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ARGONNE NATIONAL LABORATORY
P. O. Box 299
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OPERATING MANUAL FOR THE ARGONAUT REACTOR

August, 1959

This Manual was compiled for use with the Argonaut Reactor at the Argonne National Laboratory. As such, the acceptance of responsibility for the safety of other reactors using the techniques or apparatus described in these pages is not implied.

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I. INTRODUCTION

The design of the Argonaut (Argonne Nuclear Assembly for University Training) was initiated by the Reactor Engineering Division of Argonne National Laboratory to satisfy needs for a low-power reactor facility within the Laboratory, and for training uses within the International School of Nuclear Science and Engineering (ISNSE). It was intended primarily for instruction and research in reactor physics. It was also considered as a possibility that it would fulfill the requirements of universities engaged in a program of nuclear science. The cost of the facility was to be kept to a minimum consistent with the high degree of inherent safety and a great amount of flexibility in the system. The basic design stemmed from the Knolls Atomic Power Laboratory Thermal Test Reactor* (TTR), now called Nuclear Test Reactor (NTR). Modification during the course of the work justified the new name "Argonaut."

The design, construction, and initial testing phases were completed under the direction of D. Lennox, project engineer. The Argonaut became critical on February 9, 1957. At this time H. Bryant assumed the responsibility for the operation and use of the Argonaut in the International School program. In November, 1957, this responsibility was transferred to G. C. Baldwin, who was succeeded by C. Buchler on June 1, 1958.

The first manual of operation for the Argonaut was written by the group that did the design and initial testing. A more elaborate manual was drafted during the tenure of G. C. Baldwin. The present manual represents a revision of this draft, including the additional experience gained during the interim period.

An operating manual should coordinate activities properly and insure, as much as it is possible to do so by rules and regulations, the safe and efficient operation of a reactor. It is the purpose of this manual to assemble many of these controlling procedures as reasonable and proper, recognizing that the primary burden of safe operation rests with the Reactor Supervisor and his good judgment. This judgment refers to his own technical capabilities as well as the ability to recognize when and with whom to consult when reasonable doubts as to the safety of an operation exist.

The safe operation of Argonaut depends upon the design, as well as the manner of operation. The design includes many features to insure safe operation under training conditions. The operation is guided by the Summary Report on the Hazards of the Argonaut Reactor** and by the specification of procedures as discussed in Section IIB, Review of Operations and Experiments, of this report. The above guidance is intended to provide every

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*H. B. Stewart, et al., Nucleonics 11, 38 (1953).

**ANL 5647 (December, 1956).

opportunity for good judgment to be applied; to guarantee safety by the imposition of rules and regulations would reduce the value of the reactor as a scientific tool.

Since the Argonaut is primarily for the purpose of training, there will be more trainees working around and operating this reactor than normally found at other reactors. The operating manual of this reactor as compared with one of these other reactors will reflect this fact as does the number of safety features built into the Argonaut. Thus, sound instructional procedure dictates that the operation of the Argonaut must be a model of safety and proper operational techniques. There is enough information pertinent to operation of the reactor included in the manual to make it a useful aid in training programs.

II. PERSONNEL RESPONSIBILITIES AND REQUIREMENTS

A. Staff Organization and Responsibilities

The operating staff of the Argonaut consists of the following categories of individuals: Reactor Supervisor and Reactor Operator. A current list of Reactor Supervisors and Reactor Operators is posted on the bulletin board.

One Reactor Supervisor will be designated the Responsible Reactor Supervisor. It will be his duty to coordinate the activities of the individuals involved in the operation of the facility.

The Reactor Supervisor is a staff scientist or engineer who is, by training and experience, capable of understanding the reactor, can exercise judgment as to the safety of its operation, and can assume the responsibility for changes in the reactor system. He is appointed a Reactor Supervisor by the Director, ISNSE, in a letter to the Laboratory Director which contains a statement of his pertinent training and experience.

The Reactor Operator is a Laboratory employee shown to be capable of operating the reactor according to the directions of the Reactor Supervisor. He is appointed a Reactor Operator by the Director, ISNSE, in a letter to the Laboratory Director containing the recommendation of the Responsible Reactor Supervisor.

In addition to the above, there exists the category of observer, which includes all individuals learning the properties of the reactor or using the reactor as a tool, as well as those who may be merely observing in the more strict sense of the word. The numbers of these people and their activities shall be controlled by the Reactor Supervisor, consistent with the type of individual observing and the mode of operation of the reactor.

The safe operation of the reactor is the responsibility of the Reactor Supervisor and it is his judgment that determines the action, if any, required in a given situation. He will review all operations and give the instructions to the Reactor Operator. The Reactor Supervisor will control the movement of fuel as well as of the pertinent reactor keys. He is expected to know and to follow implicitly the procedures and limitations set by the Summary Report on the Hazards of the Argonaut Reactor. Any deviations from this report will be made only with the proper reviews. He should also keep the proper authorities informed of any matters related to the reactor which may be of interest or concern to the proper authorities in accordance with the policy and practice guide of the Laboratory.

The safe operation of the reactor is also a responsibility of the Reactor Operator to the extent that he follows the operating instructions given him. It is also his reponsibility to discontinue operations in the event that, in his estimation, an unsafe condition exists.

B. Review of Operations and Experiments

The operation of the reactor will be initiated by the completion of the form "Request for Argonaut Operation" (see Fig. 1). This form will contain the details of the operation, or the reference which does contain the details, and it will be posted on the bulletin board during the operation. The upper half of this form will be filled in by the person desiring the operation and the lower half by the Responsible Reactor Supervisor. The signature of the Responsible Reactor Supervisor completes the form.

It will be the responsibility of the Responsible Reactor Supervisor to review each request for operation and make a decision as to its safety or propriety. This decision may be referred to the proper authorities for review before the operation is performed; it may be made with the consultation of one or more of the Reactor Supervisors, or Laboratory scientists in the case of a somewhat new type of operation; or it may be made without consultation of other individuals in the case of a routine operation or developed experiment.

The operation of the reactor is performed only according to the directions of the Reactor Supervisor. The degree of control he exercises may vary from being at the console during a type of operation which is new, to being aware of the status of the reactor in case of a routine type of operation. In all cases, the reactor is operated according to his instructions and by his consent in the form of a completed "Request for Argonaut Operation." While the reactor is operating, it will be under the direct control of either the Reactor Supervisor or a Reactor Operator who is in such a location that he is aware of the status of the reactor at all times and can effect the proper action at any time.

Whenever work is being performed on or around the reactor, there shall be a minimum of two persons present, each to be aware of what the other is doing.

REQUEST FOR ARGONAUT OPERATION

DATE ______________________

Request is hereby made for operation of the Argonaut on ______________________________________

DESCRIPTION OF EXPERIMENT OR OPERATION: (Give brief descriptive title; include description of auxiliary apparatus required; attach additional sheets if necessary)

REACTOR CONDITIONS:

FUEL LOADING:

ESTIMATED REACTIVITY CHANGE:

OPERATION HISTORY:

COMMENTS OR REFERENCES:

____
SIGNED

REVIEW OF PROPOSED OPERATION

THIS IS CLASSIFIED AS A:

_______ Routine operation.
_______ Developed experiment, as described in:
_______ New experiment, requiring the following action:
    _______ (a) None
    _______ (b) Inform proper authorities.
    _______ (c) Request review by proper authorities.

SCHEDULED FOR PERFORMANCE ON ______________________________.

COMMENTS OR SUGGESTIONS:

ISNSE-4 (8-59)

______________________________________ RESPONSIBLE REACTOR SUPERVISOR

______________ DATE

Figure 1.

III OPERATIONAL PROCEDURES

A. Operation of the Reactor

Instrumentation Checkout

For each day that the reactor operates, a full, daily, reactor maintenance check must be made by a qualified operator who shall then sign and date the checkout sheet in the Argonaut Daily Checkout Book. The form for this checkout (see Fig 5 of Sect III B) details this procedure

Before Startup

Previous to the operation of the reactor, the operator in charge will, in all cases, comply with the following instructions:

1. Inspect the log book (see Fig. 2). This will inform him of the condition in which he may expect to find the reactor.

2. Review experimental facilities, establishing whether or not they agree with the log book as to condition, experimental equipment in them, etc. If the facilities are locked and show no signs of having been tampered with, they may be assumed to be as represented in the log book. The following are understood to be "experimental facilities": external thermal column (15 stringers), two beam holes, internal thermal column (4 stringers, one central thimble); water tank, and the core region Any inconsistency between the operator's findings and the log book should be reported at once to the Responsible Reactor Supervisor for appropriate action.

3 Secure read and post the form 'Request for Argonaut Operation,' In doing so the operator should make sure that he understands fully the procedure to be followed for the operation described. Determine whether the conditions of the reactor are those required by the particular operation and if the necessary experimental equipment is in its proper location. Make whatever changes are necessary insert experimental equipment where indicated, and make the pertinent entries in the log book under the headings "Purpose or Reference" and "Run Conditions " These entries should be written with considerable detail so that anyone reading the log book can understand the operation The necessary information for these entries will be normally found in the form "Request for Argonaut Operation " If this is not the case consult with the Responsible Reactor Supervisor

It is imperative that before startup the operator has made sure that there is complete agreement between the reactor, the log book and the form "Request for Argonaut Operation It is equally important that the operator understand each step of the operation of which he will be in charge

Argonaut Log Book

Date ________

					CONTROL				COOLING		INSTRUMENT READINGS					OPERATION
						RODS						CHANNELS				
Time	Run	Operator	Supervisor	Loading Code	Source	Shim	Coarse	Fine	Temp H_2O °F	Conditions	Power in Watts	Log	Linear #1	Linear #2	Linear #3	

Figure 2a.

PURPOSE OR REFERENCE	RUN CONDITIONS	
	IRRADIATION FACILITIES	OTHERS

Figure 2b.

General Startup Procedure

1. Secure the keys for reactor control power, and dump valve clutch.

2. Turn on both the high-voltage supplies to the four BF_3 counters.

3. Turn the pulse-height selector and the gain controls in the A I D amplifiers to their normal operating positions. The correct setting for these controls can be obtained from the Responsible Reactor Supervisor or from the latest calibration data in the reactor file. A sound criterion to determine that the settings are right is that it should be impossible, at this stage of startup, to reset the low-level trips in the count rate meter (CRM) and the source interlock chassis

4. Set range-selector switches of all three linear trip channels to their most sensitive scales (10^{-10} amp full scale).

