AN ENGINEERING DESCRIPTION OF THE SPERT-I REACTOR FACILITY

T. R. Wilson

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OF THE
SPERT-I REACTOR FACILITY

by

T. R. Wilson

A B S T R A C T

An engineering description is presented herein of the SPERT-I Reactor Facility. The SPERT-I Reactor is the first of several reactors to be built for the purpose of conducting reactor transient behavior and safety studies on heterogeneous, light-water-moderated, enriched-fuel reactor systems. The reactor consists of an open vessel into which has been placed initially a plate type, uranium-aluminum core with no provision for heat removal or coolant circulation. The reactor is remotely operated from a Control Center approximately 1/2 mile from the reactor. Reactor excursions are brought about by the rapid addition of reactivity to the reactor, and the resulting kinetic behavior of the reactor observed.

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I. INTRODUCTION

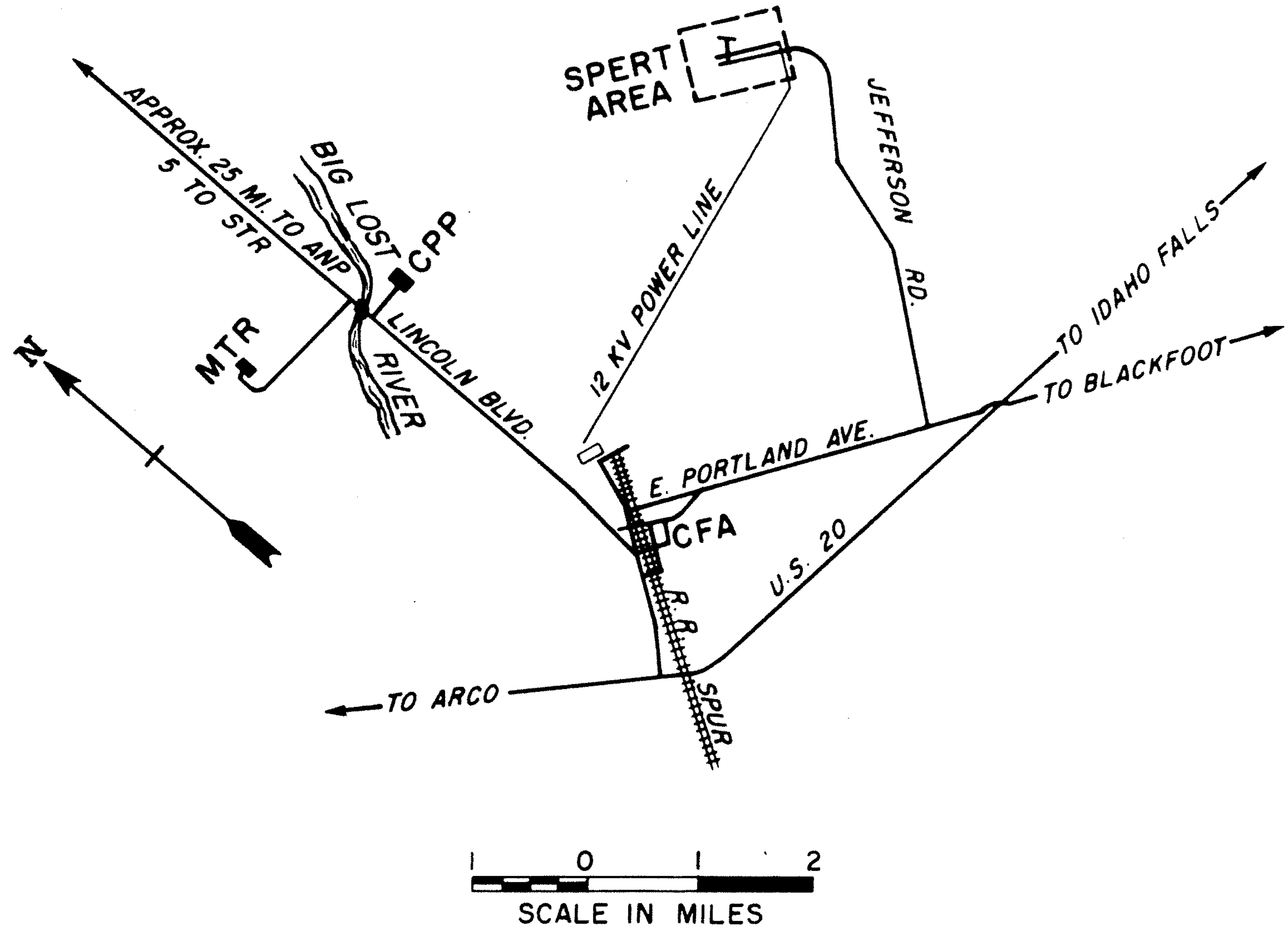
Concurrently with the accelerated nuclear power program, the U. S. Atomic Energy Commission is sponsoring an intensified reactor safety program.[1] A large part of the program is directed toward obtaining a better experimental and theoretical understanding of the factors influencing the behavior of the basic reactor types. The information obtained will aid in evaluating the hazards generally associated with reactors to be located in populated areas. As a part of the program, the SPERT Project (Special Power Excursion Reactor Tests) was established for the purpose of conducting reactor transient behavior and safety studies on heterogeneous, water-moderated, enriched-fuel reactor systems. The SPERT-I Reactor Facility represents the first of a series of facilities which will be utilized to accomplish this goal. This report presents an engineering description of the SPERT-I Reactor Facility. The experimental data reported to date are discussed in separate reports.[2,3,4]

The SPERT Project is located near the eastern boundary of the National Reactor Testing Station in Idaho. The site has been selected to minimize the hazards to the general public and private property, and to provide a minimum of interference with other facilities at NRTS.

As the starting point for the reactor transient behavior and safety studies, every effort has been made to provide a remotely operated, economical reactor facility of the very simplest design. The SPERT-I Reactor Facility consists of an open vessel into which has been placed initially a plate-type, enriched uranium-aluminum core. The reactor is water-moderated and -reflected with external heating supplied for operation up to boiling. No provisions for heat removal or coolant circulation through the core are included. In order to initiate reactor excursions, the control rod drive system has been designed to permit the addition of reactivity to the reactor by continuous control rod withdrawal at any speed up to 35 in./min, or by the instantaneous ejection of a poison rod. The reactor vessel proper is located in a pit below grade. Since the total energy released during the expected lifetime of the facility will be small, no special biological shielding is required. Protection for operating personnel is provided by evacuation of personnel from the area during operation, and by placing the reactor controls approximately 1/2 mile from the reactor.

II. SPERT SITE AND BUILDINGS

The location of the SPERT site with respect to NRTS boundaries and other installations, is shown in Figure 1. The prevailing winds are from the southwest, with the SPERT site located approximately 16 miles from



NRTS GENERAL AREA

FIGURE 1

(56-469)

the eastern NRTS boundary at the nearest point in the opposite direction from the prevailing wind. The site has been selected to minimize the hazards to the public, private property, or other U. S. Atomic Energy Commission facilities which could result from the release of radioactivity in the event of a destructive reactor test.

A general plan of the SPERT site is shown in Figure 2. The existing buildings and facilities at SPERT are located in three areas; they are the Control Center area, the Terminal Building, and the SPERT-I Reactor area. Also shown is the approximate location of the SPERT-II and SPERT-III reactors now under design and construction. As will be noted, all reactor areas are located approximately 1/2 mile from the Control Center.

A. Control Center Area

The Control Center area forms the nerve center of the SPERT operations. Within the 250 ft x 250 ft fenced area are the Control Building and the raw water supply equipment. The Control Building, constructed of galvanized iron, houses the SPERT-I reactor controls and instrumentation, administrative offices, instrument and mechanical work areas, dark room, and provides space for the controls and instruments of additional SPERT reactors. The floor plan of the Control Building is shown in Figure 3.

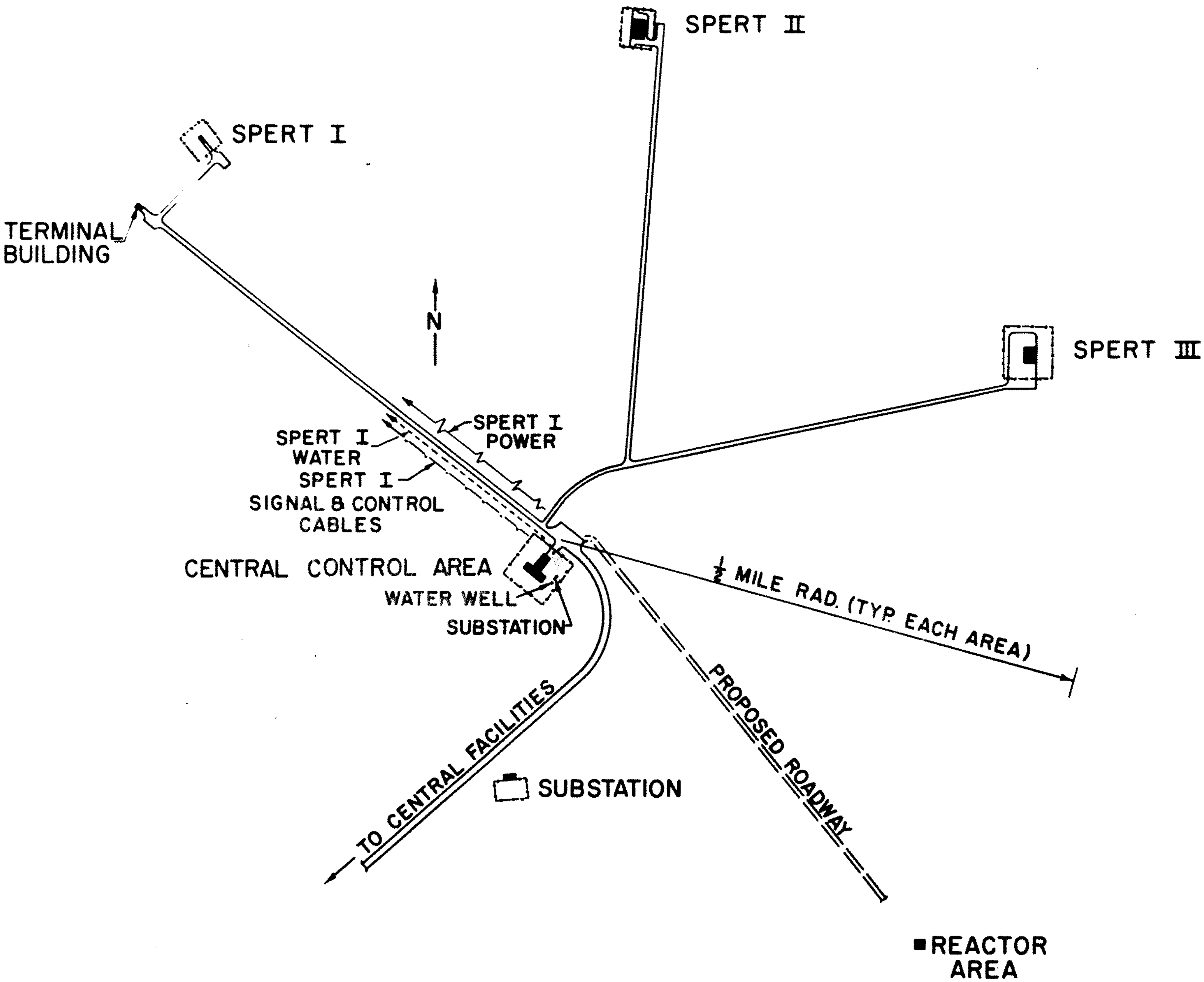
Water for the SPERT site is supplied from a drilled well located within the Control Center area. The well is drilled to a total depth of 653 ft and the casing size is 14 in. OD. Raw water is pumped from the well by a 400 gpm deep well pump to a 20,000 gallon storage tank. An automatic liquid level control maintains the tank level by intermittent operation of the pump. The water is distributed to all buildings by a continuously operating 400 gpm booster pump, which in conjunction with a pressure control valve, maintains 65 psi pressure on the distribution lines. The pumps and above-grade piping are enclosed in a 14 ft x 16 ft insulated building.

