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MASTER

High Flux Beam Reactor

HFBR PHYSICS STARTUP MANUAL

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

by
C. SASTRE

October, 1965

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

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BROOKHAVEN NATIONAL LABORATORY

Upton, New York

PHYSICS STARTUP MANUAL

1. Initial Reactor Loading and Criticality
2. Control Rod Calibration
3. Helium Pressure Effect
4. Coolant Flow Effect and Neutron Lifetime Measurement
5. Uniform Temperature Coefficient of Reactivity
6. Reactivity Effect of Thimbles and Samples
7. Partial Core Loadings
8. Reactor Noise Measurement and Xenon Effect at Intermediate Powers
9. Power Reactivity Coefficient
10. Xenon Effect Measurement at Low Power
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INITIAL REACTOR LOADING AND CRITICALITY

This phase of startup operations begins when the preoperational checks have been finished, and it ends when the reactor core is fully loaded.

I. CONDITIONS AT TIME OF BEGINNING OF LOADING

A. The initial reactor loading procedures can only begin after the following conditions are met:

1. The system test with light water has been completed, and all process instrumentation has been proven operational.
2. Control rod drive mechanisms have been checked and found to conform to specifications (rod drop time, rod withdrawal speeds, rod position indicators).
3. Poison water system has been loaded with poison and is known to be operable.
4. The core is loaded with dummy fuel elements.
5. The primary system is loaded with heavy water that has been analyzed for isotopic purity after mixing by circulation in the primary system.
6. The emergency electrical supplies are operable.
7. The intercommunication system is operating and adequate.
8. The nuclear instrumentation, safety system, and the additional startup nuclear instrumentation have been checked after installation and found operational.
9. A neutron source of approximately 10^7 n/sec is located in one of the in-core irradiation thimbles.
10. At least three independent neutron detection channels show unmistakably the effect of inserting and removing the source.

B. Note on Additional Instrumentation

In order to insure compliance with point 10 above, three counters (BF^3 or fission) and three ion chambers will supplement the normal reactor channels. These ion chambers and counters will be located in beam tubes, and their outputs will be displayed in the control room. The three ion chamber channels will have micro-microammeters and strip chart recorders. The trips of the micro-microammeters will be connected to the scram system of the reactor in a one-out-of-three logic, with a trip level at the full scale of the range setting in use. The ion chambers and counters, together with associated electronics and recorders and cables, will be supplied by Experimental Reactor Physics at least three days prior to the planned start of fuel loading. Installation and tests will be performed jointly by personnel of Experimental Reactor Physics and of Reactor Operations.

Two ion chambers for the reactivity computer will be installed in symmetrically located beam tubes.

C. Note on Temporary Safety System Changes

During the initial loading, the reactor will be unpressurized and there will be no primary D_2O flow.

The following scram and setback functions will be deactivated at the trip relays before the experiment starts and will be returned to the normal activated condition after the experiment is finished. The activation and deactivation of the trip relays will be done by the instrument technician under instructions and supervision by the Reactor Supervisor in charge of the reactor at the time, and will be noted in the Log Book.

PdRa-101	Core Diff. Pressure
PdA-102	Core Diff. Pressure
PdA-103	Core Diff. Pressure
FRa-100	Primary Coolant Flow
GA-101A	Primary Pump Power
GA-101B	Primary Pump Power
PRCa-101	Reactor He Pressure
PA-102	Reactor He Pressure
PA-103	Reactor He Pressure
GA-102A	Shutdown Pump Power
GA-102B	Shutdown Pump Power

The following trip functions will be operable during the initial loading.

Nuclear Channel 1	Power	Scram, Setback
Nuclear Channel 2	Power	Scram, Setback
Nuclear Channel 3	Power	Scram, Setback
Startup Channel 1	Power	Scram
Startup Channel 2	Power	Scram
Startup Channel 3	Power	Scram
LRa-101	Primary Coolant Level	Scram
LIa-106	Primary Coolant Level	Scram
LA-102	Primary Coolant Level	Scram
Manual Scram, Buttons 1-7		
FRa-201	Lower Thermal Shield Coolant Flow	Setback
GA-201A	Thermal Shield Pump Power	Setback
GA-201B	Thermal Shield Pump Power	Setback
FIa-203	Shutter Coolant Flow	Setback
GA-203A	Biological Shield Pump Power	Setback
GA-203B	Biological Shield Pump Power	Setback
TRa-101	Core Inlet D ₂ O Temperature	Setback
TIa-103	Core Inlet D ₂ O Temperature	Setback
TIa-104	Core Inlet D ₂ O Temperature	Setback
PIa-101A/PIa-301A	Primary-Secondary Pressure Difference	Alarm
PIa-101B/PIa-301B	Low Primary-Secondary Pressure Difference	Alarm
PIa-201	Low Helium Pressure Supply Manifold	Alarm
PIa-202	High Helium Pressure Supply Manifold	Alarm
PA-301	Low Instrument Air Pressure	Alarm
LIa-201	Low Level H ₂ O in Thermal Shield Tank	Alarm
LA-307	Low Level H ₂ O in Canal	Alarm
CRa-2	High Primary D ₂ O Conductivity	Alarm
CAB-1	D ₂ O Leak to Air, Equipment Level Stations	Alarm
CAB-2	D ₂ O Leak to Air, Operations Level Stations	Alarm
48 VDC	48 VDC Switch Gear Power Supply Off	Alarm

In addition, all indicating instruments will be operative.

II. INITIAL REACTOR STARTUP PROCEDURE

A. Preliminary Preparations

The following steps required to prepare the reactor for startup appear in a critical startup list which must be completed by the Shift Supervisor prior to the initial loading.

1. Test the emergency generator for proper operation.
2. Test the Radiation Monitoring System according to the Operating Manual.
3. Inspect the reactor vessel for debris.
4. Adjust the D_2O level to the fuel handling level (249 in.).
5. Check to see that all instruments are normal according to the Operating Manual.
6. Check building containment and instrument air system according to the Operating Manual.
7. Check that the vessel opening is covered with a dust cover and underwater lights are in place.
8. Check that the trip circuits conform to the table of "Temporary Safety System Changes."
9. Check that the three startup channels "see" the neutron source by removing and reinserting the source.
10. Check that the pump motor breakers are racked out and padlocked.

