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CEND CRITICAL FACILITIES
OPERATIONS MANUAL
BONUS CRITICAL EXPERIMENT

November 21, 1960

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U. S. ATOMIC ENERGY COMMISSION

NUCLEAR
DIVISION

COMBUSTION ENGINEERING, INC.

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PENDING PATENT CLEARANCE

CEND CRITICAL FACILITIES
OPERATIONS MANUAL

BONUS CRITICAL EXPERIMENT

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November 21, 1960

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I. INTRODUCTION

A. Need for Safe Operation

The need for safety in the operation of a critical facility cannot be over-emphasized. Although many safeguards are built into the facility, one cannot forget that a reactor is a device which could have destructive capabilities and that the seriousness of a reactor accident cannot be overstated. There is always the remote possibility of injury and/or exposure to radiation to personnel on the site if the critical assembly is handled carelessly or is improperly designed. Furthermore, the experimental program would be set back many months as a result of replacing damaged equipment, cleaning up contamination, and re-establishing safe procedures.

Experience in the operation of other reactors has shown that accidents, although improbable, can and do occur. In every case, however, the accident has been preceded by a misoperation, disregard of safety rules, improper bypassing of interlocks, misunderstanding as to operational authority, or faulty equipment, operation or design. This manual contains the procedures, rules and regulations under which the CEND Critical Facilities can be operated safely. The various control and interlock systems are described and regulations for their testing and use are set forth. Descriptions are also given of reactor checkout procedures, duties of the crew, ground rules for operation, normal operating procedures and emergency procedures.

ALL PERSONNEL ARE TO REGARD THIS MANUAL AS THE BASIS OF OPERATION. ANY DEVIATION MUST BE APPROVED IN ADVANCE AS OUTLINED IN SECTION IV A.

B. Methods of Insuring Safe Operation

1. The first and foremost prerequisite for safe operation of a critical facility lies in the attitude and level of competence of the personnel who are responsible for the administration and operation of the facility.

2. A second rule to be followed in conducting all operations is that no work will be done under extreme duress of time.

3. The rules and procedures for the facility must not be unnecessarily restrictive but at the same time should provide for safe operation. Non-realistic rules will encourage frequent violation of the letter of the law and if this practice is condoned, the spirit of the law eventually may be disregarded also.

4. All equipment used in connection with critical experimentation must have a high degree of reliability.

5. It will also be required that experimentation be performed only with cores of a type approved in the Safeguards evaluation.

6. Automatic safety devices with a sufficient speed of response and safety margin to accommodate any reactivity changes which may conceivably be encountered will at all times be provided. In addition, the control circuitry of the reactor will include automatic interlocks which will enforce an approved safe sequential startup and operational procedures.

7. It will also be absolutely necessary to ensure that all cores are properly assembled and loaded to criticality.

8. All equipment shall be designed, insofar as possible, to be "fail safe." Thus, failure of electrical power, air pressure, electronic components, etc., should automatically result in shutting down the reactor in a safe manner. Also, the failure of a mechanical component in the reactor should, at worst, not increase reactivity; the failure of an instrument should be immediately obvious or give a pessimistic reading.

9. The design of all circuits, procedures, etc., shall be such that the reactor will be safe after a sequence of three improbable events, with the following definitions:

a. "Safe" - protected from going onto a fast transient even though that transient would be terminated by temperature coefficient or water expulsion without any radiation exposure or mechanical damage.

b. "Improbable" - unlikely under realistic assumptions.

c. The primary event in the sequence, an excessive addition of reactivity, must in itself be improbable.

d. Operator error or inattention may be a primary event.

e. Inattention by the entire operating crew or their failure to institute remedial action may be considered a single improbable event in those sequences where their action could have terminated the sequence. Thus, the usual line of defense is:

(1) Improbability of cause.

(2) Attention by well-trained crew.

(3) Operation of electromechanical shutdown system despite any single failure.

10. It is considered basically impossible to protect the reactor by electromechanical means against sabotage or deliberate suicide by an

individual who is reasonably familiar with its operation. The basic safeguard here lies in the selection of personnel and in the physical security measures imposed by fences, armed guards, etc.

11. During approaches to criticality and subsequent operations, the Crew Chief will have absolute authority over the operation of the reactor. However, if any person present, regardless of rank, does not consider an act about to be taken by or under the direction of the Crew Chief to be safe, then all operations will be halted until the disagreement is resolved.

12. There will be a minimum of three qualified persons present at all times during operation of the reactor.

13. It should be understood that the rules listed in this section are necessary but not sufficient as the criteria for insuring safe operation. It should be re-emphasized that the primary safeguard in any critical experimentation lies with the operating personnel and their degree of competence.

C. References to Other Documents

1. Plant Safety Manual

The physical safety of personnel, as contrasted with safety from nuclear radiation arising from the BONUS Critical Facility operation, is covered by rules set forth in the "Plant Safety Manual." All supervisory personnel will familiarize themselves with its contents, especially the provisions relating to safety precautions, accident prevention, and the responsibility of supervisory personnel toward the safety of all persons under their supervisory control.

2. Security Manual

The Company's security provisions are covered in the manual entitled "Combustion Engineering, Inc., Security Procedures." This document covers document control, personnel security, and physical security. It is available for reference in the office of the Critical Experiment Building. In addition, the Security Department issues memorandum covering specific problems such as classified waste disposal, visitor control, etc. Copies of the latest procedures are kept with the Security Procedures Manual.

3. Accountability Manual

CEND has the legal responsibility to keep a strict account of the location of all the SS or "source and strategic" material that has been entrusted to the Division by the AEC. A list of the accountability procedures as required by the AEC will be kept at all times with the Accountability Manual.

4. Nuclear Safety Manual for CEND (CEND-0022-TM-5)

The purpose of this manual is to describe the methods and guidelines that Combustion Engineering Nuclear Division uses to maintain a nuclear safe plant. The general procedures established in it for the critical experiment facilities will be adhered to at all times and are incorporated throughout this manual.

5. CEND Critical Facilities Safeguards Reports, BONUS Critical Experiment (CEND-110)

This report, and any later supplements, describes in detail the core construction, experimental program, hazards analysis, etc., for a given series of experiments. It also provides the reactivity addition rates, rod drive speeds, water flow rate, etc., which are approved for that particular experiment. These limitations must be adhered to at all times. Supplements to the Safeguards Report will modify the appropriate sections of this manual accordingly.

II. DUTIES AND ORGANIZATION OF THE STAFF

The operation of a critical facility places a heavy responsibility on the operating personnel. They must be of sound judgment and remain calm in an emergency, and yet be prompt to act correctly when necessary. The highest quality of laboratory work must be maintained. An efficient, safe approach to every new core loading must be planned and executed. Discipline somewhat uncommon to professional work must be maintained and no uncertainty can be permitted in regard to authority and responsibility for each operation.

To accomplish these objectives, both personnel and job functions have been classified into various categories. Sections A, B, C, and D list the duties and qualifications of personnel in relationship to the various job functions. Section E summarizes which categories of personnel can perform which job functions, and Section F outlines further regulations regarding the necessary number of personnel for various additional operations.

A. Operations Personnel

1. Operator A (Operator in Training)

Personnel in this category will be in training to become qualified reactor operators. An Operator A is expected to become proficient in the following areas:

- a. He should understand the basic principles of a nuclear reactor.
- b. He should know safety rules and the reasons for them. This includes understanding this manual and the Safeguards Report, following the operating procedures and aiding in keeping them up to date, knowing the emergency evacuation procedure, and learning the Health Physics procedures.
- c. The operator must learn the purpose, function, and limitations of the reactor instrumentation and equipment and be alert to recognize any malfunctioning of same.
- d. He must learn the purpose and function of the mechanical, hydraulic, and electrical safety devices. These include safety rods, interlocks, scram circuits, operation of the dump valve, etc.
- e. He must become familiar with loading procedures and safe methods of fuel handling.

Finally, with the approval of the Critical Facility Supervisor, he will be assigned as an operator to run the reactor after he has accomplished, under direct supervision, a sufficient number of checkouts, approaches to criticality, and hours of critical operation to demonstrate his proficiency.

2. Operator B (Qualified Operator)

The duties of the qualified reactor operator consists of the functional operation of the reactor under the direction of the Crew Chief. This includes assisting in the checkout of all instruments prior to the beginning of an experiment. If any malfunctioning instruments or components are discovered by him while conducting a checkout, it is his responsibility to inform the Crew Chief of this condition. During a critical run the operator's entire effort should be directed toward the safe operation of the reactor, and he should not be burdened by secondary tasks.

His specific responsibilities include the following:

- a. He will operate the reactor in a safe and competent manner under the direction of the Crew Chief.
- b. He will conduct scheduled reactor and instrument checkouts under the direction of the Crew Chief and report all malfunctioning.
- c. He will perform core changes under the direction of the Crew Chief.
- d. He will maintain various logs and records as directed by the Crew Chief.

3. Operator C (Operator in Training as Crew Chief)

An Operator C is a person who has become a qualified reactor operator and has been selected by management for training so that he may act as Crew Chief. His primary responsibility is to increase in depth his knowledge of reactor theory, operations, and equipment.

4. Operator D (Qualified Crew Chief)

An Operator D is fully qualified to act as Crew Chief. He has been trained as an Operator C and certified as an Operator D by management on the basis that he has the necessary knowledge and experience to direct the safe operation of the reactor under all foreseeable circumstances. He must have a working knowledge of reactor theory as, for example, contained in Glasstone's "Principles of Nuclear Reactor Engineering." Furthermore, he must have a complete knowledge of the equipment (what the various functions are, why the equipment is required, and how it functions). In addition, he must have demonstrated over a protracted period of time a high level of supervisory ability, good habits of caution, safety consciousness and, above all, good judgment. At the discretion of the management, a prospective Operator D may be required to take a written examination and to give a formal demonstration of his ability to operate the reactor and direct the crew.

The specific duties of the Crew Chief include the following:

- a. He is responsible for safe operation of the reactor.
- b. He is responsible for the safety of personnel, and checks the cell before starting each run to insure that no one remains inside.
- c. He is responsible for reactor checkout as outlined in Section IV C.
- d. He is responsible for maintaining the various operation log books, equipment log books, scram records, etc. (see also Section IX).

B. Physics Personnel

1. Categories

Various categories of reactor physicists have been established as follows:

- a. Physicist A - Personnel in this category will, in general, be recent staff additions who are in training as experimental physicists and, as such, may be granted access to the control room during a run.
- b. Physicist B - When fully qualified as an experimental reactor physicist, an individual will be designated as Physicist B and may be assigned the responsibility for conducting an experiment by the Facility Supervisor.
- c. Physicist C - A Physicist C will also be fully qualified on the safety aspects of the reactor, and may act as a Safety Consultant; a Safety Consultant is required to be available during each run to aid the Crew Chief on any safety problem that may arise.
- d. Physicist D - In addition to fulfilling the requirements of Items b and c above, he will receive training as a reactor operator.
- e. Physicist E - When the Physicist E is fully qualified as a reactor operator, he may operate the reactor. It should be clearly understood that any such operation will be under the sole direction of the Crew Chief.
- f. Physicist F - The Physicist F will, in addition to the above, be qualified to act as a Crew Chief, when necessary.

2. Duties of Experimental Reactor Physicists

- a. Prior to Experimentation

The Reactor Physicist is responsible for the planning of experiments in consultation with the Facility Supervisor. He is also responsible for consulting with the Crew Chief on the feasibility of his experiment and on briefing the operations personnel on the purpose and particulars of the experiment. Following detailed planning of the experiment and the preparation of a written procedure, he will obtain management approval.

He is responsible for the procurement and/or shop fabrication of any special equipment needed for the experiment and will be responsible for seeing that such equipment is obtained on time.

b. During Experimentation

The cognizant physicist will be responsible for checking the core and any special experimental arrangements prior to each run.

The physicist will be present in the reactor control room during the run and will record the data in his own experimental log book. The operating log book which is maintained by the operating crew is intended primarily as a record of operating conditions and, incidentally, may at times include some experimental data.

The physicist may make suggestions to the Crew Chief during the run, respecting the chain of command among the operating staff. For example, if he wishes the operator to use a particular control rod for placing the reactor on a rising period prior to foil irradiation, he will make this request via the Crew Chief.

c. After Conclusion of the Experimentation

The Reactor Physicist will be responsible for analyzing and interpreting the data during his experiment. The Reactor Physicist will prepare the final report on the experiment.

