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MARTIN MARIETTA

Operating Manual for the Oak Ridge Research Reactor

Part 1

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
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ORNL/TM-506/R1 & P1

Operations Division
Reactor Operations Section

OPERATING MANUAL FOR THE OAK RIDGE RESEARCH REACTOR

Part 1

Compiled by

Oak Ridge Research Reactor Staff

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NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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TABLE OF CONTENTS

Page

LIST OF EXAMPLES

LIST OF FIGURES

LIST OF TABLES

1. OPERATING PROCEDURES

1.1. Introduction and General Principles

The operation of a research reactor requires careful attention to details and strict adherence to safety precautions so that an orderly and safe operation will be ensured. Added to the well-recognized industrial hazards present are those associated with a high-performance nuclear reactor. A serious accident could release large amounts of radioactive materials with possible large-area contamination. The probability that such a release will occur is not large; however, the significance of such an event makes safety the prime consideration in every operation.

The ORR operating manual is devoted to the presentation of detailed procedures and descriptions for every phase of operation. These procedures, in accordance with the above remarks, are designed to ensure safe and orderly operation of the facility. Adherence to these procedures is required and enforced to:

1. provide a standard, safe method of performing all operations;
2. ensure that the safety implications of routine jobs do not lose significance; and
3. ensure that non-routine operations, which quite often affect more than one part of the reactor complex, are done with due consideration of such intereffects.

Because revisions and additions are expected frequently, copies of the manual are printed in loose-leaf form. These copies which are easily revised, are distributed throughout the Reactor Operations Section. One copy remains in the ORR control room for use by the shift personnel.

The control room copy of the ORR Operating Manual is the "official" copy and should not be defaced with extraneous markings or unofficial corrections.

If errors are discovered, they should be brought to the attention of the Reactor Supervisor or his designated representative. Temporary corrections will be made by the Reactor Supervisor or his designated representative, dated, and initialed. Formal corrections will be handled in the manner described in Section 6.2.5 of this manual.

It is the responsibility of each member of the section to be vigilant and aid in keeping our operating manuals current at all times.

Procedure changes or additions must be formally written and approved by senior staff members as detailed in Section 6.2.5. A copy of each change or addition is then placed in each loose-leaf manual, thus ensuring that up-to-date procedures are always on hand.

This procedure manual shall be reviewed (and updated as necessary) once every two years as specified in the "Operations Division Procedures." The Assistant Reactor Supervisor shall be responsible for the review with help from appropriate staff members.

Each biennial review shall be documented by issuing a one-page revision to the manual to be inserted immediately preceding the Table of Contents. The documentation shall include a statement that the manual has been reviewed and updated, shall give the date of the review, and shall be signed by the Assistant Reactor Supervisor as well as by the staff members who normally sign procedure revisions.

1.2. Specific Startup Procedures

1.2.1. Personnel Requirements

As a minimum, one qualified Operations supervisor and one qualified reactor operator are required to be in the control room for a normal startup. Occasionally, a Reactor Controls Section technician or supervisor is needed on a standby basis. Personnel not required for the startup may prove distracting to the operation.

1.2.2. Responsibility

One qualified Operations supervisor shall be in charge of the startup operation. This will usually be the shift supervisor on duty. Dual supervision tends to increase the possibility of overlooking an abnormal condition or neglecting one or more startup checks and is to be avoided. The supervisor in charge must be satisfied that all of the reactor complex and the associated experiments have been properly checked and are ready for operation. He must direct the startup from the control room, giving instructions to personnel at other locations, as needed, via the intercommunication systems. The supervisor in charge when the startup checks are performed must follow through with the startup until the power level of N_L is attained.

The operator assigned to the control desk will, under the direction of the supervisor, perform those operations necessary to effect the startup. The operator must be aware of the status of the facility at all times during the startup. He will assist the supervisor in evaluating unusual situations and will call his attention to any abnormal condition or event related to the startup.

Other personnel present in the control room may have specific responsibilities related to a test, experiment, maintenance, or training. Their functions shall be clearly understood by the supervisor in charge and any changes to procedures or tests must be approved by him. Those people not directly involved in the operation may observe from the observation platform.

1.2.3. Personnel Hazards During Startup

There are many potential hazards associated with a reactor startup. The often discussed and well-known "startup accident" is of prime consideration; however, there are many less-severe potential hazards which also must receive attention. The startup serves as a final test of the integrity of the fuel, the experiments, the instrumentation, the shielding - in short, the reactor complex itself. This is particularly true of new experiments and components and of equipment which has undergone maintenance or alteration. Such items should be given special attention, but careful attention must be given to the entire complex.

Although much effort is expended toward ensuring the safety of the reactor and the experiments, the possibility of human error or equipment failure is ever present. It is, therefore, considered essential that a background radiation survey of the complex be made as soon as possible after each beginning-of-cycle startup and during other startups following experiment alterations (refer to Section 1.2.11, "Radiation Background Survey" for additional instructions on radiation background surveys).

1.2.4. General Procedures

There are certain general requirements in the startup procedure which apply in all cases. Even though they may be repeated later, they are separately stated here for emphasis.

1. Startup checks, itemized in the startup checklist (Section 8.1.3), are required prior to every startup following any work in the reactor tank and following any maintenance on components in the reactor complex. Startups following brief unscheduled shutdowns are discussed in Section 1.2.10.
2. The supervisor in charge must be satisfied that the reactor and all related equipment and experiments are ready for startup and/or power operation.
3. The supervisor in charge must remain in the control room any time that control rods are being withdrawn or any time that the reactor power is being increased.
4. In no case shall safety be compromised. A proven and satisfactory answer to any problem must exist before startup is permitted or allowed to continue if in progress.

1.2.5. Preparation for Startup

1. Determine without question that the minimum instrumentation requirements are met. These requirements are set forth in Table 1.1. It should be pointed out that the limitations indicate an absolute minimum. In all cases where practical, the normal complement of instrumentation will be made available. The failure of a particular channel is not necessarily a crucial situation in itself if the minimum complement of instrumentation can still be provided; however, repeated failures of a single channel or simultaneous failures of two or more channels would be cause for concern. Under such conditions, a very careful evaluation should be made after consulting with the Reactor Supervisor and a Reactor Controls Section representative. Should an occasion arise when the minimum instrumentation cannot be met, the reactor must be shut down.

Table 1.1. Minimum instrumentation requirements for reactor operations

Instrument channel	Normal complement	Startup to N_L with forced flow or with natural convention	Power operation
Power-level-safety	3	2	2
Log N	2	1	none
Count rate	2	1	none
Servo	1	none	none
^{16}N	2	1	1
T_{out}	2	none	2
T	2	none	1**
Reactor water flow*	1	none	1***
Reactor P*	1	none	1***
Gamma	2	none	none
Primary water makeup rate	2	1	1
POG pressure	2	none	1****
NOG pressure	2	1	1
N-facility flow	1	none	1
S-facility flow	2	none	2
Cell-vent flow	2	1	1
Pool-water flow	1	none	1

*The sensitivity of the Nos. 1 and 2 safety channels is increased by a factor of ∿45 for operation with the primary-water main flow $\leq$12,000 gpm and the reactor ΔP corresponding to a main flow of $\leq$12,000 gpm, respectively. The sensitivity of the No. 3 safety channel is increased by a factor of ∿45 when the raise-test switch is turned to the TEST position. In TEST, the primary-water main flow and reactor ΔP scram-circuit relays are bypassed. Under this condition, protection is effected in the following sequence: (1) when in servo control, the maximum power is limited by a setback at a 60% reading on the power-level safety recorders, which is equivalent to ∿400 kW; (2) a reverse will be effected when a reading of 1.8 N_L on the log-N recorder is reached. This is equivalent to ∿540 kW; and (3) a reverse will be effected at a reading of 120% on any one of the three power-level safety recorders. This is equivalent to ∿800 kW.

** ΔT channels serve as backup instrumentation for the power channels and therefore need not be redundant.

***Flow channels may utilize direct flow measurement, or measurement of core ΔP using flow-calibrated ΔP instrumentation.

****Pressurizable off-gas monitor is required only if experiments are connected to the POG system.

2. Visually inspect the following areas for proper status:
   a. Reactor pool, beam holes, experiment facilities, and sub-pile room
   b. Inside the reactor vessel
      (1) Inspection must be made to check the tank for foreign objects. Any foreign objects shall be removed prior to securing the access cover in position.
      (2) The core elements must be inspected and inventoried at least twice while referring to an ORR core sheet (Example 1.1) which indicates the current core configuration. The first inspection should be made prior to the installation of the access cover and the second while the reactor power is near the 6-MW level. The startup supervisor shall verify that all core elements are seated prior to the installation of the access cover. The inspection sheet must be signed by the supervisor performing the inspection.
3. Determine that the experiments are ready for power operation or startup by ensuring that:
   a. all maintenance or changes have been satisfactorily completed;
   b. information relative to each experiment is complete and available; and
   c. experiment personnel are informed of the startup and any special startup requests are noted.
4. Put the water system into operation in the following sequence.
   a. Fill the three pools and observe that the pool-level alarms are properly cleared by this action.
   b. Start circulation of the reactor primary coolant water and adjust it to the desired flow rate (refer to Section 5.2.1.1 for sequence of starting the primary pumps).

ORR CORE

(Inspection checklist)

POOL

W

	A-1 Be	A-2 Al	A-3 F	A-4 F	A-5 F	A-6 F	A-7 F	A-8 Be	A-9 F	
	B-1 Be	B-2 Be	B-3 F	B-4 F SR	B-5 F	B-6 F SR	B-7 F	B-8 Be	B-9 Be	
	C-1 Be	C-2 F	C-3 E	C-4 F	C-5 F	C-6 F	C-7 F	C-8 Al	C-9 Be	
S	D-1 ISO	D-2 F	D-3 F	D-4 F SR	D-5 F	D-6 F SR	D-7 F	D-8 F	D-9 Be	N
	E-1 Be	E-2 F	E-3 E	E-4 F	E-5 Al	E-6 F	E-7 Al	E-8 F	E-9 Be	
	F-1 Be	F-2 F	F-3 F	F-4 F SR	F-5 F	F-6 F SR	F-7 F	F-8 F	F-9 E	
	G-1 Be	G-2 Be	G-3 Be	G-4 Be	G-5 Be	G-6 Be	G-7 Be	G-8 Be	G-9 Be	

E

LEGEND

F = Fuel

E = Experiment

ISO = Isotope

F/SR = Fuel Shim Rod

Be = Beryllium

Al = Solid Aluminum

Example 1.1. Typical Core Configuration

UCN-5152
(3 9-63)

c. Start circulation of the pool water through the heat exchanger.

d. Place the secondary cooling loops in operable condition and set the systems on AUTOMATIC.

e. Establish the setpoint for the reactor and pool primary temperature controls and set the systems on AUTOMATIC.

f. Establish water flow to the horizontal beam-hole liners and plugs according to the directions on the status sheet. It is important to note any change in the status of the beam-hole liners since changes here will affect flux "seen" by the control chambers.

g. Establish water flow to the north and south experiment facilities according to the directions on the status sheet.

h. Place the reactor-water demineralizer in service.

i. Place the pool-water demineralizer in service.

j. Place the degasifier in service in the reactor water system.

k. Place the degasifier demineralizer in service in the reactor water system.

5. Determine that the electrical and control circuits are properly energized and that the instrumentation is properly checked. This includes assurance that:

a. the ionization chambers are properly positioned and any changes are noted and accounted for;

b. all instrumentation and controls have been properly checked and adjusted in accordance with the prestartup instrument checks section during the previous shutdowns or the current shutdown, if applicable; and

c. the log-N amplifiers and counting-rate meters are calibrated just prior to the startup.

6. Turn the "reactor-operate" key switch to ON. Announce over the public address system that the startup horn will sound. Press the "operator-start" push button. The startup horn will sound. When the horn has "timed out," the green light above the group "rod-withdrawal" switch should come on, indicating that conditions are normal for rod withdrawal.
7. Check the electronic scram circuitry and mechanism by raising the rods off their seats and scramming with the "Jordan" button at each level-safety sigma amplifier and the period-scram test button at each log-N amplifier (five tests).
8. Review and initial the startup checklist which, in effect, ensures that the preceeding preparations have been made.* Certain other details are also covered by the startup checklist.
9. Correct any abnormal conditions encountered during the preparation for startup before continuing.
10. After being assured that the complex is ready for reactor startup, announce over the public address system that reactor startup is imminent.
11. The following routine startup procedures are offered as general guidelines. Reactor and experiment conditions may require slight variations, or even combinations of the various modes of startup. In this case, special instructions will be issued by the Reactor Supervisor and the technical staff as the need requires.

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*The startup checklist is to be initialed by the supervisor in charge of reactor startup.

1.2.6. Routine Startup (via Operator-Start to N_L)*

1. After making sure that all checks under Section 1.2.5 have been satisfactorily completed, reactor startup may proceed as follows:
   a. Set one "shim-rod mode" switch on the PREFERRED position, and turn all other "rod-mode" switches to the NORMAL position. Selection of a preferred rod will depend upon rod worth, core loading, and desired effect of preferred-rod control action.
   b. Set the "raise-test" switch to the NORMAL position.
   c. Set the "scram" switch to NORMAL and clear the slow scram circuits by pressing the "scram-reset" push button.
   d. Set the "bypass-reverse" switch to NORMAL.
   e. Adjust the selected fission chamber to obtain at least 1.5 counts per second (preferably 10-50 cps) on the count-rate meter, and switch the selected channel to the AUTOMATIC mode.
   f. Observe that the servo demand is at N_L, and set the vernier at midscale.
   g. Manually withdraw shim-rods Nos. 1 and 2 to 15 in.
   h. Set the "group-rod-withdraw" switch to INTERMITTENT. All rods will withdraw intermittently under timer supervision. If a 30-s period is indicated by either the count-rate or log-N channels, rod withdrawal will be inhibited until the "group-rod-withdraw" switch is reset by turning it to NEUTRAL and then back to INTERMITTENT.** While in start,

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*Operator start (manual operation) is used only when the servo control system is not functioning or in specific cases when required to "chase" xenon.

**The 30-s inhibit can be bypassed by turning the spring-loaded "reverse-bypass" switch to BYPASS, thus permitting a 20-s period. The 20-s period, in turn, can be bypassed by holding the "reverse-bypass" switch in the BYPASS position and depressing the "fast-period permit" button. Either of the above actions requires the immediate supervision of the supervisor in charge of the startup.

rod withdrawal is inhibited if the CRM drops below 1.5 cps or exceeds 8,000 cps. During this phase of startup, when the log-N recorder indicates less than 0.001 N_L, the CRM is the only nuclear instrument channel that provides a reliable indication of neutron level or changes in neutron level.

i. When a level of 0.001 N_L is reached on the log-N channel, set the "group-rod-withdraw" switch to HIGH. The rods will be withdrawn continuously, bypassing the timer. The shim-rod withdrawal inhibits, as described in Section h, above, also apply to this mode of rod withdrawal.

2. As the reactor power level approaches and reaches 1% of full power (N_L), the following steps should be followed:

   a. For startups when xenon growth is not a problem:

      (1) Maintain the period at slightly greater than 30 s until N_L is reached.

      (2) Stabilize the power at N_L until reasonable equilibrium is reached on all instrument channels and until it is determined that all conditions are normal.

      (3) Review the startup instructions and special requests before proceeding to power.

   b. For startups following unscheduled shutdowns when xenon poisoning is a problem, refer to Section 1.2.10.

3. During normal startup, there should be no reason to insert the rods except for minor adjustments to balance or maintain certain desired relative rod positions. For such adjustments, individual rod withdraw and insert push buttons will be used. If a situation should develop requiring a rapid reduction of power, the "bypass-reverse" switch should be turned to the REVERSE position. This inserts all rods simultaneously at full speed.

1.2.7. Routine Startup (via Instrument-Start to N_L)

Make sure that all checks under Section 1.2.5 have been satisfactorily completed. Reactor startup may then proceed as follows:

1. Turn one "shim-rod-mode" switch to the PREFERRED position and all other "rod-mode" switches to NORMAL.
2. Set the "raise-test" switch to NORMAL.
3. Set the "scram" switch to NORMAL and clear the slow-scram circuits by pressing the "scram-reset" push button.
4. Set the "bypass-reverse" switch to NORMAL.
5. Set the selected fission chamber on AUTOMATIC.
6. Observe that servo demand is at N_L and set the servo vernier at midscale.
7. Manually withdraw shim-rods Nos. 1 and 2 to 15 in.
8. Press the "instrument-start" push button. The startup will proceed automatically to a power level of N_L. During the instrument start, the following events will occur as demanded by the status of start conditions.
   a. The servo mechanism will be energized.
   b. The servo limit switches will be repositioned.
   c. The selected fission chamber will be automatically inserted if necessary to produce an indicated counting rate of 20 cps.
   d. The rods will be withdrawn intermittently as long as the power level is below 0.001 N_L on the log-N recorder.
   e. The rods will be withdrawn as a group in high speed when the power is above 0.001 N_L on the log-N recorder.
   f. The servo will take control of the reactor when the power level reaches N_L; and, when an insert error is indicated by the servo system, instrument start is terminated.

1.2.8. Routine Startup (via Operator-Start with Servo to N_L)

Make sure that all checks under Section 1.2.5 have been satisfactorily completed. Reactor startup may then proceed as follows:

1. Turn one "shim-rod-mode" switch to the PREFERRED position and all other "rod-mode" switches to NORMAL.
2. Set the "raise-test" switch to NORMAL.
3. Set the "scram" switch to NORMAL and clear the slow-scram circuits by pressing the "scram-reset" push button.
4. Set the selected fission chamber to MANUAL and adjust it until the count-rate meter indicates at least 1.5 cps - preferably 10 to 50 cps. Return the selector switch to the AUTOMATIC position.
5. Observe that servo demand is at N_L and set the servo vernier at midscale.
6. Manually withdraw shim-rods Nos. 1 and 2 to 15 in.
7. Set the "group-rod-withdraw" switch to INTERMITTENT and push the servo push button. All rods will withdraw intermittently as controlled by the timer. The rods will continue to withdraw until a 30-s period is attained on log-N or the count-rate period meters. If this period is reached or if a "group-rod-withdraw" or "insert" button is pushed, the "group-rod-withdraw" switch must be reset by returning it to NEUTRAL and back to INTERMITTENT. Rod withdrawal will cease if the count-rate meter reads lower than 1.5 cps or greater than 8,000 cps. When the count-rate meter shows 8,000 cps, the fission chamber should withdraw automatically to read approximately 100 cps. While the fission chamber is in motion, rod withdrawal is prohibited.
8. At 0.001 N_L, the log-N channel is considered reliable. The "group-rod-withdraw" switch may then be turned to HIGH to withdraw rods.
9. The servo system should assume control of the reactor at N_L and maintain the power at that level by the automatic positioning of the servo-controlled rod (No. 6) within the span of the servo limits.

1.2.9. Power Escalation (from N_L to the Desired Power Level)

It has been stated earlier in this procedure that the startup and power escalation operations are the true tests of the integrity of the reactor complex, including the associated experiments. Experience has proven that these operations require the undivided attention of the operator and the supervisor in charge. It has also been clearly indicated that the process of bringing the reactor to power should not be hurried, particularly during startups following refueling or other work in the reactor tank or primary system. The following procedure is based upon these premises.

1. General procedures and considerations
   a. The power level should be held at N_L until all instrumented parameters have reached equilibrium or near equilibrium and it is determined that all conditions are normal. Any malfunctioning instrument and/or equipment required for startup and/or constant power operation of the reactor should be repaired immediately. Should it be necessary to make repairs and the nature of the repairs is such that if performed at a power level of N_L it may endanger personnel or the reactor, the reactor shall be shut down.
   b. Special instructions regarding the rate of power increase and requests from experimenters for variations from routine operation should be read carefully and all questions regarding the power escalation should be answered before proceeding.
   c. Standard procedure shall be to increase the power in steps while carefully analyzing the behavior of the reactor, the equipment associated with the reactor complex, and the experiments. As a minimum, the power will be stabilized at levels of 3-MW intervals for such observations. The time spent at

each power level shall be determined by the supervisor in charge, but must be sufficient to permit the measurements specified in the detailed procedures which follow.

d. Partial flow blockage through the fuel elements by foreign materials could produce localized boiling due to insufficient heat removal. To prevent such an event from occurring, an additional inspection of the core through the access-cover viewing port will be made at a low power (6 MW or less). If any obstructions are detected which have an equivalent diameter of 1/2 in. or greater, the reactor should be shut down and the flow restrictor removed.

e. A reactor-noise instrument channel has been provided for use during startups and at other times when unusual conditions prevail. This channel should be used to obtain data during each startup. Although this channel is valuable as a data gathering device and as a comparator, it is not to be used as a startup channel. A detailed procedure for use of the noise channel is included as Section 2.6.16.

2. Detailed procedure

When it is determined that everything is in order and that all conditions are ready for the power to be raised to the desired operating level, proceed as follows:

a. Announce over the public address system that the ORR power level will be increased. Specify the power level for the first step (normally 3 MW). Repeat once.

b. Adjust the rod positions as needed to satisfy current operating instructions and to maintain the servo-controlled rod (No. 6 rod) in a position suitable for startup demands.*

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*Rods 1 and 2 will usually be at their upper limits, i.e., fully withdrawn. Rods 3, 4, 5, and 6 will usually be ganged between 15 and 20 in. withdrawn. However, the servo-controlled rod should be maintained below 25 in. withdrawn if at all possible.

c. Determine that the noise channel is ready for operation and properly set for the first step in power.

d. Set the selected fission chamber on AUTOMATIC.

e. Depress the "run" button and determine that the reactor is in the run mode.

f. Raise the power to the desired first-step level by turning the "servo-demand" switch to the RAISE position and holding it there until the desired setpoint is reached. The servo system will withdraw the servo-controlled rod, No. 6. If the power increase is sufficiently large, the regulating rod will be withdrawn until automatically stopped by the "withdraw limit" switch. The "preferred" shim rod will then be automatically withdrawn until the regulating rod leaves the withdraw limit, i.e., when the power exceeds the demand. If the change in demand is small, then the servo-controlled rod will probably increase the reactivity sufficiently for the change and will therefore not be withdrawn to its upper limit.

g. At the desired first step in the power escalation program, normally 3 MW, and at each succeeding step:*

   (1) Observe the response of the instrumentation. Particular attention should be given to the nuclear instrumentation; however, process instruments and radiation detectors should also be checked.

---

* It should be emphasized that a startup should never be hurried. The supervisor in charge, with the help of the operator, should be assured that all essential systems are functioning normally before proceeding to the next power escalation step, regardless of the time element.

(2) Determine that the response of the servo control system is normal. If it is not, then the power level should not be increased until the cause of abnormal servo operation can be found and corrected.

(3) Obtain data from the reactor-noise instrumentation as detailed in Section 2.6.16.

(4) Check the performance and condition of the process system.

(5) If at 6 or 24 MW, see below.

(6) When the above items have been completed, and the supervisor in charge is satisfied that the complex is in order, proceed to the next power level desired.

h. At 6 MW:

(1) Obtain a heat balance, i.e., calculate the power from temperature and flow readings.

(2) Visually inspect the core in detail using viewing instruments if needed. This inspection may be made at slightly lower power levels if such a deviation fits the operation. It must, however, be made at 6 MW or below. Record the results of this inspection on an ORR lattice configuration form (see Example 1.1). This form is to be initialed by the supervisor in charge of the startup.

(3) If during the inspection, a particle(s) is detected on top of the fuel plates, and a single object is >1/2-in. diam,* the reactor should be shut down and the particle(s) removed. Such a condition should immediately be

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*Based on a decision recorded in intra-divisional correspondence, J. F. Wett, Jr. to J. A. Cox, dated August 8, 1960.

brought to the attention of the Reactor Supervisor or his designated representative. If a foreign object(s) (>1/2-in. diam) is observed inside the vessel (but not on fuel plates), the Reactor Supervisor or his designated representative should be contacted immediately.

i. At 24 MW:

(1) Following major shutdowns, and after significant changes in the core or instrumentation, a heat balance should be made after waiting at least 1/2 hour at 24 MW.

(2) Following refueling shutdowns, and after minor changes, the waiting time at 24 MW may be reduced if the supervisor in charge has determined that the response of the instrumentation and the system is essentially the same as before the shutdown.

<u>NOTE</u>: It may be necessary to adjust the chambers for the safety channels in order to obtain satisfactory agreement between the heat power and the indicated level-safety readout. The procedure for such adjustments is detailed in Section 2.6.1.

j. At 30 MW:

(1) Frequent visual inspections (usually once per shift at the beginning of each shift) should be made of the areas inside the reactor vessel and in the immediate vicinity external to the reactor vessel. Specific points of interest should be: (a) the core region, especially the fuel elements, the shim rods, the hold-down arms, and the facility tubes; (b) inside the reactor vessel outside the core region; and (c) the areas

of the poolside window and the ionization chambers external to the reactor vessel. Unusual conditions should be brought to the attention of the Reactor Supervisor or his designated representative.

(2) If during the inspection, a particle(s) is detected on top of the fuel plates, and a single object is >1/2-in. diam, the reactor should be shut down and the particle(s) removed. Such a condition should immediately be brought to the attention of the Reactor Supervisor or his designated representative. If a foreign object(s) (>1/2-in. diam) is observed inside the vessel (but not on fuel plates), the Reactor Supervisor or his designated representative should be contacted immediately.

1.2.10. Startup Following an Unscheduled Shutdown

In most instances, it will prove desirable to return the reactor to full power without refueling following unscheduled shutdowns. Time is an important consideration if this is to be accomplished before the xenon concentration increases sufficiently to prevent criticality. In no case, however, should safety be jeopardized regardless of the time element. A refueling schedule is maintained ready for use at any time. The refueling operation can be accomplished in only three to four hours and, therefore, does not represent a very great loss of operating time. It does represent an inconvenience to the experimenters and perhaps an increase in operating costs, and for these reasons should be avoided when it is possible to do so in a completely safe manner.

A plot of gang-rod position versus time following a power reduction from 30 MW to N_L is included as Fig. 1.1. This curve along with other information* can be used to estimate the time available to effect a startup.

1. Precautions

The shift supervisor should be assured that:

a. the checks specified on the "Checklist for the ORR Restart Following an Unscheduled Shutdown" are completed (Section 1.4.4, Example 1.3);
b. all parts of the reactor complex are functioning correctly or that any variations from normal are understood and nonhazardous;
c. all experiments are ready for the reactor to be restarted; and
d. in the case of an electrical power outage:
   (1) the reactor instrumentation has sufficient warmup time following the restoration of electrical power (see Section 1.4.6, Example 1.4),
   (2) the checks specified on the "ORR Power-Outage Check Sheet" are completed (Section 1.4.6, Example 1.4), and
   (3) the reliability of the level-safety channels is verified through "Jordon button" tests.

2. Procedure

a. The control-desk operator should notify the shift supervisor of the unscheduled shutdown immediately. In turn, the shift supervisor will provide specific instructions to the operator as to what actions he should take. If the shift supervisor is in another area, he should proceed immediately to the control room. In most instances, the shift supervisor should arrive in the control room before all the drives have completed their automatic rundown.

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*T. P. Hamrick, "Xenon Concentration in the ORR Core at 45-MW Operation," ORNL CF-64-10-34.

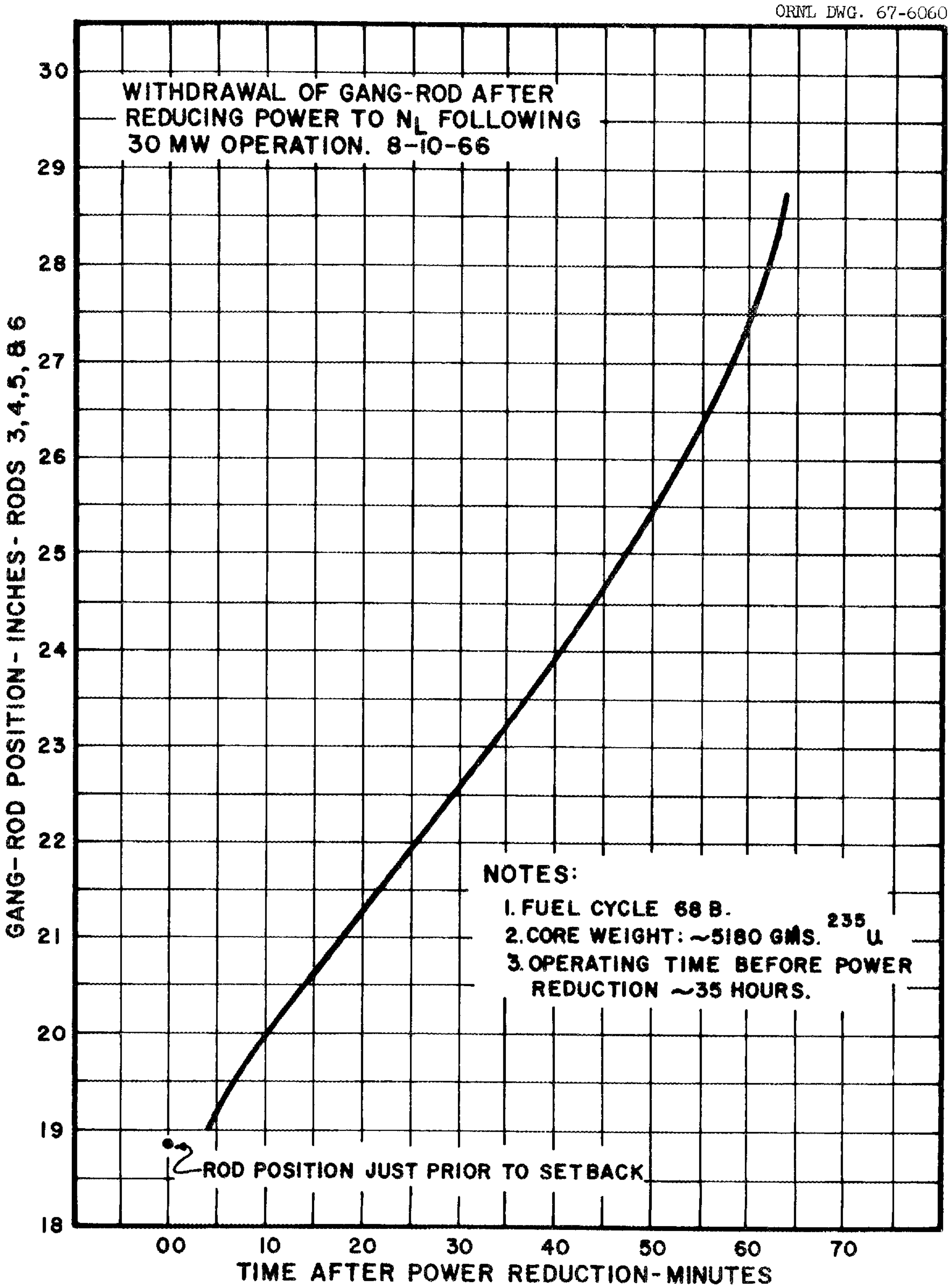

Fig. 1.1. Graph of gang-rod position versus time following a power reduction from 30 MW to N_L.

b. In all cases, the precautions listed above should be observed. "Jordon button" checks are required after a power outage and may be warranted following other unscheduled shutdowns.

c. The reactor should then be returned to power using the start-up mode which, in the judgment of the personnel on duty, best fits the circumstances. The following statements are offered as guidelines.

   (1) Instrument start affords a quick return to N_L and frees the operator from certain manual tasks, making it possible for him to observe the instrumentation almost constantly. He is, therefore, better prepared to effect the change to the "run" mode without delay. The "bypass" and "fast-period-permit" switches may be used with instrument start if needed.

   (2) If a delay at N_L is to be avoided, particularly when in instrument start, the controls should be manually switched to "Operator Start" while the reactor is slightly below N_L. The period can then be adjusted to slightly greater than 30 s to permit obtaining "run" mode.

   (3) The servo-controlled rod should be held below 25 in. withdrawn whenever possible. Power changes under servo control when the servo-controlled rod is withdrawn beyond this point are usually troublesome and must be made carefully. The difficulty stems from the fact that the worth per in. of the shim rods is quite low in this range. The reactivity assigned to the servo decreases proportionally since the servo-controlled rod span is fixed.

   (4) When it is necessary to withdraw shim rods 1 through 5 to the upper limit, and the servo-controlled rod is beyond 25 in. withdrawn, very careful manual operation may prove to be the most effective means to increase the power level. The servo demand can then be matched to the power level before returning to servo control.

1.2.11. Radiation Background Survey

Due to the many potential hazards associated with the reactor startup, Health Physics personnel should be present during all startups following all shutdowns involving maintenance on experiments and/or the reactor to monitor the most critical areas. In general, the following radiation surveys should be made during the startup and subsequent operation.

1. The beam holes, north and south facilities, and the pipe chase should be monitored during the startup if maintenance has been performed in these areas. They should be checked for fast and thermal neutrons and beta-gamma radiation.
2. A complete "Background Radiation Survey" (refer to "Background Survey" in Section 8.1.3) should be made soon after operating power is attained.
3. During continuous reactor operation, a complete "Background Radiation Survey" should be made each week.
4. Additional radiation surveys should be made by Health Physics or Reactor Operations Section personnel whenever necessary.

1.2.12. Priorities in Restarting the ORR and BSR

Specific procedures pertaining to remote operation are provided in the ORR Operating Manual, Section 1.3.7 and the BSR Operating Manual, Section 2.2.4.

On occasion, a situation may arise in which both reactors simultaneously encounter an unschedulaed shutdown, e.g., because of an electrical power outage. Operating history indicates that this occurs about four times each year. To provide for an orderly recovery from unscheduled shutdowns, it is necessary to list the priorities to be used in restarting the reactors.

When an unscheduled shutdown of both reactors occurs, the following priorities should be exercised in restarting the reactors. However, each facility should be checked to ensure that it is in an acceptable shutdown condition before any restart begins.

1. Priority number one - ORR

   Since the ORR operates at the highest neutron flux, the problem of xenon poisoning is more pressing. Consequently, following a shutdown, the ORR should be restarted as soon as possible, consistent with established operation procedures as listed in Sections 1.2.10 and 1.4.6 of the ORR Operating Manual. The BSR should remain in a secured condition until the ORR has been returned to power unless individual reactor supervision is available. In the event that the ORR has been poisoned with xenon and requires refueling, the BSR should be restarted. This should be performed prior to refueling the ORR or concurrent with the refueling if an adequate number of qualified personnel is available.

2. Priority number two - BSR

   The BSR should be restarted following the established operating procedures as detailed in Section 2.1 of the BSR Operating Manual.

1.2.13. Priorities in Making Operational Decisions: ORR and BSR

Section 1.2.12 outlines the standard priorities for deciding which reactor to start up first in case both are scrammed simultaneously by a loss of electrical power. Other circumstances might arise which could cause unusual operation at both reactors but still not shut either of them down. For instance, an automatic power setback might occur, a control system might suddenly require constant attention, or radiation alarms might sound from several sources. Unusual occurrences of this type also require that the operator and the supervisor make a decision about what to do, and sometimes the action to be taken must follow some priority order. Here again, the general priority would be: ORR first and BSR second.

It should be emphasized that either or both reactors may be shut down by the operator on his own authority if he feels that too much is going on for him to handle his responsibility properly.

It is possible that special circumstances requiring new priorities might arise. For instance, an experiment at the BSR might be so important to the Laboratory that, during the term of the special experiment, the BSR would be kept operating or started up after an electrical power outage in preference to the ORR. All likely circumstances usually cannot be anticipated; therefore, it is impossible to predict all of those with a low probability for occurrence.

1.3. Steady State Operations

1.3.1. Continuous Power Operation

During continuous power operation, equipment checks must be made and data recorded on a routine schedule. Other duties associated with reactor experiment services must also be performed.

The reactor power is held constant at a predetermined level. Power adjustments, if required, are made with the servo demand in conjunction with the servo vernier. When the reactor reaches equilibrium, fewer adjustments are required; however, no less attention should be given to the operation of the reactor. The control console must not be left unattended at any time when the shim rods are withdrawn.

The tasks of the shift supervisor are quite varied and, on occasion, require that he be in other areas. To carry out his responsibilities in other areas, as well as in the ORR building, the following general rules should be observed.

1. When leaving the ORR building, he must always inform the ORR control desk operator where he can be reached.
2. If his absence from the ORR building is of a long duration, he should make periodic calls to the ORR control desk (approximately every 30 min).

During continuous power operation, the following duties must be performed.

1. Shift supervisor

   The shift supervisor has the direct responsibility for the operation of the reactor at all times during his shift. He directly supervises startup of the reactor and any increase in power level. He makes certain that procedures are followed during reactor operation and shutdown. It is his responsibility to see that the operators on his shift meet the training and qualification standards of the Operations Division and receive training on any new procedures or equipment which may be added.

2. Console operator

   The console operator's main duty is to observe the reactor instrumentation. He should be on the alert for indications of abnormal behavior; if this should be observed, he notifies his supervision. He also records data regularly on the special data accumulation sheets (refer to Section 8.1).

3. Roving operators

The roving operators make periodic checks on the water systems in the reactor building and in the pump area, record midshift readings as per the data accumulation sheets, (refer to Section 8.1), perform pool and hot cell work, assist experimenters as needed, make routine building radiation surveys, check the operation of emergency equipment such as the emergency power generator, complete the routine check sheets, and perform other duties of a nonroutine nature as may be required.

1.3.2. Heat-Power Calculations

1. The power level of a reactor is based upon the calculated heat power; (i.e., the heat gain in the reactor and pool cooling water systems). Accurate calculations of heat power using the ΔT in °F, flow in gpm, and conversion factor of 1.448×10^{-4} must be made at all reactor power levels above N_L on the log-N meter. Detailed instructions for calculating heat power are on the "ORR Hourly Readings" data sheet (refer to Section 8.1).
2. Heat-power calculations during reduced-power operation and start-ups will be made as follows for fractions of an hour:
   a. Shutdown not resulting in a reloading of the core:

(1) Integrated heat for that portion of hour prior to shutdown = Fraction of hour prior to shutdown X Most recent hourly heat balance

(2)	Integrated heat power for that portion of hour subsequent to startup	=	Integrated instrument power for portion of hour subsequent to startup divided by 30 MW	X	Subsequent hourly heat balance after a minimum of 30 min at full power (N_F)

b. Startup after refueling: same as a (2).

1.3.3. Variations and Adjustment in Heat Power and Instruments

There are inherent characteristics in the method of operating the ORR which cause a continuous slow changing of the power level during a sustained period of operation. This is pointed out to acquaint personnel with this fact and to alert them to the importance of knowing the "whys" of power-level changes.

In normal operation, the heat power will slowly increase due to the change in position of the shim rods as fuel is depleted during the cycle. This occurs because the ionization chambers see a slowly decreasing flux as the cadmium sections of the shim rods move upward; and, since the servo system controls the reactor by maintaining a constant flux at the chamber location, the heat power (actual power) will slowly increase. Also some deviations in power level will occur due to the varying temperature of the reactor cooling water.

Deviations in power level due to the above are not to be confused with power changes from other causes such as experiment changes, the filling or emptying of horizontal beam holes or facilities, or other unexpected changes. In the event of any unexplainable power change, the reactor should be scrammed and the ORR supervisor must be notified.

The basis for power level adjustments shall be as follows:

1. adjustments in power level shall be made when the change is greater than 1% of full power for two hours;
2. adjust the power level to full power;
3. adjust the sensitivity switches on the level-safety channels Nos. 1, 2, and 3 to read 100; and
4. if unable to obtain 100, see Section 2.6.1, Safety Chambers.

1.3.4. Shim-Rod Positions

In order to maintain a reasonable uniform flux distribution, the Nos. 1 and 2 shim rods are kept at the upper limits and the Nos. 3, 4, 5, and 6 are kept as nearly even as is practical. During normal operation, keep the servo-controlled rod within 1 in. of the position of the other rods at all positions less than 25 in. The nonservo-controlled rods, excluding the Nos. 1 and 2 rods which are kept at the upper limit, are kept at equal distances withdrawn.

As the reactivity decreases due to fuel burnup and the shim rods are withdrawn to compensate, the servo-controlled rod is maintained at 25 in.* to retain adequate sensitivity for reactor control.

At least once per shift, all rod positions, excluding Nos. 1 and 2, are equalized and the rod positions, including Nos. 1 and 2, read both on the selsyns and on the measuring sticks in the subpile room.

Occasionally it is necessary to recover from a reactor shutdown after a single shim rod has dropped. To minimize the time required to attain full power so as to avoid a shutdown due to xenon poisoning, the remaining shim rods may be withdrawn while the dropped rod is being retrieved. This type of rod operation is permissible at 1% of full power (N_L) or below; however, the reactor power should not be increased above N_L until the dropped rod has been withdrawn at least 14.5 in.

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*As the other rods in gang position exceed this position.

1.3.5. Evaluating the Performance of Power-Indicating Instruments

The reactor power is displayed on several instruments in the control room. Included in this group are the recorders for the three level-safety channels, the micromicroammeter channel, the two ^{16}N channels, and the two gamma-chamber channels. The reactor power-indicating instrumentation is periodically adjusted to agree with the heat power as calculated from a heat balance across the reactor.

As mentioned in Section 1.3.3, some variations and adjustments in power are expected - some normal and some abnormal. It is most important that abnormal conditions be recognized and corrected. An improperly adjusted servo amplifier can cause the servo-controlled rod to move in and out of the reactor more often than normal. Also, certain conditions may develop in the reactor core which will cause fluctuations in reactivity. The servo system will try to compensate for these changes and in doing so will move the servo-controlled rod more than usual. When the servo-controlled rod moves in this manner from either cause, the result is the same. Reactor power recorders will show abnormal fluctuations.

It is important to determine as quickly as possible which of these two general causes (instrument trouble or other trouble) is affecting the operation. To do this, use the following procedure:

1. with the reactor as near stable as possible (i.e., reactor should be on an infinite period) place the reactor in the manual mode of operation;
2. with the reactor in manual, observe the power stability for at least 5 min as indicated on the recorders of the three level-safety channels, the micromicroammeter channel, and two gamma-chamber channels;

3. if the servo system is faulty, power fluctuations will not persist in manual operation (When this is the trouble, continue operation in manual and notify the proper personnel of Reactor Operations and Instrumentation and Controls.);
4. if power oscillations continue after switching to manual control, a condition in the reactor causing changes in reactivity can be suspected; and
5. if the power variation is due to an unknown cause, the reactor should be shut down, and the Reactor Supervisor should be notified.

If during manual operation, abnormal, unexpected variations in power are indicated simultaneously on two or more independent power instruments, the reactor must be shut down and the Reactor Supervisor notified.

1.3.6. <u>Minimum Instrumentation Limits for Constant Power Operation</u>

1. When the reactor is at constant power $\geq 3\ N_L$, the minimum instrumentation shall be:
   a. two power-level safety channels,
   b. one ΔT channel,
   c. two reactor-water exit temperature channels,
   d. two reactor primary-coolant flow channels (Flow channels may utilize direct flow measurement or measurements of core ΔP using flow calibrated ΔP instrumentation.),
   e. one ^{16}N channel,
   f. one POG channel (POG monitor is required only if experiments are connected to the POG system.),
   g. one NOG channel,
   h. one north-facility water-flow channel,
   i. two south-facility water-flow channels,

j. one cell-ventilation flow channel (including the building and filter pit radioactivity monitors),

k. one operating radioactivity monitor associated with the reactor primary cooling system,

l. one pool primary-water flow channel, and

m. one primary make-up rate channel.

The above limitations are set forth as an absolute minimum. In all cases where practical, the maximum complement of instrumentation will be maintained. Should an occasion arise when the minimum cannot be met, the reactor must be shut down immediately, and action taken to obtain necessary repairs. Operation of the reactor with minimum instrumentation requirements shall be authorized by the Reactor Supervisor or his designated representative.

1.3.7. ORR and BSR Operation from ORR Control Room

The BSR remote console located in the ORR control room contains the remote control instrumentation including two closed-circuit television sets. The BSR must be under servo control before remote operation is permissible. Normally, one operator located in the ORR control room can operate both reactors. The shift supervisor will decide when the BSR is to be operated remotely and the number of operators required to operate the reactors.

1.3.8. Responsibilities of the Operator Manning the ORR and BSR Controls

In addition to his responsibilities as the ORR operator, as described in Section 1.2, he must also attend the BSR remote console. He must be alert for any changing trends in recording information on the reactors. At the first indication of abnormalities, he is to contact the shift supervisor. For details on both the local and remote operations, refer to Section 2.2.4 of the BSR Operating Manual.

1.3.9. Number of Operators Required to Operate the ORR and BSR from the ORR Control Room

When the reactors are operating at a constant power level under servo control and conditions are normal, one operator can operate both reactors from the ORR control room. Also, if either reactor is shut down, only one operator is required in the control room. If desirable, the BSR can be operated from the BSR local console when the ORR is shut-down thereby negating the need for an operator in the ORR control room.

If a situation develops that requires the operator to concentrate exclusively on one reactor, he should immediately notify the shift supervisor so that another operator can be assigned to the controls of the other reactor. For example, two operators are required if the ORR is operated in manual control for more than a short period of time. Also, during the startup of the ORR, two operators are required. On occasion during ORR shutdown work, e.g., I&C performance checks, it may be desirable to have two console operators. Assignments are made at the discretion of the shift supervisor. The BSR must be operated from the local control room when in manual control, during its startup from source level, or during a scheduled increase in power.

1.3.10. Procedure for Accepting Responsibility of Reactor Operations by the Oncoming Shift Supervisor at the ORR and BSR

It is not possible to provide a procedure that will apply in full for every operating condition which could arise. The following procedures provide, instead, sound guidelines based on experience. The proper execution of the duties of the shift supervisor and controllers rests with well-trained and experienced personnel.

1. <u>During normal, routine operation</u>

During normal, steady-state operation, the shift supervisor coming on duty will perform the following checks in order to become aware of any changes in the status of any system, instrumentation, requirements, schedules, etc., that may have occurred during his absence:

a. check the mail box, change-memo notebooks, and sample sheets;

b. check with the shift supervisor on duty regarding the status of operations;

c. check the logbook and special-instructions notebook (new entries);

d. check all intrument readouts in the control room;

e. check attendance to determine that the required certified personnel are present for the oncoming shift; and

f. make sure that the oncoming controllers are aware of any operational changes.

If there are any questions on work assignments, change memos, or the status of any routine work in progress, the answers should be obtained and understood in detail <u>prior</u> to assuming the responsibility of the oncoming shift supervisor.

<u>NOTE</u>: If the oncoming shift supervisor has been away from the operating facility for an extended period of time (i.e., exceeding four days) due to vacation, illness, etc., he will review all log entries from the time he last made an entry in the logbook.

2. <u>During shutdown activities</u>

During shutdown conditions, special attention will be given to all operational activities and control room indications prior to assuming responsibility for supervising the oncoming shift. In addition to the items to be checked during normal, steady-state operation, the oncoming shift supervisor will also check the following items.

a. Check each work assignment listed in the shutdown schedule book. Any questions on possible conflicts in work or personnel scheduling, materials, etc., that might evolve on his shift will be directed at the Reactor Supervisor, Assistant Reactor Supervisor, or day shift supervisor.

b. If the shutdown is already in progress, check the status of each job by going down the list of Operations, P&E, and I&C work assignments and checking on each with the shift supervisor on duty.

c. Check with the P&E and/or I&C supervisors, as appropriate, to learn the status of their projects, as needed.

If there are any questions on the shutdown, maintenance, or startup activities, the answers will be obtained <u>in detail</u> prior to assuming the responsibility of the oncoming shift supervisor.

<u>NOTE</u>: If at any time activities are such that the oncoming shift supervisor is not fully informed of the status of the facility and/or jobs in progress at the time of shift change, the shift supervisor on duty will remain over on the next shift until all points in question are clarified with the oncoming shift supervisor so that he can assume his supervisory duties in a safe and reliable manner.

If emergency conditions exist, or the necessary certified personnel are not present for the oncoming shift, then the controllers on duty will remain until relieved, or until adequate additional personnel are present and in control of the situation.

1.4. Shutdowns

1.4.1. Scheduled Shutdowns

All scheduled shutdowns should have a shutdown sheet or schedule, prepared in advance (if possible) by a supervisor, listing in detail all of the work to be done. This may be fairly elaborate in the case of a quarterly shutdown. Shutdown schedules may be simpler when the shutdown is for some special reason. In general, the number of shutdowns is kept to a minimum consistent with the experiments. Whenever possible, at least 24 hours advance notice is given for a scheduled shutdown. This notice is posted on the "Shutdown Board" giving the shutdown time, approximate duration, and the reason for the shutdown.

1.4.2. Shutting the Reactor Down

1. Ten minutes prior to shutdown time, announce the forthcoming shutdown over the public-address system.
2. Shut the reactor down according to the instructions on the shutdown sheet. This will vary from time to time due to experiments which may be in the reactor.
3. Turn the scram switch to "scram" and leave it in this position.
4. Turn the key switch to the "off" position and remove the key.
5. Lower the reactor-water inlet-temperature set-point to equalize the reactor and pool water temperatures.
6. After postshutdown cooldown requirements have been satisfied, close the motorized valves and then stop the reactor-primary 6000-gpm pumps (refer to Section 5.2.1). The shutdown pump will automatically start when the 6000-gpm pumps are stopped or when the flow drops to <1500 gpm.
7. Stop the reactor-pool primary and secondary pumps.
8. Complete the ORR "Shutdown Checklist" (refer to Section 8.1.3).

1.4.3. Reporting Reactor Shutdowns

In order to maintain consistency in reporting reactor shutdowns, a rubber stamp form, Example 1.2, is used in the logbook. Each shutdown from an accountable power level should be reported in this manner regardless of the number of shutdowns that occur. The minimum accountable power level is N_L.

No more than one form should be used for each shutdown. The supervisor on whose shift the shutdown occurs will make initial use of the form for reporting the shutdown. The supervisor on whose shift the reactor reaches the minimum accountable power level following startup will be responsbile for completing the form with respect to "up," "lost time," and "time distribution."

SHUTDOWN INFORMATION

TIME: down________ up________ lost time___________h

SCHEDULE: scheduled [R] [0] unscheduled [R] [0]

MODE: scram setback reverse

CAUSE: equipment [M] [I] HE [ ] other [ ] unknown [ ]

TIME DIST: operations ______h research ______ h

CIRCUMSTANCES:____

Example 1.2

A guide to the use of the form follows.

Time

Down. Refers to the time that the reactor power level drops below the minimum accountable power level.

Up. Refers to the time that the reactor, upon startup, reaches a power level equal to or in excess of the minimum accountable power level.

Schedule. Check the appropriate square

"R" and "O" refer to "Research" and "Operations" and the checked square indicates the group responsible for the shutdown, whether scheduled or unscheduled. An unscheduled shutdown is defined as any shutdown which is required to correct an abnormality.

Mode. Check the appropriate square

Scram. A shutdown caused by the release of shim rods.

Setback. An automatic reduction in power by servo. If the setback clears before the reactor power falls below the minimum accountable power level, it does not constitute a shutdown and the form should not be used. All setbacks, however, must be reported in the customary way in the logbook.

Reverse. A reduction in power by an automatic or manual insertion of a shim rod. If, as in the case of the setback, the reactor power does not fall below the minimum accountable level, the reverse does not constitute a shutdown and the form should not be used.

Cause. Check the appropriate square

Equipment. If the shutdown was a result of equipment failure, check whether the failure was mechanical (M) or an instrument (I) failure. At times it is difficult to distinguish between instrument and mechanical failures. The mechanical failure of a limit switch or a similar device in an instrument, for example, is confusing; however, since the switch is a component of the instrument, the failure is classed as instrument failure. Compressor failures, motor failures, pump failures, etc., are clear-cut examples of mechanical failures.

HE. Indicates human error, whether due to poor judgment or inadvertence.

Other. Calls for an explanation under the heading "Circumstances," as to the cause of the shutdown. If adequate space is not provided, a continuation of the explanation should be made in the customary manner.

Unknown. Self-explanatory.

Time Distribution

Fill in a reasonable estimate of the downtime for which the research group and/or the operating group are responsible.

1.4.4. Unscheduled Shutdowns

When an unscheduled shutdown occurs, the shift supervisor should make an immediate evaluation and initiate corrective action as needed and complete "Checklist for ORR Restart Following an Unscheduled Shutdown" (Example 1.3) if applicable. The results should be detailed in the logbook. The Reactor Supervisor or his designated representative should be made aware of the anomaly as conditions dictate. If maintenance work (mechanical, electrical, or instrument) is required during other than regular duty hours, the Reactor Supervisor or his designated representative should be notified immediately.

1.4.5. Radiation Control Measures

1. Regulations for pool entry during shutdown operations
   Entry to the ORR pools during shutdown activities is subject to "contamination-zone" and "radiation-zone" regulations. These regulations are restated to ensure familiarity to all personnel.
   a. The pool and associated area must be established as a "contamination zone."
   b. A valid "Radiation Work Permit" must be on hand.
   c. The minimum personnel monitoring requirements shall be: pencil meters, direct-reading pocket dosimeter, and a film badge.
   d. The special pool gamma monitor must be in position and checked for proper operating condition.
   e. The regular pool monitron must be checked for proper operation, as per part 2, below.
   f. Upon exiting from the pool, each person shall be checked for contamination; and his exposure record shall be brought up to date.

   It is the responsbility of the shift supervisor to ensure that all regulations are followed.
2. Use of monitors in reactor pool during ORR shutdown
   A specially adapted gamma monitor has been made available to monitor general radiation background in the reactor pool during shutdown operations. This instrument has a remote chamber which

CHECKLIST FOR ORR RESTART FOLLOWING AN UNSCHEDULED SHUTDOWN

The start-up checks indicated on the following checklist shall be completed before or while restarting the ORR after an unscheduled shutdown. As noted in the list, a startup following a power outage requires that an additional set of checks be accomplished and documented, i.e., another checklist completed.

		Initial
1.	The cause of the shutdown is understood	______
2.	If due to power outage, complete additional checklist (Power Outage Recovery Checklist for the ORR)	______
3.	Any trouble or malfunction corrected or compensated for	______
	FOR ANY STARTUP	
4.	One counting channel operable and responsive if neutron level is below log-N confidence	______
5.	One log-N channel operable and responsive	______
6.	Two safety channels operable	______
7.	One ^{16}N channel operable	______
8.	One NOG vacuum monitor operable	______
9.	One building ventilation flow monitor operable	______
10.	One ΔT channel operable	______
11.	Two reactor-water exit-temperature channels operable	______
12.	One north-facility flow channel operable	______
13.	Two south-facility flow channels operable	______
14.	One POG vacuum monitor operable (only if experiments are connected to the POG)	______
15.	Primary-system cooling flow normal	______
16.	Pool cooling system normal	______
17.	Secondary systems normal	______
18.	Building containment system operable	______
19.	Electrical power supply to the area is normal	______
20.	Reactor startup procedure followed (see ORR Procedure Manual)	______

______________________ ______________
SHIFT SUPERVISOR DATE

Example 1.3

can be placed near the top of the reactor vessel with the necessary versatility to adjust the alarm point only slightly above the background at the particular location. Proper use of this instrument will detect increases in radiation level by sounding two local alarms - one alarm from the master gamma monitor at poolside and one remote alarm near the remote chamber. The regular monitron, whose chamber is suspended from the north pool parapet, also serves as a "backup" for the special monitron. The standard operating procedure for using the special gamma monitor during shutdown operations shall be as follows:

a. Immediately after lowering the reactor pool water, the chamber of the "special" gamma monitor should be placed near the reactor tank top, and the adjustment made on the monitor to give an alarm if a slight increase in the radiation level occurs.

b. The special monitor is usually adjusted with the alarm point approximately 25 mr/h above the normal radiation background level. This operation is sanctioned by the ORR Health Physics representatives. If needed, the shift Health Physics representative may be contacted.

c. The proper operation of the gamma monitor can be checked in the following ways.

    (1) The alarm condition can be checked by placing the ^{60}Co source (stored in the Health Physics Office) close to the chamber of the instrument.

    (2) The alarm condition can be checked by pressing the alarm check button on the gamma monitor which will drive the readout of the monitor upscale to the alarm point.

    (3) The sensitivity of the monitor can be observed as the remote chamber is lowered into the radiation field above the reactor-pool grating level.

During the shutdown, activities may be such that the pool level is raised and lowered several times. Each shift supervisor is responsible for replacing the monitor near the reactor tank each time the pool level is to remain down for any appreciable time.

In order to apply the intended usage of the special gamma monitor effectively, each shift should check to ensure that the monitron is set properly. This check should be made each shift by Operations personnel during shutdown week. Following the completion of the shutdown activities and just prior to raising the pool level, the "special" chamber should be removed and placed in proper storage.