B. Startup Procedure

1. Check that the pumps do not start when activating the appropriate switches with the console energized.

2. Set the range switch on the power level indicator, channel No. 4 to the highest sensitivity setting.
3. Set the range switches of the three startup channels to a setting giving a reading of about one third of full scale.
4. Check that the startup scalers are counting and that they give an audible indication of count rate, at the console and at the fuel loading station.
5. Drive the fission chambers for channels 7 and 8 of the count rate system to the down position or until the count rate meters read 10 cps.
6. Turn on the lock down switch on the console.
7. Announce the following on the PA system, "Attention, please" repeat ... "The reactor is starting up" repeat ...
8. Withdraw the main rod crown 5 in.
9. Unload the first dummy element (see attached drawing), and load a live fuel element in its place, according to the Operating Manual. Observe the power channels for changes in level. Place a temporary dust cover over the vessel opening and evacuate all personnel from the reactor pit area.
10. Announce the following on the PA system, "Attention, please" repeat ... "Control rods going out" repeat ...
11. Withdraw carefully the main rod crown and the auxiliary crown, and observe the nuclear instruments.
12. Record the readings of all operative ion chamber and counting channels to be used in inverse multiplication plots.
13. Reinsert the auxiliary rod crown and the main rod crown completely, repeat (12) and (8).

14. Unload the second dummy element from the position indicated on the attached chart, and load a live fuel element in its place, according to the Operating Manual. Observe the power channels for change in level.
15. Repeat steps (10) through (13).
16. Successive fuel elements shall be loaded one at a time, replacing dummy elements, according to the sequence shown on the attached drawing.
17. During the insertion of each fuel element and removal of each dummy, the operator shall observe the power level meters for signs of criticality. The insertion of each fuel element in its place in the core shall be slow.
18. After insertion of each fuel element, readings of all nuclear channels shall be recorded, with the rods out if the reactor is subcritical and with the rods in in all cases. These data are plotted as inverse multiplications vs. fuel loading, beginning with the first loading.
19. The loading of each fuel element will be authorized by the Reactor Division Head or his designee, with the concurrence of senior members of the Experimental Reactor Physics Division of the Nuclear Engineering Department.
20. Once the reactor attains criticality and after each loading, shutdown reactivity measurements shall be made (by scrambling the reactor) using a reactivity computer. The source will be removed for this measurement and reinserted after it.
21. The critical position of the main rod crown and auxiliary rod crown in symmetrical patterns will be recorded following loading of each element, to serve as guidance for the next loading.
22. After the loading of the core is completed the vessel will be closed.
23. Fuel elements are to be withdrawn from the vault and taken to the reactor pit singly, and only at the time needed for loading. Fuel element numbers and positions will be recorded in the Log Book.

24. The initial critical loading shall be performed under the immediate direction of the Reactor Division Head or his designee.

25. After the reactor is shut down, the Reactor Supervisor in charge of the reactor at the time will instruct the instrument technician to return the safety system to normal and will supervise this action, and this will be noted in the Log Book.

C. Personnel Restrictions

Access to the control room and loading areas and experimental floor shall be restricted to those directly involved in the startup experiments. A list of assignments of responsibility will be circulated to the RCESC in advance of the startup.

HFBR LOADING SEQUENCE

CONTROL ROD CALIBRATION

This set of measurements follows the initial reactor loading and criticality, and precedes all other physics experiments.

I. CONDITIONS AT THE TIME OF INITIATION

A. Note on Additional Instrumentation

In addition to the instrumentation required for the Initial Loading and Criticality, two boron coated ion chambers will be located in beam tubes at symmetrical positions relative to the reactor core. The output of those ion chambers will be added by an operational amplifier of computer quality. The summed signal will serve as input for the analog computer.

Signals from the rod position sensing potentiometers of each rod drive will be available at the analog computer station.

B. Note on Temporary Safety System Changes

During the control rod calibration runs, the reactor power need only be raised to levels of a few tens of watts, as needed to attain a summed current of about 10^{-6} amperes from the above two ion chambers. The reactor will be operated without flow or pressurization. The following scram and setback functions will be deactivated at the appropriate logic panel terminal board before the experiment starts and will be returned to the normal activated condition after the experiment is finished.

The activation and deactivation of the trip relays will be done by the instrument technician under instructions and supervision of the Reactor Supervisor in charge of the reactor at the time, and will be noted in the Log Book.

PdRa-101	Core Diff. Pressure
PdA-102	Core Diff. Pressure
PdA-103	Core Diff. Pressure
FRa-100	Primary Coolant Flow
GA-101A	Primary Pum Power

GA-101B	Primary Pump Power
PRCa-101	Reactor He Pressure
PA-102	Reactor He Pressure
PA-103	Reactor He Pressure
GA-102A	Shutdown Pump Power
GA-102B	Shutdown Pump Power

The following trip functions will be operable during the control rod calibration runs.

Nuclear Channel 1	Power	Scram, Setback
Nuclear Channel 2	Power	Scram, Setback
Nuclear Channel 3	Power	Scram, Setback
Startup Channel 1	Power	Scram
Startup Channel 2	Power	Scram
Startup Channel 3	Power	Scram
LRa-101	Primary Coolant Level	Scram
L1a-106	Primary Coolant Level	Scram
LA-102	Primary Coolant Level	Scram
Manual Scram, Buttons 1-7		
FRa-201	Lower Thermal Shield Coolant Flow	Setback
GA-201A	Thermal Shield Pump Power	Setback
GA-201B	Thermal Shield Pump Power	Setback
F1a-203	Shutter Coolant Flow	Setback
GA-203A	Biological Shield Pump Power	Setback
GA-203B	Biological Shield Pump Power	Setback
TRa-101	Core Inlet D ₂ O Temperature	Setback
T1a-103	Core Inlet D ₂ O Temperature	Setback
T1a-104	Core Inlet D ₂ O Temperature	Setback
PIa-101A/PIa-301A	Primary-Secondary Pressure Difference	Alarm
PIa-101B/PIa-301B	Low Primary-Secondary Pressure Difference	Alarm
PIa-201	Low Helium Pressure Supply Manifold	Alarm
PIa-202	High Helium Pressure Supply Manifold	Alarm
PA-301	Low Instrument Air Pressure	Alarm
L1a-201	Low Level H ₂ O in Thermal Shield Tank	Alarm
LA-307	Low Level H ₂ O in Canal	Alarm

CRA-2	High Primary D ₂ O	Alarm
CAB-1	D ₂ O Leak to Air, Equipment Level Stations	Alarm
CAB-2	D ₂ O Leak to Air, Operations Level Stations	Alarm
48 VDC	48 VDC Switch Gear Power Supply Off	Alarm

In addition, all indicating instruments will be operative.

II. REACTOR STARTUP PROCEDURE

A. Preliminary Preparations

The following steps appear in a Low Power startup list, and they must be completed by the Shift Supervisor prior to startup.