C. Health Physics Representative

The Health Physics representative serves at the staff level by advising and assisting the Crew Chief in carrying out his responsibility for securing the safety of all persons who might become exposed to nuclear radiations arising from the operation of the reactor, or radioactive materials. In particular, he has the following responsibilities:

1. He will provide the members of the crew with appropriate personnel monitoring devices.

2. He will aid in establishing health physics procedures for the various operations.

3. He will advise the Crew Chief as to when and to what extent protective clothing shall be worn.

4. He will assist the Crew Chief in determining when cell entry is permissible and specify time limits for work in the vicinity of the core, hot fuel, or other radioactive materials.

5. He will determine the presence of radiation zones and so inform the Crew Chief.

6. He will survey all materials to be removed from the cell, vault, or a radiation zone and report his findings to the Crew Chief.

7. He will direct the decontamination of personnel when required, determine the source of any such contamination, and report same to Crew Chief for corrective action.

8. He will take regular air samples in accordance with standard health physics procedure.

D. Critical Facility Supervisor

The Critical Facility Supervisor is a senior staff member who has been selected by management to be in charge of the over-all operation of the CEND Critical Facilities. He need not have program responsibility (planning of experiments to satisfy specific project requirements, development of techniques, etc.) for a particular sequence of experiments; he is, however, always responsible for the safe operation of all critical assemblies.

His specific responsibilities include the following:

1. Assign Operators and Crew Chiefs.
2. Train Operators and Crew Chiefs.
3. Accountability of fuel and sources.
4. Review changes in operating procedures and equipment.
5. Review checkout and maintenance of reactor equipment.
6. Determine entry of workmen into fenced area outside building.
7. Review experimental plans with cognizant physicist.
8. Maintain adequate health physics and emergency procedures.

E. Reactor Operating Crew

1. Crew Chief

There shall be one Crew Chief who shall be in charge of operating the reactor. His duties have been defined in Section A.

The following personnel may act as Crew Chief:

- a. Operator D
- b. Physicist F

2. Safety Consultant

There shall be a safety consultant in attendance at all times during the operation of the reactor. His duties have been defined in Section B.1.C. This function may be filled by the following personnel:

- a. An Operator D or a Physicist F, provided that he is not acting as Crew Chief.
- b. A Physicist C or D.

3. Cognizant Physicist

The person whose experiment is being performed on the reactor must be in attendance in the control room during all operations involving that experiment. This responsibility may be delegated to another qualified person under special circumstances with the approval of the Facility Supervisor.

The following personnel may be assigned experiments by the Facility Supervisor:

- a. Physicists B through F.

It should be noted that a Physicist F, when not acting as Crew Chief, and Physicists C through E may act as both Safety Consultant and Cognizant Physicist simultaneously.

4. Reactor Operator

This function may be performed by:

- a. An Operator B or C.
- b. An Operator D, when not acting as Crew Chief.

c. A Physicist E or F, when not acting in any of the categories described above.

d. An Operator A or a Physicist D, provided that a qualified reactor operator as defined in Section II A, above, is present in the immediate vicinity of the control console.

In summary, a minimum crew for operating the reactor consists of a Crew Chief, and Operator, and a Safety Consultant. In addition, the Cognizant Physicist, who may also be the Safety Consultant, must also be present.

F. Additional Regulations

1. Personnel acting in the categories outlined in Section D will have their names entered in the logbook prior to operation of the reactor.

2. Any deviation from the regulations established in Section D must be approved in writing by the Physics Department Manager prior to performance.

3. A minimum of two persons must be present in the building for after-hours work involving mechanical or electrical equipment but not requiring operation of the reactor. The second person is to be available for emergency action and need not be an employee regularly assigned to the building.

4. An Operator D, Physicist F and one other staff member must be present for all core loading changes.

5. Any personnel who have no immediate interest in the operation of the reactor will not be permitted in the control room in order to prevent confusion and distraction of the operating crew whose complete attention must be focused at all times on the task confronting them.

6. It will be absolutely forbidden for any personnel to be in the reactor cell with the access door closed at any time that there is fuel in the core.

III. REACTOR FACILITY

This section describes the basic mechanical, hydraulic, and instrument systems of the CEND critical facility to be used for the BONUS critical experiments.

A. Hydraulic and Mechanical Components

1. Tanks, Pumps and Valves

a. Reactor Vessel

The over-all view of the reactor structure is shown in Figure 1. A coated carbon steel tank eight feet in diameter and seven feet high and of 3200 gallon capacity is located in an opening in the first floor decking. Platforms above and below the main floor facilitate handling and maintenance of rod drives, nuclear instrumentation, etc.

b. Storage Tank

Mounted on the lowest level, twenty-five feet below the first floor level, is a coated carbon steel storage tank of 4000 gallon capacity and associated pumps and demineralizing unit.

c. Dump Valve

A six-inch ball valve located in the six-inch fill/drain line (Figures 1 and 2) serves for moderator dump. The valve is closed by a compressed air operated cylinder acting against a spring so connected that the valve opens on loss of air pressure and/or electrical power due to a scram or component failure. This valve will permit the full reactor to be emptied in 3 minutes at an initial rate of fall of about 0.68 inches per second. It should be emphasized that this system is used only as a "back-up" safety device; the primary (fast) safety shutdown mechanism consists of the rapid insertion of the safety rods.

d. Main Pump

The reactor vessel is filled from the storage tank by a 7-1/2 hp 100 gpm centrifugal pump. This pump is also used to circulate water, via the overflow line, when desired. The flow rate is limited by a locked valve acting as an adjustable orifice which can be set to meet the maximum water addition rates for various cores. The flow rate can be further reduced by a motor operated throttle valve operated from the control room.

The calibration of the locked valve is checked by observing the rate of rise of water in the reactor vessel every time the setting is changed (one inch equals 31.3 gallons in the empty reactor

vessel and 25.6 gallons when the full BONUS mockup is installed). The calibration is also checked at regular intervals by the use of an electrical probe for determining water heights. The key for this and all other locked valves is controlled by the Crew Chief, as discussed in Section IV A.

e. Overflow Lines

A permanent 3" overflow line runs from near the top of the reactor vessel to the storage tank. Provision is made for addition of a 3" overflow line inside the tank whose height would be adjustable. At present this line is blanked off.

These lines do not contain any valves or sharp bends and either one of them is adequate to take the full discharge flow from the pump without a serious rise in water level in the vessel. The superheater pressure tubes extend over the top of the vessel so that they cannot be accidentally flooded even if the overflow line became obstructed.

f. Microfill/Drain and Millidrain System (Figure 2)

Secondary hydraulic systems, the "microfill/drain" system and the "millidrain" system are employed to produce small changes in water height. The use of these systems for partial water height experiments is discussed in Section IV F.

The microfill system consists of a 20 gpm pump (supplied from the storage tank) whose outlet is connected, via a locked valve, to a line running over the top of the reactor vessel; the line runs into a tube which extends to the bottom of the vessel to prevent wave formation while the pump is being operated. Power for the microfill pump is interlocked with the control rod drives so that power is available and can be utilized only under conditions similar to those applying to control rod withdrawal after the water has been brought above the top of the core. Furthermore, the pump cannot be energized unless the "Partial Water Height" key is turned on. Lower values of flow rate will be maintained, if required, by the setting of the locked valve on the pump outlet.

The microdrain system consists of a normally closed solenoid valve in a one inch diameter drain line in parallel with the dump valve. The millidrain system, which permits more rapid draining than the microdrain system, consists of a normally closed solenoid valve in a two inch diameter line, also in parallel with the dump valve. Power for these systems is interlocked so that it is available and can be applied whenever the "Partial Water Height" key is turned on. Estimated flow rates are 60 gpm for the microdrain line and 250 gpm for the millidrain line.

g. Demineralizer Loop (See Figure 2)

A demineralizer system is provided to maintain the water at an adequate degree of purity. The system consists of a loop which contains a small pump, appropriate valving, and resin-bed ion exchange demineralizer of 4 gpm capacity. This system is supplied from the building water supply via a free-fall tank or from the storage tank and discharges into the storage tank. It may thus be operated independently of the reactor safety interlocks whenever required to maintain adequate water purity.

2. Neutron Source

The reactor startup source is a doubly encapsulated Po-Be source 2.5 inches long x 0.30 inches diameter and is stored in a 24" diameter x 24" long paraffin and borax filled steel container located on the upper platform among the rod packages. Source strength generally ranges from 20 curies initially to about 1 curie at replacement time. The source capsule is placed in a secondary sealed brass container 4.25 inches long by 0.375 inches diameter attached to a cable, and is guided into its core location by 5/8" diameter stainless steel tubing. The cable is gear driven, and, to give jam protection, a friction clutch is located between the drive unit and the motor-gear reducer unit. Up and down limit control is provided by two microswitches.

A careful check is made when locating the down limit switch to insure that the source will not be lowered below the center of reactivity in the core. By the use of suitable tubing, the source may be guided into any desired location within limitations imposed by core dimensions.

Source position is sensed by a helipot on the drive unit and indicated to ± 1 inch by a voltmeter on the console.

3. Lower Support Structure

Four support columns are used to suspend the lower support structure from the top flange of the reactor tank. The lower support is approximately six feet square, and is fabricated from coated carbon steel. The bottom grid plates, which support the entire weight of the fuel and other core components, are attached to the support structure with clamps and bolts, permitting flexibility in location. Spacers and jigs are used for final alignment prior to tightening the hold-down bolts.

B. Control Rod Drive System

1. General

The overhead control rod drive packages are supported on a grating and may be positioned at any point over the tank. Connections to the control rods are via turnbuckles and quick disconnects.

2. Safety Rods

The safety rods are moved by scrammable drive units shown in Figure 3. Structurally, the drive consists of an A.C. motor, gear box, magnetic clutch, drive shaft, pinion gear, and rod rack. The upper end of the rack actuates position indication and limit switches. Fine rod position is sensed by a precision helipot geared to the drive shaft after the clutch and is indicated by a sensitive digital ratiometer on the control console. An oil-filled dashpot assembly is incorporated into the rack vertical guide and is suitable for rods from 60 to 100 pounds in weight. Provision is made for the operation of up to eight safety rods. In general, 6 to 8 safety rods will be used; an interlock requires that an absolute minimum of two be employed.

3. Shim Rods

The shim rods are moved by non-scrammable cable drive units shown in Figure 4. Each unit consists of an A.C. motor, gear box, and drum on which a cable is wound. Limit switches indicate position and prevent overtravel in either direction. Fine position is sensed by a precision helipot. As discussed below, the interlock circuitry permits only one shim rod at a time to be withdrawn and only if the safety rods have first been withdrawn. Furthermore, the shim rods are automatically driven into the core when a scram occurs. Provision is made for the operation of up to twelve shim rods.

4. Safety Considerations

CEND Critical Facility Operating Rules require that an absolute minimum of 2% δk be available as fast safety in the form of two or more raised scrammable control rods whenever there is water in the core. The purpose of this is to provide rapid shutdown if the reactor, by some improbable sequence of events, were to become supercritical even during the initial fill.

Depending on the worth of the rods, the required fast safety can be obtained in two ways: (1) two or more scrammable rods fully withdrawn ("cocked") before water can be added to the core, or (2) all the scrammable rods withdrawn to some intermediate position in the core (safety point) prior to water addition. Method (1) has the following disadvantages:

a. There is a period of time before the rods reach the water.

b. The incremental rod worth as the rods enter the water (the top of the supercritical core) is relatively low.

c. The initial rate and shutdown margin would be halved if, for example, one of two safety rods were to become stuck.

Method (2), used at the CEND Critical Facilities, has the advantage that it will produce a larger rate of decrease of reactivity in the period immediately after receipt of a scram signal (the time when it is needed most) since more rods are starting at a point where the differential rod worth is much higher than at the top of the core.

In addition to the 2% δk fast safety requirements outlined above, it is also necessary to have a minimum of 2% δk control margin between the safety point and criticality; this is required to ensure that criticality will not be attained during the initial fill. Thus, with all control elements fully inserted, k_{eff} must be $\leq .96$, and with the safety rods at the safety point, k_{eff} must be $\leq .98$. The 2% control margin consists of the worth of the portions of the partially withdrawn safety rods still in the core and/or the worth of additional fully inserted non-scrammable shim rods. The condition in which the safety rods are at the safety point and the shim rods are fully inserted is termed "rods in safety pattern," and is a prerequisite for initial fill. After the water has risen above the core, criticality may be attained by withdrawal of the shim rods and/or further withdrawal of the safety rods from the safety point.