B. Terminal Building

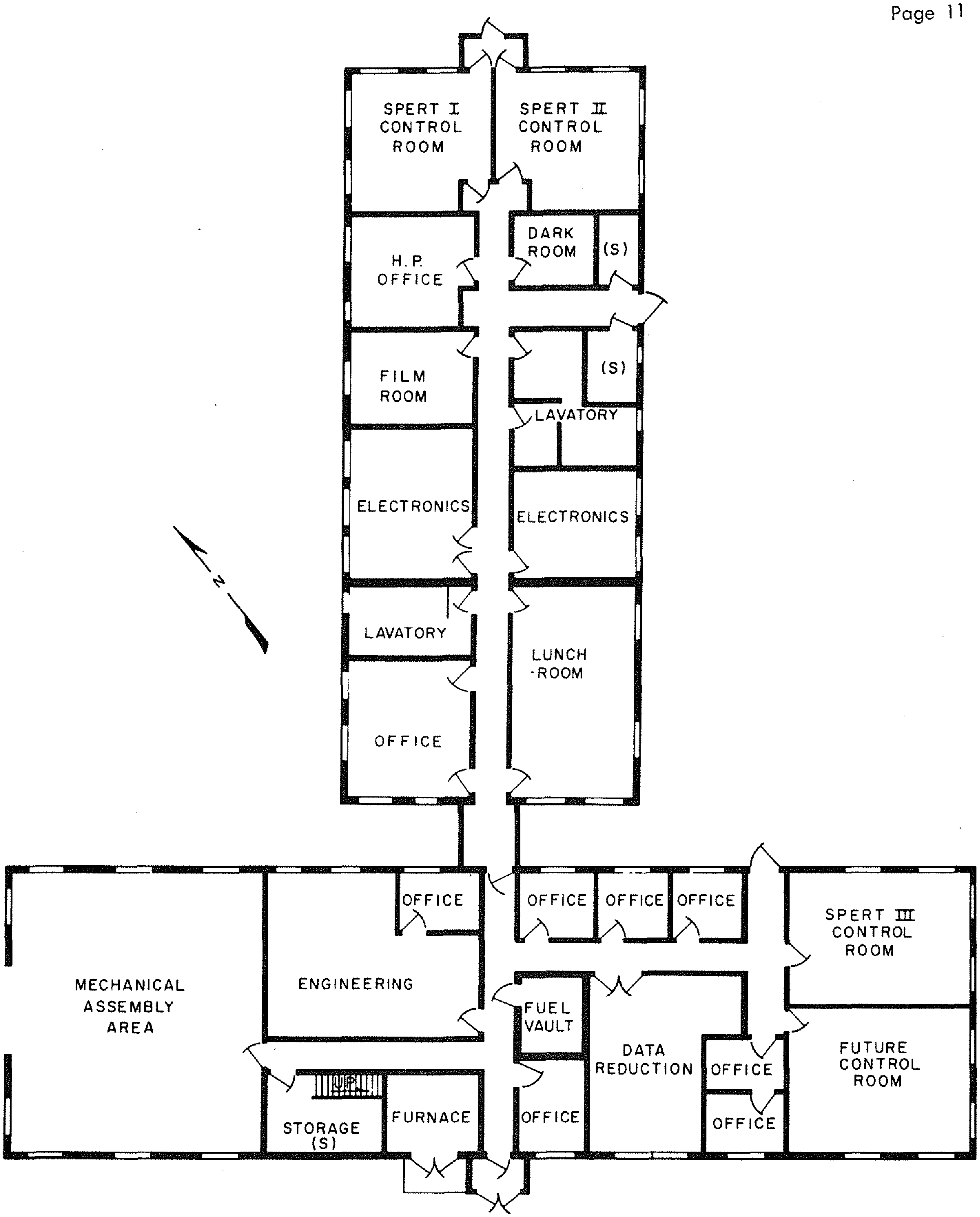
The Terminal Building consists of a 20 ft x 30 ft galvanized iron structure located approximately 2800 ft from the Control Building and 400 ft from the SPERT-I Reactor Building. The building houses the service facilities for the reactor including a 10 gpm water softener and mixed-bed deionizer, a 1000 gallon deionized water storage tank, an 18 gpm reactor-fill pump, an 85 psig compressed air system, and a personnel decontamination and change room. The philosophy followed in locating the Terminal Building has been that additional reactors of the SPERT-I type could be built on an arc having a radius of about 400 ft and surrounding the service facilities which are located in this building.

C. SPERT-I Reactor Area

The SPERT-I Reactor Area located approximately 3000 ft from the Control Building, includes two adjacent structures--the Reactor Building and the Instrument Bunker, which are enclosed within a fenced area 150 ft x 150 ft. A plan view of the two buildings is shown in Figure 4.

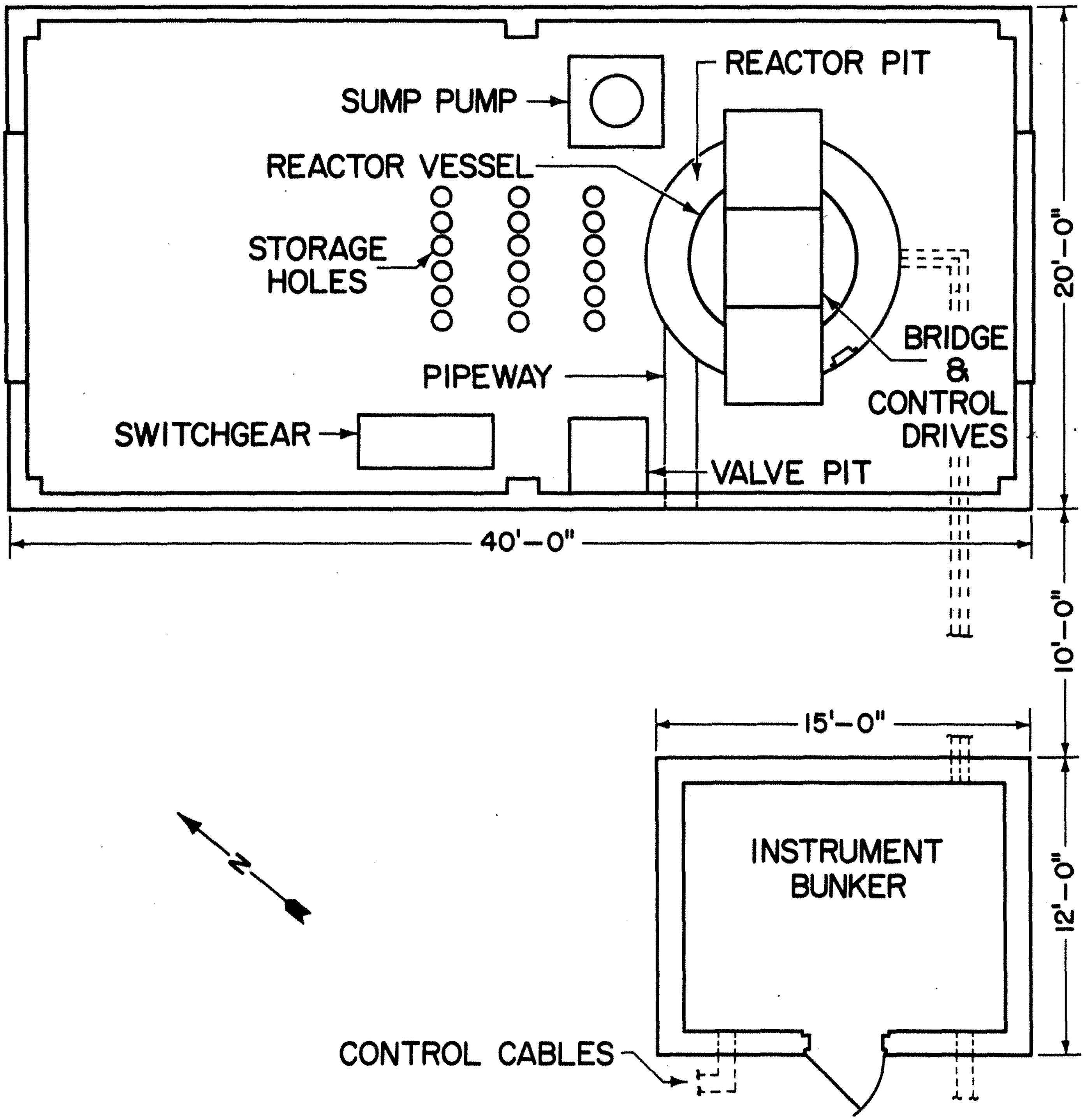


SPERT
GENERAL SITE PLAN
FIGURE 2
(57-3124)



SPERT CONTROL CENTER BUILDING FLOOR PLAN

FIGURE 3
(57-2665)



SPERT I
REACTOR BUILDING-FLOOR PLAN

FIGURE 4
(57-2663)

1. Reactor Building

The Reactor Building consists of an uninsulated, 24 ft x 18 ft galvanized iron structure which houses the reactor and associated equipment, electrical switchgear, and other auxiliary facilities. Operating experience has shown that this type structure is the minimum required to afford protection for personnel and equipment from extreme dust conditions and winter weather existing in this area. The building is heated with an oil fired, forced air circulation furnace, capable of maintaining the building at about 50°F during the coldest winter weather.

A 10 ft ID x 16 ft deep pit, or shield tank, embedded in the building floor, contains the reactor vessel. The pit is equipped with a drain and sump pump for automatic removal of waste water to a leaching pond outside the building. Adjacent to the northwest side of the reactor pit, and also embedded in the building floor, are eighteen 6 in. ID x 14 ft long tubes for the temporary storage of fuel or other radioactive material. The storage tubes contain a common drain to the building sump, and are equipped with a 4 in. thick stepped lead plug. On the south side of the reactor, four similar tubes are provided to accommodate neutron sensing devices. These pipes extend at an angle from floor level to the reactor pit wall at approximately the reactor core horizontal centerline.

The building contains a 5 ton, electric hoist, spanning an 8 ft width in the center of the building, and operable over the length of the building. Utilities supplied to the building are deionized water, raw water, 65 psig compressed air, 120 volt and 240 volt, 1 Ø, electric power, and 480 volt, 3 Ø, electric power. The water and electrical requirements for the SPERT-I Reactor are tabulated in Appendix A. An isolation transformer is utilized to supply constant voltage electric power for instrument use.

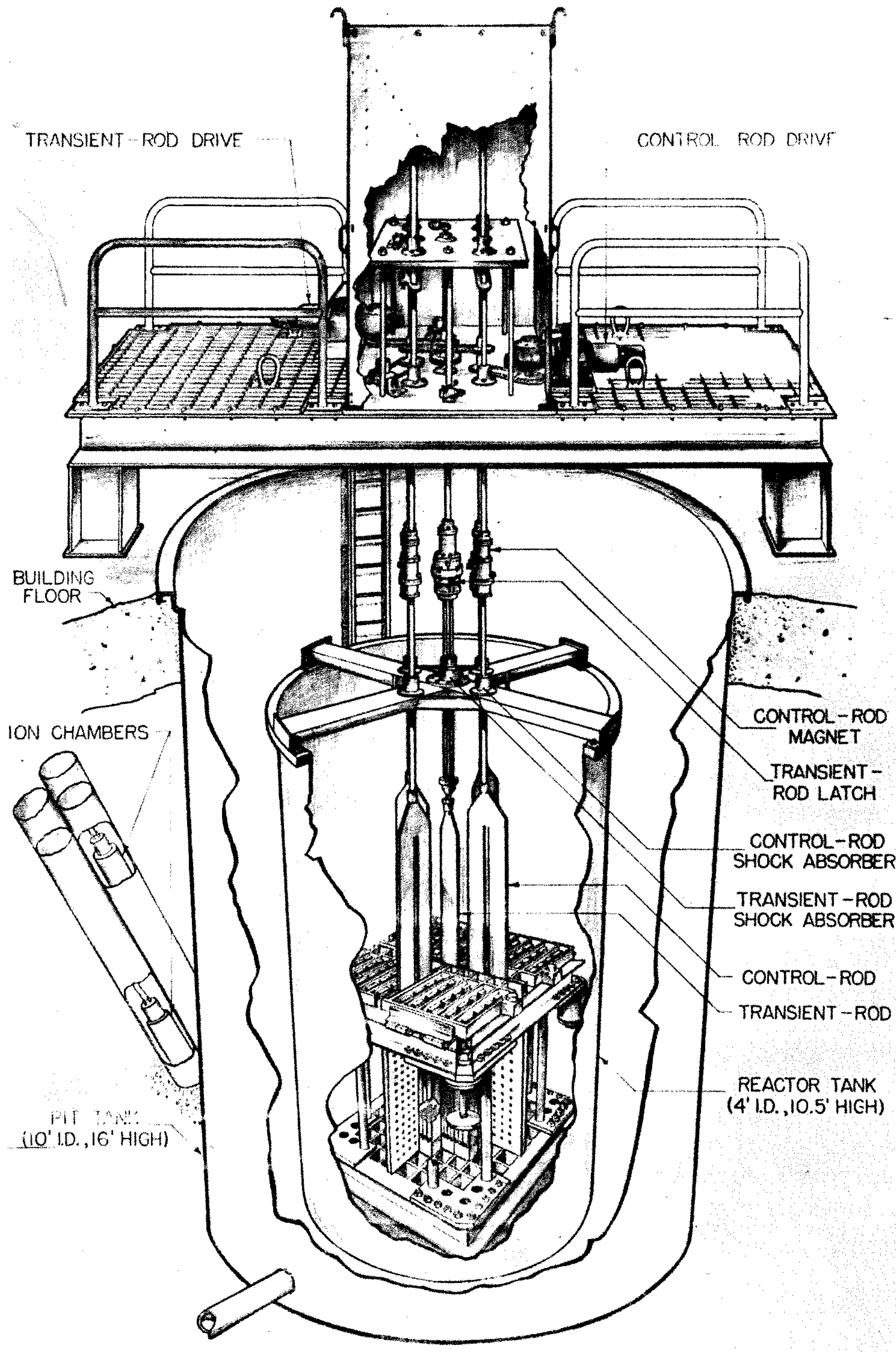
2. Instrument Bunker

The Instrument Bunker is a 10 ft x 12 ft, earth-covered, concrete block structure. Openings for instrument and electrical leads entering the bunker from the Reactor Building and leaving the bunker toward the Control Building are provided. The necessary relays required for operation of the reactor and auxiliary equipment, and the experimental instrumentation, are housed in the Instrument Bunker. The Instrument Bunker is air conditioned to remove the 7 kw heat load generated by electronic equipment such as amplifiers, power supplies, drivers, etc.