1. Test the emergency generator for proper operation.
2. Test the Radiation Monitoring System as per Operating Manual.
3. Check to see that all instruments are normal as per Operating Manual.
4. Check building containment and instrument air system as per Operating Manual.
5. Check that the trip circuits conform to the table of "Temporary Safety System Changes."
6. Check that the three startup channels "see" the neutron source, by removing and reinserting the source.
7. Check that the pump motor breakers are racked-out and padlocked.

B. Startup Procedure

1. Check that the pumps do not start when activating the appropriate switches with the console energized.

2. Set the range switch on the power level indicator, channel No. 4, to the highest sensitivity setting.
3. Set the range switches of the three startup channels to settings giving readings of about one third of full scale.
4. Drive the fission chambers for channels 7 and 8 of the count rate system to the down position, or until the count rate meters read 10 cps.
5. Turn on the lock down switch on the console.
6. Announce the following on the PA system, "Attention, please," repeat . . . , "The reactor is starting up," repeat . . .

C. Calibration of Rods in Main Crown

1. Withdraw the rod to be calibrated completely. Withdraw the main control rod crown to the estimated critical position. Withdraw the auxiliary rod crown to reach criticality, and take the reactor to a power sufficient to give a neutron signal of 80% of full scale on the reactivity computer. The power is not to exceed a level giving ten microamps ion chamber current from any of the startup chambers. Withdraw the source.
2. Maintain reactor power constant until the reactivity required to keep the power steady is less than 0.002 dollars.
3. Release the electromagnetic clutch of the rod to be calibrated.
4. After approximately 10 sec, withdraw completely the released rod to bring the reactor critical, and, using the auxiliary crown, stabilize again at a power that gives a neutron signal of 80% of full scale on the reactivity computer. Repeat step 2. At the end of step 2, the upper crown should be at the same configuration as at the end of step C2, and the auxiliary crown should be balanced.*

*Balancing the rods in a crown means equalizing the insertion of the rods in that crown.

5. After the reactivity computer is ready, drive the main rod to be calibrated "in" until the power reaches one percent of the original value.
6. Return the reactor to power with the auxiliary rod crown and repeat step 2.
7. Continue repeating steps 5 and 6, starting the motion of the rod from the position at which it was left at the end of the previous iteration, until the rod is fully seated.
8. Repeat procedure for the other main rods.

D. Calibration of Rods in Auxiliary Crown

1. Fully withdraw the auxiliary rod crown balancing with the main rod crown to reach criticality, and take the reactor to a power sufficient to give a neutron signal of 80% of full scale on the reactivity computer. The power is not to exceed a level giving ten microamps ion chamber current from any of the startup chambers. Withdraw the source.
2. Maintain reactor power constant, using the main crown, until the reactivity required to keep the power steady is less than 0.002 dollars.
3. After the reactivity computer is ready, drive the auxiliary rod to be calibrated "in" until the power reaches one percent of the original value.
4. Return the reactor to power with the main rod crown and repeat step 2.
5. Continue repeating steps 3 and 4, starting the motion of the auxiliary rod from the position at which it was left at the end of the previous iteration, until the rod is fully seated.
6. Repeat procedure for the other auxiliary rods.

E. Calibration of an Unshadowed Control Rod

The object of this experiment is to get an easily reproducible control rod pattern to measure reactivities by control rod compensation.

This reference pattern will consist of one of the main control rods partially inserted to about the core center line, the two neighboring rods removed and the rest of the rods each in an either in or out position. This reference pattern should make the reactor critical. The numbers of the control rods are given for illustration, and for convenience at the time of the experiment, they may be changed cyclically.

1. Remove the rods according to the following sequence, until criticality is reached.

M4, A4, M3, A3, M5, A5, M2, A2, M6, A6, M1, A1, M7, A7

The reactor is expected to become critical during the removal of M1.

2. Insert the last partially removed rod and return the reactor to critical with M8. Remove the source.
3. Using M8, take the reactor to a power corresponding to 80% of full scale in the reactivity computer. This power will not exceed the level necessary to obtain an ion-chamber current of ten microamps from any of the start-up channels.
4. Maintain the reactor power constant with M8 until the reactivity required to keep the power steady is less than 0.002 dollars.
5. After the reactivity computer is ready, drive rod M4 in until the power reaches one percent of the original value.
6. Return the reactor to critical using M8.
7. Repeat steps 3, 4, 5, and 6 until the rod M4 is fully seated. When M8 is fully withdrawn, use M1 or M7 for compensation.

F. Rod Crown Calibration

1. Withdraw the main rod crown a few inches to a position such that the reactor is subcritical with the auxiliary crown out.
2. Withdraw the auxiliary crown.

3. Withdraw the main rod crown to reach criticality. Remove the source.
4. Take the reactor to a power sufficient to give a neutron signal of 80% of full scale on the reactivity computer, P_0 , using the main rod crown. The power is not to exceed a level giving ten microamps ion chamber current from any of the startup chambers.
5. Maintain reactor power constant, using the main crown until the reactivity required to keep the power steady is less than 0.002 dollars.
6. After the reactivity computer is ready to record, drive the auxiliary rod crown "in" until the power reaches 1% of the original value.
7. Return the reactor to the power indicated in 4 by the use of the main rod crown.
8. Repeat step 5.
9. If the auxiliary rod crown is not completely balanced (because of differences in the drive speeds), readjust them to a balanced position without moving the main rod crown. The reactor should be critical within 0.002 dollars and the rods of the main crown should be where they were left at the end of step 8.
10. Repeat steps 6, 7, 8, and 9 until the auxiliary rod crown is fully seated.
11. Repeat steps 3, 4, and 5.
12. Without moving the auxiliary crown, balance the rods in the main crown. Adjust the main crown to maintain a steady power, P_0 , and a reactivity within 0.002 dollars of critical.
13. After the reactivity computer is ready to record, drive the main rod crown "in" until the power reaches 1% of the original value.

14. Return the reactor to power P_0 using the auxiliary rod crown and keep the reactor power constant and within 0.002 dollars of reactivity.

15. Repeat steps 12, 13, 14, and 15 until the auxiliary rod crown is fully withdrawn.

16. Shut the reactor down.

17. After the reactor is shut down, the Reactor Supervisor in charge of the reactor at the time will instruct the instrument technician to return the safety system to normal and will supervise this action, and this will be noted in the Log Book.

If at the start of C, D, E, or F, the delayed neutron source produces readings on the instruments which are equal or larger than those attainable with the external neutron source, insertion of the source is not required.

HELIUM PRESSURE EFFECT

This phase of the startup follows the control rod calibrations. The object of the experiment is to determine the reactivity changes produced by pressurizing the vessel. Pressure changes during normal operation should only influence the reactivity through elastic deformation of the system due to stress (e.g., the vessel and control rods can move slightly relative to the core). If the system is pressurized when the coolant is stagnant, other reactivity effects can be produced, such as through collapse of gas bubbles adhering to fuel elements. In this experiment, reactivity effects of pressure changes will be measured both with stagnant and flowing D_2O .