5. Reset the four high-level, the positive period and the high-multiplication trips

6 Turn on the nitrogen pressure.

7. Insert both keys and turn the control power on. A light on the front control console rack indicates that control power has been obtained.

8. Turn the master selector switch to the "Source" position. Insert the source by pushing forward on the control switch until a green light appears at the "Source" position. This operation will take approximately forty-five seconds. As the source is driven toward the "in" position, the period meter will show an indication which may result in a trip. To avoid this trip, momentarily release the control switch, as required. If a trip occurs, control power will be lost and the source motion will be automatically reversed Clear the trip and re-energize control power with the key. Continue with the admission of the source. When the source is inserted, the linear instruments should show readings of 10^{-10} to 10^{-9} ampere Their ranges should be changed as necessary.

9 Make the following log book entries in the appropriate column: Date, Time, Run, Operator Supervisor, Loading Code, Source (in condition), Instrument Reading in the Log Channel, Instrument Reading in Linear Channel #1, Instrument Reading in Linear Channel #2 Instrument Reading in Linear Channel #3, and Operation Performed (Source In)

10. Reset the low-level trips in the source interlock and the count rate channels Orange lights will then appear opposite the three safety rod positions of the master selector switch, indicating satisfaction

of interlocks for the next step A green light should also appear next to "Safety Rod Clutches Energized" at the right front console panel.

11 Raise each safety rod For that purpose, set the master selector switch to the corresponding position push forward on the control switch until the green light for that rod appears This operation will take approximately three and one-half minutes for each rod. Ordinarily no change in instrument reading occurs as a result of raising safety rods. Since there is no moderator in the reactor, a small increase in an instrument reading may result only from a change in the "shading" of one of the safety rods over one of the chambers, and, as such, is no cause for concern.

12 Turn the selector switch to the "Dump Valve" position; energize the "Dump Valve Clutch" key switch and push forward on the control switch. The dump valve will then close, the green light will appear at the dump valve position, and an orange light will appear at the "Water Level" position

13 Turn selector switch to Water Level' position. Turn pump switch to "Pump On" condition. Hold control switch in the forward position; this will energize the pump admitting water to the core. The "Pump On" green light and the "Water Flow" green light should both go on. The neutron flux level must be recorded from this time on by means of the Brown recorders. The pumping time is about twelve minutes depending on the cleanliness of the sediment screens in the water system. This operation should be timed and the Responsible Reactor Supervisor informed of unusually long pumping times

Shortly after the pump begins to operate the instrument readings will show a slight decrease. After about one and one-half to two minutes, the readings will begin to drop rapidly, and a negative period will be indicated on the period meter The instrument readings decrease to approximately one-half to one-fourth (depending on the detector location) of the initial values. This effect is caused by the water rising in the bottom of the annulus where it acts as a shield between the source and the detector. As the water level reaches the fuel region however the onset of multiplication checks the rate of decrease of the instrument reading A minimum indication is reached and is followed by a marked increase. The final instrument readings, those after water has been fully admitted to the core are less than before the admission of water This does not apply to the multiplication interlock instrument. For normal loadings, the final reading will be higher than before the admission of water Should the loading be excessive (more than 0 5% free k_{ex}), the final reading will be higher than the trip setting and the reactor will be scrammed

When water reaches the lower level float switch, it turns on the orange interlock lights for the three control rods. The selector switch now should be turned to any of the control rod positions and water will then continue to be pumped automatically until the upper level float switch is reached.*

14. Make the following log book entries: Time, Run, Operator, Supervisor, Water Temperature, Cooling Conditions, Instrument Reading in Log Channel, Instrument Reading in Linear Channel #1, Instrument Reading in Linear Channel #2, Instrument Reading in Linear Channel #3, and Operation (water up).

15. Raise the control rods as required for criticality. Close attention should be paid to instrument readings, all of which should be of the order of 10^{-10} ampere at the beginning of this step. The change in instrument readings as the rods are successively raised will depend upon the core loading geometry; with a single-slab loading, the shim rod on the far side of the annulus ordinarily should have a negligible effect; with a two-slab loading, increased multiplication of source neutrons should be observed as the shim rod is being withdrawn. During the initial withdrawal of the rods, an apparent positive period is indicated by the period meter; if rod withdrawal is stopped, this period will persist for a short time until the neutron flux level attains a new equilibrium value. The time to reach this equilibrium becomes progressively longer as each new increment of rod withdrawal brings the system closer to criticality. When the system is critical, the neutron flux does not level off when the rods are stationary; rather there is a continuous increase with time and a small, steady positive period will be observed.

When it is apparent that criticality has been achieved, and if the operation so requires, the neutron source may be withdrawn. This is accomplished by turning the master selector switch to the source position and pulling the control switch towards the operator. Depending on the flux level present when the source is withdrawn, it may be necessary to readjust the control rod positions for criticality. In doing this, care must be exercised to prevent the instrument readings from falling below the low-level trip settings. A suggested method to insure that this will not happen is to withdraw the source in a series of steps, readjusting the position of one of the control rods at the end of each step in order to keep the flux level constant. The reactor is critical if a steady flux level is maintained after the source has been fully withdrawn.

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*The two float switches which control flow conditions in the core are tied together by an aluminum bracket. This bracket may be raised or lowered with respect to the overflow line in order to obtain either a constant overflow or a static condition. In the first case, water will constantly flow back to the dump tank through the overflow line. In the second case, the higher float level switch will shut the pump off.

16. To increase the power to a desired operating level, a control rod (coarse or fine) should be withdrawn further to produce a conveniently short positive period. As the power increases it will be necessary for the operator to change scales on the range selector switches of the linear trip channels. When the instrument reading in each channel reaches mid-scale, the operator is given warning by means of a buzzer and an amber light next to the meter. The range-selector switch should not be turned until the mid-scale warnings are observed and then only to the immediately higher range position. As the reactor power increases, the sensitivity of the BF_3 counters must be decreased by reducing the amplifier gain, by raising the pulse height-selector level, or by switching from bare to cadmium-covered counters. This operation must be performed with care to avoid a low-level trip in the CRM circuit. When the reactor power nears the desired level, the rod should be returned to the position previously determined to be critical; then minor readjustments needed to maintain criticality can be made.

In all the operations described, the control switch should be pushed away from the operator if it is desired to increase reactivity and held toward the operator to reduce reactivity.

17. Make the following log book entries in the appropriate column: Time, Run Number, Operator, Supervisor, Source Position, Shim Rod Position, Coarse Rod Position, Fine Rod Position, Water Temperature, Cooling Conditions, Instrument Reading in the Log Channel, Instrument Reading in Linear Channel #1, Instrument Reading in Linear Channel #2, Instrument Reading in Linear Channel #3, Operation (reactor critical).

18. Additional entries under appropriate headings of the Log Book (Figure 2A) should be made every hour or when:

(a) reactor power level is changed;

(b) any other significant event occurs;

(c) run is terminated.

The reactor operator is expected to be thoroughly familiar with the interlock system, both in its construction details and its functional aspects During the startup of the reactor and its operation, the operator should closely watch the behavior of the interlock system. Should he detect any abnormal condition, he must immediately shut down the reactor, put the keys in the safe and inform the Responsible Reactor Supervisor.

Shutdown

Described below are eight methods to shut down the reactor. These are to be used in rotation as safety checks of the interlock(s) involved, except in the case that the shutdown is of an emergency nature, or if the nature of the operation requires a specific type of shutdown.

(a) Depression of the scram button (manual scram).
(b) Increasing the sensitivity (by ranging down), or changing the trip setting to cause a high-level trip in linear channel #1 and the CRM.
(c) Increasing the sensitivity (by ranging down), or changing the trip setting to cause a high-level trip in linear channel #2.
(d) Method (c) applied to linear channel #3.
(e) Removal of the neutron source and insertion of a control rod (shutdown caused by a low-level trip in the source interlock or CRM).
(f) Insertion of a safety rod.
(g) Turning off the high voltage to BF_3 counters.
(h) Turning off the main nitrogen supply and releasing the remaining nitrogen pressure in the line by manual injection.

The failure of any of these methods to shut down the reactor should cause the operator to manually scram the reactor and report the situation to the Responsible Reactor Supervisor.

After Shutdown

The following instructions should be observed by the operator upon termination of a run:

(a) Make entries in the Log Book under Time, Operator, Run Number, and Operation (describe method used for shutdown). Request the signature of the Reactor Supervisor responsible for the operation.
(b) If equipment is to be withdrawn from the reactor if any changes are due at this time request the presence of a Radiation Safety representative (where pertinent), perform modifications and make proper entries in Log Book under "Run Conditions." Determine that the experimental facilities are plugged and locked, that power to the crane is shut off and locked, and that the keys are put away in the key safe.
(c) If no further operation of the reactor is scheduled to follow, withdraw the reactor keys and store them in the key safe. Turn off high voltage to the BF_3 counters.

Fuel Changes

Fuel may be removed from the reactor core only after it is given a radiation level check by a representative of Radiation Safety. It should be transferred to the storage pits (see Figure 3) and remain there until activity is at a suitable level before return to the storage safe.

Figure 3 Fuel Storage Pits.

Protective cotton work gloves must be worn while handling fuel plates. Should the above monitoring reveal excessive residual activity, special handling equipment must be used.

The location of each fuel plate in the Argonaut inventory is shown by means of inventory cards bearing an inventory number (small type) and the U^{235} content of the plate in grams (large type). Three chart boards hanging from the west face of the reactor represent, respectively, Reactor Core, Fuel Safe and Storage Pits; the position of each card on the particular board corresponds to the position of the fuel plate represented by the card (see Figure 4). Each plate in the fuel inventory must be recorded on one of the boards.

Whenever changes are made in the location of fuel, the corresponding correction should be made on the inventory chart. Each new loading or change of loading should be recorded in the Log Book under the appropriate date.

Under no conditions will fuel be relocated unless requested by the Responsible Reactor Supervisor. Furthermore, the presence of a Reactor Supervisor is required when a fuel change is being made in the reactor core.

After a fuel change in the core has been made, a determination of its excess reactivity should be made at once and recorded in the Log Book and the core chart board. Measurements of excess reactivity should be made by, or under the direct control of, a Reactor Supervisor.

Except when a special authorization has been secured, the excess reactivity in the reactor above the "clean" loading will not exceed 0.5%.