III. DESCRIPTION OF THE SPERT-I REACTOR

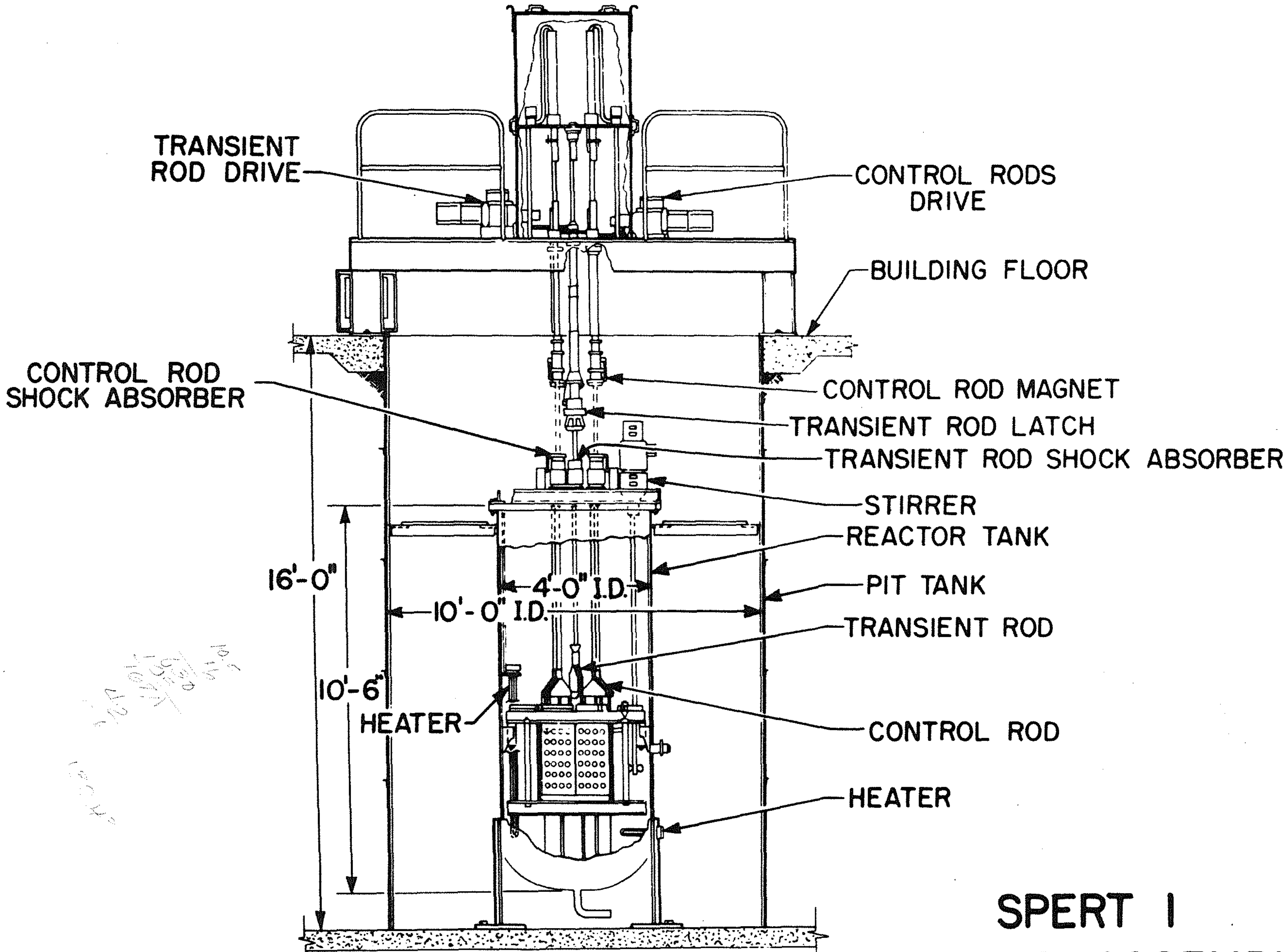
A. General Description

A pictorial view of the reactor installation is shown in Figure 5 and a reactor elevation is shown in Figure 6. The reactor vessel containing the core is situated in a 10 ft diameter pit below grade. The mechanisms for driving the control rods are supported on a bridge structure spanning the pit.



SPERT-1 PICTORIAL CUTAWAY OF INSTALLATION

FIGURE 5
(57-1740)



SPERT I
REACTOR ASSEMBLY
ELEVATION CUTAWAY
FIGURE 6

The initial core being tested in the reactor is composed of plate type fuel assemblies whose plates are fabricated of 93.5% enriched uranium-aluminum alloy clad with aluminum. The reactor is controlled by means of four blade-type poison rods operating in slots through the core. The outer four rods serve for operational control of the reactor while the central rod is utilized to initiate power excursions. The cross member supported on the reactor vessel top flange serves as a mount for the control rod shock absorbers.

The reactor and all essential auxiliary equipment are remotely operable from the Control Center Building; however, the necessary control relays and electronic equipment for the experimental instrumentation are located in the Instrument Bunker adjacent to the Reactor Building.

A summary of the nuclear characteristics and design data, including a list of the major equipment for the SPERT-I Reactor, is contained in Appendix B.

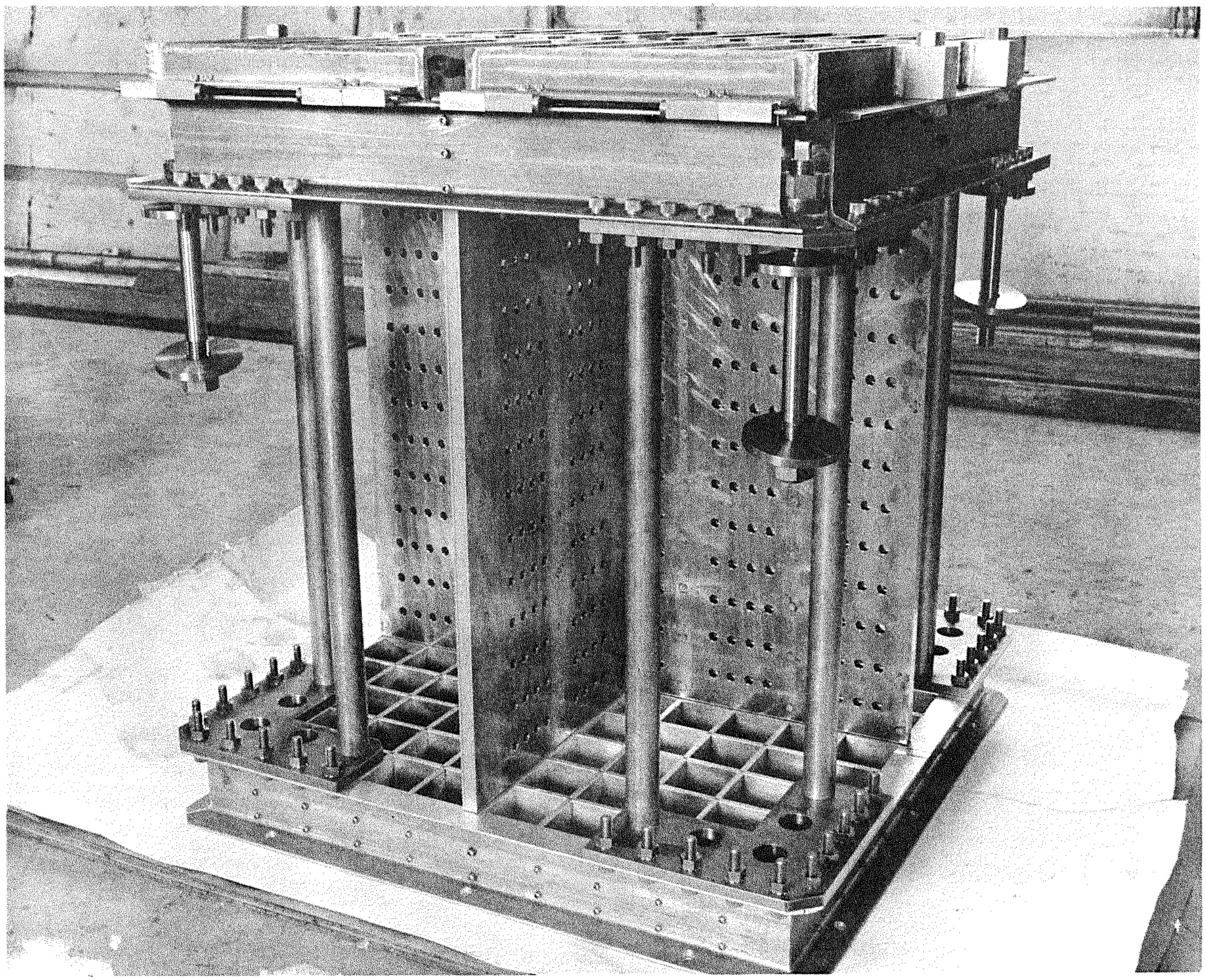
B. Reactor Vessel

The reactor vessel is a 4 ft ID x 10.5 ft high, carbon steel vessel having a wall thickness of 0.5 in. The top of the reactor vessel is open to atmosphere. The inside surface of the vessel is painted with Amercoat No. 33 to reduce corrosion of the vessel. Deionized water having a resistivity of 500,000 ohm-cm or better, is used exclusively in the reactor. The water is drained and the vessel refilled as required to maintain water quality. The vessel is equipped with remotely operated drain and fill valves operable from the Control Center Building. The vessel is also equipped with a remote indicating liquid level transmitter, electric immersion heaters (100 kw), and a 1 hp electric mixer for obtaining temperature equilibrium of the water moderator.

C. Internal Structure

The reactor internal structure is supported in the reactor vessel by four lugs welded to the inside surface of the vessel. A photograph of the structure is shown in Figure 7. The structure, whose function is to support and locate the fuel, consists primarily of the lower grid, the "hold-down" or upper grid, and the control rod guide plates or "cross".

