SAFETY ANALYSIS REPORT

IN SUPPORT FOR LICENSE RENEWAL

FOR A LOW INTENSITY TRAINING REACTOR

CAVALIER

DOCKET NO. 50-396 LICENSE NO. R-123

AT THE UNIVERSITY OF VIRGINIA

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 Introduction

The CAVALIER* reactor is currently operated under License R-123, Docket No. 50-396 by the Department of Nuclear Engineering. The CAVALIER is housed in the same building as the 2MW UVAR reactor, which has been in operation since 1960. The CAVALIER is located on the ground floor of the west wing of the building. This wing was added to the facility in 1969. The present License (R-123) was issued on September 24, 1974 and the reactor achieved criticality for the first time on October 21, 1974. The fuel elements, control rods and nuclear instrumentation are the same as is used with the 2MW UVAR reactor. The maximum operating power level is less than 80 watts and the limit on integrated power per day is less than 200 watt-hrs (limiting safety system setting). Low power operation minimizes the shielding requirements during operation, makes possible fuel element handling subsequent to operation, and reduces the hazard associated with fission product release in the unlikely event of an accident. The major accident mode for a low power reactor is a reactivity excursion. By design and by procedure the excess reactivity and reactivity insertion mechanisms for the CAVALIER are limited to such an extent that destructive excursions are essentially impossible. The main function of the CAVALIER is to provide a safe and convenient facility for laboratory training of undergraduate and graduate students. The facility can also be used for reactor experiments, such as noise measurements, which do not require high neutron fluxes. The use of the CAVALIER for these purposes frees the 2 MW UVAR reactor for full time experimental use, and eliminates the necessity for training students on a relatively high power reactor. The safety aspects of the CAVALIER

*Cooperatively Assembled Virginia Low Intensity Educational Reactor.

are maximized by maintaining low inventories of fission products and excess reactivity. The facility can thus operate without containment and with no need for emergency cooling. Conservative analysis presented in this report indicates that, even in the event of a major fission product release (TID-14844 type) from this reactor, the magnitudes of personnel exposures at the site boundary, and in the surrounding areas, are within the limits of 10CFR20, averaged over a period of a year.

Since the CAVALIER and UVAR reactors are identical in many respects, such as site and fuel element design, much of the information that would normally be included in a safety analysis report will be incorporated by references to the UVAR Safety Analysis Report, which is on file with the NRC.

2.0 THE CAVALIER SITE AND LOCATION

2.1 The CAVALIER is located in the same building which houses the 2 MW University of Virginia Reactor. This site has been described in several submissions to the NRC, [1,2,3]. A fence around the building defines a small exclusion area. Out to a distance of about 250 meters in all directions, there exist only a few University and University related laboratories and the land belongs to the University. Beyond this, on the east, is the University, and the center of Charlottesville is approximately 2 miles away. Detailed information on the site may be found in UVAR-18. [3]

Within the Reactor Building, the CAVALIER is located in a concrete reactor pit located on the Ground Floor of the west wing. Figure 2.1 shows floor plans for this wing and a portion of the rest of the building. Locations of the existing UVAR, and the CAVALIER are indicated.

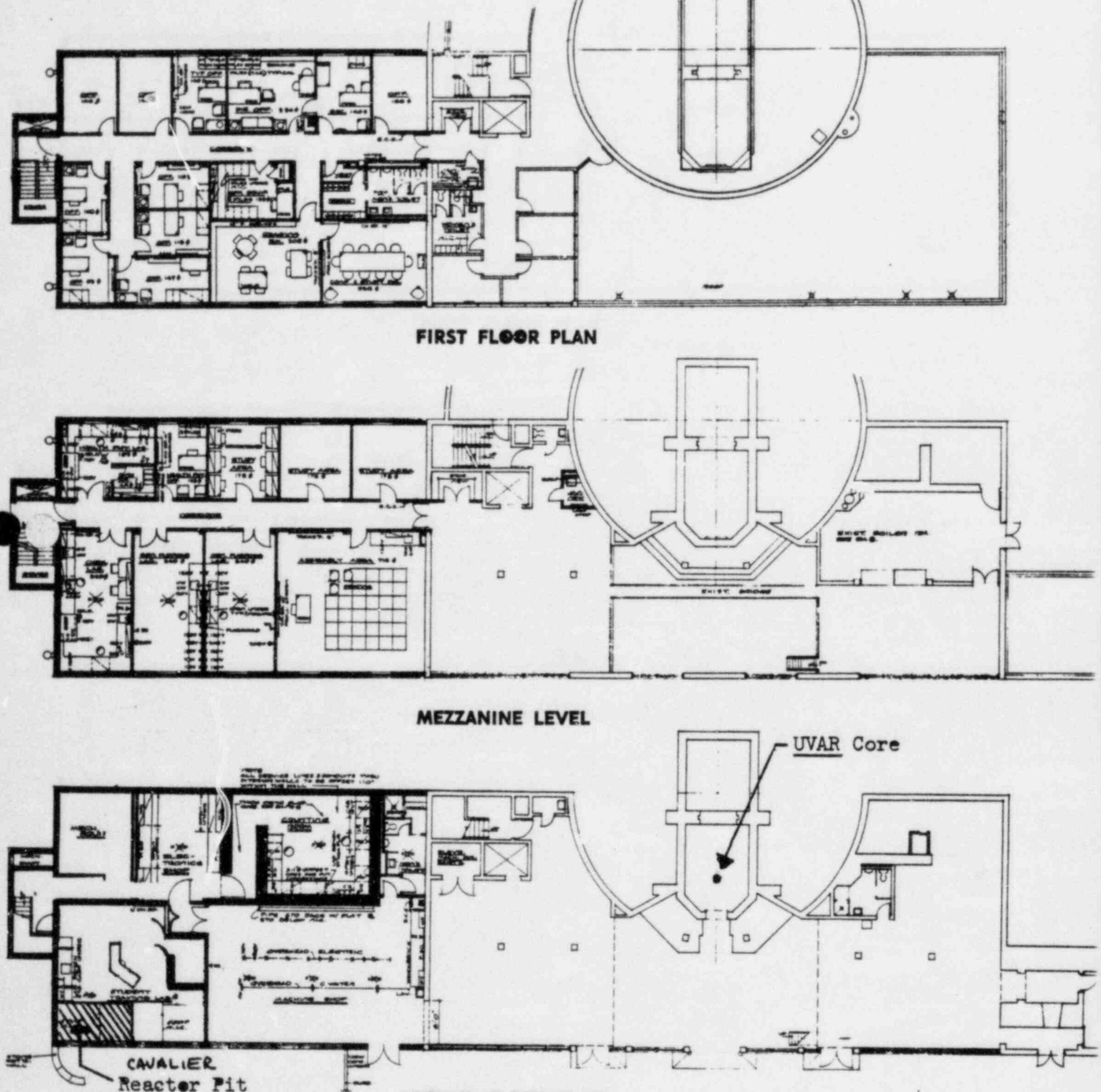


Fig. 2.1 Floor Plans, Wing Showing CAVALIER Location

Inside the pit whose depth below floor level is 9-feet, and at one end, stands a Moderator Tank, constructed of welded aluminum, 67-inches square, and 11-feet high. The reactor is located at the bottom of this tank, with a minimum of 7.25 feet of water above the core, to serve as biological shielding. At a power of 50 watts the gamma-ray dose rate directly over the core, at the top of the tank, is ~3 mR/hr. The Operating Area dose rate at this power is <1 mR/hr.

A concrete block shield wall, up to 3-feet thick, separates the Moderator Tank from the rest of the Reactor Pit, to reduce dose rates in the pit and general area.

The pit houses the clean-up demineralizer for the CAVALIER system. Plan and elevation views of the laboratory area, and pit are presented in Fig. 2.2A and 2.2B.

2.2 Health Physics Surveys

Health physics surveys were performed with the reactor power at ~ 1 watt and ~ 45 watts and the results are shown in figures 2.3 through 2.8. At a power level of 1 watt the highest dose rate was observed in the bottom of the pit adjacent to the reactor near the instrument tubes. Additional shielding was placed around this area before increasing power. At a power of ~ 45 watts the dose rate in this area is ~ 50 mr/hr. This area is inaccessible during reactor operations.

3.0 REACTOR CORE AND OPERATING LIMITS

3.1 Reactor Core Description

3.1.1 Reactor Assembly

A Grid Assembly, originally consisting of a 4x7 lattice of holes, is mounted on the bottom of the aluminum moderator tank and bolted securely to it. The hole spacings in the assembly duplicate those on

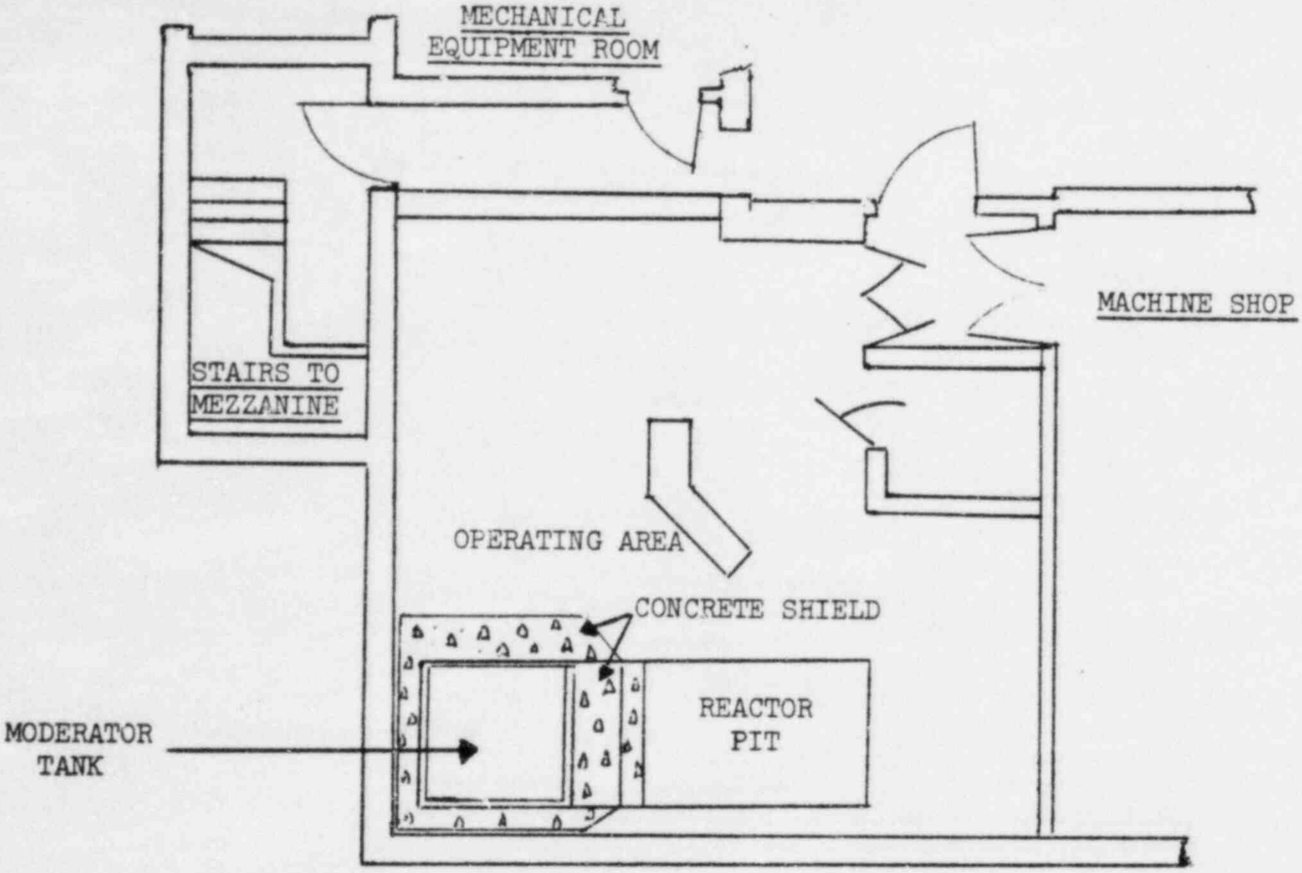


Fig. 2.2A Plan View of CAVALIER Operating Area SCALE: 1/8" = 1'

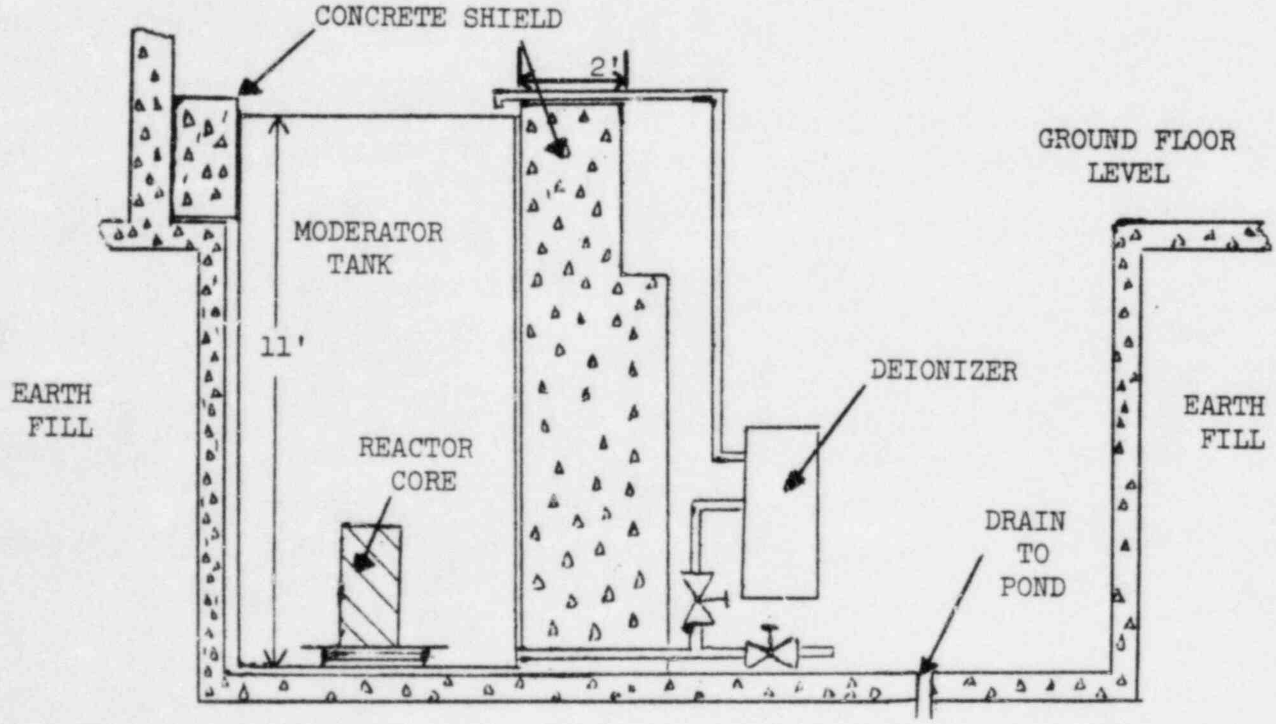


Fig. 2.2B Vertical Section Through Reactor Pit SCALE: 1/4" = 1'