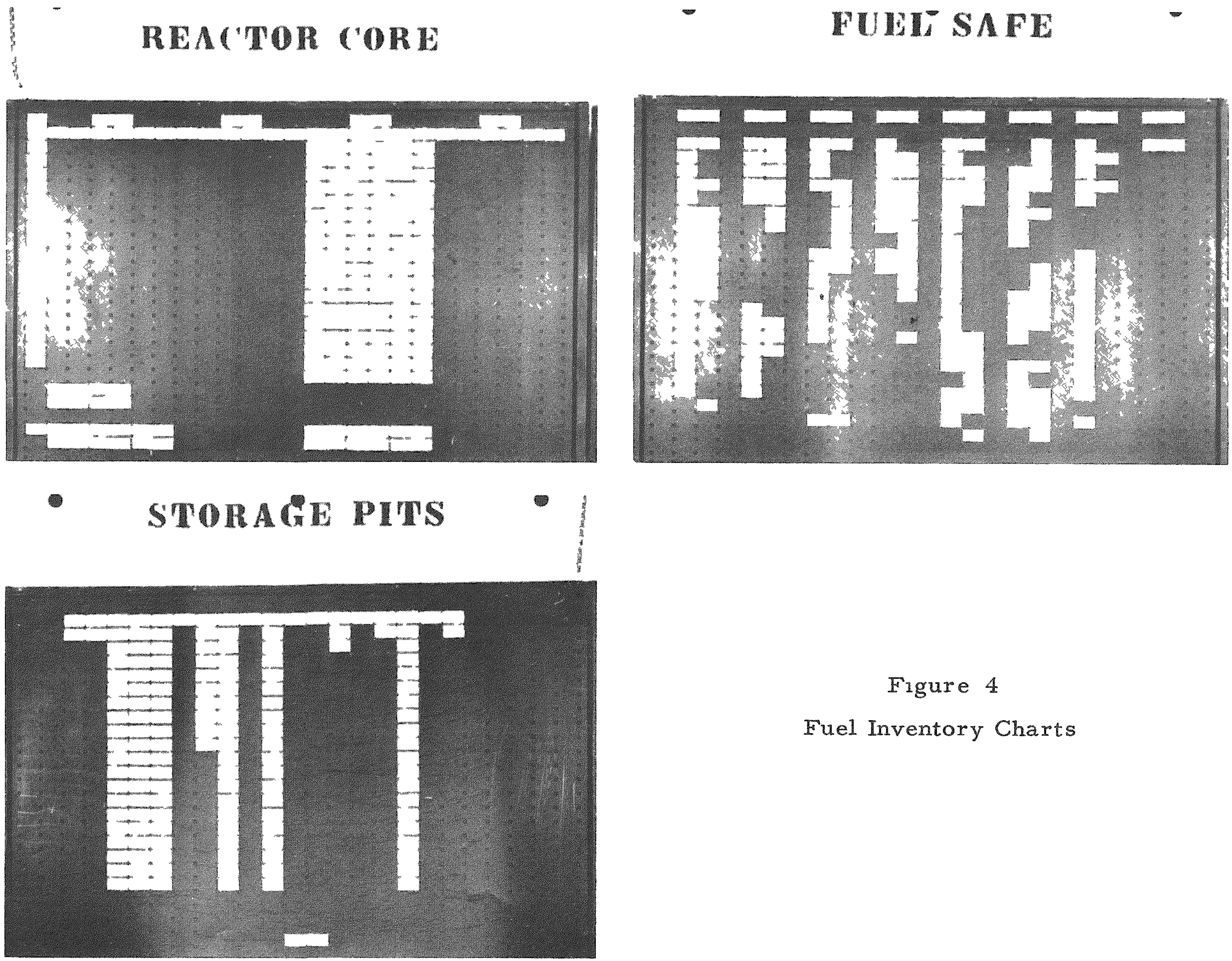

Figure 4

Fuel Inventory Charts

B. Maintenance of the Reactor

A daily reactor maintenance check must be made by a qualified operator to verfiy the reliability of the reactor interlock system. The Daily Reactor Maintenance Form (Figure 5) outlines this procedure. The signature of the operator at the bottom of this form indicates that the checkout has been satisfactorily performed.

If, at any time during this checkout, the operator finds that he cannot properly complete any of the safety checks, he should discontinue the operation, lock up the keys, and inform the Responsible Reactor Supervisor so that adequate steps may be taken to correct the fault.

If the operator has been able to complete properly the Daily Reactor Maintenance Checkout, the reactor is ready for operation. If no changes to the system are required for the coming operation, it is permissible to proceed from this point to make the reactor critical.

Various components of the Argonaut, other than those covered by the daily maintenance, should be serviced according to the following time schedule. Details of the maintenance procedure on each item should properly be in a maintenance manual and will not be given here.

	Week	One Month	Three Months	Six Months	Year
Water System					
pH, conductivity of H_2O	X				
Screen filters	X				
Water level in dump tank	X				
Electric heaters	X (when in use)				
Water pumps		X			
Ion-exchange column		X			
Fittings, valves, etc		X			
Electric motors		2 months			
Reactor vessels				X	
Instrumentation					
Trip circuit settings	X				
Recorders (oil)	X				
Gamma monitor calibration		X			
Air filters		X			
Air blowers			X		
Selsyn gears			X		
Signal light motor			X		
BF_3 preamplifiers				X	
Recorders					X
Core					
Control and safety rods			X		
Nitrogen system				X	
Neutron source	Replace as necessary				
Experimental Facilities					
Water level in water tank			X		

Figure 5

DAILY REACTOR MAINTENANCE CHECKOUT

Date

Operation Performed			Safety Check
______	1	Review, standardize and date log level chart	
______	2	Review Brown recorder charts if necessary	
______	3	Turn on high voltage to BF_3 counters	
______	4	Turn pulse height, band width and gain controls in pulse amplifiers to operating positions	
______	5	Set all linear channels to most sensitive ranges, and CRM to range which gives about a half-scale indication on instrument dial	
______	6	Clear high-level, period and multiplication trips	
______	7	Obtain keys for reactor control power, dump valve clutch, and source-hold	
______	8	Obtain control power by turning key switch to start position	
______	9	Determine trip condition in low-level trips Attempt to reset trips If resetting is not possible, check box at right	☐
______	10	Insert source hold key and energize circuit	
______	11	Turn master selector switch to source position, push control switch forward to drive source in until period meter reads about ten seconds If period trip occurs at that time, and control power is lost, check box at right	☐
______	12	Reset period trip, regain control power and drive source all the way in	
______	13	If, with source in, safety rod clutches are not energized (orange light off) before resetting low-level trips, check box at right	☐
______	14	Clear low level trips, set high-level trips at normal operating conditions (90% of full scale)	
______	15	Turn master selector switch to #1 safety rod position and drive rod out for about 15 seconds, until orange light goes off	
______	16	Induce trip condition in CRM and linear channel #1 by changing trip setting If control power is lost, and safety rod falls all the way in as indicated by orange light, check box at right	☐
______	17	Move trip settings back to normal, reset trips, regain control power	
______	18	Turn master selector switch to #2 safety rod position and drive rod out for about 15 seconds, until orange light goes off	
______	19	Change trip setting in linear channel #2 to induce trip condition If control power is lost and safety rod falls all the way in, check box at right	☐
______	20	Take trip settings back to normal, reset trips, regain control power	
______	21	Turn master selector switch to #3 safety rod position and drive rod out for about 15 seconds, until orange light goes off	
______	22	Change trip setting in linear channel #3 to induce trip condition If control power is lost and safety rod falls all the way in, check box at right	☐
______	23	Move trip settings back to normal, reset trips, regain control power	
______	24	Drive each safety rod out Insert dump valve clutch key and turn to start position Close dump valve by turning master selector switch to dump valve position and by pushing forward on the control switch until green light turns on	
______	25	Close main nitrogen supply valve, bypass dump tank float switch by depressing button in pit	
______	26	Depress scram button If dump valve opens freely and if nitrogen pressure reading in pressure gage falls to zero, check box at right	☐
______	27	Watch green light at console for nitrogen-pressure indication If light is off and control power cannot be obtained with key switch, check box at right	☐
______	28	Open main nitrogen-supply valve, regain control power with key switch	
______	29	Drive out all three safety rods, close dump valve and pump water until normal operating level is achieved, as indicated by green light Plug in photo cell Pumping time ______ minutes	
______	30	Withdraw shim control rod for about 15 seconds, until orange light goes off	
______	31	With hand gamma source induce trip condition in North area monitor If power to control rod clutches and the heating and ventilating fans is lost, and if shim rod falls all the way in, check box at right	☐
______	32	Reset area monitor trip	
______	33	Withdraw coarse control rod for about 15 seconds, until orange light goes off	
______	34	With hand gamma source induce trip condition in West area monitor If power to control rod clutches and the heating and ventilating fans is lost, and if coarse rod falls all the way in, check box at right	☐
______	35	Reset area monitor trip	
______	36	Withdraw fine control rod for about 15 seconds, until orange light goes off	
______	37	With hand gamma source induce trip condition in South area monitor If power to control rod clutches and the heating and ventilating fans is lost, and if fine rod falls all the way in, check box at right	☐
______	38	Reset area monitor trip	
______	39	Withdraw any control rod for about 15 seconds, until orange light goes off	
______	40	Interrupt light beam to photocell If power to control rod clutches is lost check box at right	☐

Checkout Completed

____

Signature

ACKNOWLEDGMENT

The draft of this manual was prepared by G C Baldwin.[1] He received valuable assistance from W E. Carey,[2] A. F. Cokeing, C. Fernandez,[3] G. S. Klaiber,[4] W Kolb (RE), J Paul and D. Thompson (EL). This revision was made by M Grotenhuis, and C. Buchler with the assitance of H. Bryant, F. S. Jerome, A F. Cokeing, R. Farrell, L. Lawyer, J. Paul and R. Springer The drafting and typing for both draft and revised copy were done by E. Martin and M. Koch

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[2]On loan from Ohio State University, Columbus, Ohio.

[3]Participant from Spain, ISNSE, Fifth Session

[4]On loan from University of Buffalo, Buffalo, New York.