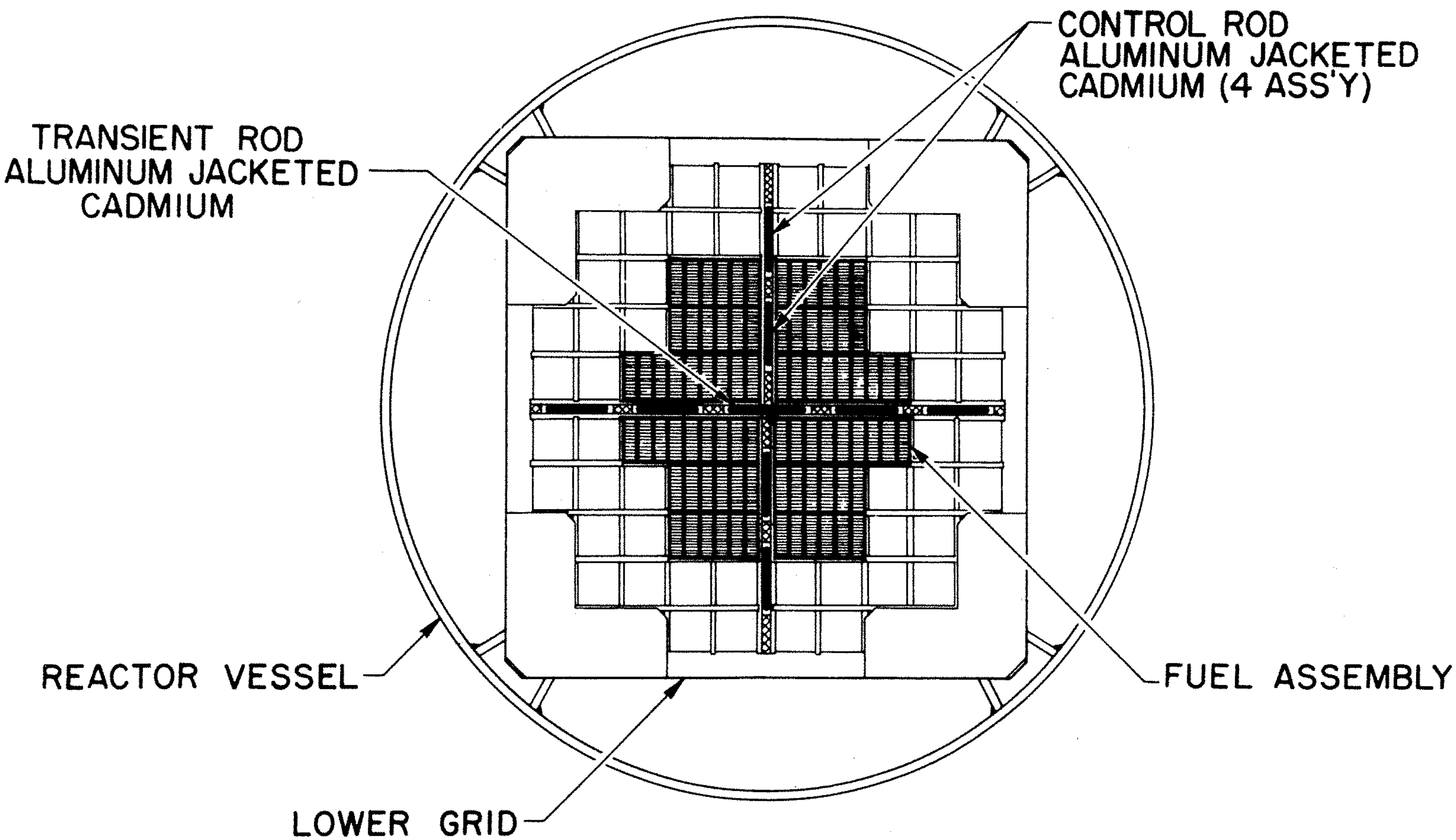
A cross-sectional view taken through the horizontal centerline of the reactor is shown in Figure 8. The reactor core is divided into four quadrants by the control rod guide plates with spaces provided for 20 fuel assemblies in each quadrant, or a total of 80 assemblies. For the majority of the experimental work, the reactor lattice consists of 28 fuel assemblies (Type A) loaded in the geometrical pattern as shown in Figure 8. This loading results in a total excess reactivity of about 4% Δk at 18°C as determined by rod worth measurements. The control rod guide plates forming the "cross", extend throughout the vertical height of the core, and are fabricated of perforated aluminum sheet. The "hold-down" (upper) grid is divided into four sections (one per quadrant), which are hinged to the internal structure. Wedge shaped, V-notched blocks, resting on the fuel assembly lifting pins, minimize movement of the fuel assemblies under normal conditions in all directions, and properly locate the assemblies with respect to each other.



INTERNAL STRUCT URE OF REACTOR-SIDE VIEW

FIGURE 7

(55-794)



SPERT-I LATTICE
28 ASSEMBLIES

FIGURE 8
(56-466)

D. Reactor Control Rods

1. Shim Rods

Four blade type control rods serve to control the reactor during operation, and a fifth rod, the transient rod, is utilized to initiate reactor excursions.

The shim rods, each having two blades, act as control rods during normal operation. The poison section of the shim rods is a 4.75 in. wide x 0.020 in. thick cadmium sheet clad with aluminum. The poison section is located in the upper portion of the blades; therefore, in the normal rest position of the rods (down), the cadmium is fully inserted in the active lattice.

2. Transient Rod

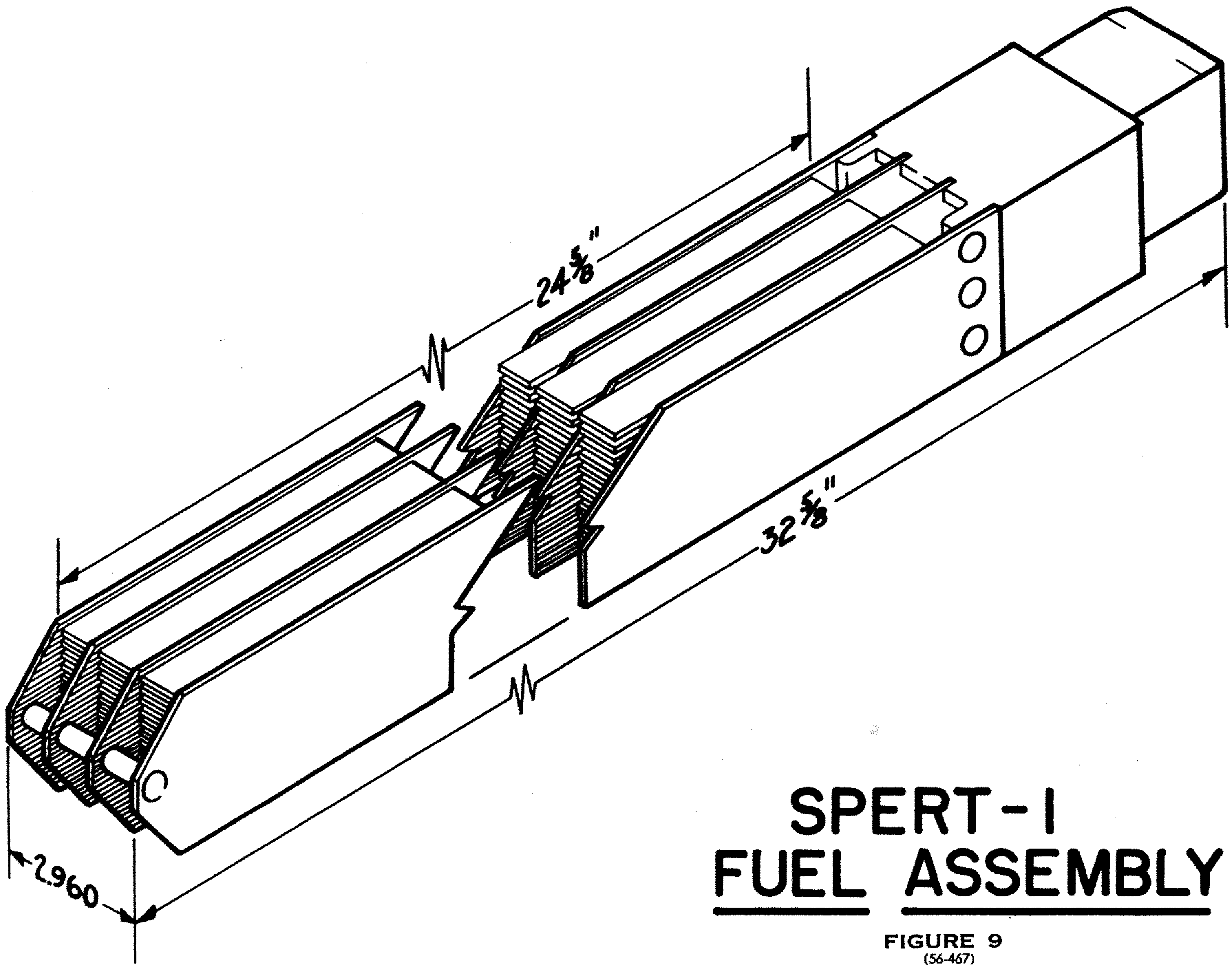
A fifth rod, referred to as the transient rod, has a single blade and is located in the geometrical center of the reactor. This rod provides a means for initiating reactor excursions by the rapid removal of poison from the core. The poison section of the blade is located in the lower section, and is therefore below the active lattice in the rest position (down) of the rod.

E. Fuel Assemblies

Figure 9 is a cutaway view of the SPERT, Type A, fuel assembly showing the general construction. The overall dimensions of the assembly are 2.960 in. x 2.960 in. x 32.625 in. The assembly consists of an end box, two aluminum side plates, two stiffener plates, a lifting pin, and 51 fuel plates. The total U-235 content of a fuel assembly is 168 g. The fuel plates consist of a uranium-aluminum alloy core 0.020 in. thick and clad on each surface with aluminum alloy (Type 1100) 0.020 in. thick. The total thickness of the plates is 0.060 in. and the average active fuel height is 23.75 in. The spacing between adjacent fuel plates is 0.117 in. Special fuel assemblies with two of the outside fuel plates unbrazed and therefore removable, are also available. A photograph of a removable plate fuel assembly is shown in Figure 10. The removable fuel plates are utilized for the attachment of thermocouples which may be conveniently inserted in the special assemblies for placement in the reactor. With spare fuel plates, the necessity of "hot" work while attaching thermocouples, is reduced.

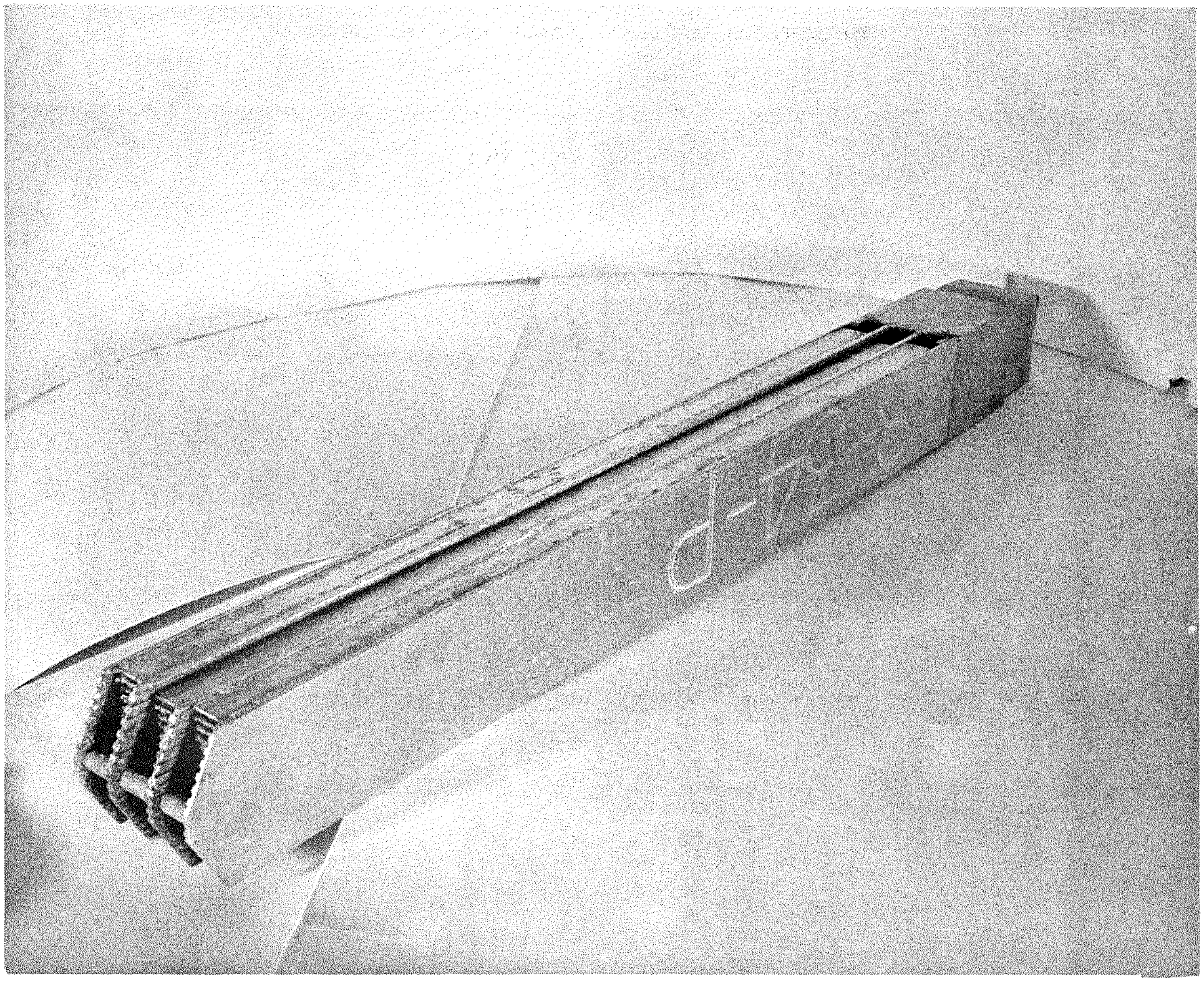
F. Control Rod Drive Mechanisms

The shim rod drive system is supported on a "bridge" spanning the shield tank approximately 7 ft above the top flange of the reactor vessel. A photograph of the bridge structure and drives, is shown in Figure 11. The four shim rods (eight blades) are driven by a single motor. A second motor is used to drive the transient rod. A total travel of about 25 in. is permissible.