Except for reactor shutdown, none of the safety rods may normally be driven below the safety point unless the shim rods are down. Thus, an absolute minimum of 2% δk is always available as fast safety. If any safety rod is inadvertently driven below the safety point, pump power and withdrawal power to all rods ("critical power") is automatically removed. To recover it is necessary to take the reactor subcritical by driving the shim rods to the down limit and inserting the startup source or, when permissible, to use the single rod recovery system described below.

5. Summary of Restrictions

The rod control circuits provide the following restrictions on the operation of the control rods:

a. Safety or shim rods may be withdrawn only one at a time by spring return switches.

b. Any number of rods may be driven down at any time, either individually or as a group. In addition, they may be driven down simultaneously with the withdrawal of one additional rod. It should be noted, however, that "critical power" is removed if any of the safety rods are driven below the safety point unless all installed shim rods are down. As a consequence of this restriction, when shim rods are present, they are the only rods that may be calibrated over their entire length unless the single rod recovery system may be used.

c. An absolute minimum of two safety rods must be installed.

6. Setting of Safety Point

The number of safety versus shim rods, their location in the core, and the location of the safety point limit switches on the safety rods are determined for each new core loading by calculation and/or by previous measurements of rod worth in similar cores. This decision is constantly evaluated during the initial loading of each core.

7. Rod Speed Control

The maximum rod speed, which is controlled by the gear box ratio, is determined by the maximum incremental worth of the control rods so that the reactivity rate of $0.04\% \delta k/sec$ is not exceeded. Speeds of approximately 5, 10, 15, and 20 inches per minute are available for all rods. The voltage to the drive motors may be reduced by a variac on the control console, thus further reducing the rod drive speed for fine control.

8. Magnetic Clutch Power

Power for the magnetic clutches on the safety rods is supplied from composite safety amplifiers; the current is adjusted to the lowest value for which there is no slippage of a suspended rod. In the event of a scram signal, this power is automatically removed causing the magnetic clutches to disengage, releasing the rods. At the same time, all of the shim rods are automatically driven into the core at their normal rate.

9. Drop Characteristics of the Safety Rods

Drop times have been measured for a fifty pound rod falling twelve inches from rest. The average of measurements made on several drives is 390 milliseconds from release of power to the magnetic clutch. These measurements are made on a periodic basis to ensure that the units are functioning properly.

10. Rod Drop Switches

Switches located on the control console permit manual interruption of current to the electromagnetic clutches on the individual safety rods. These switches may thus be used for dropping any selected safety rod at any time without scrambling the reactor. Of course, clutch power to all safety rods is independently turned off in the event of a scram signal.

11. Single Rod Recovery System

As discussed above, "Critical Power" (for withdrawing rods, microfilling, etc.) is normally lost if any safety rod is dropped or driven below its safety point unless all installed shim rods are down. This is done to insure that the required minimum of 2% δk fast safety is maintained - i.e., to prevent the reactor from being kept critical by safety rod insertion compensated by shim rod withdrawal.

On occasion, however, it is necessary and safe to operate with one of the safety rods below the safety point. This is required for:

a. Recovery from a rod drop experiment, in which a measurement of the rate of decay of neutron flux can be related to the worth of the rod which has been dropped,

b. Recovery from inadvertently driving one of the safety rods below the safety point,

c. Calibration, by period techniques, of a safety rod below its safety point when the insertion of this rod is compensated by withdrawal of another rod.

The Single Rod Recovery System will only be used if the remaining safety rods, at or above their safety point, provide the required 2% δk fast safety. The system will not permit recovery from a condition in which more than one safety rod is below its safety point or in which less than two safety rods remain above their safety points.

The Single Rod Recovery System consists of a key-switch and a rotary selector switch. These switches may only be operated by the Crew Chief. This system changes the "safety rods at or above safety point" requirement for maintenance of "critical power" to, essentially, "all but the selected safety rod at or above safety point."

In summary, this system may only be used if the remaining safety rods maintain the required 2% δk fast safety; does not alter any other required interlocks; and permits recovery only when at least two rods remain at or above their safety points and only one rod is below its safety point.

C. Nuclear Instrumentation and Scram Circuitry

1. Nuclear Instrumentation

The nuclear instrumentation is shown by the block diagram of Figure 5. Seven detectors - four BF_3 counters and three uncompensated BF_3 ion chambers - are used to cover ranges from startup to full power. Of these seven, five are capable of scrambling the reactor, three by excessively low period and two by excessively high power level.

These detectors, contained in 5" diameter aluminum tubes introduced horizontally through the reactor vessel wall, are located in the vessel at various distances from the core. The detectors are surrounded in the tube by polyethylene in order to provide some moderation for increase in sensitivity during initial fill.

The three scram channels outlined below must be operable at all times. Sufficient spare equipment is maintained to permit this.

a. Channel E - linear level scram adjustable range

- (1) Uncompensated BF_3 ion chamber (Reuter-Stokes Type RSN-5)
- (2) Beckman linear ~~ammeter~~ ^{ammeter}
- (3) Matching amplifier
- (4) Composite safety amplifier (Honeywell 4639-A)
- (5) 1500 volt chamber supply (Atomic 312)

b. Channel F - Period scram

- (1) Uncompensated BF_3 ion chamber
- (2) Log N and period ^{amplifier} (ORNL)
- (3) 1500 volt chamber supply

c. Channel G - linear level scram fixed range

- (1) Uncompensated BF_3 ion chamber
- (2) D.C. Preamplifier
- (3) Composite safety amplifier
- (4) 1500 volt chamber supply

The four information channels, of which at least one log and one linear channel are required to be operable, are constituted as follows:

d. Channels A and C - log level, period indication

- (1) BF₃ pulse counter (RCL 10502)
- (2) Preamplifier
- (3) Linear amplifier (ORNL-AID)
- (4) Log count rate meter (ORNL)
- (5) Period amplifier (ORNL)
- (6) Simplotrol meter-relay
- (7) 2500 volt chamber supply

e. Channels B and D - linear level indication, adjustable range instruments

- (1) BF₃ pulse counter
- (2) Preamplifier
- (3) Linear amplifier
- (4) Linear count rate meter (ORNL)
- (5) 2500 volt counter supply

Of these instruments, Channels A, B, C, D, and E are normally on scale during startup; at least Channel A or C, Channel B or D, and Channel E must be on scale at this time. Intermediate power is normally monitored by Channels C, D, E, and F. High power operation is monitored by Channels E, F, and G, none of which may ever be above full scale.

The response times of identical equipment of the NUSU critical assembly have been measured, as follows. Data are given below for the case of a step increase in level starting from zero input signal, the time being from application of the step to removal of clutch magnet voltage.

<u>Channel</u>	<u>Detector</u>	<u>Measuring Instrument</u>	<u>Scram</u>	<u>Time</u>
A	BF ₃ Counter	Log CRM - Period Amp.	Period	2000 msec
C	BF ₃ Counter	Log CRM - Period Amp.	Period	2000 msec
E	UIC	Beckman W ammeter	Level	275-1370 msec depending on range
F	UIC	Log N - Period Amp.	Period	95 msec
G	UIC	Composite Amp.	Level	20 msec

It can be seen that while the low level startup channels (A and C) are relatively slow (i.e., generally about 2 sec delay), a period scram with 0.1 sec delay covers the medium and high level regions and a level scram with only 0.02 sec delay will initiate a scram if the level should reach the 1000 watt (or lower) point before other instruments can respond.

2. Rod Drop Instrument Scrams

A scram by rod drop is effected by any one of the following conditions (see Figure 6):

- a. High level on Channel E
- b. Low period on Channel F.
- c. High level on Channel G
- d. Low period on both Channels A and C. This is not an officially required scram circuit and may be bypassed, if either channel is not functioning properly, at the discretion of the Crew Chief.
- e. Manual scram (also dump moderator)

Coincident with a rod scram, the following actions are performed automatically:

- a. Shim rods are driven in to the down limit.
- b. The circulating pump is turned off, preventing addition of moderator to the reactor vessel.
- c. Withdrawal power to all rods is cut off, preventing rod withdrawal until the scram is reset.
- d. The microfill system is de-activated, preventing the addition of moderator to reactor vessel.

3. Moderator Dump Instrument Scrams

Fast safety is provided at all times by the rod drop scrams outlined above. Supplementary reactivity removal is provided by dumping the moderator on verification of the single scram signal (which has already dropped the safety rods and caused the shim rods to be driven in) by an independent signal from a separate channel. This prevents loss of moderator on a spurious scram signal from any single channel.

Moderator dump is effected under each of the following conditions (see Figure 6).

- a. High level on E and low period on F
- b. High level on E and high level on G
- c. Low period on F and high level on G

- d. Low period on A and C, and high level on E
- e. Manual scram

Each channel on sensing the existence of a scram condition causes a scram by opening a relay contact. This contact remains open until the scram is reset. Since this is the case, the two and three channel requirements for water dump constitute a verification of scram rather than a coincidence. In addition, it should be noted that water dump is always preceded, if only by a few milli-seconds, by a rod scram. It should also be noted that a real transient will always initiate a moderator dump even if one of the officially required channels (E, F, or G) fails to respond at this crucial moment, i.e., any two of the three channels can produce a water dump.

Coincident with a moderator dump scram, power is also removed from any component which was receiving it via a bypass.

4. Audible Monitor

The audible monitor consists of a BF₃ counter (located in one of the instrument ports), an amplifier, a HV power supply, a count rate meter, and a speaker. The amplifier, power supply, and meter are located on the dump valve platform; the speaker is located under the rod drive platform and can be heard throughout the cell.

The audible monitor receives power via a normally closed contact on the "access door closed" relay in the interlock system, i.e., only when the cell access door is open. This is done to prevent damage to the sensitive monitor by detection and indication of a high neutron flux during reactor operation.

D. Non-Nuclear Instrumentation

1. Rod Position Instrumentation

Rod position is sensed by Helipot in the rod drive packages and is indicated for any one rod at a time either by a sensitive digital ratiometer (to $\pm .01$ inch) or by a coarse position voltmeter (to ± 0.5 inch).

2. Water Flow Instrumentation

The water flow rate in the main fill line is sensed by a pneumatic pressure differential transmitter across an orifice in a bypass line, with remote indication on the control console.

3. Water Level Instrumentation

Liquid level in the storage tank is indicated by a sight glass on the tank. The liquid level in the reactor vessel is sensed by a pressure sensitive pneumatic transmitter located on the bottom of the vessel. Remote indication is given by a guage on the control console.

Water height in the reactor tank can also be more accurately determined (± 0.01 in.) by an electrical probe attached to a spare non-scrammable control rod drive package. The probe is insulated from the rod drive cable and operates by completing an electrical circuit through the water in the reactor tank. Continuity indication is registered by a microammeter in the reactor console and position is indicated on the digital ratiometer. Variability in water height measurements from surface tension effects is reduced by always approaching the surface from the same direction, preferably from above.

The "water above core" relay in the interlock circuitry is closed by a normally open pressure operated switch which trips when the level in the reactor vessel exceeds a preset height.

4. Annunciators

The annunciator system, which consists of a horn and a panel of light, announces any abnormal conditions. The following conditions are annunciated:

- a. Scrams (type and instruments responsible)
- b. Bypasses in use
- c. Water flow or pressure higher than normal
- d. Partial water height key on
- e. Pump hold key on
- f. Any circuit breaker tripped

E. Reactor Console

The reactor operator is seated facing the central section of the console. To his right and left are two diagonally placed side sections. The sloped panel directly in front of him facilitates the manipulation of the various controls. Above it, directly in his field of vision, are those annunciators and recorders which require constant operator surveillance. Figure 7 is a photograph of the control console, and Figure 8 identifies the various components of the console.

IV. OPERATING PROCEDURES

A. Administrative Control

1. Experimental Programs and Methods

a. All experimental programs and techniques must have the prior approval of the Physics Department Manager.

b. An Experimental Safety Review Committee, consisting of senior members of the Physics Department, serves as an advisory staff to the Physics Department Manager in evaluating experimental programs and techniques. The Committee includes but is not limited to the following items in its review of each experiment proposed:

(1) the proposed core loading, number and type of control elements, location of safety point, etc.,

(2) the method to be employed in the initial approach to criticality,

(3) maximum rod withdrawal speeds and water addition rates,

(4) any special experimental arrangement, e.g., void simulation, flooding and voiding of superheater sections, partial water height experiments, etc.,

(5) the void coefficient of the proposed core,

(6) the temperature coefficient of the proposed core.