I. CONDITIONS AT THE TIME OF INITIATION

A. Note on Additional Instrumentation

The additional instrumentation required for the initial loading, including the reactivity computer, will be retained during this operation.

A signal from the Reactor He Pressure transducer will be available at the reactivity computer station.

B. Note on Reactor Changes

The reactor vessel shall be closed and bolted.

C. Note on Temporary Safety Changes

During the Helium Pressure effect run, the reactor will be operated at various pressures and at full and zero primary D_2O flow. The power will not exceed a few tens of watts, as required to give a summed current of 10^{-6} amperes from the two ion chambers located in beam tubes. The following scram and setback functions will be deactivated at the appropriate logic panel terminal board before the experiment starts and will be returned to the normal activated condition after the experiment is finished. The activation and deactivation of the trip relays will be done by the instrument technician under instructions and supervision of the Reactor Supervisor in charge of the reactor at the time, and will be noted in the Log Book.

PdRa-101	Core Diff. Pressure
PdA-102	Core Diff. Pressure
PdA-103	Core Diff. Pressure
FRa-100	Primary Coolant Flow
GA-101A	Primary Pump Power
GA-101B	Primary Pump Power
PRCa-101	Reactor He Pressure
PA-102	Reactor He Pressure
PA-103	Reactor He Pressure
GA-102A	Shutdown Pump Power
GA-102B	Shutdown Pump Power

The following trip functions will be operable during the Helium Pressure effect run.

Nuclear Channel 1	Power	Scram, Setback
Nuclear Channel 2	Power	Scram, Setback
Nuclear Channel 3	Power	Scram, Setback
Startup Channel 1	Power	Scram
Startup Channel 2	Power	Scram
Startup Channel 3	Power	Scram
FRa-201	Lower Thermal Shield Coolant Flow	Setback
GA-201A	Thermal Shield Pump Power	Setback
GA-201B	Thermal Shield Pump Power	Setback
FIa-203	Shutter Coolant Flow	Setback
GA-203A	Biological Shield Pump Power	Setback
GA-203B	Biological Shield Pump Power	Setback
TRa-101	Core Inlet D ₂ O Temperature	Setback
TIa-103	Core Inlet D ₂ O Temperature	Setback
TIa-104	Core Inlet D ₂ O Temperature	Setback
LRa-101	Primary Coolant Level	Scram
LIa-106	Primary Coolant Level	Scram
LA-102	Primary Coolant Level	Scram
Manual Scram, Buttons 1-7		
PIa-101A/PIa-301A	Primary-Secondary Pressure Difference	Alarm
PIa-101B/PIa-301B	Low Primary-Secondary Pressure Difference	Alarm
PIa-201	Low Helium Pressure Supply Manifold	Alarm

PIa-202	High Helium Pressure Supply Manifold	Alarm
PA-301	Low Instrument Air Pressure	Alarm
L1a-201	Low Level H ₂ O in Thermal Shield Tank	Alarm
LA-307	Low Level H ₂ O in Canal	Alarm
CRA-2	High Primary D ₂ O Conductivity	Alarm
CAB-1	D ₂ O Leak to Air, Equipment Level Stations	Alarm
CAB-2	D ₂ O Leak to Air, Operations Level Stations	Alarm
48 VDC	48 VDC Switch Clear Power Supply Off	Alarm

In addition, all indicating instruments will be operative.

II. REACTOR STARTUP PROCEDURE

A. Preliminary Preparations

The following steps appear in a special startup list, and they must be completed by the Shift Supervisor prior to the startup for the experiment.

1. Test the emergency generator for proper operation,
2. Test the Radiation Monitoring Systems according to the Operating Manual.
3. Adjust the D₂O level to 264 in.
4. Check to see that all instruments are normal according to the Operating Manual.
5. Check building containment and instrument air system according to the Operating Manual.
6. Establish He inlet flow and set helium pressure controllers to 10 psig thus pressurizing the reactor vessel. Check the vessel for leak-tightness at the top closure and periscope closure.

7. Lower the D_2O level to normal cold operating level of 226 in.
8. Set helium inlet pressure to 120 psig to pressurize the reactor vessel.
9. Establish normal secondary water flow as per "Secondary Cooling Water System Operating Procedures" in the Operating Manual.
10. Start primary cooling system flow as per "Primary Cooling Water System Operating Procedures" in the Operating Manual.
11. Shut down primary cooling system flow after attaining full flow of D_2O and stable coolant temperature.

NOTE: The last two steps will serve to remove bubbles adhering to fuel elements.

12. Check that the trip circuits conform to the special table of "Temporary Safety System Changes" in the Operating Manual.
13. Check that the three startup channels "see" the neutron source by removing and reinserting the source.

B. Startup Procedure

1. Set the range switch on the power level indicator, channel No. 4, to the highest sensitivity setting.
2. Set the range switches of the three startup channels to settings giving readings of about one-third of full scale.
3. Check that the startup scalars are counting and that they give an audible indication of count rate.
4. Drive the fission chambers for channels 7 and 8 of the count rate system to the down position or until the count rate meters read 10 cps.
5. Turn on the lock down switch on the console.

6. Announce the following on the PA system, "Attention, please," repeat . . . , "The reactor is starting up," repeat . . .
7. Take the reactor critical according to the Operating Manual.
8. Take the reactor to a power level sufficient to give a summed current of 5×10^{-7} amperes from the ion chambers used in the reactivity computer (50% of full scale of power). This point corresponds to a few tens of watts.
9. Maintain the reactor power constant for about 10 min, with both control rod blade crowns balanced and symmetric.
10. Increase the helium pressure in steps of 10 psi up to 200 psig, recording the reactivity before and after each change in pressure. If control rod motion is needed to keep the reactor power between 10 and 80% of full scale on the reactivity computer power scale, record the rod position and reactivities before and after each such change.
11. Repeat 10 decreasing the helium pressure to atmospheric pressure in steps of 10 psig.
12. Change rod positions, so that the auxiliary rod crown is completely inserted and the main rod crown balances the reactivity, with the reactor power steady as in 8.
13. Repeat steps 10 and 11, using the main rod crown to maintain power in the desired range.
14. Insert the main rods by manual scram or by drive motion.
15. Increase reactor helium pressure to 120 psig (the minimum allowable for NPSH) by adjusting the helium inlet valve pressure.
16. Start primary cooling system flow as per "Primary Cooling Water System Operating Instructions," in the Operating Manual (two-pump operation).