1.4.6. Power Outage - Checks to be Made

The loss of electrical power to the ORR-BSR complex is a condition which must, on occasion, be tolerated; and precautions have been taken to minimize the undesirable effects of such an incident. The outage can be of two types: (1) unscheduled and (2) scheduled. Various components (which are checked periodically following standard procedures) have been installed to provide protection when outages are unscheduled. For the power outages which are scheduled, additional precautions are taken. Checklists for each reactor facility are to be used as guides in: (1) preparing the systems to limit the possibility of hazardous conditions in the building and also limit the possibility of damage to experiment equipment and reactor components and (2) completing the necessary requirements for returning the reactor to power operation. The priority to be exercised in completing the checks should be based upon sound judgment and Sections 1.2.2 and 1.2.3 of this manual. These checklists are listed as Examples 1.4 through 1.7.

POWER-OUTAGE RECOVERY CHECKLIST FOR THE ORR

The checklist below was prepared for the situation where the reactor was at power operation when the electrical outage was experienced and the reactor will be returned to power immediately.

1. The following items must be completed before the reactor can be restarted.

	INITIAL
a. A 5-min warm-up time on the level-safety channels, after restoration of TVA power, must be observed.	_______
b. Insert the fission chambers as required.	_______
c. Recalibrate both log-N channels.	_______
d. Perform the Jordan button test on at least one sigma amplifier.	_______
e. Perform experiment checks as required by the experiment information book. This experiment information notebook should be checked for current requests.	_______
f. Place the pool cooling system in service, ensuring that the SB switch is reset and in "auto," and that the main pump, the secondary pump, and fan are restarted.	_______
g. Place the reactor cooling system in service, ensuring that the secondary pumps are restarted, the secondary fans are restarted, the primary bypass system is in "auto," and that the temperature setpoints have been established.	
h. Restart the facility cooling pump (north and/or south) and establish flow to the north and south facilities.	_______
i. The reactor can now be returned to full power following prescribed procedures.	_______

2. The following items may be completed after full power operation is obtained.

a. Return the emergency diesel-generator system to "standby" condition.	_______
b. Restart the Trane "Centravac" air-conditioning unit and associated chilled-water pumps, fan, etc.	_______

Example 1.4

INITIAL

c. Restart the cell-ventilation electric blower and stop the standby-blower operation by request to the chemical operator. ________

d. Restart the control room air conditioner. ________

e. Restart the pressurizable off-gas blower and stop the steam blower operation by request to the chemical operator. ________

f. Restart the overhead (roof) exhaust fans. ________

g. Return the electrically operated shutdown pump to "standby" condition. ________

h. Restart the building H&V units. ________

i. Restore the counting-room H&V unit and air-conditioning unit to normal operation. ________

j. Restart the pool demineralizer pump and place a demineralizer unit in service. ________

k. Restore degasifier to normal service. ________

l. The Nash-Hytor vacuum pumps should be returned to service. ________

m. Check all sump pumps and restart if necessary. ________

If a power outage occurs as a scheduled item, only those checks pertinent to "shutdown operation" need be checked at this time.

________________________________ ____________

SHIFT SUPERVISOR DATE

Example 1.4 (continued)

POWER-OUTAGE PREPARATION CHECKLIST FOR THE ORR

The items listed below are to be completed if it is known that a power outage will occur. It is assumed that the reactor is not operating. If the reactor is operating, it should be shut down prior to the outage.

1. Announce over the public-address system the expected power outage.
2. Experiment checks should be completed as required by the experiment information book. This experiment book should be checked for current requests.
3. Notify Hot Cells personnel of the planned outage.
4. Place log-N amplifiers on "ground-set" position.
5. Remove the Nash-Hytor vacuum pumps from service.
6. Remove the degasifier from service.
7. The Building 3039 stack off-gas and cell-ventilation system will switch to the diesel generator located in Building 3125, thereby allowing the continued use of the ORR cell-ventilation and off-gas systems.

Example 1.5

POWER-OUTAGE RECOVERY CHECKLIST FOR THE BSR

The diesel generator located at the ORR furnishes emergency power to specified circuits at the BSR in addition to circuits at the ORR and OGR. Refer to Section 2.1.8 of the BSR Operating Manual for detailed information on emergency electrical power circuits serving the BSR. These circuits will be automatically re-energized, upon a TVA electrical power failure, by the diesel-generator power plant.

1. The items listed below were prepared for the situation where the reactor was at power operation when the electrical outage was experienced and the reactor is to be returned to power.
   a. Return the ORR emergency diesel-generator system to "standby" condition. (NOTE: The diesel generator also supplies emergency power to the ORR and OGR. Certain requirements at the ORR and/or OGR could dictate when the diesel generator could be placed on standby.)
   b. Reset the building containment. The control room A/C unit and the pool room A/C units (Nos. 1 and 2) should start after a 3-min delay.
   c. Start the tower A/C pump and check the following A/C units for operation:
      A/C unit No. 7 located outside room 103
      A/C unit No. 6 located in room 204
      A/C unit No. 5 located in the north section of the second floor.
   d. Check the PCA control-room A/C unit No. 3 for operation.
   e. Complete the BSR prestartup checklist.
2. The items listed below were prepared for the situation where the reactor was not operating when the power outage was experienced.
   a. Complete items a, b, c, and d of the previously listed Section 1.
   b. Restart the skimmer pump.
   c. Restart the demineralizer pump.

Example 1.6

POWER-OUTAGE CHECKS FOR THE OGR

Following the deactivation of the OGR, the emergency electrical circuit supplying the Facility Radiation and Contamination Alarm System (FRCAS) was revised so that it is normally powered from the TVA electrical bus at the ORR and, upon power failure this circuit, receives power from the ORR diesel-generator power plant. In addition, the steam engine at the OGR fan house was replaced with an electric motor which also receives power during TVA power failure from the ORR diesel generator. Three areas of interest require attention following a TVA electrical power outage at the OGR and/or the OGR fan house: (1) the FRCAS which monitors the OGR building area, (2) the blower system at the OGR fan house which is designed to maintain a negative pressure on the OGR, and (3) the heating and ventilating units and the canal demineralizer in the OGR building.

1. Since the FRCAS is powered from the ORR under both normal and emergency conditions, the following checks should be made after a TVA electrical power failure to the ORR has occurred and restoration to normal has been made.
   a. Check all continuous air monitors to ensure proper operation.
   b. Check all monitrons to ensure proper operation.
2. The blower system at the OGR fan house (Building 3003) is powered by an electrical motor which, during normal conditions, receives its power from the TVA electrical bus; and, during abnormal conditions of a TVA electrical power failure, power is supplied through an automatic transfer system from the ORR

diesel-powered generator. There are no specific normal operations required by personnel either immediately following a power outage or upon restoration of TVA power; however, a patrol check at the site should be made to ensure that the automatic transfer functioned properly. An annunciator system in the ORR control room (refer to Section 7.1.2 for a description) will inform control room personnel when a TVA power failure occurs to Building 3003 and when the TVA power is restored.

3. The following checks should be completed following the restoration of TVA electrical power.
   a. A patrol check should be made through both the OGR (Building 3001) and the OGR fan house (Building 3003) to ensure that the return to normal conditions has been effected.
      (1) At the OGR, check the FRCAS to ensure proper operation.
      (2) At the OGR fan house, check the blower for proper operation.
   b. The OGR canal demineralizer pump motor, which is not on the emergency power circuit, should be restarted.
   c. The OGR heating and ventilation units should be restarted as outside weather conditions warrant.

Example 1.7 (continued)

1.5. Disassembly and Maintenance of Reactor Components

1.5.1. Removal and Installation of the Reactor-Vessel Access Cover

1. Removal of the reactor-vessel access cover
   a. Stop the main cooling pumps and remove their test blocks.
   b. Place the access-cover tool on the center post and turn clockwise (approximately 8 turns) until the four keepers are fully retracted inward.
   c. Lift the access cover using the access-cover safety hook (attached to a chain fall on the one-ton crane) by the following method:
      (1) Lower the safety hook and attach to the access-cover bail.
      (2) Using the chain fall, raise the access cover approximately 12 in. to ensure that the cover is free of the access-cover flange and guide pins.
      NOTE: Do not lift the access cover with the crane until it has been moved out of the access-cover flange by using the chain fall.
      (3) Using slow crane speed until the access cover is free of the experiment facilities, move it to storage in the third level "C" zone.
2. Installation of the reactor-vessel access cover
   a. The shutdown cooling pump may be stopped or operating.
   b. Move the access cover from storage using the access cover safety hook (attached to a chain fall on the one-ton crane) by the following method:
      (1) Using slow speed, position the access cover approximately 12 in. above the access-cover flange and guide pins with the one-ton crane.

(2) Using the chain fall, lower the access cover onto the access-cover flange.

(3) Detach the safety hook from the access-cover bail.

c. Place the access-cover tool on the center point and turn counterclockwise (approximately 8 times) until the four keepers are fully extended outward. Install torque wrench on tool and tighten center post to 35 ft-lb.

NOTE: If the shutdown pump is operating and the access cover is removed, a small (approximately 25 gpm) amount of primary coolant will flow out of the reactor vessel into the pool. An equivalent amount of flow will re-enter the system through the equalizer line; this flow will be observable on the primary makeup rate meter in the control room. As the access cover is sealed, the make-up rate meter should drop markedly.

d. Run the shutdown pump for several minutes to sweep out any air that may be trapped in the primary system. This action will minimize the probability of tripping the main cooling pumps immediately after starting them due to fluctuations in the make-up rate meter.

1.5.2. Removal and Replacement of Hold-Down Arms, Fig. 1.2

Reference Drawings

D-24090C, D-24091D, D-24092A, D-24093B, D-24094B, D-24095C, D-24096B, D-24097B, D-24098A, D-24099D, D-24100C, D-24101E, D-24102B, D-24103C, D-43558

The proper handling of the hold-down arms in the ORR core cannot be overemphasized. It is necessary to check thoroughly the position of these hold-down arms after each movement since severe trouble can arise

ORNL-LR-DWG 68258

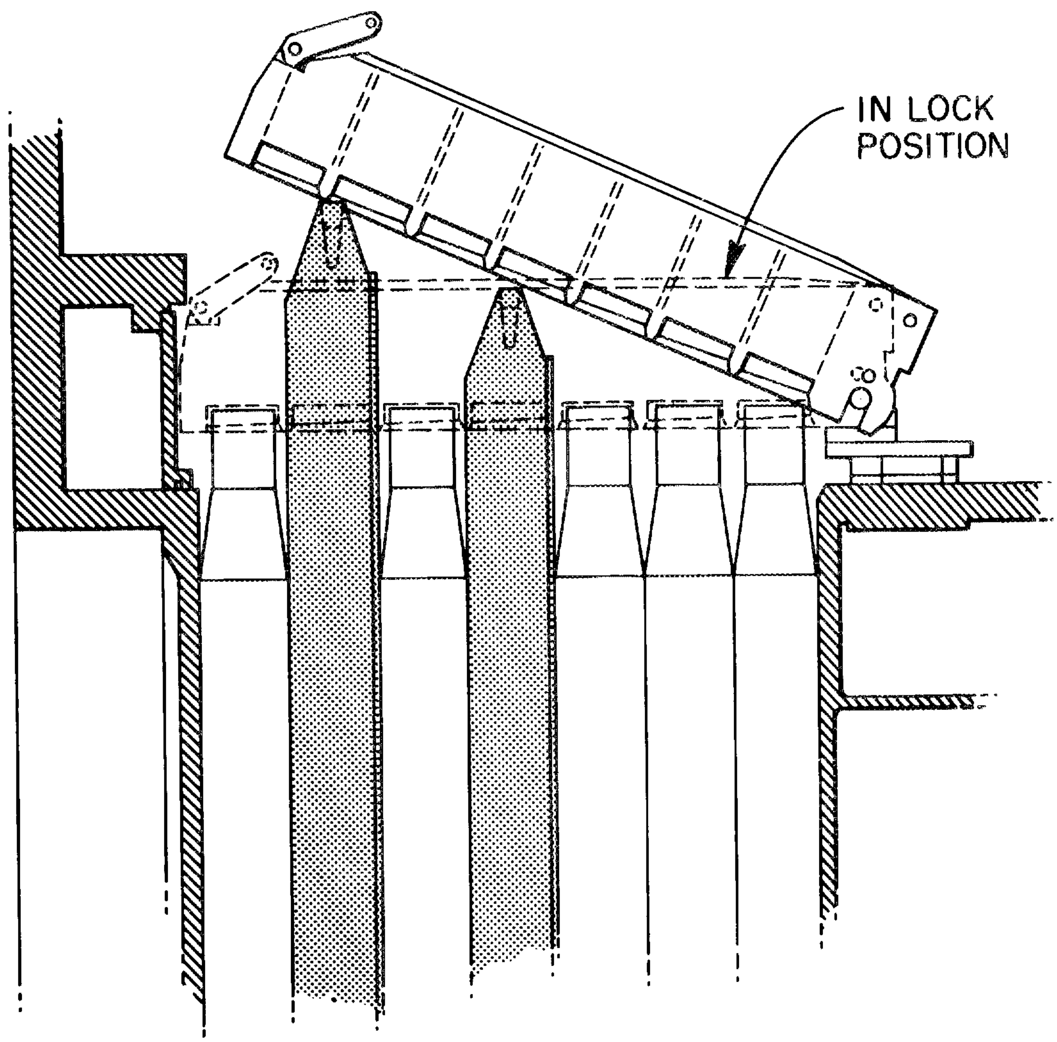

Fig. 1.2. ORR hold-down arm.

through bent shim rods if the rods should be raised without the hold-down arms being properly seated. The hold-down arms serve the dual purpose of holding the core pieces around the shim rod in position and serving as the upper shim-rod-bearing frame. At times it is necessary to remove the hold-down arms from the core for inspection. This action will be described also.

1. Removing the hold-down arms
   a. Ensure that all rods are on seat position.
   b. Engage the hinge latch located over the hinge on the east end of the arm with a hook, and pull slightly upward. When the latch is free, move the assembly eastward and it will fall free from the arm and can be laid on the hinge support.
   c. Engage the hold-down arm tool on the handle and raise the hold-down arm to a 45° angle.
   d. Engage a hook in the bar on the east end of the arm and apply a slight upward pressure.
   e. Gently apply an up-and-down motion with the hold-down arm tool until the arm seems to lock in one position.
   f. By lifting with both the hold-down arm tool and the hook, the arm will disengage from the hinge and can be lifted from the reactor tank.
2. Replacing the hold-down arms
   a. Ensure that all rods are on seat position.
   b. Engage the hold-down arm tool on the handle of the arm and lower the arm into the tank.
   c. Due to the balance of the arm, it will hang at approximately the proper angle for engaging the hinge. Slide the arm over the hinge, and the slots on the arm should engage.

d. By applying an up-and-down movement with the hold-down arm tool, the arm will lock into position on the hinge.

e. Lower the hold-down arm into seat position and lock as in the above procedure.

f. Engage the hinge latch with a hook and swing it over the hinge while applying a slight upward pressure. The tips of the hinge latch will lock into slots in the hold-down arms.

g. Disengage the hook; the hold-down arms are now ready for normal service.

1.5.3. Routine Raising and Lowering the Hold-Down Arms for Core Work

1. Raising the hold-down arms

a. Ensure that all seat lights are actuated, the drives are near the lower limit, the drive unit is in the locked position, and the magnet current is off.

b. With a hook, engage the handle of the arm and gently raise the arm.

c. When assured that the hold-down arm is free, raise it further, tilting the arm east, and let it rest in the raised position.

2. Lowering the hold-down arms

a. Ensure that the shim rods are in the seat position and that the magnet current is off.

b. Engage the handle of the raised hold-down arm, and lower it into the pre-seat position. Then place the hook tool on the handle.

c. With only slight downward pressure on the handle, insert a strong rod with a special tapping block tool attached. Use the block to tap the hold-down arm (approximately 6 in. from the west end) downward. The movement of the hold-down arm into the locked position can be felt through the tool on the handle.

d. To ensure seating and locking, use a small hook and attempt to pull the hold-down arm up by applying the hook under the hold-down arm body (6 in. from the west end). Any upward movement of the hold-down arm will indicate improper seating and locking.

e. For a final check, perform the following.

   (1) Using the raise-test switch, raise the drives 6 in.

   (2) Using a hook, raise each shim rod (one at a time) to ensure free movement. While this test is being performed, have the "popper" in service or post a man at the console to observe the CRM and have communication at all times.

f. With both hold-down arms fully seated and locked, the handles should be in similar positions.

1.5.4. Oak Ridge Research Reactor Shim-Safety Control-Rod Drive and Associated Assemblies

A notebook in the ORR control room entitled "Procedures for ORR Shim-Safety Control-Rod Drives and Associated Assemblies" contains the procedures for removal, installation, and maintenance of the assemblies. The notebook also contains the associated check sheets and method of record keeping.

1.5.5. Inserting or Removing an End-Box Adapter in the ORR Core

An end-box adapter is a stainless steel lattice component used to adapt a shim-rod position in the lower grid for fuel elements. It is normally used in all twelve possible shim-rod positions except those six which contain shim rods. The openings provided in the lower grid for shim-rod passage are slightly larger than the openings that accommodate regular fuel-element end boxes; therefore, the end-box adapters are used to size these shim-rod openings to accommodate the fuel elements. A special tool, fabricated for use in handling these end-box adapters, is of sufficient length to be used from the pool bridge. The tool is attached to the adapter and locked securely prior to removing the adapter.

It is necessary that the insertion or removal of an adapter be done in the following order.

1. Remove the core pieces from around the position containing the adapter (all eight pieces).
2. If the adapter is to be transferred to another core position, ready the position to accommodate the adapter by removing the surrounding eight core pieces.
3. Lower the tool into the adapter to be removed, rotate the knob on top of the tool clockwise to lock the tool to the adapter.
4. After securing the tool to the adapter, raise the "unit" so the adapter is free from the grid. The end-box adapter can be either transferred to another position or removed from the reactor vessel and stored under water in the pool.

2. INSTRUMENTATION AND CONTROLS

2.1. Introduction

The development of reactors introduced nuclear-instrumentation problems which were new to the instrument engineer and the solving of which usually required the efforts of specialists. As a consequence, process instrumentation came to be differentiated from nuclear instrumentation in the design of reactors. Instrumentation at the ORR is so divided; however, it should be remembered that a reactor functions as a complete system and no one variable should be overemphasized. Most engineers and scientists are aware of the consequences of the loss of nuclear measurement and rod control, but they may need reminding that the consequences can be just as serious with the loss of coolant flow and the coolant-flow meter.

In keeping with the above discussion, the importance of the instrumentation associated with the various research experiments also cannot be overlooked. Here again the consequences of loss of measurement and control could prove serious; and, therefore, at the ORR, experiment instrumentation must join with process and nuclear instrumentation in the function of safeguarding the reactor and its personnel.

To describe each instrument or even each instrument system would be a very difficult task and is beyond the scope of these procedures. It is more important that the major systems be described here and that those procedures which have proven essential to operation be presented.

2.2. General

The installation and maintenance of instrumentation is the responsibility of the Instrumentation and Controls Division of ORNL. Engineers, foremen, and technicians from this division are assigned permanently to this task and similar duties at the BSR. It is the responsibility of the Operations Division to assist with this work when necessary and to participate in thoroughly checking each instrument and instrument channel for proper operation both after repairs and on a routine basis.

As stated in the Introduction, loss of measurement or control might be serious. It follows that prevention of a misoperation is one of the most important functions of instrumentation.

This is accomplished through electrical or electronic safety circuits which are so devised that unsafe conditions will result in a reactor shutdown or a reduction in nuclear power level. Such a reduction in reactor power level will generally either remove the source of possible trouble or greatly reduce it.

The safety circuits (power reduction and/or shutdown) employed at the ORR are labeled Setback, Reverse, Slow Scram, and Fast Scram. To avoid confusion, a brief and simple explanation of each is given below. Elementary diagrams of the electrical circuits involved are presented on ORNL Drawings RC2-1-3AA through RC2-1-3C, RC2-10-2, and RC2-1-3E through RC2-1-3I.

2.2.1. Setback

This circuit is devised so that the actuation of instrument switches will result in lowering the demand setting (setpoint) of the automatic control system. This action continues until the cause is removed or until certain low-power interlocks are actuated. Under these (setback) conditions the control system will attempt to maintain the nuclear power equal to the setpoint.

2.2.2. Reverse

Activation of the reverse circuit results in simultaneous insertion of all the shim-control rods through rod-drive-motor action. Automatic control of the reactor is discontinued when the reverse occurs.

2.2.3. Slow Scram

In this action, electrical circuits, employing relays and other electrical or mechanical devices, cause a loss of current to the electromagnets supporting the shim-control rods. Time response of this system is approximately 250 ms. The complete insertion of all the shim-control rods should occur.

2.2.4. Fast Scram

This circuit with a time response of <10 ms employs electronic devices to vary the magnet current indirectly as the nuclear power or as the rate of power increases. Thus, the shim-control rods are dropped immediately when unsafe power levels are reached, or when the rate of power increase is too great.

2.3. Alarm Annunciator Panel

2.3.1. General Description

Reactor instrumentation, through the alarm annunciator panel, brings to the attention of the operator any abnormal condition of the monitored parameters. Automatic setback, reverse, or scram may occur simultaneously depending upon the seriousness of the malfunction.

The alarm annunciator panel (Fig. 2.1) consists of several stations, each of which is related to a particular variable or experiment. The stations themselves are nearly identical in construction and function and, for this reason, are described below in general terms. A detailed relationship between station and variable or station and experiment will be given later.

ORNL-DWG 84-8313

				EMERGENCY POWER											
AP 65	AP 67	AP 69	AP 71	AP 73	AP 75	AP 77	AP 79	AE 17	AE 19	AE 21	AE 23	AE 9	AE 11	AE 13	AE 15
AP 66	AP 68	AP 70	AP 72	AP 74	AP 76	AP 78	AP 80	AE 18	AE 20	AE 22	AE 24	AE 10	AE 12	AE 14	AE 16
AP 39	AP 37	AP 35	AP 33	AP 31	AP 29	AP 27	AP 25	AP 1	AP 3	AP 5	AP 7	AP 9	AP 11	AP 13	AP 15
AP 40	AP 38	AP 36	AP 34	AP 32	AP 30	AP 28	AP 26	AP 2	AP 4	AP 6	AP 8	AP 10	AP 12	AP 14	AP 16
V.B.#1				V.B.#2				V.B.#3				V.B.#4			

AE 1	AE 3	AE 5	AE 7	CLOCK PANEL								AP 41	AP 43	AP 45	AP 47
AE 2	AE 4	AE 6	AE 8									AP 42	AP 44	AP 46	AP 48
AP 17	AP 19	AP 21	AP 23	AN 1	AN 3	AN 5	AN 7	AN 9	AN 11	AN 13	AN 15	AN 17	AN 19	AN 21	AN 23
AP 18	AP 20	AP 22	AP 24	AN 2	AN 4	AN 6	AN 8	AN 10	AN 12	AN 14	AN 16	AN 18	AN 20	AN 22	AN 24
V.B.#5				V.B.#6				V.B.#7				V.B.#8			

AE 25	AE 27	AE 29	AE 31	AO 1	AO 3	AO 5	AO 7
AE 26	AE 28	AE 30	AE 32	AO 2	AO 4	AO 6	AO 8
AP 49	AP 51	AP 53	AP 55	AP 57	AP 59	AP 61	AP 63
AP 50	AP 52	AP 54	AP 56	AP 58	AP 60	AP 62	AP 64
V.B.#9				V.B.#10			

Fig. 2.1. Nuclear, process, experiment, and outside annunciators.

2.3.2. Station Description

An annunciator station consists of a signal can which is mounted behind two small translucent panels called station sections. One section is red or yellow; the other is white. A yellow section generally indicates that no setback, reverse, or scram will accompany an alarm. All stations are connected to the alarm horn.

2.3.3. Station Function

Any malfunction or abnormal condition resulting in a signal to the annunciator panel will:

1. sound the alarm horn, and
2. cause both sections (white, and red or yellow) of the receiving station to be lighted.

If an automatic setback, reverse, or scram is also initiated:

1. both sections, of the station indicating the action taken, will be lighted, and
2. a setback, reverse, or scram should occur.

2.3.4. Alarm Acknowledge

Pushing the acknowledge button at the console will silence the alarm and result in one of the following conditions.

1. The white section of the offending station will be darkened; and the red or yellow section will remain lighted, indicating that the abnormal condition still exists, or
2. the red or yellow section will darken; and the white section will remain lighted, indicating that the abnormal condition no longer exists and that the annunciator panel can be reset.

2.3.5. Alarm Reset

If the abnormal condition clears after the acknowledge button has been pushed, the red or yellow section of the offending station will be darkened; and the white section will become lighted. The annunciator panel is then reset by pushing the reset button adjacent to the acknowledge button at the console at which time the white section will be darkened.

2.3.6. Operator Response

In the event of an alarm for an unknown reason, the operator is to:

1. press the acknowldge button only,
2. observe the nature of the alarm to see if it results in a setback or scram, and
3. contact his supervisor immediately unless he has specific instructions to do otherwise.

2.3.7. Testing all Annunciators

To facilitate testing of the annunciators, a single pushbutton (annunciator test) located on the left inclined panel of the console actuates all annunciators simultaneously when pressed to verify their ability to respond to alarm conditions. The test should be accomplished as follows:

1. Press the annunciator test button and observe that the action causes all telealarm stations including poolside to be lighted (white and red or yellow) and then release the test button.
2. Press the acknowledge button (in the control room and at poolside) to clear the red or yellow section of the telealarm stations. The white section of the stations will be lighted. The annunciator panel is then reset by pushing the reset button (in the control room and at poolside) and the white section will be darkened at the stations.

2.3.8. Process Annunciators - Detailed Description

The process alarm annunciator stations for the process instrumentation are depicted on Elementary Diagram RC2-1-3G. A description of each annunciator is given in the following pages along with prescribed operator actions if the annunciator is actuated.

Annunciator: AP-1, "Test Blocks"

Alarm Condition: Main coolant pump safety blocks are removed. (These are normally removed during shutdown as a precaution to prevent inadvertent starting of pumps.)

Sensor Name: Safety blocks

Type: NA

Position: NA

Physical Location: ORR Control Room

Set Points: NA

Equipment Response: NA

Operator Actions: NA

1. This alarm is manually activated and should not occur during normal power operations.

Annunciator: AP-2, "Low Pool Temperature"

Alarm Condition: Low temperature of pool return water at 85°F

Sensor Name: TE-42

Type: Gas-filled bulb

Position: Pool return from heat exchanger

Physical Location: ORR basement west (end) on exchanger outlet elbow

Set Points: 85°F - low alarm

95°F - high alarm (AP-9)

Equipment Response: Pool tower circulation pump in the automatic mode trips out (with alarm setting at 85°F); the pump starts automatically when the alarm clears.

Operator Actions:

1. Check pool cooling temperatures on control room recorders and digital readouts. Determine if problems are in pool primary or pool secondary systems.
2. Check operation of pool temperature controller valve. Take manual control if necessary.
3. De-energize pool cooling system if necessary.

   NOTE: If possible, do not allow pool water temperature to decrease below 78°F to prevent excessive thermal stress in the reactor vessel and pool materials.

Annunciator:	AP-3, "Pool Tower Basin Low Level"
Alarm Condition:	Pool tower basin is 5 in. below normal level of 12 in.
Sensor Name:	LX-27
Type:	Conductive electrode probe level indicator
Position:	Tower basin
Physical Location:	South wall of pool basin
Set Points:	5 in. below normal
Equipment Response:	None

Operator Actions:

1. Check pool cooling system readings in control room.
2. Check drain and process water makeup system at tower basin.
3. Monitor pool secondary temperatures while restoring proper levels.

Annunciator: AP-4, "Pool Tower Basin Low Temperature"

Alarm Condition: Pool tower basin temperature decreases to 40°F.

Sensor Name: TX-27

Type: Bimetallic temperature switch

Position: Pool Tower basin

Physical Location: South wall of basin, next to level indication probe

Set Points: Alarm: 40°F

Equipment Response: None

Operator Actions:

1. Check automatic fan control operation.
2. If fans are in manual, check for proper settings.
3. If necessary, stop tower fans to prevent icing of the cooling tower.
4. Monitor primary temperature and verify proper operation of temperature controller.
5. If alarm condition is received during a reactor shutdown, open a valve on a steam line into the basin water to maintain the basin temperature above freezing.

Annunciator:	AP-5, "Pool Demineralizer Exit Resist"
Alarm Condition:	Alarms at 80% normal reading (variable setpoint) of pool demineralizer exit resistivity
Sensor Name:	AcE-3
Type:	Conductivity element
Position:	Exit line of pool demineralizer anion column upstream of ACV-3B
Physical Location:	NW corner of 3042 basement directly beneath anion tank
Set Points:	80% normal operating range
Equipment Response:	Pool demineralizer block valve, ACV-3, closes automatically, therefore removing demineralizer from service.

Operator Actions:

1. Check water quality from Building 3004.
2. Determine if demineralizer resins require regeneration by checking conductivity and pH at exit.
3. If demineralizer conductivity is acceptable (approximately 1,000,000 ohm-cm), place block valve (ACV-3) in override and investigate source of fault in sensors.
4. If demineralizer conductivity is not acceptable, remove the demineralizer from service.
5. If necessary, provide pool makeup flow from poolside water supply (in event makeup flow is stopped while the demineralizer is secured).

Annunciator: AP-6, "Storage Tank Level Hi Lo"

NOTE: Also displays at panel located at 3rd level, north, poolside railing

Alarm Condition: Alarms when water level in either primary water storage tank is below 10% or greater than 90%

Sensor Name: NA

Type: ΔP cells

Position: Mounted on the primary water storage tanks

Physical Location: On north side between two tanks

Set Points: Low level - 10% full

High level - 90% full

Equipment Response: None

Operator Actions:

1. Investigate actual storage tank levels and flow directions.
2. Check makeup and discharge piping lineups, as necessary.
3. If water is being pumped into the storage tanks, stop the operation on the high level-90% full alarm to prevent overflow of the tanks to the surrounding ground.
4. If water is being pumped from the storage tanks, stop the operation on the low level-10% full alarm to prevent possible cavitation of the fill and drain pump.

Annunciator:	AP-7, "Pool Water Activity"
Alarm Condition:	Alarms when activity of pool water returning from the heat exchanger rises to 30 mr/h
Sensor Name:	RE-3A
Type:	Geiger-Müller tube
Position:	Pool heat exchanger return to pool
Physical Location:	On horizontal section of piping, along west wall of basement, inside lead shielding
Set Points:	30 mr/h
Equipment Response:	None (recorder in control room)

Operator Actions:

1. Possible causes include reactor primary to pool primary water leaks, rupture or leak of an experiment, or fuel element failure. Investigate source of activity.
2. Check all activity meter readings.
3. Take water samples. Have Health Physics identify isotopic sources of contamination.
4. Take background readings in vicinity of alarm sensing element in basement. Determine if radiation source is external to the pool system.

Annunciator: AP-8, "Pool Water Low Resist"

Alarm Condition: Indicates poor quality pool water with variable setpoint normally 80% normal reading

Sensor Name: AcE-2

Type: Conductivity probe

Position: Pool demineralizer inlet

Physical Location: NW corner of basement of Building 3042 along floor in elbow on cation tank inlet

Set Points: <80% normal operating resistivity

Equipment Response: (Recorder in control room)

Operator Actions:

1. Check water quality from Building 3004 with water samples and by alarm panels in the control room and Building 3004.
2. In addition, pool water could be checked for conductivity to ascertain that it is not the source of poor quality water.
3. If necessary, regenerate resin in Building 3004 demineralizer following procedures.

Annunciator: AP-9, "Pool Cooling Temp >95°F"

Alarm Condition: Alarms when pool heat exchanger pool water discharge temperature is greater than 95°F. Indicates that the cooling system's capacity is exceeded.

Sensor Name: TE-42 (same as AP-2)

- Type: Gas-filled bulb
- Position: Pool heat exchanger
- Physical Location: 3042 basement, NW corner
- Set Points: High temperature alarm - 95°F
  Low temperature alarm - 85°F (AP-2)

Equipment Response: None

Operator Actions:

1. Check multipoint and digital records and determine pool primary and secondary temperatures at heat exchanger inlet/outlet.
2. If the pool secondary temperatures are high:
   a. check the manual set point adjustment on the regulating valve controller to assume proper set point; and
   b. check pool secondary system for loss of flow, fan, etc.

Annunciator: AP-10, "Pool Level"

Alarm Condition: Alarms when the water level in either reactor, center, or west pool drops 8 in. below overflow

NOTE: Also displays on annunciator panel located 3rd level, north poolside railing

Sensor Name: LS-26A - Reactor
-27A - Center
-28A - West

Type: Magnetic float switch

Position: One in each pool

Physical Location: All on north side of pool near dam abutments

Set Points: 8 in. below overflow

Equipment Response: None

Operator Actions:

1. Check actual pool level on standpipe recorder.
2. Check makeup rate. Commence makeup actions if necessary. Ensure normal makeup system has been functioning.
3. Determine leak or discharge locations, i.e.,
   a. visual check of pool and pool floor region in basement, pipe tunnel, reactor demineralizer cubicles, subpile room, etc.;
   b. check fill and drain system lineup; and
   c. check pool cooling and degasifier lineups.
4. If leak is in primary system, or a rapid loss of pool water, refer to Abnormal Operating Instructions, AOI-1 or AOI-2, Section 7.9.

   CAUTION: Each spent fuel rod in storage on the pool bottom would emit approximately 1,000,000 R/h in air. However, tests have shown that if the fuel has been removed from the core at least 24 hours, it is unlikely it would melt its cladding, even in air. Normal radiation levels above the spent fuel will be about 50 mR/h with water level at the grating level. Fuel left in the "saw box" or in "seven-up" racks on the grating, or on the isotope racks would result in unacceptable radiation levels. Those elements should be moved to the pool bottom.

   Mechanical damage to fuel elements, which would release fission product into the pool water, would result in unacceptable radiation levels and severely complicate cleanup and recovery of pool leakage.

Annunciator: AP-11, "Reactor Pressure"

Alarm Condition: Alarms when reactor inlet pressure drops below 6 psig

Sensor Name: PX-38

Type: Bellows actuated pressure switch

Position: Inlet to facility pumps

Physical Location: In overhead, in extreme NE section of pipe tunnel (i.e., north facility pump cubicle)

Set Points: Low level alarm: 6 psig

Equipment Response: None

Alarm only

NOTE: This alarm is misnamed. It will not alarm unless reactor pool level drops to the grating level (due to static head). This indication function is amply protected elsewhere, i.e., equalization leg.

Operator Actions:

1. Acknowledge alarm.
2. Notify the shift supervisor.

Annunciator: AP-12, "Facility Cooling"

Alarm Condition: Alarms on (1) low pressure on facility cooling pump discharge manifold, (2) low flow to south facility (plug and annulus) of 80 gpm, (3) low flow to south facility annulus of 75 gpm, or (4) low flow to north facility of 100 gpm.

Sensor Name: Px-39

- Type: Pressure switch
- Position: Facility pump discharge
- Physical Location: North pump cubicle in overhead
- Set Points: <6 psig

Sensor Name: FS-731-A1, -B1

- Type: Diaphragm switch and flow orifice
- Position: Inlet line, south facility
- Physical Location: Panel, basement, north pool wall
- Set Points: Alarm: ≤ 75 gpm
  Setback: ≤ 61 gpm
  Reverse: ≤ 59 gpm

Sensor Name: FS-751-A1, -B1

- Type: Diaphragm switch and flow orifice
- Position: Inlet line, south facility
- Physical Location: Panel, basement, north pool wall
- Set Points: Alarm: ≤ 65 gpm
  Setback: ≤ 51 gpm
  Reverse: ≤ 49 gpm

Sensor Name: FT-302-A1, -B1

- Type: Diaphragm switch and flow orifice
- Position: Inlet line, north facility
- Physical Location: Panel, basement, subpile door
- Set Points: Alarm: ≤ 100 gpm
  Setback: ≤ 71 gpm
  Reverse: ≤ 69 gpm

Equipment Response: Pump failure causes alarm only; further reduction causes setbacks. Even more reduction causes reverses, unless the power level is decreasing (at least 100 s negative period)

Operator Actions:

1. Check total facility cooling flow on control room recorder.
2. If facility cooling pump failure, place facility cooling pump that is in standby into service.
3. Check south facility flow readings in north basement on panel near reactor degasifier cell.
4. Check north facility flow on flow switch 302As and 302B in the north facility instrument rack near the subpile room door.
5. If flows are low in either facility, notify supervision, and consider a reactor shutdown to avoid heatup of facility systems.

Annunciator: AP-13, "ΔT"

Alarm Condition: Alarms at (1) high ΔT = 13°F or (2) loss of power on either recorder

Sensor Name: TdE 1A3, 1B3, 1A4, 1B4

Type: RTD

Position: Reactor inlet and exit lines

Physical Location: Inside pipe chase

Set Points: Alarms 13.0°F
Set back 13.5°F
Slow scram 15.5°F

Equipment Response: At 13.5°F, a set back plus backup reverse
At 15.5°F, a slow scram

Possible Causes:
1. Low core flow
2. High core power

Operator Actions:

1. Determine T_{inlet} and T_{outlet}
2. Verify ΔT reading; if necessary reduce power manually using servo demand. If further reduction is necessary, use the manual reverse, and scram.
3. Verify adequate flow rates. Use primary flow indicator.
4. Check pressure drops across inlet leg strainer and primary header strainer.
5. Check primary bypass valve position for failure.
6. Check secondary system temperatures.

Annunciator: AP-14, "Reactor Demin. Exit Resist"

Alarm Condition: Alarm indicates poor quality water at the exit of either reactor demineralizer

Sensor Name: AcE-4A (north), AcE-4B (south)

Type: Conductivity probe

Position: Outlet line of reactor demineralizer

Physical Location: Basement, pipe tunnel

Set Points: Alarms - resistivity $\leq$900,000 ohm-cm

Equipment Response: Will shut its associated demineralizer discharge valve on alarm (i.e., ACV4A or ACV4B)

Operator Actions:

1. Determine resistivity of demineralizer discharge water. If low (i.e., 900,000 ohm-cm or less), take the demineralizer out of service and regenerate demineralizer.
2. Place reactor demineralizer that is in standby into service.

Annunciator:	AP-15, "Reactor Outlet Temperature"
Alarm Condition:	Alarms (1) high reactor outlet temperature of 134°F in either header or (2) loss of power to recorder
Sensor Name:	TE-43 (south), TE-44 (north)
Type:	RTDs
Position:	Exit water lines
Physical Location:	Pipe chase
Set Points:	Alarm - power failure to recorder (wheatstone bridge) Alarm - 134°F Setback - 135°F Scram - 140°F
Equipment Response:	Increasing temperatures (as shown above) result in setbacks or scrams. A backup reverse will occur unless there is at least a 100-s negative period.
Possible Causes:	High T_{in}, high ΔT, low flow, high power

Operator Actions:

1. Check inlet temperature, ΔT, and flow indications on control panel.
2. Check power levels.
3. If temperatures and power level are abnormal or inconsistent; reduce power manually by servo demand, manual reverse, or scram.

<u>Annunciator:</u> <u>AP-16, "Reactor Inlet Temperature"</u>

<u>Alarm Condition:</u> Alarms when reactor inlet temperature is out of normal control band, <117 or >123°F

<u>Sensor Name:</u> TE-11A

<u>Type:</u> Gas-filled bulb

<u>Position:</u> Reactor inlet water line

<u>Physical Location:</u> In round manhole, along sidewalk, south of control valve pit

<u>Set Points:</u> Within normal band 117 to 123°F

<u>Equipment Response:</u>

1. Controls TCV-11 - primary bypass valve
2. Supplies one signal to set point computer for secondary bypass valve
3. No automatic protective functions

<u>Possible Causes:</u> TCV-11 failure
Secondary system failure

<u>Operator Actions:</u>

1. Determine if T_{in} is high or low and check ΔT.
2. Check position of TCV-11, primary bypass valve.
3. If T_{in} is low
   a. check TCV-11 failed in the shut position, and
   b. check secondary system temperature low. Take actions as necessary to restore proper secondary temperature.
4. If T_{in} is high
   a. check TCV-10 failed in open position, and
   b. check secondary system temperature high. Take actions as necessary to restore proper secondary temperature.

Annunciator: AP-17, "Reactor Water Activity"

Alarm Condition: Alarms on increase of primary water inlet radioactivity at 300 mr/h

Sensor Name: RE-1A

Type: Ionization chamber

Position: Inlet line near Venturi

Physical Location: In Venturi pit

Set Points: Alarms 300 mr/h

Equipment Response: None

Operator Actions:

1. Investigate source of activity and isolate source for increased activity.
2. Check ^{16}N, gamma chambers, and core flux noise monitor. If abnormal readings are present, reduce power or shut down.
3. If duplicate high readings exist, proceed with sampling of primary; use special precautions for radiation exposure control (i.e., take "cutie pie" readings at sample site, wear protective gloves, etc.).
4. If only the Venturi pit radiation alarm is affected, take radiation readings in the vicinity of pit to determine the radiation source.

Annunciator: AP-18, "R Water Low Resist"

Alarm Condition: Alarm indicates poor quality primary water by decreasing resistivity

Sensor Name: AcE-1

Type: Solubridge

Position: Facility pump bypass line, 1/8-in. SS tubing

Physical Location: 3042 basement on 1/8-in. SS tubing

Set Points: Adjustable; usually <270 K ohm-cm

Equipment Response: None

Operator Actions:

1. Monitor reactor demineralizer exit/inlet alarms.
2. Sample the primary for conductivity.
3. Investigate the cause of the alarm.

Annunciator:	AP-19, "Main Flow"
Alarm Condition:	Alarms when main flow decreases to 17,000 gpm
Sensor Name:	Venturi tube, FE-1
Type:	Venturi: differential pressure cell
Position:	Inlet line upstream of strainer basket
Physical Location:	In pit in front of pump house
Set Points:	Alarms - 17,000 gpm Setback - 17,000 (to 60% power) Scram - 14,000
Equipment Response:	Setback - 17,000 (if above 60% power) Scram - 14,000 (if not in "Test") Increases safety channel sensitivity - 12,000 gpm
Possible Causes:	Circulating pump malfunction Pipe system blockage Flow diversion between the pump discharge and the Venturi

Operator Actions:

1. Perform setback recovery procedures and, if necessary, scram recovery procedures.
2. Determine the cause of low flow.
   a. Check flow readings, strainer ΔPs, and primary makeup rate to ascertain the source of flow loss.
   b. If a loss of pump is indicated, shut the pump discharge valve, investigate the pump problem by entering the pump house, restore the pump if possible. If the pump cannot be restored, perform a shutdown.
   c. If a pipe system blockage or flow diversion (or leak) is indicated shut down the reactor. Take emergency procedures to remove decay heat if adequate shutdown flow is not provided by the system.

Annunciator:	AP-20, "LO Shutdown Coolant"
Alarm Condition:	Alarms when reactor flow drops below 1000 gpm
Sensor Name:	Venturi FE-1
Type:	Venturi
Position:	Inlet line
Physical Location:	In pit
Set Points:	Alarms - 1000 gpm Starts shutdown pump at 1500 gpm
Equipment Response:	Starts shutdown pump at 1500 gpm flow; no other actions
Possible Causes:	Loss of power to the shutdown cooling pump Pipe blockage Diverted flow upstream of the Venturi

Operator Actions:

1. If the reactor was at power, this alarm should have been accompanied by a "Main flow" AP-19 alarm and scram. Refer to this procedure.
2. If the reactor has been shut down with forced coolant flow for at least 30 minutes, loss of all pumping capability does not represent a safety hazard, as long as the primary is intact.
3. In the unlikely event that all three coolant pumps, all three pony motors, and the emergency cooling pump are all inoperative on a reactor scram, the core should be kept covered with water. Calculations and experiments indicate that damage will not occur to the ORR core if it is kept covered.

NOTE: After shutdown, the decay heat remaining in the core will decrease to about 2.1 MW immediately and to about 1.0 MW at 1 min. In addition, even with a total loss of all pumping power, it would take almost 1 min for the flow through the core to coast down to zero assuming primary integrity. Calculations show that 1 min after shutdown, with no flow, the core will be protected by natural convection with a safety factor of about 5. It would be important, however, that both the inlets and outlets of the fuel elements and the reactor tank be kept unobstructed. Extremely low forced flow rates (about 300 gpm or less) through the core may actually be detrimental to the natural convection forces of decay heat removal and may not remove the heat as well as no flow, especially during the first few minutes and hours following a shutdown.

Annunciator: AP-21, "Makeup Tank Level HI-LO"

Alarm Condition: Alarms on high level (33 in.) and on low level 9 in.) in reservoir tank

Sensor Name: LT-Pending-1

Type: "Bubbler" ΔP cell

Position: Mounted on top of makeup tank

Physical Location: Basement, makeup tank, in overhead above heat exchangers.

Set Points: 20%, 90%

Equipment Response: None

Possible Causes:

1. Sudden displacement of water from the pool to the makeup tank
2. Failure of makeup valve

Operator Actions:

1. Check the pool overflow rate.
2. Check the pool demineralizer system lineup.
3. Check the makeup valve operation.
4. Check valves for demineralizer water makeup to reactor pools.

Annunciator: AP-22, "Water Test"

Alarm Condition: Alarms when "raise-test" switch is in TEST position. Note equipment responses below.

Sensor Name: "Raise-test" switch

Type: NA

Position: Test switch in test

Physical Location: Reactor control panel

Set Points: NA

Equipment Response: Test position on the raise bypass switch will:

1. bypass the low flow and low ΔP scram protection, and
2. activate low-level scram circuit for No. 3 safety channel.

This allows reactor operation in subpower levels (less than N_L) with no flow or variable flow rates.

Operator Actions:

1. Use low-power test precaution and procedures.

Annunciator: AP-23, "No Pool Cooling Pump"

Alarm Condition: Alarms at low pool primary cooling flow of 500 gpm

Sensor Name: FE-3

Type: Orifice and ΔP cell

Position: Pool return from heat exchanger

Physical Location: Overhead, in line 203, in pipe tunnel

Set Points: Alarms: 500 gpm

Reverse: 500 gpm (if above 1.8 N_L)

Equipment Response:

1. Kicks reactor out of "run" mode. This causes a reverse to 1.8 N_L.
2. Will trip pool secondary pump to stop pool secondary flow.

Operator Actions:

1. Recover from reverse.
2. Determine the cause of the loss of pool cooling flow. Check blockage in heat exchanger and filters.
3. Monitor pool level on control panels to ensure no major loss of pool coolant.

NOTE: A major concern with the low pool cooling pump flow is the loss of cooling spray supplied to the beam-tube liners joining the reactor tank.

4. Restore pool cooling flow or shut down the reactor.

Annunciator: AP-24, "Emergency Pump Blocked"

Alarm Condition: Alarms when an electric shutdown emergency pump is blocked out (i.e., the switch block has been removed from its receptable or the graphic control panel).

Sensor Name:

Type: NA

Position:

Physical Location:

Set Points:

Equipment Response: NA

Operator Actions:

1. Monitor safety conditions for de-energized emergency coolant pump.
2. This alarm is manually activated by removing blocks.

Annunciator: AP-25, "Reactor ΔP"

Alarm Condition: Alarms on a low ΔP across the core, corresponding to a flow rate of 17,000 gpm

Sensor Name: PdT-55

Type: Bellows actuated microswitch

Position: South inlet line

Physical Location: Inside pipe chase, near RTDs, close to entrance

Set Points: Alarm: 17,000 gpm (equivalent flow because core configuration can change ΔP)

Setback to 60%: 17,000 gpm

Scram: 14,000 gpm

Increases safety channel sensitivity: 12,000

Equipment Response: Setback at 17,000 gpm

Scram at 14,000 gpm

NOTE: ΔP settings were chosen so as to be measured by equivalent flow rates, since the actual ΔP across the core would vary with core configuration, experiments in core, etc. Set points are changed with each core to match the above flow rates.

Possible Causes:

1. Malfunction of the primary bypass valve
2. High outdoor ambient temperature
3. Failure of a single primary pump

NOTE: During extremely warm weather, the bypass valve is shut forcing all primary water through the heat exchanger. This high ΔP across the heat exchanger will lower the core inlet pressure and therefore the ΔP. For some core configurations, this value can approach the alarm set point.

Operator Actions:

1. Perform setback or scram procedures as necessary and determine the cause of the alarm.
2. If setback to 60%, and conditions will not allow a return to full power, notify concerned researchers and/or experiment operators and determine their needs.
3. If experiment needs cannot be satisfied, recommend a shutdown to the reactor supervisor.
4. If hot weather has caused the bypass valve to shut, ΔP conditions can be improved by taking manual control of the bypass valve, opening the valve, and increasing T_{in}. Do not exceed T_{in} = 123°F or T_{out} = 134°F.

Annunciator: AP-26, "Reactor Tower Fans"

Alarm Condition: Alarms when either secondary cooling tower fan is de-energized

Sensor Name:

Type:

Position:

Physical Location: In secondary pump house

Set Points:

Equipment Response:

Possible Causes:

1. Power outage
2. Mechanical/electrical failure of fan/motor
3. Vibration switch cut off

NOTE: In hot weather, loss of cooling fans can result in a rapid increase in primary temperatures and a subsequent shutdown.

Operator Actions:

1. Determine the cause of fan loss.
2. Monitor primary temperatures and reduce power if necessary.
3. If tripped by the vibration switch, visually check the fan and attempt to locate the damage. If none is located, reset the switch and operate the fan in manual slow speed, monitoring for problem areas. Increase speed and continue monitoring. If, at any time, vibration or other abnormal signs develop, de-energize the fan or reduce speed.

Annunciator: AP-27, "Degasifier"

Alarm Condition: Alarms on abnormal vacuum, level, or flow indications in reactor degasifier system

Sensor Name: LE-5, Px-53 (Vacuum switch)

Type: Differential pressure cell

Position: On degasifier tank

Physical Location: Taps on bottom and top of tank

Set Points: Low level: <2 in. from bottom of sight gauge
High level: <1/4 in. from top of sight gauge
Low vacuum: 20 in. Hg in degasifier tank
Hi/Low level in condenser drain separator tank
Degasifier pump failure

Equipment Response: Sensor controls flow through LCV5A to degasifier tank

Operator Actions:

1. Investigate the source of alarm and cause of failure.
2. Notify the supervisor.

NOTE: The degasifier removes gaseous fission products from the reactor water, which if left untreated for an extended length of time, would increase the airborne radiation level in the reactor building.

Annunciator: AP-28, "Main Pump Bearing HI Temp"

Alarm Condition: Alarms when temperatures of pump bearings exceed 200°F (95°C) on the electric shutdown/emergency pump or the primary pumps. Also alarms on loss of electrical power.

Sensor Name:

- Type: Thermocouples (chromel-alumel)
- Position: On pump bearing housing
- Physical Location: In primary pump house
- Set Points: 200°F (94°C)

Equipment Response: None

Operator Actions:

1. Determine the cause of the alarm.
2. At the pump house, determine the degree of severity of temperature rise. Attempt to correct the abnormality.
3. If the bearing is excessively hot, shut down the reactor and the associated pump.

Annunciator: AP-29, "Catch Tank"

Alarm Condition: Alarms when NOG catch tank level exceeds 3/4 full or when tank is emptied

Sensor Name:

Type: Float switch

Position: At NOG catch tank

Physical Location: NW corner of catch tank located SE corner of basement

Set Points: High: 3/4 full

Low: empty

Equipment Response: None

Possible Causes: Water carryover into NOG system

Failure of float valves at NOG service ports

Operator Actions:

1. Purge tank with air to remove water to WC-19 (air supply valve located at the sump or west wall of basement).
2. If abnormally high amounts of water are detected, investigate the source.

NOTE: NOG system services a variety of primary system components plus special building radiation control areas such as experimental cells and hot cells. Abnormally excessive water in the NOG system should be investigated including possible causes and effects upon the components serviced by NOG.

Annunciator: AP-30, "Sump Hi Water"

Alarm Condition: Alarms when high-level sump pump is energized. Indicates that the 3042 ORR basement sump in-flow is greater than the capacity of the low-level sump pump.

Sensor Name:

Type: Ball float switch

Position: In ORR basement sump

Physical Location: Under steel door grating in pipe tunnel floor

Set Points:

Equipment Response: None

Possible Causes:

1. Excessive flow of ground water springs into pipe chase and/or sump.
2. Rupture/leak of primary in pipe chase.
3. Rupture/leak of pool system piping in pipe tunnel.
4. Regenerating activities of demineralizer in the ORR basement.
5. Water line breaks inside or outside the building (possible lines include process, potable, demineralizer, or fire main lines).

Operator Actions:

1. Check low-level sump pump for proper operation.
2. Investigate the source of the leak. Note the sump level. Determine if level is rising. Locate and isolate the leak.
3. Monitor pool and primary makeup rates. If these indicate leaks, take actions as described in AOI-1 or AOI-2 (Section 7.9). Locate and isolate the leak.
4. If the sump level continues to rise:
   a. obtain a sample of sump water to help identify the source;
   b. notify the Laboratory Shift Supervisor and request assistance in locating sources outside the building, i.e., process water, etc.; and

c. commence actions to provide extra dewatering capabilities to the sump and/or basement areas.

CAUTION: The ORR basememt is completely below ground level and could be flooded. Located in the basement are electrical motors, transformers, etc. and radioactive contaminated materials, equipment, resins, and filters, which can cause hazards to human safety.

5. If necessary, provide dewatering capacity in the following priority:
   a. portable pump(s)(such as Worley pumps) discharging from sump to the sump discharge header;
   b. portable pump(s) discharging from the sump or trench pit to overhead process drain accesses (for example, through floor openings near the overhead reservoir tank to floor drains on the 1st floor);
   c. lining up the fill-and-drain pump to take a suction via line 235 in the trench pit and discharging to a storage tank via valves 235A and 218B (close valve 205B to prevent discharging to the pool). This action requires removal of a blank flange - special care should be taken to prevent clogging the suction with debris; and,
   d. for extreme flooding, the use of large-scale emergency dewatering capabilities, such as the Fire Department pumper truck.

CAUTION: Severe flooding will cause (1) a loss of pool cooling and facility cooling capabilities, which necessitates an emergency reactor shutdown and cooldown as well as (2) de-energizing of electrical equipment in the basement. The elevator shaft, subpile room, and NOG systems would become inoperative. Expensive laboratory equipment as well as reactor protective and contaminated equipment could be severely damaged.

Annunciator: AP-31, "Pool Tower pH"

Alarm Condition: Alarms on (1) high pH of 7.8; (2) low pH of 7.3; or (3) loss of power to pH recorder for the pool tower

Sensor Name: AphE-6

Type: pH probe

Position: Secondary inlet to heat exchanger

Physical Location: In basement at heat adapter inlet

Set Points: High alarm - 7.8
Low alarm - 7.3

Equipment Response:
1. Starts/stops acid pump
2. No other action

Operator Actions:

1. Check float sticking on sample block discharge line. (NOTE: The pH meter samples a continuous stream of pool secondary water drawn from the inlet thorugh the pH probe and dumping into the sump next to the pool heat exchanger.)
2. Check pool tower basin pH samples and check operation of pH pump and correct if necessary.
3. If necessary, control pH with manual acid addition until the system can be restored to normal.

Annunciator: AP-32, "Freezing"

Alarm Condition: Outside temperature drops to 35°F

Sensor Name: NA

Type: Thermistor

Position: On building roof

Physical Location: Control room roof near access ladder

Set Points: Alarm: 35°F

Equipment Response: None

Operator Actions:

1. Take freezing precautions for outside or exposed equipment. These include:

   a. check to ensure all steam tracing is turned on (the tracing provides heat to instrumentation and structural components or towers).

Annunciator: AP-33, "R Exch. Sec. Pump Pressure LO"

Alarm Condition: Alarms when secondary pump discharge header drops below 25 psig; indicates failure of secondary pumps

Sensor Name: PX-56

Type: Bellows actuated pressure units

Position: Secondary pump discharge header

Physical Location: West end, secondary pump house, pump discharge header

Set Points: Low alarm: 25 psig
No other

Equipment Response: None

Possible Causes:
1. Loss of secondary pump
2. Loss of pump suction
3. Loss of secondary water on pump discharge

Operator Actions:

1. Monitor primary temperatures. Reduce power necessary to control $T_{in} < 123°F$.
2. Investigate cause of alarm. Restore secondary pumps if possible. Place spare secondary pump in service, if one pump has stopped and cannot be restarted.
3. If the secondary system is unavailable as a heat sink, shut down the reactor and continue primary flow for decay heat removal.

Annunciator: AP-34, "R Tower Basin H_2O Level"

Alarm Condition: Alarms on (1) high level, 51 in. or (2) low level, 45 in. in tower basin

Sensor Name:	LX-30	LE-30
Type:	Conductivity water level	P cell
Position:	At tower basin	
Physical Location:	South end of basin near strainers (upstream of strainers)	Inside pump house NW corner (SW corner of basin - downstream of strainers)
Set Points:	Both sensors feed same alarm level switches	

Equipment Response:
1. None on LX-30 (probe device)
2. LE-30 controls makeup water for basin from process water

Possible Causes:
1. Low levels
   - Ruptured secondary piping
   - Ruptured basin
   - Malfunctioning makeup valve
   - Loss of makeup water supply
   - Malfunction of drain valve
2. High levels
   - Malfunctioning makeup valve

Operator Actions:

1. Determine if levels are high or low
2. If low, take steps to add water to inventory.
   a. Check makeup valve operation. Take manual control to verify proper mechanical functions.
   b. Check drain valve operation.
   c. If a high makeup rate is apparent, investigate for secondary piping leaks.
3. If high water level:
   a. check makeup valve for proper operation.