2. Revisions and Deviations

a. Control, Interlock and Scram Circuitry

(1) Major changes in the facility, overall program, operating philosophy or control, will first be reviewed with the CEND Nuclear Safety Committee, composed of senior members of the Nuclear Division and then submitted for approval to the U. S. Atomic Energy Commission.

(2) Minor changes which do not affect the overall operation or safety of the reactor (e.g., the addition of extra signal lights, replacement of switches or relays) require the approval of the Critical Facility Supervisor.

b. Operating Procedures and Ground Rules

Deviations from the established operating procedures and

ground rules for a single experiment or series of experiments must be approved as follows:

(1) Approval must be obtained from the Physics Department Manager, who is advised by the Experimental Safety Review Committee.

(2) At the discretion of the Physics Department Manager, the proposed deviation may be referred to the CEND Nuclear Safety Committee for approval.

(3) If the proposed change is sufficiently basic in nature to affect the overall hazards evaluation (e.g., maximum reactivity addition rate, new methods of adding reactivity), the matter will be submitted to the AEC for approval.

3. Cell Access

a. The reactor cell is secured with a combination padlock during the evening and weekend hours and in the absence of designated members of the operating crew.

b. The combination of the cell access padlock is known only to persons qualified to act as Crew Chiefs.

c. During approaches to criticality and any subsequent critical operation of the reactor, the cell access door is secured by a doorknob lock. The key is stored in the repository described below and is controlled by the Crew Chief.

4. Reactor Keys

a. All keys are kept in a locked repository in the control room.

b. The key to this repository is kept in the Crew Chief's safe when not in use.

c. The Control Power key will be released to the operator for checkout by the Crew Chief when he removes the cell door security combination padlock and opens the doorknob lock. The Operate key will be released only after the checkout is satisfactorily completed.

d. Interlock Bypass keys will be released, as required, for testing components, by the Crew Chief.

e. The Access Door Interlock Bypass key will be released by the Crew Chief only on prior approval by the Critical Facility Supervisor for each particular use.

f. The partial water height and circulating pump hold keys

are to be operated only by the Crew Chief.

g. The doors to the control console are normally kept locked; the key is controlled by the Crew Chief and is released only for making authorized changes or repairs in the instrumentation and control circuitry.

h. The keys for the locked valves in the hydraulic system are to be used by the Crew Chief only on prior approval of the Facility Supervisor.

5. Personnel

a. The qualification of personnel as crew chief, reactor operator, etc., is determined by written or oral examination by the Critical Facility Supervisor, with approval of the Physics Department Manager.

b. The designation of personnel to act as crew chief, physicist, operator, etc., for a particular run or series of runs is performed by the Critical Facility Supervisor.

B. Interlock System

A block diagram of the interlock control system is shown in Figure 9. This circuitry acts to allow application of power to various components of the reactor only when certain conditions are satisfied. It has been designed as far as possible to be fail safe; to impose a rigid, safe startup sequence; and to make certain that unsafe post-startup operations are impossible. A detailed up-to-date wiring diagram is maintained on the wall in the Control Room.

A description of the startup procedure is given below to illustrate the logical sequences enforced by the control system. Deviations from this sequence are prohibited by both the interlock circuitry and the operating rules. The use of jumpers to short out an interlock is absolutely prohibited; however, a keyswitch operated interlock bypass system is used to provide power for testing individual components in a safe manner.

1. Startup Sequence (see figure 9)

a. Power to drive the source and rods down is available whenever the control power is turned on.

b. Rod clutch power may be obtained when:

- (1) all scram signals have been cleared,
- (2) the cell access door is closed or the dump valve is open,

(3) and the source is in place.

Note that clutch power is maintained after the source is removed, in order to permit post critical operation.

c. Withdrawal power to the safety rods in the Safety Zone may now be obtained if:

- (1) a neutron count rate meter is on scale,
- (2) no interlocks have been bypassed,
- (3) the source is still in place,
- (4) and all rods have been fully inserted.

d. Dump valve closure power is available:

- safety point,
- (1) after the safety rods have been withdrawn to the
 - (2) if the source is still in place,
 - (3) the shim rods are still at the down limit,
 - (4) and the cell access door has been closed.

e. The "Reactor On" light and Running Time meter are energized after:

- (1) the dump valve is closed,
- (2) and the Operate key-switch has been turned on.

f. The main flow control valve is normally opened at this time.

g. The main pump may now be turned on to fill the reactor vessel:

- (1) if the rods are still in the safety pattern.

The pump start switch normally acts as a spring return push button which must be held down for as long as it is desired to run the pump. For some types of Approaches to Criticality (See Section IV E) this switch can be converted to an On/Off two-position system by use of a key-switch operated by the Crew Chief.

h. The main pump is run until:

- (1) the water is brought above the top of the core.

Note that the setting of this interlock is actually at 6 inches above the top of the active fuel region, insuring that any further addition of water will have a negligible reactivity effect. For some experiments the water is raised an additional 6 inches to provide extra shielding during high level foil irradiations.

i. After the water rises above the top of the core:

(1) the rods are withdrawn from the Safety Pattern until the reactor is brought critical.

2. Post Critical Operation

a. After the water rises above the top of the core:

(1) the main pump, in conjunction with the reactor vessel overflow, may be run as a circulating system so long as the water remains above the core.

(2) Critical Power is now available for:

- (a) withdrawal of safety rods above the safety point,
- (b) or withdrawal of shim rods from the down limit,
- (c) or microfilling (see Section IV F)

as long as

- (a) the water remains above the core,
- (b) or the circulating pump is turned off and the flow control valve is closed,
- (c) and the safety rods remain above the safety point unless the shim rods are down or no shim rods are installed.

b. Note that only one means of adding reactivity (control rod withdrawal or microfilling or operation of the circulating pump) is available at any one time.

C. Facility Checkout and Maintenance

The facility and all related equipment will be inspected and maintained on a periodic basis to prevent, insofar as possible, any malfunctioning which could impair the safety and efficiency of operation of the reactor.

Appendix II describes in detail the inspection and maintenance procedures which are conducted on a daily, weekly and monthly basis. A summary of these procedures follows:

1. Daily Procedures

- a. D-1: Energizing and checkout of console and cubicle.
- b. D-2: Opening and checkout of cell.
- c. D-3: Checkout of nuclear instrumentation and scram circuitry.

- d. D-4: De-energizing and securing cell.
- e. D-5: De-energizing console and cubicle.

2. Weekly Procedures

- a. W-1: Inspection and lubrication of all mechanical equipment.
- b. W-2: Inspection of demineralizer.

3. Monthly Procedures

- a. M-1: Operational check of interlocks, bypasses and alarms.
- b. M-2: Testing of nuclear instrumentation linearity, response times, and calibration.

D. Loading Changes

- 1. All loading changes will be made with the Crew Chief and at least one other person present.
- 2. The Vault Custodian and all others having access to the vault or cell combination must be "Q" cleared personnel. Fuel out of storage must be continually attended by "Q" or "L" cleared individuals. The various storage locations are as follows: the vault, core, cell balcony, and Counting Room safe.
- 3. All work with fuel and other radioactive materials will be subject to radiation hazards evaluation by the assigned health physics representative, who will make recommendations to the Crew Chief regarding working time limitations, protective clothing, etc. (See also Section II E and Section VIII).
- 4. Insertion of the reactor source will not be required as long as the low range instruments are on scale. Indication of an instrument scram will be provided by an audible alarm in the cell connected to the scram circuitry.
- 5. The audible neutron monitor located in the cell shall be operating and clearly audible.
- 6. ALL CHANGES SHALL BE MADE WITH A DRY CORE WITH EXCEPTIONS DESCRIBED IN SECTION IV.H.3, "ACCESS DOOR BYPASS."
- 7. All changes must be recorded in the logbook prior to operation.

E. Initial Approach to Criticality

For a given core, one of the three following methods will be specified for the initial approach to criticality.

1. Type I - $1/M$ by Fuel Loading Steps

This method is used for new cores when major changes in instrumentation, interlocks or source-detector-core geometry have been effected. The probability of going critical on any step during water addition when control rods are in the safety pattern is considered remote. The procedure to be followed is outlined below:

a. Use of the "dead man" switch on the water circulating pump is not mandatory; the "hold" key may be used.

b. Beginning with no fuel, source in, water at maximum height, take counts on all channels of adequate sensitivity with rods in the safety pattern and then with all rods out; take water up, source out reading and subtract as background for all subsequent readings.

c. Insert control rods, dump water, and add fuel in initial increments of approximately 20% of the expected core loading; fill vessel with water and take counts as described above.

d. Plot $1/M$ vs fuel loading at each step, extrapolating to obtain critical loading for each case.

e. Reduce subsequent increments in order to approach criticality in a conservative manner; this will require judgment on the part of the crew, including proper interpretation of the instruments. The last fuel addition shall be limited to a reactivity change no greater than one half of the control margin provided by the rod pattern (i.e., no greater than one half the reactivity difference between the safety pattern with water up and critical).

2. Type II - $1/M$ on Water Addition and Rod Withdrawal

This method will be applied if the core characteristics are known from previous experiments and it is being re-installed or for new cores or for modifications in existing cores when the change in reactivity associated with the modifications is greater than one half of the control margin of the existing core. A stringent requirement is that no major changes in instrumentation, interlocks or source/detector/core geometry will have occurred prior to or during the core loading. Although the probability of reaching criticality on water, when all control elements are in the safety pattern, is small, the uncertainty inherent in predicting criticality or in loading requires caution in all steps leading to reactivity additions.

Under normal conditions the startup instruments are in the horizontal ports and the source is at the center of the core (16 and 24 inches, respectively from the bottom of the fuel). This configuration ensures that the addition of water in the upper half of the core is seen by the instruments as multiplication and not as attenuation, geometrical or reflector effects. Below this height the response is complex and must be known for a given source/detector/core geometry before this method may be used. The presence of the Critical Facility Supervisor or his designee in the control room is required during all approaches to criticality using this method. The procedure to be followed is outlined below:

- a. Load the full core.
- b. With the source in and the control rods in the Safety Pattern, take a zero reading on all channels of adequate sensitivity.
- c. Using the "dead man" switch on the circulating pump, raise water level to the bottom of the fuel, stop filling and take counts on all channels. Note - the use of the "hold" key on the water circulating pump is forbidden during this entire portion of the startup procedure.
- d. Continue filling in increments of about 10% of the core height, pausing long enough between water additions to observe stable neutron levels on the recorders. Measurements of $1/M$ or withdrawal of source at each level will be ordered by the Facility Supervisor on a basis of a comparison of the behavior of level recorders and period meters with a known behavior in previous similar cores.
- e. If criticality with the rods in the Safety Pattern appears imminent while the water is being raised, the reactor will be shut down. After an investigation of both the core condition and of the calculations supporting the loading which was chosen, the loading will be reduced and the procedure will be repeated.
- f. When the tank is full, withdraw control rods individually to the first of a set of incremental positions appropriate to expected core characteristics. The frequency of $1/M$ measurements will again be determined by the Facility Supervisor. The main pump "hold" key may be used at this time (since the water is above the core) to maintain circulation, if desired.

3. Type III - Quasi-Continuous Approach to Criticality

When criticality has been obtained by one of the preceding methods, and provided the core modifications have been simple and well within the control range of the rods, approaches will be made in a quasi-continuous rather than stepwise manner. All such changes are limited to less than one half of the control margin (i.e., reactivity difference between the Safety Pattern with water up and critical) whether or not compensated.

Progress in this approach will be founded on the level recorders and period meters. The probability of going critical on water addition, with control elements in the Safety Pattern, is again remote; therefore the "hold" key may be used on the water circulating pump.

The main difference between the approach to criticality described in this section and those approaches described in the previous two sections is that the approach is now quasi-continuous rather than stepwise; 1/M techniques are not used. The reactor operator will, however, pause and/or attempt to withdraw the source whenever necessary; the frequency of his pauses is now based on previous experience with the particular core.

F. Partial Water Height Experiments

1. Method (See Figure 2)

It will be necessary during each approach to critical to raise the water to the top of the core before control rods are moved from the Safety Pattern. This is done in order to demonstrate that each configuration studied is subcritical (by at least $2\% \delta k/k$) with rods at Safety Pattern and water fully up. Criticality will be obtained with the water below the top of the core only after the reactor has been brought critical by normal means - i.e., by raising the water above the top of the core with the main pump and then pulling control rods. After this has been accomplished, the main pump is turned off and the main flow control valve is closed. The Partial Water Height key-switch is then operated by the Crew Chief and the water is lowered by means of the microdrain and/or millidrain lines. The decrease in reactivity is compensated by withdrawing control rods until the reactor is critical with all rods out of the water. The "microfill" pump is used for final adjustment of level and to measure the incremental water worth under these conditions.

