam traced and insulated to keep the air and pipes above room temperature. The flow then passes into the inlet pool lines, through the sample, and to the charcoal trap. It is to be noticed that the double containment hose, shown in Figure 4-7, is swept by a separate air supply. The reason for this check is that the flexible double containment hose is a logical point for leakage and, being downstream of the sample, radioactive flow could escape to pool water and hence to atmosphere. The charcoal trap mentioned above is charged with about 180 pounds of charcoal and rests on the pool bottom. The trap is provided with water cooling passages and internal thermocouples to assure safe operation.

Leaving the reactor, the hot gases are led through the balcony shielded cubicle. Traps are provided for fission gas detector and charcoal "U" traps but the use of these instruments will not be discussed here. The reader is referred to reference 4 for additional information.

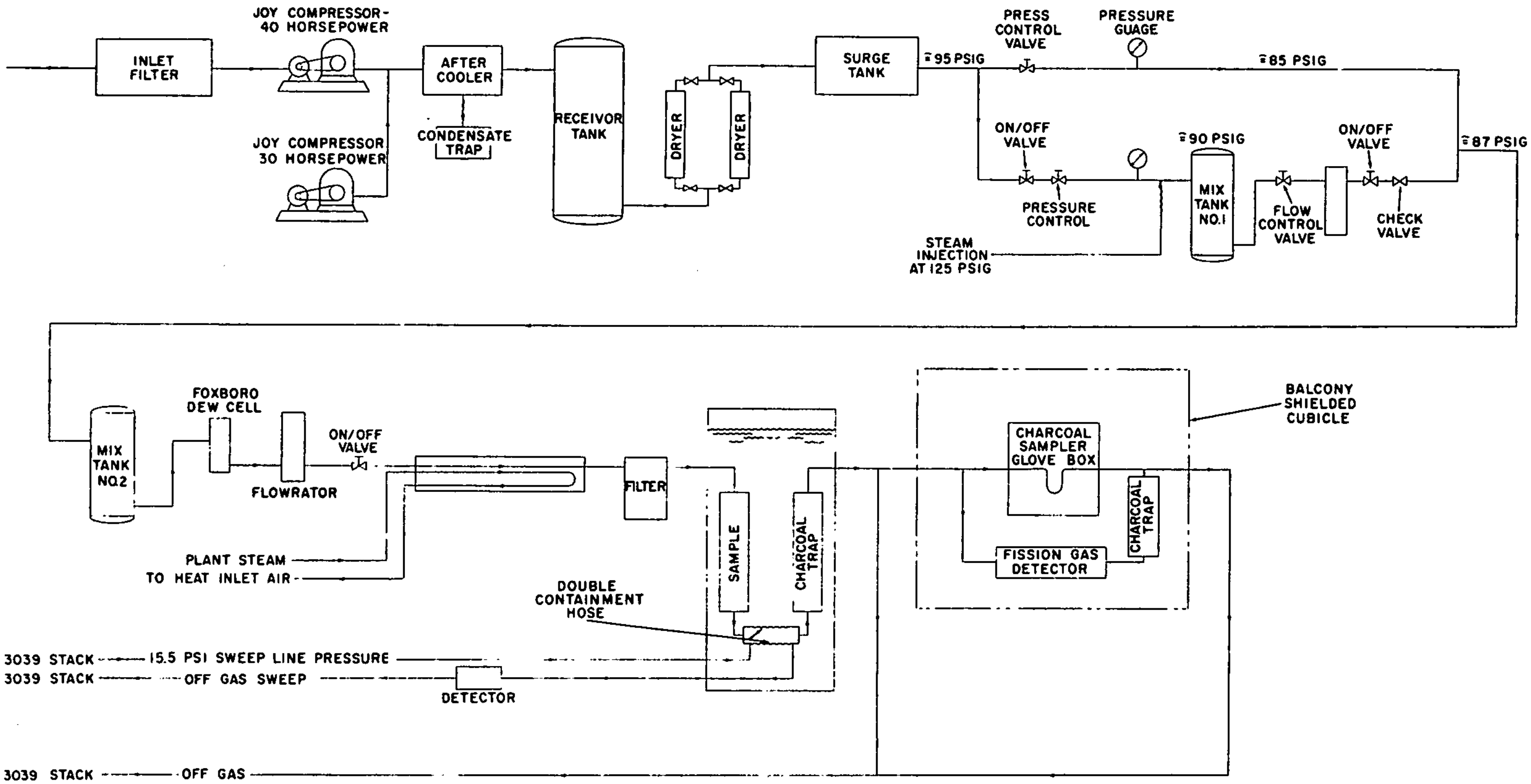


Fig. 4-7 - Simplified Drawing of F-2 Piping (D.I. 375)

The main flow enters the off-gas system which discharges into the 3039 stack. This off-gas stack serves several other ORNL buildings as well as the ORR.