Annunciator: AP-35, "R Exch Sec Temp"

Alarm Condition: Alarms at (1) low temperature 80°F (2) high temperature 123°F

Sensor Name:	TE-47A	TE-47B
Type:	Gas-filled bulbs	
Position:	Exchanger inlet	Exchanger outlet
Physical Location:	Inlet secondary pump house	In pit, west side of tower near bypass control valve
Set Points:	Low 80°F - high 123°F	

Equipment Response: Sensors provide input for the secondary pneumatic controller. No emergency actions initiated on any part of the system.

Possible Causes:

1. Low temperature
   a. Primary water flow stopped
   b. Towers having overcooling effect
   c. Tower for controllers malfunction to overcool
   d. Secondary bypass valve failed shut
2. High temperatures
   a. High ambient temperature
   b. Tower fans not functioning
   c. Secondary bypass valve failed open
   d. Primary temperature high

Operator Actions:

1. Determine high or low temperatures.
2. If low,
   a. monitor primary temperatures and note percentage of flow bypassing heat exchanger,
   b. check T_{in},
   c. check cooling towers fans - reduce their speed or secure them, and
   d. check secondary bypass valve failed shut.

3. If high,
   a. monitor primary temperatures,
   b. check the function of the secondary bypass valve and the reactor tower fans, and
   c. reduce reactor power if necessary to maintain $T_{in} < 123°F$ and $T_{out} < 134°F$. Shut down the reactor if necessary or if the secondary system cannot be returned to normal.

Annunciator: AP-36

Alarm Condition: Spare

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AP-37, "Reactor Tower Basin Temp"

Alarm Condition: Alarms when water in secondary cooling tower basin is (1) low at 65°F, (2) high at 88°F

Sensor Name: TE-48

Type: Gas-filled bulb

Position: Submerged in south end of basin pool

Physical Location: Mounted inside a pipe running from south end of basin to 2 ft from basin floor

Set Points: Low 65°F - high 88°F

Equipment Response: Same sensor provides control sensor to tower fan speed controller. No protective functions are generated with the alarm.

Possible Causes:

1. Low temperature
   a. tower fans overcooling,
   b. low ambient temperature,
   c. secondary bypass valve failed shut, and
   d. low primary demand.
2. High temperature
   a. tower fans not functioning to provide cooling,
   b. high ambient temperature,
   c. secondary bypass valve failed open, and
   d. high primary demand

Operator Actions:

1. Monitor primary temperature. Determine if basin temperature is high or low.
2. Assume manual control of bypass valve if necessary.
3. Check tower fans, pumps, etc. for proper functioning. Take manual control if necesssary.

Annunciator: AP-38, "Blank - spare"

Alarm Condition: Spare

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AP-39, "Reactor Tower pH"

Alarm Condition: Alarms when reactor secondary water (1) drops below 7.3 or (2) rises above 7.8

Sensor Name: ApHE 7

Type: pH meter

Position: Takes continuous trickle sample from pump discharge header, through pH meter, to drain

Physical Location: Sample point off the discharge line near west wall; pH probe; near the sample sink

Set Points: Low 7.3; high 7.8; acid addition system 6.8

Equipment Response:

1. Same sensor controls variable stroke pulse feeder to maintain basin pH at 7.6
2. No protection functions

Operator Actions:

1. Investigate the cause of the pH anomaly.
2. Check the operation of the acid addition pump and system. Take special precautions for handling acids.
3. If acid pump is not working properly, place the acid pump that is in standby into service.
4. If necessary, correct pH of the secondary by manual addition of acid.

Annunciator:	AP-40, "NOG Hi Temp"
Alarm Condition:	Alarms on power failure to recorder, or high temperature in filter pit exit line (indicates possible fire in filter pit)
Sensor Name:	TE-902-1, -2, -3, -4
Type:	Thermocouples
Position:	Two in each filter bank
Physical Location:	In the NOG filter pit, all downstraem of charcoal filters. Two each in both east and west filter banks
Set Points:	Alarms at 100°F (38°C)
Equipment Response:	Alarm only, no equipment protection
Possible Causes:	1. Fire in the NOG pit 2. High temperature gas source in the NOG system NOTE: Radioactive iodine (fission product), if released into the NOG system in sufficient quantity, could generate enough heat, when trapped by the charcoal, to ignite the charcoal filters.

Operator Actions:

1. Check readings on all four thermocouples to verify the abnormality.
2. Report findings to the shift supervisor and the Technical Advisor.
3. Shut down the reactor and isolate the filter pit if all readings validate a fire in the filter pit.

Annunciator: AP-41, "Pressure Off Gas Act Hi"

Alarm Condition: Alarms at POG activity greater than 4.5 mr/h

Sensor Name: RE-62

Type: Geiger-Muller tube

Position: POG filter pit exit line

Physical Location: In lead shield, on exit line elbow above ground level at POG filter pit, south of cell ventilation filter pit

Set Points: High alarm: 4.5 mr/h

Equipment Response: Alarm only

Possible Causes:
1. Failure of an experiment
2. Purging actions by experimenters

Operator Actions:

NOTE: The POG (pressurizable off-gas) system is not in operation unless a particular experiment has special needs for its service. The POG system piping is rated to withstand a positive pressure of 100 psig.

1. Check instrument status in the experiment control room, and information in the Experiment Information Book.
2. Contact the experimenter to determine causes, needs, or objectives.
3. If necessary, contact the Operations Division Experiment Coordinator or the Technical Advisor for further information.
4. If necessary, shut down the reactor.

Annunciator: AP-42, "Secondary Radiation Hi"

Alarm Condition: Alarms at 1.25 mr/h radiation levels at secondary exit header from reactor heat exchanger. (Either of two separate channels will activate.)

Sensor Name: RE-5, RE-33

Type: Geiger-Müller tube probes

Position: Two channels, near exchanger discharge header

Physical Location: At ground level just north of exchanger pit

Set Points: 1.25 mr/h

Equipment Response: No protective functions

Possible Causes: Failure in heat exchanger tube(s)

Operator Actions:

1. Check both channels of secondary radiation to verify indications.
2. Sample the secondary water to determine radiation.
3. If sampling verifies gross secondary contamination, shut down the reactor.

Annunciator:	AP-43, "NOG Hi Radiation"	
Alarm Condition:	Alarms at 40 mr/h in NOG air water separator	
Sensor Name:	RIM-67	RE-68
Type	Geiger-Müller tube	Geiger-Müller tube
Position:	On air-water separator on NOG header	Filter pit exit
Physical Location:	In ORR basement NOG water trap	South end of pit at ground level (in lead shield)
Set Points:	Alarm: 40 mr/h	(Dual sensor actuated) Twice normal background
Equipment Response:	Alarm only, no protective functions	

Possible Causes:
1. Failed experiment
2. Purging beam holes
3. Release during hot cell work

Operator Actions:

1. Determine if experimenters have been purging beam holes and initiated the alarms, or if work within the building's hot cells initiated the alarms.
2. Check the instrument status in the experiment control rooms and information in the Experiment Information Book to determine possible causes of the alarm.
3. Contact the applicable experimenter and/or the Division Experiment Coordinator or Technical Advisor to determine needs, causes, and objectives.
4. If necessary, shut down the reactor.

Annunciator:	AP-44, "Pressure Off Gas Press Hi"	
Alarm Condition:	Alarms at POG pressure greater than -25 in. water	
Sensor Name:	PT-61	PT-60
Type:	ΔP cells	ΔP cells
Position:	Reactor pool POG header	Filter pit inlet
Physical Location:	North balcony reactor pool	POG filter pit inlet
Set Points:	Alarm: -25 in. H_2O Setback: -20 in. H_2O Reverse: -19 in. H_2O	
Equipment Response:	Setback: -20 in. H_2O Reverse: -19 in. H_2O No other responses	

Possible Causes:
1. Failure of POG blower
2. Clogged filters at tank farm

Operator Actions:

NOTE: The POG system is normally not in service unless a specific experiment has POG demands.

1. Check with tank farm personnel to determine the status of blowers. A backup blower system could recover the POG system.
2. Recover from the setback and reverse.

Annunciator:	AP-45, "Normal Off Gas Press Hi"	
Alarm Condition:	Alarms on loss of vacuum to -25 in. H_2O	
Sensor Name:	PT-63	PT-64
Type:	ΔP cells	ΔP cells
Position:	Reactor pool POG header	Pipe chase - Subpile room header
Physical Location:	North balcony reactor pool	Outside pipe chase door
Set Points:	Alarm: -25 in. H_2O Setback: -20 in. H_2O Reverse: -19 in. H_2O (unless 100-s negative period)	
Equipment Response:	Setback: -20 in. Reverse: at -19 in. (unless 100-s negative period on log-N period) No other equipment responses	

Operator Actions:

1. Check with tank farm personnel to determine the status of blowers. A backup blower system could recover the NOG system.
2. Recover from the setback and reverse.

Annunciator: AP-46, "Degas. Activity Hi"

Alarm Condition: Alarms on increase of radioactivity of gaseous effluent from degasifier to 55 mr/h

Sensor Name: RE-6

Type: Geiger-Muller tube probes

Position: On reactor degasifier condenser drain moisture separator

Physical Location: ORR Building basement

Set Points: Alarm: 55 mr/h

Equipment Response: None

Possible Cause: Gaseous release into primary from fuel or experiments

Operator Actions:

1. Check other primary activity monitors.
2. Check primary water samples.
3. Notify HP for assistance.
4. If activity is increasing above normal, notify Reactor Supervisor.
5. If grossly high, or if ^{16}N shows an increase, shut down the reactor.

NOTE: If primary is grossly contaminated, ^{16}N detectors are expected to shut down the reactor automatically.

Annunciator:	AP-47, "POG Pit Hi Temp"
Alarm Condition:	Alarms on high temperature in POG filter pits at 85°F
Sensor Name:	TE-OGF-1B, and -2B
Type:	Thermocouples
Position:	Downstream section of filter bank
Physical Location:	Within POG filter pit
Set Points:	High level alarm at 85°F
Equipment Response:	Alarm only; no other function.

Operator Actions:

1. Check readings on all four thermocouples to verify the abnormality.
2. Report findings to the shift supervisor and the Technical Advisor.
3. Shut down the reactor and isolate the filter pit.

NOTE: Radioactive iodine (fission product), if released into the system in sufficient quantity could generate enough heat, when trapped by the charcoal, to ignite the charcoal filters.

<u>Annunciator:</u> <u>AP-48, "Annuli Hi Press"</u>

<u>Alarm Condition:</u> Alarms at +2 psig pressure in annuli (which are actually filled with insulation) in pool wall concrete. Normal readings in this area is -10 in. Hg (vacuum).

<u>Sensor Name:</u>

<u>Type:</u> Four pressure switches

<u>Position:</u> Both sides of embedded north and south inlet lines

<u>Physical Location:</u> North line's pressure switches: located 1st floor, floor level, at north center pool face. South line's pressure switches: located in basement, inside cell 2 equipment room, in overhead west end.

<u>Set Points:</u> High alarm: +2 psig pressure
Normal radings: -9 to -12 in. water (vacuum)

<u>Equipment Response:</u> Alarm only; no other function.

<u>Operator Actions:</u>

<u>NOTE</u>: Alarm indicates a possible large leak from pressurized (i.e., 30-35 psig) primary inlet water lines embedded in concrete into their annuli. Alarm switches are installed on inlet lines only and have separate drains to north and south cold trap station in basement. Primary discharge lines and the pool lines also drain to these cold trap stations.

1. Check primary makeup rate on control panel. If greater than normal, manually scram the reactor, secure main coolant pumps, and perform a reactor cooldown on pony motors or the shutdown pump.
2. Notify supervisor and try to locate leak source.

Annunciator: AP-49, "Filter Pit Hi Temp"

Alarm Condition: Alarms when any one of 14 thermocouples in the cell-ventilation filter pit reach 100°F (38°C) or on loss of power to recorder

Sensor Name: TECF 1-14

Type: Iron-constantan thermocouples

Position: Located throughout filter bank

Physical Location: Cell-vent filter pit

Set Points: Alarms: 100°F

Equipment Response: Alarm only

Possible Causes:

1. Fire in the cell-ventilation filter pit
2. High temperature gases in the cell-ventilation system

Operator Actions:

NOTE: Should radioactive iodine (fission product) be released into the system in sufficient quantity it could generate enough heat, when trapped by the charcoal, to ignite the charcoal filters.

1. Check readings on all thermocouples to verify the abnormality.
2. Report findings to the shift supervisor and the Technical Advisor.
3. Shut down the reactor and isolate the filter pit.

Annunciator: AP-50, "Main Duct Hi Press"

Alarm Condition: Alarms on loss of vacuum in main duct to -3 in. H_2O

Sensor Name: PS-109

Type: Diaphragm operated differential pressure microswitch

Position: Basement cell-vent header

Physical Location: East end of basement near east stairwell

Set Points: High alarm: -3 in. H_2O

Low alarm: -7 in. H_2O (AP-59)

Equipment Response:

Possible Causes: Failure of blower

Operator Actions:

1. Check with tank farm personnel to determine the status of blowers and backup blowers. A backup blower can recover the system pressure.

NOTE: Before a backup blower can regain the system it is likely that the reactor will experience a setback or reverse on low cell-ventilation flow (AP-57). Note also, that even if the system is recovered, the Technical Specifications require that a backup blower be available if the reactor is to continue operation (Para. 3.8.1.e).

2. If necessary, shut down the reactor.

Annunciator: AP-51, "Spare Blank"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AP-52, "Strainer Hi Lo"

Alarm Condition: Alarms at high or low pressure drops across primary strainers

Sensor Name: PI-1, PI-2

Type:

Position: Across the primary strainer pit (pit and valve)

Physical Location: Primary pump house strainer pit

Set Points: Low alarm: (for rupture) 6.5 psig or preset corresponding to core

High alarm: (for strainer plugging) 8.0 psig or preset value

Equipment Response: None

Possible Causes: Plugged strainer (high ΔP)

Failed strainer basket (low ΔP)

Operator Actions:

1. Check control room indicator to determine if pressure is high (plugging) or low (strainer rupture).
2. Check other primary indicators to determine system status.

Annunciator: AP-53, "Spare Blank"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AP-54, "Spare Blank"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AP-55, "Wind Speed >15 MPH"

Alarm Condition: Alarms when wind speed on roof exceeds 15 mph

Sensor Name:

Type: Propeller gear weather vane

Position: Building roof, 3042

Physical Location: Recorder is 2nd level west, sensor is NE corner

Set Points: High level alarm greater than 15 mph wind speed

Equipment Response:

Possible Causes: Impending storm

NOTE: The original intent of this alarm was to alert the operators to initiate data collection for a negative pressure study on the building containment system. After the study was completed, the annunciator was left for operator information only.

Operator Actions: No special actions required.

Annunciator: AP-56, "Building Containment"

Alarm Condition: Alarms when building has been placed in containment by (1) manual or automatic actuation of the containment circuit (see AP-58), (2) manual or automatic actuation of the Facility Radiation and Contamination Alarm System (FRCAS), or (3) manual or automatic actuation of the fire alarm system

Sensor Name:

Type: Gamma monitors, monitrons

Position: Throughout the building

Physical Location: Building 3042

Set Points:

Equipment Response:

1. All dampers allowing air into the building are shut automatically.
2. All roof fans drawing building air to the atmosphere are shut off, and their dampers shut automatically.

NOTE: In the containment mode all building air, as well as NOG, POG, and cell vents, is drawn through the filter pits to the stacks.

Possible Causes:

1. Radiation released from an experiment
2. Ruptured fuel plates
3. Fire in the building
4. Ruptured or exposed spent fuel

Operator Actions:

1. Notify the shift supervisor.
2. Determine status of the building, especially radiation levels in the control room.
3. Determine if a hazard exists for the core, spent fuel storage, or personnel.
4. If necessary, scram the reactor and evacuate the building.

Annunciator: AP-57, "Building Vent Lo"

Alarm Condition: Alarms when the flow of air through the building cell-ventilation exit duct decreases from 9000 to 6000 cfm

Sensor Name:	FE-65	FE-66
Type:	Pitot	Venturi
Position:	Downstream of cell ventilation filter bank	Upstream of pump suction

Physical Location: About 10 ft downstream of filter pit

Set Points: Low level alarm: 6000 cfm
Low level setback: 5000 cfm and reverse

Equipment Response: At 5000 cfm, control-room air conditioning unit is de-energized (to close air conditioning dampers)

Possible Causes:
1. Failure of blower
2. Misvalving in the tank farm

Operator Actions:

NOTE: Technical Specifications do not allow operation below 4000 cfm.

1. At low alarm, notify the supervisor.
2. If necessary, perform applicable setback/recover procedures.

NOTE: If backup blowers fail and cell ventilation goes to zero, the filter pit must be valved out to prevent backflow from filter pit into the building.

Annunciator: AP-58, "Containment Electrometers"

Alarm Condition: Alarms when either of two containment "electrometers" (gamma monitors) indicate high radiation levels

Sensor Name:	RE-4	RE-5
Type:	Geiger-Müller tube probe	Geiger-Müller tube probe
Position:	In building air	Within cell-vent ducting
Physical Location:	Above control room door within lead shield	Immediately upstream of filter pit
Set Points:	75 mr/h	7.5 mr/h

Equipment Response:

1. All dampers allowing air into the building are shut automatically.
2. All roof fans drawing building air to the atmosphere are shut off, and their dampers shut automatically.

NOTE: In the containment mode all building air, as well as NOG, POG, and cell vents, is drawn through the filter pits to the stacks.

Possible Causes:

1. Radiation released from an experiment
2. Ruptured fuel plates
3. Ruptured or exposed spent fuel

Operator Actions:

1. Notify the shift supervisor.
2. Determine status of the building, especially radiation levels in the control room.
3. Determine if a hazard exists for the core, spent fuel storage, or personnel.
4. If necessary, scram the reactor and evacuate the building.

Annunciator: AP-59, "Main Duct Lo Press"

Alarm Condition: Alarms when static pressure in main duct decreases to -7 in. H_2O (i.e., excessive negative pressure)

Sensor Name: PS-109

Type: Diaphragm operated differential pressure microswitch

Position: Basement cell-vent header

Physical Location: East end of basement near east stairwell

Set Points: High alarm: -3 in. H_2O (AP-50)

Low alarm: -7 in. H_2O

Equipment Response:

Possible Causes: Both normal and standby blowers running simultaneously

Operator Actions:

1. Stop backup blower operation.

Annunciator: AP-60, "Low Inst Air Press"

Alarm Condition: Alarms when air supply to cell-ventilation control panel (i.e., auxiliary panel in ORR basement) drops to 75 psig

Sensor Name: PS-111

Type: Bellows

Position:

Physical Location: East end of basement near east stairwell

Set Points: 75 psig

Equipment Response: At 62 psi, the backup steam blower will start.

Operator Actions:

1. Check with tank farm and notify supervisor.

NOTE: This air system provides control instrument air to the cell-ventilation blower controls and dampers. Loss of instrument air can have direct effects on the cell-ventilation system and, therefore, reactor operation. Without this system (or even a backup blower), the reactor system should be shut down.

Annunciator: AP-61, "Turbine Steam Lo Press"

Alarm Condition: Alarms when the steam header pressure drops to 75 psig

Sensor Name:

Type:

Position: Steam inlet header

Physical Location: At steam turbine inlet at stack area 3039

Set Points: Alarms at 75 psig

Equipment Response:

Possible Causes: Break in steam lines

Operator Actions:

1. If the steam supply is lost to the steam driven blowers and a backup blower is not available, then the reactor must be shut down according to Technical Specifications.

NOTE: Steam turbine temporarily abandoned in 1983 stack modification project.

Annunciator: AP-62, "Low Air Flow to Stack"

Alarm Condition: Alarms on low air flow of 0.1 in. H_2O ΔP in the cell ventilation system to the stack

Sensor Name: FE-119

Type: Pitot tube

Position: In duct to stack (abandoned in stack modification during project February 1983)

Physical Location:

Set Points:

Equipment Response: Reactor may be set back because of 5000 cfm "building vent low" AP-37

Possible Causes: Both normal and backup blowers in cell ventilation system are off

Operator Actions:

1. Take same actions and concerns with backflow as in AP-57, cell ventilation low flow.

NOTE: This portion of the system was temporarily abandoned in the stack modification project of February 1983.

Annunciator: AP-63, "Filter Seal Hi Level"

Alarm Condition: Alarms at high water level in cell-ventilation filter pit seal tank

Sensor Name:

- Type: Float switches (2 each)(both also supply AP-64)
- Position: In water seal tank for cell-ventilation filter pit
- Physical Location: East side of filter pit
- Set Points: High: 0.75-in.-H_2O differential between high and low actuation points

  Low: (AP-64)

Equipment Response: Sensors also control process water flow control valves for seal tank makeup

Possible Causes:

1. Water level in seal tank too high
2. Rain/ground water leakage into vent pit
3. Excessive negative pressure in NOG system (draining through CW-19)

Operator Actions:

1. Check seal tank makeup valves for proper operation.
2. Notify supervisor.

Annunciator: AP-64, "Filter Seal Lo Level"

Alarm Condition: Alarms on a low level in the cell ventilation filter pit, warning of impending loss of seal water in the pit

Sensor Name:

Type: Float switches (2 each)(Both also supply AP-63)

Position: In water seal tank for cell-ventilation filter pit

Physical Location: East side of filter pit

Set Points: High: (AP-63)

Low: 0.75-in.-H_2O differential between high and low actuation points

Equipment Response: Sensors also control process water control valves for seal tank makeup.

Possible Causes:

1. Excessive negative pressure in cell vent
2. Failure of makeup valve to open

Operator Actions:

1. Check the makeup valves for proper operation.
2. Restore proper tank level.

Annunciator:	AP-65, "Hi Lo Curr Volt dc 1"	
Alarm Condition:	Alarms on (1) overvoltage or undervoltage on primary pony motor batteries, (2) overcurrent or undercurrent on pony motor, and (3) removal of safety block	
Sensor Name:	R6	R7
Type:	Solid state bridge circuit voltmeter	Solid state bridge circuit voltmeter
Position:	Measures voltage drop across the pony motor	Measures current in the dc supply line to the pony motor
Physical Location:	Pump room north wall	Pump room north wall
Set Points:	Overvoltage alarm: 41 V Undervoltage alarm: 37 V Overcurrent alarm: 10 A Undercurrent alarm: 5 A	
Equipment Response:	All the above give alarms only; no protective functions.	

NOTE: Technical Specifications (Para. 3.8.2b) require that two of the three pony motors must be functional to continue reactor operation.

Operator Actions:

1. Check local panel in the applicable pump room to determine which of the four factors caused the alarm.
2. If the reactor system is operating normally, alarms may indicate a faulty battery charger or battery bank.

NOTES: 1. Battery charger may drop out on loss of power to the charger, etc. This circuit must be reset locally.

2. The battery charger has an internal protective coil. Should this activate, an undervoltage alarm would result and the associated pony motor could still have the battery bank to run in event of emergency.

Annunciator: AP-66, "ac Pwr dc 1"

Alarm Condition: Alarms when (1) 240-V ac electrical supply (TVA) to the battery charger is lost, (2) when safety block in control room panel is removed, or (3) overcurrent to battery charger

Sensor Name:

Type: Magnetic disconnect switch (with overcurrent protection)

Position: Between battery charger and 240-V TVA supply

Physical Location: Pump cubicle

Set Points: Alarms: Loss of power or overcurrent

Equipment Response: Alarm function on overcurrent to battery charger

Operator Actions:

1. If alarm is only on one pump, have battery charger checked for overloading.
2. If battery bank is still good (i.e., no over/undervoltage alarm), then pony motors are still functional.

   NOTE: ORR Technical Specifications (p. 3-12, para. 3.8.2.b) require that a minimum of two pump units must be available to provide at least 750 gpm for 30 min while at operation above 20 MW.
3. If all three pumps alarm, investigate circuit faults at panel 2 at the doorway of the electric shutdown pump room.

Annunciator: AP-67, "S1 dc 1"

Alarm Condition: Alarms when (1) the manually operated electrical disconnect switch between the battery charger and the batteries is opened or (2) the test block at the control room panel is removed

Sensor Name: S1

Type: Knife switch

Position: In line between battery charger and battery

Physical Location: North wall, pump cubicle

Set Points: Open or shut

Equipment Response: Alarm only; no other function. S1 switch has no automatic or protective function

Operator Actions:

1. This alarm is manually activated and should not occur during normal operations.
2. If this occurs during operation:
   a. investigate for faulty alarm circuitry, and
   b. investigate the pump house and control room for unauthorized personnel actions.

Annunciator: AP-68, "S2 dc 1"

Alarm Condition: Alarms when (1) the manually operated S2 disconnect switch between the battery and pony motor is opened or (2) the safety block at the control panel is removed

Sensor Name: S2

Type: Knife switch

Position: In line between battery and pony motor

Physical Location: North wall, pump cubicle

Set Points: Open or shut

Equipment Response: Alarm only; S2 switch has no automatic or protective function

Operator Actions:

1. This alarm is manually activated and should not occur during normal operations.
2. If this occurs during operation:
   a. investigate for faulty alarm circuitry, and
   b. investigate the pump house and control room for unathorized personnel actions.

Annunciator:	AP-69, "Hi Lo Curr Volt dc 2"	
Alarm Condition:	Alarms on (1) overvoltage or undervoltage on primary pony motor batteries, (2) overcurrent or undercurrent on pony motor, and (3) removal of safety block	
Sensor Name:	R6	R7
Type:	Solid state bridge circuit voltmeter	Solid state bridge circuit voltmeter
Position:	Measures voltage drop across the pony motor	Measures current in the dc supply line to the pony motor
Physical Location:	Pump room north wall	Pump room north wall
Set Points:	Overvoltage alarm: 41 V Undervoltage alarm: 37 V Overcurrent alarm: 10 A Undercurrent alarm: 5 A	
Equipment Response:	All the above give alarms only; no protective functions.	

NOTE: Technical Specifications (Para. 3.8.2b) require that two of the three pony motors must be functional to continue reactor operation.

Operator Actions:

1. Check local panel in the applicable pump room to determine which of the four factors caused the alarm.
2. If the reactor system is operating normally, alarms may indicate a faulty battery charger or battery bank.

NOTES: 1. Battery charger may drop out on loss of power to the charger, etc. This circuit must be reset locally.

2. The battery charger has an internal protective coil. Should this activate, an undervoltage alarm would result, and the associated pony motor could still have the battery bank to run in event of emergency.

Annunciator:	AP-70, "ac Pwr dc 2"
Alarm Condition:	Alarms when (1) 240-V ac electrical supply (TVA) to the battery charger is lost, (2) when safety block in control room panel is removed, or (3) overcurrent to battery charger
Sensor Name:	
Type:	Magnetic disconnect switch (with overcurrent protection)
Position:	Between battery charger and 240-V TVA supply
Physical Location:	Pump cubicle
Set Points:	Alarms: Loss of power or overcurrent
Equipment Response:	Alarm function on overcurrent to battery charger

Operator Actions:

1. If alarm is only on one pump, have battery charger checked for overloading.
2. If battery bank is still good (i.e., no over/undervoltage alarm), then pony motors are still functional.

   NOTE: ORR Technical Specifications (p. 3-12, para. 3.8.2.b) require that a minimum of two pump units must be available to provide at least 750 gpm for 30 min while at operation above 20 MW.
3. If all three pumps alarm, investigate circuit faults at panel 2 at the doorway of the electric shutdown pump room.

Annunciator:	AP-71, "S1 dc 2"
Alarm Condition:	Alarms when (1) the manually operated electrical disconnect switch between the battery charger and the batteries is opened or (2) the test block at the control room panel is removed
Sensor Name:	S1
Type:	Knife switch
Position:	In line between battery charger and battery
Physical Location:	North wall, pump cubicle
Set Points:	Open or shut
Equipment Response:	Alarm only; no other function. S1 switch has no automatic or protective function

Operator Actions:

1. This alarm is manually activated and should not occur during normal operations.
2. If this occurs during operation:
   a. investigate for faulty alarm circuitry, and
   b. investigate the pump house and control room for unauthorized personnel actions.

Annunciator:	AP-72, "S2 dc 2"
Alarm Condition:	Alarms when (1) the manually operated S2 disconnect switch between the battery and pony motor is opened or (2) the safety block at the control panel is removed
Sensor Name:	S2
Type:	Knife switch
Position:	In line between battery and pony motor
Physical Location:	North wall, pump cubicle
Set Points:	Open or shut
Equipment Response:	Alarm only; S2 switch has no automatic or protective function

Operator Actions:

1. This alarm is manually activated and should not occur during normal operations.
2. If this occurs during operation:
   a. investigate for faulty alarm circuitry, and
   b. investigate the pump house and control room for unathorized personnel actions.

Annunciator:	AP-73, "Hi Lo Curr Volt dc 3"	
Alarm Condition:	Alarms on (1) overvoltage or undervoltage on primary pony motor batteries, (2) overcurrent or undercurrent on pony motor, and (3) removal of safety block in control room panel	
Sensor Name:	R6	R7
Type:	Solid state bridge circuit voltmeter	Solid state bridge circuit voltmeter
Position:	Measures voltage drop across the pony motor	Measures current in the dc supply line to the pony motor
Physical Location:	Pump room north wall	Pump room north wall
Set Points:	Overvoltage alarm: 38 V Undervoltage alarm: 33.5 V Overcurrent alarm: 10 A Undercurrent alarm: 5 A	

Equipment Response: All above give alarm only; no protective functions.

NOTE: Technical Specifications (Para. 3.8.2b) require that two of the three pony motors must be functional to continue reactor operation.

Operator Actions:

1. Check local panel in the applicable pump room to determine which of the four factors caused the alarm.
2. If the reactor system is operating normally, alarms may indicate a faulty battery charger or battery bank.

NOTES: 1. Battery charger may drop out on loss of power to the charger, etc. This circuit must be reset locally.

2. The battery charger has an internal protective coil. Should this activate, an undervoltage alarm would result and the associated pony motor could still have the battery bank to run in event of emergency.

Annunciator: AP-74, "ac Pwr dc 3"

Alarm Condition: Alarms when (1) 240-V ac electrical supply (TVA) to the battery charger is lost, (2) when safety block in control room panel is removed, or (3) overcurrent to battery charger.

Sensor Name:

Type: Magnetic disconnect switch (with overcurrent protection)

Position: Between battery charger and 240-V TVA supply

Physical Location: Pump cubicle

Set Points: Alarms: Loss of power or overcurrent

Equipment Response: Alarm function on overcurrent to battery charger

Operator Actions:

1. If alarm is only on one pump, have battery charger checked for overloading.
2. If battery bank is still good (i.e., no over/undervoltage alarm), then pony motors are still functional.

   NOTE: ORR Technical Specifications (p. 3-12, para. 3.8.2.b) require that a minimum of two pump units must be available to provide at least 750 gpm for 30 min while at operation above 20 MW.
3. If all three pumps alarm, investigate circuit faults at panel 2 at the doorway of the electric shutdown pump room.

Annunciator:	AP-75, "S1 dc 3"
Alarm Condition:	Alarms when (1) the manually operated electrical disconnect switch between the battery charger and the batteries is opened or (2) the test block at the control room panel is removed
Sensor Name:	S1
Type:	Knife switch
Position:	In line between battery charger and battery
Physical Location:	North wall, pump cubicle
Set Points:	Open or shut
Equipment Response:	Alarm only; no other function. S1 switch has no automatic or protective function

Operator Actions:

1. This alarm is manually activated and should not occur during normal operations.
2. If this occurs during operation:
   a. investigate for faulty alarm circuitry, and
   b. investigate the pump house and control room for unauthorized personnel actions.

Annunciator: AP-76, "S2 dc 3"

Alarm Condition: Alarms when (1) the manually operated S2 disconnect switch between the battery and pony motor is opened or (2) the safety block at the control panel is removed

Sensor Name: S2

Type: Knife switch

Position: In line between battery and pony motor

Physical Location: North wall, pump cubicle

Set Points: Open or shut

Equipment Response: Alarm only; S2 switch has no automatic or protective function

Operator Actions:

1. This alarm is manually activated and should not occur during normal operations.
2. If this occurs during operation:
   a. investigate for faulty alarm circuitry, and
   b. investigate the pump house and control room for unauthorized personnel actions.

Annunciator: AP-77, "Spare"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Operator Actions:

Annunciator: AP-78, "Spare"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Operator Actions:

Annunciator: AP-79, "Spare"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Operator Actions:

<u>Annunciator:</u> <u>AP-80, "Primary Makeup Flow Hi"</u>

<u>Alarm Condition:</u> Alarms when primary makeup rate is greater than 30 gpm

<u>Sensor Name:</u>

<u>Type:</u> ΔP cells

<u>Position:</u> Equalizer leg orifice

<u>Physical Location:</u>

<u>Set Points:</u> Alarms: 30 gpm

Slow scram: 60 gpm

Shutdown primary pumps: 75 gpm

<u>Equipment Response:</u>

<u>Possible Causes:</u>

1. Forced cooldown
2. Primary leaks

<u>Operator Actions:</u>

1. Investigate the source of water loss from primary inventory.
2. If possible, valve out the system that contains the leak.
3. If excessive leaks cannot be isolated, shut down the reactor.
4. If major leaks are indicated, refer to AOI-I, Section 7.9.

Annunciator: AN-1, "^{16}N South"

Alarm Condition: Alarms at 110%, scrams at 145%

Sensor Name: Gamma ionization chamber (not compensated)

Type: Q-2818 (ORNL design)

Position: Reactor discharge line (south)

Physical Location: Pipe chase about same height as thermocouple, clamped to outside pipe

Set Points: Alarm: 110%

Scram: 145%

Equipment Response: None other

Operator Actions:

1. Check other primary radiation meters, especially the other ^{16}N monitor and the reactor water activity monitor.
2. If these readings are also high, scram the reactor and investigate the cause of the alarm.

NOTE: ^{16}N monitors will probably be the first indication of a radioactive material release from the core into the primary system.

Annunciator: AN-2, "Experiment Reverse"

Alarm Condition: Will alarm and indicate a reverse has been requested by a specific experiment's protective circuit

Sensor Name: Pressure switches, pressure transducers, thermocouples, etc.

Type:

Position: In experiment

Physical Location: In experiment

Set Points: Varied

Equipment Response: Reverse, i.e., all rods drive in

Operator Actions:

1. Investigate the cause of the reverse:
   a. monitor readings in the experiment control room, and
   b. contact experimenter(s).
2. If conditions cannot be corrected, shut down the reactor.

Annunciator: AN-3, "^{16}N North"

Alarm Condition: Alarms at 110%, scrams at 145%

Sensor Name: Gamma ionization chamber (not compensated)

Type: Q-2818 (ORNL design)

Position: Reactor discharge line (north)

Physical Location: Pipe chase about same height as thermocouple, clamped to outside pipe

Set Points: Alarm: 110%

Scram: 145%

Equipment Response: None other

Operator Actions:

1. Check other primary radiation meters, especially the other ^{16}N monitor and the reactor water activity monitor.
2. If these readings are also high, scram the reactor and investigate the cause of the alarm.

NOTE: ^{16}N monitors will probably be the first indication of a radioactive material release from the core into the primary system.

Annunciator: AN-4, "Experiment Setback"

Alarm Condition: Will alarm and indicate a setback to N_L has been requested by a specific experiment's protective circuits

Sensor Name: Varied

Type: Varied

Position: Within experiment circuits or experiments

Physical Location: Within experiment circuits or experiments

Set Points: Varied

Equipment Response:

1. If the alarm condition is not cleared in 5 s, and a 100-s negative period is not measured, an experiment reverse is initiated.

Operator Actions:

1. Investigate the cause of the setback:
   a. monitor readings in the experiment control room, and
   b. contact experimenter(s).
2. If conditions cannot be corrected, shut down the reactor.

Annunciator: AN-5, "Inst Start Tripout"

Alarm Condition: Alarms when the "instrument start" condition is lost

Sensor Name: NA

Type: Limit switches

Position: Startup circuitry

Physical Location: Control console

Set Points: NA

Equipment Response:

1. Returns to manual operation.

   NOTE: The alarm will not clear until the "instrument-start-request" button is depressed or until log-N = 0.6 N_L.

Possible Causes:

1. Any reverse
2. Momentary break in clutch power (i.e., during momentary power outage)

Operator Actions:

1. Notify startup supervisor; locate cause of alarm.
2. Return to instrument start or continue manual startup.

Annunciator: AN-6, "Inactive Fiss Chamber Inserted"

Alarm Condition: Alarms if the fission chamber that is not selected (for automatic operation) is not at its withdrawal limit

Sensor Name:

Type: Limit switch

Position: Fission chamber drive

Physical Location: Along the fission chamber drive chain

Set Points:

Equipment Response: Warning alarm to keep the non-selected fission chamber from being damaged.

Operator Actions:

1. Withdraw the inactive fission chamber.

Annunciator: AN-7, "1 Gamma"

Alarm Condition: Alarms at 110% power level

Sensor Name: PCP-105

Type: Gamma sensitive ionization chamber

Position: In pool on west side of reactor tank

Physical Location: Inside either north or south tubes which position the chamber at the midplane of the core

Set Points: Alarms: 110%

Scrams: 145%

Equipment Response: Alarm 110%

Scrams 145%

Possible Causes:

1. High reactor power indication
2. Flooding of beam holes

NOTE: Originally installed to verify that safety channel neutron detectors were not shielded due to beam hole flooding. Beam holes are presently drained and require special action to pipe water into beam holes.

Operator Actions:

1. Verify other power detectors indications.
2. Verify reactor ΔT readings and ^{16}N readings.
3. If other instruments indicate high levels, take corrective actions with servo, a reverse, or a scram, as circumstances demand.

Annunciator: AN-8, "2 Gamma"

Alarm Condition: Alarms at 110% power level

Sensor Name: PCP-105

Type: Gamma sensitive ionization chamber

Position: In pool on west side of reactor tank

Physical Location: Inside either north or south tubes which position the chamber at the midplane of the core

Set Points: Alarms: 110%

Scrams: 145%

Equipment Response: Alarm 110%

Scrams 145%

Possible Causes:

1. High reactor power indication
2. Flooding of beam holes

NOTE: Originally installed to verify that safety channel neutron detectors were not shielded due to beam hole flooding. Beam holes are presently drained and require special action to pipe water into beam holes.

Operator Actions:

1. Verify other power detectors indications.
2. Verify reactor ΔT readings and ^{16}N readings.
3. If other instruments indicate high levels, take corrective actions with servo, a reverse, or a scram, as circumstances demand.

Annunciator: AN-9, "Fast Scram"

Alarm Condition: Alarms when (1) a fast scram or an approach to a fast scram occurs, or (2) sigma-bus voltage decreases to the bus protection voltage

Sensor Name:

Type:

Position:

Physical Location:

Set Points: Alarms when sigma-bus voltage = 1.35 N_F or log-N period = 3 s

Fast scrams when sigma-bus voltage = 1.45 N_F or log-N period = 1 s

Equipment Response: Fast scram signals reduce electrical power to sigma bus which lowers voltage to the scram point on the magnet amplifier thus ensuring dropping of rods

Operator Actions:

1. Perform scram recovery actions.
2. Investigate the cause of the scram.

Annunciator: AN-10, "5-s Period"

Alarm Condition: Alarms when either count rate period recorder or when log-N period recorder indicates a period less than 5 s

Sensor Name: RS-96, RS-38, RS-3, and RS-63

Type: Recorder contacts

Position:

Physical Location:

Set Points: Alarms - 5 s

Reverse - 5 s (count rate reverse inhibited if log-N >1.8 N_L)

Equipment Response: Reverse at 5-s period

Operator Actions:

1. Recover from reactor reverse.
2. Determine cause of the reverse. Clear the condition and return to power.

Annunciator: AN-11, "Insert 5 Rods"

Alarm Condition: Alarms when five rod insert signal is generated from servo-reverse-limit switch

Sensor Name: Servo-reverse-limit switch

- Type: Limit switch
- Position: Servo-limit-switch chassis
- Physical Location: Control console
- Set Points: NA

Equipment Response: Simultaneous insert of all rods other than servo-controlled rod

Operator Actions:

1. Determine cause of servo system to call for power reduction.
2. Take appropriate actions for reverse recovery.

Annunciator: AN-12, "1.8 N_L in Start"

Alarm Condition: Alarms when the selected log-N recorder reads 1.8 N_L and the reactor is still in "start" mode. Concurrently a reverse is initiated.

Sensor Name: RS-7, RS-60

Type: Limit switch

Position: In the log-N recorders

Physical Location: Recorder cabinet

Set Points: 1.8 N_L

Equipment Response: Reverse initiated with the alarm

NOTE: This alarm does not occur if the reactor is in "RUN" mode.

Operator Actions:

1. Recover from reverse. Reduce power below 1.8 N_L.
2. Shift to "RUN" as described in startup procedure in Section 1.

Annunciator:	AN-13, "Safety Level"
Alarm Condition:	Alarms (simultaneous setback) when any one of the three safety recorders indicate 1.1 N_F
Sensor Name:	
Type:	Limit switches
Position:	Safety level recorders
Physical Location:	Control Room
Set Points:	Alarm: 1.1 N_F
	Setback: 1.1 N_F
	Reverse: 1.2 N_F
Equipment Response:	Setback: 1.1 N_F
	Reverse: 1.2 N_F
Possible Causes:	1. Servo malfunction
	2. Sudden reactivity increase

Operator Actions:

1. Assure power is reversed and lowered.
2. Perform setback or reverse recovery procedures.
3. Investigate the cause of the high power signal.
4. Correct condition and return to power.

Annunciator: AN-14, "Safety Trouble"

Alarm Condition: Alarms when the fast scram circuit trouble monitor receives a trouble signal from any one of four possible channels (three safety and one period). These trouble signals indicate faults within the circuits (i.e., loss of ion chamber voltage, grid voltage, etc.) and not necessarily abnormal core physical parameters.

Sensor Name: Various

Type: Various

Position: Fast scram circuits

Physical Location: Control room scram cabinets

Set Points: Various

Equipment Response: None

Possible Causes:

Operator Actions:

1. Notify the shift supervisor.
2. Check trouble monitor panel to determine which of four channels sent signals to its sigma amplifier.
3. Check the appropriate sigma amplifier to determine what signal was received.
4. The shift supervisor must evaluate the consequences of the faults. Should the fault affect one safety channel, he may elect to disconnect that one channel from the sigma bus to remove the source of the fault and to effect repairs.

NOTE: Two safety channels are required for operation. Loss of a second channel or a second safety trouble signal will result in an automatic shutdown (see AN-16, "Two Safety Troubles").

Annunciator: AN-15, "Servo Wdr Limit"

Alarm Condition: Alarms when the servo rod reaches the servo withdraw-limit. NOTE: This alarm is bypassed when (1) servo demand switch is in raise position or (2) the reactor is not in "run."

Sensor Name:

Type: Limit switch

Position: Limit switch chassis

Physical Location: ORR control console

Set Points:

Equipment Response: Stops withdrawal of servo rod

Operator Actions:

NOTE: This alarm alerts operator that the servo rod can no longer be withdrawn automatically and that power will sag if operator action is not taken.

1. Manually raise the servo limit switch using the servo rod withdrawal button. CAUTION: Always observe nuclear instrumentation when manipulating rod controls.
2. In addition, servo limit switch may be raised by withdrawing other rods.
3. Maintain servo indicator in middle position.

Annunciator: AN-16, "Two Safety Troubles"

Alarm Condition: Alarms when a second safety trouble alarm (AN-14) is received. A simultaneous reverse is initiated. NOTE: A period channel will not initiate a reverse. It takes two safety trouble signals.

Sensor Name: Various

Type: Various

Position: Fast scram circuits

Physical Location: Control room scram cabinets

Set Points: Various

Equipment Response: A simultaneous reverse is initiated.

Operator Actions:

NOTE: This alarm indicates faults within the fast scram circuitry and not necessarily core parameters out of normal.

1. Shut down the reactor and investigate the faults within the fast scram circuitry.

Annunciator:	AN-17, "Slow Scram"
Alarm Condition:	Will alarm and indicate a slow scram when a dropout or makeup relay in the scram circuit has been actuated by a specific reactor control's protective circuits
Sensor Name:	Relays
Type:	Control relay
Position:	Within reactor control panel
Physical Location:	Within reactor control panel
Set Points:	Varied
Equipment Response:	The magnet current to the six shim-safety control rods will be dut off, thereby dropping the six shim-safety control rods.

Operator Actions:

1. Investigate the cause of the slow scram.
2. Start up the reactor when the cause of the slow scram has been satisfactorily corrected.

Annunciator: AN-18, "Reverse"

Alarm Condition: Will alarm and indicate a reverse when a relay in the reverse circuit has been actuated by a specific protection circuit

Sensor Name: Relays

Type: Control relay

Position: Within reactor control panel

Physical Location: Within reactor control panel

Set Points: Varied

Equipment Response:

1. The six shim-safety control rods will be inserted as long as the reverse relay is actuated or until the respective seat switch is actuated.
2. The reactor will be switched from servo control to manual control when the reverse switch is actuated.

Operator Actions:

1. Investigate the cause of the reverse.
2. Start up the reactor or return the reactor power to the desired level as appropriate.

Annunciator: AN-19, "Spare Blank"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AN-20, "Setback"

Alarm Condition: Will alarm and indicate a setback when a relay in the setback circuit has been actuated by a specific protection circuit

Sensor Name: Relay

Type: Control relay

Position: Within reactor control panel

Physical Location: Within reactor control panel

Set Points: Varied

Equipment Response:

1. The servo demand will be lowered as long as the setback relay is actuated, thus inserting the No. 6 shim-safety control rod. A setback is terminated at N_L.
2. If the reactor is in manual operation, an experiment setback will insert the No. 6 shim-safety control rod as long as the setback relay is actuated or until the No. 6 shim-safety control rod seat switch is actuated.

Operator Actions:

1. Investigate the cause of the setback.
2. Start up the reactor or return the reactor to the desired power level as appropriate.

Annunciator: AP-21, "Spare Blank"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AP-21, "Spare Blank"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AN-23, "Sigma ac Line Mon"

Alarm Condition: Alarms when the sigma ac voltage decreases from normal value (approximately 120 V ac) to 105 V ac and remains at or below this value for 5 s

Sensor Name:

Type:

Position:

Physical Location:

Set Points: Alarms: 105 V ac for 5 s

Slow scram: 105 V ac for 5 s (clears at 108 V ac)

Equipment Response:

Possible Causes: Power failure or voltage drop

NOTE: The circuit's function is to reinforce the protection provided by fast scram circuits. The fast scram circuits would be affected by off-site power "brownout" or momentary loss.

Operator Actions:

1. Start up and recover from scram whenever abnormal conditions clear using procedures in Section 1.

Annunciator: AN-24, "Spare Blank"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AO-1, "3004 Demineralizer Resistance Low"

Alarm Condition: Alarms when the conductivity of the effluent of the in-service demineralizer columns increases to 250,000 ohm-cm

Sensor Name:

Type: Conductivity probe

Position: Demineralizer(s) common effluent to the storage canal

Physical Location: Sensing element in overhead above alley-way between the two cation tanks. The set point controller for this sensor is mounted on the west demineralizer column.

Set Points: About 250,000 ohm-cm

Equipment Response: With alarm the effluent line valve will close stopping flow to the storage tank

Possible Causes:
1. Depletion of demineralizer
2. Inadvertent sending of caustic or acid to the storage tank

Operator Actions:

1. Check the condition of in-service demineralizer by sampling pH and conductivity of effluent. If necessary, regenerate the depleted demineralizer.
2. If during regeneration the alarm sounds, check the valve line-up to ensure caustic/acid is not being sent to storage tank.

CAUTION: Do not raise the alarm set point for the purpose of silencing the alarm. Notify the shift supervisor if the set point needs to be raised.

Annunciator: AO-2, "Hot Cell"

Alarm Condition: Alarms on activation of (1) fire detection system or (2) pressure increases to -0.1 in. H_2O in either the north or south ORR pool hot cell

Sensor Name:

Type: Pressure switch

Position:

Physical Location: Reactor pool hot cell

Set Points: Alarms: -0.1 H_2O pressure

Equipment Response: Fire alarm also notifies the fire department

Possible Causes:

1. Loss of cell-ventilation service to hot cell. (NOG is a backup service.)
2. Increase in pressure in hot cell.
3. Removing top plug to load hot cell with carrier.

Operator Actions:

1. Verify the alarms.
2. Notify shift supervisor.

Annunciator:	AO-4, "Neutralization Tank H-Level"
Alarm Condition:	Alarms when the neutralizer tank is >75% filled (or full)
Sensor Name:	
Type:	Pressure switch
Position:	Building 3004, 1st Floor
Physical Location:	Neutralization tank
Set Points:	≥75% filled
Equipment Response:	None
Possible Causes:	Tank is ≥75% filled

Operator Actions:

1. Add acid or caustic to the liquid in the neutralization as applicable to achieve a pH between 6 and 9.
2. Dump the neutralized liquid to the creek.

Annunciator: AO-3, "3004 Demineralized Storage Tank Water Level"

Alarm Condition: Alarms when the 10,000 gallon demineralizer water storage tank in Building 3004 drops below 6-ft level

Sensor Name:

Type: Pressure switch

Position: Storage tank (level indication on 3004 1st floor)

Physical Location: Storage tank

Set Points: Low alarm: 6 ft

Equipment Response: None

Possible Causes:

1. Using excessive water
2. No demineralizer in service
3. Water line break
4. Building 3019 excessive water usage
5. Leak to 3001 canal
6. Demineralizer not valved in properly

Operator Actions:

1. Locate source of excessive usage.
2. Ensure demineralizers in service.
3. Ensure demineralizer valving arrangement is correct.

Annunciator: AO-5, "OGR Trouble"

Alarm Condition: Alarms on (1) high radiation levels in Building 3001, (2) high radiation in the canal water, or (3) manual activation of the OGR elevator emergency button

Sensor Name:

Type: FRCAS monitrons and CAM, elevator manual switch, canal gamma monitor

Position: Various

Physical Location:

1. The FRCAS alarm panel is located on 1st floor SE corner of 3001. It gives all monitor locations.
2. The canal gamma monitor is located in the canal storage tank discharge line supplying the canal demineralizer.
3. The elevator emergency button is on the elevator.

Set Points: Various

Equipment Response: The canal gamma monitor alarm should stop flow to the demineralizer.

Possible Causes:

1. OGR elevator stuck
2. High canal water activity level (from isotope storage tank)
3. FRCAS alarms for OGR building

Operator Actions:

1. Investigate the cause of the alarm.
2. Make necessary corrections and notify shift supervisor.
3. If the canal water activity is high, take the demineralizer out of service.

Annunciator: A0-6, "Spare"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

Annunciator: AO-7, "L-9 Monitor"

Alarm Condition: Under normal conditions, the annunciator light is on. An alarm will de-energize the light indicating a loss of power (or short) on any one of the ten L-9 subgroups of annunciator power circuits.

Sensor Name: Various

Type: Various

Position: Annunciator circuits

Physical Location: Various

Set Points: Various

Equipment Response:

Possible Causes: The L-9 circuit supplies power to all ORR annunciators. It is divided into 10 subgroups. Should any single annunciator circuit short or fault, it will de-energize its associated subgroups and therefore result in the above alarm.

Operator Actions:

1. Notify shift supervisor.
2. Push annunciator test button to determine which annunciator test is not functioning.
3. Consideration should be given to those parameters that are not energized in the alarm circuit. Increased monitoring activities of those parameters should be in effect until the circuit is repaired.

Annunciator: AO-8, "Spare"

Alarm Condition:

Sensor Name:

Type:

Position:

Physical Location:

Set Points:

Equipment Response:

Possible Causes:

Operator Actions:

2.3.9. Experiment Annunciators

These annunciators are actuated through the experiment instrumentation and serve to warn the operator of trouble at the experiment. The exact nature of the alarm condition must be determined by observing the experiment instrumentation. Since all of the stations of the panel are quite similar, a general description will be given here which will include the alarm, setback, reverse, and scram circuits. It should be noted, however, that all of these circuits are not necessarily involved for every experiment.

1. Experiment instrumentation

   The instruments used by experimenters, particularly those related to the reactor control circuits, are carefully chosen for reliability and performance. The safety of the reactor and its personnel is as dependent upon the experiment instrumentation as it is upon the reactor instrumentation. For this reason, all experiment variables which are considered safety problems are dual monitored and double tracked. For example, in the case of a temperature variable measured with thermocouples, two thermocouples would be supplied with a recorder for each thermocouple; and each recorder would have one circuit to relay an alarm, one circuit for setback, one circuit for reverse and two circuits to scram the reactor.

2. Experiment switches ("E-panel")

   To prevent extensive wiring changes each time an experiment is inserted into or removed from the reactor flux, special three-position switches, or "E" switches, Fig. 2.2, are used to effect reactor "tie-in." These switches are located on a vertical panel, Fig. 2.3, at the east end of the control room and are key operated. Their use is limited to the Reactor Supervisor or, during shutdown, to instrument engineers directly in contact with the supervisor. Each "E-panel" consists of a complex of wiring and relays which enable signals from the experiment instrumentation to be converted to a specific action; i.e., alarm, setback, and/or scram.

49143

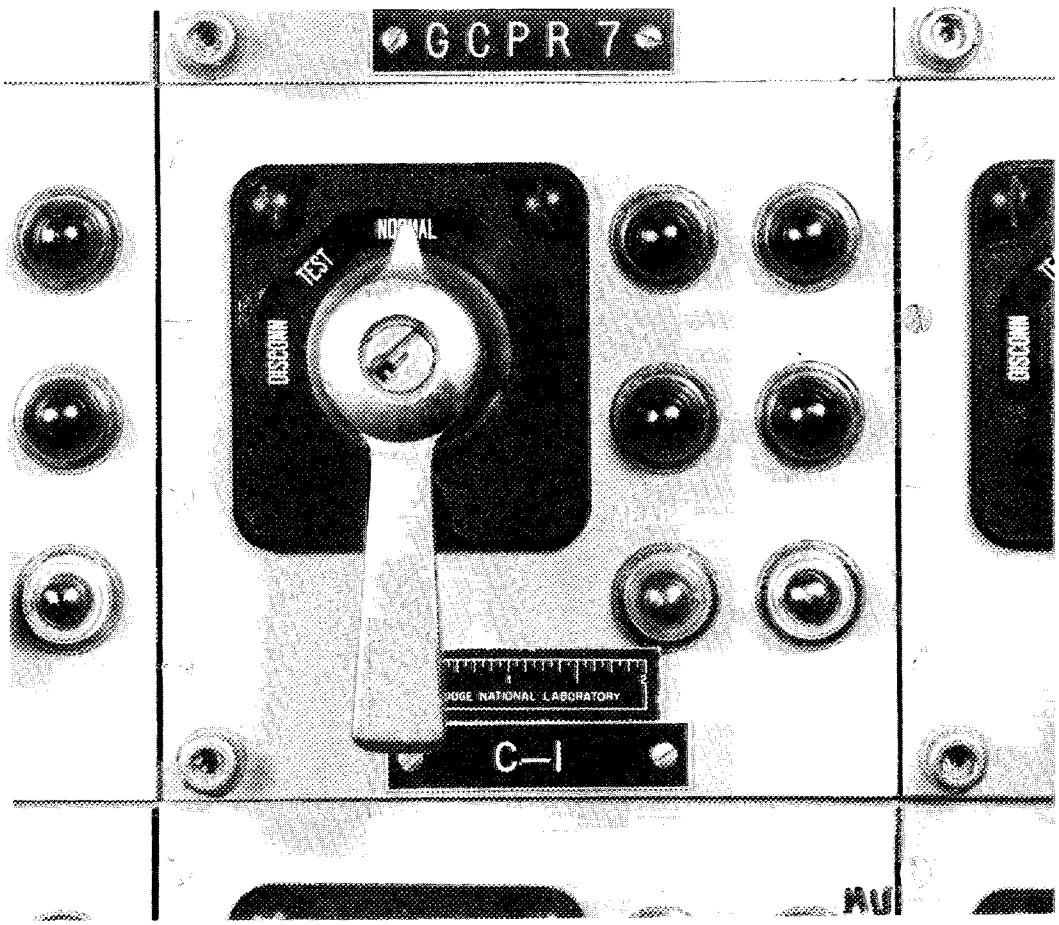

Fig. 2.2. "E" switch.