2. Interlocks (See Figure 9)

a. After "critical" power is obtained as above, the microfill/drain and millidrain system may be operated if, in addition, the Partial Water Height key-switch has been activated by the Crew Chief. The microfill/drain switch is a three-position switch with spring return from the microfill position to the center position. The microfill position is wired in series with the control rod withdrawal switches, thus ensuring that only one means of adding reactivity is possible at a given time. The microdrain or millidrain operation, as selected by a separate toggle switch, can be carried out simultaneously with control rod withdrawal; the fill/drain switch is not spring returned from the drain position since draining will never add reactivity.

b. Once the water is lowered below the top of the core:

(1) the main pump is automatically turned off if it had not been done so manually;

(2) "critical" power for control rod withdrawal and the microfill/drain system would be lost immediately if the main flow control valve were opened or if the main pump were somehow energized.

(3) the main pump cannot be turned back on until the water is again brought above the core using the microfill pump or unless the reactor is brought subcritical by driving the rods back down to the Safety Pattern.

G. Superheater Flooding and Voiding

1. Flooding and voiding of the steam spaces in each superheater fuel element will be done manually with the reactor shut down. As discussed in Section VII C of CEND-110, the BONUS Criticals Safeguards Report, this is completely safe so long as there is no water in the core proper - i.e., if the dump valve is open, since the reactor is then subcritical by at least 20% $\delta k/k$.

2. Flooding is accomplished by manually pouring water into a steam space. The water will be obtained from the storage tank via the microfill pump and line. This operation requires the presence of a reactor operator at the console, use of the "Critical Power Bypass" and "Partial Water Height" keys and is further interlocked to require that the dump valve is open, the main pump is off and the main flow control valve is closed.

3. Voiding will be accomplished by applying air pressure, via a suitable adapter, to the steam spaces in up to 32 superheater tubes at once, and expelling the water through individual small aluminum tubes permanently installed in the steam space region in each pressure tube.

H. Bypasses (See also Figure 9)

1. Philosophy

The use of jumpers for bypassing any interlock, whether for testing a component or for operating the reactor, is absolutely prohibited. Under certain circumstances, power for testing purposes may be made available to the various reactor components by the use of a key operated interlock bypass system, even though the normal requirements for performing these operations are not satisfied. However, when any interlock is bypassed, additional circuitry makes the remaining interlocks even more restrictive. THE REACTOR CANNOT BE TAKEN CRITICAL IF ANY INTERLOCK IS BYPASSED. This is accomplished by two means:

a. Reactivity cannot be increased since the usual sources of power to the control rods and both pump systems are removed while any bypass is in effect. In addition, power can be removed from the component being tested by the manual scram buttons or by a coincident instrument scram.

b. For most of the bypasses, an additional condition (e.g., dump valve open) must be satisfied before use of the key will yield bypass power to the desired component.

2. Auxiliary Conditions

The auxiliary conditions on the use of each bypass are listed below:

a. The clutch power may be energized by bypass, provided that all scrams are cleared.

b. Dump valve closure power may be obtained by bypass if the circulating pump (which pumps water into the reactor vessel) is off and all scram signals have been cleared.

c. Circulating pump power may be obtained by bypass provided that all scrams have been reset and that either water is above the core or the dump valve is open and the main flow valve is closed.

d. Power to the control rod, microfill/drain and millidrain systems may be obtained if all scrams are cleared, the dump valve is open, the flow control valve is closed, and the circulating pump is off. Note that the "only one at a time" condition still applies in this case and that there is an additional key-switch required to energize each of the systems - the Clutch Power bypass key is required to actually drive the rods up or down, and the Partial Water Height key is required to actually operate the microfill/drain and millidrain solenoids and pump.

3. Access Door Bypass

a. Under certain circumstances it becomes essential to permit cell entry with the water up; typical reasons include, but are not limited to, the following:

(1) Foil removal following irradiation - the water shields personnel from radiation.

(2) Observe existence of bubbles in moderator.

(3) Approved valving changes required during a temperature coefficient experiment.

b. A door interlock bypass system has been designed which will not allow any unsafe acts to be performed under any foreseeable circumstances. This bypass will be used only at the direction of the Crew Chief and prior permission must be given by the Facility Supervisor for each particular use.

c. The protection afforded by this bypass system is as follows:

(1) Reactivity cannot be increased from the console because the operation of the bypass key removes drive power from the control rods, the microfill/drain system and from the main pump.

(2) The control rods must be in the Safety Pattern, ensuring that the reactor is shut down by at least 2% $\Delta k/k$.

(3) The source must be in, insuring that the nuclear instrument system and the audible monitor are on scale.

(4) The conditions above also insure that the automatic scram system is operating and that at least 2% $\Delta k/k$ is available for fast shutdown by an instrument or by the manual scram button.

(5) When the bypass key is operated, the access door bypass relay will be energized and the door may be opened without causing a scram. If the door is open and any single one of the required conditions is subsequently violated, both rods and water will be dropped automatically.

It should be noted that a potential safety hazard exists to personnel working near a cocked rod under these circumstances. In the event of a scram signal from, e.g., noise generated by jarring a chamber, the falling rod could inflict serious injury.

The presence of personnel in the cell with the access door closed is absolutely prohibited at this or any other time that there is any fuel in the reactor vessel.

I. Additional Procedures

1. False Scram Recovery

a. Following a scram which caused the rods to drop but which did not cause a water dump, the Crew Chief will first determine and rectify the cause of the scram.

b. The source will be driven in, all rods fully bottomed, and the safety rods withdrawn to the safety point.

c. From this point on, the normal procedure for a continuous startup will be followed.

2. Single Rod Recovery

This system will be employed only under the conditions outlined in Section III.B.11 - i.e., if the remaining safety rods, at or above their safety points, provide the required 2% Δk fast safety. The system will not permit recovery from a condition in which more than one safety rod is below its safety point, or in which less than two safety rods remain above their safety points.

To use the system for recovery from a rod drop experiment, recovery from inadvertently driving a single safety rod below the safety point, or to prepare a safety rod for calibration below its safety point, the Crew Chief will energize the Single Rod Recovery key-switch and select the affected rod with the rotary selector switch. If, in recovering from a rod drop or from inadvertent driving of the rod below its safety point, the neutron flux level has fallen far enough prior to source insertion that the "instrument on scale" interlock is violated, then "critical power hold" will be lost automatically, and it will be necessary to bottom all rods and recover as in "False Scram Recovery", above.

3. Standby Secure

At any time when the reactor is to be unattended during the day (e.g., during lunch) the reactor may be secured without lowering the water as follows:

- a. Drive the rods down to the Safety Pattern, providing a shutdown margin of at least 2%.
- b. Insert the source.
- c. Remove the "Operate" key and place in repository.
- d. Secure the cell access door with the combination padlock.

The reactor is now secured in such manner that no manipulations of any controls on the panels can cause any possible reactivity increase.

4. Secured Shutdown

This procedure will be used when the reactor is to be unattended for a longer period of time (e.g., overnight).

a. Shut the reactor down completely, according to Procedures D-4 and D-5, Appendix II.

b. De-energize the console and cell.

c. Lock the cell access door with the combination padlock.

d. Place all keys and the log book in the repository.

e. Lock the repository and place the key in the Crew Chief's safe.

a. Shut the reactor down completely, according to Procedures D-4 and D-5, Appendix II.

b. De-energize the console and cell.

c. Lock the cell access door with the combination padlock.

d. Place all keys and the log book in the repository.

e. Lock the repository and place the key in the Crew Chief's safe.

a. Shut the reactor down completely, according to Procedures D-4 and D-5, Appendix II.

b. De-energize the console and cell.

c. Lock the cell access door with the combination padlock.

d. Place all keys and the log book in the repository.

e. Lock the repository and place the key in the Crew Chief's safe.

V. GROUND RULES FOR OPERATION

A. Summary of CEND Operating Rules

1. The following criteria, predicted by means of calculations or previous measurements, shall apply for all cores (see Table I for examples):

a. $k_{\text{eff}} \leq 0.96$ with water above the core and all control elements fully inserted.

b. $k_{\text{eff}} \leq 0.98$ with water above the core and control elements in the Safety Pattern, i.e., safety rods at the Safety Point and shim rods fully inserted.

c. $\delta k/\text{sec} \leq 0.04\% \delta k/\text{sec}$ for all reactivity addition rates when $k_{\text{eff}} > 0.96$.

2. Criticality will normally be first obtained by withdrawing rods and not by raising water.

3. Periods between 30 and 100 seconds or more will be considered normal; a period of less than 10 seconds, if obtained, will require that the operator begin inserting rods; period scrams will be set at no less than 5 seconds.

4. The normal high power level will be approximately 50 watts; the maximum operating level permitted will be 500 watts; the level scrams will be set to scram at no more than 1,000 watts on fixed scale instruments, and no more than a factor of ten above the actual power on variable scale instruments.

5. An absolute minimum of two safety rods will be employed at all times.

6. The sequence of operations will be chosen so that any positive reactivity rate can be overcome by a negative rate of equal or greater magnitude.

7. The interlock circuit will allow the addition of reactivity by only one method at a time, i.e.:

a. Addition of water by the main pump, or

b. withdrawal of a single control rod, or

c. addition of water by the microfill pump.

8. The interlock circuit will allow shim rod withdrawal only if the safety rods are at or above the Safety Point.

9. Cover plates will be installed around all cores to prevent objects from falling in and increasing the water level during partial water height experiments.

TABLE I

Various Methods of Controlling a Typical Core

Assumptions:

- 1) Core has a 2% δk excess.
- 2) Rods worth 1% each from full in to full out.
(Therefore, a minimum of six rods is required).
- 3) Rod worth is a linear function of position.

Example	Number of Safety Rods	Number of Shim Rods	Maximum Loading Change	Use of Single Rod Recovery System Allowable	k_{eff} all Rods Down	Safety Point k_{eff} (≤ 0.98)	(Shim Rods Dn.)	Critical ($k_{eff}=1$)	
							% Withdrawn Safety Rods	% Withdrawal Safety Rods	Shim Rods
1	2	4	1%	No	0.96	0.98	100	100	50
2	2	6	2%	No	0.94	0.96	100	100	67
3	4	2	1%	No	0.96	0.98	50	50	100
4	4	2	1%	Yes	0.96	0.98	50	4 @ 100	2 @ 0
5	4	2	1%	Yes	0.96	0.98	50	{ 3 @ 100 1 @ 0	{ 1 @ 100 1 @ 0
6	4	2	1%	Yes	0.96	0.98	50	67	67

Comments on Examples

1. Minimum number of safety rods available and minimum total number of rods being employed.
2. Minimum number of safety rods available; more shim rods are employed to permit a larger loading change prior to a Type III startup.
3. Four safety rods are available, but a minimum total number of rods is being employed.
4. Same as Example 3, except that criticality is attained with the safety rods further out so that one of them may be calibrated using the Single Rod Recovery System. Use of the system is permissible because $\geq 2\% \delta k$ is available in fast safety when the remaining three safety rods are withdrawn 67% or more.
5. A variant of Example 4.
6. Another variant of Example 4. It was desired here that criticality be attained with all rods banked at a common height.

B. Loading Changes

1. In loading a new core when major changes in instrumentation, interlocks, or source-core-detector geometry have been effected, the procedures outlined in Section IV.E.1 will be adhered to. These procedures call for a stepwise approach during which multiplication will be measured as a function of fuel loading at each step.
2. In loading a new core, re-installing a core whose characteristics are known from previous experiments, or modifying existing cores when the reactivity change associated with the modification is greater than 50% of the control margin of the existing core, the procedures followed in Section IV.E.2 will be adhered to. These procedures call for a complete loading or change in one step, followed by stepwise water addition and rod withdrawal, during which multiplication will be measured as a function of water addition and rod position. A stringent requirement is that no major changes in instrumentation, interlocks, or source-core-detector geometry will have occurred prior to or during the core loading or modification.
3. The following limitations will be adhered to in making changes which are to be followed by a "continuous" approach to criticality:
 - a. Such changes will be of a simple rather than complex nature, and must be of an easily predictable, reactivity worth.
 - b. Maximum fuel additions, poison removals, or other changes shall be limited such that these changes correspond to a reactivity increase of not more than one-half the reactivity difference between the Safety Pattern with water up and critical (i.e., 50% of the "control" margin). Note that, on the substitution of boron for control rods, one must assume that the boron being added has no reactivity worth, and the maximum limit specified above will be understood to refer to the reactivity worth of the control rods which are being removed. An example is given in Table I.