APPENDIX A

DESCRIPTION OF THE ARGONAUT REACTOR

Discussions of the considerations underlying the Argonaut design and operation have been given along with a description of the reactor in the following reports:

1. Lennox, D. H. and Kelber, C. N., Summary Report on the Hazards of the Argonaut Reactor, ANL-5647 (December 1956).

2. Lennox, D. H. and Spinrad, B. I., Interim Report on Argonaut, ANL-5552 (March 1956).

3. Kelber, C. N., The Theoretical Physics of the Argonaut Reactor, ANL-5710 (May 1957).

4. Armstrong, R. H., Kolb, W. L., and Lennox, D. H., Argonaut-Engineering Construction and Costs, ANL-5704 (March 1957).

5. Lennox, D. H., et al., The Argonaut Reactor: A Generalized Reactor Facility for Nuclear Technology Training and Research, Second United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, June, 1958, Paper P/10190.

6. Armstrong, R. H., and Kelber, C. N., Argonaut - Argonne's Reactor for University Training, Nucleonics 15, 62 (March 1957).

To supply details of the reactor which are pertinent to the operational procedure, the descriptions in the above reports have been amplified and modifications to the original system have been included.

Figures on the following pages show various aspects of the Argonaut. Figure 6 is a recent photo of the facility. Figure 7 is an over-all view of a model of the Argonaut, showing the facilities. Figures 8 and 9 are views of the console. Figure 10 is a plan view of the core and reflector, showing the possible fuel loadings. Figure 11 is a flow diagram of the water system. Characteristics of the system, as of the date of this report, are given in the following pages and, in some cases, represent verification of design parameters.