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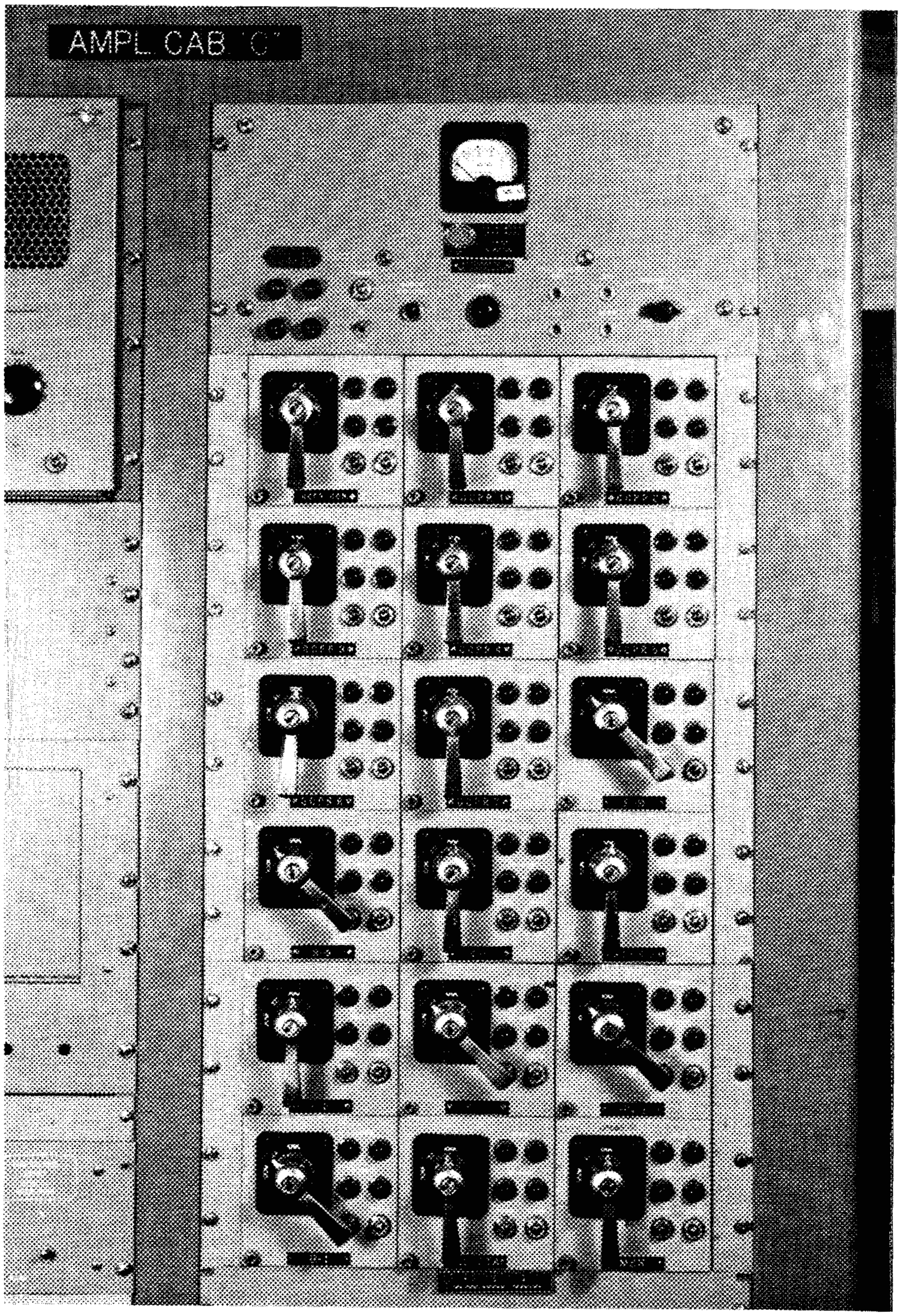

Fig. 2.3. Panel of "E" switches.

3. Normal, test, disconnect

The three switch positions are somewhat self-explanatory. The "normal" position is to be used any time the experiment is in the reactor. In this mode, the experiment is connected to the annunciator panel and, if applicable, to the reactor control circuits. A light at the "E" panel indicating that power has been supplied should be lighted. The switch is not to be turned from this mode while the experiment is in the reactor unless special instructions are issued.

The "test" mode on the "E" panel allows the experimenter to simulate any desired condition (scram, setback, etc.) without affecting the reactor. During tests, the feedback of information from the control room is the same as if the experiment were connected to the reactor, except that the experimenter's "tie-in" annunciator will be lighted. In the "test" position, the control room annunciator station for the experiment will also remain lighted and should be covered with an opaque material if the switch is to remain in this mode during reactor operation.

The "disconnect" position completely severs the experiment power from the "E" panel. In this position, the "power" light should not burn. The control room experiment annunciator station, however, should be lighted and covered if the reactor is operating.

4. Experiment alarm

Contacts in recorders or other devices at the experiment panel or apparatus serve to actuate local annunciators. Auxiliary contacts within the local annunciators open on alarm and, through the "E" panel, de-energize a relay (FR-100 series) to actuate the experiment annunciator in the control room. Alarms other than those associated with scrams, reverses, or setbacks can be made local alarms only if the experiment is manned.

5. Experiment setback or reverse

The signal for a setback or reverse comes from contacts in the experiment instrumentation itself and not through the experiment annuniciator as in the case of an alarm. A setback signal from a recorder or other device energizes a relay (RE-300 series) which in turn energizes relay R24Y (reactor setback) if the "E" panel is in the "normal" mode. Other contacts, within the same instrument, open to de-energize a relay in the RE-200 series and relay R-27 (reactor reverse) if the "E" panel is in "normal." An experiment reverse will not occur if the reactor instrumentation is indicating a negative period <100 s as displayed by the log-N period recorder.

6. Experiment Scram

A scram is initiated by contacts (two per instrument, one normally open and one normally closed) within the experimenter's recorders or other devices. The normally closed contacts open a circuit through the "E" panel to a relay (RE-400 series) which de-energizes relay R-28 if the "E" panel is in "normal." This results in a slow scram. The normally open contacts, similarly, cause a slow scram by energizing a relay in the RE-500 series which, in turn, energizes relay R-28X.

2.3.10. Outside Annunciators

The outside annunciator panel is designed to accommodate eight alarms (AO group) which could occur from operating conditions outside the ORR complex or which have little relation to the reactor.

2.4. ORR Console

The reactor control desk, or console, is located near the center of the control room and is so situated that the attending operator is normally facing the process and nuclear instrument panels, Figs. 2.4 and 2.5. This section describes the various components that make up the console and lists the functions of each.

2.4.1. Left Inclined Panel - Startup Components

1. "Scram" switch

   When not in NORMAL position, this switch turns off the current to the magnets allowing all shim rods to drop.

2. "Scram-reset" button

   With the "Scram" switch in NORMAL, the "Scram-reset" button must be pushed to get current to the magnets.

3. Key-operated switch

   OFF: With the switch in OFF position, there is no power to the reactor controls for the startup of the reactor.

   OPERATE: This position provides power to the reactor controls for the startup and operation of the reactor. NOTE: At any time that the key is in the switch, Reactor Operations Section personnel must be in attendance. The shift supervisor should have the key in his possession should the control room be left unattended.

4. "Evacuation-alarm" button

   This button, when depressed, actuates the building evacuation alarm and is to be used in accordance with the evacuation procedure at any time an emergency arises. Refer to Facility Radiation and Contamination Alarm System, Section 9.1.3, The manual evacuation button.

5. "Raise-test" switch

   RAISE: With the switch in this position, the current to the magnets is turned off. This permits the raising of the rod-drive assemblies without the shim rods attached when the shim-rod mode switch is set in RAISE.

1475-84

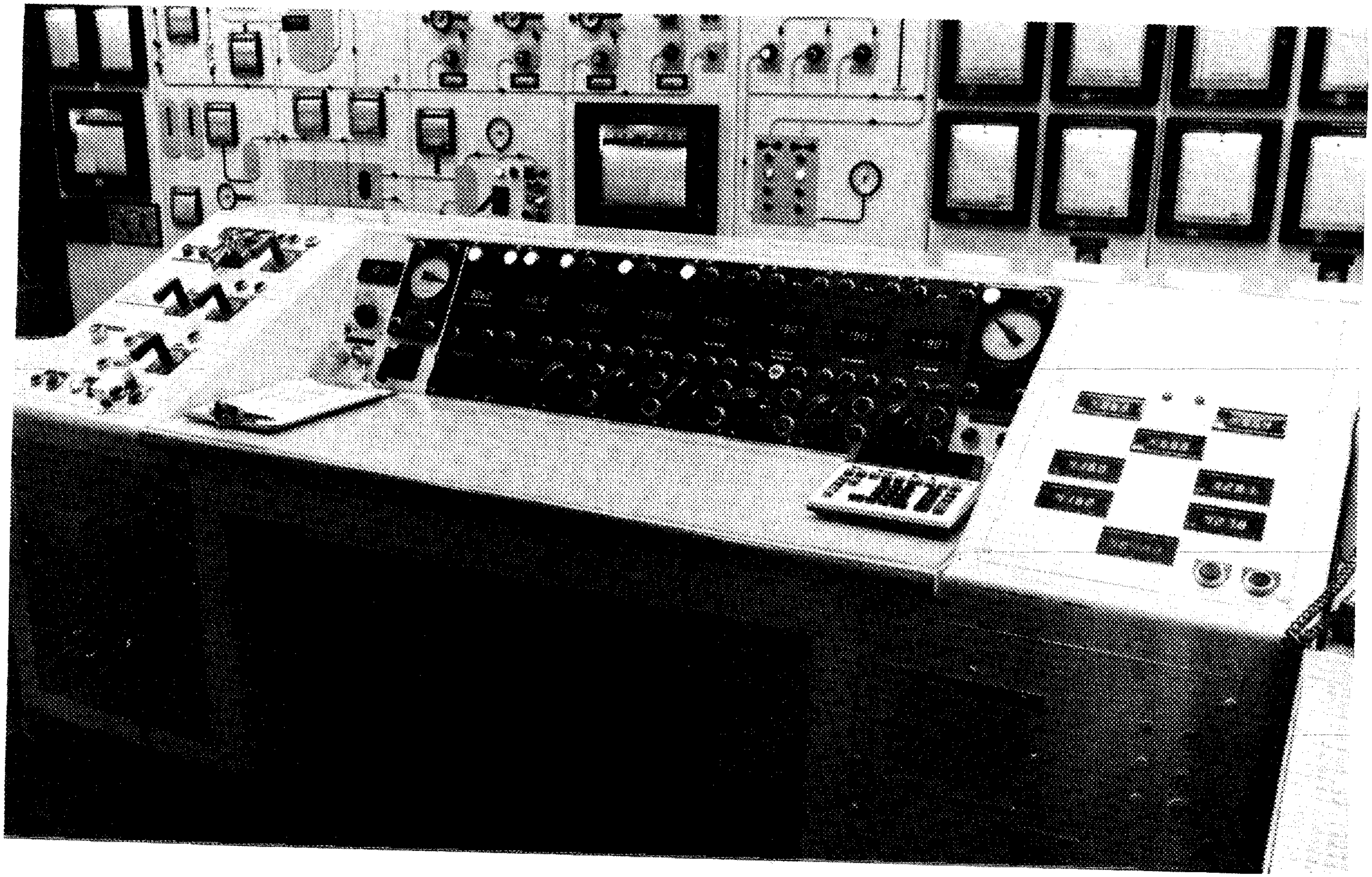

Fig. 2.4. Control console.

1476-84

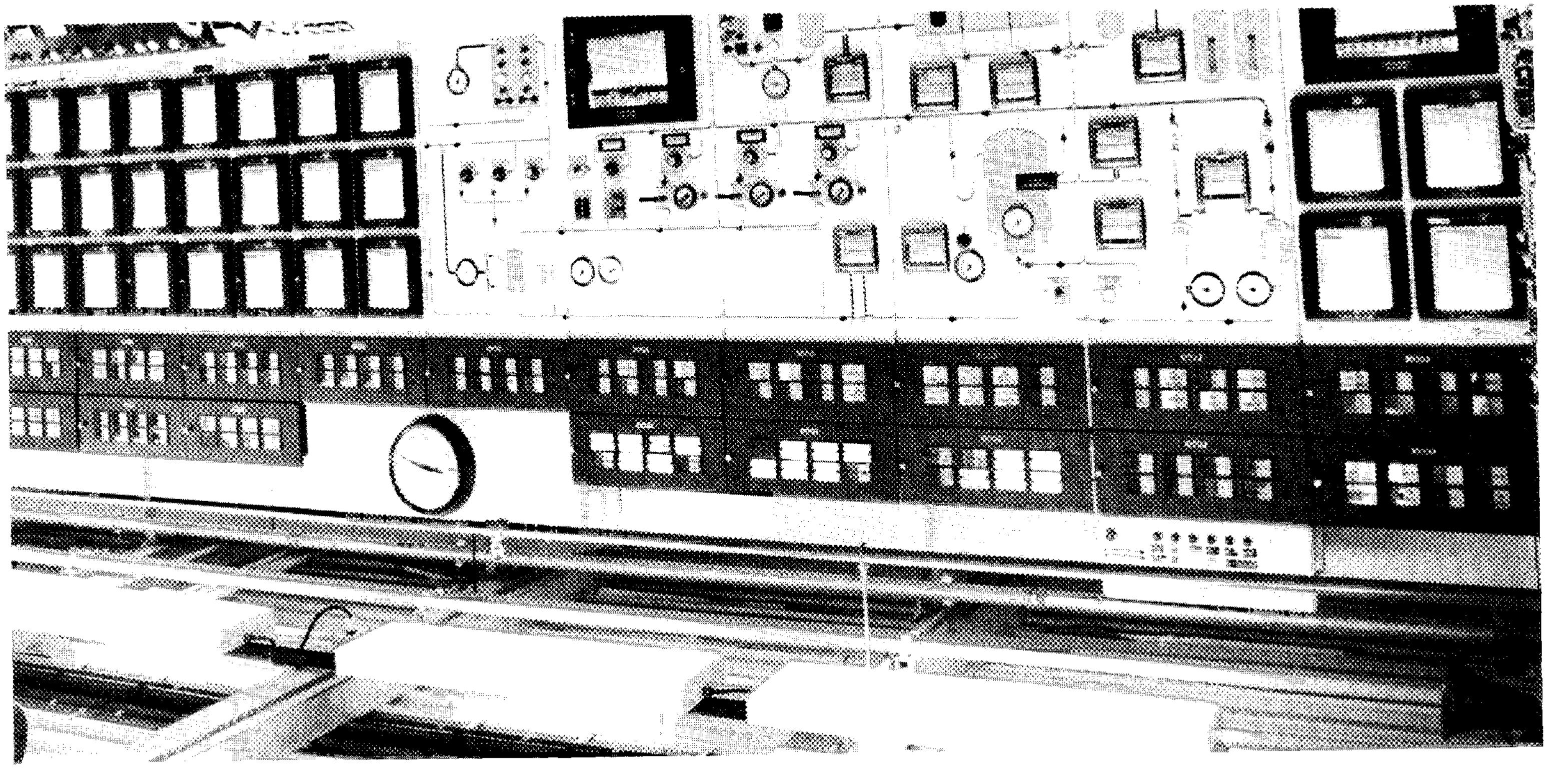

Fig. 2.5. Process and nuclear instrumentation panel.

TEST: Use of this position permits bypassing of the scram circuits of both the main flow and ΔP across the reactor. It permits checking out of the shim rod drives and operation at low power without water flow. In addition, the sensitivity of the No. 3 safety channel is increased by a factor of 45 when the "Raise-test" switch is in the TEST position.

6. <u>"Bypass-reverse" switch</u>

BYPASS: This is a spring-return position that allows the period indicated by the count-rate and log-N period recorders to be less than 30 s during the startup of the reactor. It also allows the period to be less than 20 s if the "Fast-period permit" button has been depressed during startup. It also allows group rod withdrawal after the reactor controls are in the RUN mode. The 10-s period inhibit on the count-rate-period and log-N-period recorders cannot be bypassed.

REVERSE: This is a spring-return position that inserts all rods at once. The reactor, if under servo control, is switched to manual control.

7. <u>"Group-rod-withdrawal" switch</u>

INTERMITTENT: In this position, those rods that are in either PREFERRED or NORMAL position will be withdrawn intermittently if the reactor controls are in the OPERATOR-START mode and a group withdrawal permit is obtained. A timer control supplies power to the shim-rod motors one out of six seconds. The rod-in-motion light, located in the dial of the rod-position indicator, blinks on and off with the application and removal of power to the motor. When the period decreases to less than 30 s, this "intermittent" relay is tripped out and must be reset by turning the switch to NEUTRAL and back to INTERMITTENT.

HIGH: This is a spring-return position so the switch must be held in this position by the operator. After the log-N recorder exceeds 0.001 N_L, log-N confidence, this position becomes active and allows all six shim rods to be withdrawn simultaneously at full speed. This circuit is deactivated whenever the reactor period becomes less than 30 s, unless the "bypass-reverse" switch is held in the BYPASS position to allow the period to be as short as 20 s. Reactivation is accomplished by turning the switch to NEUTRAL. The 20-s period inhibit can be bypassed by depressing the "Fast-period-permit" button, the 10-s period inhibit cannot be bypassed.

8. "Operator-start" switch

OPERATOR START WITH SERVO: This channel permits the operator to raise the reactor power level from shutdown to N_L under servo control. The mode of operation is changed from OPERATOR START to RUN when the "run" button is pushed, provided run conditions are met. When the "Operator-start" switch is actuated, the startup horn sounds, and, at the termination of the horn sound, the circuit with the "Group-rod-withdrawal" switch becomes energized.

9. "Instrument-start" switch

This switch permits the reactor power level to be raised from shutdown to N_L completely under instrument supervision. The INSTRUMENT-START mode is terminated when a servo insert error occurs (normally at N_L). When the "Instrument-start" switch is actuated, the startup horn sounds, the servo limit switches lower to the withdraw limit switch, and the fission chamber (which should be in AUTOMATIC) inserts, if necessary, to give a counting rate of at least 20 cps on the count-rate recorder. The count-rate recorder reading must be >20 cps before the INSTRUMENT-START mode can be obtained.

10. "Fast-period permit" switch

This switch permits the 20-s period inhibits on the count-rate and log-N recorders to be bypassed when the "Bypass-reverse" switch is in the BYPASS position. The 10-s period cannot be bypassed.

11. "Annunciator reset-acknowledge" button

ACKNOWLEDGE: This button permits the alarm on the annunciator panel to be silenced.

RESET: When depressed, this button permits the annunciator white section to be cleared after the abnormal condition is cleared.

When an alarm sounds, both the red/yellow and white sections of the offending station will be lighted. The "acknowledge" push button must be pressed to acknowledge the signal. When this is done, the alarm will be silenced. When the abnormal condition has cleared, the red or yellow section will darken and the white section will remain lighted. The "reset" push button will darken the white section.

12. <u>"Run" switch</u>

The RUN mode must be obtained before the power can be increased above 1.8 N_L. The operator must depress the push-button switch to obtain RUN; this ensures his presence at this time. When the log-N recorder reaches N_L, the push button should be pushed if conditions are favorable for going to full power. If RUN mode is not obtained and the power continues to increase, all rods will be reversed when the log-N recorder reading reaches 1.8 N_L. The period on the log-N and count-rate recorders must be greater than 30 s before the reactor controls will go into RUN.

13. <u>Meters indicating high sensitivity</u>

Microammeters indicate a condition of high sensitivity of the slow scram circuit which is active during low flow ($\leq$12,000 gpm), low ΔP (corresponding to a main flow of $\leq$12,000 gpm), and when the "raise-test" switch is in the TEST position. Each microammeter (one for each condition, i.e., low flow, low ΔP, TEST position) has a 0-50 range and should indicate a reading of >10 when the conditions which it monitors exist.

14. <u>Annunciator test button for telealarm stations</u>

The push button will actuate all annunciators in the control room and poolside simultaneously to verify their abililty to respond to alarm conditions. After the annunciator test button is released, the acknowledge and reset switches will function to acknowledge and reset the annunciators.

2.4.2. Center Inclined Panel - Operating Components

1. Digital voltmeter

This instrument is connected to a selector switch which permits the control-desk operator to select, for close-hand observation, the readout of one of the following: (1) the No. 1 safety channel, (2) the No. 1 gamma channel, (3) the north N-16 channel, or (4) the micromicroammeter channel. This instrument can be useful as a secondary source of information which can be read accurately and easily by the console operator during critical runs, shim-rod calibrations, and manual operation. During normal operation, the operator can also obtain a readout of any of these channels at his discretion. When not in use, the electrical power switch of the unit should be turned off to prolong the life of the unit. The power switch should be turned on minutes before using the instrument, to allow sufficient warmup time.

2. Servo and manual push-button switches

These switches are used to switch from servo control to manual control and vice versa when the respective push button is depressed.

3. "Servo set-point" selector switch

The selector switch is used to establish the demand to the servo as indicated on the demand dial in megawatts. The demand selector switch provides a rough adjustment. Fine adjustment is obtained by use of the venier control knob located above the "Servo-demand" selector switch. LOWER: In this position, the servo demand is reduced on an approximate 20-s period. If the reactor is under servo control and at power, the No. 6 rod and additional rods, if needed, will be inserted to lower the reactor power level as the demand decreases.

RAISE: In this position, a withdraw error is established via the servo amplifier (when the demand signal is greater than the power signal) and the servo-controlled rod (No. 6 rod) withdraws to raise the reactor power level. Should the servo-controlled rod reach the servo withdraw limit before the desired power level is attained, the "preferred" rod will be withdrawn. Under these conditions, that is, servo set-point selector in RAISE and servo-controlled rod at the servo withdraw limit, the withdraw-limit annunciator is not activated.

It should be noted that, if the reactor is under servo control and the servo-controlled rod has been selected as the "preferred" rod, the servo limit switches will be withdrawn when the withdraw limit is reached, provided that the servo set-point selector switch is in the RAISE position.

INSERT ERROR: When the "insert error" is actuated by the servo amplifier, the No. 6 rod will be inserted to maintain a constant power level when the reactor is under servo control.

WITHDRAW ERROR: When the "withdraw error" is actuated by the servo amplifier, the No. 6 rod will be withdrawn to maintain a constant power level when the reactor is under servo control.

4. "Fission-chamber drive" selector switch

AUTOMATIC: This permits the fission-chamber drive to operate automatically when the switch handle is pulled to its outmost position. The switch must be in automatic for an instrument start.

MANUAL: This permits the chamber to be inserted or withdrawn by manually operating the switch when the switch handle is pushed in to its inmost position.

INSERT: This permits the chamber to be inserted by manually operating the switch when the switch handle is in the MANUAL position. Any time the fission chamber is being inserted or withdrawn, the shim rods cannot be withdrawn.

WITHDRAW: This permits the chamber to be withdrawn by manually operating the switch when handle is in the MANUAL position.

5. <u>"Shim-rod mode" switches</u>

RAISE: This position permits the shim-rod drive assembly to be raised without the shim rod attached when the "Raise-Test" switch is in the RAISE position.

OFF: This position prevents withdrawal of the shim rod; however, the rod can be inserted by manually pushing its "Insert" push button or by an automatic rod reverse. This position prevents automatic "drive-down" of the drive assembly following a scram.

BLOCK: This position prevents withdrawal of the shim rod; however, the rod can be inserted by manually operating its "Insert" push button or by an automatic rod reverse. It also permits automatic "drive-down" of the drive assembly following a scram.

NORMAL: This position permits withdrawal of the shim rod by either the "Group-Rod-Withdrawal" or "Instrument-Start" switch. When using the individual rod-withdrawal push buttons, only one shim rod can be withdrawn at a time. The timer does not control the individual-rod-withdrawal push-button system.

PREFERRED: Same as NORMAL with the exception that when the reactor is under servo control, it permits the servo "preferred" limit switch to insert the shim rod. If more than one rod is in the PREFERRED mode, the lowest numbered rod will be inserted. If the Nos. 1, 2, 3, 4, and 5 shim rods are in positions other than PREFERRED and the No. 6 is in PREFERRED, the servo limit switches will be inserted to the middle limit-switch position.

When the reactor is under servo control, the No. 6 "Withdraw" and "Insert" push buttons move the limit switches up or down when the respective push button is actuated. The insertion of the limit switches is stopped when the withdraw limit switch is actuated. The withdrawal of the limit switches is stopped by the actuation of the "preferred" limit switch.

When the reactor is not under servo control, the No. 6 shim-rod "Insert" and "Withdraw" push buttons move the No. 6 shim rod down or up when the respective push button is actuated.

6. <u>Individual rod-motion push buttons</u>

INSERT: There is an INSERT push button for each shim rod. This push button permits the shim-rod drive assembly to be inserted when the "shim-rod mode" switch is on any of the five positions.

WITHDRAW: There is a WITHDRAW push button for each shim rod. This push button permits the shim-rod drive assembly to be withdrawn when the "shim-rod mode" switch is in the NORMAL or PREFERRED position.

7. <u>Servo-withdraw limit indicator</u>

This unit consists of a dial indicator and four signal lights all of which serve to show the position of the servo-controlled rod in relation to its working limits. The four lights, labeled "withdraw," "middle," "preferred," and "reverse," are located in the corners of the dial indicator.

The pointer moves around the dial in a clockwise direction as the servo-controlled rod is withdrawn or as the servo limits are adjusted downward. The extreme clockwise position should coincide with the servo withdraw limit, and the indicator light for this limit should be lighted at this point. The servo withdraw annunciator also should sound if the servo demand is not in the raise position. In normal operation this annunciator brings the operator's attention to the need for upward adjustment of servo limit switches or, possibly, upward adjustment of shim rods Nos. 3, 4, and 5. (Nos. 1 and 2 are normally positioned at their upper limits.)

A counterclockwise movement of the pointer indicates either an insertion of the servo-controlled rod or an upward adjustment of the servo limits. When the pointer moves counterclockwise from the withdraw limit position, the withdraw limit is de-energized and the middle limit is actuated. The middle light indicates a a desirable rod position and will remain lighted throughout the upper half of the control range.

Should the servo-controlled rod be inserted to below the approximate half-way point of the servo limit-switch span, the middle limit will be deactivated. At approximately three-quarters of the servo control span below the withdraw limit, the "preferred" insert limit is actuated; and the lowest numbered "preferred" rod will be inserted as long as the servo-controlled rod continues to insert. The "insert 5-rods" limit will be actuated at the lowest point of insertion on the limit-switch span. At this point, the Nos. 1, 2, 3, 4, and 5 rods will be inserted regardless of the position of their mode switches. A "5-rod insert" continues only as long as this limit switch is actuated.

8. "Shim-rod mode" switches

RAISE: This position permits the shim-rod drive assembly to be raised without the shim rod attached when the "Raise-test" switch is in the RAISE position.

OFF: This position prevents withdrawal of the shim rod; however, the rod can be inserted by manually pushing its "Insert" push button or by an automatic rod reverse. This position prevents automatic "drive-down" of the drive assembly following a scram.

BLOCK: This position prevents withdrawal of the shim rod; however, the rod can be inserted by manually operating its "Insert" push button or by an automatic rod reverse. It also permits automatic "drive-down" of the drive assembly following a scram.

NORMAL: This position permits withdrawal of the shim rod by either the "Group-rod-withdrawal" or "Instrument-start" switch. When using the individual rod-withdrawal push buttons, only one shim rod can be withdrawn at a time. The timer does not control the individual-rod-withdrawal push-button system.

PREFERRED: Same as NORMAL with the exception that when the reactor is under servo control, it permits the servo "preferred" limit switch to insert the shim rod. If more than one rod is in the PREFERRED mode, the lowest numbered rod will be inserted. If the Nos. 1, 2, 3, 4, and 5 shim rods are in a position other than PREFERRED and the No. 6 rod is in PREFERRED, the servo limit switches will be inserted to the middle limit-switch position.

When the reactor is under servo control, the No. 6 "Withdraw" and "Insert" push buttons move the limit switches up or down when the respective push button is actuated. The insertion of the limit switches is stopped when the withdraw limit switch is actuated. The withdrawal of the limit switches is stopped by the actuation of the "preferred" limit switch.

When the reactor is not under servo control, the No. 6 shim-rod "Insert" and "Withdraw" push buttons move the No. 6 shim rod down or up when the respective push button is actuated.

2.5. Reactor Instrument and Controls Maintenance Procedures

A notebook in the ORR control room entitled "Oak Ridge Research Reactor, Reactor Controls Maintenance Schedule and Checksheets" contains the "Reactor Instrument and Controls Maintenance Procedures" as follows:

Procedure No.	Title
ORR 1001	Maintenance Procedure - General Definitions
ORR 1101	Maintenance Procedure - Schedule
ORR 1102	Maintenance Procedure - Quarterly Schedule
ORR 1201	Maintenance Procedure - Nuclear System Testing and Calibration
ORR 1301	Maintenance Checksheet - Nuclear System Testing and Calibration
ORR 1302	Maintenance Procedure and Checksheet - Nuclear Control System Circuit Checks
ORR 1601	Maintenance Procedure and Checksheet - Process Pressure Switch Checks
ORR 2001	Maintenance Checksheet - Annunciator Testing

2.5.1. Shim Rod Drives - Functional Check of Mechanical Aspects (Limit Switches, Position Indicators)

1. Preparation and/or conditions for test (data sheet No. 1, Example 2.1, required)
   a. Reactor core and vessel
      (1) Core loaded and inspected
      (2) Upper bearings (hold-down arms) in operating position and checked
      (3) Shim rods properly locked and checked for free movement in their bearings
      (4) Access cover in position and secured

POSITION-INDICATOR AND LIMIT-SWITCH CHECKS
(Refer to Section 2.5.1, Steps 2.a, b, and c)

ORR Instrument-Checks Data Sheet No. 1

	Shim-rod drives					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Section 2.5.1, Step 2.a(3): Mechanical Tightness and Condition*						
Lower-limit switch	____	____	____	____	____	____
Lower-limit-switch actuator	____	____	____	____	____	____
Upper-limit switch	____	____	____	____	____	____
Actuator holding rod (conduit)	____	____	____	____	____	____
Response switch	____	____	____	____	____	____
Clutch switch	____	____	____	____	____	____
Motor-to-drive connection (coupling)	____	____	____	____	____	____
Section 2.5.1, Steps 2.b(6) through 2.b(10)**						
(6) Selsyn zero	____	____	____	____	____	____
Adjustment necessary (yes or no)	____	____	____	____	____	____
Metal scale	____	____	____	____	____	____
(7) Seat switch off, selsyn	____	____	____	____	____	____
Seat switch off, dial indicator	____	____	____	____	____	____
(8) Seat switch on, selsyn	____	____	____	____	____	____
Seat switch on, dial indicator	____	____	____	____	____	____
(9) Seat switch on, motor drive	____	____	____	____	____	____
(10) Step (8) selsyn minus step (9)	____	____	____	____	____	____

*Tighten if necessary; check if OK.

**No data entries are necessary for steps 2.b(1) through 2.b(5).

Example 2.1.

	Shim-rod drives					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Section 2.5.1, Step 2.c(2) through 2.c(9) and 2.c(11) through 2.c(15)*						
(2) Response switch actuates	+	+	+	+	+	+
(3) Clutch switch actuates	-	-	-	-	-	-
(4) 0.002-in. gap reading	-	-	-	-	-	-
(5) Step (3) minus step (4) (clutch gap)						
(6) Step (2) plus step (4) (response gap)						
(7) Lower limit actuates						
(8) Clutch to lower limit, step (7) minus step (3)						
(9) Lower limit overtravel (OK)						
(10) Upper limit, selsyn						
Adjustment necessary (yes or no)						
(11) Upper limit, metal scale						
(12) Normal recocking position						
(13) Zero recheck, selsyn						
Zero recheck, dial indicator						
(14) Snubber indicator						

*No data entries are necessary for steps 2.c(1) and 2.c(10).

Shift________ Date________ Operations engineer________

Remarks________________________________

____

Example 2.1. (Continued)

b. Reactor coolant system

(1) System filled and vented

(2) Normal full flow established

(3) Water flow and/or pressure established to rod-drive seals and shock absorbers

c. Reactor controls

(1) Startup checks, as applicable, properly completed

(2) A normal complement of startup instrumentation shall be operable and reliable

(3) "Raise-test" switch in TEST position

(NOTE: Should it be necessary to deviate from normal procedure related to startup checks, then a careful analysis of the situation must be made. The limit-switch checks require that magnet current be established and that the shim rods be moved slightly off their seats. No more than one rod should be raised from the seated position at any time; however, the reactor will be in the start mode and should be treated accordingly.)

d. Personnel required

(1) A qualified Reactor Operations Section supervisor shall be in the subpile room to supervise measurements.

(2) A qualified member of the Reactor Operations Section shall be present in the control room.

2. Procedure

a. General

(1) Establish telephone communication between the control and the subpile rooms

(2) Ensure that all systems are properly prepared for the tests as described above

(3) Check all limit switches and parts of the drive units for mechanical tightness as indicated on the data sheet

(4) Record all pertinent data and any remarks on data sheet No. 1

b. Rod position-indicator "zero" checks and seat-switch checks

(1) Install the special dial indicator in the threaded hole below the seat switch actuating rod (requires removing the plug) and tighten securely.

(2) Push the dial indicator plunger upward until contact is made with the seat-switch actuating rod through the seal plug. Initial contact will occur between the seal plug and the dial indicator shaft; however, continue to push both the dial indicator shaft and the seal plug upward until contact is made with the seat-switch actuating rod.

(3) With the dial indicator shaft pushed upward as described above, zero the dial indicator.

(4) Release the dial indicator shaft and raise the rod approximately 1 in.

(5) Scram the rod and recheck the dial indicator zero by again pushing upward until contact is established with the seat-switch actuating rod. Reset the dial indicator zero if necessary.

(6) Establish magnet current and raise the drive stepwise by jogging while maintaining an upward force on the dial indicator shaft. When the shim rod is actually raised, the dial indicator will show first movement. The selsyns, rough and fine, should agree with the dial indicator zero, the fine to within ± 0.005 in. Adjust the selsyn transmitters (subpile room) if necessary. Zero the pointer on the subpile position indicator (graduated metal scale), record the data on the position-indicator and limit-switch data sheet (data sheet No. 1).

(7) Raise the shim rod carefully and slowly by jogging or by manually turning the motor shaft while maintaining an upward "push" on the dial indicator shaft. Observe the position at which the seat switch is deactuated (seat light OFF). Record both dial indicator and selsyn readings. Readings should be between +0.175 and +0.250 in.

(8) Insert the shim rod carefully and slowly by jogging or turning the motor shaft by hand until the seat switch is actuated (seat light ON). Record both dial indicator and selsyn readings. Readings should be between +0.100 and +0.150 in. Remove the dial indicator.

(9) Raise the shim rod about 1 in. and then insert it steadily with the rod drive until stopped by the seat switch. Record the selsyn readout.

(10) Subtract the selsyn reading obtained in step B(9) from the selsyn reading in step B(8). Record the difference (overtravel); it should be approximately 0.050 in. NOTE: Proceed to the next drive and repeat steps B(1) through B(10) for all drives to be checked before starting part C below.

c. Response-switch, clutch-switch, lower-limit-switch, and upper-limit-switch checks

(1) Disconnect the response-switch leads at the connector on the operator assembly. Install the test leads on the response-switch connector and place an ohmmeter across leads A and B. Raise the shim rod to approximately 1 in; place the "shim-rod mode" switch in the OFF position; then scram and leave in the scrammed position.

(2) Lower the drive shaft to the 0.5-in. position. Then lower it stepwise until the response switch deactuates, as determined by the ohmmeter. Now raise the drive shaft manually (rotating motor drive shaft) until the response switch actuates (contacts closed) and record the distance "O" indicated by the selsyn indicator.

(3) Lower the rod drive assembly stepwise (the final steps manually) until the clutch switch is actuated (clutch light OFF) and record the position below "0" as shown by the selsyn (the minus reading).

(4) Insert a 0.002-in. feeler gauge between the magnet armature and the magnet. Lower the drive shaft manually until movement of the feeler gauge is slightly restricted. This action will establish a magnet-to-magnet-armature gap of 0.002 in. Record the distance from zero (the minus reading) as indicated by the selsyn at this point as "0.002-gap reading." Remove the feeler gauge.

(5) Subtract the selsyn reading obtained in step c(4), above, from the reading obtained in step c(3) when the clutch switch is actuated. Record as "clutch gap"; the difference should be 0.025 ± 0.005 in.

(6) Add the distance from zero obtained in step c(4), above, (negative direction) to the the distance from zero (positive direction) obtained in step c(2). The total represents the distance that the push rod moves from scram to response-switch actuation. Record as "response gap," which is normally a total of 0.405 ± 0.010 in.

(7) Lower the drive assembly manually (rotate motor shaft counterclockwise) until the lower limit switch is actuated. Record selsyn indication (distance below zero) as "lower-limit actuate."

(8) Subtract the selsyn reading obtained in c(3) from that obtained in step c(7). Record the difference as "clutch to lower limit." Normal difference should be 0.090 ± 0.010 in.

(9) Continue to lower the drive assembly manually until the selsyn indicates an additional 1/16-in. (0.060) of travel below the "lower-limit actuate." The drive assembly should still be free to operate, i.e., should not jam. Check "lower-limit overtravel check" space on the data sheet.

(10) Change controls from TEST to RAISE and switch rod-mode switches to RAISE. All rods should remain in their seats while the drive assemblies are raised to very near the upper limit. While the drive assemblies are in motion, manually actuate each upper-limit switch to ascertain that rod-drive power is interrupted.

(11) After the rod drive assemblies have been raised to approximately 29 in., stop the motors by turning mode switches to OFF and raise each drive assembly manually until the upper-limit switch is actuated. Record the selsyn position on the data sheet as "upper limit." Reading should be 29.250 ± 0.010 in. Adjust if necessary.

(12) Record the reading from the subpile position indicator (graduated metal scale).

(13) Turn the shim-rod mode switches to NORMAL and allow the drives to recock normally. Record the selsyn positions under "normal recocking position."

(14) Recheck selsyn "zero" as described in steps b(1) through b(6). Record the results. Readings may be zero ± 0.020 in. Replace the seal plugs.

(15) Raise each rod, in turn, about 3 in. and, using a flashlight and small magnifying glass, estimate the position of the pointer on the spring snubber position indicator in relation to the center position line. Each division line is 0.025 in. Record as above center line or below center line. Normally, this is approximately -0.015 in.

(16) Check all response-switch connectors to be certain that they are properly reconnected.

d. Each drive unit is checked following Steps 2.a, b, and c.

2.5.2. Safety System, Release Mechanism, and Shim-Rod Performance Checks

1. The safety and control system calibration and functional checks, properly executed, provide assurance that the nuclear instrument electronic gear is calibrated and is responding to input signals. Section 2.5.1, likewise, provides assurance that the mechanical portions of the shim-rod drive and release mechanisms are properly adjusted and functioning correctly. The next step is to determine that these systems, when interconnected, will perform as designed. This portion of the instrument-tests procedure is designed to accomplish such a performance check and, at the same time, to provide a check of shim-rod performance. These objectives are accomplished by actually operating the shim rods while making the required measurements. The following definitions are presented to avoid confusion.

a. Drop current is defined as that current which is passing through the magnet coil when scram action of the scram-latch mechanism is effected. (The magnet current is slowly reduced to determine this value.)

b. Drop point is defined as that power level (as shown by the level-safety recorder) where the magnet current is reduced to the drop current.

c. Simulated N_F current is defined as that magnet current produced by the magnet amplifier when the input voltage to three level-safety sigmas is adjusted to produce readings of 100 (NF) on the level-safety recorders after the drop point has been established.

d. Simulated N_L current is defined as that magnet current produced by the magnet amplifier when the input voltage to three level-safety sigmas is adjusted to 22 V. This should produce readings on the level-safety recorders of 1% N_F (N_L for the ORR) after the drop point has been established.

e. Release time is defined as the time interval between an intentionally introduced fast scram signal and the first detectable movement of the magnet armature.

f. Push-rod-response time is defined as the time interval between an intentionally introduced fast-scram signal and the actuation of the push-rod response switch. In effect, this is the release time plus the time required for the push rod to move through approximately 80% of its total travel.

g. Time-of-flight is defined as the time interval between the introduction of a fast-scram signal and the actuation of the seat switch by the rod being tested. Time-of-flight measurements are normally started with the rod withdrawn to the upper limit of its travel.

h. An operating cycle is defined as that period of time (usually thirteen weeks) comprised of:

   (1) several weeks (usually twelve) during which the reactor is operated as nearly continuously as possible, followed by

   (2) an extended scheduled shutdown of approximately one week's duration for experiment and reactor maintenance and changes.

2. Usual operating values

The parameters defined above are expected to vary somewhat due to slight differences in the various components. The values of the normal range are listed below to serve as guidelines.

Parameters	Usual operating values
Shim-rod drop current	38 ± 6 mA or ±2 mA from previous data on the same unit
Magnet release time	4.5 ± 2 ms or ±1 ms from previous data on the same unit
Push-rod response time	20 ± 4 ms or ±2 ms from previous data on the same unit
Shim-rod time-of-flight (from 29.250-in. position)	≤350 ms at 18,000 gpm flow ≤1000 ms at no flow
Shim-rod-time-of-flight (normal range)	280-315 ms at 18,000 gpm flow 700-810 ms at no flow

Investigation and evaluation will be required if the data fall outside the above listed values. The evaluation will be made by the Reactor Supervisor or his designated representative and the Reactor Controls supervisor responsible for reactor instrument maintenance.

2.6. Special Instrument Procedures

Reference

Reactor Controls Change Memorandum, ORR No. 65.

2.6.1. Positioning of Ion Chambers

The proper operation of the ORR control and safety system depends upon proper location of ion chambers. Since the flux at any ionization chamber location can, and usually does, vary during a reactor operating cycle and can change from cycle to cycle, this procedure will establish certain ranges of normal operation. Experience has shown that approximately a 5% change in neutron flux at a chamber location is expected during a fuel cycle due to a change in rod positions caused by fuel burnup.

Since reactor heat power is the calibrating parameter and is approximately proportional to the neutron flux in the reactor, it will be the basis for chamber positioning. Disagreement between neutron chamber readings and heat-power measurements will be compensated by adjusting the chambers and/or the sensitivity switch according to this procedure. No chamber should be moved to a less sensitive position without complete confidence in the information used as a basis for such a change.

1. Safety chambers
   a. Gain adjustment on safety amplifiers. Limited adjustments of the chamber-current input to the safety sigma amplifiers can be made by a gain adjust switch to maintain a reading of "100" on the safety-amplifier output when the reactor is operating at 30 MW. This is provided to minimize the need for manual repositioning of the safety chambers. This adjustment switch permits periodic correlation of the safety-amplifier output (as read on the safety recorders) to the reactor heat power. This is necessary to compensate for the changing parameters which affect the neutron flux as seen by the detectors.

The technique for adjusting the signal input to safety amplifiers Nos. 1, 2, and 3 is detailed in the following procedure.

(1) If a reading of "100" can be obtained on the safety recorders by adjusting the sensitivity switch (with the reactor at 30 MW at the beginning of an operating cycle), no repositioning of the chambers should be made for 24 hr after attaining the 30-MW level. If, however, this can not be achieved, repositioning of the chambers will be made without waiting for xenon equilibrium to be reached.

(2) After 24 hr at 30 MW, the safety chambers should be repositioned so that the safety recorders read "100" with the selector switch in the range of 9 to 12. CAUTION: Observe the procedure for manual adjustment.

(3) During the remainder of the fuel cycle, with the reactor at 30 MW, a reading of "100" on the safety recorders should be maintained by adjusting the selector switch to the required position.

(4) If agreement as specified in step 3 can not be maintained, manual adjustment of the chambers may be made.

b. Manual adjustment. The position of the safety chambers and sensitivity switches should be such that full-power operation causes the channels to operate at 100% of N_F. Higher readings than this can cause the reactor to be subject to unnecessary shutdown or momentary interruption in operation. Lower readings effectively raise the reactor scram point. These chambers should be relocated only with the reactor operating at or near full power and only with complete confidence in the heat power level of the reactor. Obviously, if these chambers prevent, by their safety action, attainment of full power, the movement of the chambers must be done at a lower (measurable) heat power. This condition is not likely to exist except when the normal operating level has been changed, a chamber replaced, core configuration changed, or when beam-hole liner environment has been changed.

Under these conditions, routine procedures are inadequate. While the safety chambers are being moved, the reactor should be operating on servo so that the operator will be free to observe critical instrumentation. All chambers should not be repositioned at the same time; i.e., if repositioning of all three chambers is required to obtain the desired reading, one chamber will remain unchanged until reliability is established on the repositioned chambers.

2. Servo-micromicroammeter chamber

The proper operation of the servo requires that the chamber delivers up to 20 microamperes at full power. For this reason, the range chosen for proper control is from 18.2 to 20 microamperes for full-power operation. If the chamber is too close to the reactor, the servo can never demand full power; whereas, if the chamber is too far away, the range of operation of the servo is reduced, preventing proper functioning of the reactor setback. Proper calibration is then obtained at the beginning of the cycle by positioning the chamber to give a current of 18.2 uA (or slightly more) at full power. This is done with the reactor being manually controlled and by reading the output of the micromicroammeter. It should be noted that, as a general rule, this chamber should be moved only after the safeties have been placed in their proper place since manual operation is more likely to produce power drifts than servo operation. This rule is especially important if there is evidence that the safety chambers are too far from the reactor core (reading too low).

3. Log-N chambers

The location of these chambers is critical because of their interaction with the servo control features of the reactor near N_L (1% full power). In order that the reactor may be put into the RUN mode, the log-N recorder readout must indicate above 0.6 N_L. If the log-N chamber position is too far from the core (relative to the servo chamber), the lower end of the servo range (1.1 N_L) will be attained before the log N reads 0.6 N_L. In this case, the servo will control at this level and the RUN mode cannot be established by normal procedures, since the servo demand can be increased only after the RUN mode is established. This requires the operator to turn off the servo, raise power manually, push the "run" button, raise the demand and then return to servo operation. On the other hand, if the log-N reads greater than 1.8 N_L before the RUN mode has been established, a reverse is initiated; thus the log-N chamber must not be too close to the reactor. If the servo chamber is presumed to be properly positioned (as it usually is from the previous run), then the log-N chambers should be positioned so that the recorder readout is 1.1 N_L when the servo is controlling at its lower demand limit. This should be done with the reactor operating in servo and with the log-N period circuits disabled, if this appears to be necessary to prevent scrams and control actions. (Since two log-N channels are in the circuitry, it is easy to position the "non-selected" chamber without removing control functions of the "selected" log-N channel.)

If, after reaching full power, it should become evident that the servo chamber should be moved, as in the paragraph above, the log-N chamber should be moved to give the same current ratio change. Due to nonlinearities in the log-N channel, the log-N recorder readout will not in general read 100% at full power, even though it may read 1% at 1% power.

The discussion above is for routine chamber relocation. Unless gross changes in loading or operation of the reactor occur, such repositioning should seldom be required. There is a "shading" effect between nearby chambers which may have to be considered during the above operations. If possible, an adjacent chamber should not be used as a power reference during movement of a second chamber.

2.6.2. Dual Log-N System

To minimize reactor down time due to instrument failure in the log-N channel, a second log-N channel is on standby and may be placed in service when needed.

This design is intended to provide two complete log-N channels from the chamber to the output of the period amplifier. Each channel is independent except for the switching mechanism which permits the use of either, but not both, channels at any time. The selection of a channel as the operating channel with the "SB" switch will: (a) connect all reactor control functions associated with the log-N and log-N period to the recorder switches of the operating channel only; (b) connect the input of the period sigma amplifier to the output of the period amplifier of the operating channel; (c) connect the safety-trouble monitor circuits associated with the period sigma amplifier to only the operating channel; (d) actuate pilot lights at the recorders (log-N and period) and log-N amplifiers to indicate the "operating" channel; and (e) completely remove the remaining channel from reactor controls thereby permitting maintenance, calibration, etc., without endangering the operation of the reactor.

To effectively utilize this dual system, certain steps must be followed; they are listed below.

1. Prior to startup

   a. Check to ensure that with the "SB" switch in position No. 1, the channel designated as No. 1 will be the "selected" channel; this will be indicated by:

      (1) Pilot lights, located in the center of the right side of both the log-N and the period recorder doors, will be energized. (These recorders are located on the graphic panel.)

(2) Pilot light, located between the log-N amplifier and period amplifier cabinet A, will be energized.

b. With the "SB" switch in position No. 2, channel No. 2 will be selected and will be indicated by:

(1) Pilot lights, located in the center of the right side of both the log-N and period recorder doors, will be energized. (These recorders are located on the graphic panel.)

(2) The pilot light, located between the log-N amplifier and the period amplifier in amplifier cabinet C, will be energized.

c. Both channels should be calibrated and ready for service.

d. One of the two channels should be selected for use. The channel to be used will normally be alternated from one cycle to the next.

e. The circuit is designed to "make, before break" which ensures that one channel will always be selected regardless of the SB switch position. As the SB switch is moved from one position to the other (e.g., channel No. 1 at midposition to channel No. 2), the panel lights associated with the channel No. 1 will be de-energized. Channel No. 1 will, however, remain the selected channel until position No. 2 is actuated, thereby energizing the complete channel including the panel lights associated with the circuit and de-energizing No. 1 channel from the reactor controls.

2. <u>During operation</u>

a. The channel <u>not selected</u> is available for calibration, maintenance, etc.

b. If the selected channel should become defective during operation, regardless of its effect on reactor power:
   (1) calibrate the "not selected" channel and ensure that it is operating properly before it is selected;
   (2) using the SB switch, select the channel which is operable; and
   (3) the defective channel will then be available for repair.

2.6.3. Servo Limit Switch Assembly

The servo system for the ORR has been designed to use any shim rod as the servo-controlled rod. Because the reactivity of each rod is approximately 8%, a device is needed which limits the amount of reactivity controlled by the servo to a value of approximately 0.5% maximum, while allowing the servo controlled rod to operate at any point in its travel. This device, the servo limit switch assembly, consists of a set of limit switches, an actuating cam, a mechanical differential and associated drive motors, indicators, etc. The control circuits for moving the actuating cam and those circuits involving the limit switch contacts are constructed so as to limit the amount of positive reactivity which can normally be added to the reactor by the servo. This is done without limiting the amount of negative reactivity available to the servo, and without reducing the rod worth available for shimming and safety. A block diagram of the system is shown in Fig. 2.6.

The operation of the servo limit switch assembly is as follows. The fine position selsyn transmitter, TX-2, rotates one revolution per inch of travel of the shim rod. The output of this transmitter is fed into a control transformer, CT-1, which is made to reproduce the position of TX-2 by means of a modified Brown amplifier and the motor M-2. TX-3 is a selsyn transmitter used to retransmit fine position information if needed. It is not used in the ORR, but could be used if TX-2 were too small to drive both RX-2 and CT-1. The position of the shaft of M-2, and hence the position of the shim rod drive, is fed into a mechanical differential. If M-3 is not rotated, the output shaft of the differential

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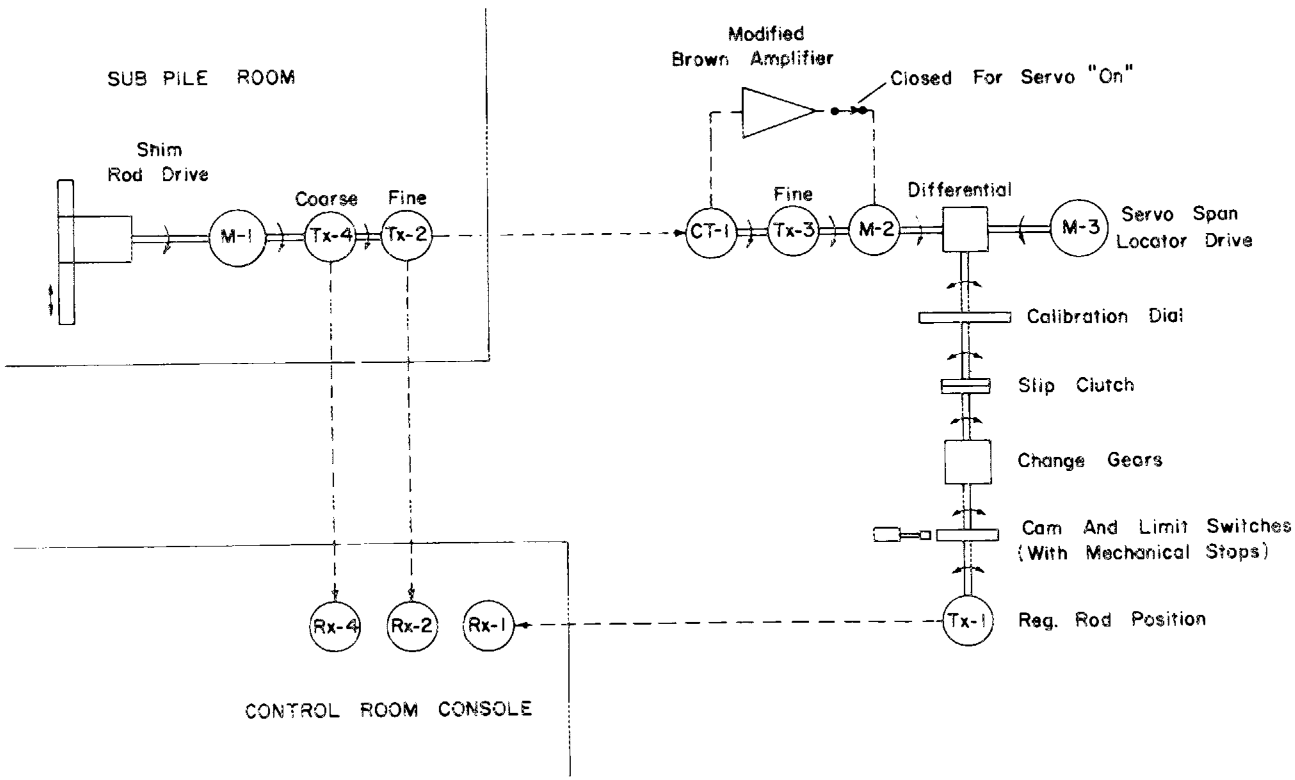


Fig. 2.6. Block diagram-servo limit switches.

rotates through an angle which is half that of the angular rotation of M-2. Thus one inch of rod motion is reproduced as one-half revolution of the output shaft of the differential. The calibration dial has 200 divisions and so reads motion of the rod in hundredths of an inch. If M-2 is stationary, rotation of M-3 also moves the output shaft of the differential. The output shaft then is a measure of the difference between the rotation of M-2 (rod position) and M-3. We call M-3 the "servo span locator drive" since its function is to fix the location of the portion of the shim rod travel which is to be used for servo control. Its motion is subject to all shim rod interlocks.

The output shaft drives, through a slip clutch and two changeable spur gears, a limit switch actuating cam with mechanical stops at each end. The switches are spaced over a 180° arc and are successively actuated and maintained in the actuated position as the cam rotates over the allowed 180°. The arrangement of the circuits is such that M-3 and the shim rod drive motor are prevented from driving the cam into the mechanical stops in either direction. The amount of motion of the shim rod required to drive the cam 180° is determined by the change gears. The choice of gears is made on the basis of rod worth in $\Delta k/k$ per inch near the center of the shim rod motion so that over the span something like 0.5% $\Delta k/k$ is turned over to the servo. If the servo-controlled rod reaches either end of the span, it is necessary, in order to move the regulating rod farther, to energize M-3 which moves at a speed which is equivalent (in terms of rotation of the cam) slightly less than normal shim speed. To move M-3 in a direction to allow the servo-controlled rod to withdraw (effectively "withdraw the limit switches") the operator must manually operate the "withdraw" switch for the servo controlled shim rod. This operation is automatic in two special cases during start. To allow the servo controlled rod to insert ("insert limit switches") the operator must actuate the "insert" switch for the servo-controlled rod. This is done automatically by certain "reverse" signals in the reactor control system.

TX-1 is a selsyn transmitter which rotates 270% for 180° rotation of the limit switch actuating cam, thus its shaft position is an indication of the relative position of M-2 and M-3 and, therefore, the position of the regulating rod in its available span. Withdrawal of the shim rod moves the selsyn indicator towards its upper limit while "insertion of the limit switches" (actually manipulation of the shim rod insert switch or automatic operation of the shim rod insert relay) moves the indicator in the same direction, provided the servo controlled rod is not moved.

In the ORR, No. 6 shim rod is presently used as the servo-controlled rod and the detailed operation of the system is as follows.

1. Servo operation of the reactor
   a. Motion of the No. 6 rod is coupled to one input of the mechanical differential through the fine position transmitter, a control transformer, and a torque amplifier.
   b. Number 6 rod moves only in response to a signal from the reactor power level servo.
   c. The servo span locator drive motor (M-3) is coupled to the other input of the differential and operates on manual and automatic shim rod operate signals, except that the "Insert 5 rods" signal does not operate the motor.
   d. The output of the differential drives the limit switch actuating cam and selsyn transmitter, TX-1, through a changeable gear ratio which is used to set the span of servo controlled operation of No. 6 rod. This cam has mechanical stops and a slip clutch. The limit switches which are encountered as the regulating rod is inserted are in the following order:
      (1) withdraw limit (contacts closed in withdraw limit only);
      (2) middle limit (contacts closed as rod is inserted until the middle limit switch is reached, then it opens and remains open for remainder of stroke);
      (3) preferred limit (contacts close upon reaching this limit and remain closed); and
      (4) insert 5 rods (reverse) limit (closed at this limit only).

e. The limit switches perform the following function as the servo controlled rod progresses from the withdraw to the reverse limit.