17. Repeat steps 7-11, except that the helium pressure is to be maintained between 120 and 200 psi.
18. Return the helium pressure to 200 psi and set the rods in a symmetrical and balanced configuration. Record critical rod positions.
19. Insert all control rods, retaining full flow.
20. Start the eductor according to the Operating Manual.
21. Take the reactor to critical according to the Operating Manual. Set the rods in the "reference pattern" used in the rod calibration experiments. Record critical rod positions.
22. If the effect of the operation of the eductor on reactivity is estimated to be less than .2 dollars from the difference in control rod positions, the reactor will be shut down by inserting all control rods retaining full flow, the eductor will be turned off, the reactor will be taken to critical at a power level appropriate for the operation of the reactivity computer (not to exceed a current of ten microamps on any of the start-up ion chamber channels) and the eductor will be turned on to observe the reactivity change if any. A record of reactivity vs. time will be made.
23. Shut the reactor down.
24. After the reactor is shut down, the Reactor Supervisor in charge of the reactor at the time will instruct the instrument technician to return the safety system to normal and will supervise this action, and this will be noted in the Log Book.

COOLANT FLOW EFFECT AND NEUTRON LIFETIME MEASUREMENT

This phase of the startup operation follows the helium pressure effect experiment.

The object of the experiment is to establish the size of changes in reactivity produced by introducing coolant through the core. At an appropriate stage, the neutron lifetime will be measured.

Two effects will be looked for: A steady state change due to differential pressure across the core and a random reactivity change due to vibration of the structure and the statistics of helium bubble formation.

The steady state effect will be estimated with the aid of a calibrated control rod. The random variation of the neutron level under different flow conditions will be analyzed for r. m. s. noise and for power spectrum.

From the power spectrum analysis of the recording taken at no flow, the ion chamber system will be calibrated absolutely, yielding in this way a preliminary power calibration of the reactor.

A. Note on Additional Instrumentation

The instrumentation used for the helium pressure effect will be retained. An F. M. tape recording unit will be added, receiving its signal from the same ion chamber amplifier used for the reactivity computer. In addition, a signal from a core differential pressure transducer will be available for simultaneous recording.

B. Note on Temporary Safety System Changes

During the determination of the coolant flow effect, the reactor power need only be raised to levels of the order of a few tens of watts. The reactor will operate at full pressurization of 200 psig and at various flow rates.

The following scram and setback functions will be deactivated before the experiment starts and will be returned to the normal activated condition after the experiment is finished. The activation

and deactivation of the trip relays will be done by the instrument technician under instructions and supervision by the Reactor Supervisor in charge of the reactor at the time, and will be noted in the Log Book.

PdRa-101	Core Diff. Pressure
PdA-102	Core Diff. Pressure
PdA-103	Core Diff. Pressure
FRa-100	Primary Coolant Flow
GA-101A	Primary Pump Power
GA-101B	Primary Pump Power
PRCa-101	Reactor He Pressure
PA-102	Reactor He Pressure
PA-103	Reactor He Pressure
GA-102A	Shutdown Pump Power
GA-102B	Shutdown Pump Power

After the no-flow experiment and before starting the pumps for the one-pump run, the Reactor Supervisor in charge of the reactor at the time will instruct the instrument technician to return the safety trips FRa-100 (Primary Coolant Flow) and GA-101A and GA-101B (Primary Pump Power) to the normal one pump operation condition. The Reactor Supervisor will supervise this action and note the change in the Log Book.

Before starting the two-pump run, the Reactor Supervisor will instruct the instrument technician to set the trip of FRa-100 for two-pump operation, will supervise this action, and note the change in the Log Book.

The following trip functions will be operable during the coolant flow effect run.

Nuclear Channel 1	Power	Scram, Setback
Nuclear Channel 2	Power	Scram, Setback
Nuclear Channel 3	Power	Scram, Setback
Startup Channel 1	Power	Scram
Startup Channel 2	Power	Scram
Startup Channel 3	Power	Scram
FRa-201	Lower Thermal Shield Coolant Flow	Setback
GA-201A	Thermal Shield Pump Power	Setback
GA-201B	Thermal Shield Pump Power	Setback
FIa-203	Shutter Coolant Flow	Setback
GA-203A	Biological Shield Pump Power	Setback
GA-203B	Biological Shield Pump Power	Setback
TRa-101	Core Inlet D ₂ O Temperature	Setback
TIa-103	Core Inlet D ₂ O Temperature	Setback
TIa-104	Core Inlet D ₂ O Temperature	Setback
LRa-101	Primary Coolant Level	Scram
LIa-106	Primary Coolant Level	Scram

LA-102	Primary Coolant Level	Scram
Manual Scram, Buttons 1-7		
PIa-101A/PIa-301A	Primary-Secondary Pressure Difference	Alarm
PIa-101B/PIa-301B	Low Primary-Secondary Pressure Difference	Alarm
PIa-201	Low Helium Pressure Supply Manifold	Alarm
PIa-202	High Helium Pressure Supply Manifold	Alarm
PA-301	Low Instrument Air Pressure	Alarm
LA-307	Low Level H ₂ O in Canal	Alarm
CRA-2	High Primary D ₂ O Conductivity	Alarm
CAB-1	D ₂ O Leak to Air, Equipment Level Stations	Alarm
CAB-2	D ₂ O Leak to Air, Operations Level Stations	Alarm
48 VDC	48 VDC Switch Gear Power Supply Off	Alarm

In addition, all indicating instruments will be operative.

I. REACTOR STARTUP PROCEDURE

A. Preliminary Preparations

The following steps appear in a special startup list, and they must be completed by the Shift Supervisor prior to first startup of the reactor.

1. Test the emergency generator for proper operation.
2. Test the radiation monitoring system according to the Operating Manual.
3. Check to see that all instruments are normal according to the Operating Manual.
4. Check building containment and instrument air system according to the Operating Manual.
5. Check that the trip circuits conform to the table of "Temporary Safety System Changes."

6. Check that the three startup channels "see" the neutron source by removing and reinserting the source.
7. Set the helium pressure inlet and outlet controllers to 200 psig.

B. Startup Procedure

1. Set the range switch on the power level indicator, channel No. 4, to the highest sensitivity setting.
2. Set the range switches of the three startup channels to a setting giving a reading of about one third of full scale.
3. Check that the startup scalers are counting and that they give an audible indication of count rate.
4. Drive the fission chambers for channels 7 and 8 of the count rate system to the down position or until the count rate meters read 10 cps.
5. Turn on the lock down switch on the console.
6. Announce the following on the PA system, "Attention, please," repeat . . . , "The reactor is starting up," repeat . . .
7. Take the reactor critical according to the Operating Manual.
8. Increase the reactor power to a level providing a summed current of 10^{-6} amperes from the two analog computer ion chambers, and stabilize. This point corresponds to a few tens of watts.
9. Maintain the reactor power constant to within 2% for two hours using the minimum possible number of control rod motions. Noise measurements will be made during this period.
10. Find the critical position with the auxiliary crown "in," and all but one of the main rods either in or out.
11. Shut down the chain reaction by scram action or by rod drive motion.