VI. HEALTH PHYSICS PROCEDURES

A. Radiation Zones, Hazards, and Health Physics Requirements

This section contains a summary of the Health Physics procedures in force in Building 2.

1. No person shall enter a radiation area or contaminated area for routine work unless he complies with the applicable Extended Special Work Permit prepared by the assigned Health Physics representative and approved by the Crew Chief.

2. No person is allowed to enter and/or work in a radiation area or contaminated area until the assigned Health Physics representative assesses the radiation levels.

3. A radiation area is defined as any location where the radiation level is in excess of 2.5 mr per hour. A contaminated area is defined as any location which contains loose radioactive material in places where it may constitute a hazard. Upon determining the existence of such an area, the assigned Health Physics representative is responsible for notifying the Crew Chief and for posting warning signs containing the words "Radiation Area" or "Contaminated Area" in each instance in such areas.

4. No material is to be removed from a radiation area or contaminated area without the consent of the Crew Chief, who will be advised in such matters by the assigned Health Physics representative.

5. No smoking, eating, or drinking will be allowed in a radiation area, or contaminated area.

6. All persons entering Building 2 will be issued film badges by the guard. In addition, permanently assigned personnel will receive dosimeters. These badges and dosimeters will be returned before personnel leave the building.

7. Personnel will consult with the Crew Chief regarding exposure time, special clothing, gloves, etc., prior to entering a radiation area or contaminated area. The Crew Chief, when possible, will consult with the assigned Health Physics representative prior to issuing such permission.

8. Upon leaving a contaminated area, personnel will check their hands, shoes, and outer clothing with monitoring equipment stationed at the exits, at the direction of the Crew Chief. If contamination is suspected or detected, the assigned Health Physics representative will be notified immediately.

9. Extended health physics permits will be employed for all routine tasks presenting no special radiation or contamination problem. All permits are subject to continual revision as necessary by the assigned Health Physics representative, in consultation with the Crew Chief.

10. Any work which will create a radiation hazard not covered in an existing permit must be provided for under an applicable Special Work Permit prepared in advance. If such a hazard is created inadvertently, the person responsible must immediately inform the Crew Chief and the assigned Health Physics representative. It is the responsibility of the person causing the hazard to take adequate steps to protect other personnel prior to evaluation of the situation by the Crew Chief and the assigned Health Physics representative.

11. Any abrasion, cut, or scratch incurred in a radiation area or a contaminated area will be reported to the Crew Chief and the Health Physicist immediately. Personnel with open or partially healed abrasions, cuts, or scratches must report this fact to the Crew Chief and Health Physicist prior to entering a radiation area or a contaminated area. The purpose of this is to prevent any radioactive or toxic material from entering the wound. Where any contamination is considered possible, the Crew Chief will not permit the injured to risk such exposure. It should be noted that contamination is not always present in a radiation area and that minor injuries alone will not affect the work in an uncontaminated radiation area.

12. In summary, any unnecessary radiation exposure is to be completely avoided. Where exposure to radiation is unavoidable during the normal performance of assigned tasks, radiation dosage up to the amounts and kinds permitted by the normal Atomic Energy Commission recommendations may be incurred. Only in cases of dire emergency will dosage as high as that allowed by the AEC emergency recommendations be incurred. It will be necessary that a written report of any overexposure be filed with the Commission.

B. Health Physics Permits

Copies of the extended Health Physics Special Work Permits will be found in Appendix A.

VII. EMERGENCY PROCEDURES

A. Alarm Systems

1. Radiation Monitors

Self-contained γ -sensitive radiation monitors are installed in both cells, the vault, and the pre-assembly room. These units give local indication whenever excessive radiation levels exist, and also light individual warning lights and sound bells in each control room and at the guard's desk.

The units in the cells are turned off automatically when the "reactor on" lights on the respective consoles are turned on by the interlock circuitry (Figure 9). At the same time, red warning lights are lighted on the second floor indicating which reactor is "on" and warning personnel not to enter the air conditioning rooms adjacent to the reactor cells.

2. Lower Cell Emergency Switches

Switches are installed on the shower handles near the demineralizers in the lower reactor cells which give warning by a bell and light in both control rooms and at the guard's desk if personnel have been injured by acid and activate the shower while recharging the demineralizers.

3. Scram Switches

Switches are installed at the upper and lower levels of each cell which allow the reactor to be manually scrambled.

4. Evacuation Switches

Emergency evacuation switches are mounted in both control rooms and at the guard's desk. When any of the switches are thrown, all air conditioning in the building and cells is turned off, sirens are sounded in the cell hallways and on the second floor and a horn is sounded in Building 1; if the switches in the control rooms are thrown, the respective reactor is also scrambled and a light at the guard's desk indicates the reactor on which the incident occurred.

B. Nuclear Incidents

Due to the nature of the work and the type of materials handled, dangerous amounts of radiation and/or contamination could result from an accident. The following procedures have been established to minimize equipment damage and personnel injuries caused by accidents with these materials:

1. An alarm system has been installed in the building (Section A, above). Any of the operations personnel may initiate an alarm, and the Crew Chief on the reactor involved in the incident will be responsible for executing the emergency procedures. In his absence, the Facility Supervisor or another person qualified to act as Crew Chief shall assume responsibility.

2. When the siren sounds, all people in the building will assemble near the guard's desk. The following procedures will be followed at the assembly point:

a. The guard on duty will contact supporting services. This includes Health Physics, Medical, Fire, Safety, Security and Management.

b. A count will be made to see that everyone from the evacuated area is present. The Crew Chief with the guidance of supporting services will direct the rescue of any trapped personnel.

c. Health Physics and Medical procedures will be followed for determining radiation exposures of all people from the evacuated area.

d. Evaluation of radiation zones and the extent of damages will be determined. Senior personnel will determine further procedures to be followed.

e. The Crew Chief on the reactor involved in the incident is in complete command of all supporting services until relieved by higher administrative authority.

3. An over-level alarm from the pre-assembly room or vault will be considered cause for throwing the emergency evacuation switch, unless previous warning of trip is given (for example, transport of a large source through the room).

4. In case of a nuclear accident, the Crew Chief shall enter in the log book a list of personnel present, their duties at the time of the incident and their location. All other pertinent data regarding the accident will also be recorded.

C. Fire with Nuclear Involvement

Uranium fires burn at a very high temperature and cannot be extinguished by any simple means. The Crew Chief will direct the fire fighting activities so as to prevent the formation of a critical mass and to confine the fire and limit its spread.

Should a uranium fire occur:

1. Pull Fire Alarm Switch.

2. Turn off the air conditioning.
3. Notify Health Physics, the Experimental Physics supervisor and the Accountability representative immediately.
4. Assess the radiation hazard.
5. Don mask with self-contained air supply and protective clothing.
6. Attempt to isolate other flammable materials from the burning uranium.
7. Use "MET-L-X" (Yellow) fire extinguishers to blanket the uranium and allow it to burn out. DO NOT USE WATER.

D. Fire, No Nuclear Involvement

Fire alarm switches and alarm bells are located on both the first and second floors. The alarm is also sounded in the company fire house. The procedure on discovery of fire will be:

1. Pull Fire Alarm switch.
2. Announce location and nature of fire over building intercom system.
3. If fire is judged safely controllable, obtain appropriate extinguishers and proceed to fight fire until fire marshall can take over.

Fire wardens, selected to cover the various areas, will proceed to location and take charge of operation. All personnel not summoned will evacuate the building by the nearest safe exit after securing classified material and closing door to their room or area.

E. Electrical Fires

Electrical fires may be caused by short circuits or heating through overloads. The following procedure is recommended in addition to the steps above:

1. Turn off switch at the source of power.
2. Isolate the source of trouble before restoring power.
3. Use only CO₂ extinguishers on any electrical fire. DO NOT USE WATER.

F. Source Breakage or Gross Contamination

1. The discoverer will notify the Crew Chief who will immediately shut down the air conditioning unit, announce evacuation need, and call for assembly at the guard desk.

2. Discoverer will notify his supervisor and health physicist as to the extent and nature of the contamination.

3. Health Physics representative with the approval of the Crew Chief will be responsible for the following items:

- a. Don protective clothing.
- b. Survey building personnel.
- c. Determine perimeter of contamination area.
- d. Seal off area.
- e. Direct decontamination of personnel.

4. Further cleanup action, etc., will be taken at the direction of management.

G. Possible Overexposure of Personnel to Radiation

Possible overexposure of personnel shall be handled as follows:

1. Supervisors will immediately report cases of possible over-exposures to the Health Physics representative. Film badges will be immediately examined and an investigation made of all the circumstances. If exposure has exceeded permissible tolerances, this fact will be documented by Health Physics and reports given the Critical Facility Supervisor and the Physics Department Manager.

2. The Health Physics Department will make a urinalysis of all cases where ingestion and/or inhalation of contamination is suspected.

3. Blood samples will be taken if the remotest possibility exists that the exposure was greater than 2R.

THE INDIVIDUAL'S LIFE MAY DEPEND ON HOW SOON THE APPROPRIATE MEDICAL ACTION IS TAKEN IN CASES OF SEVERE OVEREXPOSURE.

H. Injuries

1. Any injuries involving rupture of the skin which are sustained in a radiation area or a contamination area will be reported immediately

to the assigned Health Physics representative for survey.

2. Any injuries requiring first aid treatment will be attended by the designated qualified first aid attendant immediately.

3. Injuries requiring the services of a physician will be referred to the plant physician. If this is not possible, the patient's personal physician will be notified.

4. All injuries will be reported according to procedure set forth in the Plant Safety Manual, Part II.

VIII. PROBLEMS IN RESPONSIBILITY

A. Health Physics

1. The Crew Chief will, in general, be guided by the recommendations of the assigned Health Physics representative.

2. If an emergency does not exist and a disagreement arises between the Crew Chief and the assigned Health Physics representative, the disagreement will be resolved at a higher administrative level. No action will be taken during this time which could possibly result in an overexposure to any personnel.

3. If, in an emergency, the Crew Chief decides not to follow the recommendations of the assigned Health Physics representative, he must file a written report of his actions with the Physics Department Manager within twenty-four (24) hours.

B. Procedures and Nuclear Safety

During approaches to criticality and subsequent operations, the Crew Chief will have absolute authority over the operation of the reactor with the following exceptions:

1. If any person present, regardless of rank, does not consider an act about to be taken by or under the direction of the Crew Chief to be safe, then all operations will be halted until the disagreement is resolved.

2. Any person present, regardless of rank, may at any time scram the reactor if, in his opinion, such action is necessary to avert a hazardous condition. If, however, a disagreement arises as to whether scrambling the reactor will reduce or increase the hazards involved, the Crew Chief will be responsible for assessing the situation and determining the appropriate course of action.

IX. LOGS AND RECORDS

A. Operations Log

1. A log book will be maintained which describes in detail all events relating to the reactor and its operation.

2. Among other entries, the following will be included:

a. The names of the responsible Crew Chief, Safety Consultant, Operator and the Cognizant Physicist.

b. Daily entry indicating that the facility checkout was completed.

c. Details of approaches to criticality and operations while critical.

d. All details describing any loading changes.

e. Description of the experimental arrangement with regard to number and location of control rods, locations of the various neutron detecting instruments, etc.

f. In addition, the log will contain entries regarding the repair, modification, and maintenance of various mechanical or electrical components (See also Section E).

3. This log must be maintained whether or not the reactor is in operation.

B. Operations Record

1. A record will be maintained which indicates the total number of approaches to criticality, the number of hours of operation, and the number of scrams experienced.

2. This information will be used in preparing the annual report to the AEC.

C. List of "Qualified" Operators and Physicists

A record will be maintained and lists posted regarding those persons who have been approved by the Facility Supervisor as "qualified" operators and Physicists (See also Section II).

D. Fuel Records (Including Accountability)

1. Highly Enriched Fuel

Two sets of records are required for maintaining the inventory of highly enriched fuel maintained at the facility. The vault record gives the location in the vault of each individual piece of highly enriched fuel in storage. The core record lists the location of all pieces of highly enriched fuel in the core.