(1) With the actuator in the withdraw limit (servo-controlled rod at upper end of its servo span)

(a) Number 6 rod cannot be withdrawn any farther.

(b) The servo span locator drive motor cannot be energized to move the limit switch actuating cam farther into the withdraw limit.

(c) An annunciator sounds, indicating that No. 6 rod has been withdrawn, by the servo, to this limit and cannot add more reactivity. The operator must then manually add more reactivity by pulling another shim or by operating M-3 (using shim rod No. 6 manual controls). Operating M-3 moves the actuating cam out of the withdraw limit which then allows the servo error to move the regulating rod out to add the required reactivity to satisfy the servo demand. This is done at approximately 85% shim speed and under shim rod interlocks. (In case the operator is manually raising power demand, the annunciator is not operated and the "preferred" shim rod is withdrawn until the limit switch actuator leaves the "withdraw" limit.)

(2) With the actuating cam at or below the preferred limit

(a) If any rod but No. 6 is the "preferred" rod, this preferred rod is inserted until a servo withdraw error causes No. 6 rod to move the actuating cam to a point above the middle limit.

(b) If No. 6 rod is "preferred," the servo span locator drive motor turns in a direction to move the limit switch actuator out of the preferred limit and continues to run until the actuator gets above the middle limit. (During this time, No. 6 rod and the actuating cam may be moving in response to servo errors.)

(3) With the actuating cam at the "reverse" or "insert 5 rods" limit

(a) Number 6 rod cannot be inserted.

(b) All rods except No. 6 insert until the servo causes rod No. 6 to move the actuator away from the reverse limit.

(c) An annunciator indicates the condition.

(4) The middle limit switch is used to effect the seal on the "preferred insert" action (see 2 above) and to forewarn the operator that the servo rod is approaching the "preferred" limit switch.

2. <u>Manual operation</u>

a. The servo limit switches and the cam operating motors M-2 and M-3 are rendered inoperative.

b. Number 6 shim rod operates just as do all other shims.

3. <u>Instrument start</u>

An "instrument start request" energizes the servo span locator drive until the limit switch actuating cam engages the "withdraw" limit switches, after which the instrument start can proceed.

2.6.4. <u>Gamma Chambers</u>

Two sealed ionization chambers, sensitive only to gamma radiation, are installed in slant tubes on the northwest and southwest sides of the reactor. The purpose of these chambers, which are less sensitive to environment changes caused by beam-hole operation than the other ionization chambers because of location, is to provide additionnal protection when beam holes are drained or filled with water. The chamber center line is about 3 in. above the core center line. The signal and supply cables are routed through penetration JB-B84, south, for the No. 1 gamma chamber and through JB-B67, north, for the No. 2 gamma. The signal cables are routed through the preamplifier chase and thence to the control room.

Two gamma composites (RC2-10-14) are located in the top left side of amplifier cabinet "A" with the No. 1 on top. These composites contain the 300-V power supply for the chambers and a monitoring circuit for: (1) signal-cable-braid breakage, (2) loss of high voltage at the chamber, and (3) decrease of high voltage to <170 V. These monitors actuate the appropriate annunciators, gamma No. 1 at AN-7 and gamma No. 2 at AN-8. The composites contain a ten-position sensitivity switch which gives a 1.4% per step control of the signal output. The switch permits the operator to keep the gamma readout at 1.00 N_F (100) throughout the cycle in a manner similar to the level safeties. In addition to the ten-position sensitivity switch, the composites contain a toggle switch which allows large (>14%) sensitivity changes to compensate for shading effect of large experiments that can be, during full-power reactor operation, inserted into or withdrawn from the reactor vessel pool window as follows: Toggle switch "up" - experiment inserted into the pool window position thereby shading the gamma chamber (sensitivity of the composites increased in this position). The "up" position of the toggle switch is selected after the experiment is inserted to the pool window which returns the composite readout to the full-power value. Toggle switch "down" - experiment withdrawn from the pool window position thereby removing the shading of the gamma chambers (sensitivity of the composites decreased in this position). The down position of the toggle switch must be selected before retraction of the experiment which reduces the readout. As the experiment is retracted, the composite readout returns to the full-power value. A recessed "scram test" button is provided on each composite to produce an input signal to the recorder(s) which simulates the chamber output current at scram conditions. This button, when pushed, produces a signal which drives the recorder of that circuit to a level of $\geq$150% of nominal full power.

Two gamma recorders are located in vertical board No. 9. These recorders read similar to the level safeties 0 to 2.0 N_F and a scram (both makeup and dropout) at 1.45 N_F. The alarm actuates annunciators AN-7 and AN-8.

During full-power operation, the sensitivity switch should be adjusted so that the gamma recorders display a reading of about 100 (1.0 N_F).

2.6.5. Operation of E-Panel Switches

ORR experiments are connected to the reactor safety circuits through the E-panels. All the E-panels are provided with individual, keyed switches (Fig. 2.2). Only two keys are provided for each switch; one is locked in a safe and the other is locked in a key rack located in the ORR control room. The key rack, in turn, is provided with a lock which requires keys carried by shift or day supervision.

Sometimes it is desirable to remove an experiment from the safety circuit while the reactor is operating, providing the experiment has been properly neutralized. There is, however, a possibility that the wrong experiment may inadvertently be removed from the safety circuit. In order to minimize such an occurrence, the following procedure should be observed when removing an experiment from the safety circuit while the reactor is operating or during shutdown if the shutdown occurred for the purpose of neutralizing the experiment.

1. The supervisor informs the control-desk operator of the specific experiment to be removed from the safety circuit and requests that he observe the annunciator panel while the E-panel switch is turned to "disconnect."
2. The supervisor removes the experiment from the safety circuit by turning the E-panel switch to "disconnect."

3. The control desk operator announces to the supervisor which experiment annunciator alarm has sounded, indicating that it has been removed from the safety circuit.
4. The supervisor should check the experiment control panel and observe that the "experiment tie-in" annunciator is in the alarm condition, indicating that the experiment has been disconnected from the reactor safety circuit.

When an experiment is removed from the safety circuit, a notation should be made in the log book as to why the experiment was removed from the safety circuit giving the name of the supervisor who performed the above procedure.

Insofar as reactor safety is concerned, there is no difference between "test" and "disconnect." The "disconnect" position disconnects the experiment from the reactor safety circuit and opens the circuit from the "E-panel" to the experiment, thereby preventing the experimenter from performing any instrument checkouts in the safety tie-in system. The "test" position disconnects the experiment from the reactor safety circuit but allows continuity from the experiment to the "E-panel" which permits the experimenter to simulate any desired condition (scram, setback, or alarm) without affecting the reactor. The indiscriminate use of the two modes for disconnecting an experiment from the reactor safety system does not in any way jeopardize reactor safety. The advantage in adhering to the use of the "disconnect" position when an experiment is not in the reactor is better control of experiment instrument checkout. The "disconnect" position is used when an experiment facility is not in use; and "test" is used for experiment instrument checkout.

2.6.6. Fission Chamber

Each time after the reactor has been brought to full power, the fission chamber should be completely withdrawn. This will prolong the life of the chamber and its component parts. Normal operation is with the fission chamber withdrawn to the withdraw limit.

2.6.7. Instrument Warm-Up Time Following a Power Outage

Occasionally it is necessary to return the reactor to power as soon as possible following a power failure to avoid xenon poisoning. However, speed must never jeopardize safety in this phase or any phase of operation.

Following a power outage, all electrical instrumentation on affected circuits is temporarily dead. After the power is restored, there is a minimum warm-up period necessary to provide the reliability required. A review of the safety instrumentation indicates that a warm-up time of five (5) minutes is adequate to provide a reliable control system for startup. This warm-up time is the minimum to be observed for safety level channels, and all other channels will be reliable before this specified time.

The procedure to follow when recovering from a power outage regardless of its duration is to complete the "Checklist for the ORR restart following an unscheduled Shutdown," Section 1.4.6, Example 1.3.

2.6.8. Facility Flow Instrumentation

Instrumentation has been provided for the north and south facilities to provide an automatic reduction in reactor power should the flows drop to undesirable levels. Since present components at the south facility depend on a water-filled cavity for shielding, a monitron is installed in this vicinity which will sound a siren if radiation becomes excessive. This description is intended to give brief information on flow-switch identification and readout information.

1. North- and south-facility flows

   The facility flows (south-facility annulus FE-731A and FE-731B, south-facility 24-in. plug FE-751A and FE-751B, and north facility FE-302A and FE-302B) have alarms and setbacks in the control circuit as part of the process system.

Since each of these systems is "double-tracked," there are six contacts in the annunciator circuit in series with PX-39 (facility-pump discharge-pressure switch) which operate the "facility-cooling" as long as the servo demand is above N_L. The auxiliary reverse-request relay (AG-31) is also operated by low flow. The setpoints are as follows:

	Normal flow 110 gpm	
FS 731A1	80 gpm	Alarm
731A2	61 gpm	Setback
731A3	59 gpm	Reverse
731B1	80 gpm	Alarm
731B2	61 gpm	Setback
731B3	59 gpm	Reverse

	Normal flow 100 gpm	
FS 751A1	75 gpm	Alarm
751A2	51 gpm	Setback
751A3	49 gpm	Reverse
751B1	75 gpm	Alarm
751B2	51 gpm	Setback
751B3	49 gpm	Alarm

	Normal flow 140 gpm	
FS 302A1	100 gpm	Alarm
302A2	71 gpm	Setback
302A3	69 gpm	Reverse
302B1	100 gpm	Alarm
302B2	71 gpm	Setback
302B3	69 gpm	Reverse

The ΔP transmitters for the south facility (FE-731 and FE-751) are located at the south-facility transmitter rack on the south side of the basement.

All switches and the north-facility transmitters for FE-302 are located in the north-facility transmitter rack in the basement just north of the door to the subpile room.

The recorders for the south facility are in the old south-facility switch panel in the basement on the north side of the pool structure. The red pen of each recorder is on FE-731 (annulus flow, 150 gpm FS). The green pen of each recorder is on FE-751 (24-in.-plug flow, 100 gpm FS).

The north-facility flow is not recorded at the present time but is indicated in the north-facility transmitter rack on the two 2-in. receiver gauges in the lower right-hand corner of the rack. To convert readings on all of the receiver gauges in the rack flow, use the following conversions:

FE-731	Flow 15 $\sqrt{\text{\% of full-scale reading}}$	gpm
FE-751	Flow 10 $\sqrt{\text{\% of full-scale reading}}$	gpm
FE-302	Flow 20 $\sqrt{\text{\% of full-scale reading}}$	gpm

The total facility flow has a readout in the control room; however, the total flow can also be determined from the receiver gauge located in the south facility transmitter rack by the following conversion:

FE-10	Flow 50 $\sqrt{\text{\% of full-scale reading}}$	gpm

The contacts for all flow switches are summed up in the basement switch panel and brought up to terminal strip FF1 (just under CP-18) in terminal box "A" in the control room.

2. <u>GCR loop no. 2 (cold finger), 18-in. plug flow</u>

The 18-in. plug of GCR loop No. 2 can cause a reactor alarm on high radiation and on low flow. The radiation detector is a monitron with the chamber portable to provide positioning at the desired location. This unit will actuate a local siren if the radiation level becomes excessive. A reactor alarm also occurs on the cold finger low flow of 2.5 gpm. The signals on plug flow (cold finger) enter the control circuit through the "E" switch labeled "south-facility 18-in. plug."

2.6.9. Low-Level Scrams

The reactor control circuitry is designed to provide additional safety protection when it is intended that the reactor be operated without the normal full water flow. Such "low-level" protection is effected by increasing the sensitivity of the No. 3 safety channel by a factor of approximately 45 when the "raise-test" switch is placed in the TEST position. (The sensitivity of the Nos. 1 and 2 safety channels is also increased by a factor of approximately 45 for operation with the primary-water flow rate $\leq$12,000 gpm and the reactor ΔP corresponding to a main flow of $\leq$12,000 gpm, respectively.)

In TEST, the primary-water flow rate and ΔP scram-circuit relays are bypassed; however, under this condition, protection is effected in the following sequence: (a) when in servo control, the maximum power is limited by a setback at a 60% reading on the power-level safety recorders (this is equivalent to approximately 400 kW); (b) a reverse will be effected when a reading of 1.8 N_L on the log-N recorder is reached (this is equivalent to approximately 540 kW); (c) a reverse will be effected at a reading of approximately 120% on any one of the three safety recorders (this is equivalent to approximately 800 kW); and (d) a "fast scram" will be effected at a reading of approximately 140% on any one of the three safety recorders (this is equivalent to approximately 1000 kW).

Standard operating procedure for utilizing the protection offered by these circuits shall be as follows.

1. Prior to beginning a critical run or low-power run (when normal water flow conditions have not been established):
   a. place the "raise-test" switch in the TEST position; and
   b. observe that the No. 3 microammeter, which is mounted on the ORR console just above the key switch, is reading upscale. This indicates that the "low-level" scram is in effect.
2. After completing all critical or low power runs, the "raise-test" switch should be returned to "normal" position.

It is important to note that if the reactor is operating at power greater than approximately 450 kW, either with or without water flow, a scram will occur if the "raise-test" switch is turned to the TEST position.

2.6.10. Dual Count-Rate Channels

Reference: Reactor Controls Change Memorandum No. ORR 63

There are two permanent count-rate channels in the control and safeguard system. Dual channels enhance continuity of operation since only one channel is required for startup operation. The components of both count-rate channels and their locations are presented in Table 2.1.

A selector switch (S23) has been provided so that either channel No. 1, channel No. 2, or both may be connected to the reactor control and safeguard system. The setpoints for interlocks are the same for each channel; however, when both channels are selected, an interlock on either channel will initiate safeguard action. The normal method of operation is with only one channel selected (i.e., not both). Neon indicator lamps are located on the doors of the log-count-rate and count-rate-period recorders. If either No. 1 or No. 2 channel is selected (i.e., the selector switch is not on the "both" position), the indicator lights for the selected channel are turned on.

The function of the poolside system for audible indication of counting rate is identical for each channel. The audio scaler is located in the left section of amplifier cabinet "E"; the audio amplifier is located in the right section of amplifier cabinet "E." When the audible system is turned on, the position of the toggle switch (on the audio scaler) should be checked to ensure that a reliable channel is connected to the audible system. The preferred method of operation is that the position of the toggle switch be changed to correspond with changes in position of the channel selector switch.

Table 2.1. Dual count-rate channels

Item	Channel No. 1	Channel No. 2
Location of components		
Fission chamber	Vertical guide tube (northernmost of two outside NW corner of reactor tank)	Vertical guide tube (southernmost of two outside NW corner of reactor tank)
Preamplifier	In guide tube	In guide tube
Power supply	Amplifier cabinet "E" (right section)	Amplifier cabinet "E" (second section from right)
A-1 amplifier	Amplifier cabinet "E" (right section)	Amplifier cabinet "E" (second section from right)
Count-rate recorder	Vertical board No. 8	Vertical board No. 8
Count-rate-period recorder	Vertical board No. 9	Vertical board No. 9
Chamber-position controls and selsyn	Console panel "D"	Console panel "C"

NOTE: Amplifier cabinet "E" is located in the control-room annex.

In order to prevent excessive burnup of the fission chamber in a channel not selected, an annunciator will remain in the alarm condition until the fission chamber for that channel is fully withdrawn. The preferred method of operation is that the channel not selected be in the automatic mode. If the channel not selected is unreliable, it should be fully withdrawn prior to startup.

2.6.11. Routine Adjustments to the Reactor Power Transmitter

A reactor-power-indicating system has been installed to provide a readout of reactor power at the experiments. This is an information channel only, and it measures the reactor power from the input signal to the Doelcam preamplifier of the servo amplifier. Periodic adjustments will be necessary to ensure agreement with the reactor heat power.

To maintain correlation between this readout and the reactor heat power, routine adjustments, if needed, will be made as listed below.

1. At 12:30 A.M. each day, the heat balance of the reactor should be verified as 30 MW (+0-1%).
2. The "adjust" potentiometer, located on the power transmitter in amplifier cabinet "C," should then be adjusted so that it reads 30 MW.
3. If adjustments on this power-display system are necessary at other times, an announcement should be made over the public-address system to inform the experimenters; otherwise, they would assume that a change in reactor power had been made.

2.6.12. Limits of Variations in Magnet Currents

Although much effort has been expended to provide "drift-free" characteristics in the ORR magnet-amplifier magnet circuits, occasional small variations are likely to occur.

It is important that the magnet currents be checked daily and that the variations be controlled within a certain range. Operational inconveniences can occur resulting from unscheduled shutdowns if the magnet current is allowed to decrease to the magnet drop point; and, conversely, if the current is allowed to increase, the electronic high level scram point will also increase. Normally, the current-power relationship is adjusted to provide an electronic high-level scram at approximately 145% of normal power.

To permit some degree of flexibility and remain within operational and safety bounds, an analysis has been made on the performance data of the magnets and magnet amplifiers. The results indicate that a variation of ± 5 mA from the beginning-of-cycle posted value can be tolerated, and the high-level scram point will vary accordingly from 1.4 to 1.5 N_F (see Fig. 2.7). Based on performance data, should the current decrease to the −5 mA point a maximum decrease in holding force of approximately 2% will occur. Under this condition, the weakest magnet still provides an excess holding force of 60%.

Should the occasion arise when the magnet current falls outside the bounds (± 5 mA of the posted value for the beginning of the cycle), contact the Reactor Supervisor or his designated representative who, with the I&C engineer, will make an evaluation.

2.6.13. Fission-Chamber Channel - Pulse-Height Setting (PHS)

The fission-chamber channel consisting of a fission chamber, a preamplifier, a linear amplifier, a logarithmic count-rate meter, a scaler, and a recorder is the one channel used to monitor subcritical neutron multiplication from source level to 10^{-4} percent of full power at the ORR. Because a reliable channel is a prerequisite for startup operation, two channels have been provided (see Section 2.6.10).

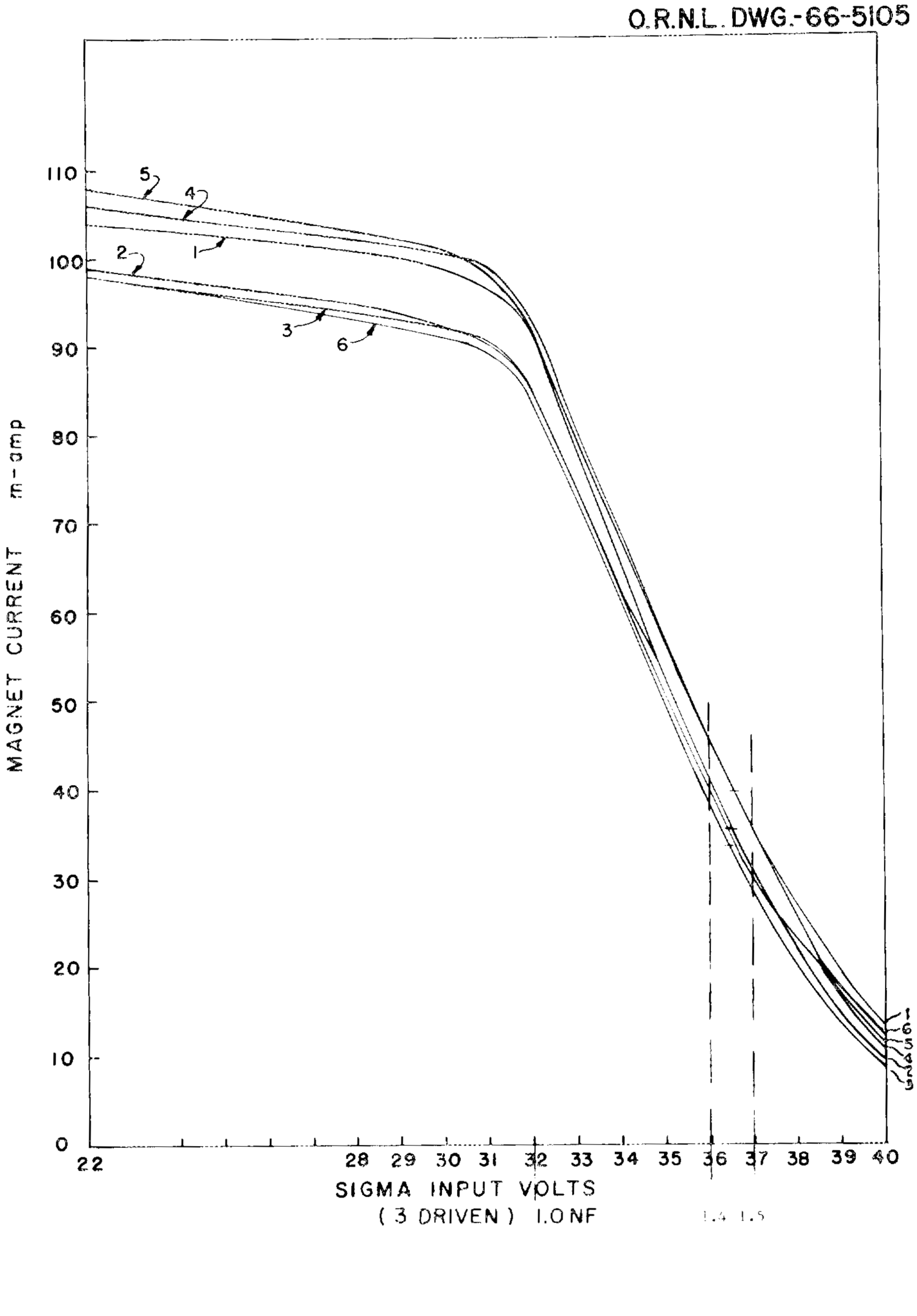


Fig. 2.7. Magnet current relationship to voltage input to sigma amplifier.

Two specific tests are performed to ensure that the channel(s) are reliable.

1. Prior to every reactor startup:
   a. The fission chamber is withdrawn and inserted to check the response. The readout of the channel should respond accordingly; i.e., for movement to a lower neutron flux level, the recorder readout should be reduced.
   b. The logarithmic count-rate meter is checked by introducing a 60 counts/second input to the unit. This is performed by switching the "cal-use" switch to the "cal" position and adjusting the "adj" 60-counts/second knob to obtain a reading of 60 counts/second on the recorder.
2. The discrimination point for the pulse height is determined prior to the beginning of each operating cycle in order to eliminate the contribution of the alpha pulses which is always present due to the uranium coating inside the chamber. This pulse-height setting is determined to ensure that the response of the channel is due to neutrons.

2.6.14. <u>Component Replacement in the Reactor Control System</u>

1. <u>Procedure for replacing a magnet amplifier while the reactor is operating</u>
   a. Removal
      (1) Turn the "normal-exchange" switch on the rear of the chassis to EXCHANGE on the amplifier still operating.
      (2) By means of the "current adjust" potentiometer on the front panel, adjust the current to read full scale.
      (3) Remove all cables from the defective amplifier, being careful not to allow the magnet leads to become grounded.
      <u>CAUTION</u>: B+ and magnet return leads will be approximately 300 V above ground.
      (4) Remove the defective amplifier from the panel rack.

b. Installation

(1) Install the replacement unit.

(2) Reconnect the amplifier and magnet power ac leads.

(3) Place a shorting jumper between the magnet B+ and magnet connectors.

(4) Set the "current adjust" for 50 mA.

(5) Allow 30-min warmup time.

c. Adjusting new amplifier

(1) Attach the variable-voltage box to the sigma-bus input connector.

(2) Set the voltage box to read 38.5 and adjust the magnet current to read one-half of the posted operating current.

(3) Increase the voltage box reading to 43.5 V and observe that the magnet current decreases to less than one-half of the posted drop current.

(4) Remove the shorting jumper and the voltage box and reconnect all remaining cables. Readjust the current to one-half of the operating current; return the "normal-exchange" switch on the other amplifier to NORMAL and balance the current on both amplifiers to the posted operating current.

2. Procedure for replacing safety preamplifier while the reactor is operating

a. Removal

(1) Remove the sigma-bus lead from the sigma amplifier associated with the faulty preamplifier.

(2) Turn off the corresponding safety recorder and manually crank the recorder pen below a scale reading of 50. This removes the channel from all control functions.

(3) Disconnect all cables from the preamplifier and remove preamplifier.

b. Installation

(1) Install the spare preamplifier and reconnect all cables with the exception of the chamber signal lead.

(2) Allow 30-min warmup time.

(3) Adjust the preamplifier grid-offset potentiometer on the sigma amplifier until the meter reads zero.

(4) Depress the "Jordon button" and observe that the meter reads full scale or above.

(5) Reconnect the chamber signal lead to the preamplifier.

(6) The meter should now be reading approximately 1.00 (with the reactor at full power).

(7) The sigma-bus lead may now be reconnected to the sigma amplifier and the recorder turned on.

3. <u>Procedure for replacing safety sigma amplifier while the reactor is operating</u>

a. Removal

(1) Turn off the safety recorder associated with the faulty channel and manually crank the recorder pen below a scale reading of 50.

(2) Disconnect the faulty sigma amplifier from the sigma bus. This removes the sigma amplifier from the safety system, and all other connecting cables may then be removed from the chassis.

(3) Remove the sigma-amplifier chassis from the panel rack.

b. Installation

(1) Install the replacement unit.

(2) Reconnect all cables with the exception of the sigma-bus cable.

(3) Leave the recorder OFF.

(4) Allow a minimum of 30-min warmup time.

c. Calibration and adjustments

(1) Replace the preamplifier input to the safety sigma amplifier with a voltage source variable between 22 and 37 V.

(2) Set the voltage box to 22 V and adjust the "zero" potentiometer until the meter reads zero (on POWER position).

(3) Set the voltage box on 32 V and adjust the "high cal" potentiometer until the meter reads 1.00.

(4) Repeat steps 2 and 3 until no further adjustment is necessary. Set the voltage box on 37.0 V.

(5) The meter should read 150 $\pm$ 2.

(6) Disconnect the voltage box and reconnect the preamplifier.

(7) Disconnect the chamber signal lead from the preamplifier.

(8) The meter should read zero. If not, adjust the "preamplifier grid offset" until the meter does read zero.

(9) Reconnect the chamber signal lead to the preamplifier.

(10) Depress the "Jordon button." The meter should read off scale. Release the "Jordon button."

(11) If proper response is not obtained, determine and correct the trouble. (If trouble is encountered, the entire test procedure must be repeated.)

(12) If all tests were normal, the meter will now be reading 1.00 (with the reactor at full power). The recorder may now be placed back in service and the sigma-bus lead reconnected to the bus.

4. <u>Procedure for replacing safety chamber while the reactor is operating</u>

a. Removal

(1) Remove the sigma-bus lead from the sigma amplifier associated with the faulty chamber.

(2) Remove wire No. L-1 from the terminal board on the back of the associated safety recorder.

(3) L-1 is control power and must be worked hot. Tape the exposed lead while it is loose.

(4) Remove the defective chamber's signal and high-voltage leads from the preamplifier junction box.

(5) Since the removal of the chamber will have interaction on the installed chambers, the chamber should be retracted slowly and under the direct surveillance of the shift supervisor. Since the chamber will be radioactive, it must not be removed from the water without a radiation survey.

b. Installation

(1) Installation of the replacement chamber must be directly supervised by the shift supervisor since the chamber will have some interaction on the other installed chambers.

(2) Attach the replacement chamber cables.

(3) Position the sensitivity switch on the sigma amplifier for a reading of 100 on the recorder.

(4) Operate in this manner for a period of at least 24 hours.

(5) If the channel operated satisfactorily during the test period, reconnect the sigma-bus lead to the sigma amplifier and reconnect wire No. L-1 to the recorder terminal board.

NOTE: If the defective chamber is adjacent to the servo micro-microamplifier chamber, the reactor should be placed in manual control while moving chambers, and the operator should be cautioned to be especially alert during this operation.

5. Procedure for replacing period sigma amplifier while the reactor is operating

a. Removal

(1) Disconnect the faulty period sigma amplifier from the sigma bus. This removes the sigma amplifier from the safety system, and all other connecting cables may then be removed from the chassis.

(2) Remove the chassis from the panel rack.

b. Installation

(1) Install the replacement unit.

(2) Reconnect all cables with the exception of the sigma-bus cable.

(3) Allow a minimum of 30-min warmup time.

c. Calibration and adjustments

(1) Replace the period amplifier input to the period sigma with a variable voltage source.

(2) Set the input to 22 V and adjust the "zero" potentiometer until the meter (in POWER position) reads 0.0.

(3) Set the input to 32 V and adjust the "high cal" potentiometer until the meter reads 100.0.

(4) Repeat steps 2 and 3 until no further adjustment is necessary.

(5) Set the input to 37 V. The meter should read 150 $\pm$ 2.

d. Operational tests

(1) Turn off the "in-use" log-N level and period recorders.

(2) Place the "in-use" log-N in GROUND SET.

(3) Connect a voltmeter to the sigma-bus output of the period sigma amplifier.

(4) With the log-N period at ∞, the panel meter should read 0.0. (If not, check dc level of the period amplifier.)

(5) Depress the "period test" pushbutton on the log-N amplifier. The sigma-bus output should read >43 V.

(6) Return the log-N to OPERATE and verify that the period and level meters correspond with previous recorder readings.

(7) Turn on the "in-use" log-N level and period recorders.

(8) The sigma-bus lead may now be reconnected to the period sigma amplifier.

2.6.15. ORR Shim-Safety Rod Response Time Measuring System

1. Introduction

The time required for the ORR safety system to complete safety action in response to either short-period or high-level scram demands must not exceed an established maximum. To demonstrate an acceptable time response for each of the shim-safety rods and their actuating system, it is necessary to make routine measurements. The new rod-drop test system described herein is used at the ORR for making such measurements.

2. General description

Each test consists of scramming a shim-safety rod from its fully withdrawn position and measuring time intervals between the initiation of a simulated scram signal at the input of one safety channel and the seating of the rod. Three significant intervals are measured for the following sequential action. First, the time for the safety system instrumentation to respond to a scram request and reduce the magnet current to a value insufficient to hold the armature; second, the time for the push rod, which releases the ball-latch mechanism, to complete its stroke; and third, the time of flight of the rod to its fully-inserted position. The first of these two intervals provides a means for monitoring the response time of the safety system, while the third represents the overall shutdown action including detection of incipient failure due to rod misalignment or friction.

Other features of the system are that it is permanently installed and connected to the instrumentation channels and rod-actuated switches, it does not compromise the independence or performance of the safety channels, and it is designed to be used by the reactor operating personnel for routine prestartup checks as well as by maintenance personnel for trouble shooting.

3. Detailed description

Physically, the test system consists of three interval timers, six independent isolator and pulse-shaping networks (one per shim-safety rod) for extracting information from the decay of the self-induced potential generated when the magnet holding current is cut off; a control panel containing the necessary dc supplies, channel selector switches, and additional pulse-shaping networks; and a means for testing the system. A "response" switch is installed in each rod-drive actuator to indicate time of travel of the mass accelerated to effect rod release. A rod-drop-test pushbutton and isolating network were installed in each of the three level-safety sigma amplifiers to complete the system. The general arrangement of the system is shown in Fig. 2.8.

After a particular rod has been fully withdrawn, its test is initiated by operating the rod-drop-test pushbutton on the selected sigma amplifier. This introduces a simulated scram signal, as shown in Fig. 2.9, which follows the normal neutron flux signal path through the safety instrumentation and cuts off the magnet current as indicated in Fig. 2.10. The scram-signal rise simultaneously starts the three interval timers through an RC derivation network.

The magnet-release timer is stopped by a pulse generated from information received from the electro-magnet coil but related to armature movement. Figure 2.11 shows the potential across the magnet coil as a function of time after a scram signal, with the magnet armature (abnormally) held in place to prevent its release. When the magnet current is cut off, the potential rises to a peak established by a voltage limiter, then decays exponentially. Figure 2.12 shows the same potential with normal armature movement. The exponential decay is perturbed by the motion of the armature when it is pulled free of the magnet by the release spring, the magnet holding force having decayed

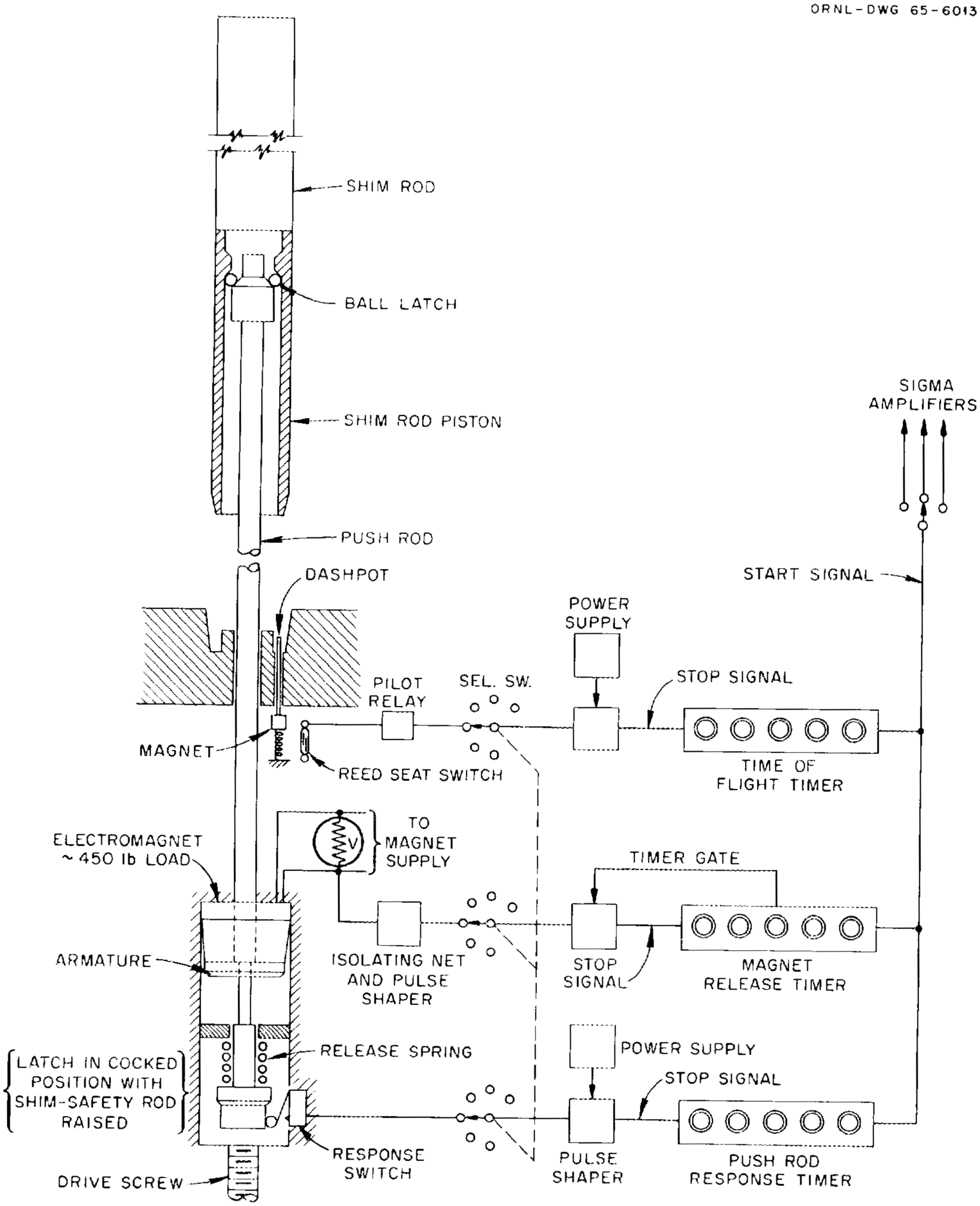


Fig. 2.8. ORR shim-rod-drop test system.

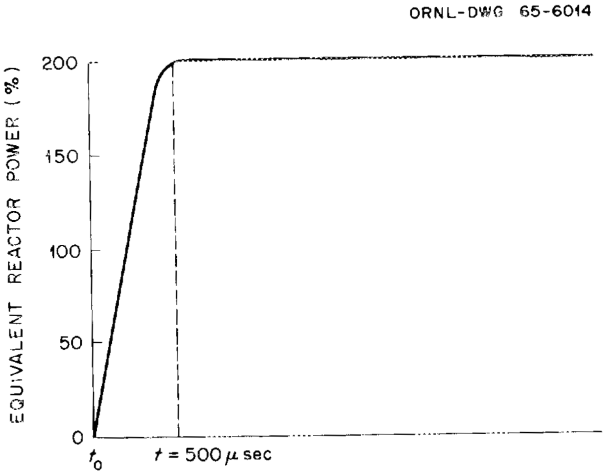


Fig. 2.9. Simulated scram signal.

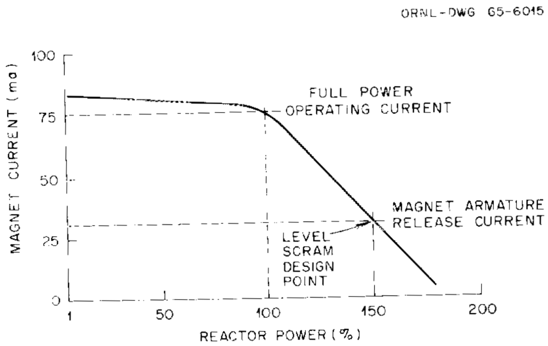


Fig. 2.10. Magnet current vs reactor power.

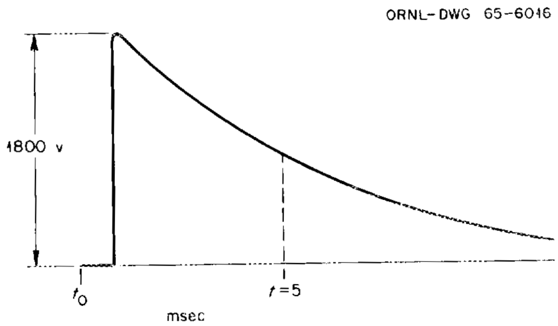


Fig. 2.11. Potential across magnet coil as a function of time after a scram signal with the magnet armature (abnormally) held in place to prevent its release.

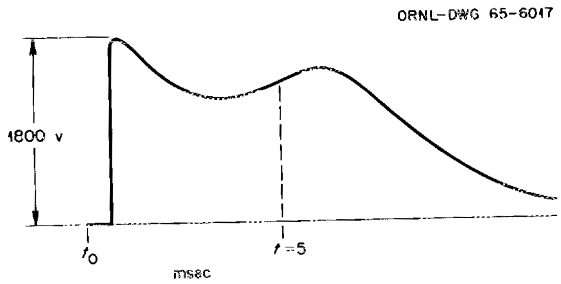


Fig. 2.12. Potential across magnet coil as a function of time after a scram signal with normal armature movement.

to its release value. A typical decay time of 5 milliseconds is shown. The shaping circuit of Fig. 2.13 is used to convert the variations in potential to the form shown. The first of the two pulses is blanked off by making use of a gate signal from the interval timer as shown in the circuit of Fig. 2.14. The remaining pulse, which gives a measure of magnet release time is differentiated to the form shown and becomes the stop signal for the timer.

The push-rod response timer is stopped by a pulse from the response switch which is actuated after the push rod has traveled approximately 0.4 in. of its 0.5-in. stroke. This information is of importance because it not only includes the electromechanical delays but it also provides a check on friction or other factors which could affect the latch action.

The time for the shim-safety rod to insert fully into the reactor (approximate 30-in. travel) is measured in a similar fashion using the seat switch to provide a stop signal for the time-of-flight timer. To prevent spurious noise spikes on the long switch leads from stopping the timers, the pulse-developing circuits are normally energized. Capacitor discharge upon the opening of the field contact produces an output pulse, shown in Fig. 2.15, that is typical for both the push-rod response and the time-of-flight stop signals.

The following tabulation gives times in milliseconds for the six rods:

Rod No.	1	2	3	4	5	6
Magnet release	4.6	4.7	4.5	4.6	4.8	4.4
Push-rod response	21	21	21	21	22	21
Time of flight	313	306	314	305	316	307

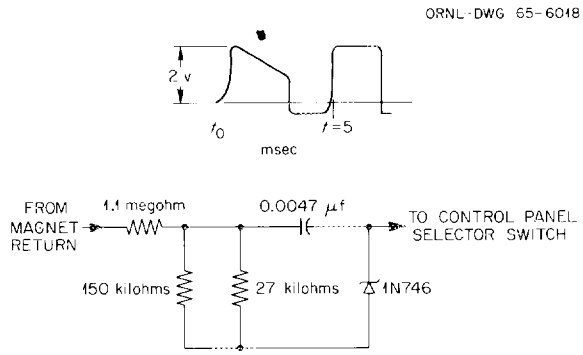


Fig. 2.13. Shaping circuits.

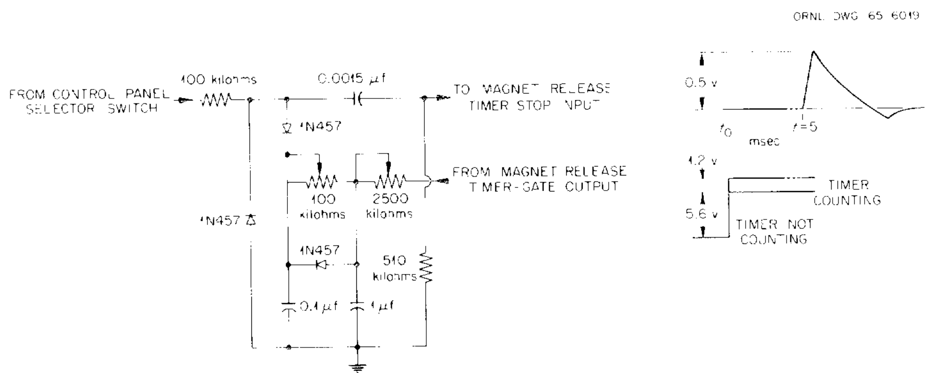


Fig. 2.14. Magnet-release time pulse differentiator and gated blanking circuit.

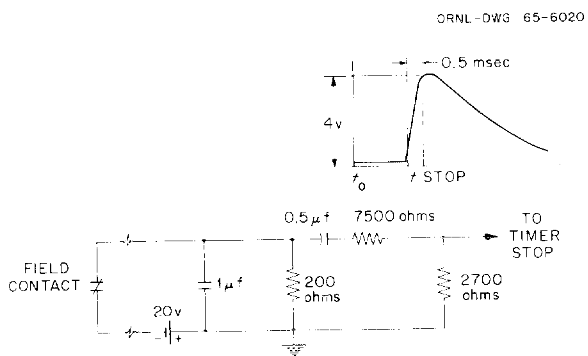


Fig. 2.15. Push-rod response and time-of-flight pulse-developing circuit.

The readout deviations are less than ±0.5 ms for magnet release measurements, ±1.0 ms for the push-rod release, and ±10 ms for the overall time of flight. It should be noted that the "time-of-flight" values are composed not only of the actual in-motion time of the rod but also include the time required to release, the deceleration time of the rod in the shock absorber, and the decay time of an electromechanical relay de-energized by the seat switch. Detailed measurements and tests made during the development of the ball latch and actuator system showed that motion of the shim-safety rod starts at 1.5 to 2 ms after start of the motion of the magnet armature. These tests also showed that the observed shim-safety rod time of flight at normal coolant flow is about 50 to 75 ms longer than it would be if the shock absorber did not slow the rod down during the final 6 in. of travel. Inasmuch as the delays are reproducible, it is not necessary to make provisions for more elaborate measurements in the reactor. Of course, any significant departure from the normal would require investigation to determine the reason for the departure.

2.6.16. Flux Noise Monitor

1. Function

The flux noise monitor system is an analytical diagnostic system provided for monitoring of the reactor flux for excessive fluctuations which could indicate fuel-channel boiling. This instrument channel has no control or alarm features.

The flux noise instruments are used routinely during any startup following refueling or following any other work which requires opening the reactor tank or any part of the reactor primary system. Nonroutine use should include such occasions as unusual flow conditions, shim-rod vibration, experiment movement or oscillation, and special tests. The supervisor in charge should obtain data from this channel at any time he suspects that unusual reactor flux noise is present or might occur.

2. Description

The system consists of an uncompensated ion chamber and appropriate power supply, a flux noise monitor circuit (RC2-10-28) to select a current to translate into a reactor power level, a variable sensitivity strip chart recorder for monitoring flux noise, and an alternate switch selectable ion chamber current monitoring channel with a picoammeter which drives a strip chart recorder for monitoring reactor full-power operation.

With the reactor at full power of 30 MW, the ion chamber current will be 30 microamps to the flux noise monitor unit. Design criteria required a full-scale recorder display signal of ±4% at any desired power level in three 3-MW steps.

3. Operating procedure

a. Begin with the noise monitor selector switch in the 3-MW position.

b. Make the following adjustment to the recorder.

(1) Turn power on.

(2) Turn chart speed switch to "1" position.

(3) Set pen heat control for a dark trace.

(4) Set attenuator to CAL position.

(5) Set pen to the middle of chart paper using position control.

(6) Depress CAL button; pen should move four divisions to the left. (Adjust gain if pen does not move four divisions to the left.)

(7) Set attenuator control to 1 mV/mm.

(8) Reset pen to the middle of chart using position control.

c. Pen should be in the center of the chart paper and the chart should be moving. The recorder is now ready for operation.

d. If the recorder signal level exceeds two major divisions on the chart, a careful analysis of all other nuclear instrumentation should be performed before increasing reactor power.

e. At completion of noise monitor use, perform the following:

   (1) Turn recorder power off.

   (2) Return selector switch to the $\mu\mu$A position.

   (3) Remove chart data and file with shutdown schedule.

3. FUELS* AND REFUELING

3.1. Introduction

There are four principal areas of concern regarding the storage and handling of fuel at the ORR. The first is the problem of maintaining the reactor itself within specified limits of excess reactivity. The second involves maintaining a place of storage outside of the reactor that is safe by both criticality and radiation standards. Third, fuel movements must be scheduled and effected to minimize personnel radiation exposure, as well as to retain criticality safety. Fourth, records must be maintained to indicate the location, amount, and condition of all fissionable material within the ORR area.

3.2. Fuel Units in Use at the ORR

3.2.1. Fuel Elements

The standard fuel elements used in the ORR are of the aluminum-clad-plate-type design (Figs. 3.1 and 3.2) and now contain a total of 285 g of ^{235}U when new. Each fuel element is made of 19 composite plates containing the ^{235}U fuel in the form of an aluminum-clad uranium-oxide (U_3O_8). The fuel-element end boxes were designed to minimize the pressure drop across the core.

The individual fuel plates are of a sandwich-type construction and are composed of a fuel-containing matrix completely clad with aluminum. The cladding is metallurgically bonded to the fuel matrix. The fuel-containing matrix is a mixture of uranium-oxide and aluminum containing approximately 30 wt% uranium-oxide with the remainder being aluminum.

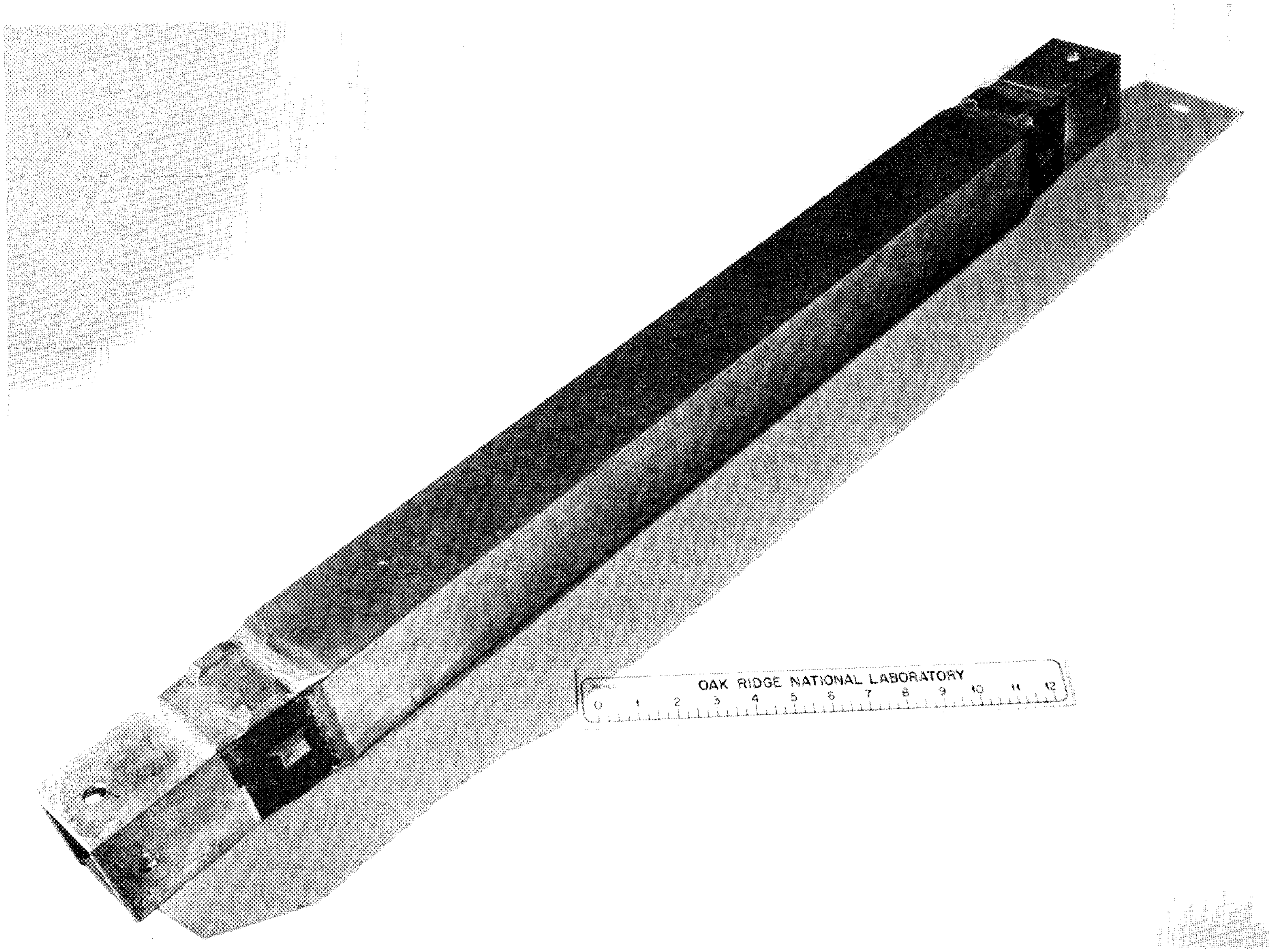


Fig. 3.1. Fuel element.

Fig. 3.2. End view of fuel element.

Uranium used in the matrix contains a minimum of 93 wt% ^{235}U, and the aluminum is of a high purity grade. Each of the 19 fuel plates contains approximately 15 g ± 4% of ^{235}U, and each fuel element contains a total of 285 g ± 2% of ^{235}U. Cladding of thickness 0.015 in. and a matrix thickness of 0.020 in. make up the total 0.050-in. thickness of the inner fuel plates of an element. The core has a width of 2.5 in., thus providing 0.15 in. of aluminum on each edge of the fuel plate, and the active length of a fuel plate is 23 5/8 in. The two outside fuel plates of an element are similar to the inner ones except that the cladding thickness is 0.0225 in., giving a total plate thickness of 0.065 in. Before assembling into elements, the 2.8-in.-wide plates are curved to a 5 1/2-in. radius. Characteristics of the fuel elements are given in Tables 3.1 and 3.2.

Table 3.1. Dimensions of a typical ORR fuel element

Unit	Nominal dimension[a]
Element assembly:	
Length	38 3/8
Width (through the side plates)	2.996
Width (centerline through outside fuel plates)	3.068
Plate spacing	0.104 (min)
Inside fuel plates:	
Thickness (overall)	0.050
Length (overall)	24 5/8
Clad thickness	0.015
Core thickness	0.020
Core length	23 5/8
Core width	2.5
Width (before bending)	2.8
Outside fuel plates:	
Thickness (overall)	0.065
Length (overall)	27 1/8
Clad thickness	0.0225
Core thickness	0.020
Core length	23 5/8
Core width	2.5
Width (before bending)	2.8
End box locating pads:	
Distance (through flat sides)	3.032-3.034
Distance (concave to convex side)	3.186-3.188
Miscellaneous:	
Effective fuel length	23.625
Effective volume	228.4 $in.^3$
Metal volume	89.59 $in.^3$
H_2O volume	138.8 $in.^3$
Heat transfer area	16.58 ft^2

[a]In inches unless otherwise indicated.

Table 3.2. Weights of a typical ORR fuel element

Description of components	Nominal weight (kg)	
Nineteen fuel plates:		3.30
Core (approximately 30 wt% uranium oxide, balance aluminum)	1.19	
Cladding (aluminum)		
Thirty-four 0.015-in.-thick sections	1.77	
Four 0.0225-in.-thick sections	0.34	
	3.30	
Two side plates (aluminum)		1.15
Two combs (aluminum)		0.01
		4.46

3.2.2. Shim Rods

Each shim rod consists of three main sections: the upper or cadmium poison section, the middle or follower section, and the lower or piston section.

1. Poison section

   The cadmium section consists of a 0.040-in.-thick sheet of cadmium which is jacketed on both sides with 0.020 in. of aluminum. This composite sheet is formed into a hollow square box-like structure 2.345 in. square by approximately 30 1/2 in. long. This cadmium-box insert is contained in an aluminum shell whose outer dimensions are identical to those of the follower section and whose nominal wall thickness is 0.234 in. There is no size transition between the follower section and the poison section; instead, the outer parts of the sections form one continuous profile (see Figs. 3.3 and 3.4).

   The general characteristics of the shim rods are given in Table 3.3.

2. Fuel section

   The fuel section of the shim rod is very similar in construction to the ORR fuel elements. It is of the aluminum-clad-plate-type design and contains a total of 167 g of ^{235}U. Characteristics of the fuel section are given in Tables 3.4 and 3.5. Each follower contains 14 fuel-bearing plates besides the two outer curved solid aluminum plates that form part of the outer housing.

   The fuel plates are of the sandwich-type construction and are somewhat thicker than the fuel plates used in the fuel elements. The uranium-oxide aluminum fuel core (approximately 30 wt% uranium oxide) is 0.020 in. thick and is clad with a 0.020-in.-thick layer of aluminum to form a 0.060-in.-thick plate. Each plate contains 11.0 g $\pm$ 4% of ^{235}U. Fuel plates are formed with a 5 1/2-in. radius before they are assembled into the follower section.

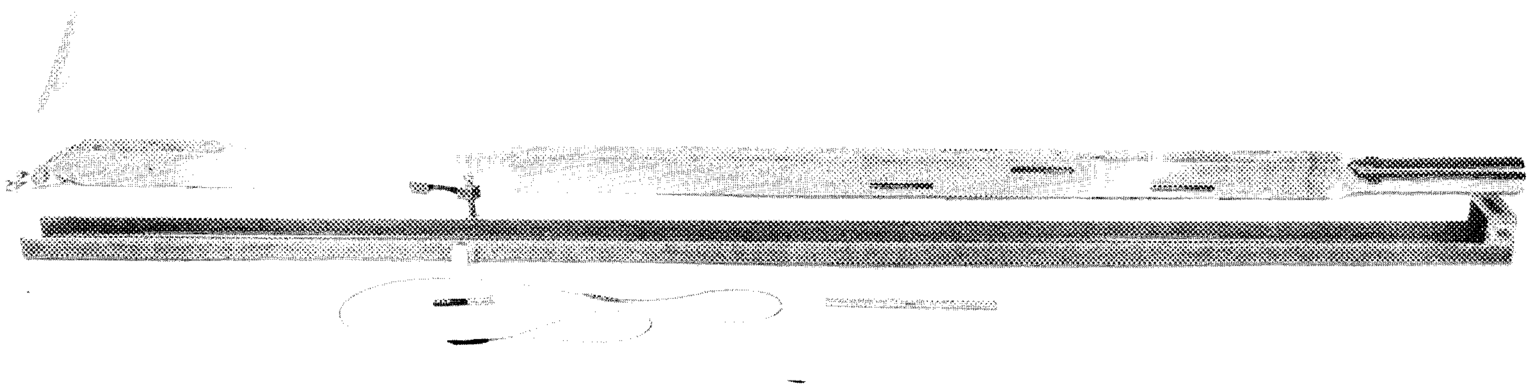


Fig. 3.3. ORR shim rod and carrier.