II. ONE-PUMP OPERATION

A. Preliminary Preparation

1. Start primary pump GA-101A as per "Primary Cooling Water System Operating Procedures" in the Operating Manual.
2. Establish sufficient secondary water flow to the primary cooler EA-101A, to maintain the same core temperature as before, as per "Secondary Cooling Water System Operating Procedures" in the Operating Manual.

B. Startup Procedure

Repeat steps IB1 to IB11 above.

III. TWO-PUMP OPERATION

A. Preliminary Preparations

1. Start primary pump GA-101B, to maintain the same core temperature as before, as per "Primary Cooling Water System Operating Procedures" in the Operating Manual.
2. Establish sufficient secondary water flow to the two coolers EA-101A and EA-101B, to maintain the same core temperature as before, as per "Secondary Cooling Water Operating Procedures" in the Operating Manual.

B. Startup Procedure

1. Repeat steps IB1 to IB11 above.
2. After the reactor is shut down, the Reactor Supervisor in charge of the reactor at the time will instruct the instrument technician to return the safety system to normal and will supervise this action, and this will be noted in the Log Book.

UNIFORM TEMPERATURE COEFFICIENT OF REACTIVITY

This phase of the startup operation follows the coolant flow effect experiment.

The object of the experiment is to measure the effect on reactivity of a uniform change of temperature of the core and reflector.

A. Note on Additional Instrumentation

The ion chamber channels used during critical loading will be retained. A digital voltmeter will be used to display the position of one main control rod.

B. Note on Temporary Safety Changes

During the uniform temperature coefficient run, the reactor will be operated at normal pressure (200 psig) and various temperatures. The reactor power will not exceed a few tens of watts, as required to give good signals to the neutron level indicators. The energy required to heat the system will be supplied by the primary pumps.

No scram or setback function will be deactivated. The trip points will be set according to the reactor operations manual, except for the trips of TRa-101, TIa-103, and TIa-104, which will be set 10°F above the limit of temperature selected for this run. See C in this section. The resetting of the trip points will be supervised by the Reactor Supervisor in charge of the reactor at the time and it will be noted in the Log Book.

I. REACTOR STARTUP PROCEDURE

A. Preliminary Preparations

The following steps appear in a special startup list, and they must be completed by the Shift Supervisor prior to startup for the experiment.

1. Test the emergency generator for proper operation.
2. Test the Radiation Monitoring Systems according to the Operating Manual.
3. Check to see that all instruments are normal according to the Operating Manual.
4. Check building containment and instrument air system according to the Operating Manual.
5. Set the helium pressure inlet and outlet controllers to 200 psig.
6. Start primary and coolant system flow according to the Operating Manual.
7. Establish secondary water flow as per "Secondary Cooling Water System Operating Procedure," and adjust flow to obtain a primary inlet water temperature of 65°F.
8. Check syphon break valve according to the Operating Manual.
9. Check that the trip circuits conform to the table of "Temporary Safety System Changes."
10. Check that the three startup channels "see" the neutron source, by removing and reinserting the source.

B. Startup Procedure

1. Set the range switch on the power level indicator, channel No. 4, to the highest sensitivity setting.

2. Set the range switches of the three startup channels to settings giving readings of about one third of full scale.
3. Check that the startup scalers are counting and that they give an audible indication of count rate.
4. Drive the fission chambers for channels 7 and 8 of the count rate system to the down position, or until the count rate meters read 10 cps.
5. Turn on the lock down switch on the console.
6. Announce the following on the PA system, "Attention, please," repeat ..., "The reactor is starting up," repeat ...
7. Take the reactor critical according to the Operating Manual.
8. Take the reactor to a power level of a few tens of watts.
9. Take the control rods to the "reference pattern" and record the final critical position.

C. Experimental Sequence

1. Reduce the secondary flow to obtain increments of the core inlet D₂O temperature of about 5°F, using the main control rod connected to the digital voltmeter to maintain a constant power. At each temperature, wait for a few minutes until equilibrium is reached, and record the temperature and the rod position.

Continue the increments up to a temperature of 150°F. If subsequent re-examination of the system shows that it is possible to increase the maximum temperature above 150°F, this upper limit will be changed accordingly.

Repeat the measurements during a decreasing sequence of temperatures down to 65°F.

REACTIVITY EFFECT OF THIMBLES AND SAMPLES

This set of measurements will be done after the control rods are calibrated.

The object of the experiments is to find the change in reactivity produced by the insertion in irradiation facilities of samples of different materials and possibly of different sample holders, and to measure the changes in reactivity produced by insertion and flooding of thimbles.

The samples to be tested will be canned in aluminum and will consist of inert materials as: cadmium, aluminum, lead, stainless steel, and plastic. In addition, partially or totally empty cans will be used for estimation of the void effect. All cans will be tested to insure that they sink in heavy water.

I. CONDITIONS AT THE TIME OF INITIATION

A. Note on Additional Instrumentation

Same as used in control rod calibrations.

B. Note on Temporary Safety System Changes

During the "reactivity effect of samples" runs, the reactor power need only be raised to levels of a few tens of watts, as needed to attain a summed current of about 10^{-6} amperes from the two ion chambers connected to the reactivity computer. There will be no primary flow and no pressurization of the vessel. The safety system will be modified as in the control rod calibration run, and the same precautions will be taken.

II. REACTOR STARTUP PROCEDURE

A. Preliminary Preparations

The following steps appear in a special startup list, and they must be completed by the Shift Supervisor prior to first startup of the reactor.

1. Test the emergency generator for proper operation.
2. Test the radiation monitoring system according to the Operating Manual.
3. Check to see that all instruments are normal according to the Operating Manual.

4. Check building containment and instrument air system according to the Operating Manual.
5. Check that the trip circuits conform to the table of "Temporary Safety System Changes."
6. Check that the three startup channels "see" the neutron source by removing and reinserting the source.

B. Startup Procedure

1. Set the range switch on the power level indicator, channel No. 4, to the highest sensitivity setting.
2. Set the range switches of the three startup channels to a setting giving a reading of about one third of full scale.
3. Check that the startup scalers are counting and that they give an audible indication of count rate.
4. Drive the fission chambers for channels 7 and 8 of the count rate system to the down position or until the count rate meters read 10 cps.
5. Turn on the lock down switch on the console.
6. Announce the following on the PA system, "Attention, please," repeat ..., "The reactor is starting up," repeat ...
7. Take the reactor critical according to the Operating Manual.