SPERT-I
FUEL ASSEMBLY

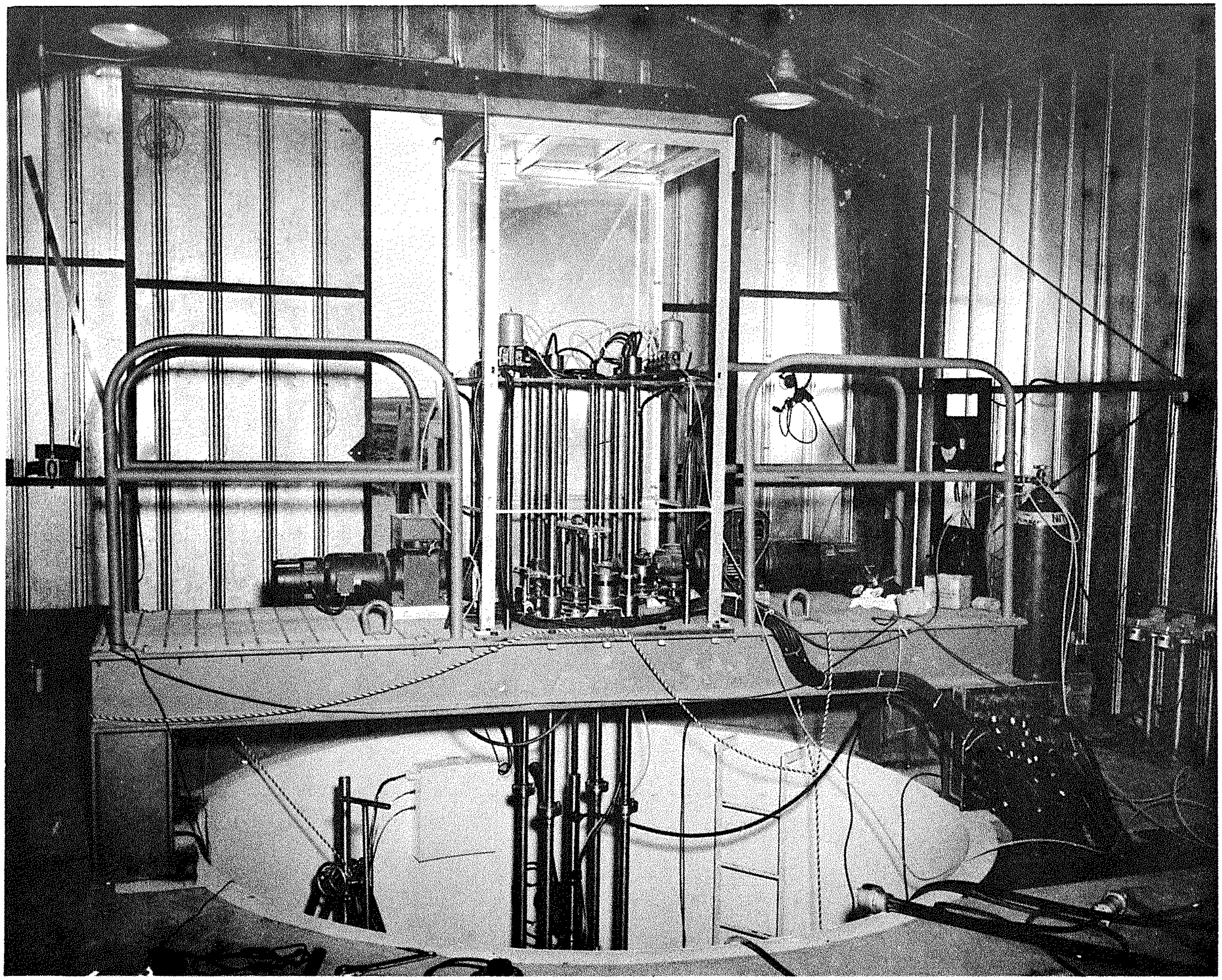
FIGURE 9
(56-467)



TYPE A FUEL ASSEMBLY WITH REMOVABLE PLATE

FIGURE 10

(57-2598)



CONTROL ROD DRIVE SUPPORT STRUCTURE

FIGUE 11
(55-1977)

Both drive systems consist of a 1/2 hp 480 volt, 3 Ø, induction motor driving a Graham, Model 150, variable speed transmission. The motors operate at 1150 rpm and are equipped with magnetic brakes. The output speed of the transmission may be remotely controlled from the Control Building. Chain and sprocket drives acting on a ball nut and screw permit control rod withdrawal rates up to 10 in./min. A photograph of the drives is shown in Figure 12. Rates up to 35 in./min have been achieved by changing the size of the drive sprocket.

The shim rod drive rods are coupled to the shim rods by means of magnetic clutches. Interruption of the magnet current permits the shim rods to be released and poison inserted in the core. The shim rods are accelerated through the first 2 in. of their downward travel by means of small air pistons and plungers. A cross section of the magnet and air piston is shown in Figure 13. With 65 psi air pressure acting on the piston, a force of 260 lb is applied to the shim rod. The measured average rod drop time in water from interruption of the magnet current to the rod seat (24 in.) is about 150 msec.

The transient rod drive is coupled to the transient rod by a mechanical latch. The latch may be disengaged by air pressure acting on a release ring. A cross-sectional view of the transient rod latch mechanism is shown in Figure 14 and a photograph of the latch in Figure 15. The transient rod is also accelerated in its downward travel by means of an air piston; however, a piston having a larger area is employed. The measured average drop time of the rod is 80 to 120 msec depending upon the release position or the amount of reactivity to be added to the reactor.

Continuous position indication of the shim rod and transient rod drives is obtained to the nearest 0.01 in. using selsyn transmitter-receivers and register indicators. Both upper and lower limit switches are provided on the drives.

Deceleration of the rods is accomplished by conventional, oil filled, shock absorbers. The shock absorbers are mounted on steel beams supported by and crossing the top flange of the reactor vessel.

G. Special Features

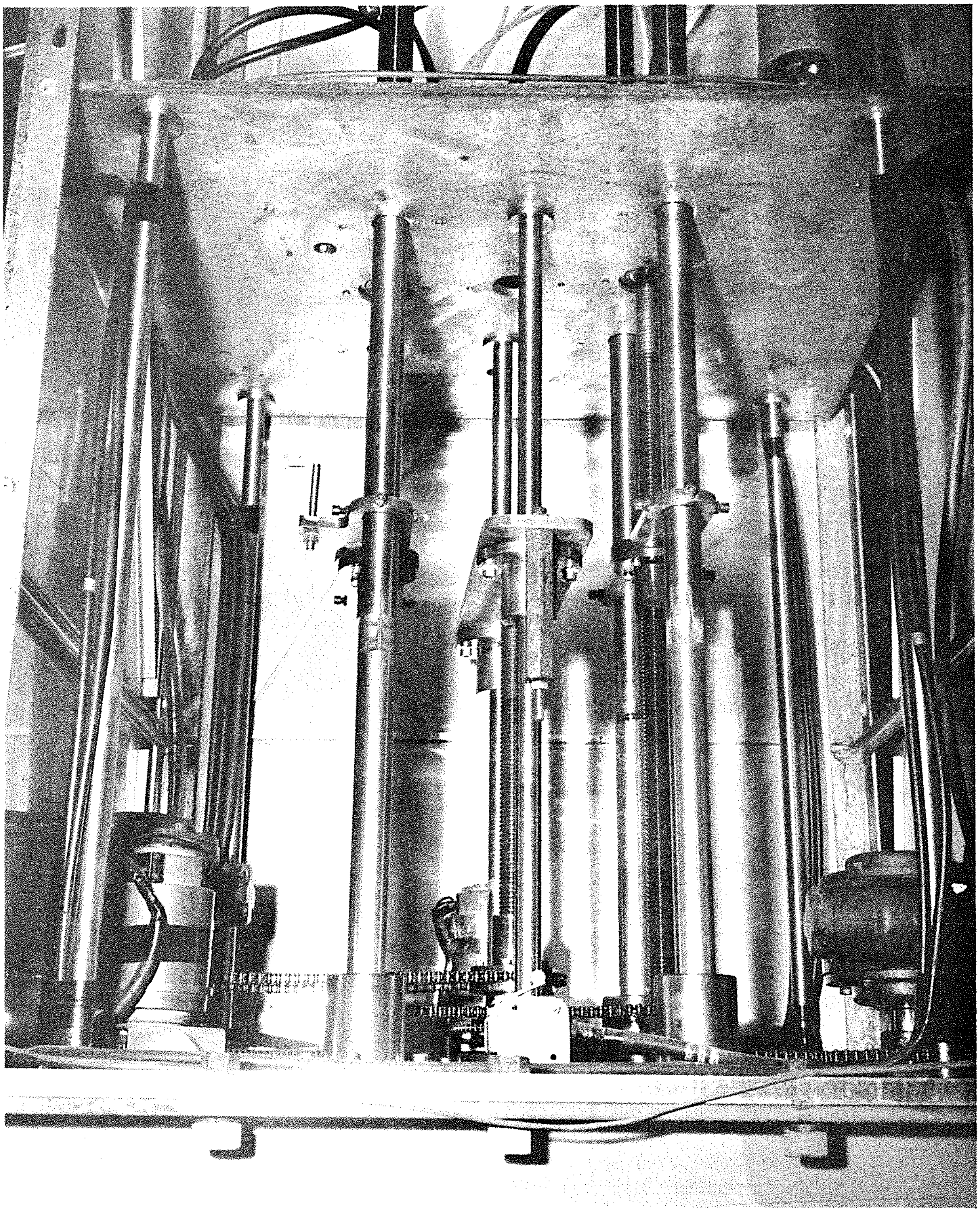
Since reactor behavior is closely associated with the moderator behavior, provisions are available for observing and photographing the reactor during reactor excursions.

1. Television Camera

A remotely controlled, closed circuit, television camera is provided to observe the reactor during operation, and to visually survey the reactor area prior to and following reactor operation.

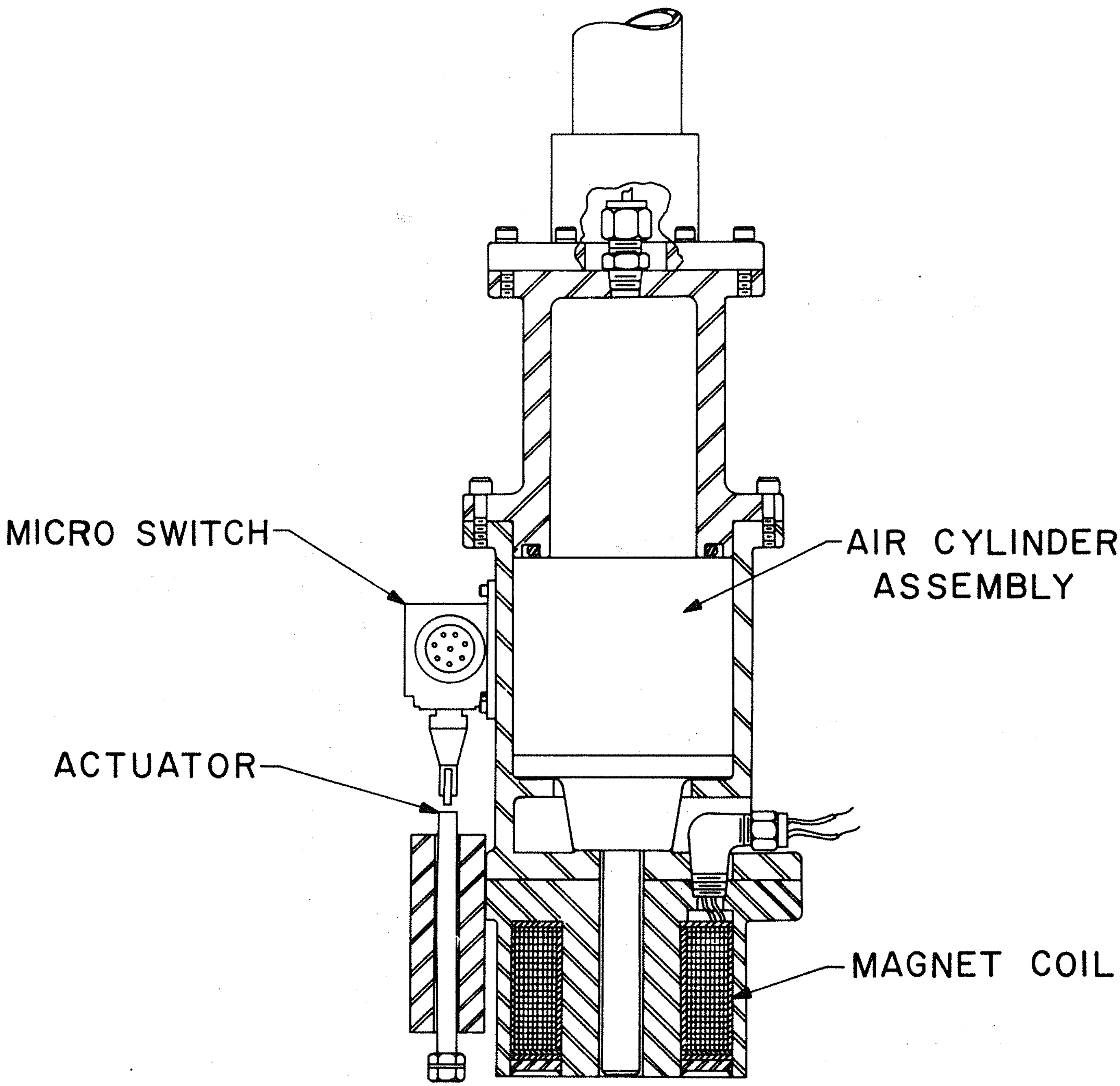
2. Camera Port and Periscope

In order to photograph the moderator phenomena between the fuel plates of a fuel assembly during a reactor excursion, a special camera port or view tube is installed through the reactor vessel shell.