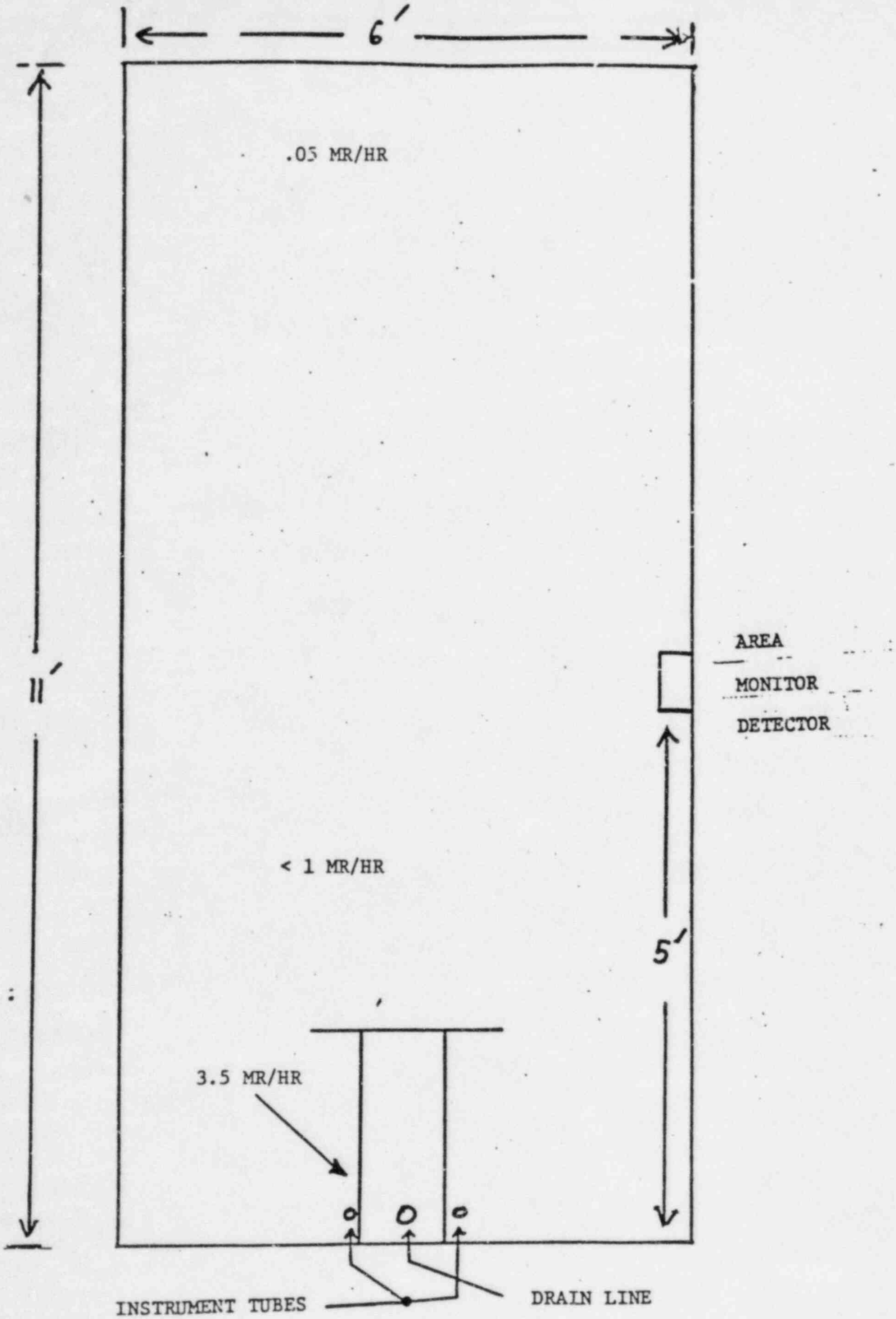


FIGURE 2.3 POWER LEVEL 1 WATT

CAVALIER FACE SURVEY

REACTOR FACILITY - UNIVERSITY OF VIRGINIA

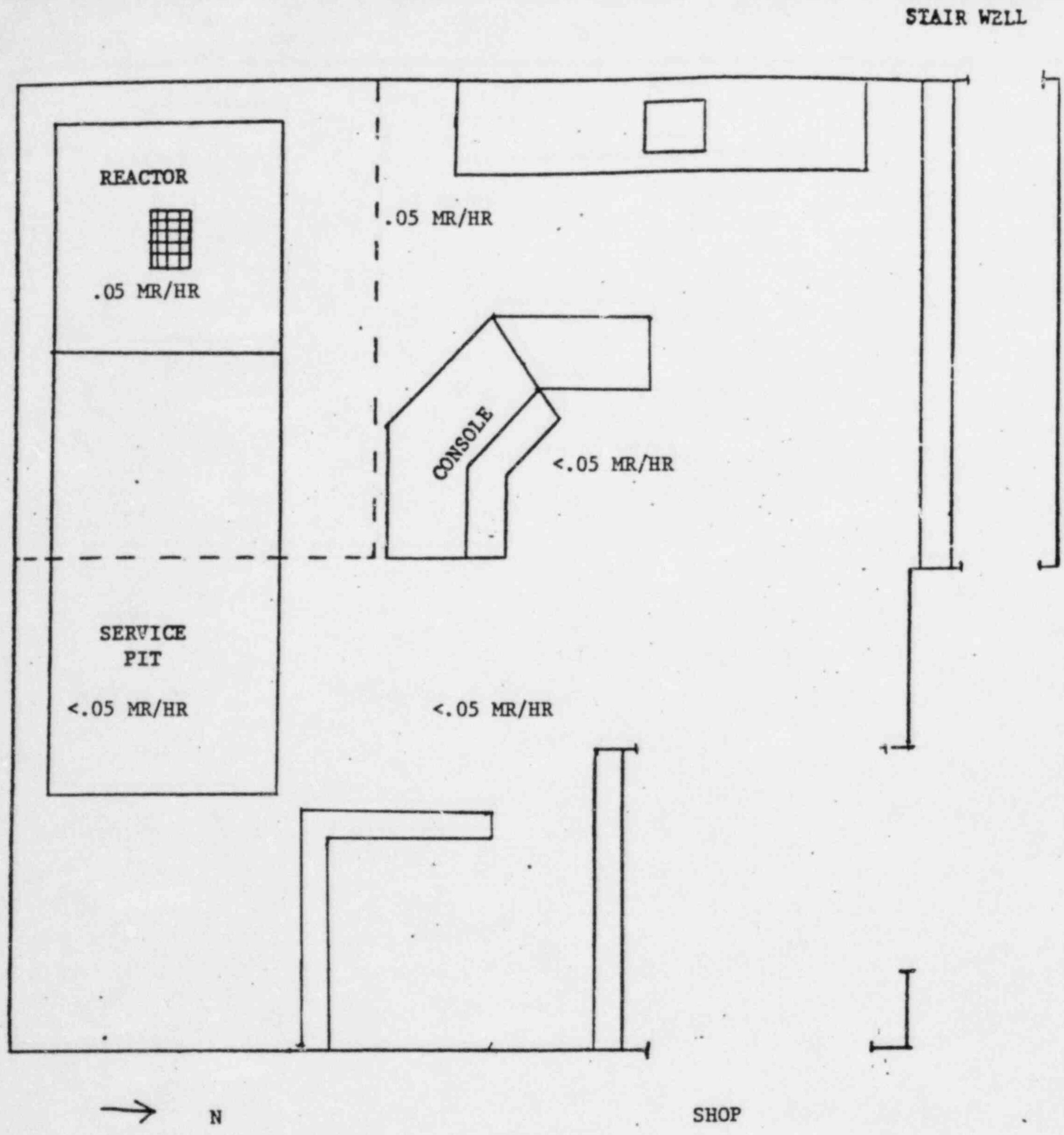
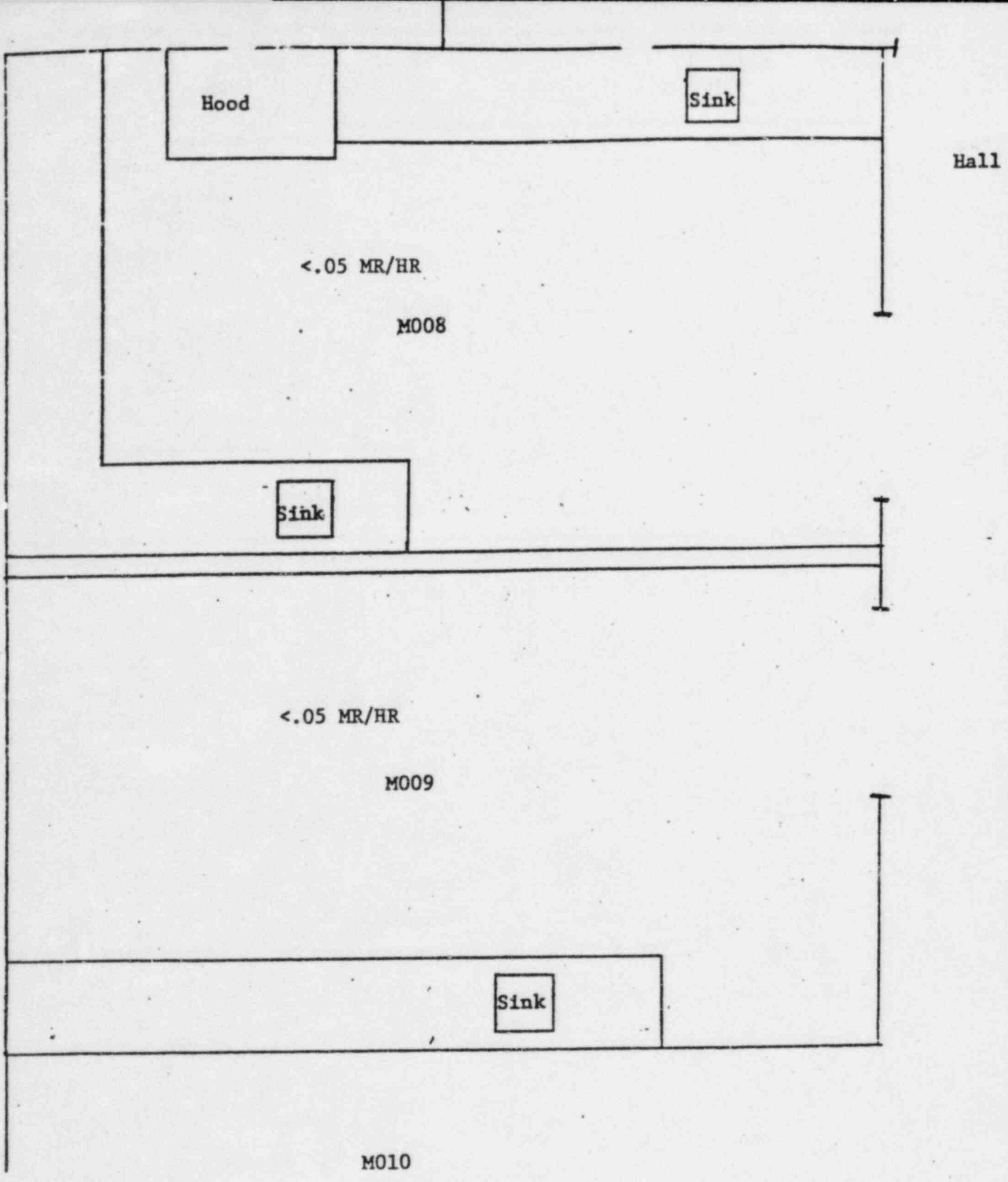


FIGURE 2.4 POWER LEVEL 1 WATT

CAVALIER - Control Room

REACTOR FACILITY - UNIVERSITY OF VIGINIA



Second Floor Survey

Rooms Above CAVALIER

FIGURE 2.5 POWER LEVEL 1 WATT

REACTOR FACILITY - UNIVERSITY OF VIRGINIA

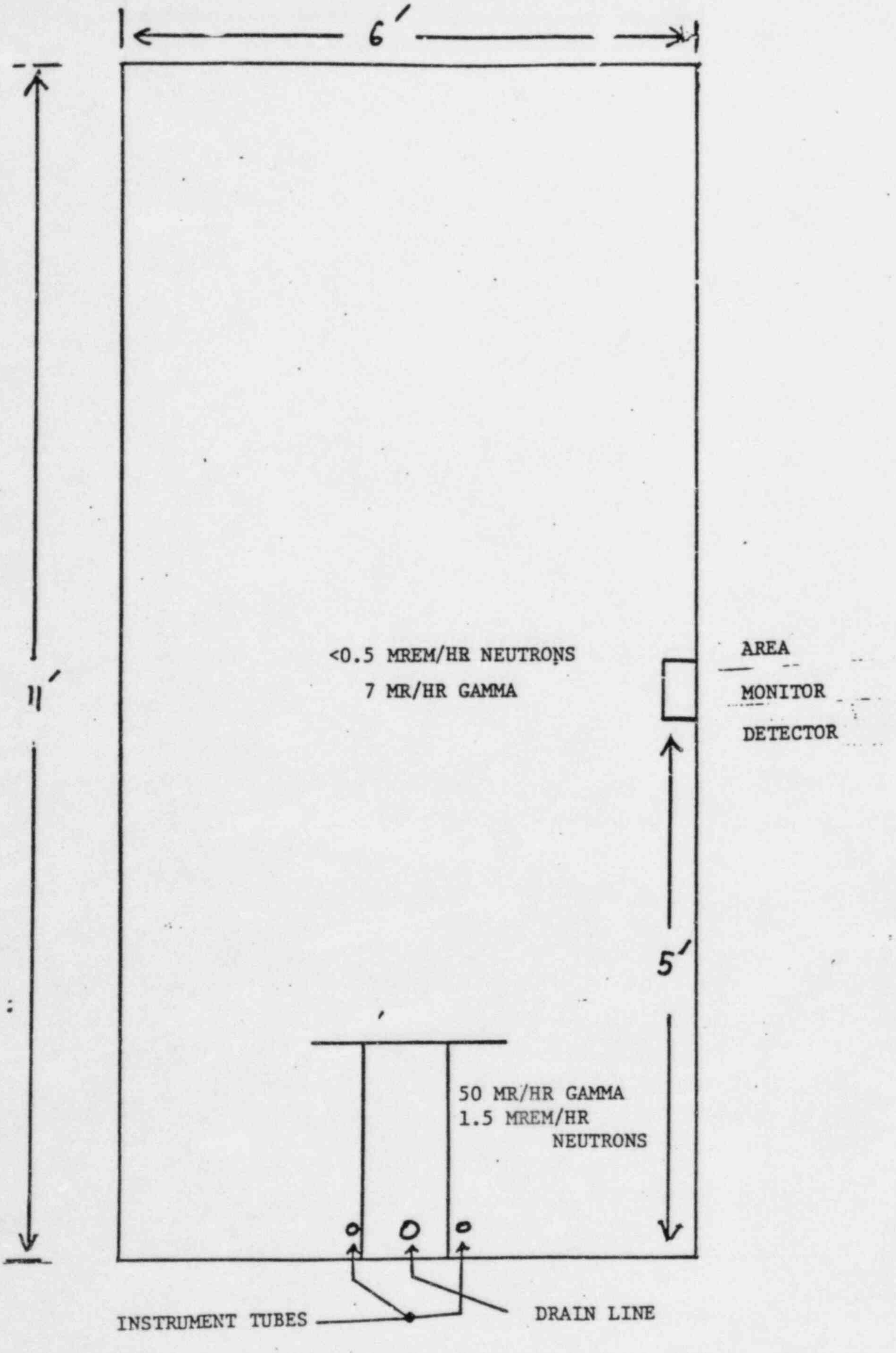


FIGURE 2.6 POWER LEVEL 45 WATTS

CAVALIER FACE SURVEY

REACTOR FACILITY - UNIVERSITY OF VIRGINIA

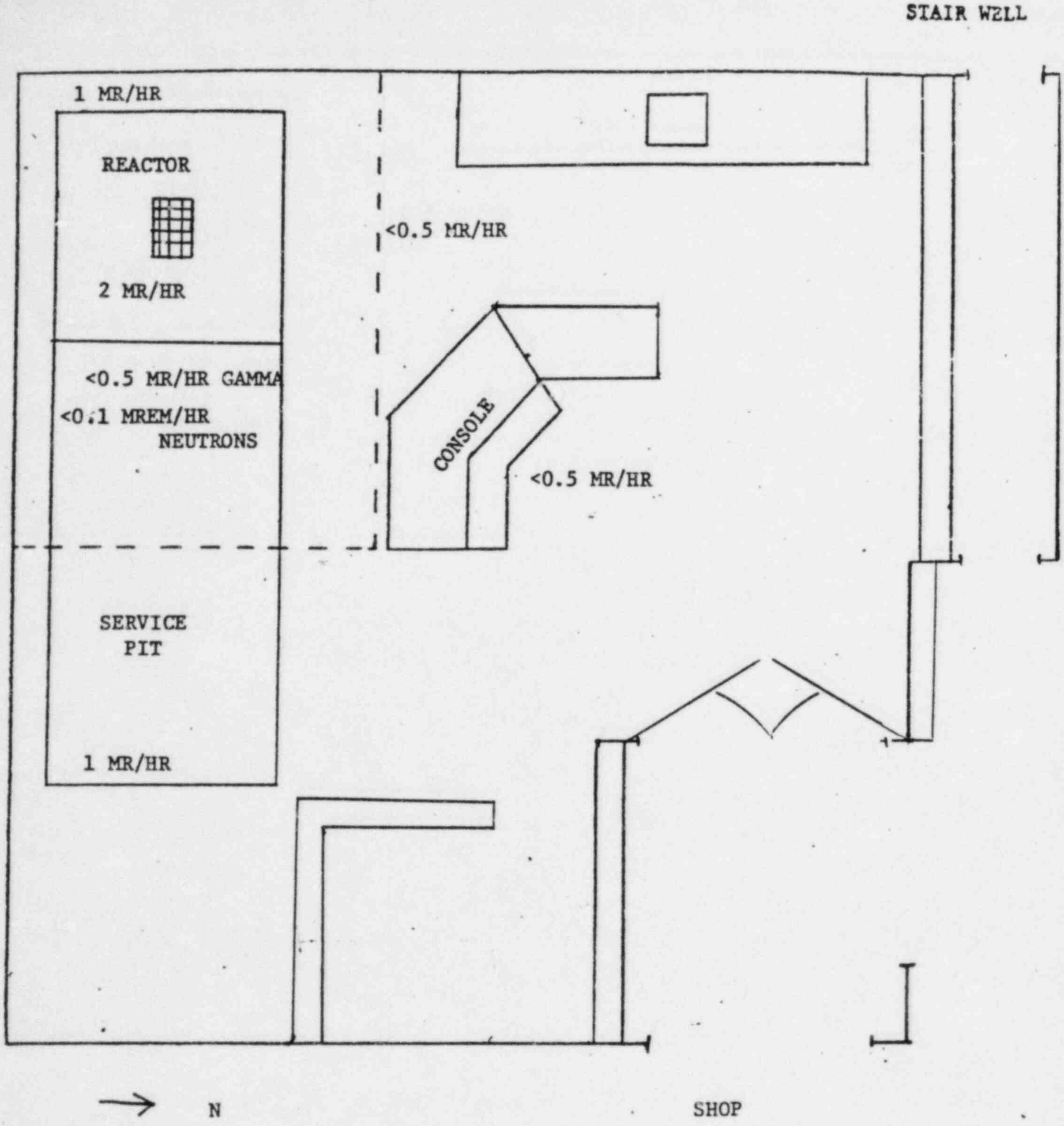
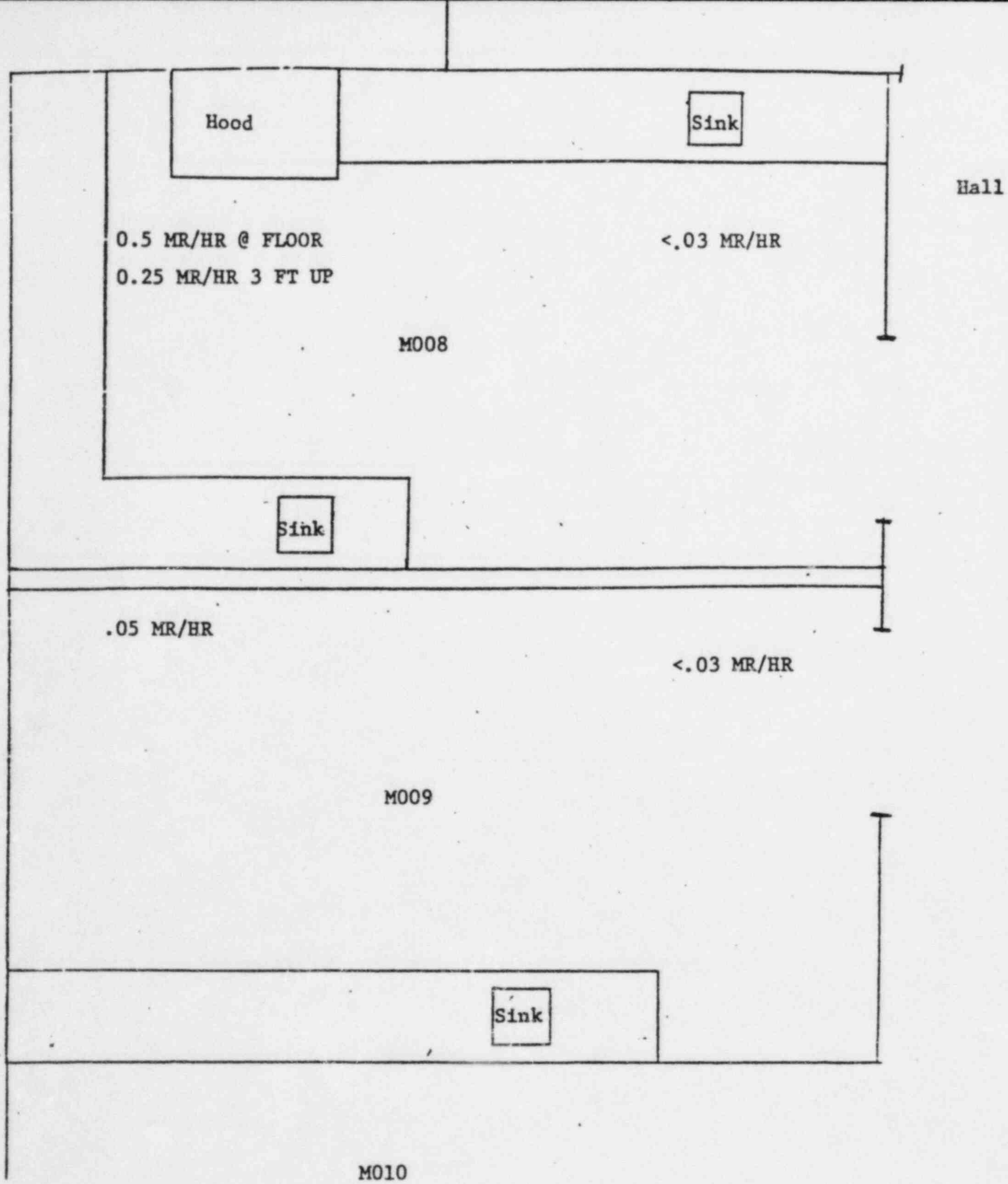


FIGURE 2.7 POWER LEVEL 45 WATTS

CAVALIER - Control Room

REACTOR FACILITY - UNIVERSITY OF VIGINIA



Second Floor Survey

Rooms Above CAVALIER

FIGURE 2.8 POWER LEVEL 45 WATTS

REACTOR FACILITY - UNIVERSITY OF VIRGINIA

the UVAR grid plate providing means of positioning the fuel elements in a close packed array. The Grid Assembly, shown in Fig. 3.1 provides support and lateral stability to the elements.

3.1.2 Fuel Elements

Fuel elements for the CAVALIER are identical to those for UVAR, and are described in UVAR-18 [3]. The standard fuel element is approximately 3-inches by 3-inches cross section with an active core length of about 2 feet. The element is generally similar to the MTR type element but is made with 12 flat plates. In the control rod fuel element, the six plates in the center are missing to allow space for insertion of a control rod. The standard fuel element contains about 165 grams of U-235 and the control rod fuel element contains bout 82.5 grams. (see figures 3.2 and 3.3).

Half loaded fuel elements are also used, in order to assure sufficient flexibility in loading the reactor so to maintain the minimum amount of excess reactivity. A half loaded fuel element is made up of alternate fuel-bearing plates and contains 82.5 grams of U-235. The fuel plates are of the sandwich type construction with a 0.020-inch meat and 0.15-inch cladding. The water gap between plates is 0.211-inch and the metal to water ratio for the standard fuel element including side plates is 0.40.

Also available for use in the CAVALIER are MTR type curved plate elements. The standard fuel element has 18 fuel plates and a loading of ~195 grams of U-235. The control rod fuel elements have 9 fuel plates with a loading of ~97.5 grams of U-235. Partial loaded fuel elements are also available for use. The construction of these elements is the same as the flat plate elements as shown in Figure 3.4.

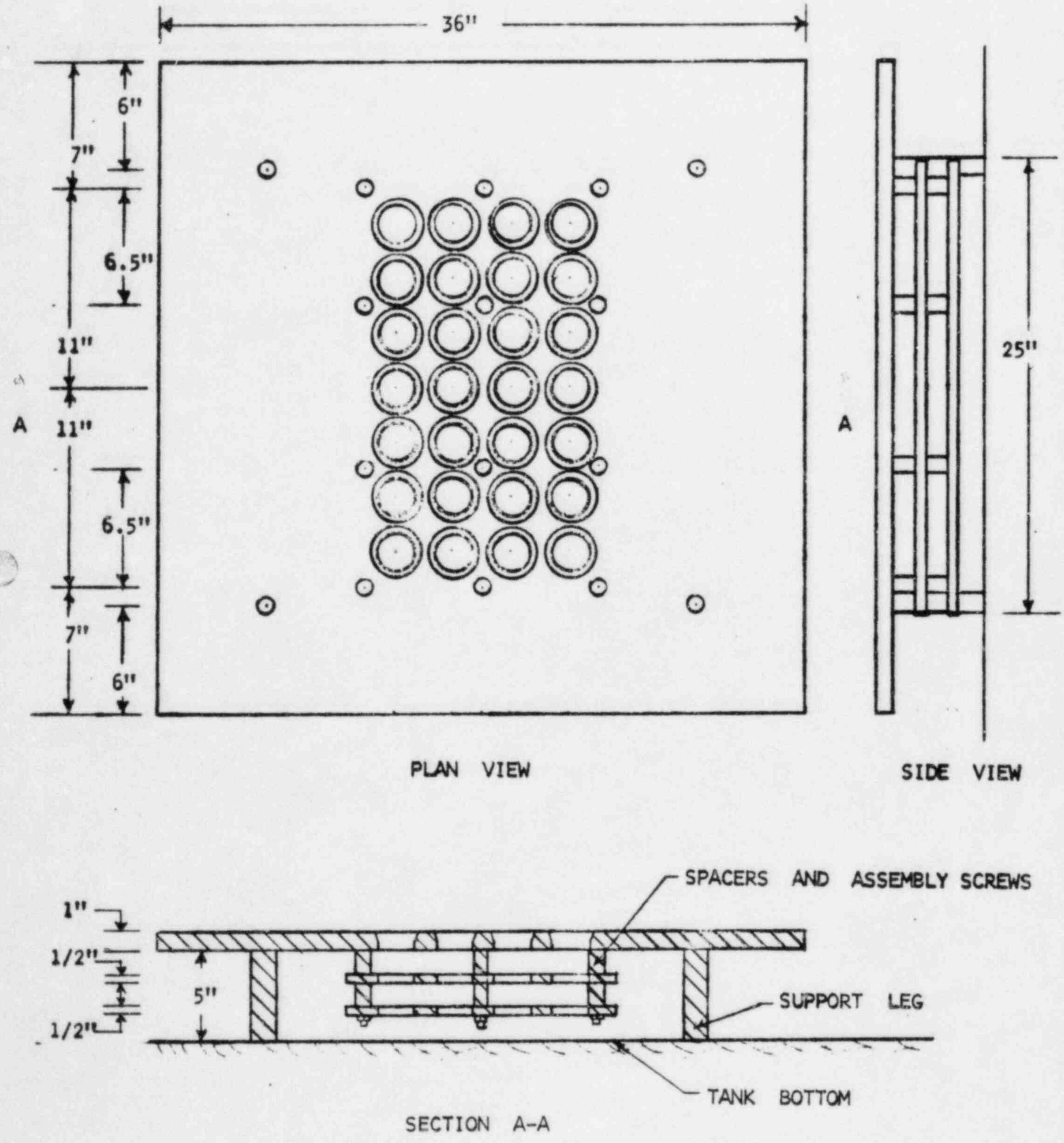


Fig. 3.1 Grid Plate Assembly

SCALE 1/8" = 1".