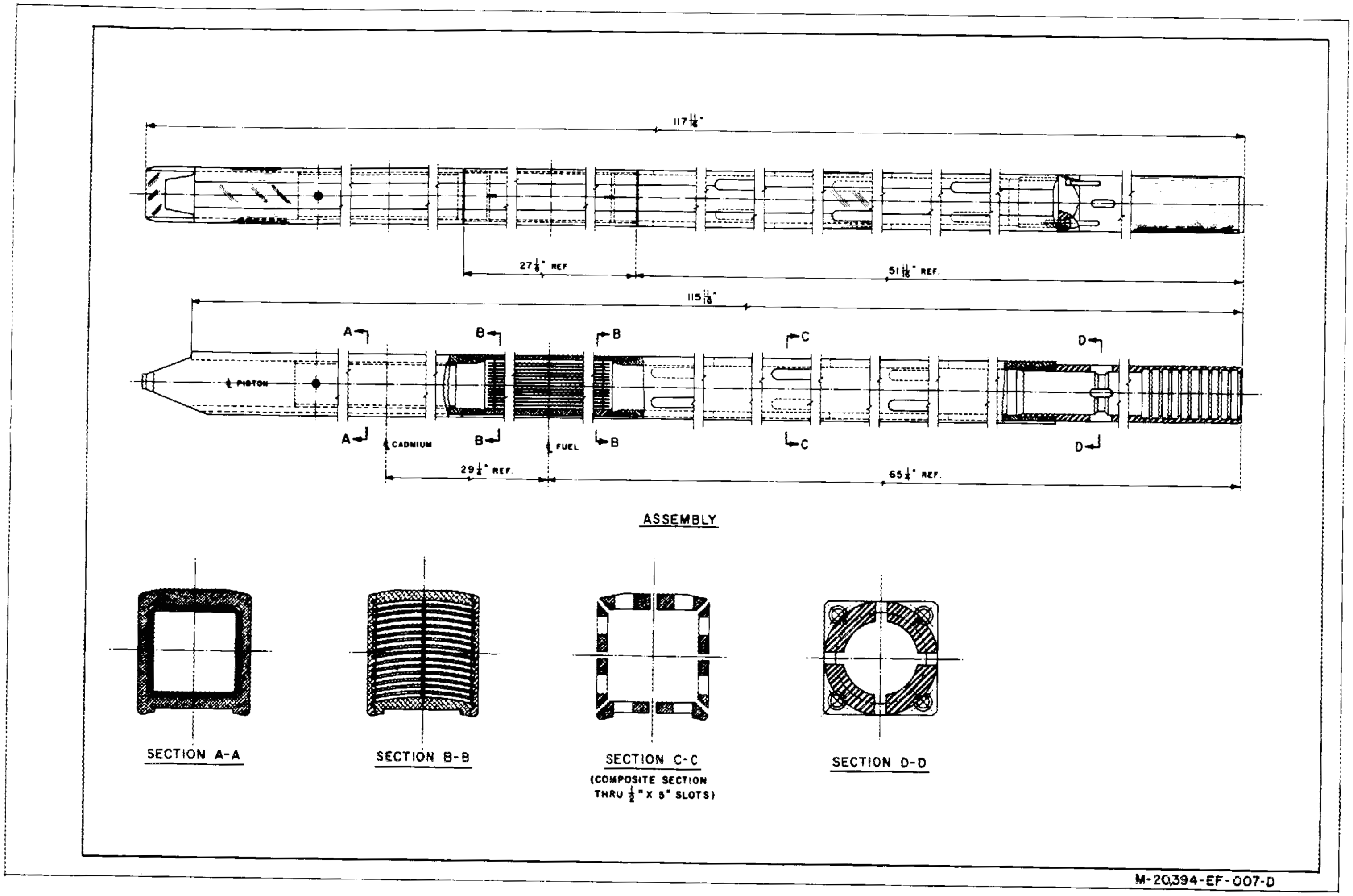


Fig. 3.4. Shim-rod assembly.

Table 3.3. Characteristics of a typical ORR shim rod

Unit	Nominal dimension (in.)
Shim rod assembly:	
Total length (poison, follower, and piston)	117 11/16
Width (through flat sides)	2.838
Width (centerline through curved sides)	3.029
Centerline cadmium to centerline follower	∿29 1/4
Bottom of cadmium to top of fuel in follower	∿2
Upper poison section, jacketed cadmium insert:	
Length (overall)	30 3/4
Length (cadmium)	30 1/2
Outside dimensions (width)	2.345
Insert thickness	0.080
Cadmium thickness	0.040
Jacket thickness	0.020

Table 3.4. Characteristics of a typical ORR shim-rod fuel follower

14 plates

Unit	Nominal dimension[a] (in.)
Fourteen-plate fuel follower section	
Plate spacing	0.117 (typical)
Plate thickness (overall)	0.060
Plate length (overall)	24 5/8
Clad thickness	0.020
Core thickness	0.020
Core length	23 5/8
Core width	2.5
Plate width (before bending)	2.8
Miscellaneous:	
Effective fuel length	23.625
Effective volume	228.4 $in.^3$
Metal volume	122.6 $in.^3$
H_2O volume	105.8 $in.^3$
Heat transfer area	12.22 ft^2

[a]In inches unless otherwise indicated.

Table 3.5. Weights of a typical ORR shim-rod fuel section

Description of components		Nominal weight (kg)
Fourteen fuel plates:		2.70
Alloy cores (approximately 30 wt% uranium oxide, balance aluminum)	0.93	
Cladding (aluminum)	1.77	
	2.70	
Heel and toe plates, curved sides (aluminum)		1.50
Two side plates (aluminum)		1.14
Two combs (aluminum)		0.01
		5.35

3. Piston section

The shim-rod assembly is terminated at the bottom end by a stainless steel cylindrical piston section which serves as a portion of the shock-absorbing mechanism and is an important part of the scram mechanism. The piston is equipped with:

a. roller bearings to guide the shim rod over the drive tube;

b. a swivel joint to ensure alignment between the piston and guide tube;

c. two inside tapered shoulders which serve as part of the ball lock mechanism for mechanically affixing the shim rod to the drive tube and as part of the scram mechanism (the rod is supported on six sperical balls during normal operation); and

d. a precisely machined piston which serves as part of the shock absorber for the shim rod.

3.3. Accountability and Records

3.3.1. Introduction

Three separate records are maintained on each fuel unit (fuel element or shim rod).

1. Fuel-accountability ledger books are maintained with individual, fuel-unit, ledger sheets filed in sections according to unit location (i.e., core, vault, or pool); these sheets contain the past and current inventory of total uranium, ^{235}U and ^{236}U. Each section of the ledger has a master control sheet showing the total inventory of uranium and ^{235}U in that location.
2. A fuel inventory card file is also maintained. A card for each fuel unit shows the past and current ^{235}U inventory and is filed in sections according to location (i.e., pool or core). These two sections are divided into sub-sections according to the ^{235}U inventory (e.g., all units containing 180 to 190 g of ^{235}U would comprise one sub-section).
3. Tags bearing individual unit-identity numbers are kept on location-indication boards which graphically display the core, pool storage racks, etc.

Additional records may be maintained for operations convenience.

3.3.2. Responsibility and Procedure for Maintaining Records

Accountability records are maintained by the ORR balance area representative.

Accountability records are maintained in the following manner:

1. At the end of each month, the current inventories of uranium and ^{235}U are compiled and reported to the ORNL Accountability Office [forms UCN-2676 (Example 3.1) and UCN-3683 (Example 3.2)] in triplicate.

MONTHLY INVENTORY WORK SHEET FOR ____________ [a]

MATERIAL BALANCE AREA REPRESENTATIVE [b]	MATERIAL BALANCE AREA CODE [d]	CONTROL AREA [f]
INVENTORIED BY [c]	DATE INVENTORIED [e]	REPORTING UNITS [g]

ITEM NO. BATCH NO. [h]	CHEM. OR PHY FORM [i]	TAMPER SEAL NO. [j]	CONT. NO. [k]	GROSS WT. [l]	NET WT. [m]	SS NET WT. [n]	ISOTOPE WT. [o]	ASSAY [p]	MEAS. METHOD CODE [q]	SPECIFIC LOCATION OF MATERIAL [r]	REMARKS [s]

DISTRIBUTION:
WHITE - Accountability Office
CANARY - MBA Representative
BLUE - Originator

MEASUREMENT METHOD CODES:
A - Piece or container count; B - Weighed value;
C - Supported by analytical measurements; D - Check
Security Seal; E - NDA Equipment; F - Other____________

SIGNED ____________

UCN-2676
(3 3-79)

Example 3.1

CONSOLIDATED MONTHLY INVENTORY

FOR MATERIAL BALANCE AREA ____________ AS OF ____________

MATERIAL	METHOD B Book P Phys	INVENTORY PER MBA ELEMENT	INVENTORY PER MBA ISOTOPE	INVENTORY CONTROL (PER ACCT. OFFICE) ELEMENT	INVENTORY CONTROL (PER ACCT. OFFICE) ISOTOPE	INVENTORY DIFFERENCES (+) PLUS (−) NEGATIVE ELEMENT	INVENTORY DIFFERENCES (+) PLUS (−) NEGATIVE ISOTOPE
DEPLETED URANIUM							
ENRICHED URANIUM							
<20% U-235							
≥ 20% U-235							
PLUTONIUM-242							
AMERICIUM - 241							
AMERICIUM - 243							
CURIUM							
BERKELIUM							
CALIFORNIUM							
PLUTONIUM							
LITHIUM-6							
URANIUM-233							
NORMAL URANIUM							
NEPTUNIUM-237							
PLUTONIUM-238							
DEUTERIUM-GAS							
D_2O HEAVY WATER							
TRITIUM							
THORIUM							

EXPLANATION OF DIFFERENCES (PER ACCTG. OFFICE)

DISTRIBUTION:
WHITE - ACCOUNTABILITY OFFICE
CANARY - MBA REPRESENTATIVE

UCN 3683
(3 4-81)

Example 3.2

EXPLANATION OF DIFFERENCES: ______
(PER MBA)

1. Are all containers properly labeled as to: (a) Material type? YES ☐ NO ☐ (b) Drum, box, bottle, or container number? YES ☐ NO ☐

(c) Gross, tare, and net weights? YES ☐ NO ☐ (d) SS net weight and % U^{233} or U^{235}? YES ☐ NO ☐ (e) Analytical data expressed in g/g or mg/ml? YES ☐ NO ☐

(f) Date analyzed and analytical date report number? YES ☐ NO ☐

If any of the above are NO, explain why ______

2. Are laboratory reports and weighing data on file to support measurement data reflected in the inventory method on reverse side and also in item 1 above? YES ☐ NO ☐

3. Can items in inventory be traced through the records to this material balance report? YES ☐ NO ☐. If NO, why? ______

4. Does each individual possessing SS materials have an itemized listing of all materials in his possession? YES ☐ NO ☐. If NO, why? ______

5. Describe exact method of inventory if measurements other than analysis, weight, or volume measurements were used. Explain why more precise methods were not used: ______

6. On irradiated materials which may not be amenable to measurements, are up to date records of material quantities, container or bin number and storage facility layouts available? YES ☐ NO ☐. If NO, why?

When will these materials be measured? ______

INVENTORIED BY ______
(Signature Required)

INVENTORY ATTESTED:

______
(Signature of Supervisor Required)

Example 3.2 (continued)

2. For transfers between balance areas or sub-balance areas, form UCN-2681 (Example 3.3), in triplicate is used.
3. For transfers within the ORR sub-balance area, form UCN-1909A (Example 3.4) is used. The form is filled out by the shift supervisor in charge of the actual transfer and is sent to the balance area representative. Information required for each unit transfer is:
   a. source - former location of unit;
   b. unit number - fuel-element, shim-rod, or fission-chamber identity number;
   c. receiver - new location; and
   d. remarks - additional information as may be requested, such as condition of element, radiation level external to shipping casks, etc.

3.3.3. Procedure for Calculating Consumption of Uranium

Normally, ^{235}U consumption by neutron absorption is not considered for small items; e.g., fission chambers, foils, etc. In fuel elements and control elements, the consumption of ^{235}U by neutron absorption is calculated due both to fission (burnup) and neutron capture (^{236}U formation).

Following any partial or complete reloading of the reactor, the number of MWh accumulated during the preceding period of reactor operations is obtained from the ORR logbook. With this information, the number of grams of ^{235}U consumed may be computed as follows:

$$\text{Grams } ^{235}\text{U fissioned} = (\text{MWh}/24) \times 1.07 \text{ g } ^{235}\text{U/MWd} \quad .$$

Since the consumption of ^{238}U and ^{236}U is negligible in ORR fuel elements, the consumption of ^{235}U due to fission is equal to total loss of uranium.

ORNL NUCLEAR MATERIALS INTRA-LABORATORY TRANSFER

DATE 1	TRANSACTION TYPE 2	TRANSACTION NO. MC- 5886

	MBA 3	CONTROL AREA	MBA REPR. SIGNATURE 5		PURPOSE OF TRANSFER-TRANSACTION 7
FROM				NM MGMT. AUTHORIZED 6	
TO				NM MGMT. REVIEWED	

LINE	ITEM NUMBER 8		PROJECT NO. 9	M/T 10	C/P 11	OWNER CODE 12	PIECE NO. 13	COUNTRY OF ORIGIN 14	GROSS WT. (lbs.) 15	MAT'L NET WT. 16	ELEMENT WEIGHT 17	WT. % ISOTOPE 18	ISOTOPE WEIGHT 19
	FROM	TO											
1													
2													
3													
4													
5													

LINE	LIMITS OF ERROR 20		WPAS NO. 21	DATE EXP. TO RETURN 22	I/C 23	S/C 24	MEASUREMENT 25		ANALY. REPORT NO. 26	ASSAY REPORT NO. 27	TAMPER SEAL NO. 28	CONT. NO. 29
	ELEMENT	ISOTOPE					DATE	METH.				
1												
2												
3												
4												
5												

LINE	PERTINENT COMMENTS 30
1	
2	
3	
4	
5	

DISTRIBUTION: White - Accountability Office
Canary - Receiver
Blue - Shipper

UCN-2681
(3 3-79)

Example 3.3

TRANSFER MEMO

FROM | DATE

TO | SHIFT

SOURCE	TYPE UNITS	NO. UNITS	RECEIVER	REMARKS

UCN-1909A
(3 10-62)

Example 3.4

Next, the fraction of the total uranium consumption (burnup) is calculated for the individual element. This fraction is called the burnup factor (BF) and is defined as:

$$BF = \frac{\text{Average flux in fuel unit}}{\text{Average flux in core}} \times \frac{^{235}\text{U in fuel unit}}{^{235}\text{U in core}} \quad .$$

Following this, the burnup factors are multiplied by the previously calculated burnup to determine the burnup per element during the previous operating period. The current burnup is then subtracted from the uranium content of the element at the start of the operating period to obtain the current uranium content. A new total burnup is computed by adding the current burnup to the previous total burnups.

To calculate the current production of ^{236}U, the current burnup is used in the following formula:

$$\text{Grams } ^{236}\text{U produced} = (0.183 \text{ g } ^{236}\text{U/g burnup}) \times \text{grams burnup} \quad .$$

The number thus obtained plus the current burnup is subtracted from the ^{235}U content of the element at the start of the operating period to obtain the current ^{235}U content. To obtain the new total ^{236}U production, the new total burnup is used in the above equation.

To calculate the burnup of the individual fuel elements by hand is time consuming; therefore, the Laboratory's Computing Center is utilized for calculating the burnup. The necessary information in entered on form UCN-14741 (Example 3.5). The printout sheet from the computing center is usually returned within the same day to the balance area representative.

The current burnup, new total burnup, uranium content, ^{235}U content, and ^{236}U production are recorded in the ledger book.

FUEL BURNUP SHEET

REACTOR: ORR = 1, BSR = 2

CYCLE	NO. OF ELE.	MEGAWATT HOURS	LAB.	DIS. CARDS	NEW	HISTORY	DATE IN	DATE OUT	DAY IN	DAY OUT	REACTOR

POS.	ELEMENT	FLUX	TOTAL U	U-235	BCF	CONDITION	
1 2	3 4 5 6 7 8 9 10	11 12 13 14 15	16 17 18 19 20 21 22	23 24 25 26 27 28 29	30 31 32 33 34	35 36 37 38 39 40 41 42	43 44 45 46

UCN-14741
(3 6-82)

Example 3.5

3.4. Fuel Storage and Handling

References

ORNL-CF-58-9-40, "Critical Experiments with Arrays of ORR and BSR Fuel Elements"

Nuclear Safety Requests for:

1. ORR pool racks for stationary-type fuel elements,
2. ORR pool racks for shim-rod storage,
3. 7-element storage basket,
4. HFIR fuel element shipping cask,
5. add-on pool storage rack, and
6. ORR (3042) vault.

3.4.1. General Requirements - Fuel Storage

Fuel storage is defined as the temporary retention of fissionable material outside of the reactor core. This material will normally be in the form of standard fuel units; however, fissionable material belonging to research groups may also be stored.

1. Criticality safeguards

   The methods of preventing and/or handling criticality hazards outside of the reactor core must be approved by the ORNL Criticality Review Committee. It is an ORNL policy that the design and intended use of fuel-unit storage racks and transfer casks be approved, in writing, by the chairman of that committee or his designated representative. Design of storage racks for ORR fuel is based on experimental evidence which indicates the following conclusions for cold, clean ORR-BSR fuel elements.

   a. Optimum spacing is obtained with 0.2 in. between the locating bosses of adjacent elements.
   b. A single, infinite row of vertical elements is probably subcritical if the distance between the locating bosses of adjacent elements is 1.5 in. or more.
   c. If fuel elements are arranged in a uniform pattern, there is very little difference in the critical mass between 140- and 200-g ^{235}U elements in the storage racks.

d. An 11 x 12 matrix of approximately 160 g ^{235}U elements showed no multiplication when closely packed with 0.020 in. of cadmium sheet separating the rows.

e. Apparently, two adjacent infinite rows of 168-g ^{235}U elements are subcritical.

This information was used in the initial design and approval; however, minor changes, e.g., installation of a 6-in. bumper on the storage racks to ensure separation, have since been made, and use of the racks for storage of elements with ^{235}U content of $\leq$300 g has been approved by the Criticality Committee as indicated by the referenced Nuclear Safety Requests.

2. Storage racks

The storage of fuel elements is handled by the following types of racks.

a. ORR pool racks for stationary-type fuel elements. These racks which have a capacity of 30 elements each were designed and are used exclusively for the storage of irradiated stationary fuel elements which may be reinserted into the reactor or which may be decaying prior to shipment to the chemical processing plant for uranium recovery. Figure 3.5 indicates a typical rack. These racks are located in the ORR pool.

b. ORR pool racks for shim rods. These racks, which have a capacity for eight units, were designed and are used for the storage of irradiated shim rods which are decaying to await shipment to the chemical processing plant.

ORNL-LR-DWG 37765A

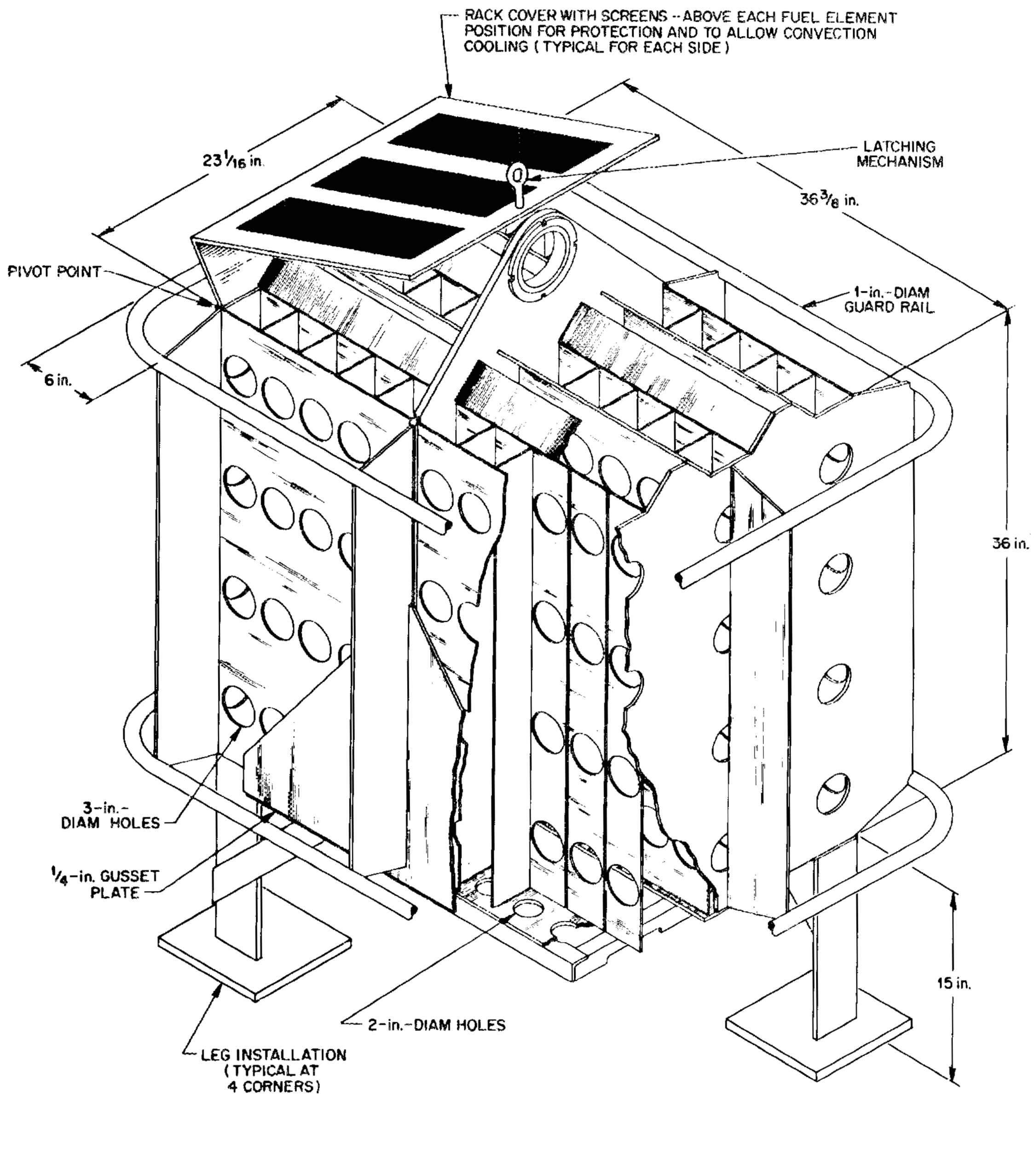


Fig. 3.5. ORR fuel storage rack.

c. Seven-element storage basket. This storage facility was designed, built, and is used exclusively for the temporary storage of spent fuel sections which have had the extraneous materials, e.g., end boxes from stationary fuel and extra aluminum sections from the shim rods, removed prior to loading the units into the seven-element transfer carrier and shipping to the chemical processing plant. Refer to Section 3.4.7 for more detailed information on this rack.

d. HFIR fuel element shipping cask. This shield is used to transfer the spent fuel to the chemical processing plant. It is shown in Fig. 3.6. It contains a rack which can hold up to seventeen vertically oriented ORR or BSR fuel elements.

e. Add-on pool storage rack. These racks, which have a capacity for 15 units each, were designed and are used for the temporary storage of irradiated fuel. The racks are also designed to be installed on top of a loaded ORR pool rack for stationary-type fuel elements (Fig. 3.5). Uses of the add-on racks are approved by the ORNL Criticality Review Committee on a case by case basis.

f. ORR (3042) vault. Unirradiated stationary fuel is stored by this facility to await its use in the reactor. A metal storage rack designed especially for this use is contained therein. It is used exclusively for fuel in this category; and storage of beryllium pieces, heavy water, or ordinary water in this area is prohibited. Access to this vault is permitted for authorized personnel only as it is maintained under a security lock at all times.

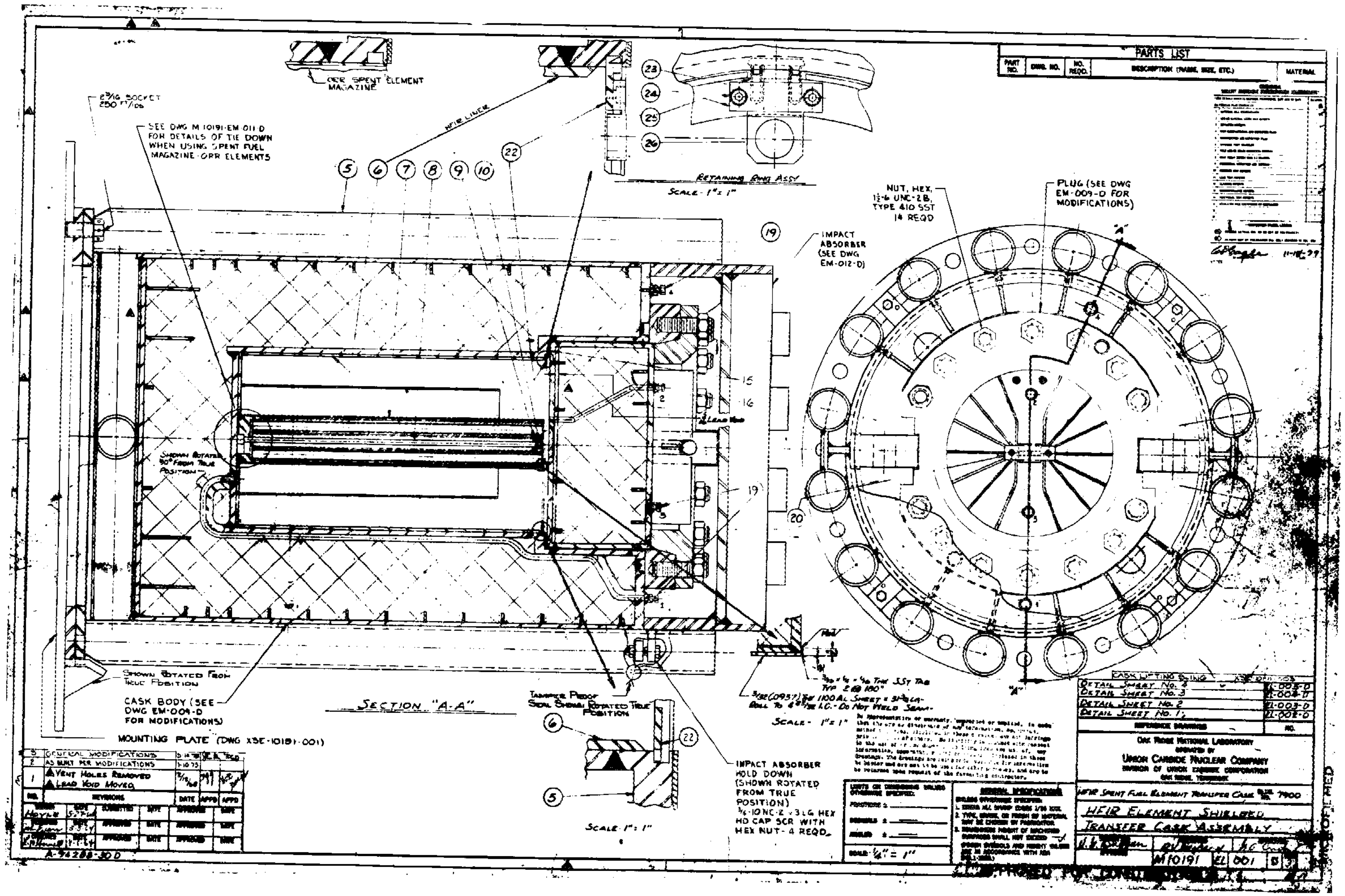


Fig. 3.6. HFIR fuel element shipping cask.

3. Storage of research fissionable material

Storage of fissionable material belonging to research groups is more flexible. Special problems associated with a particular experiment are brought to the attention of the ORR operating staff by the Reactor Experiment Coordinator, Operations Division. A special location may be provided for storage of experiments or experiments may be suspended in the pool.

Care must be taken not to subvert criticality safety by suspending experiments containing fissionable material near standard storage racks; as a general rule, at least 12 in. of separation should be maintained.

3.4.2. General Requirements - Fuel Handling

1. Authorization

Fuel handling at the ORR is accomplished by transfer of an identified fuel unit from a specified location and placing it in another specified location without subverting criticality safety and with minimum radiation exposure to personnel. No fuel unit will be moved unless specified by a written order from the Reactor Supervisor or his designated alternate. Fuel handling is accomplished by the operating crew under the direct supervision of the shift supervisor, and each fuel unit moved must be identified. The shift supervisor must authorize the movement of each unit into and out of the reactor and/or storage-rack position. Each unit shall be identified as it is relocated with the identification of fuel units being made by either an operator or a supervisor. At the completion of fuel relocation, a transfer memorandum is prepared by the person who supervised the transfer (see Example 3.4). The information on the transfer memorandum should also be recorded in the current ORR logbook.

2. Precautions

The following precautions must be followed during fuel transfer.

a. To preclude a loss of identity during dual transfers, one fuel unit must be in its receiving core positon (but not necessarily seated) before the second unit is lowered into the reactor tank.

b. Vertical movement of fuel units (except when in a shipping carrier) must be performed manually.

c. Health Physics coverage is required when removing a loaded fuel shipping carrier from the pool. A crew member or supervisor may monitor the radiation level during fuel transfers in the pool or core.

d. Fuel units must be handled with tools specifically designed for this work. Hooks without guards to prevent the hook from hitting the fuel plates will not be used.

e. Prior to the fuel transfers, the second level balcony should be zoned off using the chains and signs provided. Personnel should be excluded from this area unless permitted by Health Physics following a survey of the radiation levels.

3.4.3. Removal and Insertion of Fuel Elements in the Core

References

D-24078 and D-24326

The various operations involving the removal and insertion of fuel elements in the ORR core are as follows:

1. Removal of fuel from the core

a. Insert the fuel-handling tool into the end box and pull up the locking mechanism on the tool. If the tool is properly aligned in the fuel element, the locking prongs will be pulled in and the tool will drop down farther into the end box (approximately 1 in.). This movement can be felt by the operator on the bridge. Release the locking mechanism and the prongs will engage the holes in the end box.

Before removal of the initial element from the core, mark the tool shaft to determine the seat position of the fuel element in the core.

b. Apply an upward pressure to the tool and the element should release from the lower grid.

c. Raise the element approximately 6 in. from seat and move it up and down to ensure that the tool is firmly engaged. Reseat the element and check the mark made in step 1.a. (This applies to the initial element moved.)

d. Remove the element from the core, and identify it as the proper one listed on the reloading schedule.

e. Transfer the element to its proper location, and disengage the tool by lifting the locking mechanism, then the entire tool from the element.

2. Insertion of fuel into the core

a. Consult the reloading schedule as to the proper location of the desired element.

b. Engage and lock the fuel element to the fuel-handling tool; lift the element for identification.

c. Upon proper identification, the element is moved to the core and slowly inserted into the proper location. If, during the insertion of an element, abnormal deviations of the count rate are indicated (by the poolside, audible indicator of fission chamber counting rate), the element should be immediately removed from the core. An evaluation should then be made to determine the cause of the deviation.

d. Seat the element and check the seat position by referring to the mark on the fuel-handling-tool shaft.

e. Unlock the tool and remove from the element.

The above procedure assumes that the equipment to be used has been checked and found to be in proper working order and that the hold-down arms have been raised.

3.4.4. Removal and Insertion of Shim Rods

The various operations involving the removal and insertion of shim rods in the core are as follows:

1. Locking and unlocking the rods
   a. Before the shim rod can be removed, it must be unlocked from its drive. Before a rod is unlocked, a seat light should be showing and the drive should be raised approximately 1 in. from the lower end of its travel (i.e., the operator unit not in contact with the relocking mechanism). Magnet current must be off. The actual unlocking is done in the subpile room.
   b. The upper housing of the operator unit on each drive contains a spring-loaded handle connected to the shock absorber unit. Pull outward on the handle to clear the locked position recess in the upper housing. With the handle held out, rotate counterclockwise and release the handle into the unlocked position recess. By the action of the release spring in the lower housing of the operator unit, the handle rotation allows the shock absorber unit to be lowered approximately 0.625 in. and the push rod in the ball engagement mechanism assembly to be lowered approximately 0.537 in. The lowering of the push rod allows the four stellite balls in the engagement mechanism to fall into recesses, thereby unlocking the shim rod from the drive unit. The unlocked position is verified by manually lifting the shim rod. Reversal of this procedure will lock the shim rod.

2. Tool descriptions

   a. Shim rod hook tool

      A deep hook is secured to the end of a support tool long enough to reach the top of the shim rods.

   b. Shim-rod carrier

      The shim-rod carrier, Fig. 3.3, is used for additional stiffening of the unirradiated shim rod in transport and to prevent damage in handling due to dropping or bending. The carrier, essentially, is a piece of 3-in. aluminum channel with brackets at each end to hold the rod on the channel. The rod must be placed with the concave side next to the carrier.

3. Procedures

   a. Insertion of unirradiated rod

      The unirradiated rod must be brought from the 3027 vault to poolside in the small aluminum carrier. A special wire choker is threaded through the shim-rod handle and attached to the small crane hook. The rod is lifted by the crane and allowed to hang vertically while the carrier device is removed. The rod is then raised, moved over the pool, and lowered into the water until the shim-rod hook tool can support the rod. The choker is then removed. The bridge is then moved over the empty core position and the rod lowered into position. The shim-rod drive will normally be raised approximately 1.0 in. and in the unlocked position. After the rod has seated, the drive is locked (Section 3.4.4.1). It is then checked for locking by lifting the rod until it is stopped by the rod-locking device. The shim-rod hook tool is then removed. An irradiated shim rod is inserted in the same manner, except there is no carrier device, and the rod must not be removed from the pool. A rod which has been placed in the core must be locked and tested by the same crew that inserted it. A checklist for shim rod insertion is shown in Example 3.6. Completion of this form is required for each rod insertion.

b. Removal of irradiated rod

Removal of an irradiated rod is accomplished in the following manner. The four fuel elements immediately adjacent to the rod are removed to ensure subcriticality with the rod raised or removed. The rod drive is unlocked. The rod is picked up using the shim-rod hook tool. The rod is raised to sufficient height to clear the tank top (under radiation surveillance) and the bridge is moved west. As soon as the piston section of the rod clears the tank, the rod is lowered sufficiently to clear the gratings and minimize radiation exposure. Identification of the rod is made, and it is then placed in either the shim rod storage rack or a fuel element storage location. A checklist for shim-rod removal is shown in Example 3.7. Completion of this form is required for each rod removal.

Shim-Rod Insertion Checklist

In preparation for this operation, make sure the necessary tools are checked and available, the balcony cleared and roped off, the procedure for rod transfer reviewed, etc. The shift supervisor must closely supervise all parts of operation and initial at completion of operation.

____ 1. Ensure that the four fuel elements (N, S, E, and W) immediately adjacent to the rod have been removed, the rod drive is unlocked and near lower limit, and the hold-down arms are raised.

____ 2. Place the motorized bridge so the operator and shim-rod hook tool will be directly over the rod.

a. Applies to irradiated rods

____ (1) Lower the shim-rod hook tool and engage in the rod.

____ (2) Under radiation surveillance, raise the rod from storage location. Identify rod.

____ (3) Move bridge eastward. When near tank, raise rod under radiation surveillance enough to clear tank top. Immediately lower rod when above access flange until radiation subsides. Maximum reading ______ mr/h.

b. Applies to unirradiated rods

____ (1) Ensure that rod is secure in the carrier.

____ (2) Attach the shim rod to crane hook using a wire choker and lift unit to vertical position.

____ (3) Raise rod, move over pool, and lower into water until only the top of the rod is out of the water.

____ (4) Attach the shim-rod hook tool and remove the wire choker.

____ 3. Position bridge so that rod is directly above the core position it will go in. The rod must hang vertically. Place the poolside popper in service.

____ 4. Lower the rod slowly until the rod is down. Do not unhook the shim-rod hook tool. A seat light will show if the drive was unlocked.

____ 5. Send an operator to subpile room to lock the drive by rotating the locking handle.

____ 6. The locking of the rod must be checked by lifting up gently on the rod with the shim-rod hook tool. A small upward movement will indicate the rod is free to move between seat and cross.

____ 7. An additional check can be made by raising the drive 5 in. and noting that the rod now can be raised some 5 in. also. Run drives back down, and ensure that rod can no longer be raised.

____ 8. Remove the shim-rod hook tool.
Other fuel or rod movements may now be made.

A ROD THAT IS REPLACED IN CORE <u>MUST</u> BE LOCKED AND CHECKED BY THE CREW PUTTING IT IN THE CORE.

Date ____________________ Supervisor ____________________

Shift ____________________ Rods moved and checked ____________

Example 3.6

Shim-Rod Removal Checklist

In preparation for this operation, make sure the necessary tools are checked and available, the balcony cleared and roped off, the procedure for rod transfers reviewed, etc. The shift supervisor must closely supervise all parts of operation and initial at completion of operation.

_____ 1. Ensure that all seat lights are showing and that drives are near lower limit and drive unit is in locked position. Ensure that magnet current is off.

_____ 2. Raise both hold-down arms.

_____ 3. Remove the four fuel elements immediately (N, S, E, and W) adjacent to the rod or rods to be moved. (This ensures subcriticality.)

_____ 4. Raise drives approximately 1 in. so that the operator unit will not be in contact with the relocking mechanism. Unlock rod by rotating locking handle. Leave drive unlocked.

_____ 5. Place the pool-side popper in service.

_____ 6. Position bridge above core with the shim-rod hook tool directly over rod.

_____ 7. Lower shim-rod hook tool to rod and engage in rod handle.

_____ 8. Raise rod slowly about 1 ft making sure rod is unlocked and free of the drive.

_____ 9. Clear bridge and poolside of unnecessary people. Make certain bridge can be moved.

_____ 10. Under radiation surveillance, raise rod enough so that piston will clear top of tank. Move bridge west promptly until rod can be lowered. Lower rod until radiation level is tolerable. _____ maximum reading mr/h.

_____ 11. Identify rod.

_____ 12. Move rod to storage location and place there.

_____ 13. Unhook tool from rod.

_____ 14. Complete transfer memo.

Date ______________________ Supervisor ______________________

Shift ______________________ Rods moved ______________________

Example 3.7

c. Placing shim rod on the pool bottom for temporary storage

To place a shim rod on the pool bottom (during shutdowns when the center-pool water level is lowered for maintenance work), the shim-rod hook tool is used in the bail end. A second hook tool is engaged in the extrusion above the piston end of the rod as close to center as possible for support. Simultaneously, the bridge is moved while lowering the rod, using both hook tools, to the desired location on the floor. The reverse procedure is used for picking up the rod. Care must be exercised that the rod does not rest on the bottom of the pool in such a fashion (i.e., top and bottom supported only) as to bend the rod.

3.4.5. Preparing Fuel Elements and Shim Rods for Shipment

References

E-20262, E-20263, E-20264, E-20265, E-20266, E-20267, E-20268, E-20269, E-29270, E-29271, E-29272, E-29273, E-29283, E-29284, D-24078, D-24110, EJ-014-D, EJ-015-D, EJ-016-D

1. Introduction

After allowing a decay period of approximately five months, spent fuel elements and shim rods are prepared for transportation to another plant where the fission products and the unused uranium-235 are chemically processed.

The preparation consists of sawing the fuel sections from both the fuel elements and the shim rods; seventeen of these sections are shipped in one 11 1/2-ton carrier. A motorized, underwater saw is provided in the center pool to perform the cutting phase of the operation (refer to Fig. 3.7).

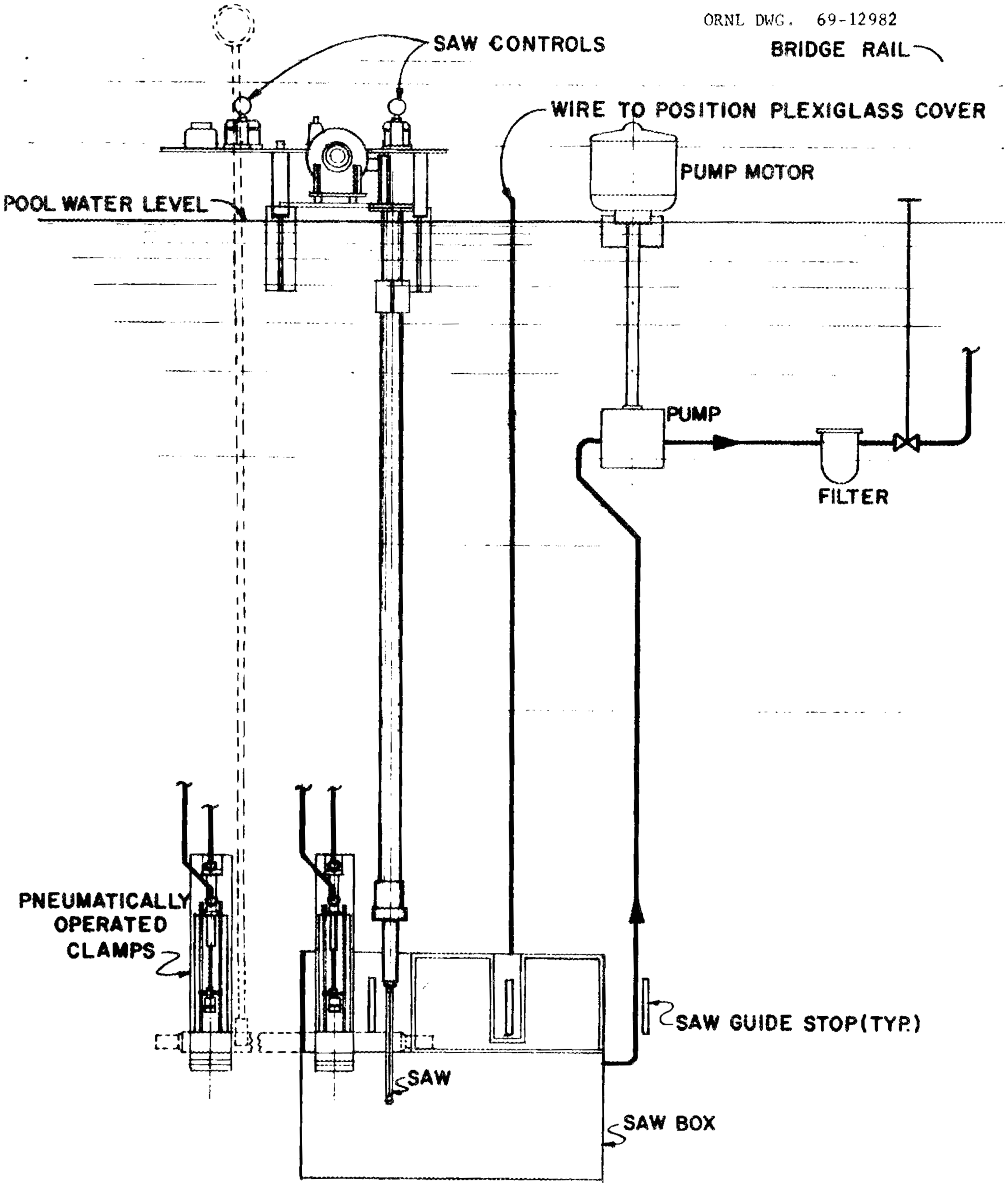


Fig. 3.7. Schematic diagram of underwater saw equipment.

2. Precautions

The greatest hazard in the entire operation is the possibility of sawing into the fuel and subsequently releasing the highly radioactive fission products into the pool cooling system. It is, therefore, imperative that the following precautions be taken.

a. Routine procedures for handling fuel in the pool should be followed to prevent radiation exposure (this includes restricting access to the balcony area).

b. The No. 2 "radiation-monitoring" switch (saw position) must be selected on the electrometer located at the hot cells; and the sensing element must be in position on the outlet water line from the saw box.

c. Prior to beginning the sawing operation, the reliability of the radiation-monitoring system must be verified (i.e., by checking the systems with a radioactive source until an alarm is initiated).

   NOTE: Before the sawing operation is started, a water flow of approximately 8 gpm is established from the saw box to the ILW drain (WC-19). The water flow and radiation-monitoring system must be in service during the sawing operation.

d. Before each cutting, the stack of previously removed end boxes and bails in the saw box should be moved away from the saw blade so that there is no contact on the downward stroke of the saw; failure to do this could cause the saw blade to buckle and saw outside the intended cutting zone.

e. The shift supervisor (or other supervisor in charge) should be familiar with the dimensions of the fuel sections relative to the inscribed saw-cutting marks on the fuel element or shim rod (see Fig. 3.8); and he must verify that the saw blade travel does not deviate from these marks during the cutting operation.

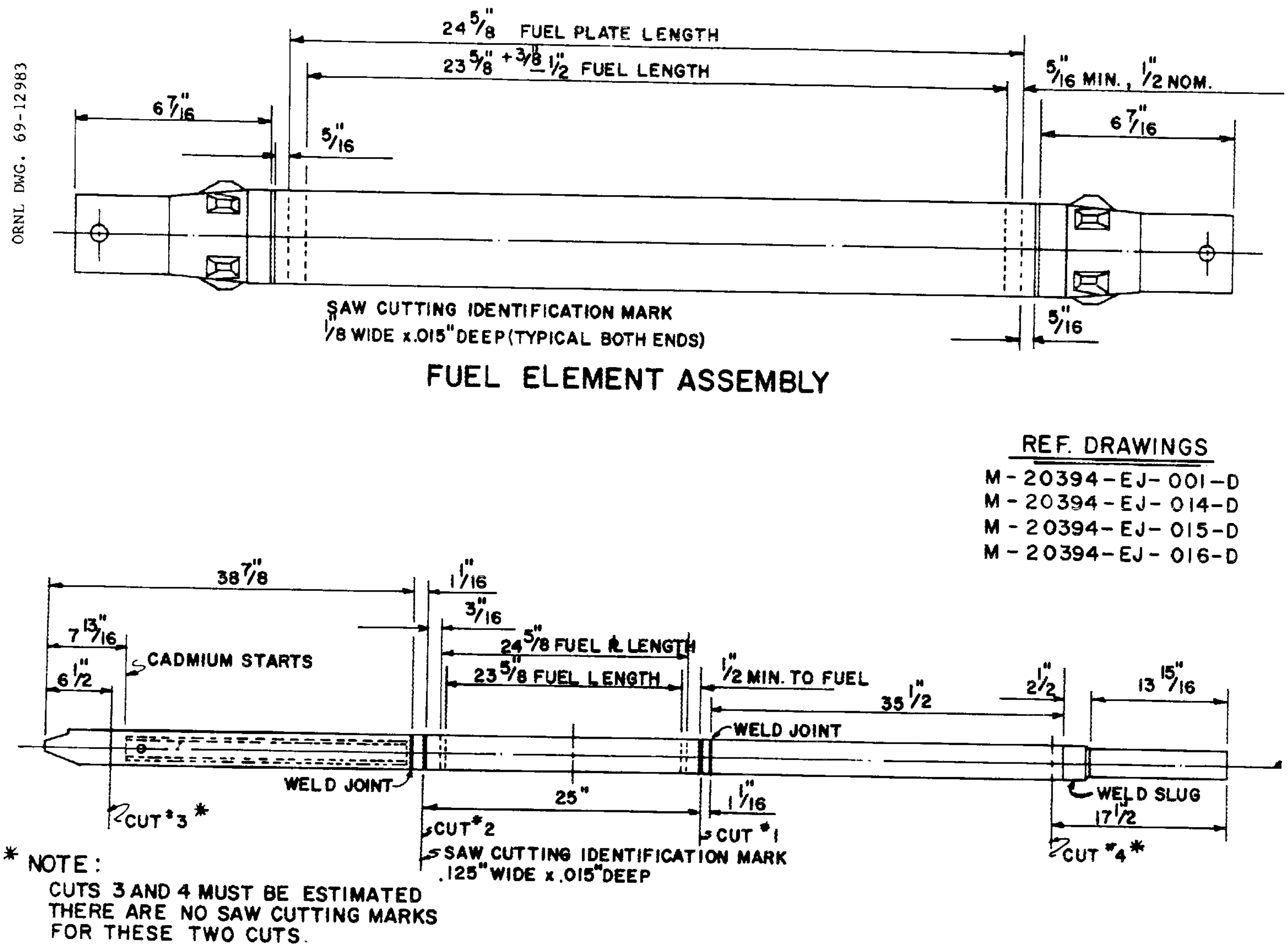


Fig. 3.8. Fuel element and shim-rod assembly (saw cutting marks).

f. If at any time during the sawing operation, the radiation monitor alarms, the saw motor should be de-energized immediately. The operation must not be resumed until an evaluation of the situation is made by a senior staff member.

3. Description of equipment

a. Underwater saw

The saw consists of a standard heavy-duty hacksaw blade attached to a rigid, vertical shaft (14 ft, 6 in. long) which extends about 2 ft above the surface of the pool water. A gear box with a crank and cam arrangement converts the rotary motion of an electric motor to reciprocating movement of the vertical shaft. Horizontal movement of the blade is provided by a pneumatic piston attached near the top of a guide tube around the reciprocating shaft.

b. Holding mechanism and saw box

The fuel element or shim rod to be cut is held in place by two pneumatically operated clamps. The portion of the element or rod to be cut off projects into an adjacent collection box. Effluent water from the collection box is pumped to an underwater filter, a rotameter (at the side of the pool), and, finally, to the hot-drain system (WC-19).

c. Tools

The following tools are used to handle fuel elements and shim rods:

(1) A fuel-element grabber tool having short pieces of aluminum angle for jaws. It is used to clamp across the corners of the element.

(2) A pincer-like swivel tool. It is used to grasp sawed elements by the flat sides. Elements, while in the horizontal positon, are grasped (near the end) with this tool for insertion into the vertical storage rack.

(3) A hook with safety closure mounted on a short shaft. It is used to transfer and position shim rods.

(4) A short, flat hook to engage slots in shim rods. It is used for positioning the shim rod and transferring sawed pieces.

(5) A hook with an up-and-down swivel. This hook makes it possible to pick up a fuel element, lay the element in the cutting trough, and maintain secure control of the element.

d. Miscellaneous equipment

(1) Two circular storage racks with space for fuel sections from a total of 14 fuel elements (or shim rods) are located in a vertical position - seven in a rack.

4. Procedure for sawing fuel elements

a. Ensure that all steps listed under Precautions have been taken.

b. Position the element in the saw assembly.

(1) Remove the designated element from its storage position and verify the identification numbers. (Use the swivel hook on the hook tool.)

(2) Place the element in the saw assembly V-groove trough with the convex side up. Remove the swivel hook tool.

(3) Clamp the fuel-element grabber tool near the center of the element.

(4) Move the element in the saw holder, with the saw mark side up, to the approximate position for sawing.

(5) Clamp the element in place with the pneumatically operated clamps by moving the "vibe-clamp" valve control (located on the underwater saw control station) to the north of the EX (exhaust) position. (NOTE: Approximately 70 psig air pressure, as indicated by the gauge at the control station, is required for proper saw operation. Instrument air is supplied by opening the air-supply header valve on the south side of the pool near the parapet wall. The red-handled valve should also be open, and the pressure gauge immediately downstream should indicate approximately 70 psig.)

(6) Verify that the element remains in the proper position after the clamps are secured by visually checking the saw-cutting marks relative to the saw blade. For this check, the saw blade should be positioned against the element by moving the "saw feed" valve to CYL.

c. Establish water flow through the collection box.

(1) Notify the tank-farm operators that approximately 150 gal of water will be transferred into the hot-drain system (i.e., for each element to be sawed).

(2) Start the underwater pump by depressing the "start" button located on the south wall of the pool.

(3) Open the purge-line valve until a flow rate of at least 50% of full scale is indicated on the rotameter located on the south pool wall. (The valve is located about 6 ft under water and is equipped with an extension handle.)

d. Operate the sawing equipment.

(1) Start the underwater saw by depressing the "start" button located at the control station.

(2) Start the cut by moving the "saw-feed" valve to CYL (cylinder position). (NOTE: The shift supervisor must observe the entire sawing operation. If the saw blade deviates from the cutting zone, the operation should be stopped and the condition corrected.)

(3) When the end box falls into the collection box, the saw motor should be de-energized, the blade retracted, and the pump de-energized.

(4) Release the pneumatically operated clamps and reverse the element in order to saw off the remaining end box. (The fuel-element grabber tool should still be attached to the element.)

(5) Position the element [as in steps b(4) through b(6)].

(6) Establish purge water flow [as in steps c(1) through c(3)].

(7) Operate the sawing equipment [as in steps d(1) through d(3)] and saw off the remaining end box.

e. Store the sawed fuel-element section.

(1) Release the pneumatically operated clamps and transfer the element to the grating.

(2) Place the element on the grating (with the convex side up) and remove the grabber tool.

(3) Grasp the element about 1 in. from the end containing the comb (in the center of the flat sides) with the pincer tool. Raise the tool; the element should swivel to the vertical position.

(4) Place the element in one of the circular storage racks. Record the position.

(5) If no more elements are to be sawed, close the purge-line valve and the air-supply valves to the saw assembly and place the "radiation-monitor" selector switch on No. 1.

5. <u>Procedure for sawing shim rods</u>

   a. Ensure that all steps listed under <u>Precautions</u> have been taken.

   b. Position the shim rod in the saw assembly.

      (1) Using the hook tool with safety closure, remove the designated shim rod from its storage position and verify the identification number.

      (2) Move the shim rod near the saw assembly and engage the flat hook in one of the lower slots on the convex side. Raise the hook to make the shim rod horizontal.

      (3) Place the shim rod in the V-groove trough of the saw while guiding the piston end to the west of the collection box with the flat hook. The convex (saw mark) side of the shim rod should be facing upward.

   c. Remove the piston section.

      (1) Position the shim rod until the saw blade is aligned 17 1/2 in. from the piston end of the rod (see Fig. 3.7).

      (2) Remove the flat hook.

      (3) Secure the shim rod in place with the pneumatic clamps.

      (4) Verify that the element remains in the proper position after the clamps are secured by visually checking the position of the piston relative to the saw blade.

      (5) Install the grabber tool on the piston end just west of the proposed cut. The tool must be maintained in position by an operator who will maintain a level position and a slight clockwise twist on the piston end during the sawing operation. This will prevent binding near the end of the saw cut which could result in a broken saw blade or damage to the saw holder.

(6) Establish purge water flow [as in steps c(1) through c(3)].

(7) Operate the sawing equipment [as in steps d(1) through d(3)] and saw off the piston.
(NOTE: The shift supervisor should observe the entire sawing operation. If the saw blade deviates from the cutting zone, the operation should be stopped and the condition corrected.)

(8) When the piston section has been sawed, release the pneumatically operated clamps.

(9) Transfer the piston section of the shim rod using the grabber tool from the collection box to the C-zone for decontamination and subsequent reuse.

d. Remove the extrusion section.

(1) Engage the flat hook in one of the upper slots of the shim rod and slide the rod west to approximately the correct location for the second cut.

(2) Attach the grabber tool to the extrusion section of the shim rod near the midsection of the extrusion.

(3) Maintain the shim rod in a horizontal position (with the grabber tool) with a slight clockwise twist to avoid damaging the saw blade.

(4) Secure the shim rod in place with the pneumatically operated clamps.

(5) Verify that the remaining section of the shim rod remains in the proper position after the clamps are secured by visually checking the saw-cutting marks relative to the saw blade.

(6) Make the second shim-rod cut [as in steps d(1) through d(3)].

(NOTE: The shift supervisor should observe the entire sawing operation. If the saw blade deviates from the cutting zone, the operation should be stopped and the condition corrected.)

(7) Release the pneumatically operated clamps.

(8) Remove the extrusion section (which should still be attached to the grabber tool) from the saw box area and place it on the grating in a horizontal position. Remove the grabber tool.

e. Remove the fuel section.

(1) Attach the grabber tool to the mid-area of the fuel section and slide the rod west to approximately the correct location for the third cut.

(2) Maintain the shim rod in a horizontal position (with the grabber tool) and with a slight clockwise twist to avoid damaging the saw blade.

(3) Secure the shim rod in place with the pneumatically operated clamps.

(4) Verify that the remaining section of the shim rod remains in the proper position after the clamps are secured by visually checking the saw-cutting marks relative to the saw blade.

(5) Make the third shim-rod cut [as in steps d(1) through d(3)].

(NOTE: The shift supervisor should observe the entire sawing operation to ensure that the saw blade does not deviate from the intended cutting zone. If so, the operation should be stopped and the condition corrected.

(6) Release the pneumatically operated clamps.

(7) Remove the fuel section (which should still be attached to the grabber tool) from the saw box area and place on the grating in a horizontal position. Remove the grabber tool.

(8) Reposition the fuel-element section on the grating, if necessary, then grasp it about 1 in. from the end with the comb in the center of the flat sides with the pincer tool. Raise the tool; the fuel section should swivel to the vertical position.

(9) Transfer the fuel section to one of the circular storage racks. Record the position.

f. Remove the cadmium section

(1) Attach the grabber tool to the mid-area of the cadmium section and remove hook with safety closure from the bail.

(2) Position the remaining portion of the shim rod so that the bail end is facing west. (The convex side should be facing upward.)

(3) Position the shim rod until the saw blade is aligned 6 1/2 in. from the bail end of the shim rod.

(4) Secure the section with the pneumatically operated clamps.