An itemized description of the F-2 system limitations is presented below:

1. Compressors:
   a. The #1 Compressor
      1. Manufacturer - Joy Mfg. Co.
      2. Output Pressure - 125 psig.
      3. Outlet Temperature - ≅110° F
      4. Flow - 130 scfm
      5. Horsepower - 40
      6. RPM - 600
      7. Size - 8 x 7

   b. The Stand-By Compressor
      1. Manufacturer - Joy Mfg. Co.
      2. Output Pressure - 150 psig
      3. Outlet Temperature - ≅110° F
      4. Flow - 110 scfm
      5. Horsepower - 30
      6. Size - 7 x 7

2. Receiver Tank:

   a. Manufacturer - Niles Steel Tank Co.
   b. Capacity - 22 cubic feet
   c. Maximum Operating Pressure - 135 psig
   d. Thickness - 1/4 in. carbon steel on shell and head
   e. Maximum Temperature - 650° F

3. Dryers

   a. Manufacturer - C. M. Kemp Mfg. Co.
   b. Model - 15E
   c. Flow Rate - 100 scfm
   d. Pressure - 100 psig
   e. Temperature - 65° F
   f. Drying cycle - 8 hours

4. Sample Thermocouple Recorders:

   a. TR-4, 5, 6, 7, 8, 9, 10, 11 single-point, continuous type, Minneapolis Honeywell, Brown Electronik
      1. Range change kits for Pt - Rh and Cr-Al available for above recorders.

   b. TR 10 sixteen-point printout type,
      1. Presently setup for Pt/Pt - 10 Rh

   c. TR 13 sixteen-point printout type,
      1. Presently setup for chromel-alumel

5. Sample Pressure Instrumentation

   As was previously explained, no instrumentation are reserved for sample readings. However, it is possible that the following cubicle instruments could be utilized.

   a. Foxboro Dynaformer Pressure Cell and Power Supply
      1. 316 Stainless Steel Bourdon Type
      2. Calibration Accuracy to within ±1/4% of rating at any point within its range.

b. Indicating Meter with Foxboro Dynaformer Pressure Cell
   1. Westinghouse Type K-24
   2. 0-200 Microammeter 270°F scale
   3. Range 0 - 100 psig linear graduations

6. Piping from Compressors to Console Room

   a. 1-1/4 in. N. P. S. air
   b. Pressure-300 psig

7. Piping Inside Console Room

   a. 1-1/4 in. N. P. S. on all lines taking total mixed (water injected and dry air) flow
      1. Pressure-300 psig.

   b. 1 in. N. P. S. on all lines in water injection branch (see Figure 4-7)
      1. Pressure-300 psig.

   c. 3/4 in. N. P. S. Steam line for water injection
      1.. Pressure-300 psig

8. Piping from Console Room to Reactor Pool

   a. 1-3/4 in. N. P. S. air
   b. Pressure-300 psig.

9. Piping and Instrumentation within Balcony Cubicle is shown on drawing ORNL Q-2000-3.

10. Piping within Reactor Pool is shown on Figure 4-3

11. Off-Gas Line within Reactor Pool Wall

    a. 3 in. line

BIBLIOGRAPHY

1. Adams, R. K., Davis, D. G., and Hyland, R. F.,"Instrumentation Flow Plan Symbols and Recommended Drawings," Oak Ridge National Lab., ORNL 57-2-1.

2. Cagle, C. D., and Costner, R. A. Jr.,"Initial Post Neutron Measurements in the ORR,"Oak Ridge National Laboratories, ORNL 2559.

3. Cole, T. E. and Gill, J. P.,"The Oak Ridge National Laboratory Research Reactor," A General Description, Oak Ridge National Lab., ORNL 2240.

4. Collins, E. S., Conn, P. K., and Trice, J. B.,"Fission Product Monitoring Techniques in Gas Cooled Reactors," General Electric Aircraft Nuclear Propulsion Department, June 17, 1959.

Notation - Abbreviations

℄	-	centerline
Cr-Al	-	chromel-alumel
ETR	-	Engineering Test Reactor
kw	-	kilowatts
LITR	-	Low Intensity Test Reactor
MTR	-	Materials Test Reactor
MW	-	megawatts
$n/cm^2/sec$	-	neutrons per square centimeter per second
ORNL	-	Oak Ridge National Laboratory
ORR	-	Oak Ridge Research Reactor
P_t-R_H	-	platinum-rhodium
scfm	-	standard cubic feet per minute
sch 40	-	schedule 40 designation
ss	-	stainless steel
X-10	-	Area designation at Oak Ridge National Laboratory
Y-12	-	Plant designation at Oak Ridge National Laboratory

AIRCRAFT NUCLEAR PROPULSION DEPARTMENT

GENERAL ELECTRIC