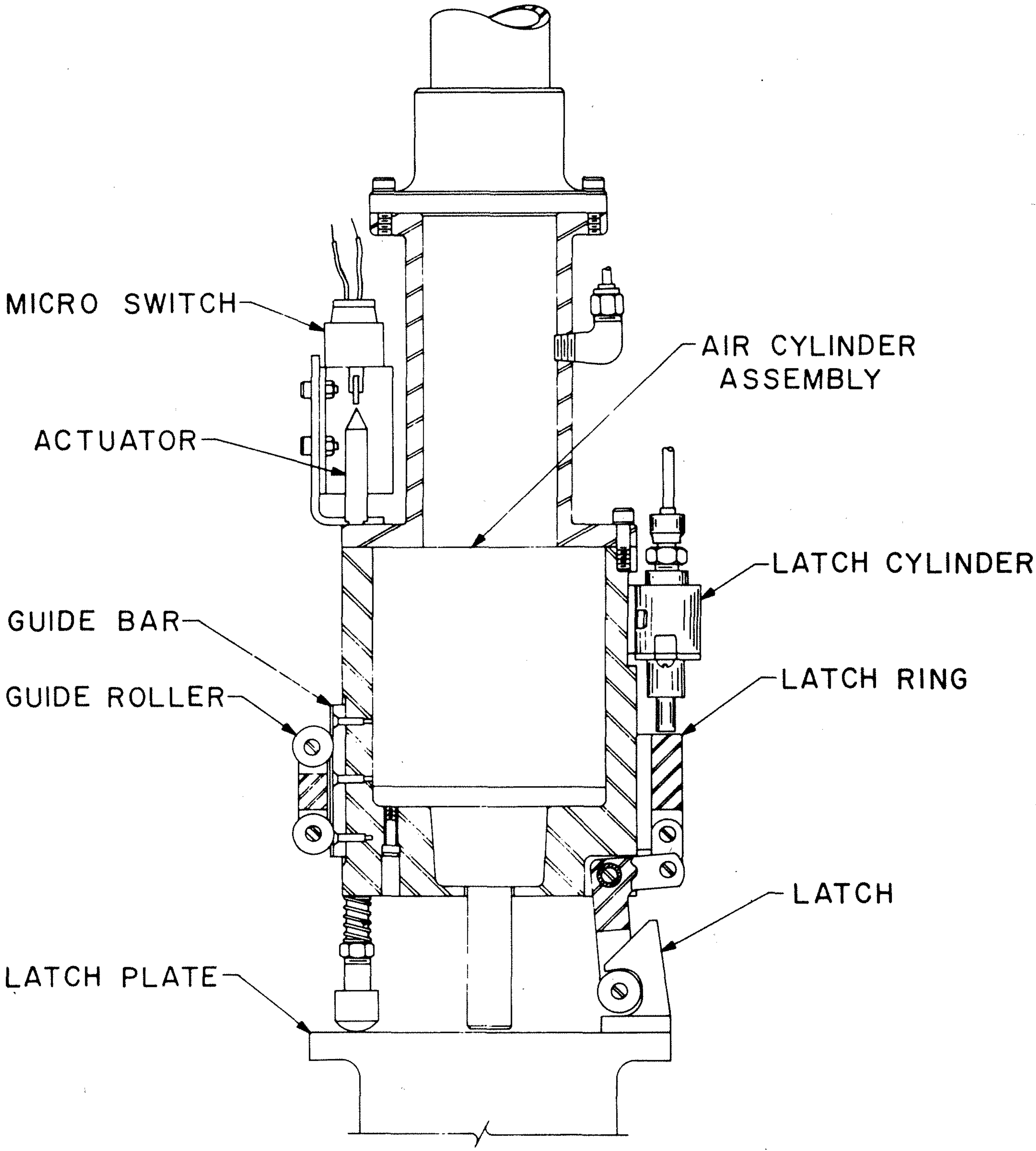


CONTROL ROD DRIVE MECHANISM

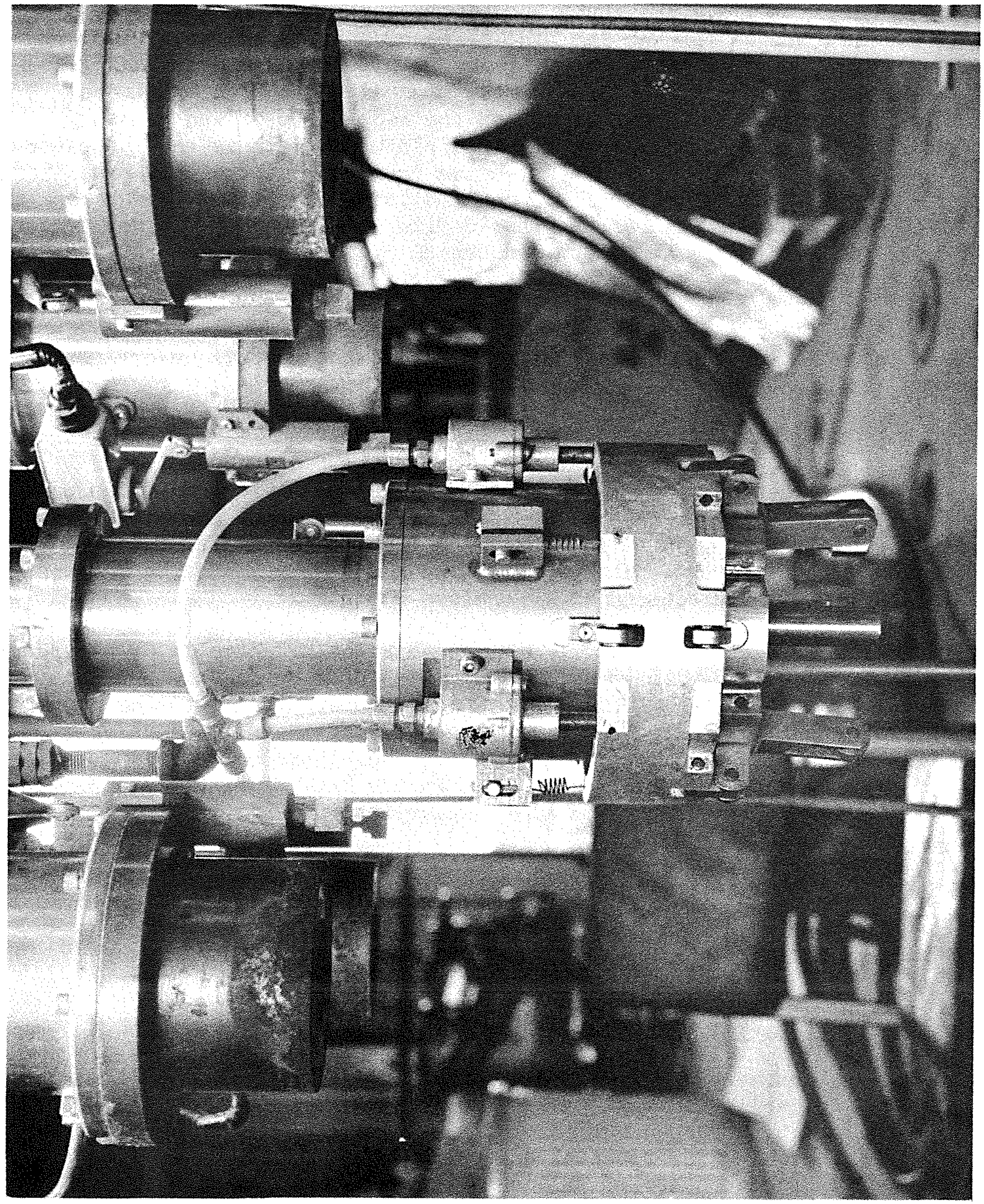
FIGURE 12
(57-2594)



SPERT-I
SHIM ROD MAGNET
FIGURE 13
(57-2671)



SPERT-I
TRANSIENT ROD LATCH
FIGURE 14
(57-2672)



TRANSIENT ROD LATCH
FIGURE 15
(57-2595)

The camera port consists of 1.5 in. ID water filled, stainless steel tube, which penetrates the reactor vessel wall through a 3 in. nozzle at about core centerline. The outer end of the tube is sealed by means of a non-browning glass window. The inner end of the tube rests in a 1.5 in. circular opening milled through the side plate of a fuel assembly. The circular opening in the side plate is sealed by a second non-browning glass window to prevent any disturbance of the moderator flow pattern inside the fuel assembly. The opening through the side plate of the assembly exposes to view the edges of several fuel plates as well as the moderator between the plates. A periscope extending from the outer end of the camera port to the reactor building floor, permits location of a movie camera several feet from the edge of the shield pit. The periscope is designed for use with a 16 mm movie camera and has an effective aperture of 3.6. A schematic layout of the periscope and camera port is shown in Figure 16.

Several means of lighting have been attempted and successful photographs have been obtained; however, development is underway to improve the light source.

IV. REACTOR CONTROL AND INSTRUMENTATION

The instrumentation for the SPERT-I Reactor is divided into two categories—"operational" or reactor control instrumentation, and "transient" or experimental instrumentation. Only the operational instrumentation is discussed in this report. The SPERT-I transient instrumentation and associated problems are discussed in a separate report.[5]

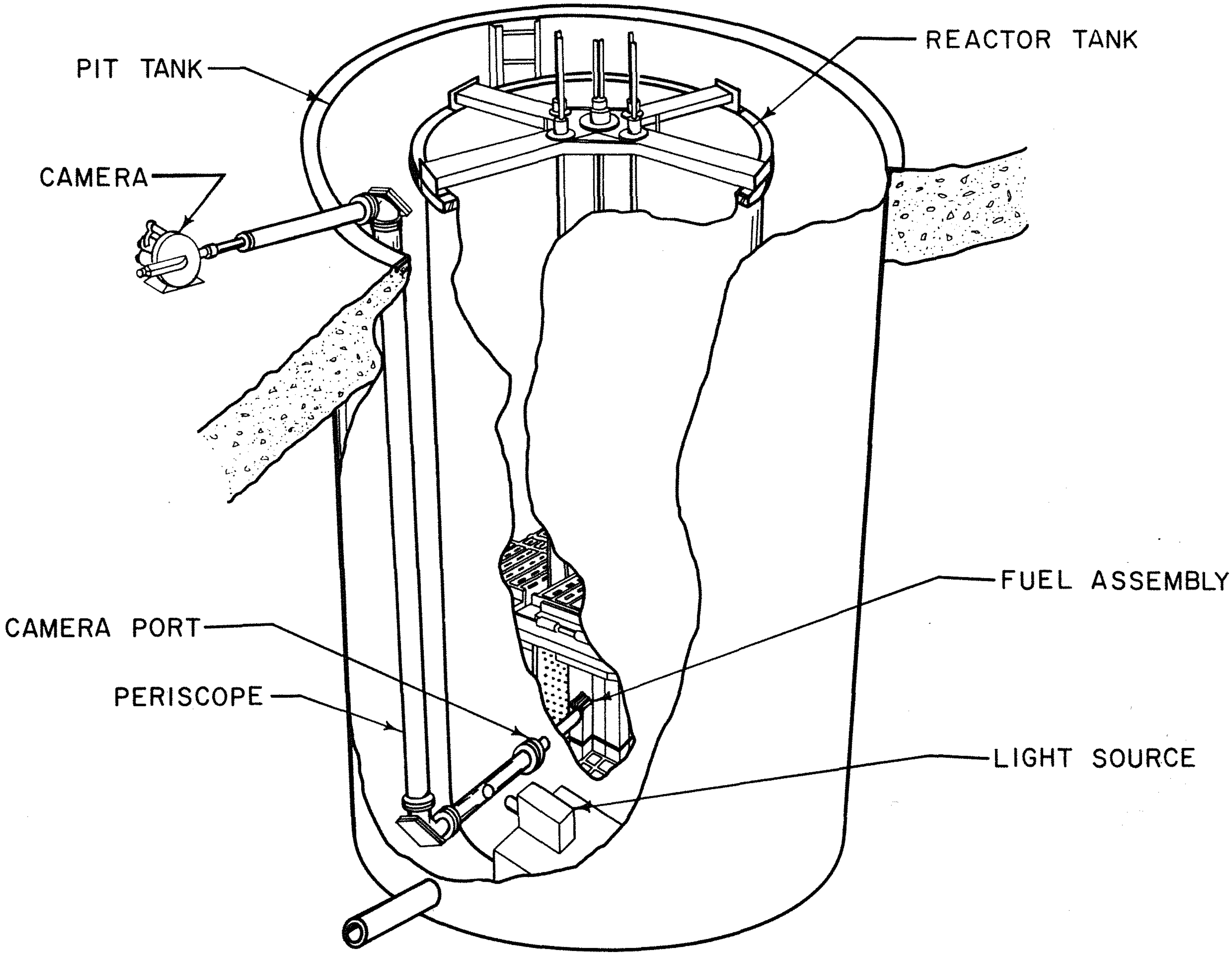
Since all reactor operations are viewed as being potentially hazardous, operation of the SPERT-I Reactor is accomplished by remote control from a distance of about 3000 ft. This also includes operation of the principal auxiliary facilities such as the reactor vessel drain and fill valves, electric immersion heaters, electric mixer, etc. Remote operation of the latter equipment is further necessitated by the lack of biological shielding in the immediate vicinity of the reactor vessel.