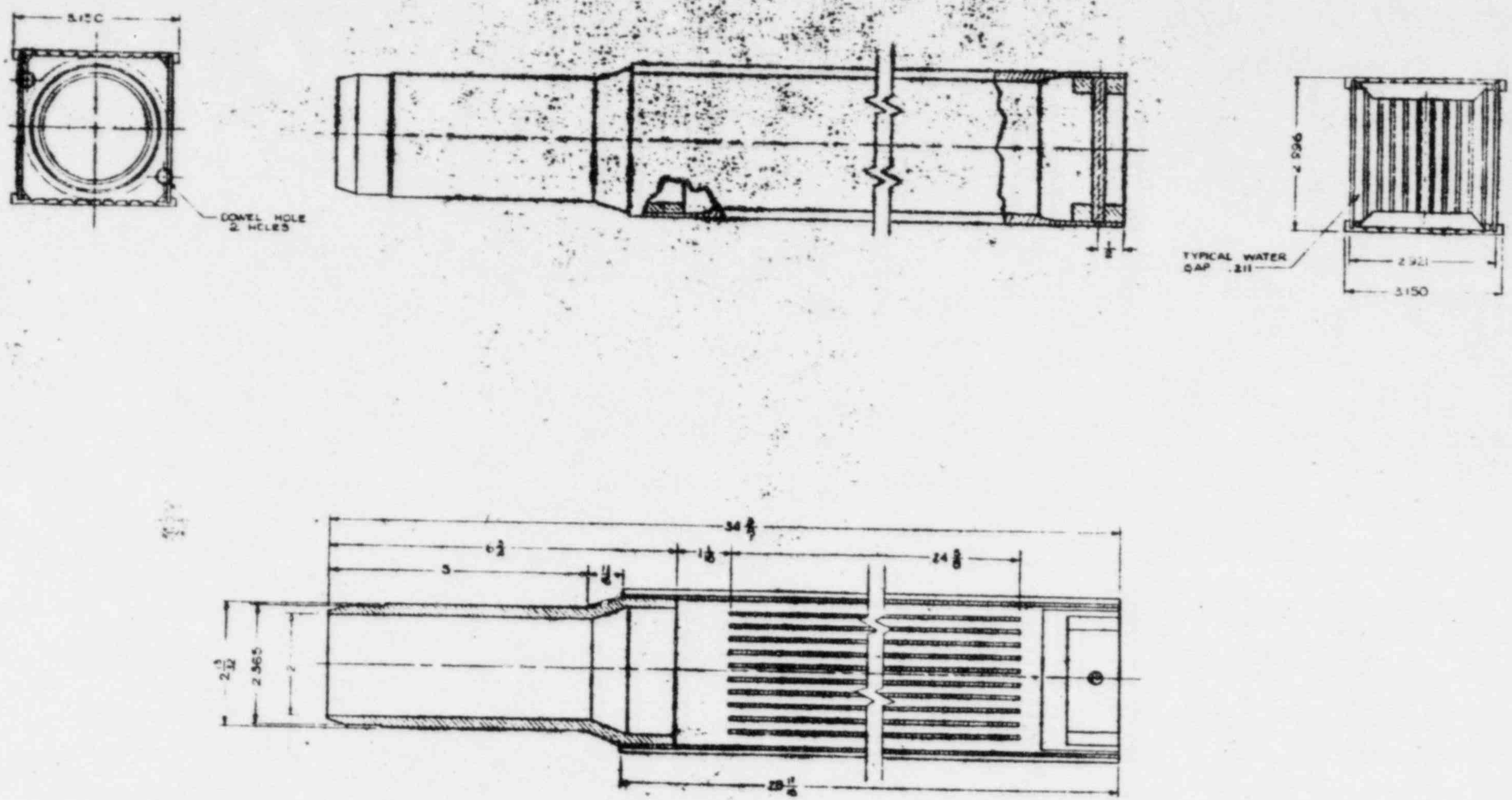


Fig. 3.2 Standard Fuel Element

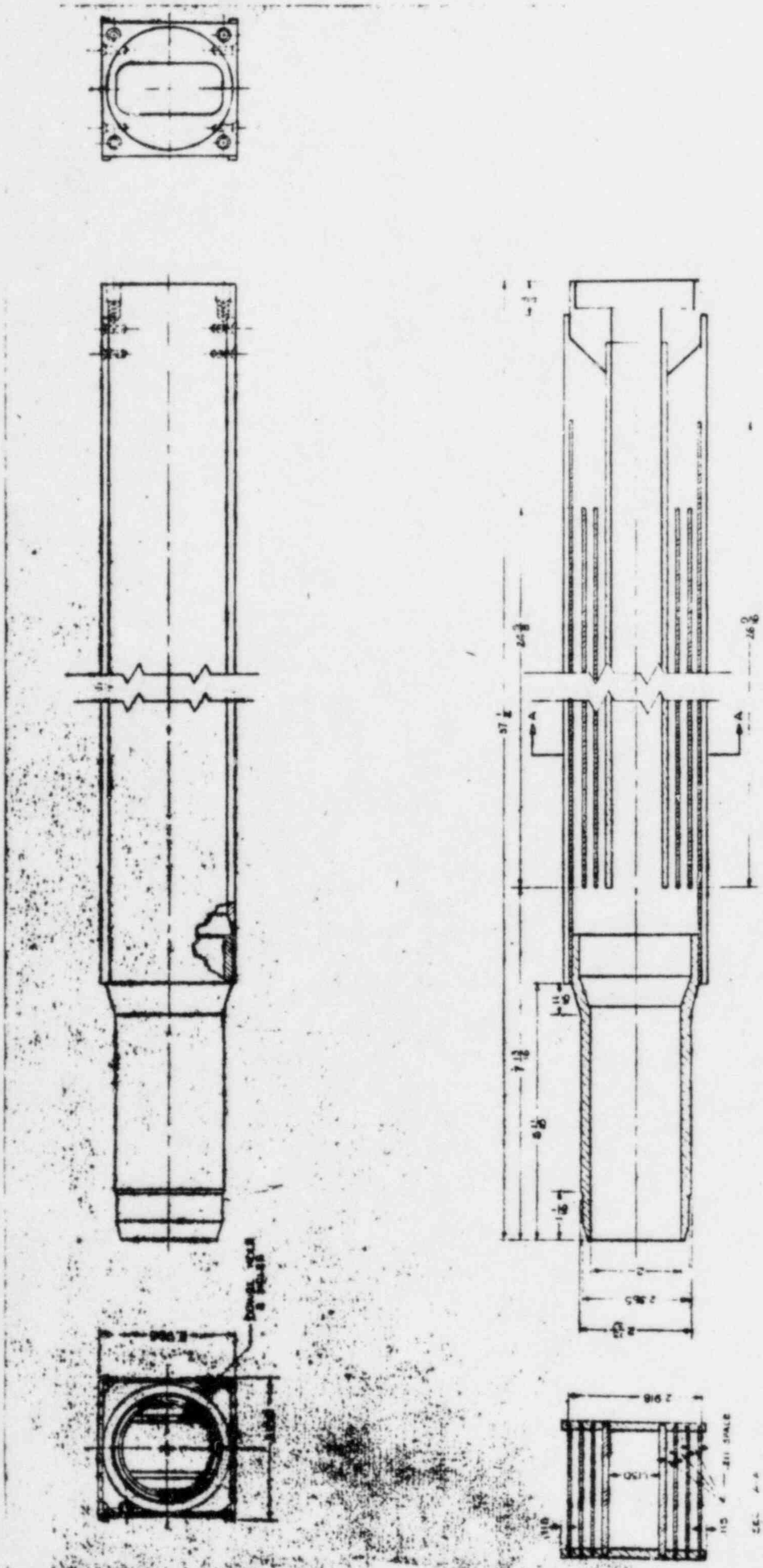
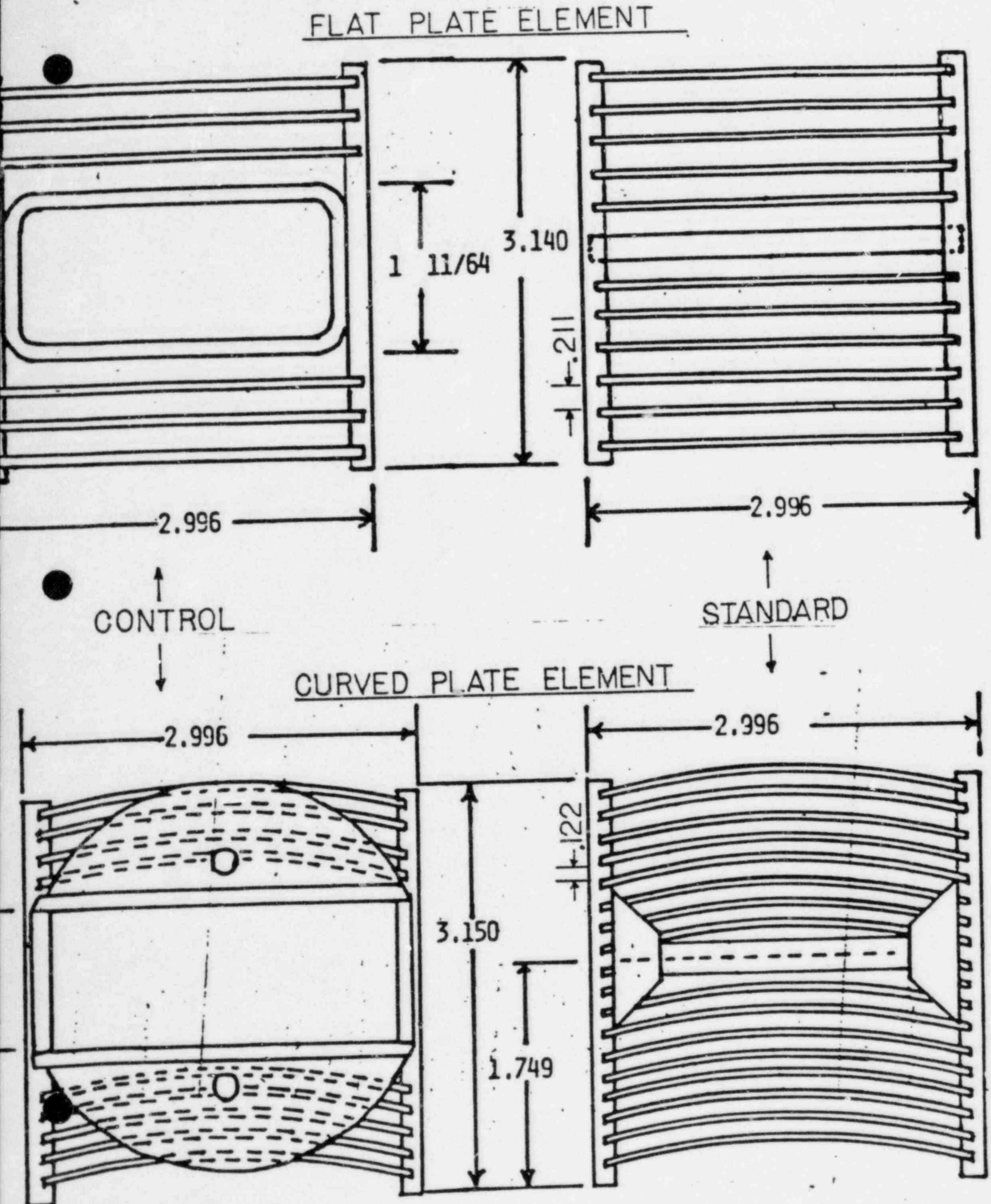


Fig. 3.3 Control Rod Fuel Element

FIGURE 3.4


FLAT PLATE ELEMENT
1 11/64
3.140
.211
2.996
2.996
CONTROL
STANDARD
CURVED PLATE ELEMENT
2.996
2.996
.122
3.150
1.749

3.1.3 Critical Loadings

A water reflected 4x5 array of fuel elements, containing 16 standard and 4 control rod elements will be critical with about 1.6 percent excess reactivity, depending on the position of the control rod elements. The addition of a 6-inch graphite reflector on all sides reduces the critical size to 4x4 (still 4 control rods). Table 3-1 gives various fuel element and critical array data for the 4x5 water reflected and 4x4 graphite reflected cores.

3.1.4 Reflector Options

The normal CAVALIER configuration will include a water reflector. In this geometry open-work (wire mesh) aluminum boxes are mounted along the sides of the core to eliminate the possibility of a reactivity addition resulting from an object dropped alongside the core. On one side of the core, special purpose, non-fuel bearing elements may replace the aluminum boxes. These could include radiation baskets, instrument tubes, etc. A water reflected configuration is shown in Fig. 3.5.

The CAVALIER may be operated with a graphite reflector by placing the open (water filled) aluminum boxes with aluminum boxes filled with graphite bars. The size of these boxes are such that a single box would cover a side of the core (the UVAR graphite elements are fuel element sized and fit into individual grid plate positions). A graphite reflected core arrangement for CAVALIER is shown in Fig. 3.6.

3.1.5 Control Rods

The shim rods for CAVALIER are of the bayonet type, having an elongated oval cross sectional shape and rectangular grooves along each side. The control material is boron stainless steel. The very low neutron flux of CAVALIER precludes problems of radiation heating and

TABLE 3-1

REACTOR DATA

		Graphite Reflected(1)	Water Reflected
Active Core Dimensions			
Length	in.	23.5	23.5
Width	in.	12.13	12.13
Depth	in.	12.60	15.94
Active Core Volume	Liters	59.53	74.43
	$in.^3$	3.63×10^3	4.54×10^3
Number of Standard Elements		12	16
Number of Control Rod Elements		4	4
Mass U^{235}	Kg	2.31	2.97
Mass AL(2)	Kg	44.78	57.23
Mass H_2O at 100^oF(2)	Kg	42.30	52.88
Metal to Water Ratio(2)	$\frac{\text{vol AL}}{\text{vol } H_2O}$	0.394	0.394
Atomic Ratios in Active Core(2)			
Atoms U^{235}		1	1
Atoms AL		172	168
Molecules H_2O		239	232
Average Thermal Flux at 10W Operation	$\frac{\text{neut}}{cm^2 sec}$	1.1×10^8	8.5×10^7
Σ_f, U^{235}		0.0573	0.0555

(1) An infinite water reflector follows the 6-inch graphite reflector.

(2) Calculated on basis of complete loading of standard fuel elements.

Table 3-1
(Continued)

Fuel Elements - U-AL Alloy Clad with Al		Flat Plate	Curved Plate
Overall Dimensions			
Length	in.	34.38	34.38
Width	in.	2.996	2.996
Depth	in.	3.150	3.150
Standard Element			
Number of Plates		12	18
Width	in.	2.886	2.754
Thickness (inner plates)	in.	0.050	0.050
(outer plates)	in.	0.050	0.065
Length	in.	24.63	24.63
Cladding Thickness (inner plates)	in.	0.015	0.015
(outer plates)	in.	0.015	0.0225
Fuel Thickness (U-AL Meat)	in.	0.020	0.020
Fuel Width	in.	2.50	2.375
Fuel Length	in.	23.5	23.5
U^{235} vol % in Alloy		3.67	not known
Weight U^{235} per element	gm.	165 ± 3%	195 ± 3%
Water space between plates	in.	0.211	0.122
Side Plates - Overall			
Length	in.	28.69	28.69
Width	in.	0.188	0.188
Depth	in.	3.150	3.150
Number of Grooves		12	18
Depth of Grooves	in.	0.138	0.100
Width of Grooves	in.	0.055	0.058

Partial Elements - Same as standard elements with only one-half of the U^{235} content.

Control Rod Element - Only half the number of fuel plates that are in a standard element with a central gap to allow for insertion of absorber.

TABLE 3-1
(Continued)

Control Rods

Shim Safety Rods

Number		4
Absorber Material	Boron-Stainless Steel 1.5% Boron	
Dimensions, Overall		
Width (Approx.)	in.	1
Depth (Approx.)	in.	2.38
Length (Approx.)	in.	27.5
Travel (Approx.)	in.	24
Weight (Dropping Section)	kg	5.5
Drive - Electric motor, 115 V 60 cycle, split phase, through reduction gear and rack and pinion drive		
Drive Speed	in/min	Approx 3.7
Release - Magnetic Clutch		
Typical Reactivity, fully inserted % $\frac{\Delta K}{K}$	3.0	
Typical Reactivity per inch % $\frac{\Delta K/in}{K}$	0.125	
Typical rate of Reactivity Increase in up travel % $\frac{\Delta K/sec}{K}$		0.008

Reactivity Coefficients

Temperature Coefficient	$-1.16 \times 10^{-4}/^{o}F$
Void Coefficient	$-7.2 \times 10^{-3}/\%$ void

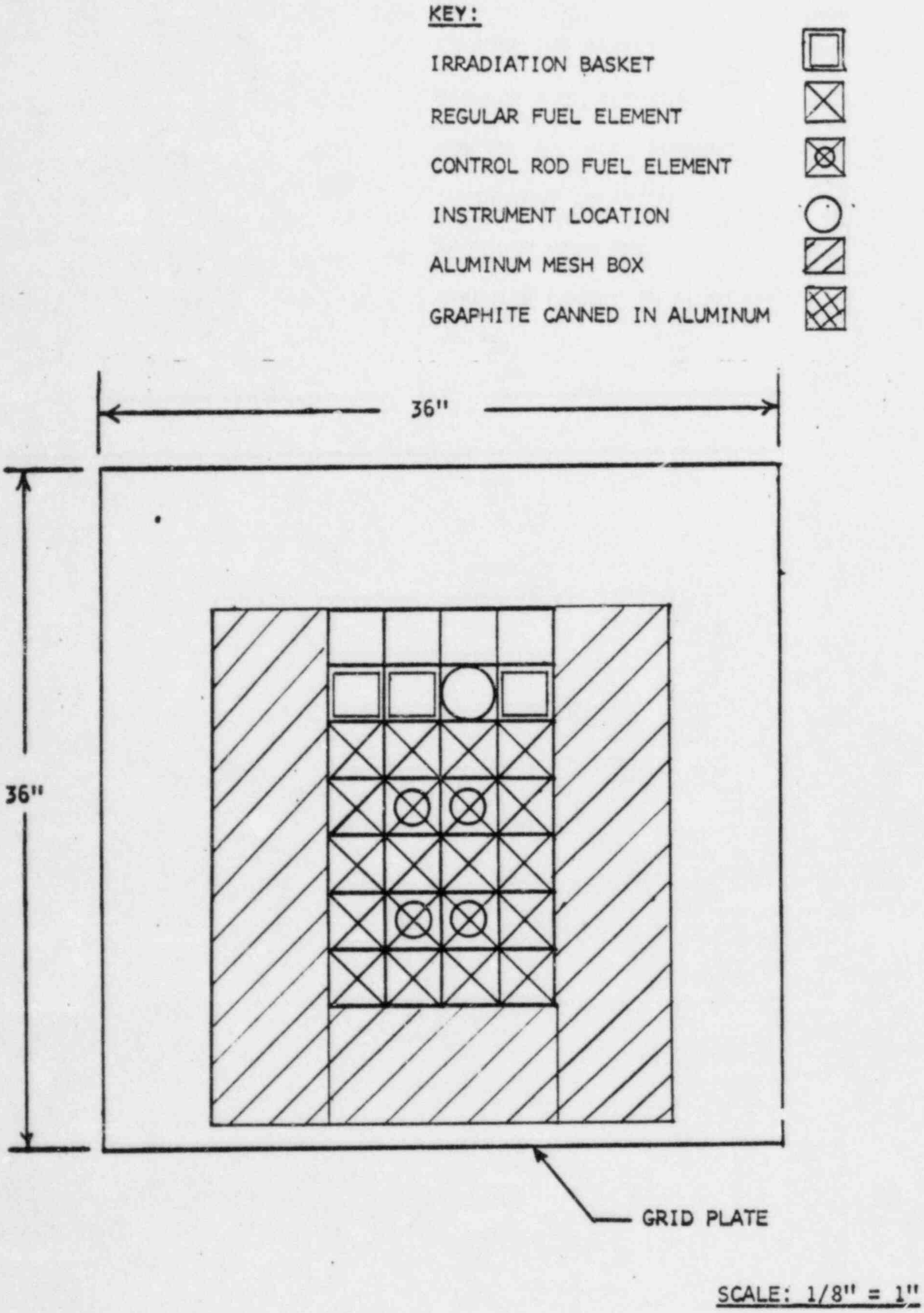


Fig. 3.5 Typical Water Reflected Loading

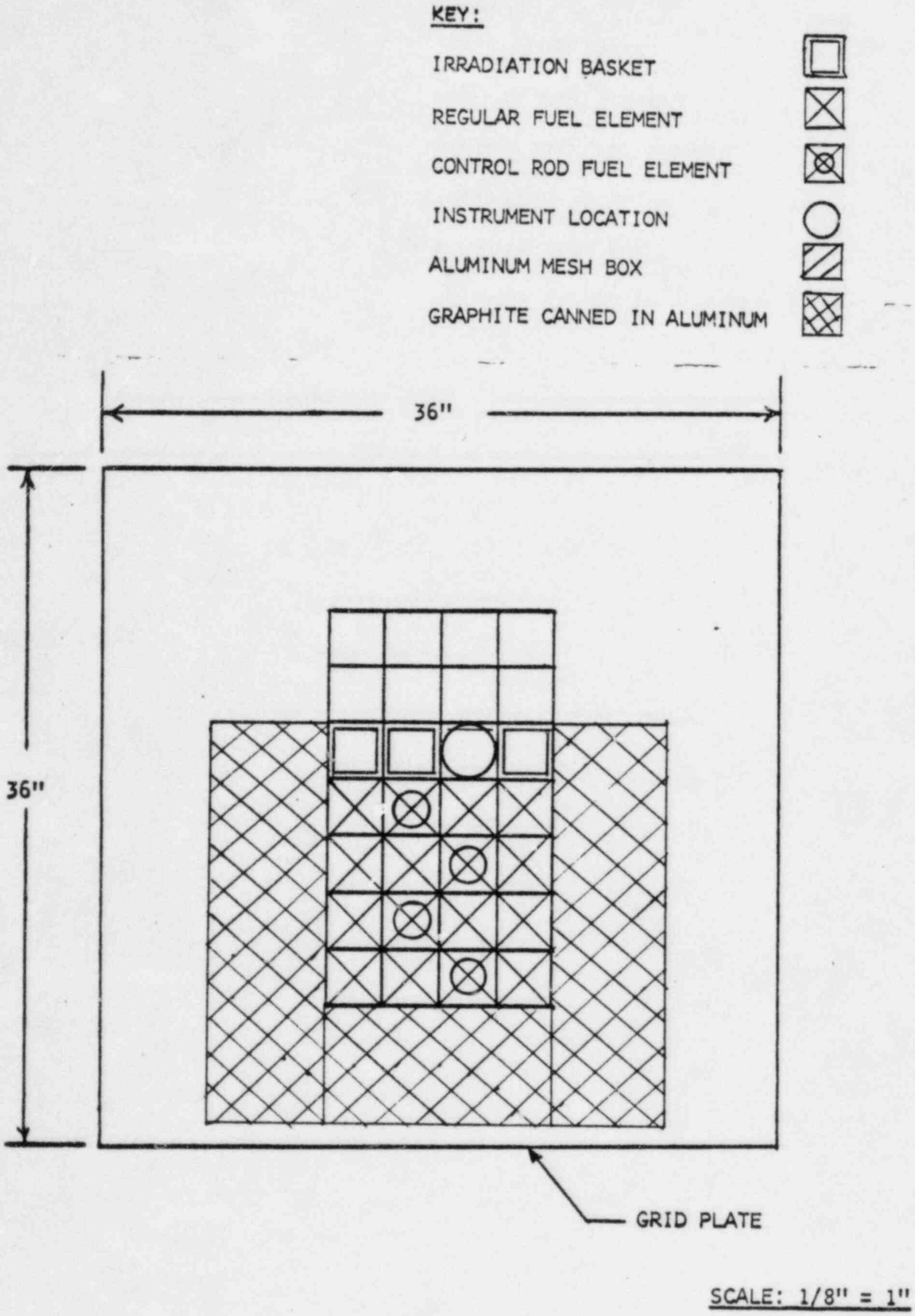


Fig. 3.6 Typical Graphite Reflected Loading

damage to the control rods. Three of the control rods are those removed from the UVAR reactor several years ago; the fourth rod is new, but similar in design to the ones taken from UVAR. The control rods move in the slot at the center of the Control Rod Fuel Elements (See Fig. 3.3 and Fig. 3.4).