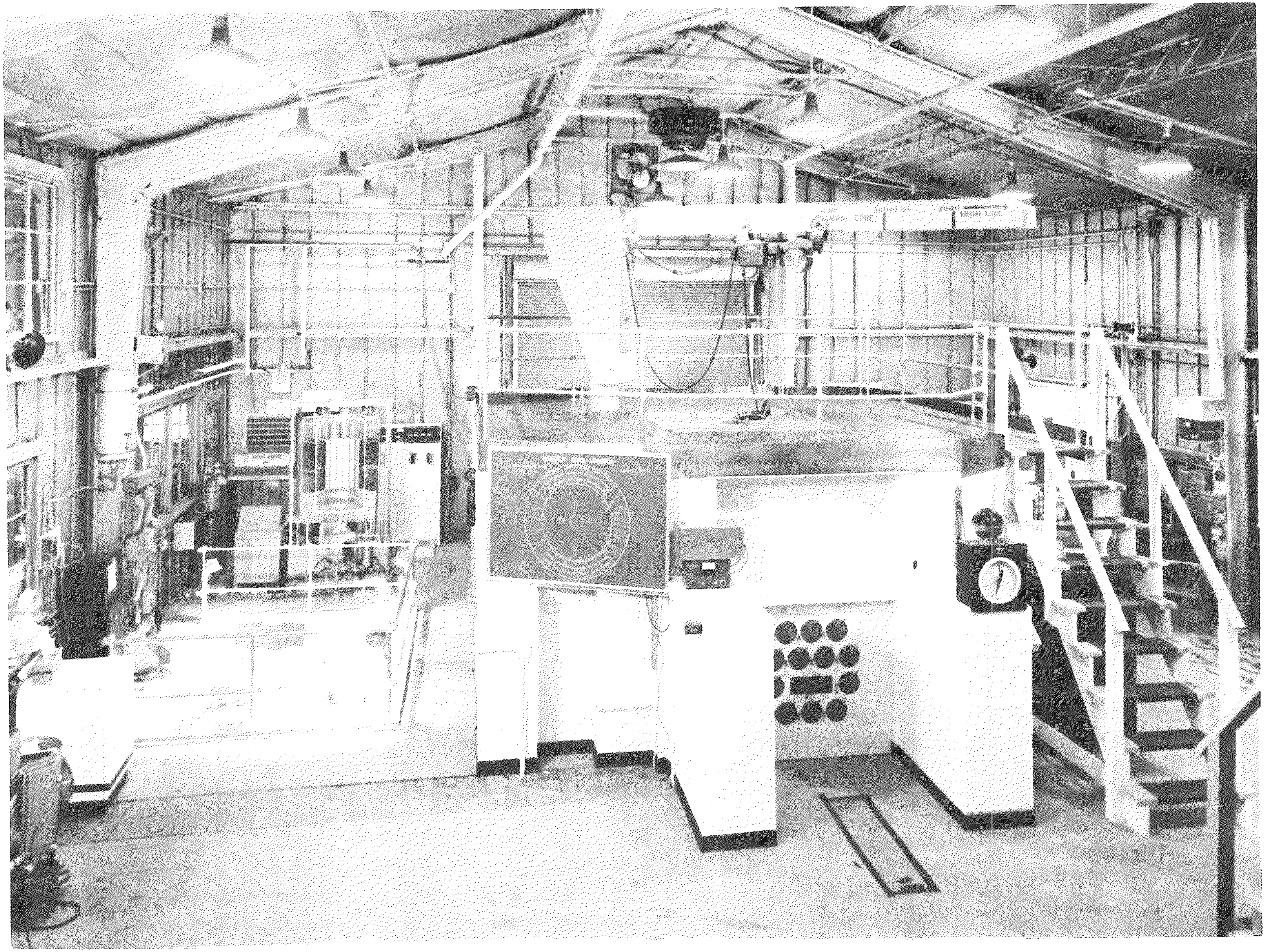

Figure 6. The Argonaut Reactor

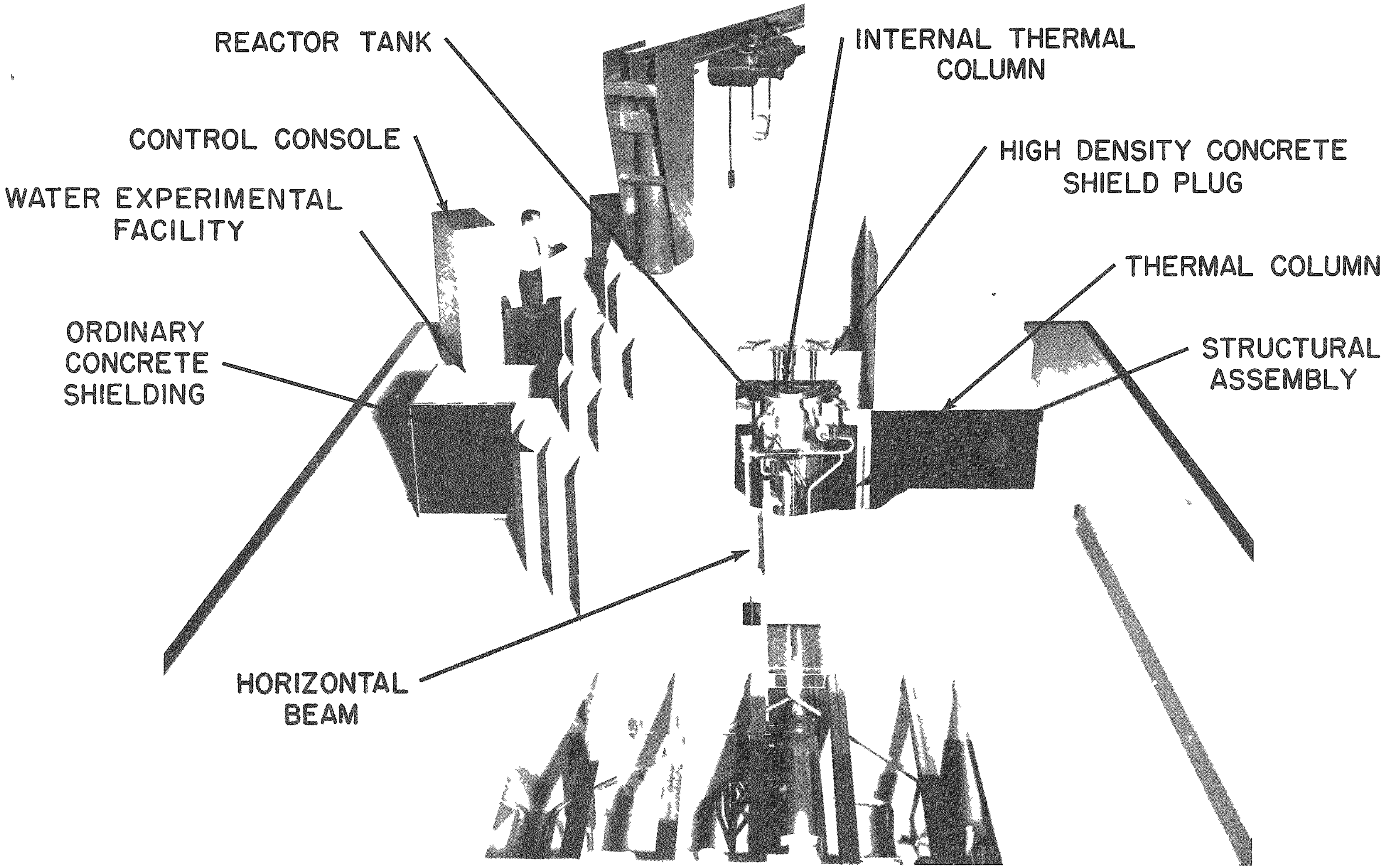

Figure 7. Isometric View of the Argonaut Reactor

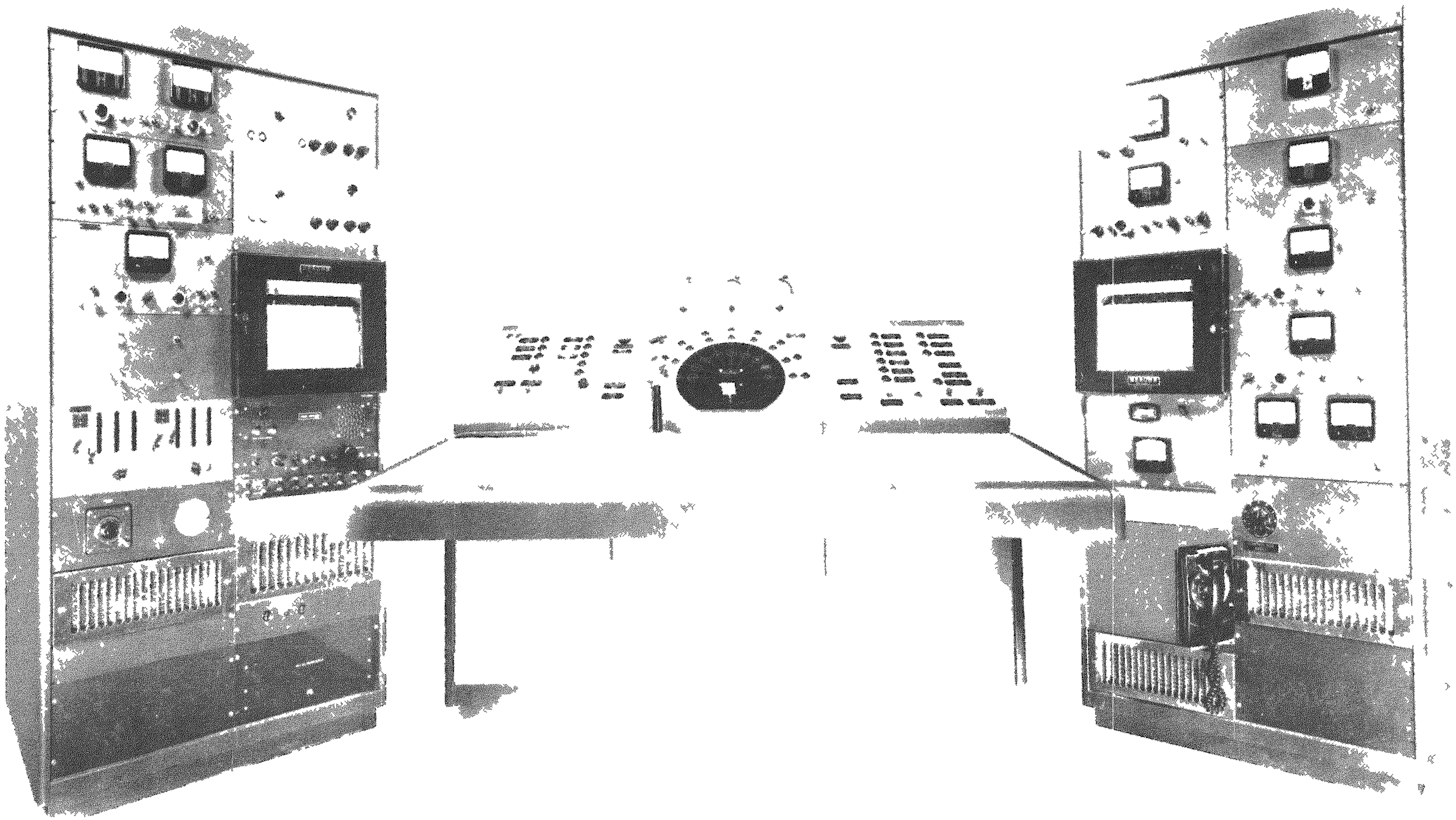

Figure 8. Control Console of Argonaut

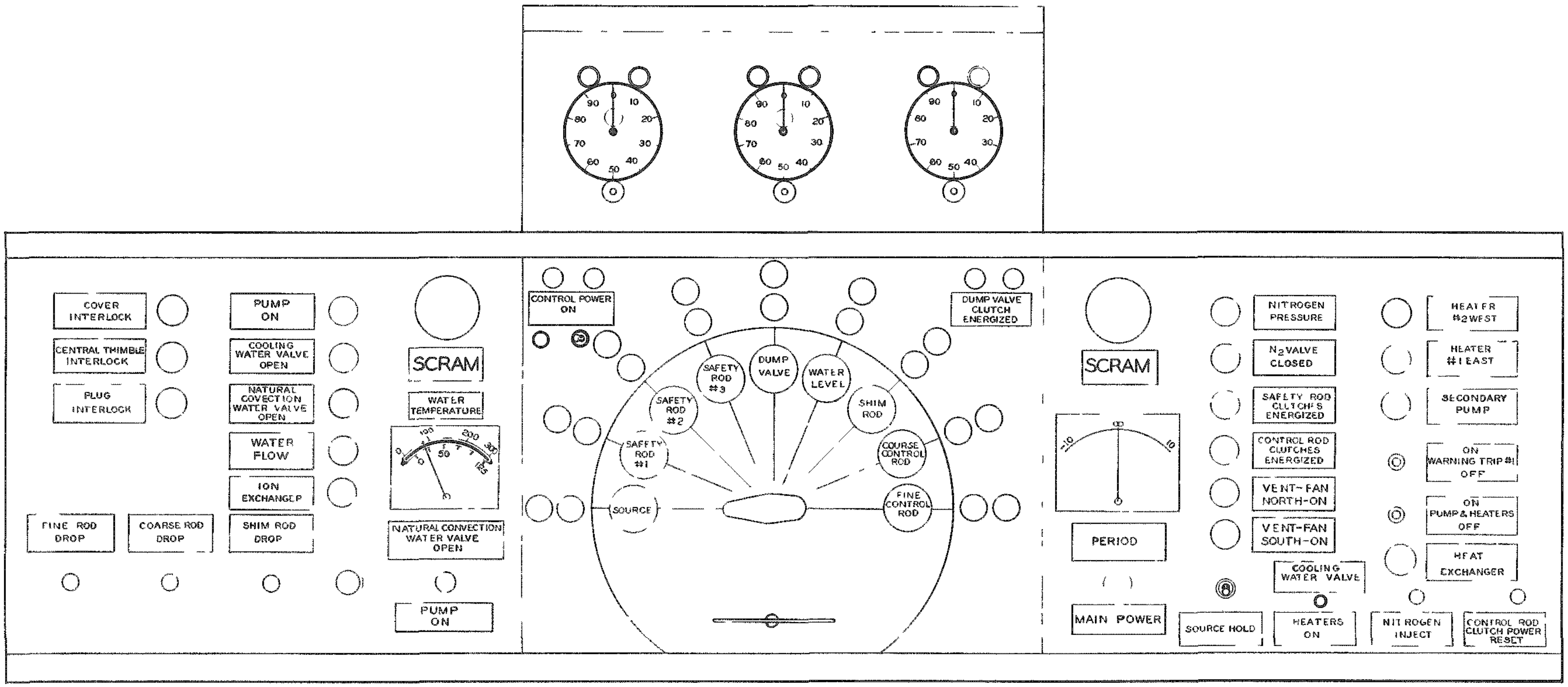

Figure 9. Line Drawing of Control Console

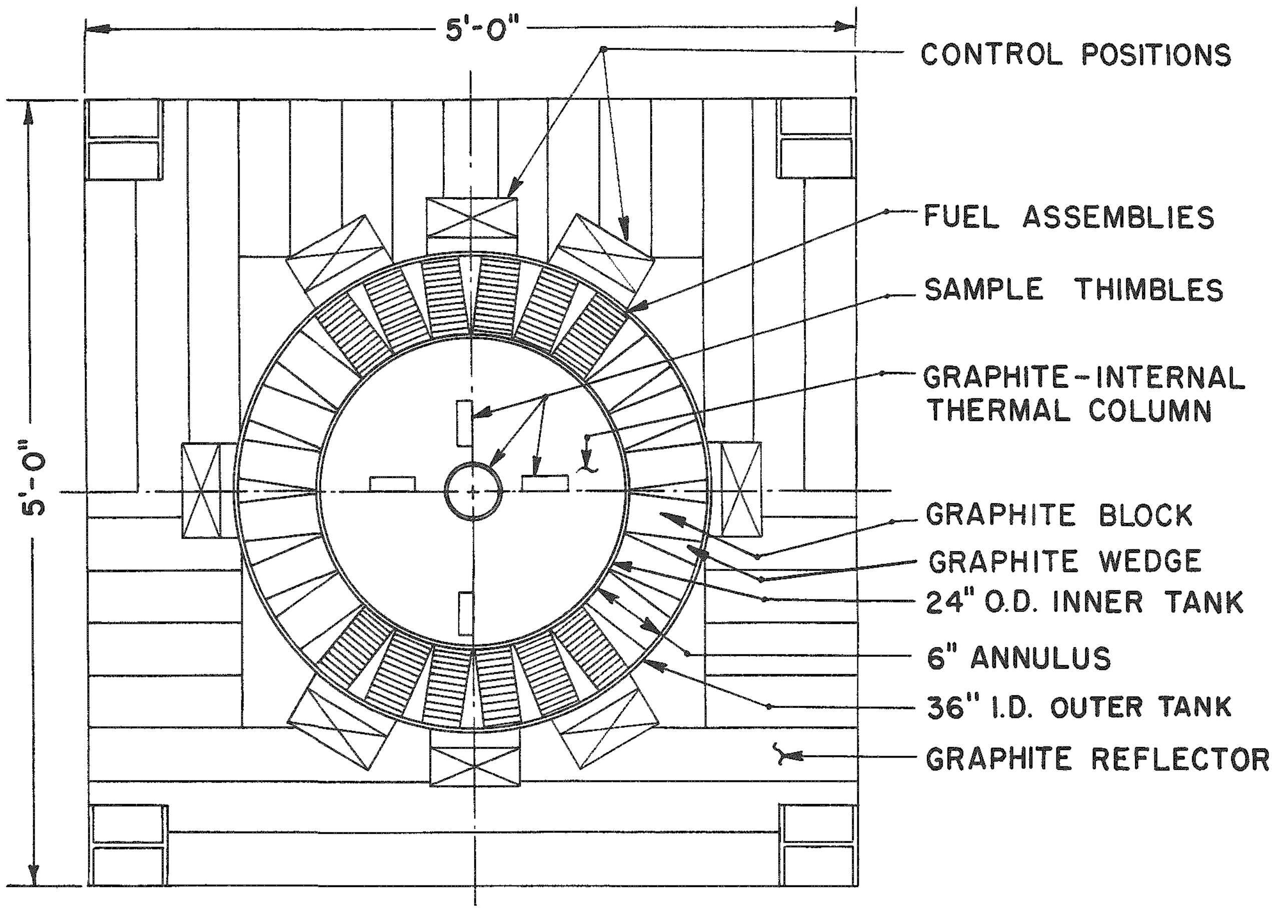

Figure 10. Plan Section of Core Lattice and Reflector

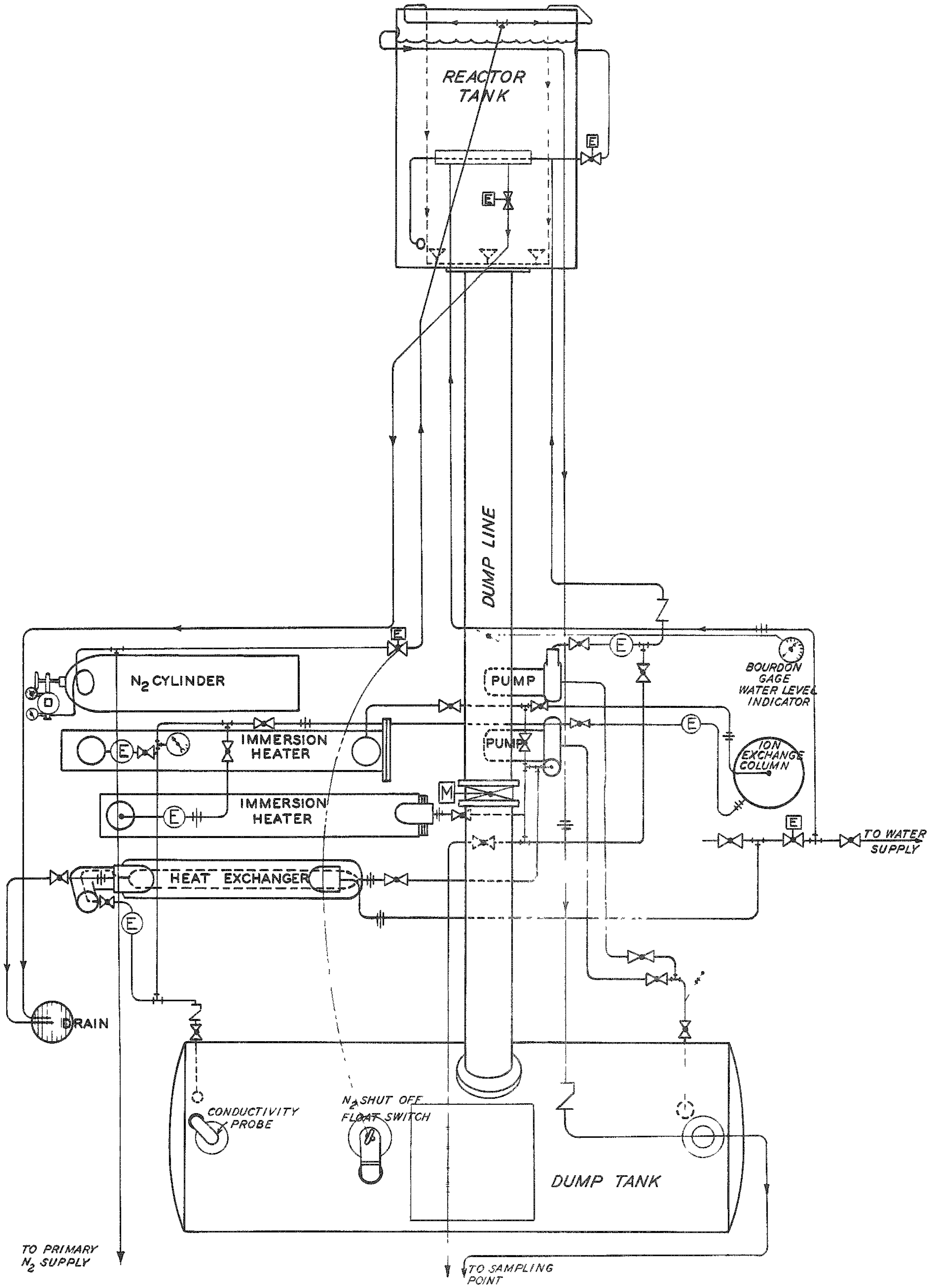

Figure 11. Flow Diagram of the Water System.

CHARACTERISTICS OF THE ARGONAUT

General

Type:	Training Reactor
Design Power:	10 kw
Normal Operating Power:	~100 watts
Normal Operating Schedule:	8 hours a day, 5 days a week.
Principal Uses of Reactor:	Education and training

Fuel

Normal Fresh Loading:	1 slab:	2.0 kg U^{235}
	2 slabs:	3.6 kg U^{235}
	3 in. annular:	4.0 kg U^{235}
Total Fuel Inventory:	6 kg U^{235}	
Fuel Element Shape:	24 x 2.84 x 0.098-in. plates	
Fuel Alloy:	39 w/o Al, 7.8 w/o $U_3^{235}O_8$, 31.2 w/o $U_3^{238}O_8$; Al matrix.	
Fuel Dimensions:	24 x 2.84 x 0.094 in.	
Cladding Thickness:	0.002 in. (avg.)	
Cladding Material:	Aluminum	
Type of Subassembly:	Stacked parallel plates	
Number of Elements per Subassembly:	Seventeen	
Subassembly Dimensions:	6 x 3 x 24 in.	
Normal Number of Subassemblies in Core:	1 slab:	6 subassemblies
	2 slabs:	12 subassemblies
	3 in. annular:	24 subassemblies
Normal Arrangements of Subassemblies	1 slab or 2 slabs in cylindrical annulus.	
Normal Lifetime of Standard Subassemblies:	Indefinite	

Reactor

Over-all Active Core Dimensions:	1 slab:	Annular sector - 30 in. OD, 24 in. ID, 24 in. high, subtending a 90° angle.
	2 slabs:	2 of above diametrically opposed.

Core-Containing Vessel:	2 concentric aluminum tanks, one 30 in. in diameter, 48 in. high; the other 24 in. in diameter, 48 in. high. Material: Aluminum Mean Operating Pressure: Atmospheric Mean Operating Temperature: Room temperature
Moderator:	H_2O between plates, graphite between subassemblies.
Reflector:	Vertical: 1 ft of water Radial: 1 ft of graphite
Biological Shield:	Ordinary concrete on sides; heavy concrete top plug, masonite and steel in some experimental facilities. Present shield is sufficient for normal operating power of approximately 100 watts.
Reactor Control:	I. Control and Safety Mechanisms: a. Three 7x7 in. cadmium vertical safety blades, steel cladding, motor drive. b. Three 7x7 in. (or less) cadmium vertical control blades, steel cladding, motor drive. c. Water moderator and reflector dumping. d. Inert gas injection in core. II. Scram-initiating Features: a. High-level, low-level, and period trips. b. High-background monitors, and personnel alarm. c. Experimental facilities and top shield interlocks. d. Manual III. Startup: Manual; automatic operation at power available.