2. Low Enrichment Fuel Rods

Records will be kept showing the number of rods of each type which are stored on the balcony in the cell and the number of rods which are loaded into the reactor.

E. Equipment and Instrument Log

A detailed record will be kept on preventive maintenance, revisions, repairs, or replacements to all equipment, instruments and circuits employed in the facility. A chronological record will be maintained in the Operations Log Book. Individual records will be maintained for each major component.

F. Drawings File

A file will be maintained of all circuit drawings and diagrams, components, and any manufacturers' literature on the various pieces of equipment. This file and the drawings contained therein will be kept up-to-date at all times.

X. SECURITY AND VISITOR CONTROL

A. Security

The standard AEC regulations on security will be followed. The experimental physics personnel have the responsibility that classified material and information of which they have knowledge, control or access must be continually located in an approved repository when unattended. No classified material or information may be removed from the area by other than an authorized courier without first obtaining the permission of the Security Officer and the authorization of the Facility Supervisor. No disclosure of information or access to material of a restricted nature will be permitted personnel who do not require that information in the performance of their work. Specific cases are covered in the Security Manual which governs plant security.

B. Visitor Control

Owing to the nature of the critical experiments which are carried out in Building 2, it is necessary to restrict entry to these buildings to a minimum. It is also necessary that people not normally working in this area and who, therefore, may be unfamiliar with the necessary precautions, should request permission when they require entry into the area. There are five categories of people who will have access to these buildings:

1. Employees of the Nuclear Division regularly assigned to Building 2 will have picture badges at this location and the security guard will permit them to enter.

2. Employees of CEND not regularly assigned to Building 2 who because of work requirements will from time to time need access to the buildings. These people will be admitted by the guard but are required to sign in. The guard will notify either the Facility Supervisor or Crew Chief of their presence. A list of such personnel will be maintained at all times.

3. For all other employees of the Nuclear Division, entry is contingent upon clearance with either the Facility Supervisor or the Crew Chief. The guard will determine that they have the necessary security clearance and they will also be logged in. The above supervisors will determine whether an escort is required in each individual case.

4. Sales and repair personnel representing outside firms will be allowed entry at the discretion of the Facility Supervisor.

5. All individuals not listed in items 1 through 4, above, will be allowed to enter the building only upon prior approval by the Physics Department Manager or higher administrative authority.

All uncleared individuals (employees and non-employees) must be escorted at all times when in Building 2.

APPENDIX I

EXTENDED HEALTH PHYSICS SPECIAL WORK PERMITS

Following are Extended Special Work Permits
issued to cover:

- A-1 Inspection of Reactor Room and Equipment
- A-2 Handling of Sources
- A-3 Handling of Fuel
- A-4 Work on Reactor Core

COMBUSTION ENGINEERING, INC.

SPECIAL WORK PERMIT

(EXTENDED)

Date: _____

No. A-1

DESCRIPTION OF WORK Inspection of Reactor Room and Equipment

	<u>Equipment Required</u>
1. H.P. survey before entering Reactor Room	
2. Equipment for general release must be checked by Health Physics.	1. Lab coats
3. Hand count required if inspection requires handling of equipment.	2. Gloves*
	3. Safety Shoes*
	4. Gamma-Neutron Film Badges and Dosimeters

Monitoring: As necessary for the inspection.

- * 1. Above clothing requirements do not exist for a general visual inspection.
2. No entry to be made into reactor cell unless specifically approved by Crew Chief and Health Physics.
 3. Respiratory protection as required by air contamination levels.
 4. Head and shoe covering as required based on contamination levels.
 5. Deviation from above can only be made by mutual agreement between Health Physics and Crew Chief.

COMBUSTION ENGINEERING, INC.

SPECIAL WORK PERMIT

(EXTENDED)

Date: _____

No. A-2

DESCRIPTION OF WORK Handling of Neutron and Radium Sources

1. Hand and shoe count required after completion of job if in contaminated area.

Equipment Required

2. Equipment for general release must be checked by Health Physics.

1. Gamma-Neutron Film Badges and Dosimeters
2. Lab coats*
3. Gloves*

Monitoring: Continuous for period of use.

1. Health Physics and source custodian to be notified before any use or transferal not described in previous notification.
2. Source should be stored in container at all times when not used.
3. Radiation area to be roped off and posted about any source required to be left out of container.
4. A damaged source creates an emergency situation. Notify Health Physics immediately and clear area of personnel.

*Full protective clothing and respirators are required when work is performed on installation of the reactor source in a source capsule.

COMBUSTION ENGINEERING, INC.
SPECIAL WORK PERMIT

(EXTENDED)

Date: _____

No. A-3

DESCRIPTION OF WORK Handling Uranium in Vaults and Pre-Assembly Room
(Fuel Strips, pellets, powder or solutions, etc.)

1. Hand and shoe count required after completion of job.
2. Equipment for general release must be checked by Health Physics.
3. Work tables to be papered and, when contaminated, disposed of as solid waste.
4. All work involving the handling of pellets is to be performed on the exhaust hood when possible.

Equipment Required*

1. Safety Shoes
2. Lab Coats
3. Gloves
4. Respirators*
5. Head Covering*
6. Neutron-Gamma Film
Badges and Dosimeters

Monitoring: During operation as required by Health Physics.

1. Only authorized personnel permitted in these areas while this work is being performed.
- * 2. Head covering and respirators will be worn as required for fuel strips, pellets, powder, or other contaminated materials.

COMBUSTION ENGINEERING, INC.

SPECIAL WORK PERMIT

(EXTENDED)

Date: _____

No. A-4

DESCRIPTION OF WORK Work on Reactor Core (Handling of Fuel or
Equipment)

1. Hand and shoe count required after completion of job.
2. Equipment for general release must be checked by Health Physics.

Equipment Required

1. Safety Shoes
2. Gloves
3. Head Covering*
4. Respirators*
5. Neutron Gamma Film
Badges and Dosimeters
6. Lab Coats or Coveralls

Monitoring: Before entering reactor room and during work on critical assembly.

- *1. Respiratory protection and head and shoe covering as required by air or other contamination.
2. No entry to be made into reactor room unless specifically approved by Crew Chief and Health Physics.

APPENDIX II

A. Procedure D-1 - Daily Console Checkout

1. Generator Check - Power for the instrumentation is normally obtained from an MG set located in the Air Conditioning Room on the second floor of the building. The appropriate rheostats should be adjusted so that the exciter current and output voltage are as marked on tags. The regulator polarity switch should be reversed daily.
2. Instrument Power at Console - The switch in the Air Conditioning Room is normally thrown to make connection with the MG set. If the MG set is not operating, the switch is thrown so that power will be taken from a transformer fed from a separate supply line. Power from one of these sources is always left on to insure stability and prolong the life of the electronic instrumentation.
3. Instrument Voltage - The voltage to the instruments is read on a voltmeter on the front of the cubicle. The reading should be as marked on the tag.
4. Control Power Key Switch - This key is issued by the Crew Chief and is used to supply power to all of the interlock and control circuitry.
5. Source in Up Position - The source should have been left up (in shield) following the previous shutdown. Check for burned out "up limit" light if not on. Contact Crew Chief and Health Physicist to determine trouble if light still remains out.
6. All Rods Down - Check that all "down limit" lights are lit. Proceed as in (5) if any light is off.
7. Cell Air Conditioning On - This is turned off at night when the cell is secured so that the noise from its operation will not activate the Kidde alarm.
8. Digital Voltmeter On - Power to this instrument is normally left on.
9. Console Exhaust System Operating - This is connected to the first floor air conditioning; check that air is entering the cubicle.
10. Temperature Indicator On, Standardized, and Battery Supply OK - Power to the temperature indicator is normally left off overnight, and turned on prior to each run during the checkout. The temperature indicating system consists of the thermocouples installed at various points in the core, reactor vessel, line and tank heaters, etc. Signals from the thermocouples are fed to an indicator on the console. Check the

battery indicator ("white" indicates correct battery voltage), standardize the instrument, and determine reason if the indicator shows a temperature above 77° F.

11. Record Operating Time in Log and Reset Meter - The previous day's operating time will be read from the running time meter and entered into the logbook. This meter runs continuously as long as the "Operate" key is turned on; which is normally just after the safety rods are withdrawn to the safety pattern. It stops running in the event of any type of scram signal.

12. Zero Safety Amplifiers - The "zero adjust" pots on the composite safety amplifiers are adjusted so that the "percent power" meters on the amplifiers zero properly when no external signal is applied.

13. Recorders On, Ink and Paper OK - Power to the recorders is normally left on; a check is made that it actually is on. The chart drives must be turned on at this time. The three nuclear recorders on the cubicle can be switched from the console to indicate the outputs on channels B-D-E, B-D-G and A-C-F, respectively. Their operation is checked later during steps 19 - 24, and they are set to read the low level channels prior to startup.

14. Rod Drop Panel Switches Set to Normal (On = Up) Position - These switches enable magnet power to be removed from selected rods, e.g., for terminating a foil irradiation.

15. Channel G High Voltage Power Supply On and Voltages Normal - Power to this instrument is normally left on; a check is made that it actually is on. The correct voltage is indicated on a tag attached to the supply.

16. All Amplifiers On and Settings Normal - Power to the amplifiers is normally left on; a check is made that it actually is on. The correct settings are indicated on tags attached to the instruments.

17. Check Beckman ~~MM~~-Ammeter, Channel E - Set zero and then set to operating range.

18. Check Log CRM and Period Amplifier, Channel A - For steps 18 - 22, each instrument is calibrated with its internal pulse or voltage source. The calibration includes tracking the instrument and its appropriate recorder. The actual calibration is done on the recorder. If the difference between the recorder reading and the instrument meter is excessive (10-20%) notify the electronics technician and Crew Chief and insure that remedial action is taken. Following the calibration, the function switch is returned to the operating position, and any scrams reset.

19. Check Log CRM and Period Amplifier, Channel C.

20. Check Log N - Channel F.

21. Check CRM - Channel B.

22. Check CRM - Channel D.

23. Initials of Checkout Person - The person conducting the checkout must initial the check sheet, and make an entry in the operating log. He must inform the Crew Chief and make an entry in the log concerning any abnormal or unusual conditions.

B. Procedure D-2 - Daily Cell and Equipment Checkout

1. Guard Notified of Cell Entry - This alerts the guard that Kidde alarm will be tripped.

2. Procedure D-1, Steps 1 - 6 Have Been Completed - This insures that the source and the rods are in their safe positions.

3. Air Compressor In Cell #2 Turned On - This compressor supplies air for both reactors.

4. Check Console and Instrumentation for Abnormal Conditions - This step will preclude cell entry under any abnormal or unexplained conditions.

5. Reset Scrams on Instruments - All console instrumentation must be in the normal operating condition.

6. "Operate" Key Out - This key should be in the repository, but a double check is made to prevent any unsafe remote operations.

7. Bypass Circulating Pump Interlock - This is done to allow testing of pumps in the lower cell.

8. Health Physics Representative Present, Core Surveyed - Entry is made with the Health Physics representative in attendance, and a survey of the core is made prior to any further action.

9. Turn Off Kidde Alarm, Battery Checked.

10. Lighting Panel Switches - Turn on floodlights, and cell and basement lights as needed. Check that lights which normally are left on overnight have not burned out.

11. Space Heater - Turn on if required by climatic conditions. Heater is turned off at night to prevent noise from actuating Kidde alarm.

12. Turn On Circulating Pump Switch in Power Panel - This makes power available to this unit, but does not turn it on.

13. Neutron Monitor - This equipment is located on the platform below the reactor vessel and acts as an audible monitor during loading operations. The BF_3 counter is normally located in one of the instrument ports. Power to this instrument is turned on when the access door is opened. A check is made at this time that background radiation is audibly detected.

14. All Rods Down and Hanging Free - A visual inspection is made to insure that rods are not binding.

15. Core Complete and Unobstructed - A visual check is made to insure that no unusual conditions exist.

16. Rod Drive Package Check - A visual inspection is made to insure that the cooling fans are operating, all connector plugs are inserted, and that there are no oil leaks or other visible abnormalities.

17. Source Drive Check - An inspection is made to insure that the limit switches and wires are free, and that no abnormal conditions exist.

18. Sump Pump Locked Out - This switch, located at the foot of the stairs, is kept locked out at all times so that the pump cannot operate automatically. This is done to prevent contaminated water from being released before a sample has been analyzed.

19. Water Level in Dump Tank - The levels are observed on a sight glass located on the side of the tank. Check that the amount in the tank is appropriate for the day's test.