Because the neutron fluxes in CAVALIER are so low (1 hour in UVAR is equivalent in neutron fluence to ~ 10 years in CAVALIER) no radiation damage problems are expected either for the old rods or the new one.

3.1.6 Control Rod Drives

The control rod drives for CAVALIER were obtained from Battelle Memorial Institute where they had been used with the VMR critical Assembly [4]. The drive assembly consists of a motor-clutch unit, linear potentiometer position indication, a rack and pinion drive and a hydraulic shock absorber. Such a system, as employed at VMR, is shown in Fig. 3.7. Scram action is controlled by a magnetic clutch, which when unpowered, or in the tripped condition, allows the control rod and its entire drive mechanism to fall to the low limit. Position indication follows the rod position at all times in such a system, in contrast to the UVAR rod drives in which the position of the drive mechanism is indicated, but the control rods themselves become disconnected from the drive, on a scram.

The VMR drives have been modified to reduce the rod drive speed to approximately 3.5-inches per minute. ~~Preliminary~~ measurements indicate that the rods ~~will~~ drop on scram with an acceleration of about 0.7 g, resulting in a 24-inch travel time of about 0.5 second. Rod drive speed

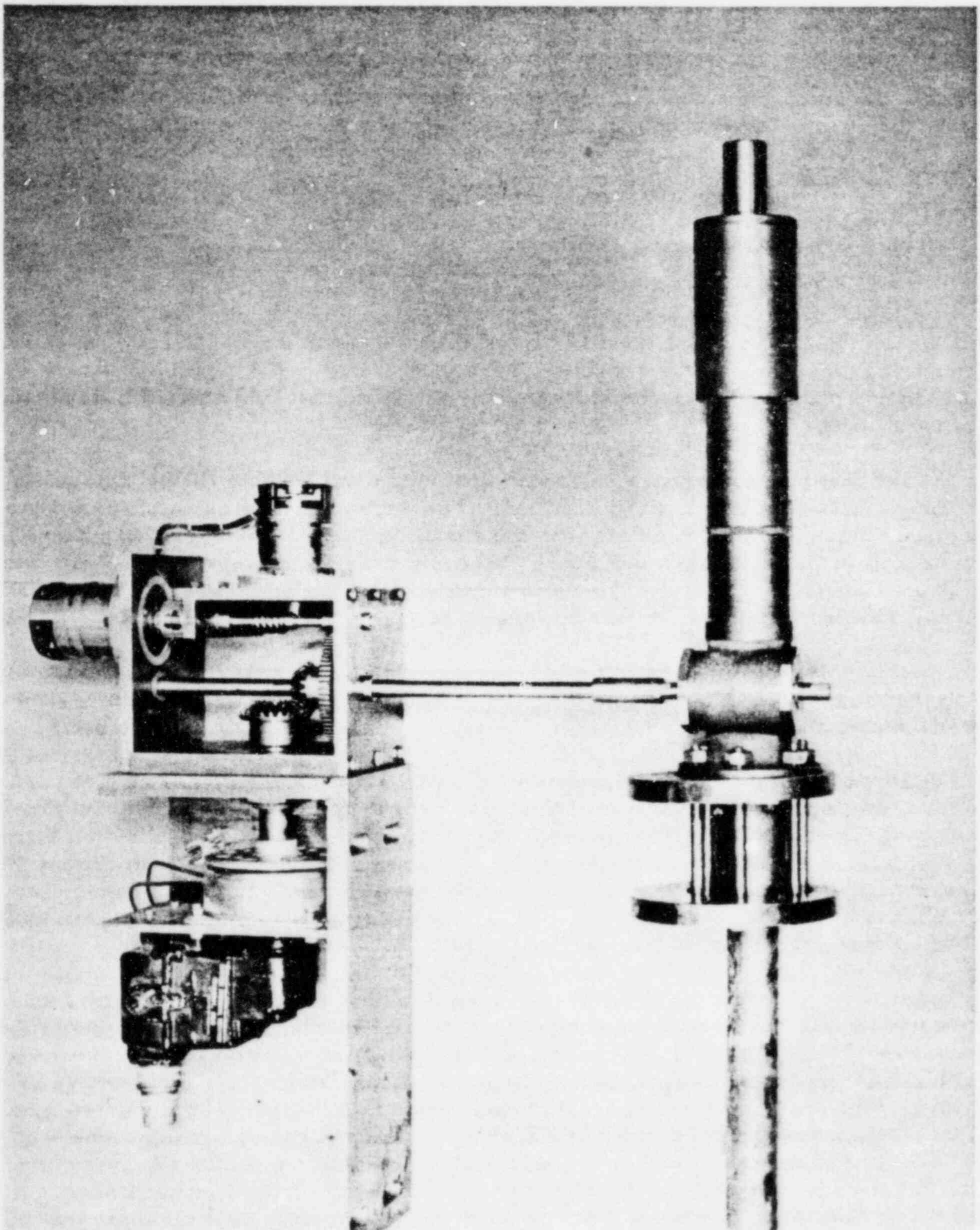


Fig. 3.7 Rod Drive Unit

and actual release and drop times as measured for the final system are recorded in Table 3-2, Control Rod Drive System Data.

Structural support for the control rod drives is provided by a network of channel steel mounted on top of the moderator tank and centered above the grid plate. A plan view of this arrangement is shown in Figure 3.8. The moving position of the rod drives is enclosed in a tubular guide extending from the top of the tank down to the control rod fuel element. Positive holddown for the control rod fuel element is affected by a support arm extending from the channel steel frame to a bracket on the tubular guide. The support arm is bolted in place to allow easy removal for fuel handling operations. A vertical section of a control rod drive assembly is shown in Figure 3.9. The motor clutch units of the control rod drives are bolted to the deck plates which form the enclosure for the moderator tank. The rod drive arrangement for a typical core loading is shown in Figures 3.10 and 3.11.

Undesired upward rod motion, such as could be caused by physical manipulation of the rack at the rack and pinion mechanism, is prevented by a sonenoid operated pawl engaging a racket gear on the motor-clutch unit drive shaft as shown in Figure 3.12. The pawl has a ratchet action which allows downward rod motion under all conditions (solenoid activated or not), while outward motion can occur only when the pawl is pulled free of the gear by the solenoid. The solenoid is energized when the console key switch is energized.

3.1.7 Startup Neutron Source

The low neutron flux levels attained during CAVALIER operation preclude the use of an Sb-Be neutron source as employed in the UVAR.

TABLE 3-2

CONTROL ROD DRIVE SYSTEM DATA
INITIAL CHECKOUT OF SYSTEM IN 1974

Rod Number	Magnet Release Time	Free Drop Time	Rod Speed
1	50 msec.	489 msec.	3.78 in/min.
2	49 msec.	480 msec.	3.80 in/min.
3	82 msec.	568 msec.	3.80 in/min.
4	87 msec.	467 msec.	3.78 in/min.

Average Over Past 5 Years

1	62.0	463	3.8
2	51.5	449	3.6
3	82.0	478	3.9
4	71.5	500	3.8

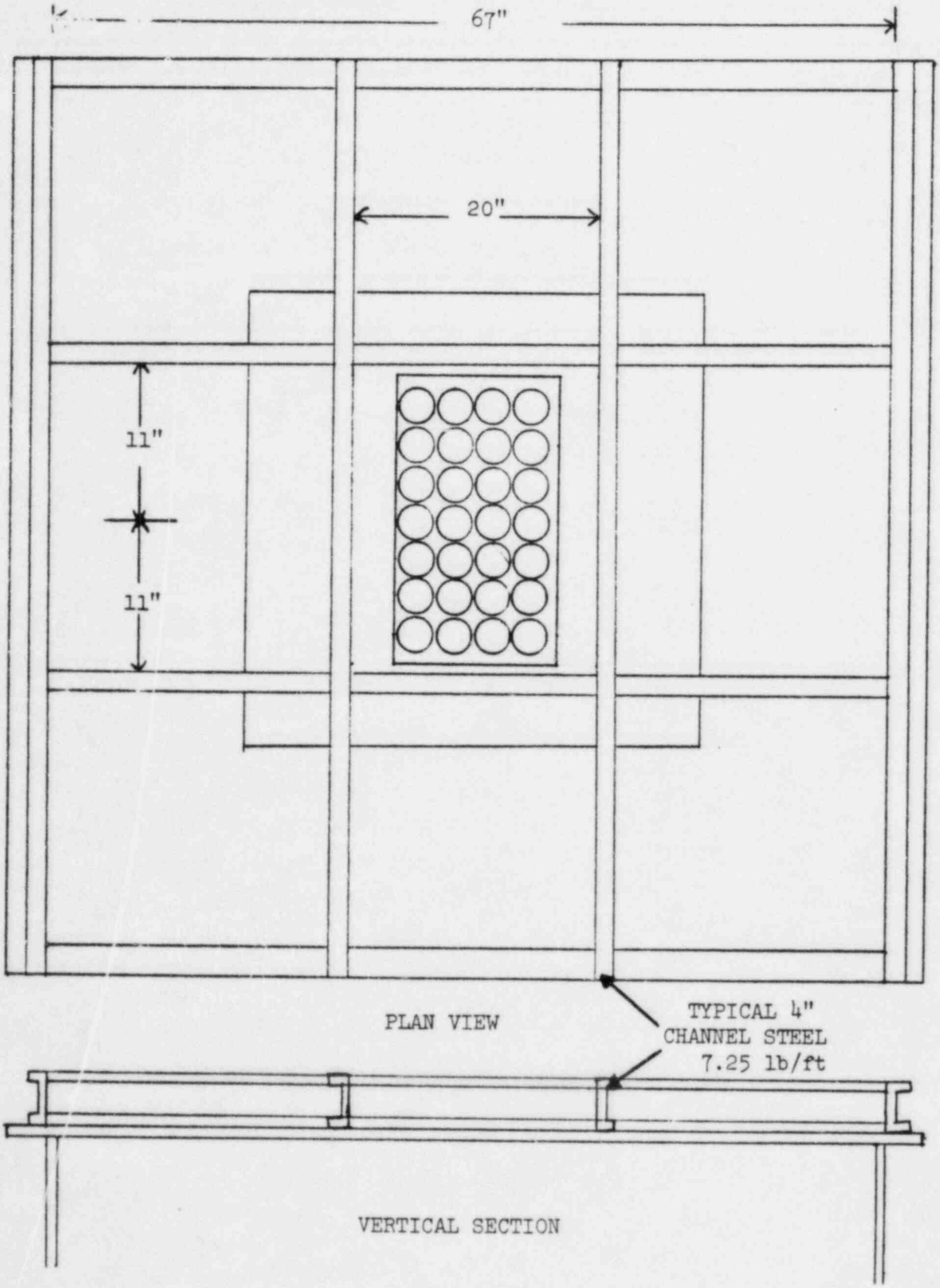


FIG. 3.8 Channel Steel Support Network

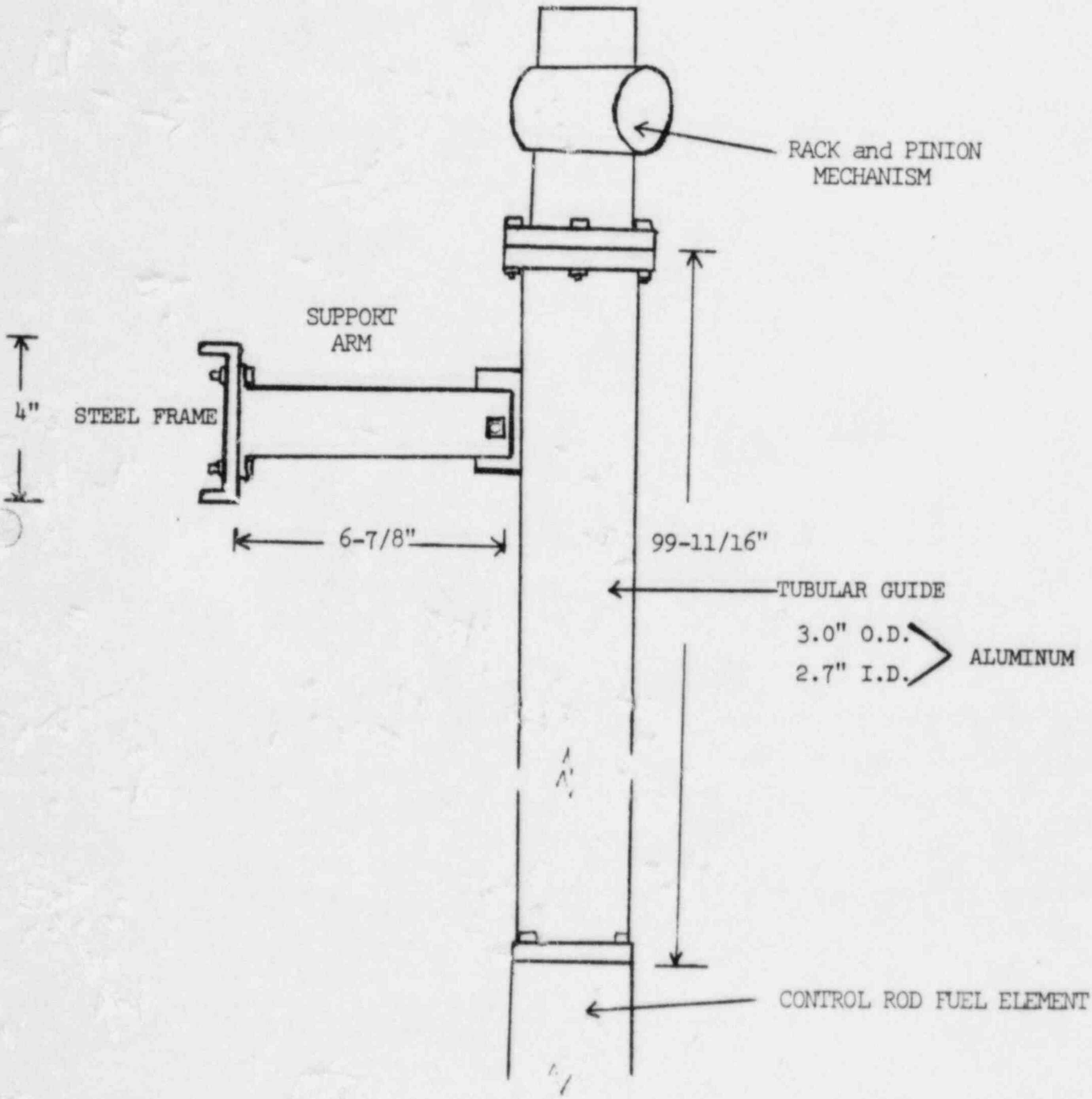
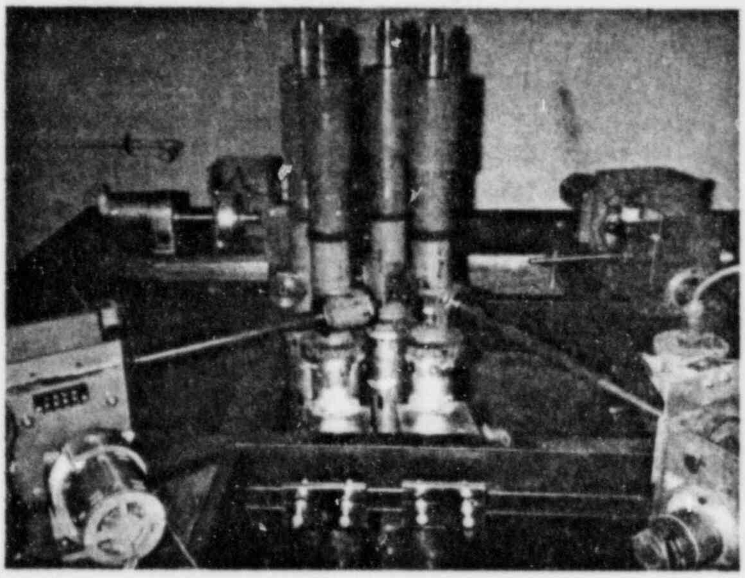
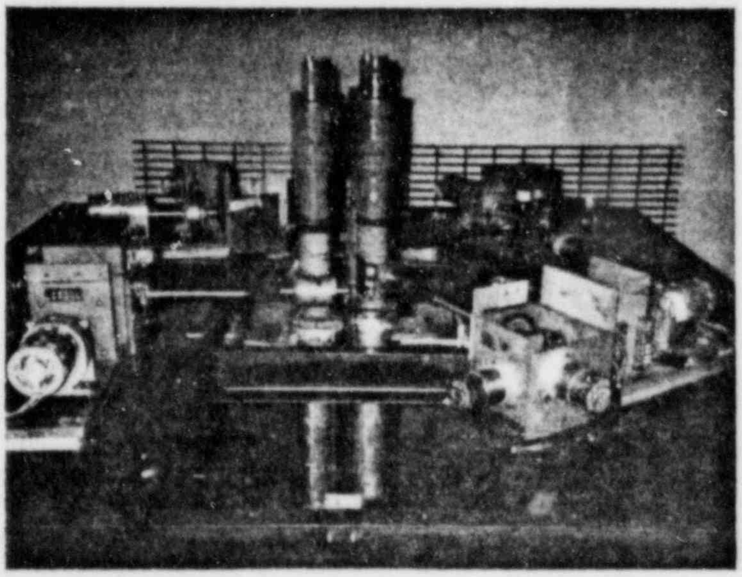


FIG. 3.9 Rod Drive Structural Support.



A. Side View



B. End View

Fig. 3.10 Rod Drive Arrangement for Typical Core Loading

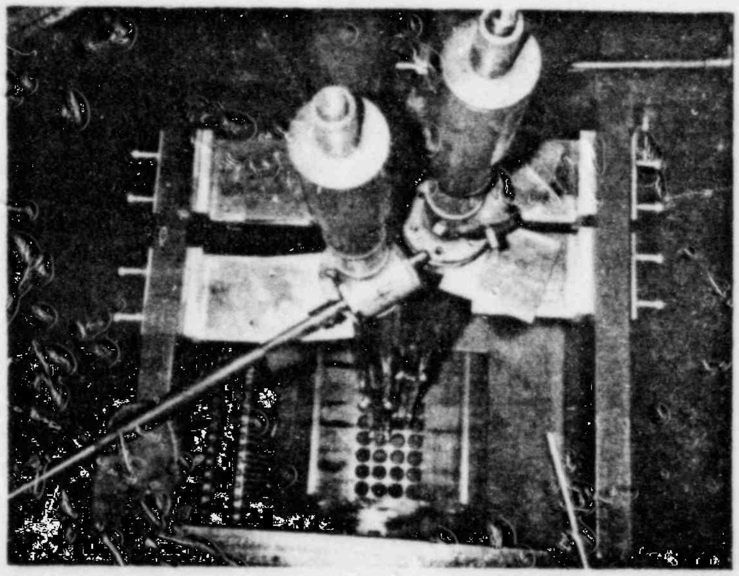


Fig. 3.11 Top View of Typical Core Loading

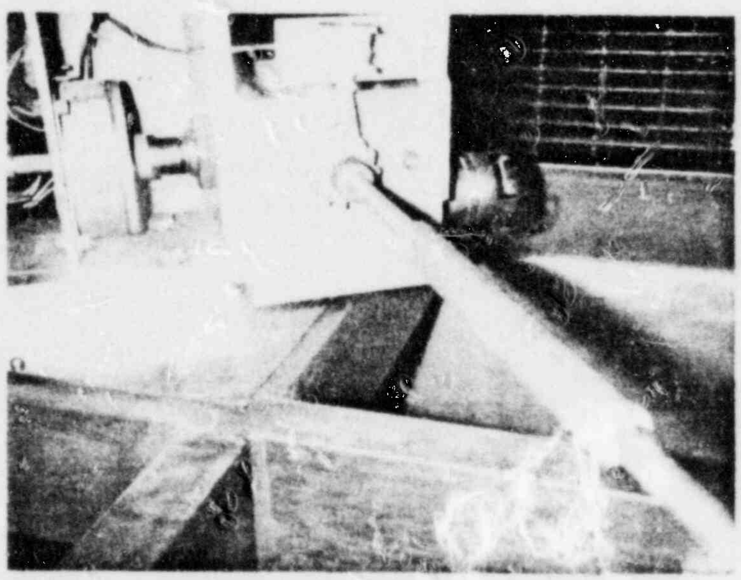


Fig. 3.12 Outmotion Latch

A Pu-Be neutron source is therefore used as a startup neutron source in CAVALIER. The neutron source is enclosed in an aluminum tube which extends down into the wire mesh screens or graphite reflector beside the core. The source is attached to a motor drive cable allowing it to be withdrawn from the core a distance of approximately 3 ft. after reactor startup has been accomplished. No danger of source damage due to internal heating is presented because of the low neutron flux levels present in the moderator tank.

3.2 Operating Limits

In this section the operating limits for CAVALIER will be listed and discussed briefly. In particular, the bases for establishing the various limits will be discussed.

3.2.1 Operating Limits List

1)	Maximum Average Power (S.L.)	240 watts-hours/day
2)	Maximum Power Level (S.L.)	100 watts
3)	Maximum Excess Reactivity	1.6% $\Delta k/k$
4)	Shutdown Margin	With the rod of highest worth fully withdrawn, the reactor shall be > 0.4% $\Delta k/k$ subcritical.
5)	Minimum Operating Period	5 seconds
6)	Maximum Worth of an Individual Experiment	0.5% $\Delta k/k$

3.2.2 Maximum Average Power Limit

The maximum average power limit of 240 watt hr/day (i.e., 10 watt average power) was chosen to limit the buildup of fission product inventory in the fuel. By keeping the fission product inventory low, fuel handling outside of the tank can be performed, and the hazards associated with fission product release in the evento f an accident are minimized. The inventory of I-131 as a result of long operation at an average power of 10 watts is equal to that generated in a 10 Mw-sec excursion. The latter value represents an upper bound on the possible energy release by an excursion in the CAVALIER. In general the proposed limits are quite conservative. This approach is believed justified by the fact that much use will be made of the facility for student training.

3.2.3 Maximum Power Level

The maximum power level, greater than the average power, was chosen on the basis of possible need for higher fluxes in activation experiments, and in maneuvering during training. The limit of 100 watts was determined by the radiation levels above the water of the Moderator Tank. At 100 watts with 7.25 ft. of water above the core, the gamma-ray dose rate has been extrapolated to be 20 mR/hr at the top of the tank, and at the nearby areas accessible to personnel, less than 1 mR/hr. The fast neutron dose rates at these positions are negligible (less than 10^{-3} mRem/hr.). Gamma-ray dose rates are based on calculations and actual measurements.