Primary Coolant

Fluid:	Water
Circulation: a. Direction of flow:	Upward
b. Flow induced by forced circulation.	

Heat-dissipation Method:	Water to water heat exchanger.
Average Core Heat Flux:	360 $Btu/ft^2/hr$ at 10 kw.
Ratio of Maximum to Average Heat Flux:	Three
Means of Purification:	Mechanical filter and ion-exchange column.

Nuclear Data

Fuel Loading

a. Minimum Critical Mass:	1980 grams U^{235} for 1-slab loading.
b. Normal Fresh Fuel Loading:	2010 grams U^{235} for 1-slab loading.
c. Excess k, fresh loading:	0.5%

Fluxes:

a. Avg. Thermal Flux:	2×10^{11} $n/cm^2/sec$ at 10 kw
b. Peak Thermal Flux:	5×10^{11} $n/cm^2/sec$ at 10 kw
c. Avg. Fast Flux:	4×10^{11} $n/cm^2/sec$ at 10 kw
d. Peak Fast Flux:	5×10^{11} $n/cm^2/sec$ at 10 kw

Reactivity Coefficients:

a. Temperature:	1×10^{-4}	k/k/° C
b. Void:	2×10^{-3}	k/k/% void

INSTRUMENTATION

Proportional BF_3 Counters

Four BF_3 counters are provided, primarily as startup instrumentation; however, sufficient range is obtained to extend to higher power levels by choice of location, amplifier gain and pulse height discrimination, and the use of cadmium covers. All counters are located on the East face of the graphite reflector. The typical locations of the four counters designated A, B, C and D are shown in Figure 12. Each is provided with a preamplifier, accessible for servicing by removal of the square top-shield plug. Two A 1 D linear amplifiers on the left-hand control console rack provide pulse height selection and linear amplification for two of the four counters, selected by a switch on each amplifier. A dual scaler on the left-hand control console rack with automatic timer may be used for registry of counts, as in

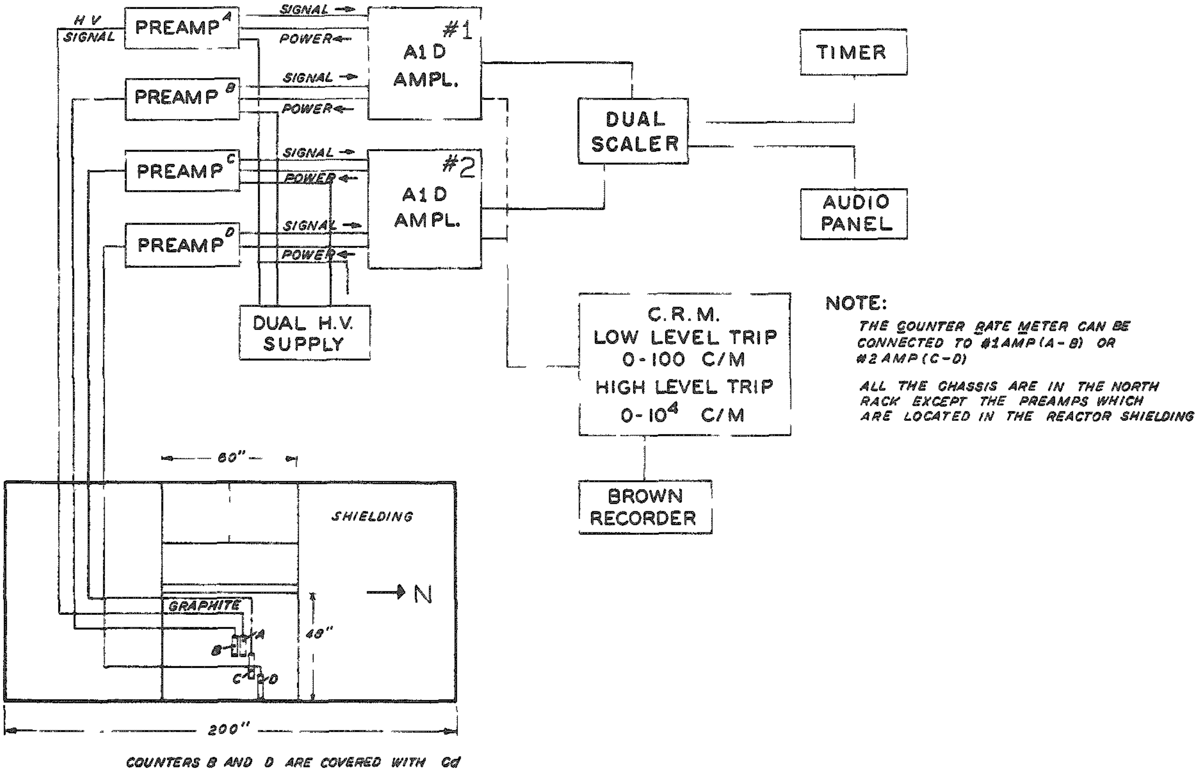

Figure 12. BF_3 Proportional Counter Channels.

approaches to criticality. The output of either linear amplifier, but normally that of Channel 2, is fed into a counting rate meter circuit and recorded by a Brown chart recorder on the left-hand control console rack. The count rate meter has a low-level trip, adjustable from 0 to 100 counts per minute, and a high-level trip adjustable from 0 to 100% of full-scale reading (10^2, 10^3, 10^4 counts per minute as selected manually). Counters B and D are cadmium-covered.