(<u>NOTE</u>: Since it is important that the cadmium section is not penetrated by the saw blade, the shift supervisor should be certain of the cutting zone after the clamps are secure; and he must observe the entire sawing operation to ensure that the saw blade does not deviate from the intended cutting zone. The upper end of the cadmium section is 1 in. past the rivet - toward the bail end.)

(5) Operate the sawing equipment [as in steps d(1) through d(3)] and saw off the bail.

(6) Release the pneumatically operated clamps.

(7) Transfer the cadmium section of the shim rod to the grating.

(8) If no more units are to be sawed, close the purge-line valve and the air-supply valves to the saw assembly and place the "radiation-monitor" selector switch on No. 1.

(9) Return the tools to storage.

3.4.6. Shipping Fuel Units to the Fuel Recovery Plant

References

ORNL drawings M-10191-EL-001-0 through -006-D and -010-D, M-10191-EK-088-D

1. Introduction

Following a decay period of approximately five months (specifically, at least 150 days), spent fuel elements and shim rods are prepared for transportation to another plant where they are chemically processed to recover the unused uranium-235. A detailed procedure of the preparations is given in the preceding Section, 3.4.5.

When the prepared fuel pieces are to be shipped from their storage positions in the ORR pool, they are individually transferred into an 11 1/2-ton shipping carrier that has been lowered into the pool. The carrier presently in service, designated HFIR fuel element shipping cask, has been adapted to carry 17 vertically oriented ORR or BSR fuel pieces.

The following procedure covers the preparation of the shipping carrier upon delivery at the ORR, the loading of the carrier, and the handling after removal from the ORR pool.

2. Precautions

In addition to the usual precautions required when handling highly radioactive fuel pieces, of primary concern are: (1) the prevention of any damage to the pool liner and in-pool equipment when positioning the 11 1/2-ton carrier in the ORR pool and (2) the decontamination of the carrier as specified.

To avoid any possible radiation hazard that might result if the water shielding for the operating reactor were lost due to leakage through a damaged pool liner and to meet the safety requirements for the commercial transportation of highly radioactive materials, it is imperative that the following precautions be taken.

a. Routine procedures for handling fuel in the pool should be followed to prevent radiation exposure (this includes restricting access to the balcony area).

b. Routine procedures for working over the fuel-storage racks should be acknowledged (i.e., the lids of the racks should be closed).

c. Due to the size and weight of the shipping carrier, extreme caution must be exercised when rigging the carrier to the 20-ton overhead crane. [The chain links of the A-frame assembly (Dwg. M-10191-EL-006-D) must not be twisted, and the locking pins in the special crevises must be in place and secure (Dwg. M-10191-EK-008-D)].

   At no time should the carrier be placed on the floor of the pool or any other floor area other than that designated by the floor color-code posted in the 2nd-level truck bay area.

d. To avoid damage to the pool liner (and in-pool equipment) from inadvertent collisions of a minor nature, all positioning of the carrier over and in the pool must be performed very slowly.

(The supervisor in charge should direct the positioning of the carrier.) In addition, the carrier must never be positioned over the reactor pool.

e. Fuel pieces must always be transferred to the carrier individually using the designated tool. Under no circumstances shall the carrier basket be handled in any manner other than as specified in this procedure. The transfer operation must be performed by the operator under the direction of the supervisor in charge.

f. To prevent the inadvertent raising of the carrier during the loading operation, the electrical breaker for the overhead crane must be placed in the OFF position until after the carrier top is repositioned over the mouth of the carrier.

g. The water around the fuel elements in the cavity of the loaded carrier must be removed, and the carrier must be purged with air and leak-checked prior to shipment. The gamma-heat generation from one ORR fuel element after a 150-d decay period is approximately 210 W. Actual temperature measurements made on a carrier 24 h after loading with seven depleted fuel pieces indicated no significant temperature differential across the carrier shielding; however, considering the actual time before the carriers are unloaded and the overall seasonal temperatures encountered during transit, the removal of the water is mandatory. NOTE: During the water-purging operation, the air pressure in the cavity should not be allowed to exceed 20 psig.

h. Radiation levels must be monitored during the following operations: (1) when the carrier lid is raised to allow inspection of the top gasket and interior; (2) when fuel is being transferred; (3) when the loaded carrier is being raised from the water; (4) when the water is being removed from the cavity of the carrier (the exit-line tubing should be monitored); and (5) when the carrier is emptied of water.

i. The specified radiation and contamination limitations must be met prior to the removal of the carrier from the ORR building (i.e., the beta-gamma radiation level must not exceed 200 mr/h at contact and the contamination level must not exceed 1000 dpm cm^2 beta-gamma and/or 30 dpm cm^2 alpha. The actual radiation and contamination levels must be recorded on a radiation-identification tag and secured to the carrier.

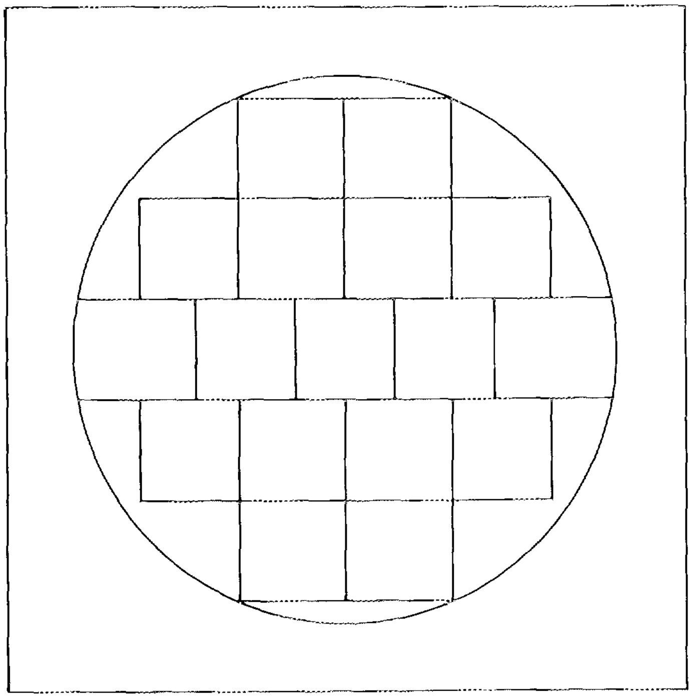
j. The records pertaining to uranium accountability must be properly maintained. The supervisor in charge of the carrier loading should verify the identification numbers of the elements and indicate their relative position in the carrier as required on the Fuel Element Shipping Carrier Form (See Example 3.8); he should also enter a similar diagram in the ORR log. In general, the initial handling of the standard forms required for the shipment of the fuel pieces from the ORR, and subsequently from ORNL, is the responsibility of the Reactor Operations Section SS accountability officer and the foreman assigned to maintaining the records on the individual fuel pieces. These individuals supply the necessary information required on the fuel-element shipping carrier form and the ORNL - Source, Nuclear, and Special Materials Transfer Form (the latter form is prepared in triplicate; for distribution practices, refer to Example 3.9).

FUEL ELEMENT SHIPPING CARRIER

The ORR spent fuel element magazine has been inserted in cask ________ ORR Supervisor ____________

DATE | SOURCE

ELEMENT NUMBER	CORE INSERTION DATE	ORIGINAL WEIGHT		CORE REMOVAL DATE	SHIPPING WEIGHT		TOTAL	TOTAL
		U	25		U	25	26	Mwd
TOTAL								



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CARRIER ____________________

Example 3.8

3. Description of equipment

a. HFIR fuel element shipping cask (see Fig. 3.6)

The subject carrier is a lead-filled stainless steel (type 304) shell about 10 in. thick. The cask contains a cylindrical basket 32 in. long with seventeen 3 1/8-in. by 3 13/32-in. spaces - each designed to accommodate one vertically positioned fuel piece. The carrier has a circular base 46 3/8 in. in diameter and is encircled with 16 vertical sections of 4 in. pipe which serve as fins for heat removal. The carrier has facilities to allow purging the water from around the fuel elements (using compressed air) after they are loaded and removed from the pool.

b. Lifting equipment

An A-frame-type lifting assembly with chains and shackles is used to lift the carrier (using a 20-ton overhead crane). A manually operated chain hoist, also attached to the A-frame assembly, is used to remove the carrier's top plug. (This assembly is stored in the HFIR sling storage area except for the chain hoist, which is stored in the ORR sling storage area.)

c. Tools

A pincer-like swivel tool is used to transfer the individual fuel pieces from the 7-element storage racks to the carrier. Wrenches are used to remove and/or install the carrier's top plug and pipe connections. (The wrenches are stored in a plastic bag in the storage box located by the carrier delivery area.)

d. Water-purging and leak-testing equipment

Four pipe connections and associated equipment are used to pressure test and/or purge water from the carrier following loading (see Fig. 3.9). The connections are described below:

Connection No.	Access to	Use
1	Bottom of element cavity	To drain element cavity
2	Top of element cavity	To pressurize element cavity
3	Plug lead cavity	To pressurize plug lead cavity
4	Cask lead cavity	To pressurize cask lead cavity

4. Procedure for loading the fuel carrier at the ORR

a. Remove the carrier from the delivery truck.

(1) Place blotting paper on the floor area west of the 2nd-level C-zone (an area slightly larger than the base of the carrier is adequate).

(2) Using the A-frame assembly and the 20-ton overhead crane, remove the carrier from the delivery truck and place it on the blotting paper. Ensure that the lifting device is properly attached to the 20-ton hook and that none of the chain links are twisted (see Fig. 3.10).

(3) If removing the carrier from the delivery truck was the only objective at this time, remove and store the A-frame lifting assembly.

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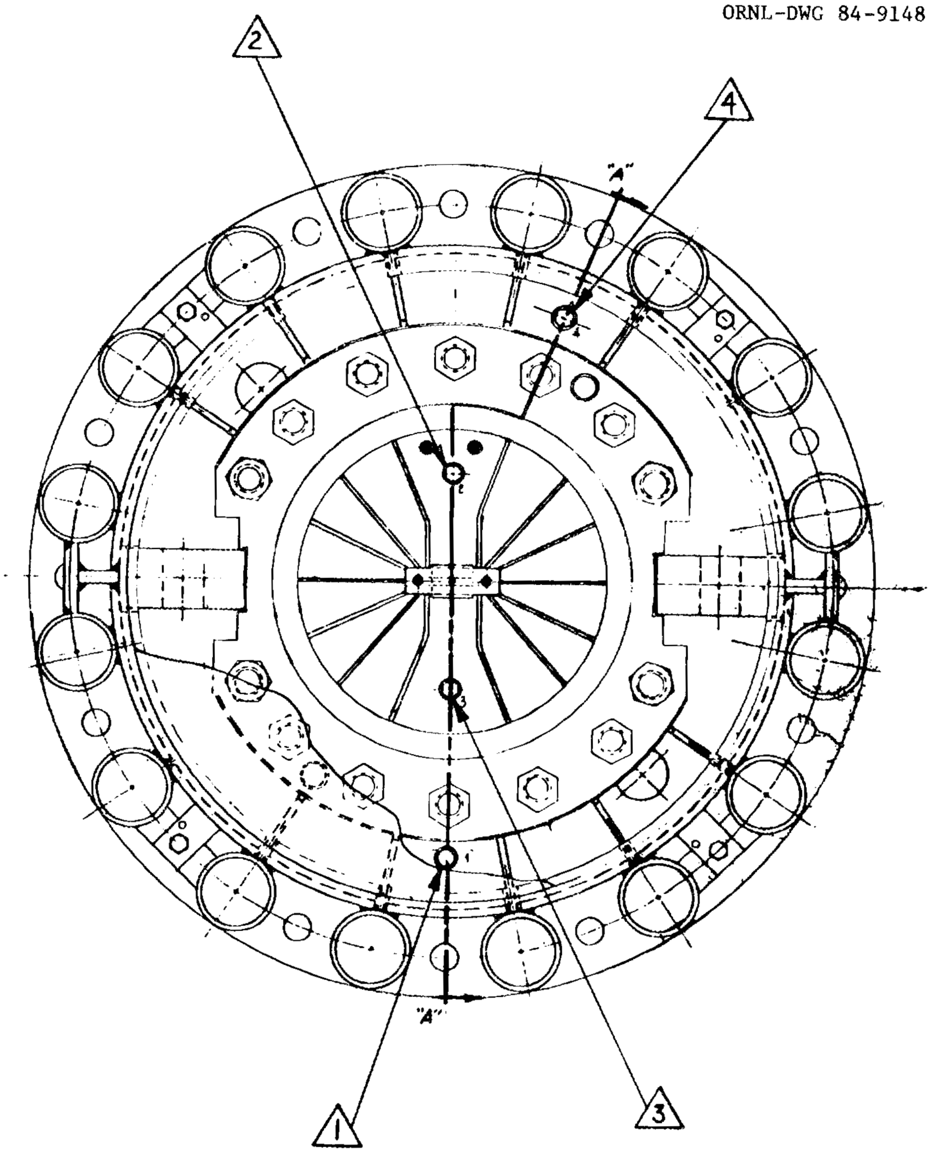

Fig. 3.9. Transfer cask (top).

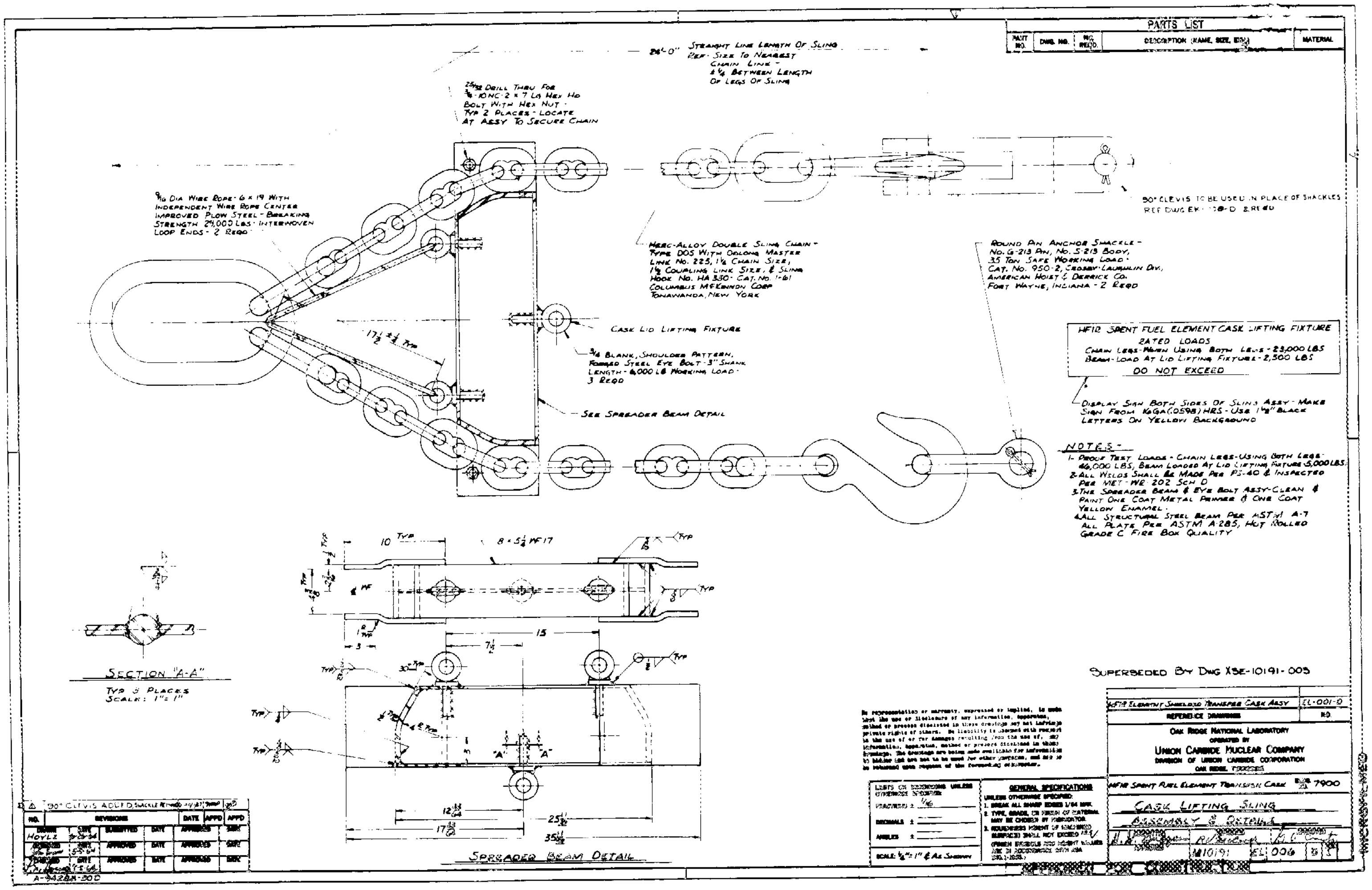

Fig. 3.16. Lifting sling.

b. Prepare the carrier for the pool

(1) Have the Health Physicist check the carrier for transferable contamination. NOTE: If the carrier is contaminated (i.e., >1000 dpm/100 cm^2 beta-gamma and/or >30 dpm/100 cm^2 alpha), the carrier must be cleaned before it is placed in the pool water.

(2) Examine the carrier for (a) possible damage incurred during transit, (b) radiation-identification and/or other tags, (c) debris, and (d) a wire used to seal the lid. Remove any tags, debris, and/or the wire seal.

(3) Remove the nuts securing the top.

(4) Inspect the gasket. The gasket is a special material which must be obtained from the HFIR maintenance supervisor. (CAUTION: To accomplish this, the lid must be raised slightly using the chain hoist on the A-frame. Have the Health Physicist monitor the radiation level of the cavity as the lid is raised.)

(5) Inspect the inside of the carrier, i.e., the ORR fuel element magazine should be in place, secured, and free of damage.

(6) Install drain hose in connection No. 1. Open connection No. 2 for venting. NOTE: This step will allow some water to siphon from carrier as the carrier is raised above the pool water level on removal of loaded carrier from the pool. The partial draining of carrier will allow the securing of the lid without forcing contaminated water from carrier cavity.

c. Place the carrier into the center pool

NOTE: If applicable, raise the carrier 1 in. off the floor to be sure that a proper hookup has been made.

(1) Raise the carrier to the upper-limit travel of the 20-ton crane.

(2) Position the carrier over the center pool.

(3) Attach a 1-in.-diam rope to the carrier top; the remainder of the rope should be placed on the motorized bridge.

(4) Spray the carrier with demineralized water. (This step is found to be somewhat effective in "sealing" the porous metal surface of the carrier from the contaminated pool water and, consequently, facilitates the decontamination procedure upon removal.)

(5) Position the carrier over the 4-ft wall that is located underneath the center pool close to the east end (exact location is given in Fig. 3.6).

(6) Slowly lower the carrier into the pool until the top of the carrier is at about the same depth as the top of the two seven-element storage racks located on the grating. Due to the size of the carrier, extreme care must be exercised in manipulating the crane controls for the positioning of the carrier. (CAUTION: Ensure that the carrier is not allowed to collide with the pool liner or any in-pool equipment. The shift supervisor must observe this activity.)

(7) Using the chain hoist, raise the carrier top until the base of the top plug is about 2 in. above the vertical pipe sections and fins on the cask sides.

(8) Secure the 1-in.-diam rope to the motorized bridge and move the bridge eastward until the top is moved away from the mouth of the carrier.

d. Load the carrier

(1) Place the electrical breaker for the overhead crane in the OFF position (located on the southside walkway of the 3rd level). This switch must remain in the OFF position until the 17 elements are loaded and the carrier's top plug is positioned over the mouth of the carrier.

(2) Using the pincer-like swivel tool, raise a fuel element from the seven-element storage rack. Monitor the radiation level at the pool parapet during this step.

(3) Identify the element number; it should correspond to one listed under "element number" on the fuel element shipping form.

(4) Place the element in one of the 17 positions in the shipping carrier basket.

(5) Record on the fuel element shipping form (see example) the position in which the element was placed relative to the yellow lifting lug inside the element basket or magazine. (NOTE: The yellow lug location will have to be indicated on the schematic diagram of the basket positions shown on the shipping form.)

(6) Repeat steps (2) through (5) until the 17 elements have been loaded into the carrier. (CAUTION: Do not attempt to expedite the loading procedure by either transferring more than one fuel piece at a time or by removing the carrier's 17-position basket.)

e. Install the top on the loaded carrier

(1) Move the motorized bridge westward until the carrier top is positioned over the mouth of the carrier.

(2) Using the chain hoist, lower the carrier top into the seated position. Pipe connections No. 1 and No. 2 must be aligned as shown in Fig. 3.9 to achieve the best seal of the carrier top. (Two guide pins are provided on the carrier to facilitate the necessary alignment.)

(3) Carefully inspect the carrier top for proper seating. If one side appears uneven, raise the lid and repeat step (2).

(4) Place the electrical breaker for the overhead crane in the ON position.

f. Remove the loaded carrier from the pool

NOTE: Remove the carrier slowly so that the pool demineralizer pump will not be starved.

(1) Position the carrier in the pool so that it can be raised without obstruction from in-pool equipment. (CAUTION: Ensure that the carrier is not allowed to collide with the pool liner or any in-pool equipment. The shift supervisor must observe this activity.)

(2) Have a Health Physicist monitor the radiation level of the carrier as it is slowly raised from the water. If the radiation level is in excess of 200 mr/h at contact, inform the Reactor Supervisor.

(3) As the carrier is being raised, rinse it with demineralized water. Water will start draining from the carrier into the center pool via the siphon drain tube.

(4) When access to the carrier top is achieved (while standing on the motorized bridge), place the nuts on the studs and secure them. Torque to 100 ft-lb in 50 ft-lb increments.

(5) Remove the 1-in.-diam rope.

(6) Using rags, wipe all surface areas of the carrier while it remains suspended over the pool, preferably before it is allowed to dry.

(7) Return the carrier to its original position in the truck bay; however, leave the carrier suspended about 4 ft above the floor level. NOTE: Before moving the carrier from over the pool, stop the water drainage by raising the drain hose to break the siphon effect.

(8) Have the Health Physicist obtain a smear of the bottom surface of the base. If the transferable contamination level is <1000 dpm/100 cm^2 beta-gamma and <30 dpm/100 cm^2 alpha, lower the carrier to the floor. If it is contaminated in excess of the specified limits, repeat the cleaning operation of the carrier base.

(9) Remove the A-frame assembly and return it to storage if applicable (i.e., if the carrier is not to be shipped relatively soon). Remove the siphon drain hose. Close connections Nos. 1 and 2.

(10) Torque carrier top nuts to 100 ft-lb in 50 ft-lb increments.

g. Purge the pool water from the cavity of the carrier.

(1) Connect the clear Tygon-hose end of the drain-line assembly to the ILW valve located on the north balcony (labeled 2). (NOTE: "Clear" Tygon hose is used for this application to allow the easy viewing of the purged water; however, in order

to comply with the requirement of using only "colored" Tygon hose at the ORR to ensure visibility in the event any of the plastic would ever be placed in the pool, a colored-tape wrapping is secured to the hose at various locations.)

(2) Remove the cap from the carrier's drain line.

(3) Connect the other end of the drain-line assembly to connection No. 1 on the carrier top (refer to Fig. 3.9).

(4) Ensure that all connections are secure; then open the valve to the ILW system.

(5) Remove the cap and plug from the carrier's connection No. 2.

(6) Connect the end of the air-purge supply line into the carrier's top vent.

(7) Connect the end of the air-purge supply line to the plant air-supply line (located by the stairway).

(8) Ensure that all connections are secure. (NOTE: If the connections are not secure, the contaminated pool water will be forced out around the gasket area and it will recontaminate the carrier. In addition, an inadequate purge will be established due to the loss of air pressure.

(9) Adjust the air regulator until the pressure gauge indicates 8 psig. (CAUTION: Do not pressurize the cavity to greater than 20 psig without explanation.)

(10) Open the air-supply valve to the carrier. At this time, water should be observed leaving the carrier through the clear Tygon hose. (CAUTION: The radiation level of the water must be monitored.)

(11) After all the water has been removed (normally after approximately 40 min the water flow through the clear tubing will cease), purge the carrier with dry air for 1/2 h.

(12) Remove the drain line fitting from the carrier and allow the negative pressure of the ILW system to remove any residual water in the Tygon hose.

(13) Install the carrier's drain-line cap.

(14) Remove the air-supply line from the carrier and install the plug and cap. (NOTE: Wrap a piece of pipe tape around the threads of the plug before reinstalling it.)

(15) Place the air-purge and drain-line equipment into a plastic bag and return them to the storage box.

h. Perform pressure tests as follows:

NOTE: See Fig. 3.9 for connection location. In each case below, apply air pressure. Close inlet air valve and disconnect air line. Observe gauge. If pressure decreases before end of test period, notify supervision.

(1) The cask lead cavity should hold an air pressure of 10 psig for approximately 15 min. Connection No. 4 is used for this test.

(2) The plug lead cavity should hold an air pressure of 10 psig for approximately 15 min. Connection No. 3 is used for this test.

(3) The element cavity should be pressure tested at 20 psig for approximately 30 min. Connection Nos. 1 or 2 may be used for this test.

i. Prepare the carrier for shipment.

(1) Have the Health Physicist determine the contamination and radiation status of the purged carrier. Continue the cleaning operation as needed to decontaminate the carrier to the specified limits. The beta-gamma radiation level, after removing the water from around the fuel pieces, should not exceed 200 mr/h at contact anywhere on the carrier; if it does, the Reactor Supervisor should be notified.

(2) Have the Health Physicist prepare a radiation-identification tag (i.e., a Radiation Hazard Materials Transfer tag) and secure it to the carrier.

(3) Inform the Reactor Operations foreman in charge of maintenance that the carrier is prepared for shipment from the ORR building and submit to him the fuel element shipping carrier form. He will handle the arrangements for the transfer of the carrier from the ORR building to the shipping point.

3.4.7. Moving "7-Up" Racks

In the preparation of depleted fuel for shipment for reprocessing, the end boxes are removed from the fuel elements and the fuel sections are cut out of the shim rods. Until these fuel sections are placed in the seven-place shielded carriers for shipment, they are stored in two seven-place, circular storage racks known as "7-up" racks. These racks are normally located on the center pool grating which is 14 ft below the water level when the pool is full.

If the center pool water level has to be lowered, the fuel racks are transferred to the pool floor before the lowering of the water level begins. The movement of the racks containing fuel sections will be made under the supervision of the shift supervisor who will ensure that all necessary steps are taken to prevent the racks from being overturned or raised out of the water. Extreme caution should be exercised to avoid overturning the rack. While it is not possible to produce a critical assembly with seven depleted fuel elements, the possibility does exist that the spilled elements might be so arranged with other fissionable material to produce a critical assembly. When the rack is in the upright position, adequate separation from other materials is assured by the 6-in. guard ring.

When a "7-up" rack containing fuel elements is moved, the following procedure will be used.

1. Zone the 2nd-level balcony using the chains and signs provided, and make certain no personnel are permitted to remain on the balcony. High radiation levels could be produced on the balcony as the rack is moved by the pool wall thimbles.
2. Station one person at the crane circuit breaker to stop the current to the crane if the crane switch should stick.
3. Use a tool with a hook on it. The hook should be checked to determine that it will support the rack.
4. Position the small crane directly over the "7-up" rack so that the crane will lift the rack vertically without sliding it along the grating or floor.
5. Engage the hook in the rack bail and lift the hook until the bail is vertical to ensure that the bail does not stick in some other position causing the rack to tilt.
6. Engage the tool with the crane hook and raise the crane until the rack is off the grating or floor. This will prevent the rack from being turned over if the crane is moved horizontally.

7. Move the crane vertically and horizontally into place over the new position.

   NOTE: The crane should not be moved vertically and horizontally simultaneously. All moves should be made slowly while the operator who is operating the crane and the supervisor observe closely to see that the rack does not strike anything.
8. Lower the rack into the new position.
9. Disengage the tool from the crane hook.
10. Disengage the hook from the bail.
11. Return the hook to its storage position.
12. Take down the signs and chains used to zone the 2nd-level balcony.

3.5. Refueling the ORR

3.5.1. General Considerations in Refueling

As previously discussed, an operating cycle for the ORR consists of twelve weeks of operation and approximately a one-week quarterly shutdown. This twelve weeks of operation is in turn divided into fuel cycles (i.e., periods of operation during which the fuel units in the core remain unchanged by transfer or rearrangement). Since the reactor must be shut down on a planned schedule for refueling and to accommodate the research programs, a maximum operating period of about two-to-three weeks is dictated following the beginning of an operating cycle (the actual period may be less depending on the length of the preceding quarterly shutdown). However, the allowable excess reactivity is sufficient to operate the reactor at 30 MW for a maximum period of about 24 days. A "typical" operating cycle may consist of fuel cycles as shown in Table 3.6.

Table 3.6. Typical operating cycle for ORR

Fuel cycle designation*	Operating period (weeks)	Reason for termination**
A	∿2 1/2	Refueling and experiment work
B	∿2 1/2	Refueling and experiment work
C	∿2 1/2	Refueling and experiment work
D	∿2 1/2	Refueling and experiment work
E	∿2 1/2	Quarterly shutdown

*This designation follows operating cycle number (e.g., cycle 163-A).

**Refueling is usually the reason for termination of a fuel cycle prior to the quarterly shutdown; however, experiment work and minor reactor component maintenance may accompany the refueling shutdown.

Deviation from this "typical" operating cycle is due to unscheduled shutdowns caused by experiment difficulties, instrument malfunction, etc. Because of the buildup of xenon concentration after a reactor shutdown, reloading is required following many such shutdowns to minimize reactor downtime. Following operation of the ORR at 30 MW, about 20-21 of the centrally located elements must be replaced by a mixture of new, unirradiated elements and partially depleted elements (which have remained out of the core a sufficient time for xenon decay).

The operating criteria for the ORR stipulates that "the excess reactivity loading above clean-cold-critical will not exceed that which will permit achievement of criticality with the rods withdrawn less than one-half their reactivity worth." In actual practice, the group worth of the four fuel-cadmium shim rods as a function of position is assumed to be symmetrical about the midposition (calibration curves for individual rods indicate this assumption to be correct). Prior to the beginning of each operating cycle, the fully withdrawn position of each shim rod is determined; the average fully withdrawn position is then calculated. The operating limit is taken as one half of this average position.

3.5.2. Scheduled Reloadings

1. The reactivity effects and power distributions for all normally used ORR reloadings have been learned through experience. This knowledge allows all ORR reloadings to be grouped into three classifications. Each classification has a different set of surveillance activities that are required to ensure that the reloading is suitable for operation. These surveillance activities are:
   a. determine that the fuel weight change for each core position is approximately ± 15 g and that the fuel weight change for the total core is approximately ± 100 g;
   b. determine that the control rod positions at criticality are greater than the posted minimum rod positions;
   c. calibrate the control rods; and
   d. determine that the power produced in any element is less than 30(0.127-0.00159n) MW, where n is the number of fuel elements in the core, or 2.43 MW, whichever is less.
2. The classifications are listed below.
   a. Similar reloading. This type of reloading is determined, by Technical Section personnel and the ORR supervisor, to have the same operating characteristics as the core loading it replaced. Therefore, the reloading is suitable for ORR operation. The surveillance activities required for this type of reloading are 1.a and 1.b above.

b. Previously used reloading. This type of reloading has been used before but is dissimilar to the core loading it replaces. The surveillance activities required for this type of reloading are 1.a, 1.b, and 1.c.

c. Unfamiliar reloading. This type of reloading has no previously used core loading to which it can be referenced. Therefore, surveillance activities 1.a, 1.b, 1.c, and 1.d must be performed to ensure the reloading is suitable for ORR use.

3. Other principles involved in determining suitable ORR core loadings are listed below.

   a. The most desirable position of the control rods at critical with the reactor cold and xenon free is that defined by the operating criteria for the ORR (defined above in Section 3.5.1).

   b. The effect of the fuel contained in the rod followers was measured by calibrating rods containing various fuel weights in their followers. These measurements were made in the same core location and with the same fuel distribution in the core. (The results of these measurements are shown in Fig. 3.14.)

4. Reloading instructions are transmitted to the shift supervisors on form UCN-2274 (Rev. 2-67) as shown in Example 3.9. This form is used for scheduled reloadings and for unscheduled reloadings (see Section 3.5.3, Reloading to Remove Xenon Following an Unscheduled Shutdown).

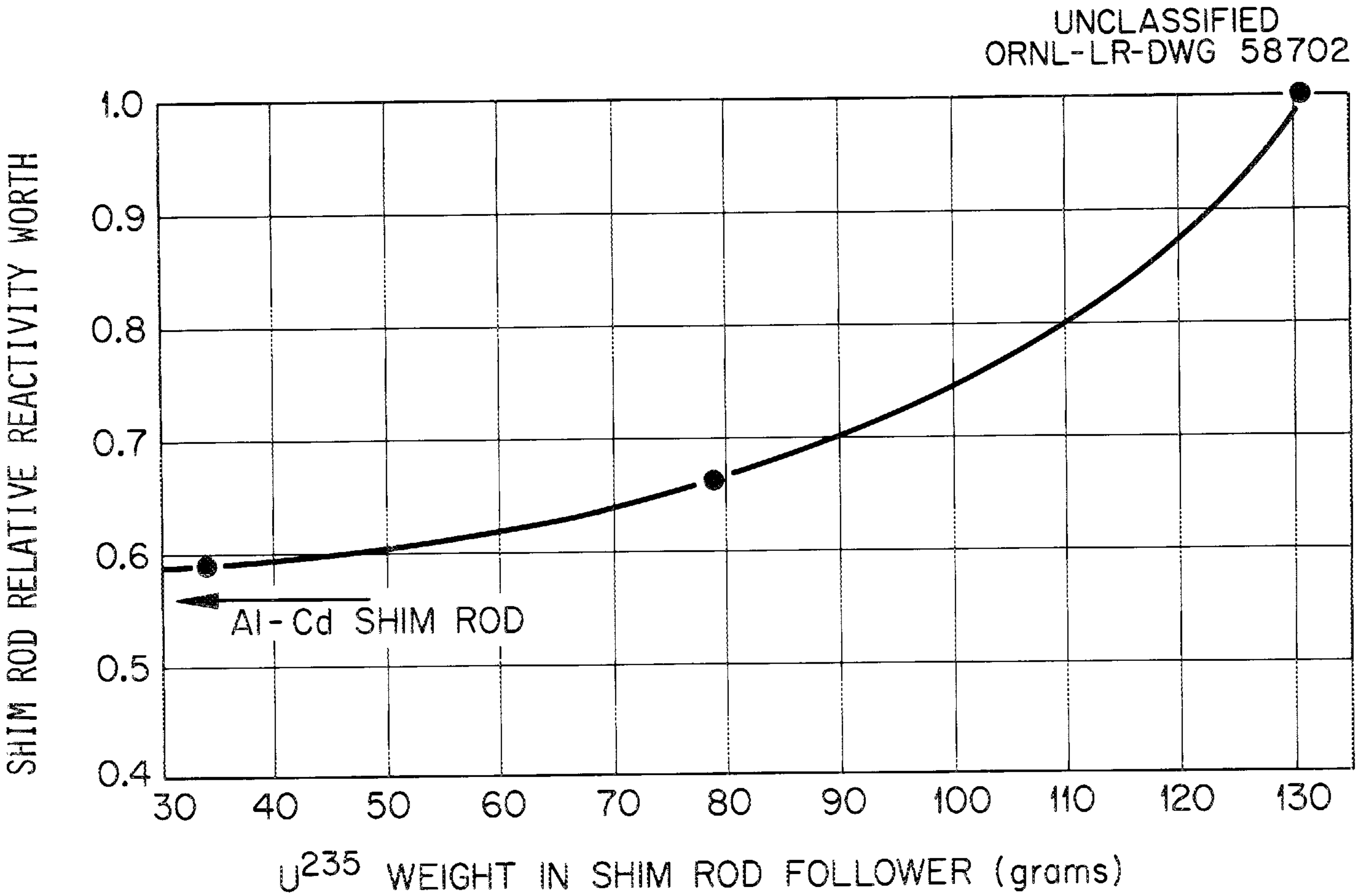

Fig. 3.11. Shim rod reactivity worth as a function of follower U-235 contents.

ORR REPLACEMENT LOADING

PURPOSE: ☐ SCHEDULED RELOADING ☐ UNSCHEDULED RELOADING	ENDING CYCLE BEGINNING CYCLE	PREPARED BY	CHECKED BY

DATE:	ELEMENTS REMOVED		CHANGE IN	ELEMENTS INSERTED		
CORE POSITION	OR NUMBER	WEIGHT U^{235}	WEIGHT U^{235}	OR NUMBER	WEIGHT U^{235}	LOCATION
NEW ELEMENTS	**SUBTOTAL**					
	SHIM RODS					
	OTHER UNITS					
	TOTAL					

UCN-2274
(3 2-67)

Example 3.9

3.5.3. Reloading to Remove Xenon Following an Unscheduled Shutdown

It was stated previously that written instructions from the Reactor Supervisor (or his designated alternate) are required before reloading is performed. This requirement must be met even in the case of reloadings to remove xenon following an unscheduled shutdown (see the discussion in Section 3.5.1). Since such shutdowns may occur on off-shifts or on weekends, a replacement loading is prepared following each reloading. This replacement loading is posted in a "Special Instruction" book in the ORR control room and remains in effect until the next reloading.

This replacement loading is prepared as follows (see Example 3.9).

1. The elements to be removed are listed by identity numbers. The ^{235}U content of each element is listed; the value listed is the ^{235}U content at the time of the last previous reloading.
2. For each element scheduled for removal, a replacement element is selected; the ^{235}U content of the selected element should be listed (this value should be about ± 5 g of the ^{235}U content listed for the element scheduled for removal).
3. The difference in ^{235}U content should be listed as "change in ^{235}U weight." As stated above, this value will normally be ± 5 g; however, some changes of up to ± 15 g ^{235}U will sometimes be required for normal fuel elements.
4. Subtotals will be obtained for the three columns indicated on the replacement loading form. The subtotal of "change in ^{235}U weight" will normally be less than ± 100 g ^{235}U.
5. The supervisor who prepared the replacement loading should sign the form.
6. This replacement loading is then approved by the Reactor Supervisor or his designated representative (see upper right corner of Example 3.9).

NOTE: No deviation from any replacement loading shall be made without the approval of the Reactor Supervisor or his designated representative.

4. RESEARCH

4.1. Facilities

4.1.1. Beam-Hole Facilities

The beam-hole facilities include six horizontal beam holes on the east face of the reactor. These facilities have been provided for experiments using collimated neutron beams. The beam holes, Fig. 4.1, are of circular cross section, decreasing in diameter from approximately 9 1/8 in. at the face of the concrete to approximately 6 3/4 in. at the reactor vessel. The pipe which forms a beam hole is designated as the liner. Each beam hole is equipped with a collimator plug or, in its absence, a dummy plug. The plug seals the outer end of the beam hole and extends inward to within 3 ft of the reactor vessel. These facilities are serviced with water-cooling supply and return, plant air reduced to 15 psig, helium, waste-water drain, and off-gas.

Since the beam-hole liners are anchored at both the reactor tank and at the concrete shield, they must be water cooled to prevent excessive stresses from developing in the reactor vessel due to temperature variations. Constant beam-hole liner temperatures are ensured by jetting water from manifolds on the top and bottom of each liner in the reactor pool. Water for these jets is furnished by routing part of the water returning from the pool cooling heat exchanger to the jet manifolds as shown in Fig. 4.2. About one-third of the total pool cooling flow of 750 gpm is jetted on the beam-hole liners. The temperature of this returning water is about 85°F.

The reactor cannot be operated at full power unless the beam-hole liner jet cooling system is in operation. A relay in the pool cooling water flow meter prevents raising the reactor above 1.8% of full power without adequate cooling flow. Since the beam-hole liner jet system is the only pool cooling water return line that contains no cut-off valve, operation of the liner jet at any significant reactor power is ensured.

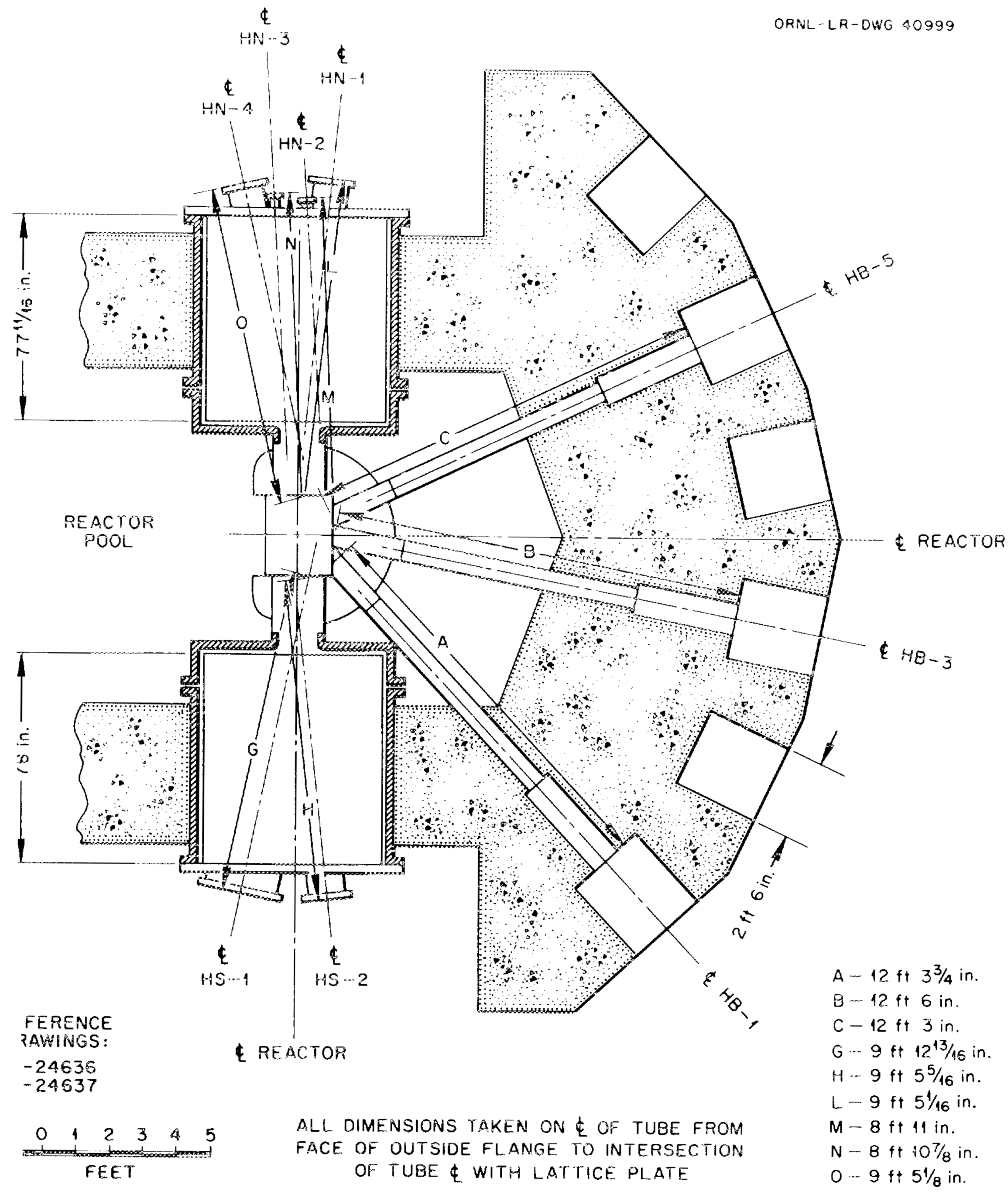

Fig. 4.1. Beam holes.

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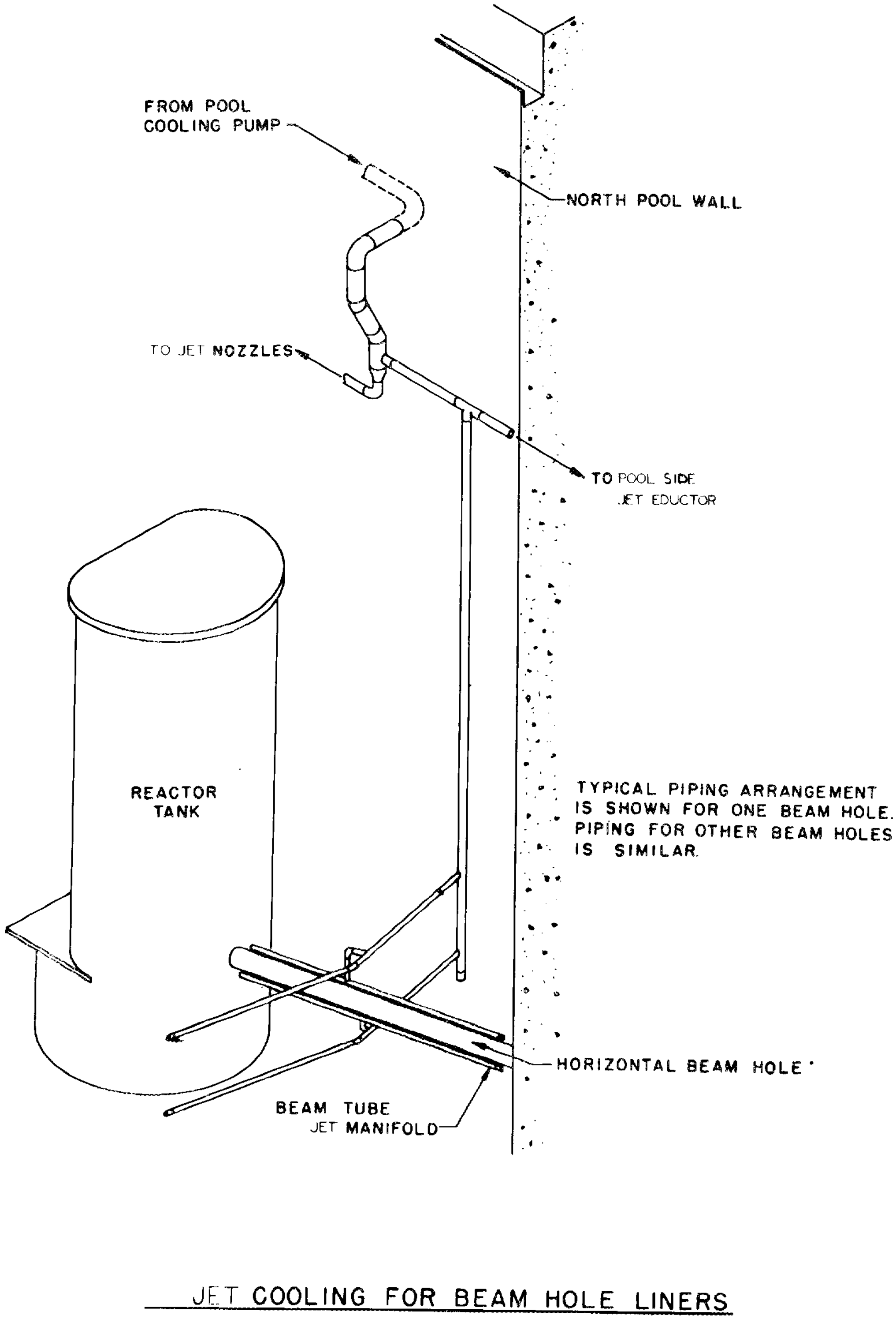

Fig. 4.2. Jet cooling for beam liners.

During the installation or operation of an experiment, biological shielding can be obtained by filling the liner and plug with water. Removable shielding may also be located, for equipment, etc., in the space available in front of the beam holes. A typical experiment is shown in Fig. 4.3.

4.1.2. Engineering Test Facilities

The two large penetrations to the reactor core, located on the north and south sides of the reactor, are designated as the engineering test facilities. Two large water-tight bulkheads, approximately 5 1/2 ft in diameter, pierce the shield to a point just outside the reactor tank, opposite the core, where a transition section, of obround shape approximately 19 x 25 in., penetrates the tank. Since only one of these large holes is needed at the present time, two 10-in.-diam holes and two 4-in.-diam holes are built into the large plug for the north side and are known as HN-1, HN-2, HN-3, and HN-4. The south facility is known as HS.

Shielding is provided by lead bricks on the outside and water on the inside of the plug. The water, circulated by a pump, also serves as a coolant for the facilities. About 500 gpm is taken from the reactor inlet coolant line and is sent to three systems. About 75 gpm goes to the reactor demineralizer system, about 50 gpm goes to the vacuum degasifier, and the rest flows through the large facilities before returning to the exit stream from the reactor as shown in Fig. 4.4. A typical engineering loop experiment in one of the 10-in.-diam holes is also shown in Fig. 4.5.

4.1.3. Vertical Facilities

Since the control rods are driven from the bottom of the reactor, the top is available for experiments. Flanges in the tank cover provide for as many as ten experiments such as those shown in Fig. 4.6. The experiments are inserted into curved tubes which, in most cases, extend from above the normal pool water level to the reactor core level. The tubes can be inserted either into a core position or into voids in the

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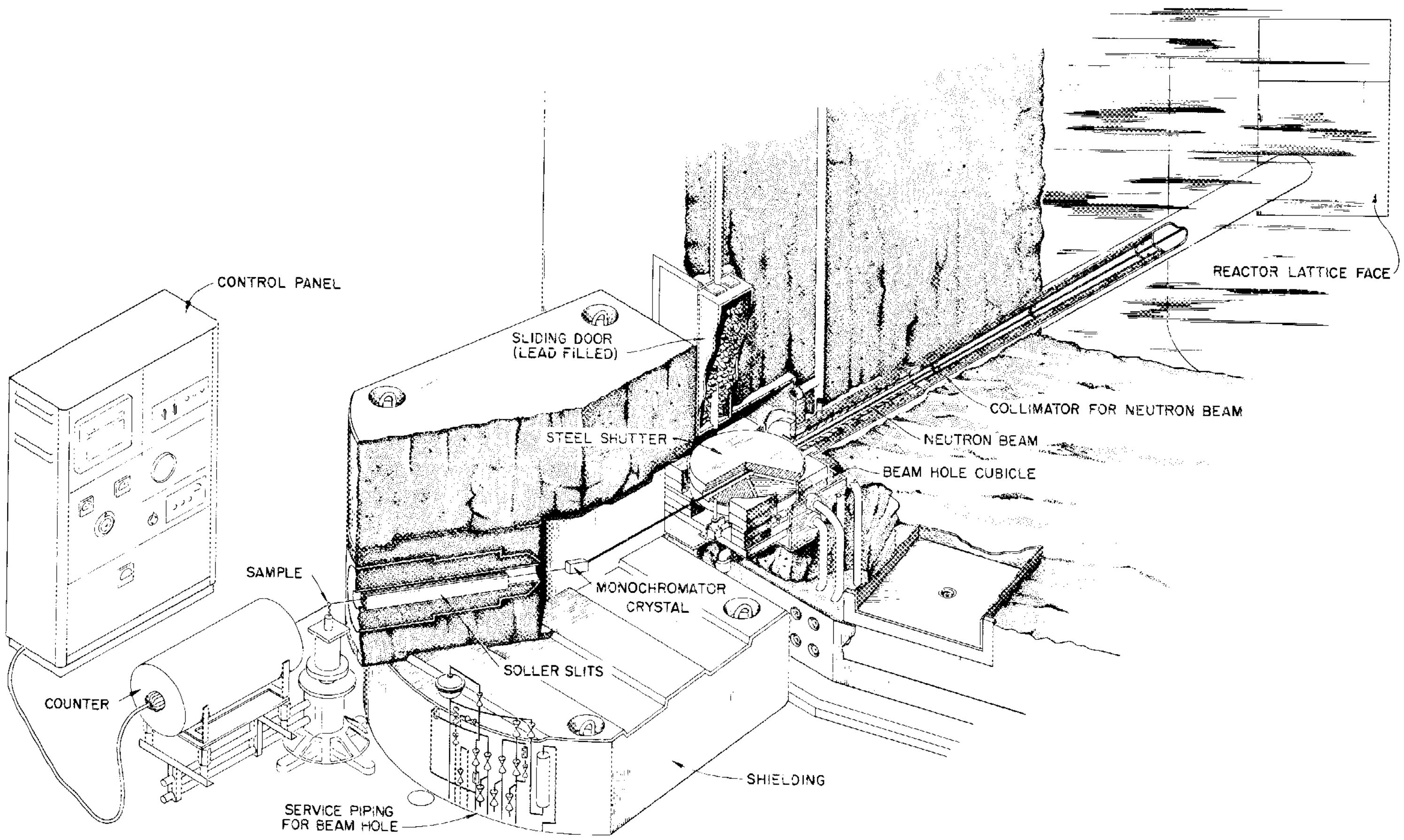

Fig. 4.3. Neutron beam experiment showing removable shielding outside reactor.

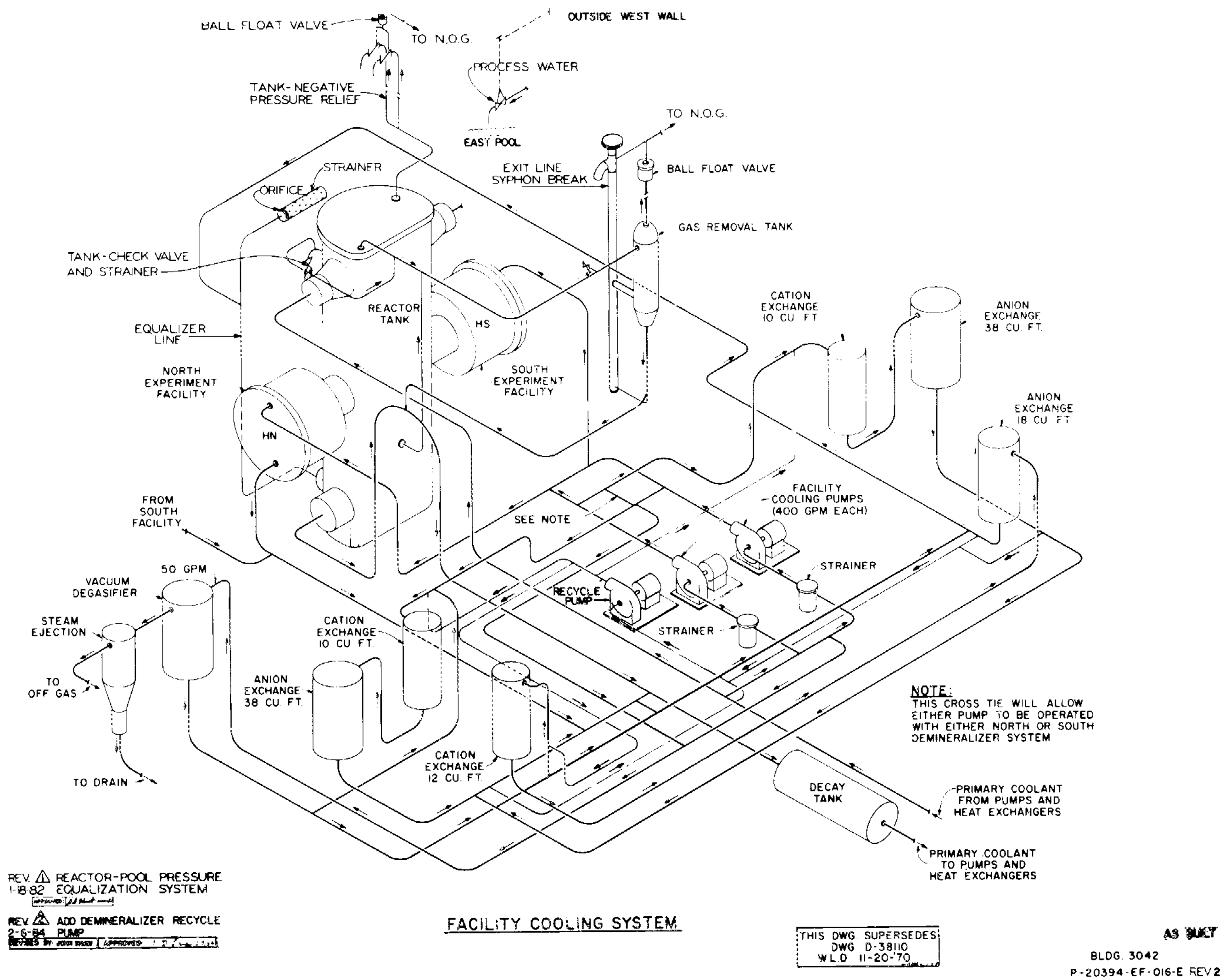

Fig. 4.4. Reactor primary demineralizer flow system and facility cooling system.