3.2.4 Maximum Excess Reactivity

Excess reactivity provisions are made to allow for experiments and operating maneuverability. For 1.6 percent $\Delta k/k$, a maximum superprompt insertion of about \$1 is possible (\$1 = 0.80 percent $\Delta k/k$). The SPERT experiments, for fuel elements similar to those of UVAR and CAVALIER, gave an energy release of approximately 10 Mw-sec for a superprompt reactivity of \$1, and little core damage or fission product release were noted. [5] In Chapter 9 the effects of a 10 Mw-sec excursion are analyzed.

3.2.5 Shutdown Margin

The required shutdown margin is 0.4% $\Delta k/k$ with the most reactive rod fully withdrawn. This margin will ensure that a shutdown can be obtained and maintained in the event of a scram without further operator action.

3.2.6 Minimum Operating Period

For administrative purposes, a minimum operating period of 15 seconds is imposed, backed up by a period trip at a value greater than 5 seconds. This value will provide an adequate safety margin in the case of an abnormal reactivity insertion. The Safety Analyses of Chapter 9 are based on a period trip which operates at 5 seconds. The scram on period at no less than five seconds is to insure that the safety limit on power is not exceeded. Assume the reactor is on a period of 5.01 seconds (just missing a scram on period) and scrams on power level at 80 watts (the limiting safety system setting). The magnet release time is no greater than 0.1 seconds and the free drop time for the rods is no greater than 0.7 seconds. (See Technical Specification on Rod Drop Times.) The very conservative assumption is made that the rods must drop all the way to terminate the 5.01 second period, 0.8 seconds elapse after the scram is initiated at 80 watts. The peak power will be

$$P = 80 \exp [0.8/5.01]$$

$$P = 93.85 \text{ watts}$$

The safety limit of 100 watts is not exceeded. This is the worst case. If the reactor is on a shorter period, it will scram on period at a lower power level, and if the reactor is on a longer period, it will scram at 80 watts with less of a power overshoot.

3.2.7 Maximum Worth of an Individual Experiment

A limit of 0.5 percent $\Delta k/k$ is put on any single experiment. This limits to about 1.4 seconds, the reactor period associated with an experiment failure, well below prompt critical. Thus the worst possible experiment failure, aside from presenting little or no hazard to the operators, will involve no damage to the fuel or system equipment.

4.0 INSTRUMENTATION

4.1 Introduction

Since the CAVALIER is a low power reactor, the instrumentation system is designed on the basis of only two ranges of reactor power; source level and power level. The CAVALIER nuclear instrumentation system is based on equipment provided by the Bailey Meter Company, some of which is modified to meet specific requirements of the CAVALIER system. The functional operation of this equipment was described in UVAR-18 [3]. Figure 4.1 shows, in block diagram form, the principal elements of the CAVALIER Control and Safety System.

4.2 Source Range Channels and Detectors

The Bailey Meter System source range instrumentation provides power level and period indication over six decades of reactor power. The source range detectors are BF_3 counters which are mounted under the grid plate on opposite sides of the core. The counters used are effective over a range of 10^{-1} to 10^4 n/cm^2-sec at the detector location with a sensitivity of approximately 13 cps/nv which corresponds to a maximum count rate of 10^5 counts per second. The BF_3 counters operate satisfactorily in gamma-ray fluxes up to 100 R/hr. The exact positions of detectors may be manually adjusted to obtain optimum operating conditions. At power levels exceeding the maximum count rate of 10^5 cps.

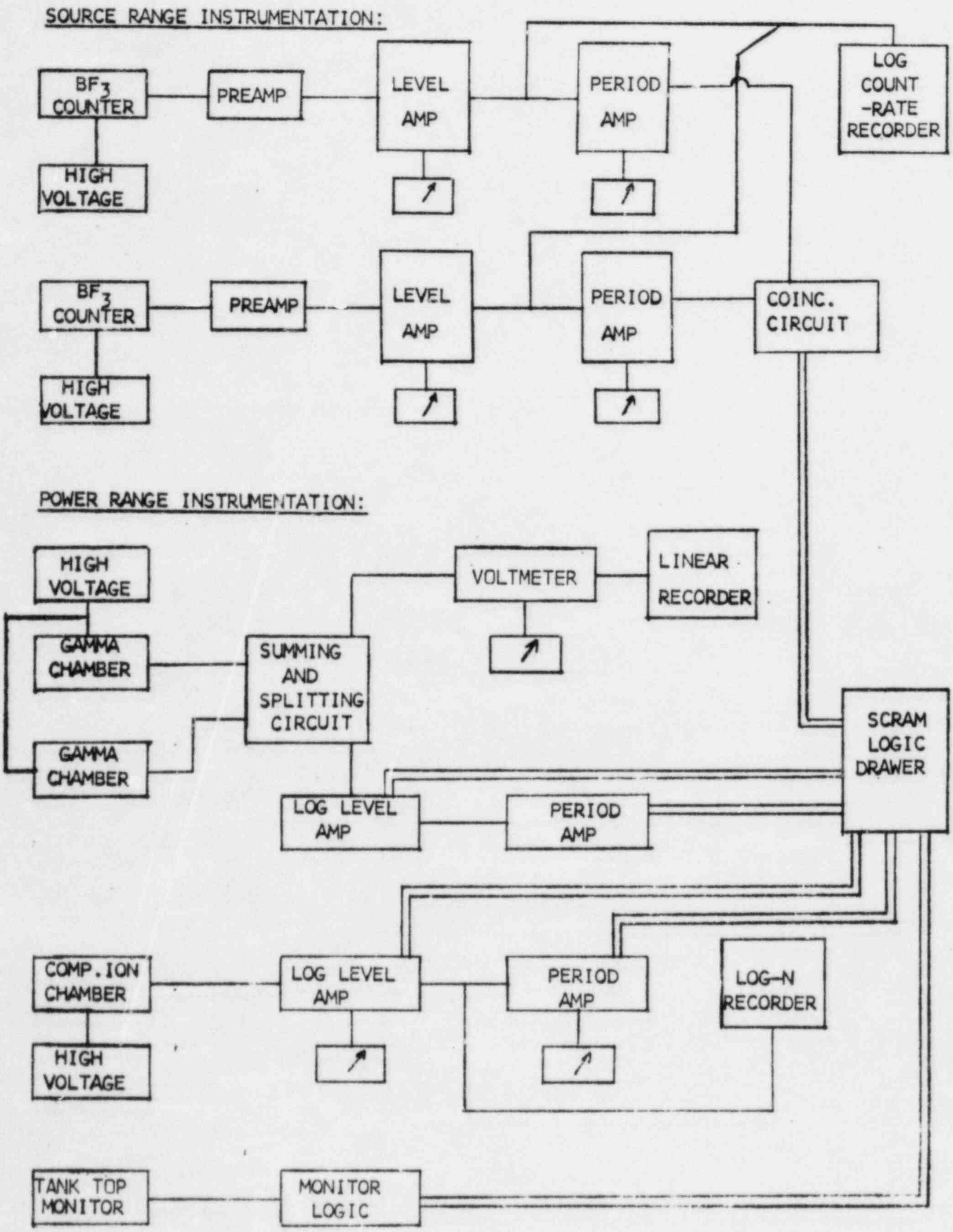


Fig. 4.1 CAVALIER Control and Safety Systems, Block Diagram
DOUBLE LINES REPRESENT TRIP SIGNALS.

the high voltage supplies to the BF_3 counters must be secured to prevent damage to the detectors. This is accomplished by manual switches on the source range drawers.

Two channels of source range instrumentation are used in the CAVALIER. These channels are identical except that one of them contains an audio amp. Figure 4.2 shows one of the source range channels connected for operation. Modules not necessary for an understanding of the operation of this instrument have been omitted.

Pulses from the BF_3 counter are amplified and discriminated to remove gamma-ray effects. The resulting neutron pulses are applied to the log integrating circuits which produce a DC output logarithmically proportional to reactor power. The DC signal is amplified by Amplifier S and applied to a local meter and a chart recorder. Amplifier S also provides signals to the period circuit and a low count rate interlock bistable.

The input to the period circuit is differentiated and amplified by a parametric amplifier arrangement. The output is applied to a local meter and a period scram bistable. The instrumentation system is connected such that an unsafe signal from the period scram bistables in both instruments in coincidence will cause a scram to be initiated. Since the high voltage to the BF_3 detectors must be turned off when operating in the power range, period scram protection from the source range channels is not required (see Technical Specification 3.4).

4.3 <u>Neutron Power Range and Period Channel</u>

The power range channel provides indication of reactor period and power level over seven decades from neutron fluxes of 10^3 to 10^{10} n/cm^2-sec at the detector location. In the CAVALIER system one neutron

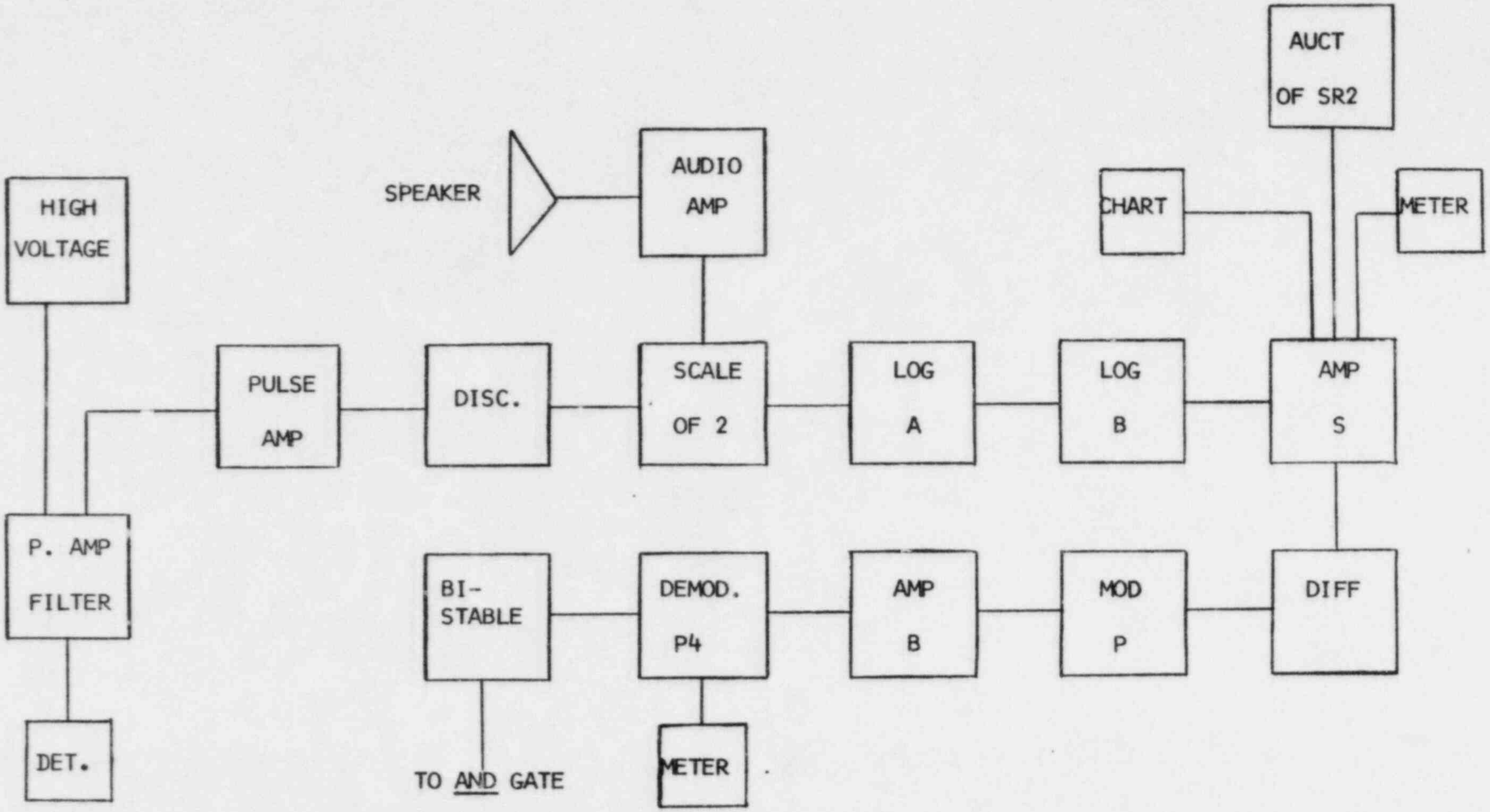


Fig. 4.2 Source Range Channel

sensitive logarithmic power range channel is employed. Figure 4.3 shows the modules necessary to understand the operation of the channel; other modules have been omitted.

This channel receives a current input proportional to reactor power from a neutron sensitive, compensated ionization chamber. The input current, which may range from 10^{-11} to 10^{-3} amps, is modulated with a 10 kHz sine wave and a series circuit of diodes converts the linear current signal into a logarithmic voltage signal in the Modulator L. The AC signal is now amplified in an Amplifier B. After amplification, the Demodulator LP demodulates the AC signal and a voltage divider prepares the DC signal for the appropriate output. The level signal is displayed on a panel meter (1-15 volt, 0-1 ma) and is also available for a remote recorder. Two bistables are employed in the level section of this channel; both of which are driven by the Demodulator LP. One controls the low-count interlock in conjunction with the source range channel bistables. The second initiates a high power scram. A level signal from the Demodulator LP is also supplied to the period circuit.

Since, in the power range, the neutron flux will be greater than at source level, a non-coincident period signal is used rather than the two-out-of-two coincidence used for the source range instrumentation.

The CIC detector for the Log N and Period Channel is located in a position perpendicular to the grid plate. Since the influence of gamma rays can be compensated for and the upper limit of the detector is above the maximum flux, the detector is located as close to the core as physically possible.

4.4 Gamma-Ray Power Range Channel

A gamma-ray sensitive power range channel is used as a means of absolute power level determination since a heat balance cannot be

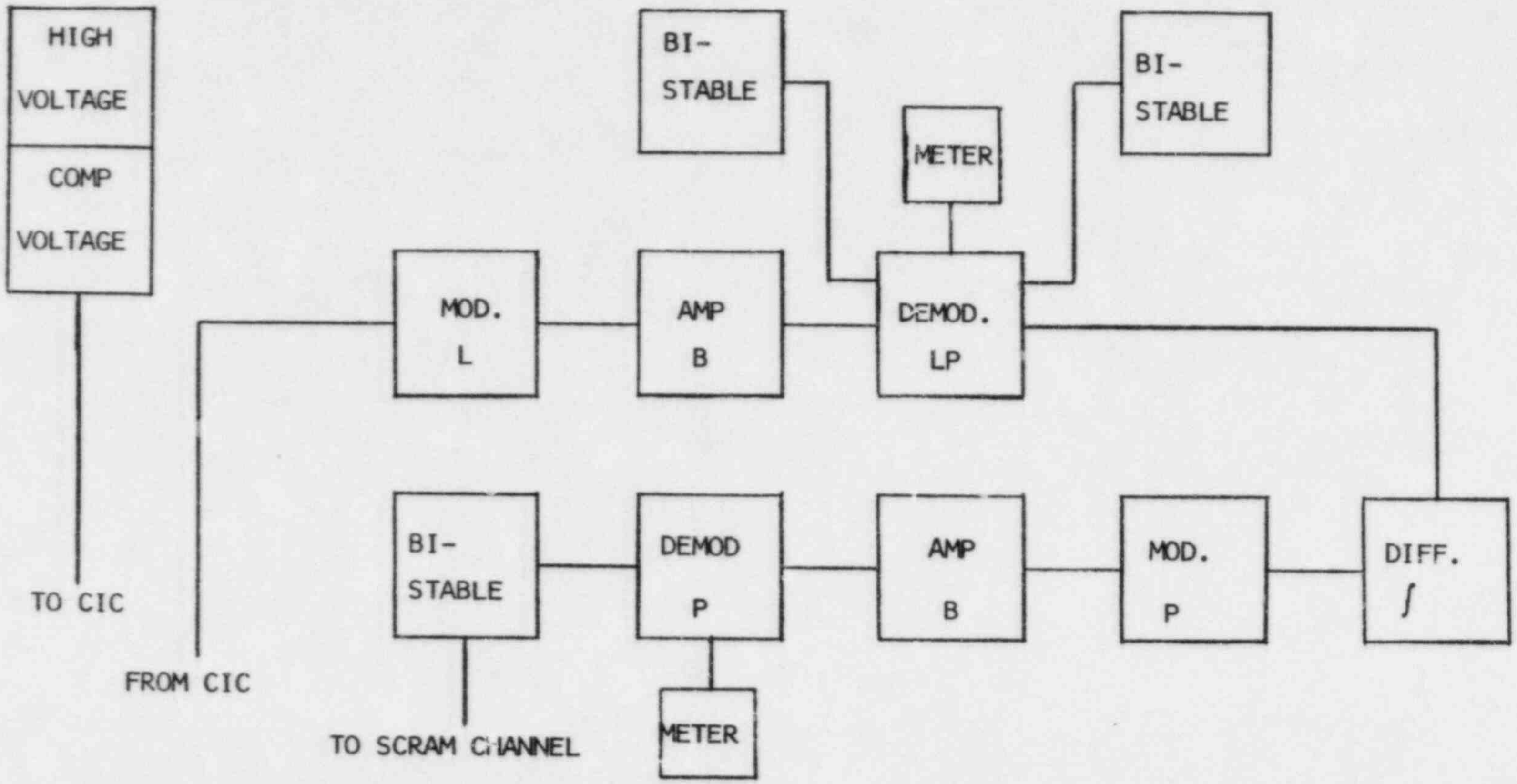


Fig. 4.3 Logarithmic Power Level Channel

performed on this reactor. This system also allows altering of the core configuration without disturbing the calibration of the channel.

The detectors are two gamma-ray sensitive ionization chambers mounted at opposite ends of the moderator tank approximately 30 in. above the top of the active fuel. The channel is sensitive to gamma-ray dose rates from 10 mr/hr to approximately 11 R/hr corresponding, at this location, to power levels of 0.1 to 110 watts.

The output of each detector is applied to a summing and splitting circuit which sums the current from the two detectors and provides both a voltage and a current output. The voltage output is applied to a voltmeter and a chart recorder and is used as a linear power channel. The current output is applied to a log power level and period channel similar to that described in Section 4.3. The log channel provides both level and period scram trip signals to the safety system.

4.5 Area Monitoring System

In addition to the Bailey meter reactor instrumentation and safety system a three channel gamma-ray sensitive area monitoring system is installed. The monitors are located at the top of the moderator tank, in the equipment area of the reactor pit, and near the control console in the operating area of the reactor room.

Each area monitoring channel is an independent unit consisting of a detector, both high and low voltage power supplies, a metering circuit, and a alarm circuit. The monitor sensing the radiation level at the top of the moderator tank initiates a reactor scram and a shutdown of the reactor room ventilation system in the event of high levels. The remaining two channels provide warning alarms in the event of high radiation levels.

Radiation levels at the three locations are displayed on individual meters on the control console over a range of .01 to 1000 mr/hr.

4.6 Safety System

The Safety System receives logic data from all of the other monitoring systems and analyzes it. In addition to initiating scrams, this system controls the rod withdrawal interlock function and supplies annunciators with signals to visibly display the state of the reactor.

4.6.1 Reactor Scram Circuit

The scram logic is binary and originates in bistables which are located in the various channels discussed earlier. The bistables produce a safe, or "on," signal of 10 volts DC and an unsafe, or "off," signal or 0 volts. The trip point of the bistables is manually variable. Each logic signal has one bistable associated with it, implying that one bistable cannot control two logic functions.

The Safety System can be divided into two sections. The function of the first section is only to interrupt the rod-drive motor circuit. The second section terminates the current supply to the rod hold magnets when the logic is unsafe, causing a reactor scram.

Figure 4.4 is a block diagram of the Scram System including only the modules necessary to understand its operation. Some of the components illustrated are not acutally found in the Safety System instrument rack.

All bistable logic signals from the various systems are directed to the Mixer Drivers and an Auxiliary Control which annunicates the reactor state. Those system which do not have bistables, such as tank water level, have relays which interrupt a 10 volt signal to the Mixer Drivers and Auxiliary Controls. Ten volt supplies are included in the Safety

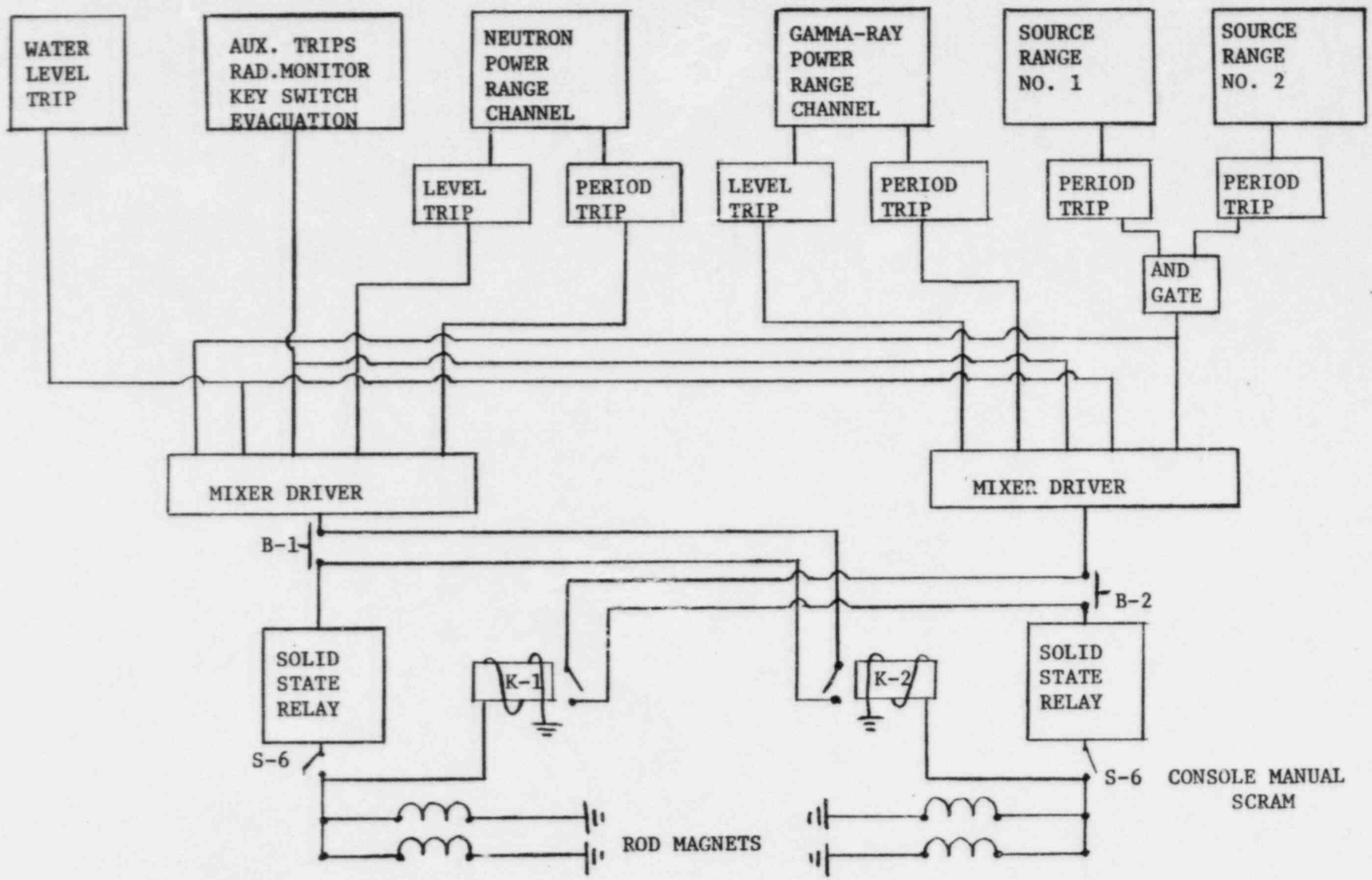


Fig. 4.4 Safety System

System for this purpose. As far as the system is concerned, these relays operate as bistables giving a 10 volt safe signal and 0 volt unsafe signal.