Due to the nature of the reactor experiments being conducted, the SPERT-I instrumentation has been confined to the basic components required for operation. No servo system or other automatic safeties have been included other than a programmed control rod "scram". A schematic block diagram of the operational instrumentation is shown in Figure 17.

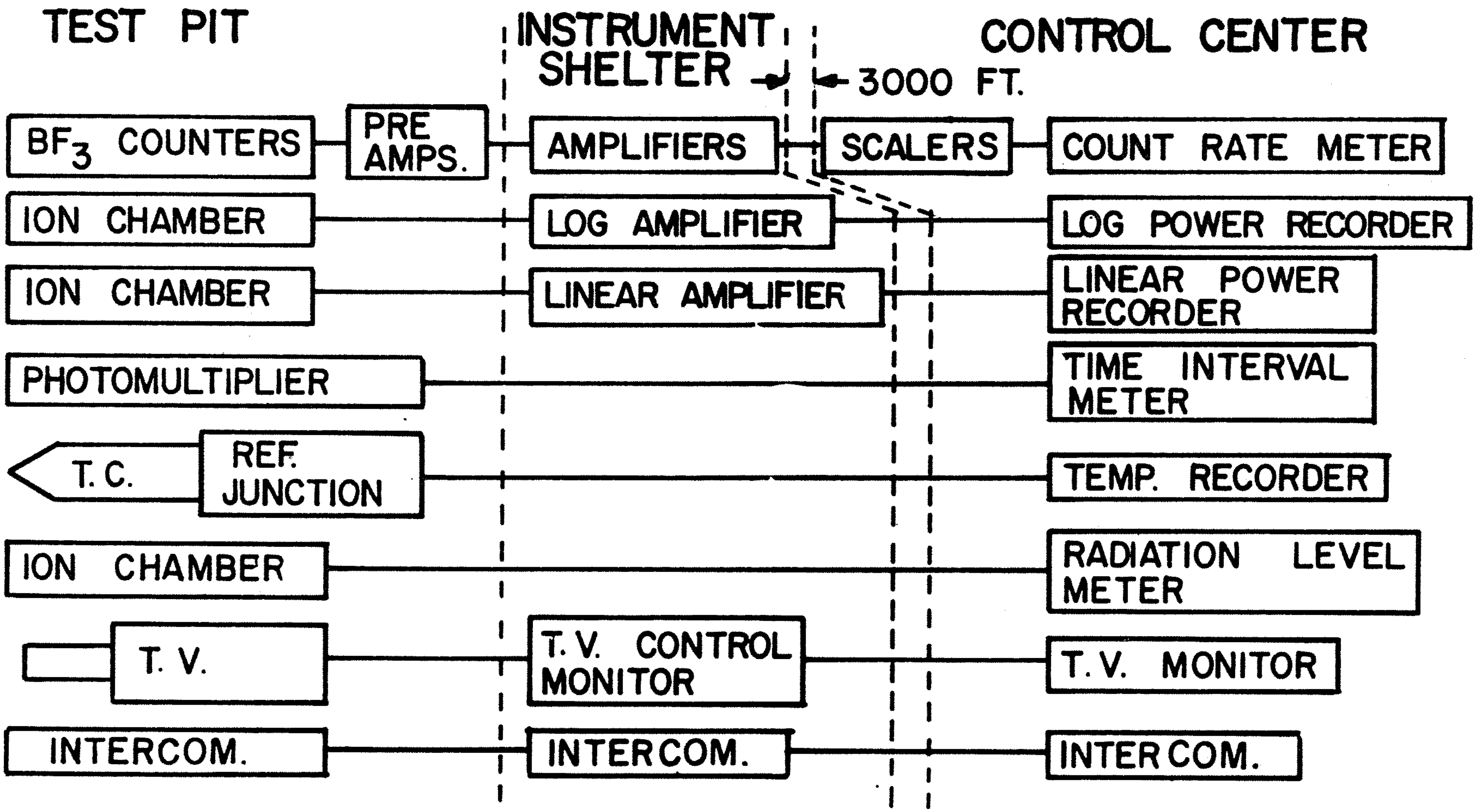
A. Neutron Detectors and Power Recorders

BF_3 chambers are employed to detect the neutron level or reactor power from source level (less than 5 mw) to about 50 watts. The chambers are located in 6 in. pipes buried in the reactor building floor adjacent to the shield tank. The pipes extend diagonally down to approximately 2 ft below the reactor core horizontal centerline and are sealed by 1/4 in. steel plate at the shield tank wall. Two BF_3 chambers are employed. Signals from these chambers are amplified and transmitted to count rate meters located in the Control Center.

The reactor power level in the range from 10 watts to 10 Mw is detected by a B-10 lined ion chamber filled with an argon-CO_2 mixture. The chamber



SPERT I
CAMERA PORT & PERISCOPE
FIGURE 16



SPERT I OPERATIONAL INSTRUMENTATION BLOCK DIAGRAM

FIGURE 17
(57-842)

1—10—57

is uncompensated for gamma radiation. The ion chamber is located in one of the ion chamber tubes adjacent to the shield tank as shown in Figure 5. A signal supplied by the chamber is amplified in a logarithmic amplifier and recorded at the Control Center on a six decade, strip chart type, "log power" recorder.

A second indication of the reactor power is supplied by the "linear power" recorder. A B-10 lined chamber, identical with that used in conjunction with the "log power" recorder, operates through a linear amplifier to provide the signal for the "linear power" recorder. The "linear power" recorder is supplied with a manually operated range change selector switch and covers the reactor power range from 100 watts to 100 Mw. The instrument is of particular value for determining the critical rod position of the reactor.

All ion chambers have been calibrated utilizing the reactor vessel as a calorimeter and employing nuclear and electrical heating.

B. Gamma Detectors

The radiation level in the vicinity of the reactor vessel and at other points in the Reactor Building is detected by gamma sensitive chambers and indicated in the Control Building on four decade dial indicators calibrated in r/hr. Full scale reading on the indicators is 1000 r/hr. The devices supply continuous information regarding the gamma radiation level in the Reactor Building. The information is used extensively by Health Physics and operating personnel to determine the accessibility to the reactor area following operation of the reactor.

C. Temperature Instruments

The temperature of the water moderator-reflector is measured by copper-constantan thermocouples located in the water above, below, and inside the reactor core. The thermocouple leads extend to a reference junction maintained at $50^{\circ}C \pm 0.1^{\circ}C$ and mounted on the shield tank wall. The signals from the thermocouples are transmitted without amplification direct to multi-range recorders at the Control Center. The multi-range recorders are equipped with five ranges and automatic range selection. The range span of recorders is 0 to 10.2 mv.

D. Rod Position and Motion Controls

A description of the mechanical components associated with the rod drive systems has been presented in section F, "Control Rod Drives". In this section a more detailed description is presented of the equipment utilized to indicate the speed and position of the control rods and the control rod drives.

A distinction should be made here between the position indication provided for the control rods and the position indication provided for the control rod drives. No position indication is provided which operates directly from the control rods other than the seat indicators described in the following paragraphs.

When the control rods are coupled to the rod drives by means of the magnetic clutches (shim rods) or the mechanical latch (transient rod), the position of both the rod drives and the position of the actual poison blades relative to the core, are indicated by continuous position registers at the reactor console. This continuous position indication of both the shim rods and the transient rod is supplied by selsyn transmitters connected directly to their respective rod drives by means of a chain and sprockets. The selsyn receivers are located in the reactor console and coupled to register indicators by a flexible shaft. Switches that operate informative lights are provided to indicate when the rod drives are in contact with the control rods. The contact switches are actuated by physical contact of the rod drives and the control rod extensions, and indicator lights on the reactor console transmit the information to the operator. The rod drives are also equipped with upper limit switches which upon actuation, stop the rod drive motors and by indicating lights inform the operator that the maximum upward travel of the rod drives has been reached.

When uncoupled from the drives, the shim rods and the transient rod are free to travel by virtue of gravity to their down positions. Seat switches which actuate indicating lights on the reactor console, are therefore provided to verify the position of the rods to the operator under these conditions. The switches used for the contact indication, upper limit indication, and rod seat indication are hermetically sealed switches.

Control of the rod drive speeds is achieved in the Graham transmissions by means of an electric motor. Operation of the electric motors is accomplished by means of toggle switches mounted on the reactor console, and in addition to changing the output speed from the transmission, operation of the motors drives a helipot from which a speed indication is obtained.

All relays employed in the control circuits are hermetically sealed, quadruple pole, double throw, plug in type relays for ease of maintenance.

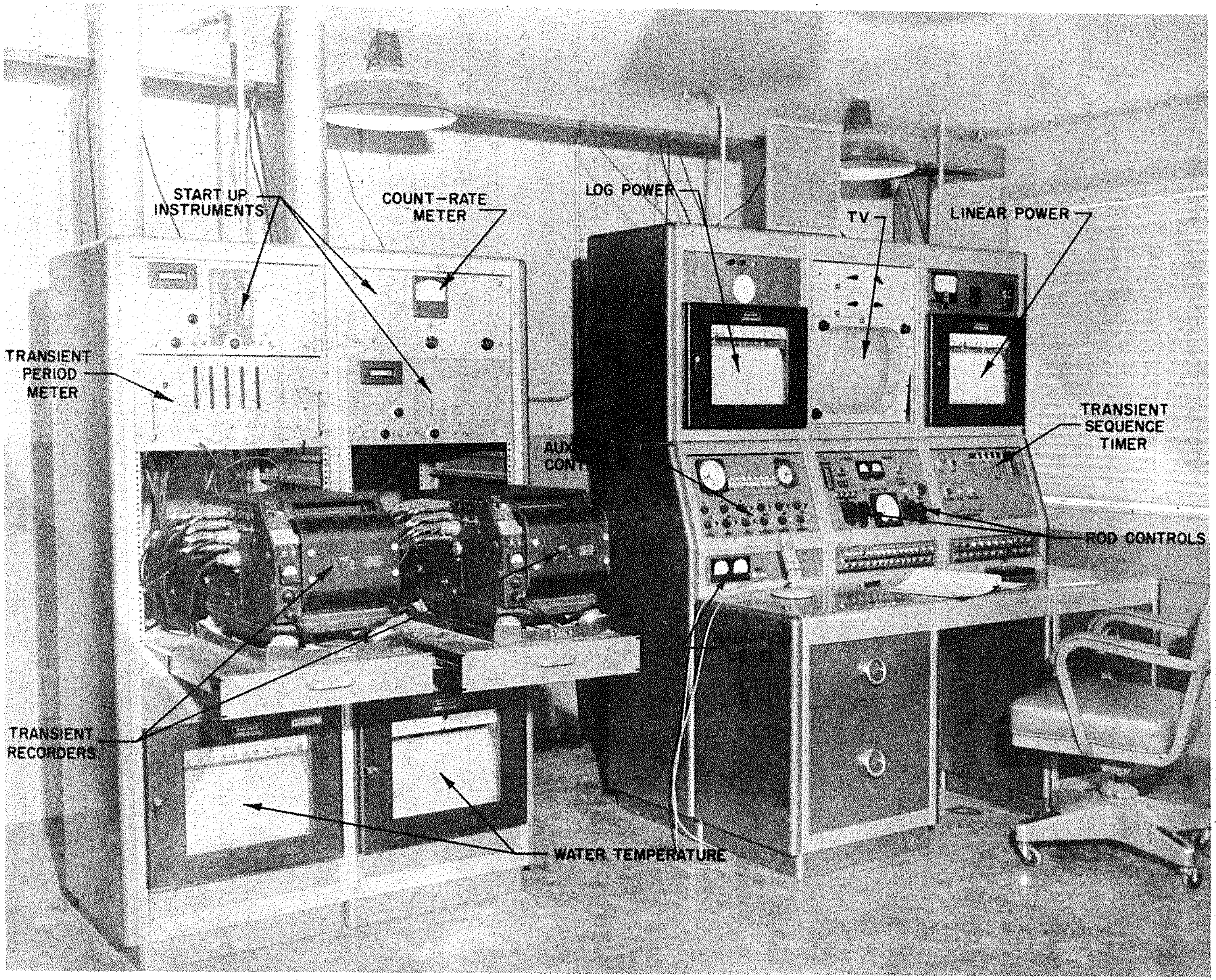
E. Control and Signal Cables

The cables connecting the SPERT-I reactor with the Control Center are of two types distinguishable by the function which they fulfill; i.e., those transmitting intermittent ac power such as reactor control circuits, and those transmitting instrument signals. The cables have been laid on the surface of the ground; however, to prevent electrical interference, the signal cables are separated from the power cables by a distance of about 15 ft throughout the length of the 3000 ft run.