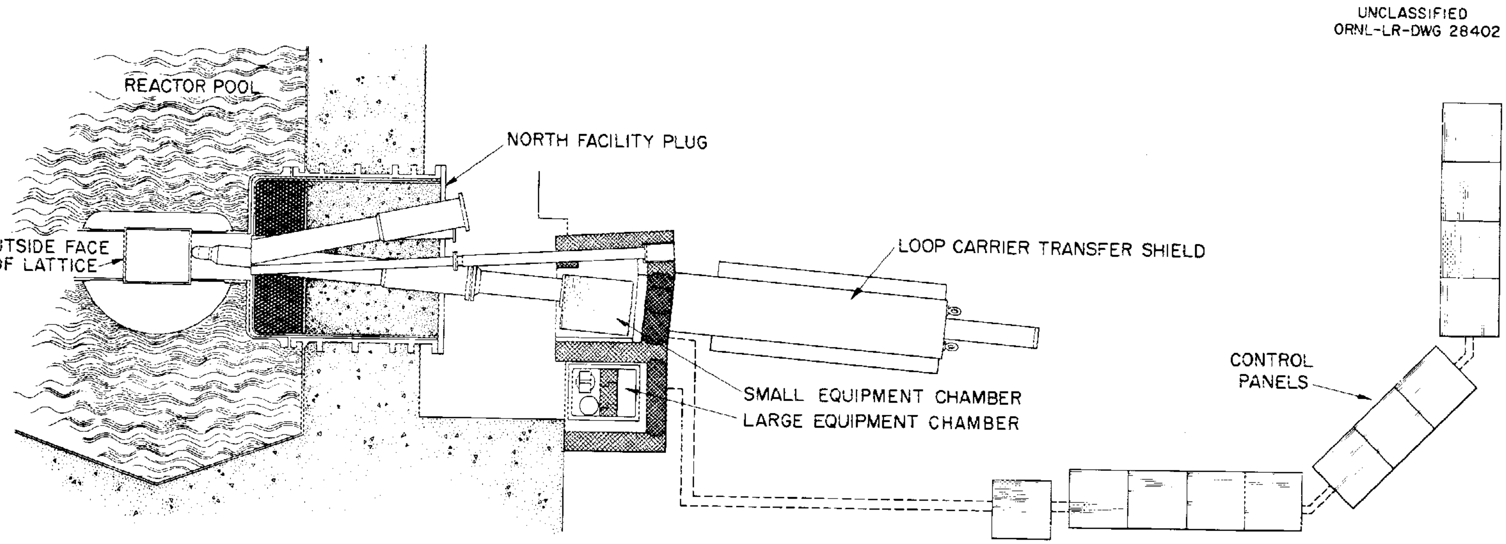

Fig. 4.5. Loop experiment in large facility.

beryllium. The curved tube enters the reactor tank through an access flange allowing insertion and removal of fuel through the top of the reactor without disturbing the experiment. The experiments may be connected to shielded rooms in the basement where compressors, heat exchangers, and other equipment are located. The pool provides shielding for the connecting pipes and permits the experiment to be removed from the reactor tank without shielding other than the pool water. Figures 4.7 and 4.8 are schematics of typical, vertical loop experiments.

4.1.4. Pool-Side Facility

The flat, west side of the reactor tank provides a facility where experiments may be inserted into the pool adjacent to the reactor core with a minimum of difficulty, Fig. 4.9. The facility was designed to permit large "bulk shielding" type experiments to be placed close to the core; however, experience has shown that it is also useful for smaller experiments which would be awkward to install in one of the other facilities or require a lower neutron flux than the core provides.

4.1.5. Experiments not Requiring External Connections

Experiments which do not require external connections may be irradiated inside beryllium reflector elements which have 2-in.-diam inserts, or they may take the place of a reflector piece entirely. Radioisotope targets may be irradiated in the same manner. Experiments requiring fast neutron flux may be inserted either adjacent to fuel elements or inside modified fuel elements.

Used fuel elements removed from the reactor tank through the pool can be placed in a gamma-irradiation facility where experiments may be conducted in gamma radiation fields of the order of 10^7 r/h. A neutron flux due to D (γ,n) H of about 10^4 $n \cdot cm^{-2} s^{-1}$ results from the natural abundance of deuterium in the water; however, in the gamma facility this is minimized by having each element in a cadmium box (presently not in use).

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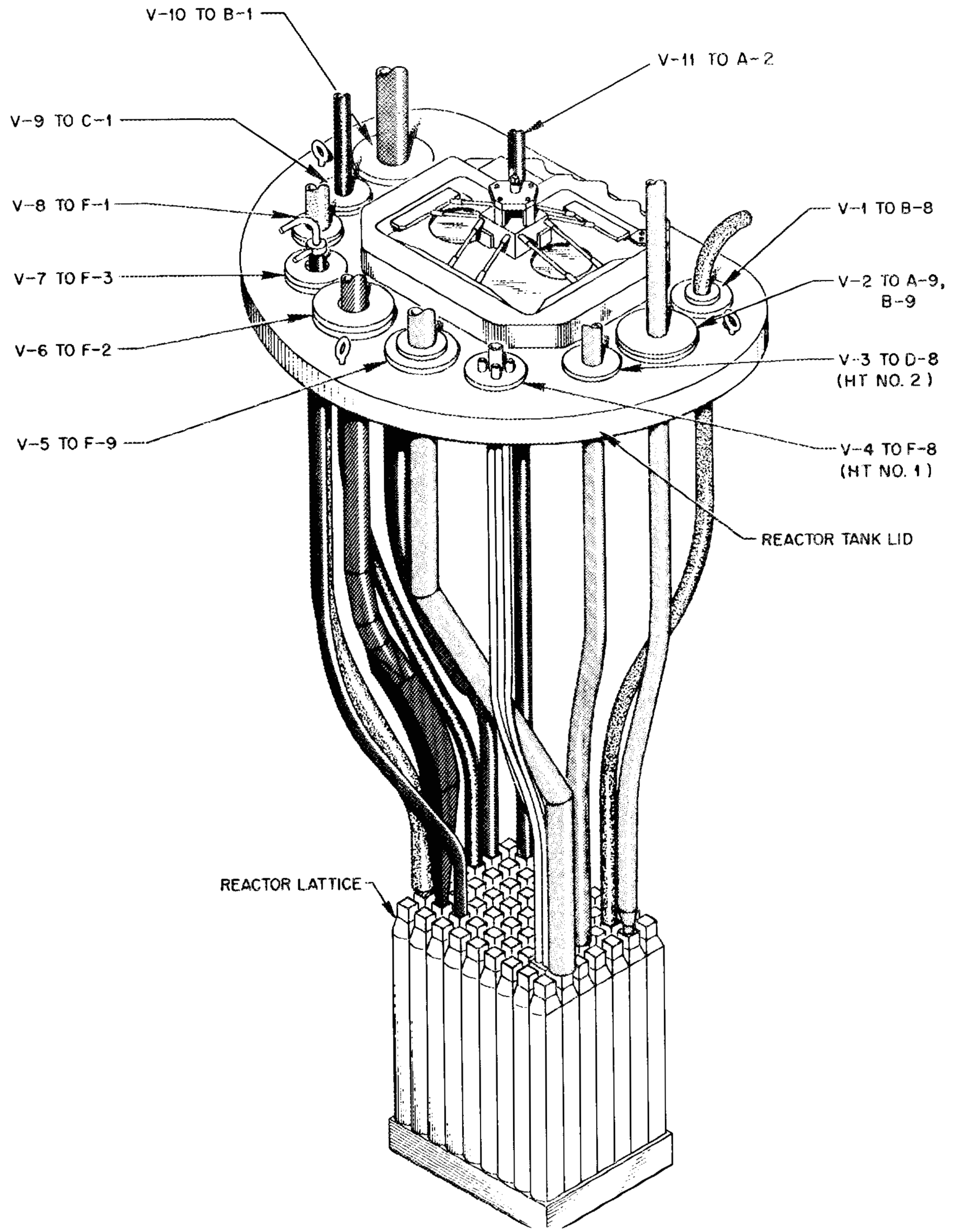

Fig. 4.6. Typical in-core experiments.

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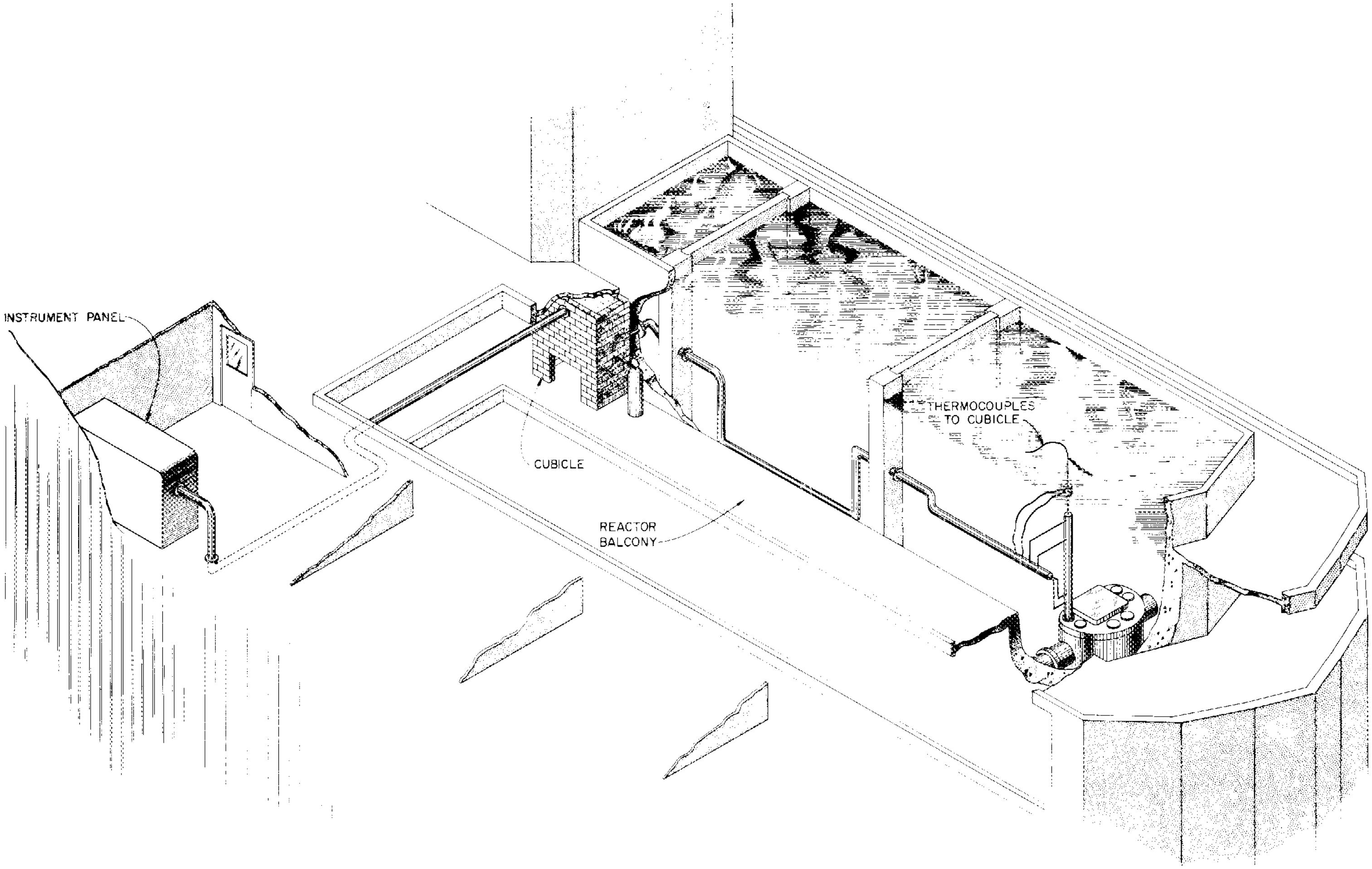

Experiment ORR C-1

Fig. 4.7. Typical vertical facility.

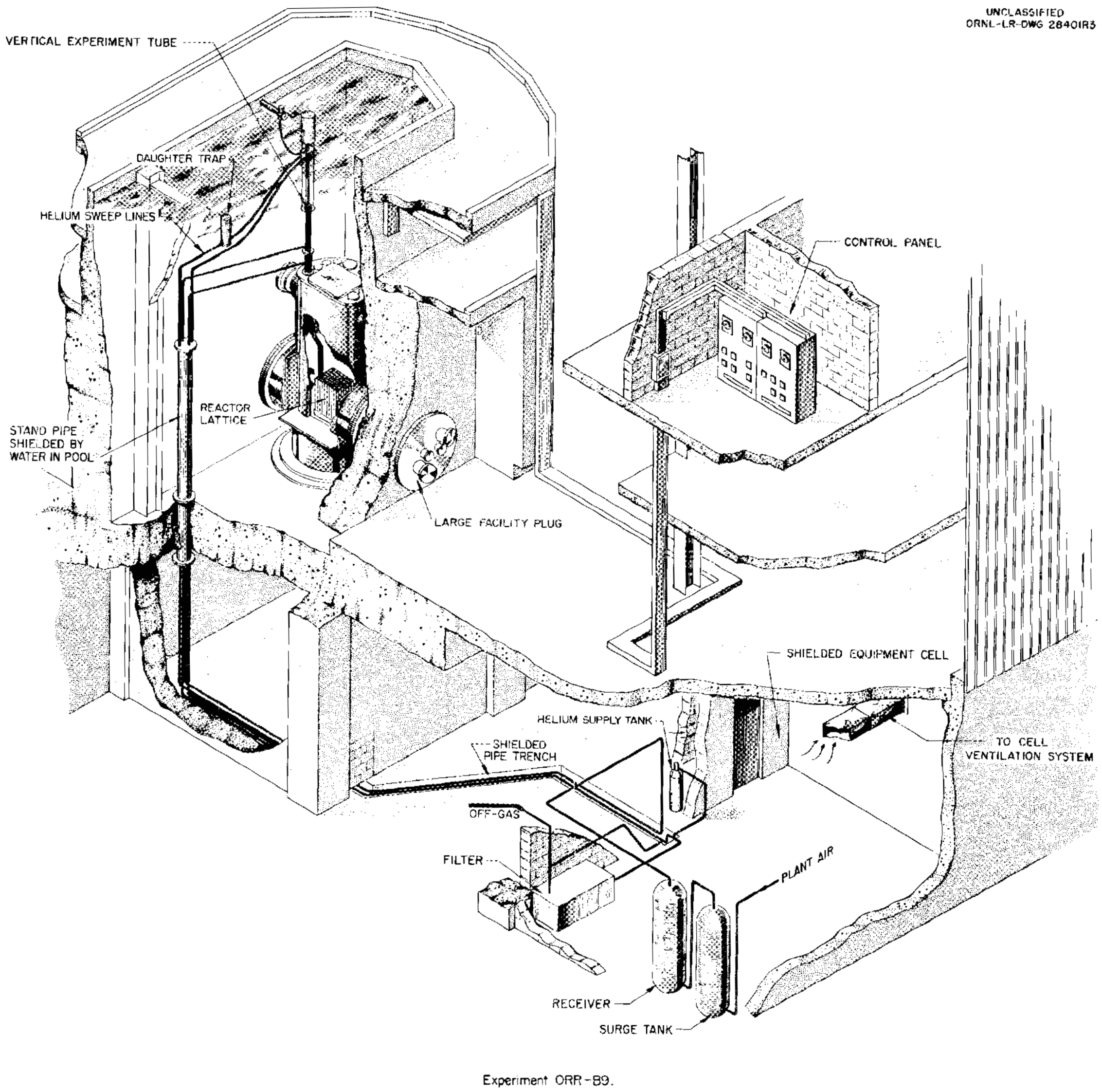

Fig. 4.8. Vertical loop experiment showing provisions for shielding piping and equipment.

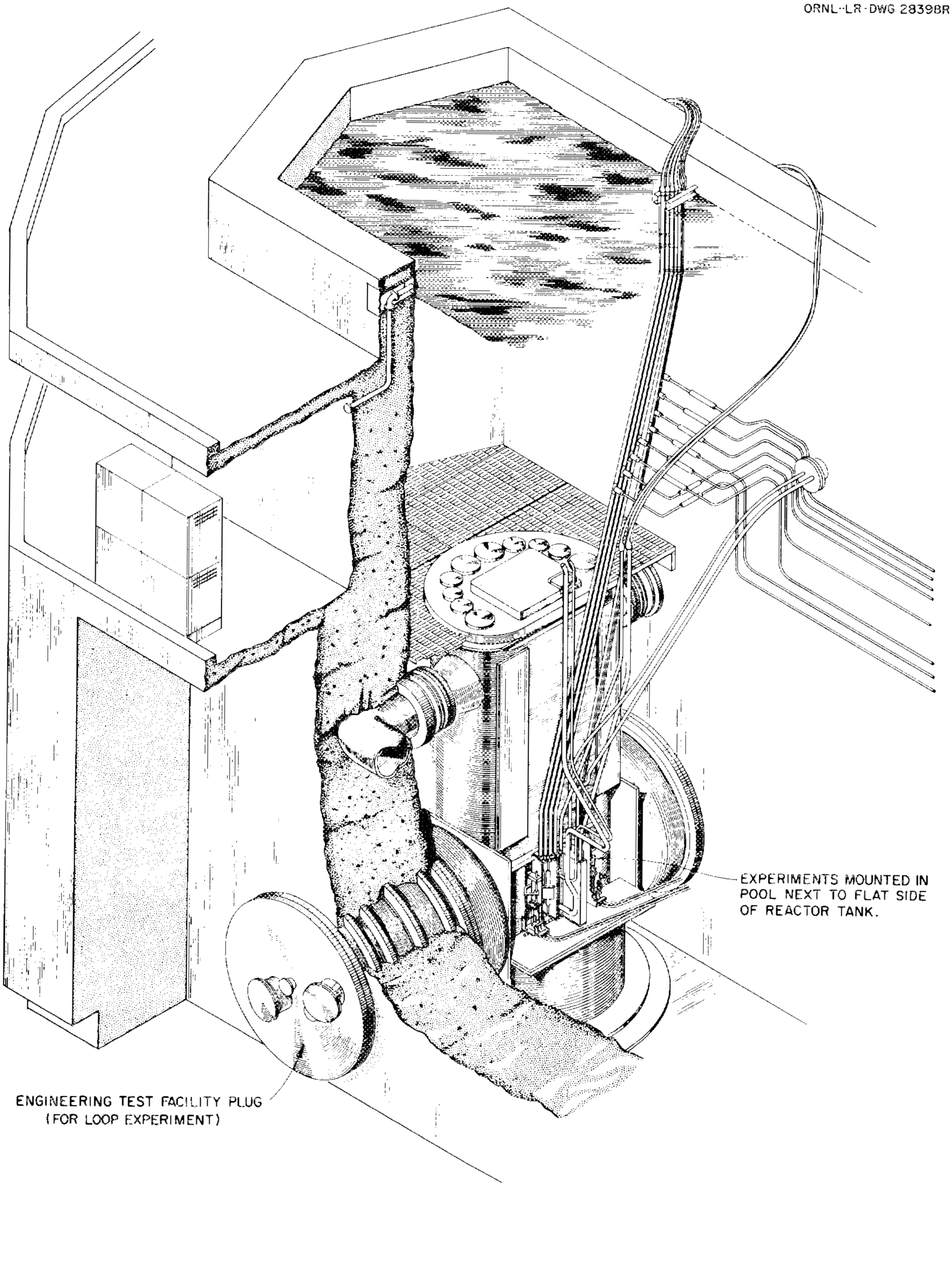

Fig. 4.9. Pool experiment showing simplicity of mounting next to reactor core.

4.1.6. Hot Cell Facilities

A hot cell, Fig. 4.10, is located above the west end of the storage pool. The cell is arranged so that irradiation targets or experiments may be transferred from the pool into the cell through openings in the bottom of the cell. It is intended for use in disassembly and preliminary inspection of experiments and targets.

The hot cell is divided into two sections, each of which has walls of dense concrete 3.5 ft thick. It is designed to shield 10^6 curies of ^{60}Co, or the equivalent, with a radiation level, outside the cell, of less than 5 mr/h. Each section is completely lined with stainless steel. The cell is equipped with sprays for cleaning, hot drains, and hot off-gas connections. For experimental work, a pneumatic hoist, manipulators, and lead-glass windows are provided for the necessary handling of irradiated materials inside the cell. The hot cell is operated by the Hot Cells Operations Group, Operations Division.

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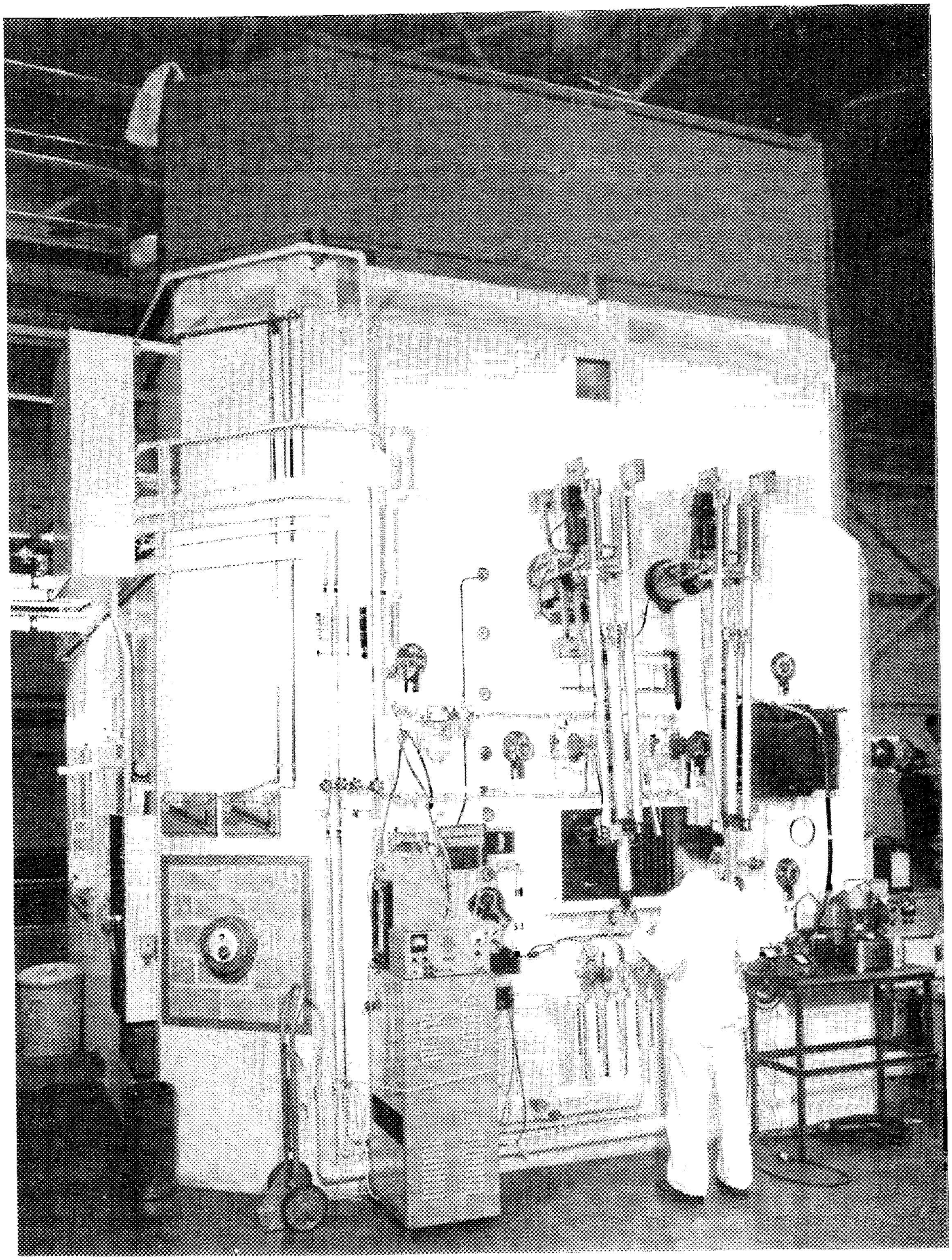

Fig. 4.10. ORR hot cell.

4.2. Experiments - Requirements and Procedures

4.2.1. Handling of Research Experiments (Approvals, Records, etc.)

1. Review and approval of new experiments and irradiation facilities.

   The procedures for initiating new research experiments from the time of first contact by the research personnel with Operations personnel until the termination of the experiment operation are detailed in ORNL/TM-8308, "Oak Ridge National Laboratory Research Reactor Experimenters' Guide."

2. Maintaining records on experiments

   a. Material and categories. Any pertinent information regarding the experiment (i.e., copies of all correspondence, the Experiment Review Questionnaire, records of meetings, commitments, blueprints, etc.) will be maintained on file. Such files will be categorized as either "active" (the experiment is proposed or in progress) or "inactive" (the experiment has been terminated and removed from the reactor).

   b. Reactor Experiment Coordinator. A file will be maintained by the Reactor Experiment Coordinator on all active experiments. Inactive files may be maintained for a period of time or destroyed depending on the discretion of the Reactor Experiment Coordinator. (In general, the material on file in this office will be the same material maintained on file in the Reactor Operations Section.)

   c. Reactor Operations Section. All pertinent information relative to the experiment will be maintained on file by the Reactor Operations Section (this includes copies of all material filed by the Reactor Experiment Coordinator).

For this section, files maintained on active and inactive experiments are listed below.

(1) Files on active experiments

(a) An experiment notebook containing the current Experiment Safety Checksheet, the Experiment Status Change Request Sheets, an Experiment Information Sheet, and other pertinent information is located in the ORR control room. (Prior to the beginning of each operating cycle, the contents of this notebook are checked by the Reactor Supervisor to ensure that all information is current.)

(b) Supplementary information (e.g., correspondence, prints, etc.) on each experiment is filed in the Reactor Supervisor's office. (This information is stored for a minimum of six months in these files.)

(2) Files on inactive experiments. An inactive file containing information on terminated experiments is retained in the Reactor Supervisor's office for reference purposes.

4.2.2. Checking on Safeguards Prior to Installing an Experiment into the Reactor

In order to eliminate, insofar as possible, experiments being installed without reliable instrumentation, all instrumentation must be checked prior to the insertion of the experiment into the reactor, both initially and before each reinstallation. The instrument field engineer will be required to perform the necessary checkout. If there is any question of the reliability of the safeguard instrumentation, the insertion of the experiment assembly will normally be delayed until a later shutdown.

4.2.3. Installing an Experiment Access Tube into the Core

1. Introduction

Experiment access tubes are installed in the reactor via special access flanges on the top of the reactor vessel (Fig. 4.6 illustrates typical installations). It is necessary that these access-tube assemblies be constructed with complex bends so that, once installed, they do not interfere with access to the core pieces or other experiments.

The access tubes terminate in the core; consequently, they must either fit into a standard hollow beryllium core piece or be equipped with special core inserts.

The experiment access tube is prefitted in the ORR mockup facility located in Building 3005. The following precautions apply.

2. Prefitting in the ORR mockup

a. Precautions

(1) There should be no handling of the irradiation capsule by Operations personnel unless the experimenter's representative is present. The experimenter is expected to make a similar arrangement with P&E.

(2) In the installation of the capsule in the ORR mockup for fitting up, a sufficient number of people must be on hand to do the necessary lifting and guiding of the capsule assembly into place while it is being hoisted by the crane. This should be the responsibility of the experimenter's representative with assistance from P&E and Operations' supervision.

(3) A chain-fall hoist should be used between the capsule assembly and the LITR hoist hook to allow small, careful lifting adjustments to be made. It will probably be necessary to provide some kind of platform on the mockup tank top to provide operator access to the chain fall.

b. Prefitting operation (performed by P&E personnel in the following manner)

(1) The core positions in the row and column of the core position receiving the experiment access tube are filled with core elements; this provides a means of checking the "fit" of the tube.

(2) The experiment access tube, with the associated core piece, is positioned in the selected core position.

(3) After lifting the tube 3/16 in. from the bottom of the core piece, the flange of the tube is tack welded to the tube.

(4) After the tack welding, the tube is checked again for proper fit. (An Operations' supervisor verifies the proper fit after both the tack weld and final welding.)

(5) The unit (flange-to-tube) can be permanently welded and, upon completion, should be checked again for proper fit.

(6) The experiment, after the final welding, is ready for insertion into the reactor. Removal from the mockup must be carefully accomplished by following the precautions given above.

3. Installation in the Reactor

a. Precautions

(1) Ensure that all Operations' rules regarding pool entry are followed. This includes providing radiation surveillance by Health Physics personnel when applicable.
NOTE: Experiment access tubes are usually inserted with the water in the reactor pool at grating level.

(2) Ensure that the actual insertion of the experiment assembly into the core is performed manually (i.e., using a chain fall or "come along" between the assembly and crane hook).

(3) Ensure that the gasket to be used between the experiment tube and the reactor tank is a full-faced gasket with its edges cut back 1/8 in. from the edge of the flange (inside and outside) to minimize the exposure of the gasket to the reactor water flow.

b. Preparations

(1) Prepare the core position to receive the experiment by removing the core piece already installed and ensuring that core pieces are in all positions directly north, south, east, and west of the core space. (For example, should the experiment assembly enter position C-2, then core pieces should be placed in all other "C" positions and all other "2" positions. This will provide a means of checking the "fit" of the tube.) Record all necessary transfers. (NOTE: Since preparation of the core normally requires handling of highly radioactive core pieces, such transfers should be completed before the water level is lowered.)

(2) Lower the water to grating level, if applicable.

(3) Survey the pool, post the radiation levels, and have a Radiation Work Permit prepared.

(4) Remove the blank flange from the proper access port and inspect the stud bolts for thread damage. If they show signs of galling, have them repaired or replaced.

(5) Provide an underwater light for illumination inside the tank during the insertion.

(6) Secure the experiment to the small crane (with rope) so that it is suspended in the vertical position. (NOTE: Use chain fall or "come along" between the experiment assembly and crane hook; the experiment assembly must be installed into the core manually.)

c. Procedure for installing the core insert and the experiment assembly

(1) Core insert

(a) Check the new core insert for proper dimensions, if applicable. (A previously irradiated core piece would, of course, be inserted into the core prior to lowering the water.)

(b) Determine that the core pieces adjacent to the new insert are neither too tight nor too loose.

(c) Lower the hold-down arms and determine that their freedom of movement and locking is not affected by the newly installed core piece. Raise the hold-down arms.

(2) Experiment assembly

(a) Ensure that all pertinent dimensions have been checked.

(b) Using the slow-speed crane control, lower the experiment assembly through the vessel's access port to within 6 to 12 in. of the top of the core. Avoid striking the core or other experiment tubes.

(c) Manually (i.e., using the chain fall or "come along") guide the tube into the core insert or into the empty core position (if the core piece is part of the experiment assembly).

(d) Adjust the tube for the best fit, making use of the special "slip flange" or triple flange if provided. Tighten the nuts securely.

(e) Repeat items c(1)(b) and (c); however, leave the hold-down arms down.

d. Vibration and leak checks

It is necessary that the experiment-access-tube installation be checked for leaks and/or excessive vibration which could result in harm to the reactor, the experiment, and/or personnel.

(1) Prepare the core for normal flow in accordance with the existing procedure. (CAUTION: Ensure that establishing the primary flow will not present any problems because of other work in progress on the water systems.)

(2) Replace the reactor tank access cover.

(3) Perform the startup checks pertaining to water flow. If the primary pumps are to be operated with the reactor pool water at the grating level, the north and south pressure equalization valve located in the lines from the north and south gas-removal tanks to the reactor vessel must be opened.

(4) Start the reactor water flow; and, gradually increase the flow rate while checking the experiment tube for vibration. (The tube can be seen through the plastic viewing window.)

(5) Check for water leaks at the access port.

(6) When the vibration tests are completed and the water level is at the grating, stop the primary pumps and close the north and south pressure equalization valves.

4.2.4. Final Checking of Experiment Safeguards (After Installation and Preceding Subsequent Startups)

1. Introduction

After the experiment assembly has been installed and connected to the reactor control circuitry, a final check on the safeguard instrumentation must be performed by the instrument engineer in charge of experiments. These tests are made while the reactor is shutdown by simulating the various alarm, setback, and scram conditions and verifying that their action is as stipulated in the circuitry diagram and/or experiment information sheet.

Although the initial experiment inspection and checkout is quite thorough, it is realized that the checkout cannot ensure that all safeguard instrumentation will continue to function properly throughout the lifetime of the experiment. Consequently, it is necessary that prestartup checks be made on all experiments each quarter and following experiment maintenance or revision.

2. General procedural requirements

   a. I&C personnel will prepare a checksheet indicating the parameters that are being monitored, the specific alarm, setback, reverse, and scram action setpoints and any equipment or utilities vital to the safe operation of the experiment (e.g., air, water, off-gas, etc.).

      Although some variations in the check sheet may be required from time to time to cover special features of some experiments, for general use the form illustrated in Example 4.1 should be used.

      The instrument portion of the checklist should be signed and dated by the instrument engineer in charge of experiments; the remainder will be completed by the Reactor Supervisor.

   b. Any unusual conditions such as erratic instrument readouts should be recorded on the check sheet and brought to the attention of the Reactor Supervisor.

   c. There shall be absolutely no modifications, changes, or alterations in any safeguard instrumentation on the experiment systeml without the written approval of the Reactor Supervisor. Before any changes may be made,

EXPERIMENT SAFETY CHECK SHEET

EXPERIMENT	CHECKED BY
REACTOR & FACILITY	DATE CHECKED
INSTRUMENTATION	

INSTRUMENT IDENTIFICATION	PROPERTY MONITORED	TRIP POINTS			BATTERY CONDITION	COMMENTS
		ALARM	SETBACK	SCRAM		

UCN-2011
(3 8-60)

Example 4.1

the changes proposed must be submitted in writing to the Reactor Supervisor for approval. (Copies of the proposed changes must also be sent to the Reactor Experiment Coordinator, the instrument engineer, and the experimenter.)

4.2.5. Requirements for Inserting an Experiment While the Reactor is Operating

1. Introduction

One of the many advantages of the ORR's experiment facilities is that some experiment assemblies may be designed to be inserted into the core, or removed, while the reactor is critical and operating at full power.

2. Precautions

a. The reactivity change resulting from inserting or removing the experiment assembly must be known to be less than 0.5% $\Delta k/k$. (This will be assessed by reviewing previous data in similar experiment assemblies or by a direct measurement.) If the reactivity worth of an experiment cannot be determined, the experiment will not be accepted for insertion into the reactor while the reactor is critical.

b. A written procedure and check sheet must be prepared by the experimenter and submitted to the Reactor Supervisor when such an experiment insertion (or withdrawal) from the core is to take place.

c. A locking device, approved by the Reactor Supervisor, shall be installed on those experiment assemblies having "insert-and-withdraw" features to ensure that the assembly does not enter the flux zone inadvertently.

d. The experiment instrumentation must be checked by placing the key-operated "E-panel" switch for the particular experiment in the TEST position; the alarm, setback, and scram circuits should then be checked from the experiment station to the E-panel station. These instrument checks are performed by an I&C engineer under the surveillance of the ORR shift supervisor.

e. The "E-panel" switch must be in the NORMAL position before the experiment is inserted into the core.

3. Procedure

a. Following the installation of the locking device described above, lower the experiment assembly into the experiment facility but not into the flux zone.

b. Ensure that the various connections required for the installation have been completed.

c. Ensure that the safeguard instrumentation from the experiment station to the E-panel has been checked by the instrument engineer following the above-mentioned work.

d. Turn the "E-panel" switch to the NORMAL position.

e. Ensure that, when an alarm and momentary setback is initiated from the experiment station, the proper annunciator in the control room alarms and there is an actual reduction in the reactor power. This is the final check required by the I&C engineer following the experiment installation.

f. Remove the locking device.

g. Insert the experiment into the flux zone.

h. File the I&C check sheet in the Experiment Notebook located in the ORR control room.

4.2.6. Requirements for Changes in Operating Experiments

1. Introduction

During the operating life of an experiment, it may be desirable or necessary to deviate from the normal operating conditions for which the experiment was initially approved. This may include changes in the experiment instrumentation or in the mechanical layout of the experiment. The request for a change may be initiated by the experimenter, Operations personnel, or the Reactor Experiment Review Committee. When a change in the operating parameters of the experiment or a mechanical change is desired, a formal procedure must be followed to ensure that thorough reviews are made.

If the proposed change results in operating conditions which exceed the levels for which the experiment was approved, the Reactor Supervisor will consult with the Reactor Experiment Coordinator who will decide if approval by the Reactor Experiment Review Committee is required. Evaluation of the proposed modifications will be made; and, if approved, the following procedure will apply.

2. Procedure

a. For a change in instrumentation

(1) An Experiment Status Change Request Form (Example 4.2) must be initiated by the experimenter. This form should be completed in detail and should include the alteration(s) requested and the reason(s) for them. It should also be signed by the experimenter.

(2) The Reactor Supervisor will sign the form if approval is given.

EXPERIMENT STATUS CHANGE REQUEST | DATE

REQUESTER

EXPERIMENT IDENTIFICATION

CHANGE(S) REQUESTED

REASON FOR CHANGE

PRECAUTIONS TO BE TAKEN

CHANGE(S) APPROVED BY

OPERATIONS

EXPERIMENTER

OTHER

CHANGE(S) COMPLETED BY

NAME

DIVISION | DATE

UCN-2166
(3 2-67)

Example 4.2

(3) The change request form will be given directly to the I&C foreman responsible for performing the work. The change will then be completed under his supervision.

(4) After the alteration(s) has been completed and the checkout of the affected circuit(s) completed [e.g., the alarm and setback circuits should be checked by actuating the switch(es) at the experiment and by observing that the proper response occurs in the reactor control system], the person(s) completing the job will sign the form to signify that the circuits perform as designed.

(5) The completed form will then be returned to the Reactor Supervisor; it will be placed in the Experiment Information Notebook to become a part of the experiment file. (After the experiment is terminated, this form and the other experiment information in the Experiment Information Notebook will be placed in the inactive experiment file.)

b. For a change in mechanical components

The experimenter requesting the change will, in essence, follow the same procedure as detailed in the preceding section. The exception would be that the work assignment will be given to the P&E foreman.

It should be noted that, on occasion, approval for a change may be given with just information indicated on "red-lined" prints. This is done to expedite a particular job; however, such authorization is given with the full understanding that the experimenter assumes the responsibility of having the indicated changes made on the original drawings with proper approvals.

In general, if the proposed alteration results in a change in operating parameters within the approved operating range, or, if the proposed change affects only part of an operating experiment's instrumentation and does not reduce the required number of safeguards, the change may be approved by the Reactor Supervisor.

If the proposed change(s) results in operating conditions which exceed the levels for which the experiment was approved, the Reactor Supervisor will consult with the Reactor Experiment Coordinator who will decide if approval by the Reactor Experiment Review Committee is required. Evaluation of the proposed modifications will be made; and, if approved, the above procedures will apply.

4.2.7. General Services to Unmanned Experiments

1. Introduction

Following the installation of an experiment, the research personnel generally observe their instrument readouts during the initial startup of the reactor to ensure that all conditions are satisfactory and to make any final adjustments, if applicable. However, during most of the operating time, experiments are not manned by the research personnel. In order to ensure that the experiments are monitored properly, certain surveillance-type services are provided by Operations Division personnel. The following procedures summarize the general services provided; and some guidelines are given for corrective action in the event difficulties are encountered.

2. General

Installed experiments fall within one of two categories: (1) retracted from the flux zone and (2) inserted into the flux zone. For those in category (1), the experiment will usually be unmanned both during reactor startup and during reactor operation. However, the experimenter must still verify that the experiment is ready for reactor startup. (This verification can be either verbal or written. At any rate, approval must be indicated in the Information Notebook.) For category (2), the experiment is normally manned during reactor startup; and communication between the experimenter and the Operations supervisor responsible for reactor startup must be established. Experiments in both categories must have all instrumentation checked out and so indicated by a completed Experiment Safeguard Check sheet; and their "E-panel" switches must be in the NORMAL position. [An exception to this would be an experiment in category (1) which is retracted and mechanically secured so that it cannot be inserted.]

Prior to reactor startup, those services requested by the experimenter will be indicated on the Experiment Information Sheet (Example 4.3). These sheets, approved by the Reactor Supervisor, are maintained in the Experiment Notebook located in the ORR control room. If further services are desired by the experimenter, a request must be submitted to the Reactor Supervisor for review. If approved, these additional instructions will be placed in the Special Instructions Book located in the control room. For requests of a minor nature (e.g., the occasional recording of data, icing a cold trap, etc.) a formal review by the Reactor Supervisor is not required. However, written

EXPERIMENT INFORMATION

DATE	APPROVED BY	DATE	CHECKED BY

APPROVAL LETTER ON FILE ☐ Yes ☐ No

EXPERIMENT CLASSIFICATION ☐ Repeat ☐ Near Repeat ☐ New

REMARKS:

EXPERIMENT LOCATION	REACTOR	DATE INSERTED	FACILITY

EXPECTED DURATION OF EXPERIMENT

BRIEF DESCRIPTION OF EXPERIMENT

WHOM TO NOTIFY IN CASE OF TROUBLE

NAME	BUSINESS PHONE	HOME PHONE

SPECIAL STARTUP INSTRUCTIONS

WHAT TO DO IN THE EVENT OF AN ACCIDENTAL SHUTDOWN

WHAT SERVICES (GAS, STEAM, CASKS, ETC.) ARE REQUIRED FOR THIS EXPERIMENT

WHAT TO DO IN THE EVENT OF POWER FAILURE

NOTIFY EXPERIMENTER BEFORE SCHEDULED SHUTDOWN?

UCN-4404 (3 6-76)

Example 4.3

SPECIAL CHECK OR READINGS TO BE MADE

POSSIBLE TROUBLES		
SIGNAL RESPONSE	CAUSED BY	WHAT TO DO
ALARM ONLY		
ALARM AND SETBACK		
ALARM AND SCRAM		

ANY OTHER INSTRUCTIONS

Example 4.3 (continued)

instructions for the Special Instructions Book are always applicable. In addition, all services performed must be logged by the shift supervisor under RESEARCH, item VI of the general, daily-log format.

3. Procedures for alarms and/or power reductions from experiments

If an alarm should occur, the experiment must be checked for verification that the alarm is for a real cause; and, if so, the experimenter should be notified. If a scram or setback from an experiment occurs, the reactor must remain shutdown or the power level held at N_L, until the trouble has been eliminated. Again, the person responsible for the experiment should be notified and, if necessary, asked to help repair the trouble. Also, if the abnormality results in a prolonged shutdown of the reactor, the Reactor Supervisor should be informed. (The special instructions on the experiment information sheet should always be checked when trouble occurs with an experiment.)

4. Emergency or accidental shutdown of the reactor

If an emergency or accidental shutdown should occur or a change in reactor power is required (not necessarily due to a research experiment), the experiment information sheets should be checked for any special requests concerning shutdowns (prior to startup). Generally, if the reason for the shutdown has been determined and the abnormality has been cleared, the reactor should first be returned to the original operating range (observing any requested rate of power increases from N_L to N_F) if only notification is requested by the research personnel. All the research experiments should be checked for any abnormalities after a reactor startup in any case.

5. Informing research personnel prior to utilities shutdown

The research experiments rely upon a continuous supply of utilities (i.e., water, electrical power, off-gas, etc.) whether the reactor is operating or not. Reactor Operations personnel should acquaint themselves with these utilities and the adjustments to be made to the equipment. When a shutdown of utilities is required (even though the reactor may be shutdown), research personnel using the utilities involved should be notified as soon as possible.

4.2.8. Handling of Instrument Failures in an Experiment's Safeguard Instrumentation

1. Introduction

Experiment instrument failure will occur on occasion; however, whenever possible, the condition should be handled safely and rapidly to minimize the loss of reactor operating time and to avoid having to reload the core. It should be recognized that, although reactor experiments have been approved with a minimum of safeguard instrumentation, under certain conditions it is feasible to block or disarm one channel of a dual-tracked safeguard provided it is definitely established that the experiment is functioning normally and that the trouble stems from a failed instrument.

2. General rules

The following rules concerning experiment instrument failures should be followed.

a. An experiment "E-panel" switch must never be turned to the TEST position while the experiment assembly is in the reactor core while the reactor is operating. Some experiment assemblies are designed to be retracted under abnormal conditions; however, this does not mean that the experiment is sufficiently retracted to be considered "out of reactor." The condition, if any, under which an experiment "E-panel" switch may be turned to TEST will be given in the Experiment Information Notebook.

b. Conditions under which certain instruments may be blocked out will be listed in the Experiment Information Notebook. If insufficient information is given, contact the Reactor Supervisor for advice as to what action should be taken.

c. If an approved method for disarming or blocking a failed experiment cannot be found, the reactor must be shut down rather than turn the "E-panel" switch to TEST.

d. If it becomes necessary to block an experiment recording instrument, this usually can, and may, be done by turning the recorder "on-off" switch to the OFF position and then driving the recorder indicator downscale to clear the alarm condition (refer to item 3).

e. When an instrument failure has occurred, the initial action should be to block the instrument, retract the experiment assembly, if possible, and start up the reactor. After the reactor has been returned to power, the experimenter should be notified and appropriate steps taken to repair the instrument.

f. If, of course, it is not obvious that an instrument failure has occurred, sufficient time must be taken to resolve the difficulty with the equipment. (This may lead to reloading the core since several telephone calls will probably be made, and the experimenter may want to check the experiment personally before the reactor is started again.)

g. Setpoints should never be adjusted to void safeguard action by an instrument.

h. If the operating conditions of an experiment in the reactor are to be changed, it may be advisable to change the setpoints. This, however, must not be done without permission from the experimenter and the Reactor Supervisor. If, for any reason, adjustments to setpoints involve exceeding the initial approved conditions, a comprehensive review must be made by the experimenter, the Reactor Supervisor, and the Reactor Experiment Coordinator. Such action will be documented by completing an experiment status change request form.

i. Special instructions given on the experiment information sheet will supersede any general rule if there is any conflict in instructions.

j. Prior to making telephone calls regarding an experiment failure, the shift supervisor should make a thorough check of all the experiment instrumentation, noting any abnormal conditions. (This may prevent subsequent calls.)

The purpose of this procedure is to emphasize the importance of handling instrument failures in a safe but rapid fashion. In order to do so, the shift supervisors must familiarize themselves with all experiments associated with the reactor safety system. (It is suggested that the shift supervisor familiarize himself with the blockout possibilities and other phases of each experiment as soon as it is installed rather than wait until troubles develop and then have to read and decide about corrections.)

3. Procedure for blocking out a malfunctioning instrument

Since all safeguard recorders have "fail safe" features (e.g., the indicator will drive full scale when a thermocouple opens), the reactor power level will be set back to N_L in the event of instrument failure. A general procedure to correct the condition (assuming there remains adequate safeguard instrumentation and safety is not jeopardized) is as follows:

a. Investigate the experiment control room and determine the nature of the failure.

b. Deactivate the instrument, if applicable. Generally, this means turning the recorder switch (inside the recorder cabinet) to the OFF position and then driving the recorder indicator downscale to clear the action setpoints.

c. The shift supervisor has the prerogative of: (1) posting an observer at the experiment instrumentation to monitor the operating parameters on the non-safeguard instrumentation and comparing them with the one remaining safeguard recorder -- with instructions to immediately cause the reactor to be shut down if comparative readings vary significantly or (2) use a preselected thermocouple (designated by the experimenter) to replace the faulty thermocouple. (The thermocouple replacement operation merely involves the removal of the plug of the faulty thermocouple from the thermocouple patch panel and inserting the plug of the designated replacement thermocouple.)

If adequate excess reactivity is available in the reactor, the latter (2) is the preferred option. If option (1) is selected, the experiment instrumentation must be manned by an observer until two duplicate safeguard instruments are reliable.

4.2.9. Removing an Experiment from the Core

1. Introduction

The procedure for removing an experiment assembly is, in essence, the reverse of the insertion procedure; however, since the experiment will now be highly radioactive, the usual radiation-exposure precautions must also be exercised. (This includes providing Health Physics coverage and an off-gas line when applicable.)

2. Removal from the core

a. Remove the bolts securing the flange to the reactor tank top (if applicable).

b. Provide an underwater light in the vessel.

c. Prepare the experiment assembly for removal from the tank by securing the experiment with ropes that are attached to the small crane.

d. Raise the experiment tube (including the core insert, if it is attached) until it is clear of the core. (CAUTION: This must be done manually; do not use the crane. A chain fall or other manually-operated lifting device may be employed if the assembly cannot be raised by hand.)

e. Transfer the experiment assembly to a storage location on the north or south wall of the reactor pool and attach a radiation tag (provide all the pertinent identification on the tag).

NOTE: When removing an experiment assembly from a "dry" experiment tube, the following rules must be observed.

a. Always provide an "off-gas" funnel.

b. When possible, pull experiment leads, thermocouples, etc., into a container (such as a section of Tygon hose) that is attached to the off-gas system.

c. Before removing the experiment assembly from the reactor in the shield, cover the shield with plastic to prevent the spread of any contamination which may have collected on the shield.

4.2.10. Monitors at Horizontal Beam Holes

1. Beam hole shutter position monitor alarm

Ref: Drawings Q-2949-1 and M-11284-PF-001-D

The horizontal beam holes, HB-1 through HB-6 are used for beam-type experiments which require that a beam of neutrons be emitted under controlled conditions from the reactor core through an open shutter and sample, before finally being absorbed in a neutron shield ("catcher").

Each beam hole is equipped with a shutter to stop the beam during maintenance or changes of samples. As a means for identifying the position of the shutter (whether or not it is open to provide a beam of neutrons) from a vantage point in the immediate vicinity, a monitoring system providing a visual and audible signal has been installed. Each of the beam holes has its individual system.

A system consists of shutter position sensing micro-switches which transmit signals to a "Tel-Alarm" unit. The "Tel-Alarm" will give an audible alarm and illuminate the red portion of the "Tel-Alarm" unit when the shutter is rotated to the "open" position. The alarm may be silenced by pressing the "acknowledge" button; however, the red portion will remain illuminated until the shutter has been closed. When the shutter is closed, the "all clear" condition exists illuminating only the white portion of the "Tel-Alarm" unit. The "Tel-Alarm" unit can then be returned to the "non-alert" condition (no illumination) by pressing the "reset" button.

These systems were designed and installed as an "information only" device, especially for personnel who frequent the vicinity, and it should be noted that each experimenter is responsible for his own and coworkers' safety by ensuring that all are familiar with the experiment.

2. Beam hole radiation monitor

Ref: Drawings Q-2091 series

A portable radiation monitor for a horizontal beam hole is available for service and usually placed in service by the ORR Health Physicist as deemed necessary. The detector is a beta-gamma, Geiger-Mueller tube used to monitor the background radiation level and transmit a signal to a Model No. Q-2091-1 electrometer. The detector is mounted on the beam hole shielding near the beam hole to be monitored. The electrometer, which has a maximum reading of 25,000 cpm and a variable alarm point, is equipped with a local alarm. The alarm setting is usually 15,000 cpm.

The purpose of this installation is to alert personnel in a beam hole area of changes in the radiation background. It does not supplant the Facility Radiation and Contamination Alarm System described in Section 9.2.

4.3. Handling and Scheduling of Small Irradiation Targets (Samples)

4.3.1. Introduction

The production of radioisotopes and the irradiation of small targets is a small but very significant function of the ORR. The very nature of these activities makes it extremely important that good quality assurance measures be employed in the preparation and handling of the targets. The following procedures and guidelines are to be employed in order to ensure efficiency and safety in these operations.

4.3.2. Facilities Available

Hydraulic tube No. 2, core position D8, was the principal facility used for isotope production and small target irradiations; however, presently, this facility is out of service. Also available for use are the poolside facility, the isotope stringer, and the N_F tray. Each of these facilities is described elsewhere in this manual.

4.3.3. Definition of Radioisotope Target (Small Target)

A target or sample is defined as a quantity of an element or compound, usually very carefully prepared, which will be irradiated to produce a transmutation. An experiment, by contrast, is irradiated for the production of data.

4.3.4. Requests for Irradiations

All requests for target irradiations will be processed through the Isotope Sales Group of the Operations Division. Standard request forms are available through this group, and a request form must be completed for each target irradiated. The Isotope Sales Group will determine that the target is properly packaged and sealed and will maintain records of leak tests performed. Other data relative to each target will be retained by the Isotope Sales Group.

4.3.5. Approval of Targets

All targets will be approved by the Reactor Experiment Coordinator of the Operations Division. The Isotope Sales Group will maintain a list of approved targets and packaging methods, making it unnecessary to contact the Reactor Experiment Coordinator when irradiations are simply duplicates of those previously approved.

4.3.6. Scheduling of Irradiations

Scheduling of irradiations of approved targets will normally be done by the Isotope Sales Group, working with the customer and the ORR day shift supervisor. It is essential that the reactor operating schedule, the shift schedule, and the customer's schedule all be considered during the scheduling process.

4.3.7. Target (Sample) Handling at the ORR and Irradiation Records

NOTE. All irradiation targets are popularly referred to as samples and will be designated as such in this portion of the procedure.

1. Logging in samples

Samples will be received by the ORR day supervisor. He will prepare an ORR Sample Schedule Sheet (Example 4.4) and also enter the required information in the ORR Sample Schedule log book which is maintained in the day shift supervisor's office. Information needed on the ORR Sample Schedule Sheet and in the log will be:

a. the irradiation facility to be used, and the position in that facility -- using remarks section if necessary;
b. the date the sample is submitted to ORR personnel;
c. the sample number (see instructions below);
d. the name of the person who approved the irradiation;
e. the name of the person receiving the sample
f. the material to be irradiated (chemical formula) and its weight;
g. the customer's name, division, and charge code;
h. the schedule dates and times for the irradiation;
i. the scheduled dates and other information relative to disposition (shipping) of the irradiated sample; and
j. any other information pertinent to the handling or storing of the samples.

4.3.8. Inspection of Samples

The supervisor who receives the sample will personally inspect that sample before accepting it for irradiation. An inspection is made of the container to ensure physical condition is acceptable and that it is the correct size dimensionally. The supervisor will look for anything odd and will see that the description in the sample book is correct. He will also verify that the sample has been processed through Isotope Sales and has been properly leak tested.

ORR SAMPLE SCHEDULE SHEET

☐ HYDRAULIC TUBE NO. 2

☐ OTHER (Specify) ____________

DATE	SAMPLE NO.
APPROVED BY	RECEIVED BY
MATERIAL AND WEIGHT	
CUSTOMER	DIVISION
CHARGE CODE	POWER LEVEL REQUIRED

IRRADIATION TIME SCHEDULE

	SCHEDULED		ACTUAL		
	DATE	TIME	DATE	TIME	BY
IN					
OUT					

TUBE NO. 21 22 23 24 25 HYD. TUBE ONLY

POSITION (EAST TO WEST) 1 2 3 4 5 HYD. TUBE ONLY

FLOW METER READINGS (HYD. TUBE ONLY)

NO. 1	NO. 2	NO. 3	NO. 4	NO. 5

DISPOSITION	PICKUP BY	DATE	TIME
SCHEDULED			
ACTUAL			

REMARKS:

UCN-5561A (3 5-76)

Example 4.4

4.3.9. Identification of ORR Irradiation Samples

In order to give efficient service to all customers, it is imperative that the exact location of all samples be known at all times. To accomplish this, each sample submitted for irradiation will be assigned a number as described below.

1. Capital letters in alphabetical order will designate the operating year and Arabic numerals will designate the month during which the sample is inserted into the reactor.
2. Samples irradiated during each month will be numbered consecutively beginning with 1 for the first sample each month. A dash will separate this number from the preceding month-identification number.
3. For example, the first sample number to be assigned in May 1958 was A-5-1, the second A-5-2. The first sample assigned in January 1962 was E-1-1 indicating the first sample in the first month of the fifth year of operation.
4. The numbers shall be clearly etched with a vibratool in at least two places so that difficulty in identifying samples after irradiation will be minimized.

4.3.10. Sample Schedule Rack

A rack located in the control room serves as a storage place for unirradiated samples and "sample schedule sheets" for the ORR and BSR. The rack consists of clips for storing schedule sheets of samples prior to irradiation, slots above the clips for sample sheets which refer to samples being irradiated, and slots for sample sheets for samples in postirradiation storage. In addition, there are spaces below the clips for preirradiation storage of identified samples.

4.3.11. Irradiation of Samples or Targets

1. The sample or target to be irradiated, along with its schedule sheet, will be placed in the control room by the day shift supervisor. After being numbered, the sample or target will be placed in the storage rack in the control room or be stored in an appropriate shielded container if radioactive.
2. At the time designated on the sample sheet, the roving operator will place the sample or target in the designated position for the irradiation, using appropriate procedures.
3. The operator will make appropriate entries on the sample schedule sheet and then place that sheet in the proper slot on the control room sample schedule rack.
4. The roving operator, at the beginning of his shift, checks the sample schedule rack to determine if any samples are to be inserted or retracted during his shift.
5. At the time indicated on the sample schedule sheet, the operator will remove the sample from the designated irradiation position and store the sample in an appropriate storage position or will ship the sample via shielded container.
6. The operator will, after sample removal, make appropriate entries on the sample schedule sheet and either:
   (a) give the carbon copy of the schedule sheet to the person claiming the sample and place the original schedule sheet in the control room, or
   (b) place the sample schedule sheet in the proper slot (postirradiation storage) on the sample sheet rack.
7. The original copy of the schedule sheet, after the sample is claimed, goes to the day shift supervisor for filing. He will make appropriate entries in the sample log book if necessary.

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