Each of the Mixer Drivers is a 28 input OR gate. When any one of the logic inputs is unsafe the Mixer Driver has an unsafe output. All inputs must be safe for a safe output. For redundancy, two Mixer Drivers are used. In the event of failure of one Mixer driver, the remaining, unfailed Mixer Driver can secure the reactor.

The Mixer Driver output is the input for the Solid State Relays. By referring to the diagram, (Fig. 4.4) it can be seen that the signal from Mixer Driver to Solid State Relay must pass through relay contacts controlled by another Solid State Relay. This design feature allows any combination of one Mixer Driver and on Solid State Relay to secure the reactor.

The Solid State Relays can supply up to 5 amps DC in the presence of a safe signal. No current is available in an unsafe condition. One Solid State Relay supplies current to two rod magnets and one relay.

If either Mixer Driver output signal is unsafe, the associated Solid State Relay ceases to supply current. This causes the magnets to be deenergized and the relay associated with the other Solid State Relay to open. The opening of this relay causes the second Solid State Relay to stop supplying the current, causing the magnets associated with it to be deenergized and the relay to open.

Once a safe signal returns to the Mixer Driver output, the system can be placed back on line. This must be done manually for the relays which control the input to the Solid State Relays are open. These relays can be closed by engaging the reset buttons B1 and B2.

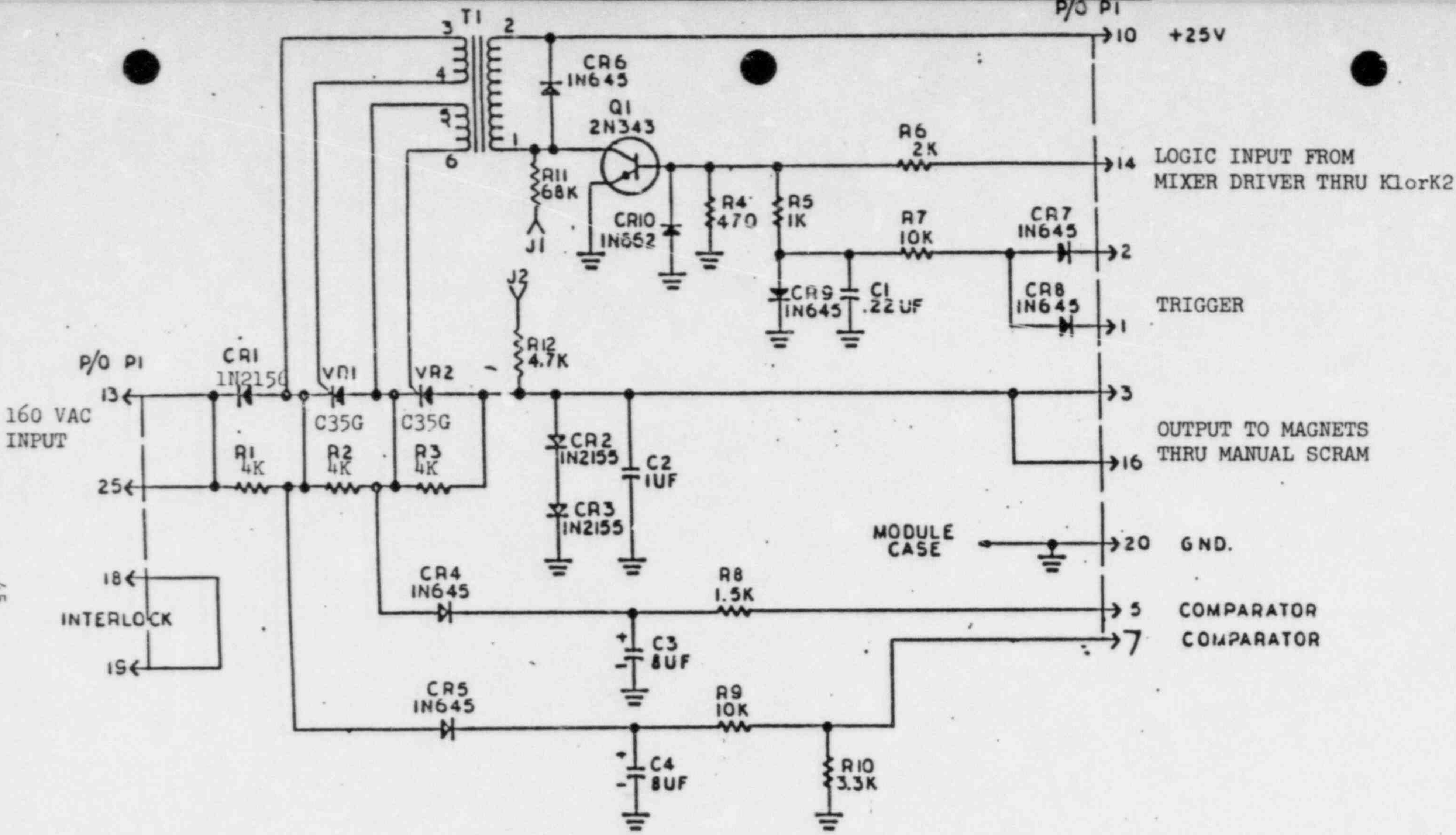
The system is designed so that both Mixer Drivers must fail or two diodes in each Solid State Relay must fail before a "can't scram" condition will exist. The operator must test the Mixer Drivers for failure, but indication is provided for Solid State Relay failure. In the event of Solid State Relay failure, annunciator lights on the front panel of the scram channel will light. If one of these lights is on, a "can't scram" condition will exist for that Solid State Relay. However, the other Solid State Relay will still be capable of dropping two safety rods.

It should also be noted that the manual scram signal is on the SSR output side and thus will be operable even in the event of simultaneous failures of both of these modules.

4.6.2 Safety Response to a Single Fault

Figure 4.5 is a detailed schematic diagram of one of the two identical solid state relays (SSR) used in the CAVALIER safety system. Each SSR is contained in a separate module and is connected to the scram logic drawer (SLD) chassis by means of a 25 pin cannon plug. The positioning of the SSR modules on the SLD chassis is shown in Figure 4.6. (Modules not directly involved in this discussion have been omitted for simplicity).

The SSR acts as a controlled power supply for the rod magnets. (Refer to Fig. 4.5) 160 VAC is supplied to the SSR module on pins 13 and 25 from an external transformer. The 160 VAC input is rectified by diode CR-1, passes through two SCR's and appears at pins 3 and 16 as 70 VDC. The presence of the 70 VDC at the output is controlled by the SCR's and VR-1 and VR-2. The SCR's will conduct only if a trigger pulse is applied to the gates at the beginning of each rectification cycle. The



NOTES:

1. UNLESS OTHERWISE STATED:

RESISTANCE VALUES ARE IN OHMS

FIGURE 4.5 CAVALIER SAFETY SYSTEM - SOLID STATE RELAY

SCR trigger pulses are supplied by transistor Q-1. Transistor Q-1 can conduct and produce trigger pulses only if a safe (+10VDC) signal is present at pin 14. This safe signal is supplied from the mixer driver modules through crossconnect relays K-1 and K-2 (refer to Fig. 4.4.)

The operation of an SSR module during an automatic scram is described by the following sequence. A scram trip sensed by the mixer driver is transmitted to the SSR as an unsafe (OV) signal on pin 14. The OV signal causes transistor Q-1 to cutoff stopping the production of SCR trigger pulses. The absence of trigger pulses causes SCR's VR-1 and VR-2 to stop conducting. The SSR output to the magnets at pins 3 and 16 drops from -70VDC to OV.

The manual scram portion of the safety-system consists of a rotary, snap action switch located on the control console. The switch consists of four enclosed decks; each deck contains one set of single pole, double throw contacts. The output from each SSR module passes through a separate deck on the manual scram switch and is fed to the scram magnets and cross connect relays (refer to Figure 4.4). A manual scram is initiated by rotating the scram switch through 90° to the "scram" position. This breaks the circuit and de-energizes the magnets and cross connect relays. Notice that only one set of manual scram switch contacts need open to de-energize all four magnets due to the operation of the cross connect relays.

The design of the CAVALIER safety system precludes the possibility of a signal component failure resulting in an inability to scram. A mechanical failure of the manual scram switch would not affect the ability of the SSR modules to process an automatic scram, and a component failure within the SSR module would not affect the operation of the

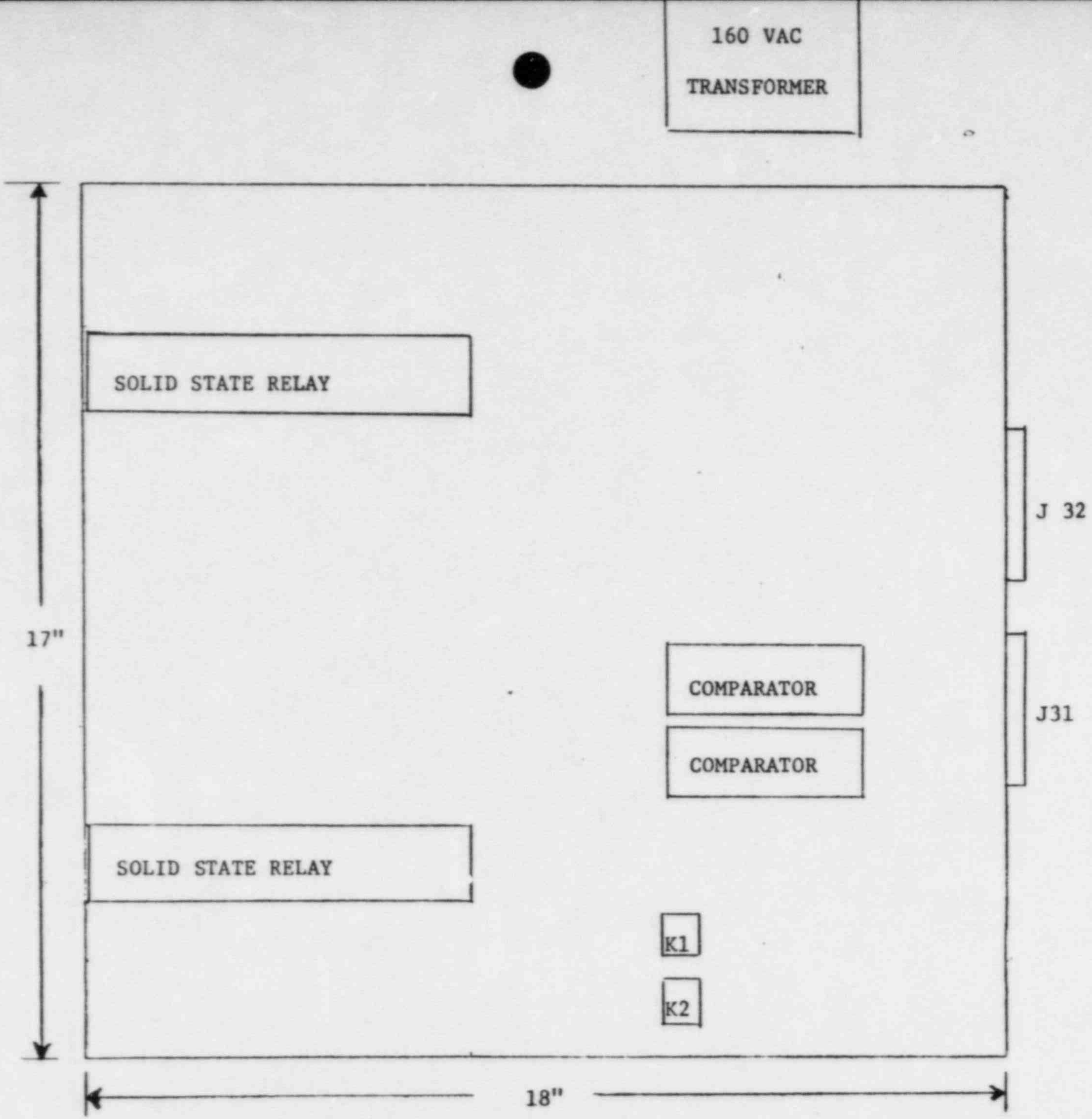


FIGURE 4.6 CAVALIER SCRAM LOGIC DRAWER PHYSICAL LAYOUT

manual switch. The remaining possibility for a signal fault failure is an inadvertent short circuit that would bypass both the SSR module and the manual scram switch. It is obvious from Fig. 4.4 that there is no single short circuit that can bypass both SSR's and both sets of manual scram switch contacts; and, since only one SSR or one set of manual scram switch contacts is needed to cause all four rods to scram, a short circuit of one SSR and one set of manual contacts would not render the system incapable of performing its function. Further analysis is presented to show that it is not possible for a single short circuit to bypass both one SSR and one set of manual scram switch contacts.

Since the scram logic drawer chassis and the manual scram switch are physically situated in different sections of the control console, a short common to both the SSR and manual switch must involve the leads returning from the manual switch to the cross connect relays K-1 and K-2 (refer to Fig. 4.4). Figure 4.6 gives the physical layout of the scram logic drawer showing the relative locations of the solid state relays, comparators, cross connect relays, and external connectors J-31 and J-32 which are Winchester type plugs. Also shown is the 160VAC transformer which supplies the AC input to the SSR modules. This transformer is external to the chassis and is connected to the SSR's through a separate plug beneath the drawer.

The output form the SSR's exits the scram logic drawer through J31 while the leads returning from the scram switch enter the drawer through J32 and travel through a separate cable run to K-1 and K-2 (refer to Fig. 4.6). Even though the components (SSR's and cross connect) relays are contained on the same chassis some degree of physical separation is attained which reduces the likelihood of a common short circuit.

Two possibilities exist for a short circuit that would completely bypass both the SSR and the manual scram switch. The first situation is a short circuit from pins 13 or 25 of the SSR modules to one of the cross connect relays K-1 or K-2. In this case the SSR and scram switch would be bypassed, and 160 VAC would be applied to the scram magnets which are DC devices and will not hold a rod with an AC voltage applied. Actual tests conducted with spare rod magnets have confirmed that they will not function with an AC voltage. So this fault rather than preventing a scram will actually cause the rods to drop into the core.

Since it is known that the magnets require a DC voltage to hold the rods, it is obvious that a short circuit bypassing both the automatic and manual scram would have to bypass both VR-1 and VR-2 in the SSR and the manual scram switch without bypassing CR-1 in the SSR modules. Since CR-1, VR-1, and VR-2 are physically enclosed in the SSR module, the only possible mechanism for such a short would be from pins 5 and 7 of the SSR module to K-1 or K-2. Actually, the leads from pins 5 and 7 of the SSR modules go to the comparator modules on the SLD chassis (refer to Fig. 4.6). The comparators are simple voltage sensing circuits which monitor the conditions of VR-1 and VR-2 in the SSR and provide the SSR failure indication (Section 4.61.). Minimum physical separation exists at this point, and a short between the comparator module plug and the cross connect relays K-1 or K-2 would be the most probable occurrence.

Figure 4.7 is a schematic diagram of the overall system conditions that would exist if a short circuit developed from pin 5 of the SSR module to cross connect relay k-1. A short circuit from pin 7 to K-1 would result in an essentially identical situation and the following analysis is therefore applicable to either case.

Referring to Figure 4.7 it can be seen that VR-1 and VR-2 conduct during the negative alternation of the 160VAC input cycle. During this time diode CR-4 is reversed biased and cannot conduct. Therefore, an automatic scram signal, which will remove the trigger pulses from VR-1 and VR-2 preventing them from conducting on the negative alternation, will cause the -70VDC to be removed from the rod magnets. Also initiation of a manual scram with the scram switch will remove the -70VDC from the magnets. During the positive alternation of the 160VAC input Cr-1, VR-1, and VR-2 are reversed biased and cannot conduct. At this time CR-4 is forward biased and will conduct allowing current flow through the magnets. However, voltage measurements taken at pins 5 and 7 show that the circuit resistance reduces the voltage to less than +5VDC which is far below the minimum value required to support the rods (approximately 40VDC). It can therefore be concluded that a short circuit from pins 5 and 7 of the SSR to cross connect relays K-1 or K-2 will not disable either the automatic or the manual scram functions.

It is, therefore, not possible for a single fault in the form of a component failure or an inadvertent short circuit to prevent the operation of both the automatic and the manual scram portions of the CAVALIER safety system.

4.6.3 Rod Withdrawal Interlock Circuit

The rod withdrawal interlock circuit prevents reactor startup under improper conditions. Outward rod motion is possible only when at lease one of the source range instruments is indicating >2 cps and all instrument test switches are in the "operate" position. An input from the neutron sensitive power range channel is also provided to satisfy

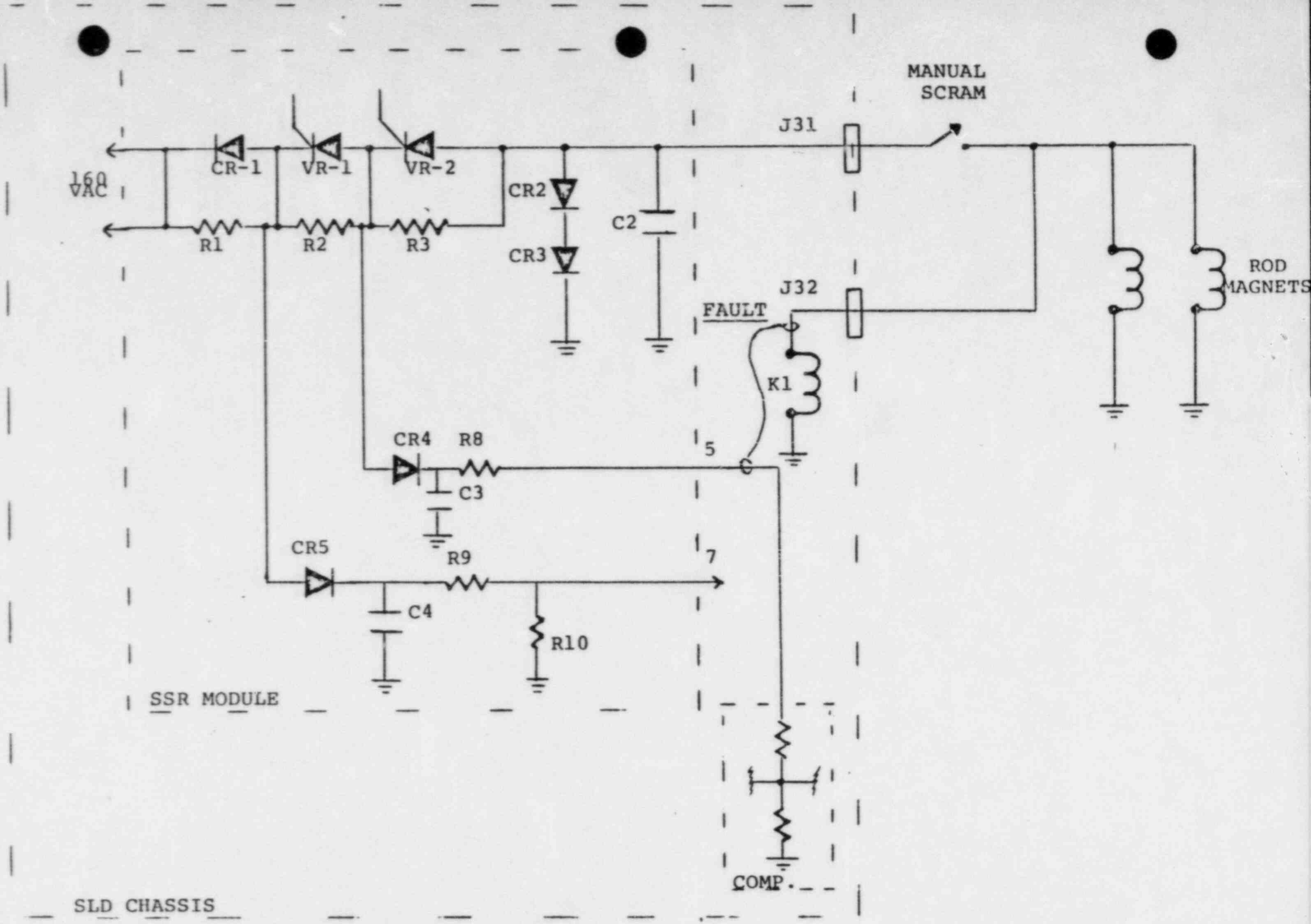


FIGURE 4.7 SCHEMATIC DIAGRAM FOR FAULT ANALYSIS

the interlock during operations at power which may require high voltage to be removed from the source range detectors. (See Section 4.2).

Figure 4.8 is a block diagram of the rod withdrawal interlock circuit. A bistable from each of the source range instruments provides a +10V output when indicated count rate is >2 cps. A bistable from the neutron sensitive power range (Log N) provides a +10V output when neutron flux at the detector is $>2 \times 10^3$ nv. These bistable outputs at +10V will cause a +10V output from the NA-45.

The auxiliary control relay (ACR) receives inputs from the NA-45 gate and from a +10V power supply through all instrument test switches. Both ACR inputs must be at +10V to cause an output to the rod permissive relay. Low signal levels in the reactor instrumentation or any of the instrument test switches out of "operate" will cause one of the ACR inputs to fall to 0V which will de-energize the rod permissive relay.

4.7 Instrument System Response

Figure 4.9 shows in graph form the typical response of each of the instrumentation channels in the CAVALIER control and safety systems for the range of reactor power proposed. The exact positions of the various sensors may be adjusted to improve sensitivity and possibly increase the degree of overlap. In particular the Logarithmic Power Range Channel may be positioned to be "on scale" at source range, and that at least one of the Source Range Channels shall be capable of remaining operable up to maximum power of 100 watts.