20. Check Sump - Check height of float probe and, if near start level, have Health Physics representative sample liquid in sump for contamination. If cleared by Health Physics representative, switch sump pump control to "auto" position. It may be necessary to raise the float probe to start. If on manual operation, pump must be turned off promptly when sump is empty to prevent possible burnout of bearings. Lock out pump switch when complete (See step 18).

21. Circulating Pump Check - Close main flow control valve (this allows pump bypass to become effective and prevents water from being pumped into the reactor vessel). Establish loop between outlet of the pump and the storage tank by opening Valve #12, Figure 2. Turn pump on, check oil level in sight glass, check for noise and vibration. Bleed air from casing if absence of discharge pressure indicates need and then stop pump.

22. Close Valve #12 to prepare system for normal operation, and check other manually operated valves for correct status.

23. Inspect Piping for Leaks - If any leaks are observed, notify Crew Chief and take remedial action under his direction.

24. Demineralizer - Turn on if required as indicated by water conductivity meter on the demineralizer.

25. Check High Voltage Supplies - The high voltage supplies for channels A, B, C, D, E, and F are located on the platform under the reactor vessel. Check that these units are on, and that the voltage is correct as indicated on the tags attached to the supplies.

26. Dump Valve - Check that air pressure is correct as indicated on the tag. Check the spring for failure or obvious set.

27. Remove Pump Bypass Key

28. Initials of Checkout Person - The person conducting the checkout must initial the checkout sheet and make an entry in the operating log. He must inform the Crew Chief and make an entry in the log concerning any abnormal conditions.

C. Procedure D-3 - Daily Scram Circuit Checkout

1. All steps of Procedures D-1 and D-2 Completed OK.

2. Energize Clutch and Critical Power Bypasses - This is done to allow raising of the rods slightly for testing, without causing undue exposure to radiation from the regular reactor source.

3. Raise Rods - All rods to be moved during the day's operation will be raised a few inches off the down limit switches to test that they actually move up, and to prepare them for scram testing.

4. Energize Dump Valve Interlock Bypass and Close Dump Valve - This checks that dump valve can be closed, and prepares it for scram testing.

5. Select Channel A on Recorder No. 3.

6. Scram Channel A - Place neutron hand source near Channel A detector and observe timing light and scram indication on Channel A period amplifier; observe recorder response. The rods and dump valve should not scram at this time. Do not reset the scram on Channel A.

7. Select Channel C on Recorder No. 3.

8. Scram Channel C - Repeat Step 6, noting that the safety rods should scram and the shim rods drive in, but that the dump valve should not open at this time. Do not reset scram on Channel C.

9. Select Channel E on Recorder No. 1.

10. Scram Channel E - Repeat Step 6, noting that the dump valve should open.

11. Select Channels B, D and F on Recorders #1, 2 and 3.

12. Check Channels B, D and F - Place neutron hand source near detectors and observe response on recorders. It should be noted that the neutron hand source will generally not be strong enough to produce an indication on Channels F and G. Their operation is checked while the reactor is being brought to power.

13. Instrument Location - Check that location of all instruments is as specified in operating log.

14. Use Built-in Scram Tests to Scram Safety Amplifiers.

15. Scram Channel F Using Period Test.

16. Test Manual Scram.

17. Remove All Bypass Keys - Keys should be returned to the Crew Chief.

18. Select Startup Instrumentation - Select startup channels on recorders and set instruments to startup ranges.

19. Clear Scrams and Reset Annunciator Panel - If any scrams cannot be reset, or any abnormal condition is shown on annunciator panel, consult with Crew Chief and take corrective action before proceeding.

20. Status of Special Switches - The person conducting the checkout must check that the Crew Chief has operated all special switches--Partial Water Height, Circulating Pump Hold, etc.--as appropriate for the day's operations, and has made an appropriate entry in the Operating LogBook.

21. Initials of Checkout Person - The person conducting the checkout must initial the checkout sheet and make an entry in the operating log. He must inform the Crew Chief and make an entry in the log concerning any unusual condition.

D. Procedure D-4 - De-Energize and Secure Cell

1. A Health Physics survey of the core must have been made since the last shutdown of the reactor.
2. Check for unusual conditions in upper and lower cell.
3. Check that sump pump is locked out.
4. In power panel, turn off power to the circulating pump, and main power switch.
5. Turn off the space heater (if on).
6. Turn on Kidde alarm, after checking that control power has been turned off at the console (Procedure D-5). The alarm may be tested by operating the "test" switch after warming up. Subsequent movement in the cell will trip the alarm, giving an audible indication that the alarm is operating properly. Return the "test" switch to the normal position.
7. Turn off all lights from the lighting panel except a night light in the upper cell. The hallway lights should be left on at all times.
8. The cell access door should be secured with both the combination padlock and the doorknob lock.
9. Notify the guard so that he can check that the Kidde alarm can be reset from the main guardhouse.
10. Check that compressor in Cell #2 has been turned off.

E. Procedure D-5 - De-Energize Console

1. Check for any unusual conditions or indications.
2. Turn off recorder chart drives.
3. Turn off control power.
4. Turn off cell air conditioning.
5. Crew Chief will return all keys to the repository, and secure same.
6. If an instrument power outage is anticipated, turn off each instrument in the console and cubicle, and then all circuit breakers. This will minimize the exposure of instruments to power surges.

7. Demineralizer on if required.

Weekly Procedures

F. Procedure W-1 - Check and Lubricate Mechanical Equipment

The equipment requiring lubrication and inspection not performed on a daily basis will be checked periodically as specified in the equipment maintenance procedures and the manufacturers' literature.

G. Procedure W-2 - Demineralizer

The demineralizer conductivity will be checked on a weekly basis. When the conductivity exceeds the posted value, the resins will be re-generated in compliance with the procedures outlined in the manufacturers' literature.

Monthly Procedures

H. Procedure M-1 - Operational Checks of Interlocks, Bypasses, and Alarms

1. The interlock circuitry will be thoroughly tested on a monthly basis to be sure that it operates in conformity with the Block Diagram, Figure 9. Special emphasis will be placed on insuring that the circuitry will not allow violation of the interlocks, which enforce established and approved operational procedures.

2. The interlock bypasses will be tested on a monthly basis to guarantee that they will become operative only when the required conditions for their safe use have been satisfied.

3. A monthly test will be made to insure that operating the evacuation alarm switch in the control room will completely scram the reactor, shut off the cell and first floor air conditioning units, and actuate alarm sirens located throughout the building.

4. The radiation monitors will be checked in detail on a monthly basis with gamma-ray sources. The response of each monitor chamber should be noted and compared to that of the previous test.

I. Procedure M-2 - Response, Linearity, and Calibration of Nuclear Instrumentation

1. Gain of amplifiers and pre-amplifiers will be checked monthly with a pulser and an oscilloscope. Output wave forms will be checked for abnormalities indicating incipient failure.

2. Linearity of the pulse channels will be investigated with a neutron source or a variable frequency pulse generator, and the appropriate calibrations performed so that the various components of a channel will "track" properly together.

3. A neutron source and a standard geometry will be employed to check the response of each channel over a period of time, and to allow checking of discriminator settings on the various amplifiers.

4. The response of period circuits will be checked by the introduction of exponential signals of the appropriate rise time. This will allow the checking of scram settings and the calibration of period meters, etc.

5. Level scram circuits will be checked by the introduction of appropriate step functions. Both the instrument and rod drop response times will be recorded and compared over a period of time to insure that the various trip circuits respond adequately, and to aid in locating incipient trouble.

FIG. 1
CROSS SECTION OF CELL

FIG. 2
FLOW DIAGRAM

SYMBOL LIST

- GLOBE VALVE
- GATE VALVE
- GLOBE VALVE WITH LOCK SHIELD
- GLOBE VALVE REMOTE OPERATED
- BALL VALVE REMOTE OPERATED
- FLOAT OPERATED VALVE
- Y STRAINER
- PUSH BUTTON SWITCH @ CONSOLE
- PUSH BUTTON SWITCH LOCAL
- FAUCET
- CONDUCTIVITY METER
- PRESSURE GAUGE
- FLOW MEASURING DEVICE
- WATER TRAP
- SOLENOID VALVE
- PUMP

FIG. 3
SAFETY ROD DRIVE PACKAGE

ITEM	QTY	DESCRIPTION	UNIT	REMARKS
1	1	CONTROL ROD DRIVE MECHANISM ASSEMBLY	1	
2	1	POSITION AND CABLE TENSIONING BRACKET	1	
3	1	MOTOR MOUNT BRACKET	1	
4	1	ROD PULLEY MOUNTING BRACKET	1	
5	1	CABLE AND TITING ASSEMBLY	1	
6	1	AC LOW VOLTAGE SERVO MOTOR	1	SEE DRAWING FOR SIZE
7	1	CABLE SPOOL	1	
8	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
9	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
10	1	SPEED REDUCER 500 TO 1 24" 10	1	
11	1	V GROOVE PULLEY	1	2 1/2" DIA. ALUM. 1 1/2" DIA. X 1 1/2" LONG
12	1	HEX SOCKET SET SCREW - FLAT POINT	1	3/8" DIA. X 1 1/2" LONG
13	1	V GROOVE PULLEY	1	2 1/2" DIA. ALUM. 1 1/2" DIA. X 1 1/2" LONG
14	1	SPRING PIN	1	3/8" DIA. X 1 1/2" LONG
15	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
16	1	ROUND BELT END LEAD	1	3/8" DIA. X 1 1/2" LONG
17	1	SOCKET HEAD CAP SCREW	1	3/8" DIA. X 1 1/2" LONG
18	1	CHARMUEL	1	3/8" DIA. X 1 1/2" LONG
19	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
20	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
21	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
22	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
23	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
24	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
25	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
26	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
27	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
28	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
29	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
30	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
31	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
32	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
33	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
34	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
35	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
36	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
37	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
38	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
39	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
40	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
41	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
42	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
43	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
44	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
45	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
46	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
47	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
48	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
49	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
50	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
51	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
52	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
53	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
54	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
55	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
56	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
57	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
58	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
59	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
60	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
61	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
62	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
63	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
64	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
65	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
66	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
67	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
68	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
69	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
70	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
71	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
72	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
73	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
74	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
75	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
76	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
77	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
78	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
79	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
80	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
81	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
82	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
83	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
84	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
85	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
86	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
87	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
88	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
89	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
90	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
91	1	ANGLE BAR	1	3/8" DIA. X 1 1/2" LONG
92	1	STOP BOLT	1	3/8" DIA. X 1 1/2" LONG
93	1	BEARING	1	3/8" DIA. X 1 1/2" LONG
94	1	ROD PULLEY	1	3/8" DIA. X 1 1/2" LONG
95	1	FLANGE END LEAD SCREW	1	3/8" DIA. X 1 1/2" LONG
96	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
97	1	CLIP	1	3/8" DIA. X 1 1/2" LONG
98	1	BOLT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG
99	1	SPRING LOCK WASHER (LIGHT)	1	3/8" DIA. X 1 1/2" LONG
100	1	NUT REGULAR HEXAGON	1	3/8" DIA. X 1 1/2" LONG

5- ALL TAPER PINS TO BE LOCATED AFTER ALIGNMENT OF COMPONENTS
 4- USE ITEM NO. 89 FOR ROD SPEED OF 20 INCHES PER MINUTE
 3- USE ITEM NO. 40 FOR ROD SPEED OF 15 INCHES PER MINUTE
 2- USE ITEM NO. 41 FOR ROD SPEED OF 10 INCHES PER MINUTE
 1- USE ITEM NO. 11 FOR ROD SPEED OF 5 INCHES PER MINUTE

FIG. 4
SHIM ROD DRIVE PACKAGE

CHANNEL

NOTE:

CHANNEL 'A'-D MAY BE CONNECTED VIA PATCH CORDS
TO SCALERS ON THE CONSOLE AND IN THE COUNTING ROOM.

NUCLEAR INSTRUMENTATION BLOCK DIAGRAM

NOTE

1. ALL CONTACTS NORMALLY OPEN - I.E. CLOSED FOR NO-SCRAM CONDITION, OPEN ON SCRAM OR POWER FAILURE.
2. SLAVE RELAYS DROP RODS, DUMP WATER, ETC, IF DE-ENERGIZED.

ROD DROP AND WATER DUMP SCRAMS

FIG. 7
BONUS REACTOR CONSOLE

FIG. 8
ARRANGEMENT OF BONUS REACTOR CONSOLE