III. METHOD OF MEASUREMENT

The measurement technique will depend on the knowledge of the reactivity effect of a sample, the magnitude of the reactivity effect, and the sign.

For samples whose effect on reactivity is unknown, the reactor will be taken critical with the rods in the reference pattern at a power giving currents of the order of microamperes on the startup ion chambers. The critical rod position will be noted.

The reactor will be taken subcritical by a few dollars. The sample will be inserted in the required place. The reactor will be taken critical to approximately the same power level as before and the new critical control rod position will be noted with the rods in the reference pattern. From the difference, the effect of the sample on reactivity will be estimated.

For samples whose effect on reactivity is known to be less than 20 cents, the critical rod position may not be sensitive enough. In this case, the reactor will be taken critical at a power corresponding to currents of the order of the microampere from the startup ion chambers, with the sample inserted if its effect is an increase of reactivity or removed if its effect is to reduce reactivity. The source will be removed.

Once the reactor is stabilized, the sample will be removed (or inserted) and the resulting negative change in reactivity will be measured with the reactivity computer.

The effect of the thimbles in reactivity will be estimated by change in critical control rod positions, shutting the reactor down to effect the change.

PARTIAL CORE LOADINGS

This phase of the startup operation will precede any operation of the core at powers above one kilowatt.

The object of the experiment is to check on the hold down margin of the reactor at partial fuel loadings.

A. Note on Additional Instrumentation

The ion chamber channels used during critical loadings will be retained. The reactivity computer will be available for shutdown checks.

B. Note on Temporary Safety System Changes

During the partial core loading runs the reactor power need only be taken to levels of a few tens of watts as needed for the operation of the reactivity computer channel. The reactor will be operated without flow or pressurization. The vessel will remain open during this experiment.

The following scram and setback functions will be deactivated at the appropriate logic panel terminal board before the experiment starts and will be returned to the normal activated condition after the experiment is finished.

The activation and deactivation of the trip relays will be done by the instrument technician under instructions and supervision of the Reactor Supervisor in charge of the reactor at the time, and will be noted in the Log Book.

PdRa-101	Core Diff. Pressure
PdA-102	Core Diff. Pressure
PdA-103	Core Diff. Pressure
FRa-100	Primary Coolant Flow
GA-101A	Primary Pump Power
GA-101B	Primary Pump Power
PRCa-101	Reactor He Pressure
PA-102	Reactor He Pressure
PA-103	Reactor He Pressure
GA-102A	Shutdown Pump Power
GA-102B	Shutdown Pump Power

The following trip functions will be operable during the control rod calibration runs.

Nuclear Channel 1	Power	Scram, Setback
Nuclear Channel 2	Power	Scram, Setback
Nuclear Channel 3	Power	Scram, Setback
Startup Channel 1	Power	Scram
Startup Channel 2	Power	Scram
Startup Channel 3	Power	Scram
LRa-101	Primary Coolant Level	Scram
Lla-106	Primary Coolant Level	Scram
LA-102	Primary Coolant Level	Scram
Manual Scram, Buttons 1-7		Scram
FRa-201	Lower Thermal Shield Coolant Flow	Setback
GA-201A	Thermal Shield Pump Power	Setback
GA-201B	Thermal Shield Pump Power	Setback
FIa-203	Shutter Coolant Flow	Setback
GA-203A	Biological Shield Pump Power	Setback
GA-203B	Biological Shield Pump Power	Setback
TRa-101	Core Inlet D ₂ O Temperature	Setback
TIa-103	Core Inlet D ₂ O Temperature	Setback
TIa-104	Core Inlet D ₂ O Temperature	Setback
PIa-101A/PIa-301A	Primary-Secondary Pressure Difference	Alarm
PIa-101B/PIa-301B	Low Primary-Secondary Pressure Difference	Alarm
PIa-201	Low Helium Pressure Supply Manifold	Alarm
PIa-202	High Helium Pressure Supply Manifold	Alarm
PA-301	Low Instrument Air Pressure	Alarm
Lla-201	Low Level H ₂ O in Thermal Shield Tank	Alarm
LA-307	Low Level H ₂ O in Canal	Alarm
CRA-2	High Primary D ₂ O Conductivity	Alarm
CAB-1	D ₂ O Leak to Air, Equipment Level Stations	Alarm
CAB-2	D ₂ O Leak to Air, Operations Level Stations	Alarm
48 VDC	48 VDC Switch Gear Power Supply Off	Alarm

In addition, all indicating instruments will be operative.

II. REACTOR STARTUP PROCEDURE

A. Preliminary Preparations

The following steps required to prepare the reactor for startup appear in a critical startup list which must be completed by the Shift Supervisor prior to the initial loading.

1. Test the emergency generator for proper operation.
2. Test the Radiation Monitoring Systems according to the Operating Manual.
3. Inspect the reactor vessel for debris.
4. Adjust the D₂O level to the fuel handling level (249 in.).
5. Check to see that all instruments are normal according to the Operating Manual.
6. Check building containment and instrument air system according to the Operating Manual.
7. Check that the pump motor breakers are racked out and pad locked.
8. Check that the neutron source is in place and that at least three neutron channels give unmistakable readings. That is, that the three instruments change their readings as the source is inserted and removed.

B. Procedure for Core Changes

1. Set all neutron channels at their most sensitive scale or at such scale as needed to give an indication of about one third of full scale.
2. Remove the main crown 4 in. to 26 in. , test the scram, and reposition the main crown to 26 in.

3. Remove the 14 outer fuel elements slowly, one at a time, keeping constant voice communication with the operator at the console, return them to the vault.
4. Insert the appropriate fuel element holding plate.
5. Clear the reactor loading area of personnel.
6. Announce the following on the PA system, "Attention, please," repeat ... "Control rods going out," repeat ...
7. Withdraw carefully the main rod crown and, if necessary, the auxiliary crown until reaching criticality.
8. Note the critical rod position.
9. Take the reactor to a power of a few tens of watts as necessary to get a signal of 80% power in the reactivity computer. The power is not to exceed a level giving ten microamps ion chamber current from any of the startup chambers. Remove the source.
10. After a few minutes, scram the reactor and note the shutdown reactivity. Insert the source.
11. Remove the main crown to 26 in.
12. Remove the appropriate fuel element holding plate.
13. Move the 14 fuel elements from the inner to the outer positions. Record all fuel element position changes.
14. Insert the appropriate fuel element holding plate.
15. Clear the reactor loading area of personnel.
16. Repeat steps 6, 7, 8, 9, 10, 11, and 12.
17. Insert three fuel elements to reach the configuration shown in the Hazards Report Figure 4.26.