The response of the Linear Power Channel, the sensors for which are two ionization chambers sensitive only to gamma rays, is drawn for a lower level of readable ionization current of 10^{-12} amp (10 mR/hr), corresponding to a power of 0.1 watt. The chamber position for this

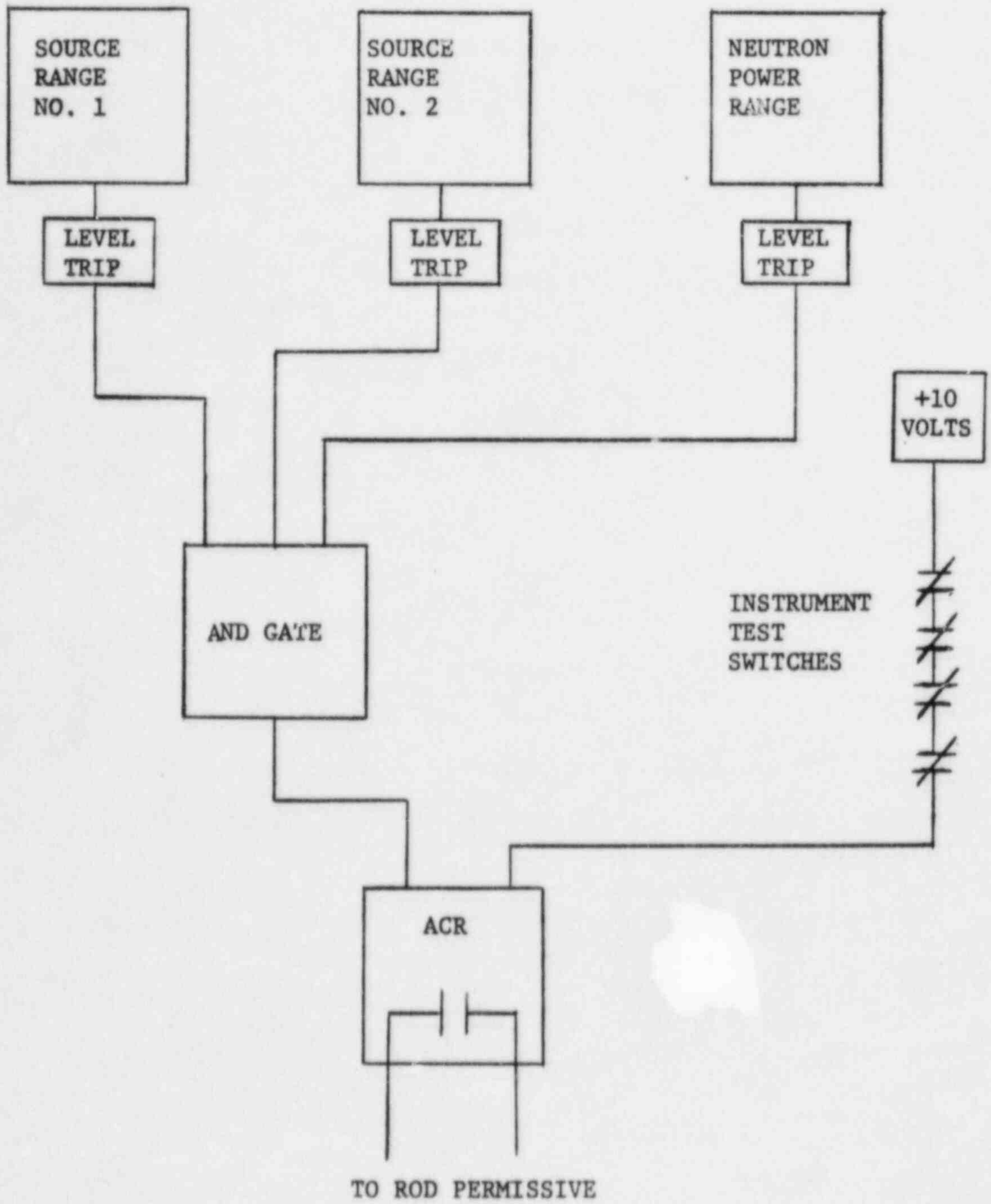


Fig. 4.8 Rod Withdrawal Interlock Circuit

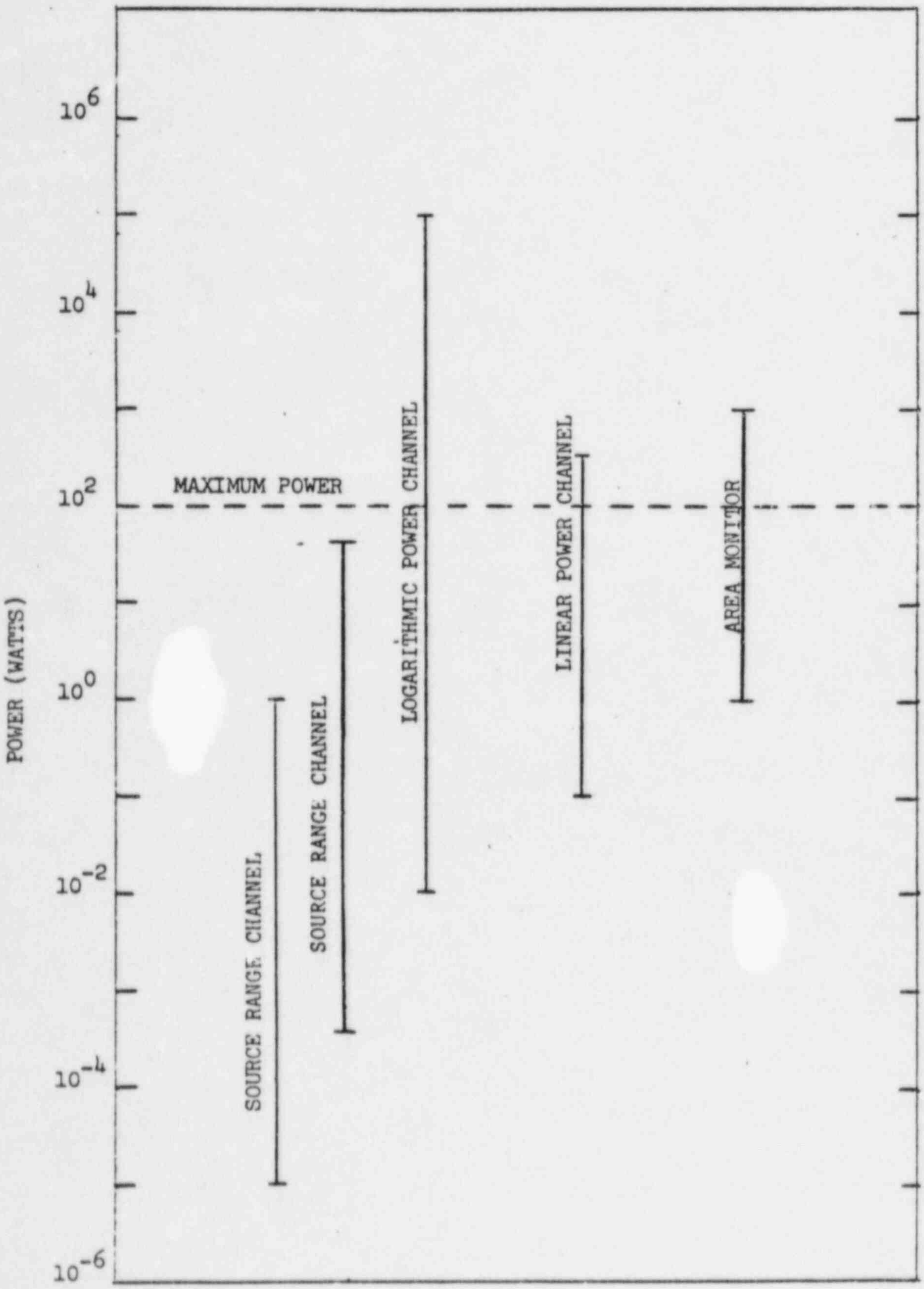


Fig. 4.9 Range of Instrument Response

reading is at the side of the moderator tank, about 30 inches above the top of the active fuel. The readings at this position have been verified by measurements made on the UVAR pool reactor.

The gamma-ray source strength of the CAVALIER core is not always proportional to core neutron, or thermal, power. Short-lived fission products must build up to their equilibrium levels upon start-up, and after shutdown fission product gamma-ray decay persists long after neutrons have died away. The Linear Power Channel gamma-ray chambers are placed as far from the core as possible to maximize the prompt gamma-ray signal, a hard energy spectrum, and to minimize the fission product contribution, a softer spectrum.

Figure 4.10 shows the calculated response of the Linear Channel for a step function power operation, for two operating time histories. Some experimental points are shown as well, measured for a detector position similar to that used for the CAVALIER.

For a step power increase, the calculated gamma chamber response is within 95% of an equilibrium value within about 8 minutes, and the measurements for a more reasonable approach to power (50 sec period) show 95% at ~45 sec.

Shutdown from prolonged operation represents the most severe Linear Channel error problem. For a 10-hr run at 10-watt power the apparent gamma-ray chamber power is 0.5 watts (5%) after 10-minutes, and does not reach the lower level sensitivity of the chamber, 0.1 watt (1%) until about 2.5 hours after shutdown. For shorter periods of operation (e.g. 1 hour) the 5% value comes in about 3 minutes and 1% at 40 min.

For a 1-hour run at 100 watts, followed by a scram and an immediate return to 10 watts, which would require at best about 20 minutes, the

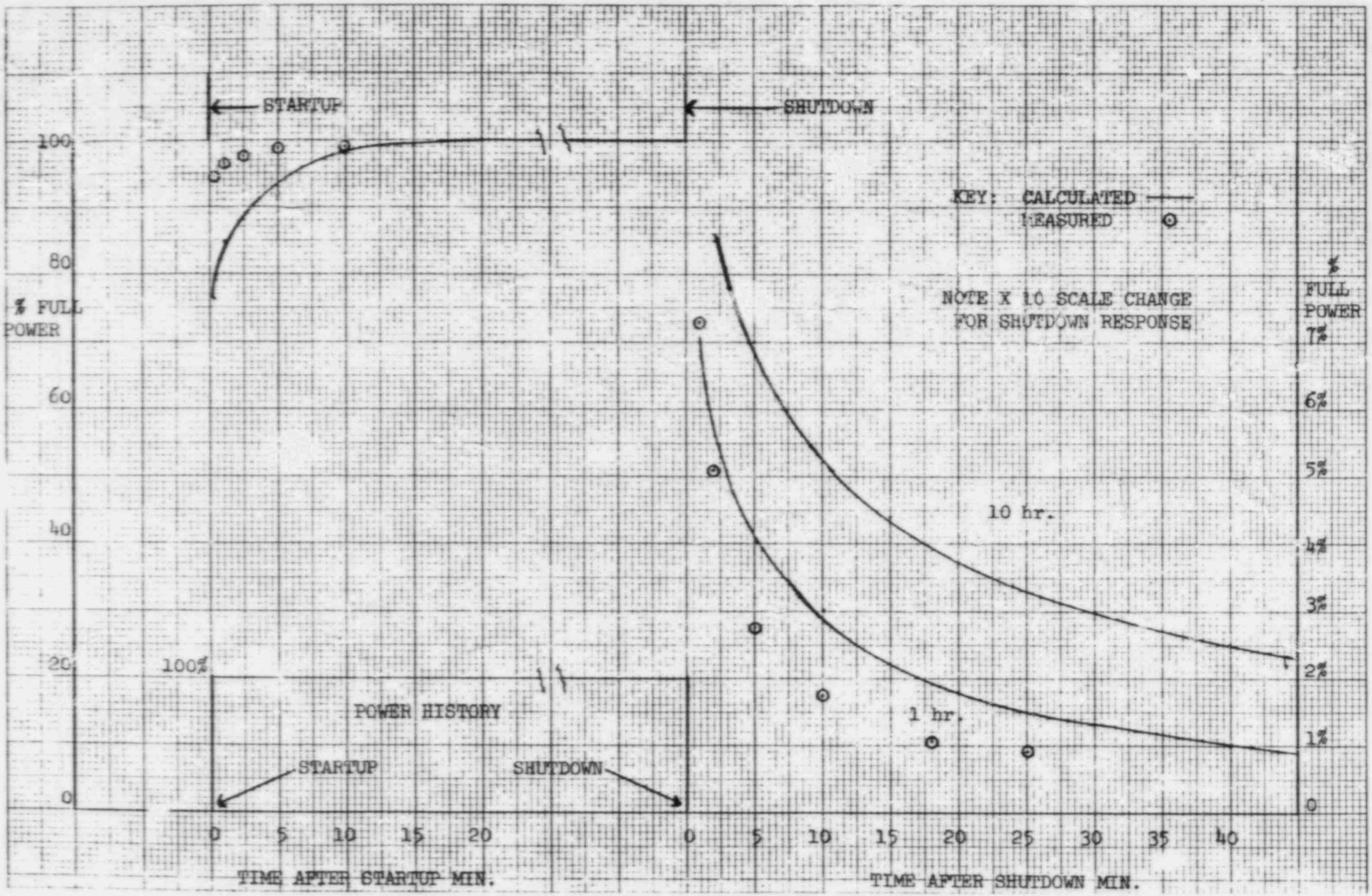


FIG. 4.10 Response of Gamma-Ray Sensitive, Linear Power Channel to a Square Wave Power Step. Chamber Position at Tank Wall, 30 in. Above. Core.

error in a supposed 10-watt reading would be about 2% of the 100 watt steady state value, or~20% of 10 watts. This represents an extreme test of the system. If the wait time has been 1 hour, the error in the 10-watt value would have been~7%.

The long-term fission product buildup due to multiple operating periods will contribute far less than lowest signal (0.1 watt), as determined from UVAR measurements.

In summary, there will be some errors in the Linear Power signal, all of them leading to apparent power levels which are higher than actual, except for the brief, slight under-reading at start-up. However, for sustained operations and for normal operations near the average rated power, the gamma-ray sensing system offers an absolute power measure which will be relatively unperturbed by core loading or configuration changes. In a system where thermodynamic power calibration is not practical, these latter advantages outweigh the errors in short-term transient response.

Figure 4.11 shows the response that would be observed on the log gamma channel, under the maximum error conditions of 2% of the 100w steady state value, as true power increases on a stable period of 5 sec. The error in the indicated power becomes less significant as true power level increases and is within 4% of true power by 50 watts. Since indicated power is higher than true power, the error is conservative.

The period indication from this channel will also contain a significant error initially because it indicates the rate of change of indicated power. Again this error becomes less significant as the power level increases, and the indicated period is within 2% of the actual period by a power level of 50w.

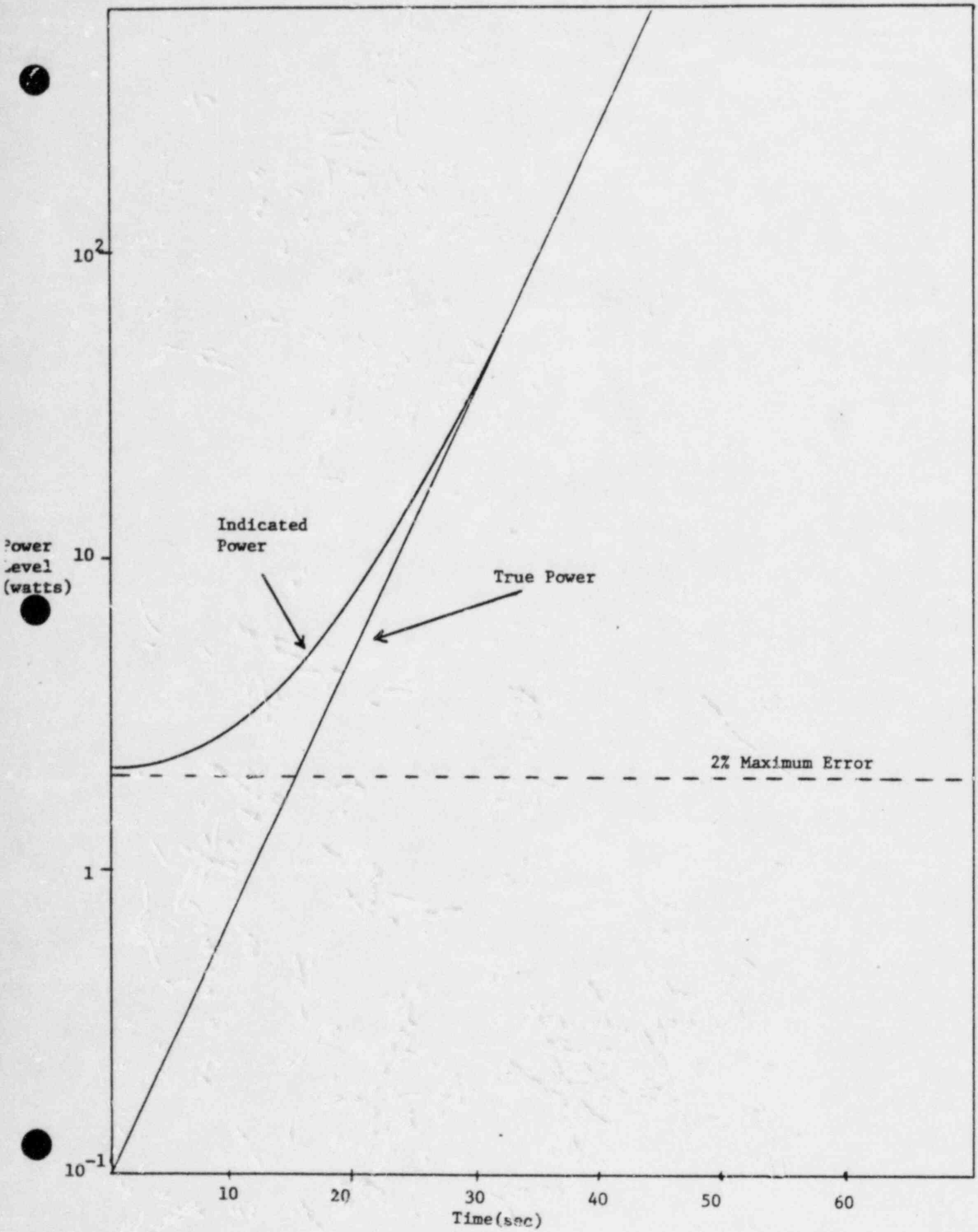


Figure 4.11
Log Gamma Channel Response

5. AUXILIARY SYSTEMS

The only auxiliary system associated with the operation of the CAVALIER are the water cleanup and building ventilation systems. Also discussed in this chapter will be the various communication systems available to the CAVALIER operation.

5.1 Water Cleanup System

A mixed-bed deionizer, employing throw away resins, is used to keep the water in the CAVALIER tank at conductivity of less than 5×10^{-6} mhos/cm. The Moderator Tank water is continuously pumped through the deionizer at about 5 gpm. Demineralized water to fill and make-up the Tank will be taken from the large, regenerateable demineralizer which serves the UVAR. Discharged resin from the CAVALIER demineralizer is considered as potentially radioactive and is monitored to determine if it shall be disposed of as hot or normal waste. The conductivity and pH of tank water is periodically measured and the water periodically assayed for radioactivity.

5.2 Ventilation

The building heating and air conditioning system supplies air to the Student Laboratory, in which the CAVALIER is located. There is no return air system, as Student Lab air is forced into adjoining room and spaces.

The CAVALIER operating procedures provide that doors to the Student Lab will be normally closed during reactor operations, but may be opened momentarily for personnel entrance or egress. Further, the gamma-ray monitor above the Moderator Tank has an output so that a scram signal resulting from high radiation at this point also trips off the supply air blower to the room and closes a damper in the air supply line.

The provisions of the above paragraph are intended to provide for the partial isolation and retention of radioactive materials in the Student Laboratory in the event of an incident.

5.3 Communication

The following means of communication will be provided within the Student Laboratory area: An outside telephone; building loudspeaker microphone, building intercom master station, and a building evacuation alarm initiation button and horn. There are two exits from the Student Lab which lead to other portions of the building (see Fig. 2.1).

6. Operations and Experimental Program

6.1 Introduction

The CAVALIER is operated primarily as a training and educational reactor. The operations and experiments performed fall into three basic categories.

1) Operator training and laboratory experiments using only installed equipment and instrumentation. Examples of activities performed in this category are formal instruction in reactor operations under the direct supervision of a licensed operator and performance of Nuclear Engineering Laboratory course experiments such as approach to criticality and control rod calibration.

2) Laboratory experiments and research projects designed to measure reactor parameters using equipment and instrumentation in addition to that installed. Examples of activities in this area are reactor flux and power mapping and reactivity effects.

3) Laboratory experiments and research projects using the reactor for the irradiation of materials. An example of this type of experi-

ment would be neutron activation analysis of samples for elements with extremely short half lives.

The design of the CAVALIER system and the operating limits imposed by Section 3.2 naturally limit experiments to those not requiring high neutron fluxes or long irradiation times.

6.2 Experimental Facilities

The experimental facilities in the CAVALIER system consist of irradiation baskets which may be inserted into the reactor grid plate as shown in Figure 3.5. Provisions are also made for a hydraulic or pneumatic rabbit that can be mounted into the grid plate. there are no penetrations in the Moderator Tank for experimental facilities.

6.3 Analysis of Experimental Program

Operations and experiments falling into the first category listed in Section 6.1 involve normal operation of the CAVALIER system and the analyses given in Chapter 9 apply. Activities performed under the second or third categories require the insertion of equipment or instrumentation into the core area and, therefore, require further analysis.

The safety oriented considerations applicable to the activities covered by the experimental program are reactivity effects, mechanical stress effects, and material content of the experiments performed. Thermal-hydraulic effects are not significant due to the low power limitations of the CAVALIER system.

6.3.1 Reactivity Effects

The limiting period necessary to prevent reactor power from exceeding the 100 W safety limit during the 0.8 second rod drop time is 0.166 seconds (see Section 9.3). The reactivity needed to cause such a period is 0.8% $\Delta K/K$. The reactivity worth of experiments is limited in value to prevent the addition of this amount of reactivity. The reactivity worth of movable experiments is limited to amounts which can be compensated for by manual rod motion.

The total worth of all experiments is limited to less than 1.6% $\Delta K/k$ which is consistent with the maximum excess reactivity limitation specified in Section 3.2.4. While the simultaneous failure of all experiments in the reactor is considered highly unlikely, the results of such an occurrence is analyzed in Section 9.4 and it is shown that resulting doses to unrestricted areas are within the limits of 10 CFR 20 averaged over one year.

6.3.2 <u>Mechanical Stress Effects</u>

Mechanical stress effects will be limited by designing experiments so that the structural support is provided completely by the grid plate and the channel steel support network on top of the moderator tank. Under no circumstance will the fuel elements or control rod drives be used in the structural support system of an experiment.