B^{10} Ion Chamber Linear Safety Trip Channels

Four B^{10}-lined parallel plate ionization chambers are located in the South face of the reflector (see Figures 13 and 14. Their sensitivity is 10^{-14} ampere/nv. Compensation for gamma radiation is provided in channels 1 and 2. Three chambers are connected to five-tube linear DC amplifiers located on the right-hand console rack (channels 1, 2, and 3). Regulated positive and negative voltage supplies are also located in the right-hand console rack. The sensitivity is adjustable by a decade step switch.

The fourth B^{10} chamber is for log level and period indication. The circuit includes a logarithmic preamplifier, located in the South trench, and log level and period meter chassis on the right-hand console rack,

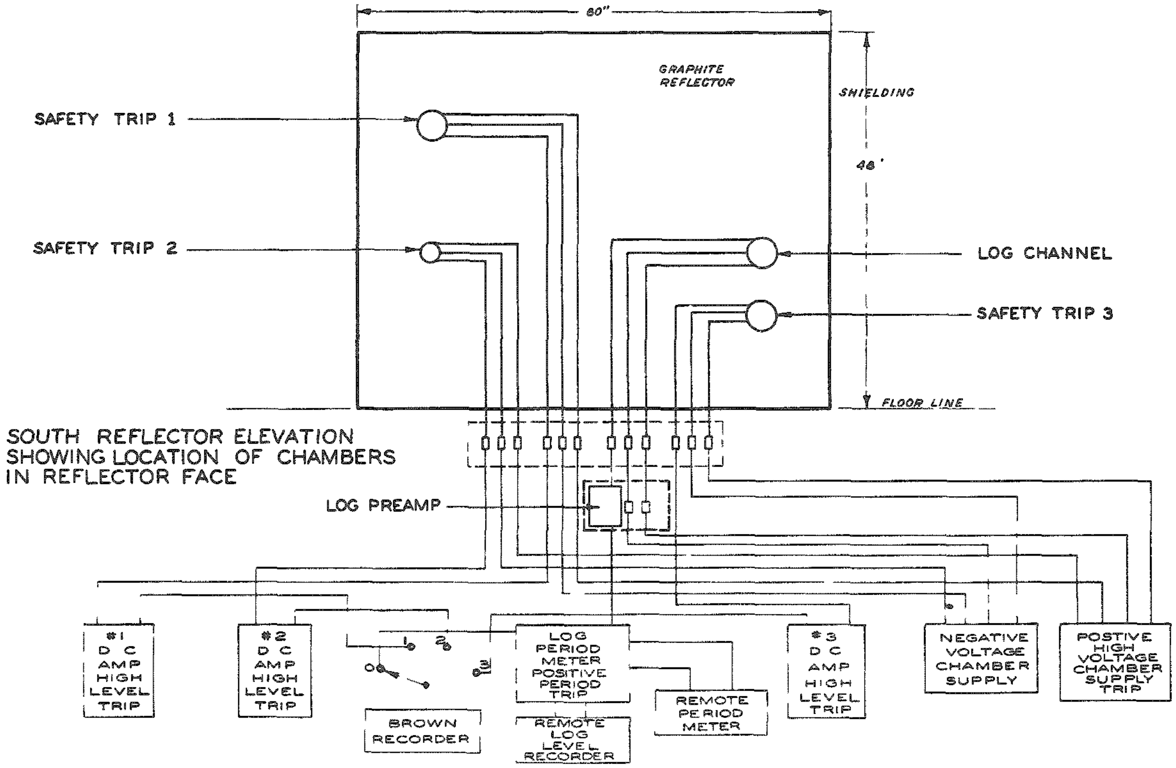

Figure 13. B^{10} Ion Chamber Channels

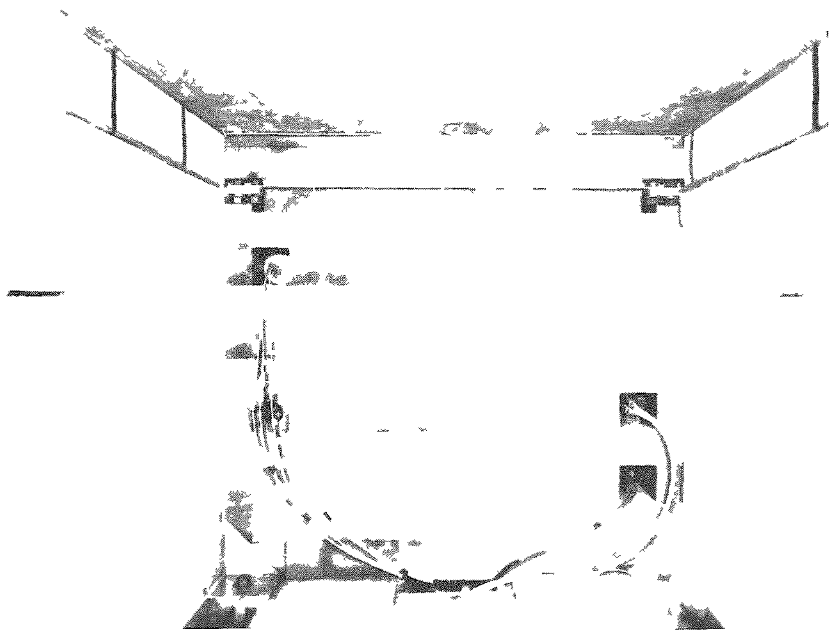

Figure 14. South Face of the Reflector (Water Tank Rolled Out), Showing the B^{10} Ion Chamber Instrumentation.

with a remote period meter on the front console rack and a remote chart recorder located at the Northeast corner of the reactor shield. A test switch, accessible from the back of the chassis, provides calibration check of the -10 and +10-second period positions.

Source Level and High Multiplication Interlock

A low source level interlock is provided by a B^{10}-compensated ionization chamber (10^{-14} amp/nv) located in the outer reflector, behind Safety Rod No. 3 (see Figure 15). A chassis on the left-hand control console rack contains a high-gain linear current amplifier with high- and low-level trips. This circuit insures that, during startup, the neutron flux

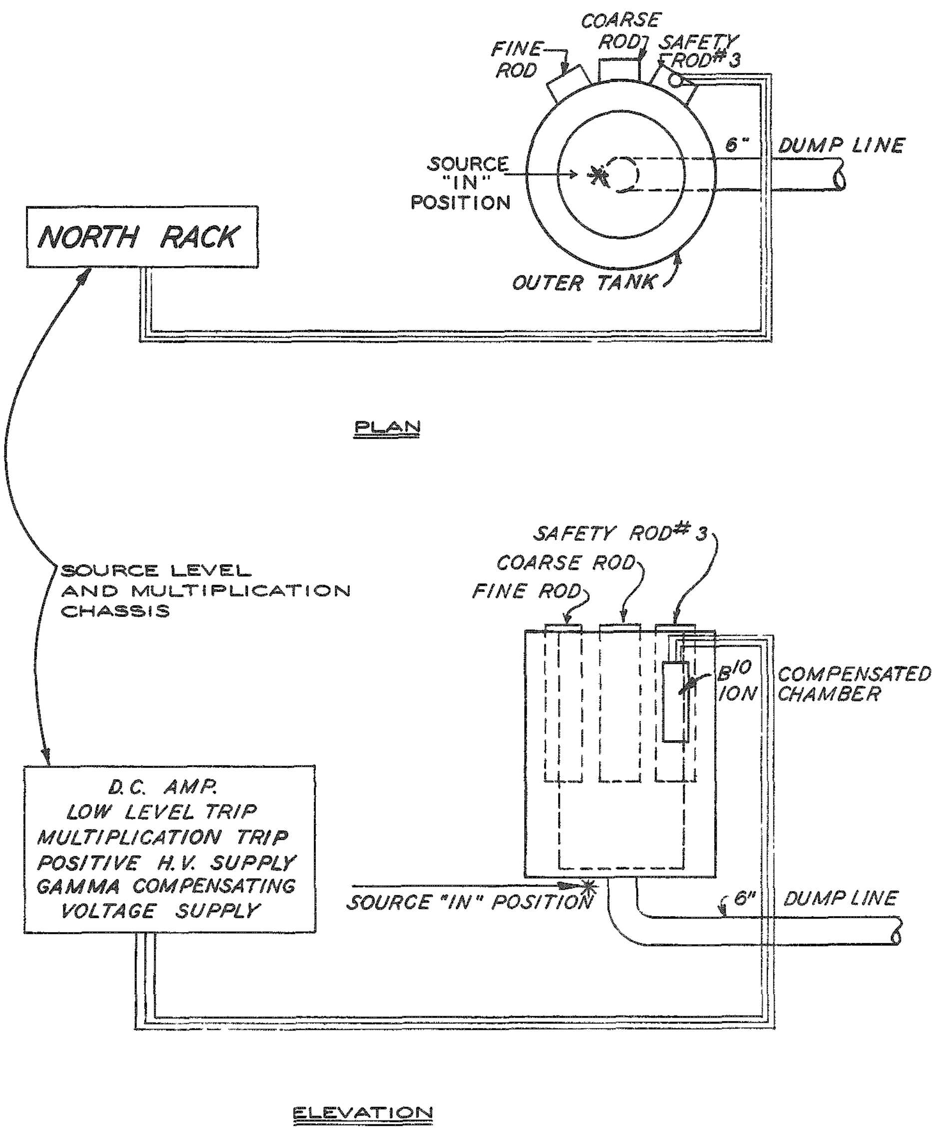

Figure 15. B^{10} Ion Chamber of Multiplication and Low Source Level Interlocks.

is sufficient to take all instrument readings well above noise level, and that a sufficient number of fissions are occurring in the reaction to make the reactivity statistically well defined.