Two types of cables are in service. The power cables are neoprene covered, 19-conductor cables, the conductor size No. 16 BWG wire. The signal cables are shielded, coaxial cable, also neoprene covered.

F. Reactor Console

Figure 18 is a front view of the reactor console. For the convenience of the operator in distinguishing the functions of the various



SPERT-1 REACTOR CONSOLE

FIGURE 18
(57-1216)

controls on the reactor console, the lower section is divided into three panels. From left to right the panels contain the controls associated with the auxiliary facilities, the conventional reactor controls, and the controls associated with initiating a reactor transient, and will be discussed in that order.

The left hand panel contains the controls, indicating meters, and informative lights associated with the auxiliary facilities. The controls on this panel consist of ON-OFF push button controls for the sump pump, electric mixer, electric immersion heaters, the reactor fill pump and inlet valve, and the reactor tank drain valve. Red and green lights indicate the condition of each item of equipment. Indicators on this panel include the reactor tank liquid level and two gamma radiation level indicators. The upper portion of the left hand panel houses the reactor logarithmic power recorder.

The center panel contains the control switches, indicators, etc., associated with operation of the reactor in the lower section, and a television receiver with controls for remote camera operation in the upper section.

Two 3-position pistol grip switches located on the right and left center of the panel, are provided for controlling the movement of the shim rods and the transient rod respectively. These switches form the heart of the reactor controls. Each switch is equipped with Withdraw-Neutral-Insert positions, and supplied with a spring return from the Withdraw to the Neutral position. Although only ganged operation of the shim rod drives is permissible, individual rod insertion or withdrawal may be achieved by controlling the magnet current supplied to the individual magnets. Four toggle switches, one for each of the shim rods, are located in the upper left corner of the center panel, and control the supply of current to the magnets. Register indicators located immediately above the pistol grip switches continuously indicate the rod drive positions to the nearest 0.01 in. A fifth toggle switch is provided to control the air supply to the shim rod air piston accelerators. Withdrawal of the shim rods is not permissible without this air supply.

A 4 in. dial indicating count rate meter is located in the geometric center of the panel. The count rate meter is utilized by the operator primarily during reactor start-up; however, the meter is equipped with a range selector on the immediate left which permits use of the meter as a power indicator.

Immediately above the count rate indicator are two smaller dial type meters which indicate the drive speeds of the shim rod drive and the transient rod drive speed in in./min. Selection of the desired drive speed is achieved by toggle switches located directly beneath the indicating meters.

A manual scram button and a scram reset button are located toward the right hand side of the center panel. Indicating lights on the center panel include the seat lights for each of the four shim rods and the transient rod, and upper limit lights for the shim rod and transient rod drives.

A small procedure panel equipped with red and green lights and located directly below the center control panel supplies the following information to the operator:

1. Power on.
2. Transient Rod - armed or unarmed.
3. Count Rate Meter - reading or not reading.
4. Log Power Recorder - reading or not reading.
5. Scram - scram or reset.
6. Shim Rod Magnets (1 thru 4) - on or off.
7. Shim Rod Contact (1 thru 4) - contact or open.
8. Shim Rod Air - on or off.
9. Transient Rod - contact or open.

The right hand panel of the console contains the linear power recorder in the upper portion and the controls, sequence timer, informative lights, etc., necessary to initiate a reactor transient.

The primary feature of the panel is the sequence timer which in accordance with a pre-set schedule starts cameras, recording equipment, etc., initiates injection of the transient rod, and at the desired time scrams the shim control rods and shuts off equipment. In addition to the timer, the panel is equipped with key interlock push buttons for arming the transient rod; i.e., supplying air to the air piston used to accelerate the rod, and for starting the reactor transient, i.e., starting the sequence timer.

If for any reason the reactor operator desires to interrupt the experiment after pushing the transient start button, a sequence stop button is provided which will stop the sequence timer if the transient rod has not yet been released. However, if the transient rod has been released, pushing the sequence stop button will not disrupt the programmed shim rod scram nor will it prevent an immediate manual scram.

Toggle switches and indicating lights have been provided for the control of individual items of equipment such as cameras, recorders, etc., connected to the sequence timer. Individual items when not in use may be removed from the timer circuit by means of a toggle switch. Indicating lights inform the operator which items of equipment are in the timer circuit.

G. Operating Procedures

1. Fuel Handling

The SPERT experimental program requires the frequent handling of radioactive fuel assemblies for the purpose of installing pressure and temperature detectors, and occasionally requires complete unloading and loading of the core. Because the total power (or nvt) generated during the lifetime of any core will be small, no special provisions for remote fuel loading and unloading were included in the design. Although more than 500 transient and stability tests have been conducted with the initial core, the fuel may still be unloaded or loaded by the use of longhandled tools. Should the need arise, a transfer cask is available which may be utilized for unloading the reactor core without overexposure to personnel.

2. Typical Transient Test

The experimental procedure for a typical transient test will best serve to explain the general mode of SPERT operations.

Prior to reactor operation of any type, all personnel are withdrawn from the reactor area to the Control Center and the road to the reactor is barricaded. The water temperature and water head above the core having been established to the desired conditions, the initial step is to determine the critical position of the four shim control rods with the poison section of the transient rod entirely out of the core. With the critical position established, the reactor is made subcritical by pulling the transient rod poison upward into the core in preparation for the transient. The four shim control rods are then further withdrawn to a point dependent upon the reactivity to be added to the reactor. Ejection of the transient rod will then make the reactor supercritical by the desired amount. At any time thereafter, the transient may be initiated by arming the transient rod and starting the transient sequence timer. The sequence timer starts recording equipment, initiates ejection of the transient rod, and at the desired time inserts the shim control rods and stops recorders all in accordance with a preset schedule.

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REFERENCES

1. R. H. Graham, D. G. Boyer, "AEC Steps Up Reactor Safety Experiments", NUCLEONICS 14, No. 3 (1956).

2. W. E. Nyer, S. G. Forbes, F. L. Bentzen, G. O. Bright, F. Schroeder, and T. R. Wilson, "Experimental Investigations of Reactor Transients", IDO-16285 (1956).

3. S. G. Forbes, F. Schroeder, and W. E. Nyer, "Instability in the SPERT-I Reactor Preliminary Report", IDO-16309 (1956).

4. F. Schroeder, S. G. Forbes, W. E. Nyer, F. L. Bentzen, and G. O. Bright, "Experimental Study of Transient Behavior in a Subcooled, Water-Moderated Reactor", NUCLEAR SCIENCE AND ENGINEERING, Vol. 2, No. 1, (1957).

5. F. L. Bentzen, "SPERT-I Instrumentation", IDO-16316 (1957).

APPENDIX A

SUMMARY OF POWER AND WATER REQUIREMENTS

I. MAJOR POWER REQUIREMENTS

	Maximum Estimated Load - kw
A. Control Center Area	
General Use	30
Instrument	10
Building Lighting	20
Deep Well and Booster Pump	95
Oil Furnace	1
Hot Water Heaters	5
Guard Station Light & Heat	20
Fence Lighting	10
B. Terminal Building	
General Use	5
Reactor Fill Pump	2
Air Compressor	5
Hot Water	3
Lighting & Heating	5
C. SPERT-I Reactor Area	
General Use	20
Instrument Power	10
Sump Pump	1
Electric Hoist	3
Electric Mixer	1
Process Heaters	75
Building Lighting & Heating	5
Guard Station Light & Heat	15
Fence Lighting	10
TOTAL	351

II. RAW WATER REQUIREMENTS

	Maximum Usage gpm
A. Control Center	
Laboratory	10
General Use	15
B. Terminal Building	
Deionizer Inlet	20
Air Compressor	5
General Use	10

C. Reactor Building

	Maximum Usage gpm
Shield Tank (Emergency Only)	100
Air Conditioner	5
General Use	20
TOTAL	185

APPENDIX B

SUMMARY OF THE NUCLEAR CHARACTERISTICS AND DESIGN DATA

I. REACTOR CORE

A. Fuel Assemblies, Type A

Type - 93.5% enriched uranium-aluminum alloy,	aluminum clad plates.
U-235 per assembly (average)	168 g
M/W ratio, assembly only	0.78
Fuel plate spacing	0.1165 in.
Over-all Dimensions	
Width	2.960 in.
Thickness	2.960 in.
Length	30.625 in.

B. Fuel Plates

Over-all Dimensions	
Thickness	0.060 in.
Length	24.625 in.
Clad thickness, each side	0.020 in.
Clad material	Al, type 1100
Fuel Core - 93.5% U-Al alloy	
Thickness	0.020 in.
Width average	0.68 in.
Length average	23.75 in.
U-235 per plate average	3.294 g

C. Control Rods

Type - Blade, aluminum clad cadmium	
Poison width	
Shim rods	3.75 in.
Transient rod	4.75 in.
Poison thickness	0.020 in.
Poison Length	24.00 in.

D. Reactor Nuclear Data

Critical mass, 18°C (23 assemblies)	3.86 kg U-235
Excess reactivity, 18°C (28 assemblies)	4%
Prompt neutron lifetime	50 ± 5 μsec
Temperature coefficient	
20°C	-0.9×10^{-2}%/°C
97°C	-2.0×10^{-2}%/°C
Core void coefficient, average	-3.5×10^{-4}%/cm^3 void
Core void coefficient, max. @ center	-7.2×10^{-4}%/cm^3 void
Volume water in core	5.4×10^4 cm^3
Maximum/average flux ratio	1.9

II. DESIGN DATA

A. Reactor Vessel

Design Pressure	atmospheric
Design Temperature	212°F
Inside Diameter	4.0 ft
Over-all height	10.5 ft
Wall thickness	0.5 in.
Weight, approximately	2750 lbs
Capacity	948 gal
Material	carbon steel, painted

B. Major Equipment Requirements

Description	No. Req'd	Make or Model
1. Control Rod Drive Motors	2	Type-Induction, 1 hp, 480 v, 60 cycle, 3 phase
2. Variable Speed Transmission	2	Graham Transmission Inc., model 150 MW-18
3. Electric Immersion Heaters	6	Heatube Corp. 24 kw each, ss jacketed
4. Electric Mixer	1	Mixing Equipment Co. model M-1 with 1 hp motor
5. Temperature-Indicating Controller	1	Minneapolis-Honeywell, Series 614C1B-26, Range 0-100°C
6. Reactor Vessel Liquid Level Transmitter	1	Manning, Maxwell & Moore-Electronic press transmitter, Cat. No. 14552
7. Reactor Fill Pump	1	Fairbanks-Morse Pump Co., Westco model SR4 K11 AIU 1146
8. Reactor Building Sump Pump	1	Atlas Equipment Co., model Aurora 1-1/2 MSM
9. Plant Air Compressor	1	Schramm Inc., model 1KB3 with 1 hp motor
10. Water Softener	1	Elgin Softener Corp., capacity 16,000 gal @ 10 gpm

Description	No. Req'd	Make or Model
11. Water Deionizer	1	Elgin Softener Corp. Ultra Deionizer - capacity 6,700 gal @ 10 gpm
12. Control Cables		
Power Cables	21,000 ft	Type - 19-conductor, #16 AWG, neoprene jacket
Signal Cables	165,000 ft	Coaxial Cable, Type 8/AU
Signal Cables	108,000 ft	Coaxial Cable, Type 62/AU
13. Relays	42	Advance Electric & Relay Co., hermetically sealed, type TD4C-115VA-T5A
14. Switches	8	Electro-Snap Switch & Mfg. Co. 4 pole, double-throw, 115 v, hermetically sealed, type H-2