18. Insert the appropriate fuel element holding plate.
19. Repeat steps 5, 6, 7, 8, 9, and 10.
20. Secure the reactor.

REACTOR NOISE MEASUREMENT AND XENON EFFECT AT INTERMEDIATE POWERS

This type of experiment will be performed at each step of reactor power escalation.

The object of the measurement is to search for any abnormalities in the reactor that can result in spontaneous changes of the reactor power level, as flow instabilities, vibration, or boiling, and to measure the power dependence of reactivity effects due to xenon poisoning.

A. Note on Additional Instrumentation

An ion chamber will be located in such a position in the reactor as to give a current of the order of 10^{-7} to 10^{-6} amperes at the power at which the measurement is to be done. In addition, the output of other transducers may be simultaneously recorded for the purposes of cross-correlation.

An F. M. multichannel recorder will be available to store the data.

B. Safety System Condition

All safety channels required for normal operation will be operative.

C. Experimental Sequence

1. Start the reactor as per HFBR Operations Procedures Manual.
2. Take the reactor to the desired power level.
3. Stabilize power and temperatures.
4. Maintain constant power and core inlet D₂O temperature for 24 hr, recording balanced control rod positions every 15 min. During this time noise measurements will be made.
5. Shut down the reactor.

POWER REACTIVITY COEFFICIENT

This experiment will be undertaken after the reactor has been taken to a power of the order of 20 to 30 MW, and a good power calibration is available.

The object of the experiment is to measure the reactivity change per megawatt under steady state conditions, excluding changes in xenon poisoning.

The experiment consists of putting the reactor on a positive period of the order of 100 sec and observing the reactivity as a function of power.

A. Note on Additional Instrumentation

The normal reactor instrumentation will be supplemented with a reactivity computer. The reactivity output and a signal proportional to power level will be used to drive an x-y recorder. (The power coefficient is equal to the slope of the curve.)

The reactivity computer will receive its reactor power signal from a special preamplifier connected to the ion chamber of Nuclear Channel No. 6.

B. Safety System Condition

No scram or setback function will be deactivated. The trip points will be set according to the reactor operations manual.

C. Condition of the Reactor Previous to the Run

The reactivity loss due to xenon generated in previous runs should be less than 0.01 dollars.

D. Experimental Sequence

The reactor will be taken critical according to the Operating Manual. When the period meters indicate a stable period, and at a power of the order of a few kilowatts, all rod motion will be discontinued.

Two runs will be made. In one, the secondary coolant flow will be constant, and in the other an attempt will be made to keep the core inlet D₂O temperature constant.

XENON EFFECT MEASUREMENT AT LOW POWER

This phase of the reactor evaluation experiments follows the power escalation to 5 MW.

The object of the experiment is to establish the time dependence of the changes in reactivity due to xenon buildup and decay induced by operation at 3 MW and subsequent shutdown. The observed changes will be used to adjust the parameters of the mathematical model used to predict xenon poisoning.

The reactivity defect due to the xenon in the core will be measured by the change in control rod positions required to keep the reactor power constant.

The reactor will not have been operated at powers above 1 kW for at least 80 hr prior to this run.

A. Note on Instrumentation

The normal reactor instrumentation will be used for this experiment.

B. Safety System Condition

All safety channels required for normal operation will be operative.

I. REACTOR STARTUP PROCEDURE

The reactor will be started as per HFBR Operations Procedures Manual, using only one primary pump. Secondary flow will be throttled down.

II. EXPERIMENTAL SEQUENCE

1. Take the reactor to a power of a few kilowatts and find the critical position of the balanced control rod crowns.
2. Take the reactor to a power of 3 MW, keeping the core inlet D₂O temperature constant by adjusting secondary flow.

3. Maintain the reactor power at 3 MW for 30 hr, keeping the core inlet temperature constant and recording the rod crown positions every 15 min.

During this run the rod motions which are required to keep a constant power should be made keeping all rods as equally inserted as possible.

4. Insert the rod crown to take the reactor subcritical by about one dollar. Let the reactor reduce power to 1 KW without rod motions. Power data will be recorded with an automatic data logger during this time.

5. Keep the power between 1 and 5 KW with as few rod crown motions as possible for 40 hr, recording the rod crown positions after each motion. Reactivity will be followed during this time with a reactivity computer.

XENON EFFECT MEASUREMENT AT HIGH POWER

This phase of the reactor evaluation experiments will be undertaken only after escalation to the design power of 40 MW.

The objects of the experiment are to establish the size of the changes in reactivity due to xenon buildup and decay induced by operation at 40 MW and subsequent shutdown, and to evaluate the ability of the reactor control system to follow transient xenon reactivity changes. The information obtained will be used to refine the parameters of the mathematical model used to predict xenon poisoning.

The reactor will not have worked at power levels higher than 1 kW for at least 80 hr prior to the experiment.

A. Note on Instrumentation

The normal reactor instrumentation will suffice for this experiment.

B. Safety System Condition

All safety channels required for normal operation will be operative.

C. Reactor Startup Procedure

The reactor will be started as per HFBR Operations Procedures Manual, using two primary pumps.

D. Experimental Sequence

1. Take the reactor to a power of a few kilowatts and find the critical position of the balanced control rod crowns.
2. Take the reactor to a power of 35 MW, keeping the core inlet D₂O temperature constant by adjusting the secondary flow.
3. Maintain the reactor power at 35 MW for 20 hr, keeping the core inlet D₂O temperature constant and recording the balanced control rod crown positions every 15 min.

4. Increase the power to 40 MW, keeping the core inlet D₂O temperature constant and recording rod positions at suitably short intervals.
5. Maintain the power at 40 MW for 30 hr, keeping the core inlet D₂O temperature constant, and recording the balanced rod crown positions every 15 min.
6. Take the reactor subcritical by about one dollar with the main crown.
7. Let the reactor power decrease to 10 kW. A record of the power decrease will be kept by an automatic data logger.
8. Maintain the power between 10 and 50 kW with the minimum possible number of control rod motions. Record of crown position will be kept after each rod motion.
9. When the rod crowns are fully withdrawn, shut the reactor down.
10. Attempts to restart the reactor will be made every 30 min after some time to be determined by computations by the Experimental Physics Group.
11. When the reactor can attain criticality it will be taken to a power level of 10 kW.
12. The power will be maintained between 10 and 50 kW for 30 hr with as few rod crown motions as possible. The reactivity will be monitored during this time with a reactivity computer and all rod crown motions will be recorded.