It is designed also to detect excessive multiplication of source neutrons arising from too much reactivity in the core, and, in that event, to terminate startup. The input sensitivity is adjustable in three factor-of-two steps in order to compensate for the decay of the Sb- Be source. The multiplication factor at which the interlock acts may be selected by a top switch at the front of the chassis. This interlock will prevent startup of the reactor if the free k_{ex} built into it is larger than a present value. Its calibration, however, does not remain valid if the core geometry is changed. Furthermore, the adequate location of the detector is a determining factor in the ability of the interlock to detect unduly large reactivities. In particular, the location described here (behind Safety Rod No. 3) is adequate for a one-slab loading in the north end of the core.

Area Monitors

Three 27-liter ionization chambers with DC amplifiers are mounted in the reactor room: one on the North side of the reactor at the external thermal column; one over the fuel storage pits; and one on the South wall. The monitors detect and warn of excessive radiation level in the reactor room, interrupt power to the ventilating and heating fans to confine possible escaping airborne activity, and drop the control rods.

Each instrument has a range-selector switch permitting choice of full-scale sensitivity of 2, 20, 200 and 2000 mr/hr. A stop switch on each monitor prevents them from use above 200 mr/hr, except for the monitor over the fuel storage pits, which stops at 2000 mr/hr.

Personnel Monitors

Individuals going to the reactor top are detected by a personnel interlock consisting of a light source and photo cell. Should this occur, the control rod clutches are de-energized (see Interlock System below).

Current Source

A current source is located on the right-hand control console rack which may be connected in place of any of the cables normally leading in from the B^{10} detectors. This is used to test amplifier and trip circuit response.

Interlock System

The interlock system of Argonaut as shown in Figure 16 is designed to be "fail safe," i.e., loss of line power or failure of any component of the

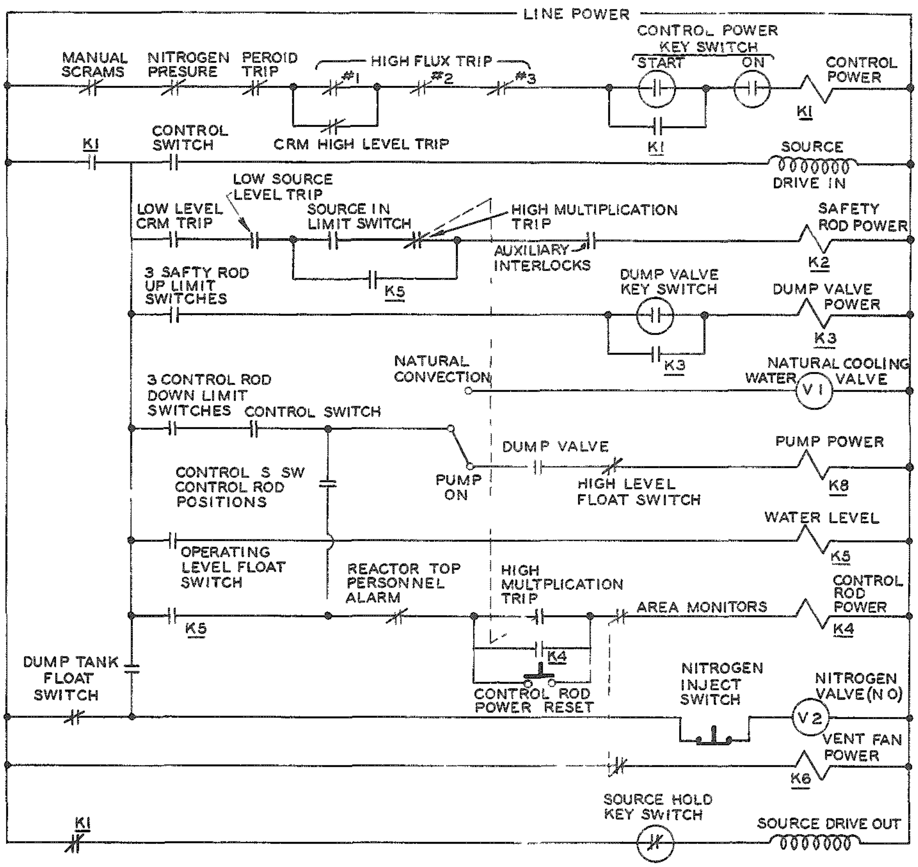

Figure 16. Interlock System

system will lead to a safe situation; ordinarily this is a shutdown of the reactor. A detailed, up-to-date diagram of the complete system is on file in the office in Building D-25.

Control power must first be obtained through a key switch. The key is kept locked in the combination file when not needed. This key switch permits Relay K1 to be energized, provided six trip contacts shown in the upper circuit are all in the closed positions. If the key is removed, control power is lost. Control power will also be lost and the reactor scrammed if, at any subsequent time,

a. pressure is lost in the nitrogen system;

b. high-flux trips occur in safety channels 2 or 3;

c. a high-flux trip occurs in channel 1 accompanied by a high-level trip in the counting rate circuit (this feature permits use of the No. 1 safety channel with the Brown chart recorder near full-scale level without attendant risk of an unintentional trip);

d. a trip occurs in the period circuit, i.e., the instrument indicates ten seconds or less;

e. any one of five manual scram buttons is depressed; scram buttons are located at either side of the front control console, in the pit near the dump valve, on a lead through the reactor top, and next to the remote log level chart.

Control power having been obtained, the neutron-source drive can be energized through the control switch and the source inserted. If control power is subsequently lost, the source will be automatically withdrawn from the reactor unless the key-operated "Source Hold" switch is in open position. This key is removed after checkout according to checkout procedure. Insertion of the source closes a limit switch which will be bypassed by contacts of Relay K5 at a later point in the startup procedure. Satisfaction of this interlock and auxiliary interlocks on the top shield plug and internal thermal column allows Relay K2 to energize the three safety rod clutches, unless low- or high-level trips are registered on the source-level interlock circuit or a low-level trip is registered on the counting rate meter. (The auxiliary interlocks are indicated by green lights at the extreme left of the control console.)

Relay K3 may next be energized in the startup sequence, provided upper limit switches on all three safety rods are closed. A manually operated key switch completes the interlock circuit for Relay K3, allowing the dump valve to be closed by operation of the control switch. The "dump valve" key switch is bypassed by a contact of Relay K3 and may then be removed.

After the dump valve is closed, with the toggle switch on the front console at the "Pump On" position, water may be pumped into the reactor vessel by operating the control switch, provided limit switches indicate full insertion of the control rods and the water level is below a "High Level Float Interlock" in the reactor vessel. A high-multiplication trip in the source interlock circuit, which de-energizes the safety rod clutches, insures that the k_{ex} in the reactor is below a preset value.

When water has reached the lower or "Operating Level Float Interlock," Relay K5 is energized. Contacts of Relay K5 perform the following functions:

a. Water is pumped automatically and control rod clutches are energized, provided the control selector switch is turned on to any of the three control rod positions.

b. The "Source-In" limit switch and high-multiplication trips are bypassed, permitting raising the reactor flux level and removal of the source without the interlock protection needed prior to this point in the startup procedure. The control rods may be raised in any sequence so long as Relay K4 remains energized. Automatic water pumping continues until the "High Level Float Interlock" is reached.

Interruption of a personnel alarm on the reactor top or indication by the Area Monitors of excessive radiation levels outside the reactor shield will de-energize Relay K4. Should either of these trips open, control rods will be dropped, causing the reactor power to fall. However, as soon as the cause for the trip is eliminated, the control rod clutches may be re-energized by depressing a reset button on the control console. This may be done in spite of a trip condition in the high multiplication interlock.*

Admission of nitrogen to the spargers in the reactor vessel is blocked by the nitrogen valve, V2, which is held closed by line voltage applied through normally closed contacts of the storage tank float switch (when water is not in the reactor vessel) or by control power voltage (when water is in the reactor vessel). When control power is lost after water has been admitted to the core, nitrogen is injected until sufficient water has returned to the storage tank to close the storage tank float switch. A manually operated push button at the control console allows nitrogen to be injected at other times.

In the event of high radiation levels inside the building the "Area Monitor" interlock will disconnect power to the building vent and heater fans and drop the control rods.

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*The multiplication trip circuit contains two interlocks: one is in the safety rod power circuit, the other is in the control rod power circuit. The latter is superfluous as a multiplication trip. It does, however, provide a convenient interlock to insure a full insertion of the control rods with a gamma monitor or personnel monitor trip. Without this interlock, a slight interruption of the gamma or personnel monitor circuits would drop the control rods a small amount. This could occur unnoticed by the operator. Without the control rod power reset button (shown in Figure 16), it would be impossible to regain control rod power until the background level had dropped to startup level.

APPENDIX B

MISCELLANEOUS

Reactor Keys

Keys required for reactor operation, for access to fuel storage pits, and for the crane and console racks are kept in the top drawer of a combination file in the reactor room.

Fuel Control

Fuel may be locked in the combination storage safe, in the storage pits, or in the reactor core. It may be locked in place by a combination on the storage safe, the lock on the storage pits or by de-energizing the crane and locking it. Only the responsible reactor supervisor may request the movement of fuel from one place to another.

Log Books and Charts

Completed log books and daily log level charts will be kept in the reactor office file.

Radiation Monitoring

All personnel in Building D-25 for any extended period are provided pocket dosimeters and film badges located on a rack at the Southeast entrance to the reactor room. For transient personnel, "rover" dosimeters are provided.

A hand-and-foot monitor is also located at the Southeast entrance. Survey equipment in Building D-25, maintained and operated by the radiation Safety section of the Industrial Hygiene and Safety Division, includes two Juno beta-gamma survey meters, a portable G-M survey meter and a neutron monitor consisting of a BF_3 counter, counting rate meter and paraffin moderator.

General Safety Equipment

Two fire extinguishers and a Scott Air-Pak are in the reactor room. Fire retarding paint is used to coat all exposed wood surfaces in Building D-25.

Safety shoes and safety glasses are furnished on request to all personnel.