The stored mechanical energy within an experiment will be limited by limiting the pressure buildup to a maximum of 200 psi, designing experiments to withstand pressures a factor of two greater than the maximum expected, and requiring prototype testing of all experiments for which pressure buildup is expected.

The results of a fuel clad failure due to mechanical stress affects would be less severe than the fission product release analyzed in Section 9.4.4.

6.3.3 <u>Material Content of Experiments</u>

The material content of experiments is significant for several reasons. High cross section materials will have a reactivity effect which must be considered and limited as discussed in Section 6.3.1; radioactive materials present a potential radiological hazard; and highly reactive or corrosive chemicals present a threat to the fuel clad integrity.

The low thermal neutron flux (1.1×10^{9} neut/cm^{2}-sec @ 100W) and the limitation on integrated power (240 watt-hr/day) limit the radiological hazard associated with the irradiation of materials in the CAVALIER system. As an example consider the irradiation of an air sample for 2.4 hours at a 100 W power level. At the completion of the experiment the Ar-41 concentration in the air sample is 3.1×10^{-3} μCi/cm^{3}. An experimental failure resulting in the release of one liter of air at this concentration to the student laboratory (1.8×10^{8} cm^{3} volume) would result in a concentration after mixing of 1.73×10^{-8} μCi/cm^{3} of Ar-41 which is below the 10 CFR 20 limit of 4×10^{-8} μCi/cm^{3} for unrestricted areas.

The radioactive material content of all experiments will be limited as follows. For singly encapsulated experiments the radioactive material present shall be limited to that amount which if released will result in doses no greater than 10% of the equivalent annual doses stated in 10 CFR 20 for persons in unrestricted areas continuously for two hours after time of release or for persons in restricted areas during the length of time required to evacuate the restricted area. The radioactive material content of a doubly encapsulated or vented experiment will be limited to that amount which if released would result in doses of less than 0.5 rem to the whole body or 1.5 rem to the thyroid of persons occupying an unrestricted area continuously for two hours after release or less than 5 rem to the whole body or 30 rem to the thyroid of persons occupying a restricted area during the length of time required to evacuate the restricted area.

Highly reactive or explosive chemicals, cryogenic liquids, unknown materials with the exception of trace materials will not be placed within the reactor core or moderator tank.

Chemicals which are highly corrosive to aluminum must be doubly encapsulated prior to insertion into the reactor core or moderator tank. Such chemicals include mercury, alkalies, chlorinated solvents, and anhydrous ethyl, propyl, or butyl alcohols.[1]

The results of a fuel clad failure due to the corrosive effects of these chemicals would be less severe than the fission product release analyzed in Section 9.4.4.

6.4 Administrative Controls of Experiments

All previously untried experiments will be reviewed and approved by the Reactor Safety Committee. This review will assure that all experiments are within the limitations of regulatory criteria, technical specifications, and approved operating procedures.

Experiments will be conducted with the explicit approval and under supervision of the Licensed Senior Operator in charge of reactor operations. The Licensed Senior Operator must determine that the persons conducting the experiment have sufficient knowledge and training to conduct the experiment safely.

All experimental equipment will be inspected by the Senior Operator in charge to determine that the equipment meets the design requirements and limitations imposed by the Reactor Safety Committee and the approved operating procedures for the reactor.

7.0 HEALTH PHYSICS

7.1 General Information

The Reactor Facility is a research tool of the University and as such, subject to use by all of its schools. It is the responsibility of the operations staff and the Health Physicist to provide and maintain full use of this tool, yet prevent undue risks and hazards to the individual workers, the University, and the Community at large.

The Health Physicist is responsible for assuring that those measures and regulations pertaining to the Health Physics aspects of the Reactor and its operation are carried out and maintained. The Director of the Reactor Facility is advised by the Health Physicist in all pertinent matters. The close association but independence of the Health Physics and Reactor Facility operations has worked well at other reactor installations, and the University has patterned its organization accordingly.

7.2 Education in Health Physics

It shall be the duty of the Health Physics Office to instruct all personnel about the risks and hazards of radiation, and the means of lessening this danger to themselves and others. This shall be done as follows:

(A) Each individual will be given an indoctrination lecture about Health Physics, followed by a question and answer period, so that the biologic aspects and the genetic aspects of radiation change are understood.

(B) On-the-spot lectures will be given during a particular phase of operations to emphasize the protection aspects of Health Physics.

(C) Pre-experiment evaluation of the hazards of a particular experiment will be determined by the individual proposing the experiment and the Health Physicist.

(D) A radiation log will be prepared for each "permanent" worker at the facility. In this log will be recorded all the monthly dose data.

7.3 Personnel Monitoring and Protection

The Health Physicist is charged with the procurement and maintenance of the detection equipment and the film badges for personnel exposure monitoring.

Film badges: These will be used for monthly checking of personnel gamma and/or neutron dose. This will be through a commercial supplier.

Pocket chambers: Direct reading - will be worn by personnel working in high radiation areas.

Finger badges - will be worn by personnel handling radioactive material who could receive 25% of MPC extremity dose as specified in 10 CFR Part 20. Street clothes will be worn by the majority of workers at the facility; however, if there is a possibility that contamination with resultant spread could occur, protective and/or disposable clothing will be provided and worn.

7.4 Permanent Monitoring and Surveys

Stationary radiation monitors associated with CAVALIER operations are mounted in the following areas:

1) At the top of the Moderator Tank.

2) In the Reactor Pit, outside of the concrete shield wall.

3) Near the Reactor Control Console.

The readings of these monitors are displayed individually on the CAVALIER instrument console. The existence of radiation in any of these areas causes an audible alarm to sound at the console. Initiation of the Moderator Tank monitor alarm scrams the reactor.

In addition, numerous portable instruments are available for surveying all areas in the facility.

Calibration of these instruments are on a regular basis established by the Health Physicist. The results of each calibration are recorded and maintained as a permanent record.

The initial run of any new type experiment or the use of radioactive materials will be extensively monitored and a permanent record maintained of the results, if the work is such that the Health Physicist determines a possible radiological hazard to personnel exists.

Surveys of the facility with protable apparatus will be made at random as well as sampling of air, smears on tables, walls, and work areas on a regular basis established by the Health Physicist. These will be considered as spot surveys and will be recorded.

7.5 Prohibitions and Sanctions

The Reactor Safety Committee and Director are responsible for regulating and enforcing the various regulations necessary to run the facility. The Health Physicist will report to these persons on irregularities and recommend necessary steps for correction, and the Director will decide the disciplinary action; however, if it is apparent to the Health Physicist that emergency orders are necessary, he may order the necessary steps to be taken as his own responsibility.

Certain areas will be designated as "No Smoking Areas," and safe areas for eating and drinking when deemed necessary by the Health Physicist.

As Part of its ALARA Program the University has established a whole body personnel dose investigation limit of 0.125 rem/quarter which is 10% of the limits in 10CFR, Part 20.

If any individual receives a radiation dose in excess of these limits as determined by ionization chambers, film badges, or any other methods, the Health Physicist will notify the Facility Director. The Health Physicist will provide information concerning the amount and type of exposure and recommend actions that should be taken by the individual to avoid future, similar exposures.

7.6 Waste Disposal

The Health Physicist will check on all waste and refuse, monitoring it prior to release to disposal areas.

Water and sewage: This system will be separate and not connected to the water drainage systems that may be used to remove radioactive material.

Dry litter and waste will be stored until it has decayed to safe levels or disposed of in sealed storage bins. No material may be released without the approval of the Health Physicist.

Liquid Waste: The CAVALIER demineralizer is a non-regenerable type and therefore there is no liquid waste from this system. If the water in the CAVALIER tank has to be drained it will be sampled and analyzed for specific activity and released directly to the pond.

The water released from the pond is sampled at the beginning, during, and at the end of each release and the results of these samples will be maintained in a permanent record by the health physicist. No waste is released with an active concentration in excess of $1x10^{-7}$ microcuries per milliliter. This limit is based on 10 CFR Part 20 limits for facilities with no iodine 129 or radium present.

7.7 Shipping and Transport

Intradepartmental shipments of radioactive materials: Insofar as possible, all radioactive material will be used at the reactor site. However, when it is necessary to ship material from the reactor to one of the schools on campus, the regulations governing shipments of radioactive material as outlined in 10 CFR Part 71 will be followed. Radioactive material will not be allowed to leave the reactor site unless the recipient is properly licensed under NRC regulations.

Intrastate shipments: Should it be necessary to ship radioactive material to areas other than the immediate campus area, 10 CFR Part 71 will be followed.

8.0 ADMINISTRATION

8.1 General Organization

The organization of the University of Virginia as related to ensuring the safe use of radioactive materials is shown in Figure 8.1. This organization consists of two major committees; the University Radiation Safety Committee and the Reactor Safety Committee.

The Radiation Safety Committee is appointed by the President of the University and must approve the possession and use of radioactive materials at the University with the exception of those associated with the Reactor Facility. Production, possession and usage of radioactive materials at the reactor come under the reactor license and are reviewed by the Reactor Safety Committee. However, if a radioisotope is made in

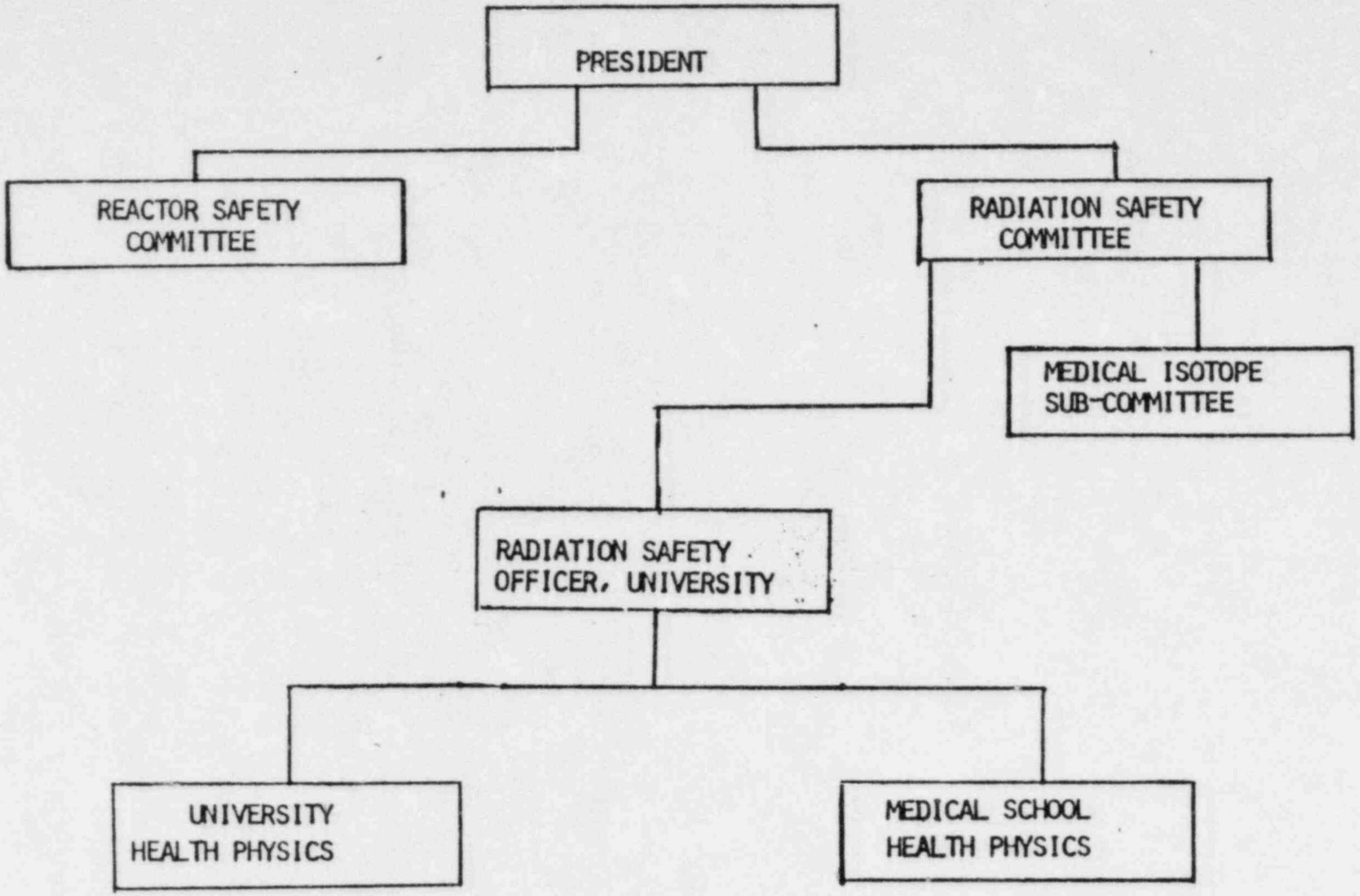


FIGURE 8-1 RADIATION-SAFETY ORGANIZATION AT THE UNIVERSITY OF VIRGINIA

the reactor for use outside the Reactor Facility its possession and use must be approved by the Radiation Safety Committee.

8.2 Reactor Safety Committee

The UVAR reactor is operated under NRC License R-66 granted in 1960. As required by the license, a Reactor Safety Committee was appointed at the time. The Committee is also responsible for the safety of operations of the CAVALIER. The organization within the University is shown in Fig. 8-1 and the organization of the Reactor Facility is shown in Fig. 8-2.

As a minimum, the Reactor Safety Committee is composed of at least five members and includes the Radiation Safety Officer, a member of the organizational structure responsible for reactor operations and an individual from outside the department of Nuclear Engineering and Engineering Physics. Senior members of the Reactor staff attend committee meetings in an advisory capacity, but there is only one vote by the Reactor Staff. This is to prevent domination of the Committee by members of the operating organization of the reactor. The Committee reviews and approves all experiments that affect the safety of the reactor. These include critical experiments, as well as experiments in which the reactor is used as a source of radiation. There are written reactor-operating procedures and written emergency procedures approved by the Committee.

Although the Reactor Safety Committee has the authority to question procedures relating to exposure of personnel to radiation, the immediate responsibility for compliance with Title 10, Code of Federal Regulations, Part 20, rests with the Reactor Staff and, in particular, with the Health Physicist. All personnel, including students who work routinely at the Reactor Facility, wear film badges. Occasional

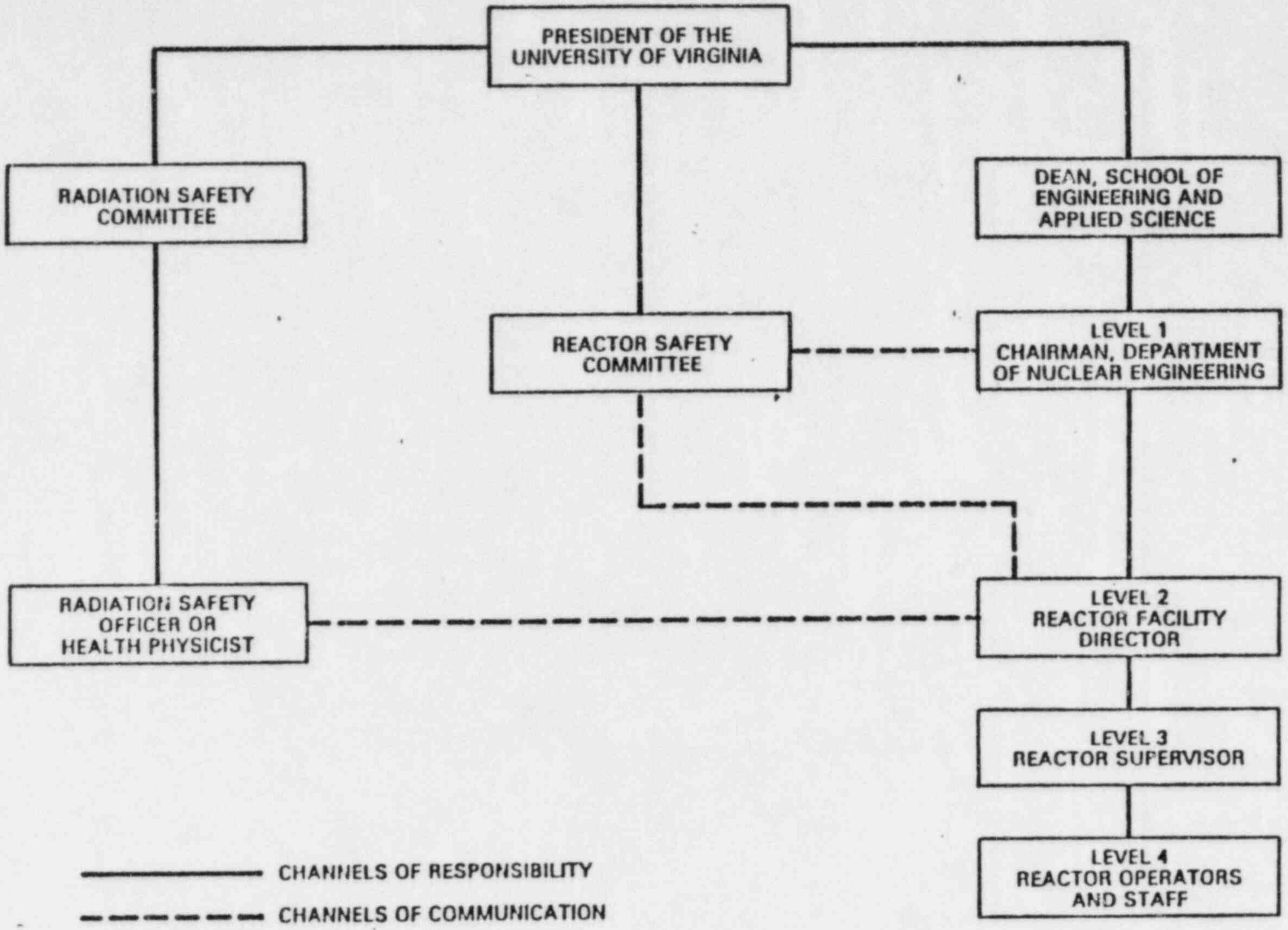


Figure 8-2 Organizational structure of UVA relating to reactor facility

visitors are issued pocket dosimeters. For large groups of visitors, two pocket dosimeters are worn by the staff member acting as a guide. This permits tours to be conducted without issuing large numbers of individual pocket dosimeters.

It also should be emphasized that, although the Reactor Safety Committee approves the safety of all operations and experiments, the detailed routine enforcement of reactor safety is the responsibility of the operating staff. The reactor log book and all other records are open for inspection by the Reactor Safety Committee. These records, plus all the records of the activities of the Safety Committee, are open for inspection by the representative from the NRC Division of Compliance. An annual report is submitted to the NRC Division of Regulation listing any changes to the facility and describing any minor incidents pertinent to safety. Major incidents are reported immediately, as required in the Technical Specifications.

8.3 Procedures

The reactor is operated in accordance with written procedures established under the approval of the Reactor Safety Committee. These procedures include normal startup, operation and shutdown of the reactor as well as emergency procedures and special procedures for unusual operations. General procedures for the handling of experiments are promulgated but these are supplemented by special procedures which apply only to the experiment under consideration in light of the facts surrounding that experiment.

All procedures concerning the operation of the reactor and associated experiments must have the approval of the Reactor Safety Committee and may be changed only by their authorization. However, in the final analysis, the safe operation of the reactor is dependent upon the Reactor Staff and their exercise of good judgement.

9.0 SAFETY ANALYSIS

9.1 Introduction

Inasmuch as the maximum power level of CAVALIER is far below that which would give rise to core melting in the event of a loss-of-coolant accident, the principal accident mode for the system is a reactivity excursion. Several types of excursions are discussed below, and the hazards associated with them determined. Also, the radiation hazard to CAVALIER operators and persons in the adjacent spaces are determined, for the loss-of-shielding (water) accident and for various excursions.

9.2 Loss of Moderator Tank Water

A loss of water from the Moderator Tank, though not serious from the standpoint of core melting, would result in high radiation levels above the Tank, and in the laboratory on the mezzanine floor above CAVALIER.

Calculations have been performed to obtain upper limit values of dose rates under such circumstances. Also, since fuel elements must be handled after their use in CAVALIER, calculations have been performed to determine the dose rate from individual fuel elements. In the analytical model used, no credit for air shielding, self-shielding by the fuel elements themselves, or in the case of the laboratory above, shielding by the floor. The results of these calculations are presented in Table 9.1, for several combinations of power history and wait time.

The results shown in Table 9-1 indicate that while the initial dose rates above the core are high, after a loss-of-water accident, they would not lead to significant exposes, and that they decrease rapidly

TABLE 9-1

DOSE RATES FROM SHUTDOWN CORE AND FUEL ELEMENTS

Fission Product Source and Model Geometry	Reactor Power History	Time After Shutdown	Dose Rate at Distance Shown, R/hr		
			150 cm	220 cm*	550 cm**
REACTOR CORE	100 hr-at 10 watts	17 min (10^3 sec)	2.4	1.2	0.18
AS A	100 hr-at 10 watts	28 hr (10^5 sec)	0.3	0.15	0.025
POINT SOURCE	1 hr -at 100 watts	17 min (10^3 sec)	9.5	4.6	0.7
	1 hr-at 100 watts	28 hr (10^5 sec)	0.09	0.046	0.006
AN AVERAGE	100 hr-at 10 watts	17 min (10^3 sec)	0.14		
FUEL ELEMENT	100 hr-at 10 watts	28 hr (10^5 sec)	0.018		
AS A	1 hr-at 100 watts	17 min (10^3 sec)	0.56		
LINE SOURCE	1 hr-at 100 watts	28 hr (10^5 sec)	0.005		

*Top of Tank
**Ceiling of Student Lab

with time. Also, the dose rates associated with handling fuel elements after operation are seen to be quite low, if an adequate waiting time (~1 day) is allowed prior to fuel handling, after operations.

In a separate calculation, in which the shielding effects of the Mezzanine Level floor are accounted for, the 24-hour integrated dose in the Mezzanine Level laboratory directly above CAVALIER was determined. The floor, an 8-inch prestressed concrete slab, with a 2-inch topping was taken to be equivalent to 5-inches of ordinary concrete. These results are presented in Table 9-2. Again, the resulting doses are not excessive, and for the rather conservative conditions assumed, in no case exceeds the 500 mR yearly dose limit of 10 CFR-20.

9.3 Transient Analysis of Ramp Reactivity Insertion

The range of response for the log power channel shown in Figure 4.9 is quite conservative. This compensated ion chamber will respond at source level. However, for this analysis, it is assumed that the log power channel is on scale and will respond and initiate a scram at 10^{-3} of the safety limit or at 0.1 watts. Again it is conservatively assumed that the rods must drop all the way and it takes 0.8 seconds to terminate the power rise after the period scram is initiated at 0.1 watts. The limiting period is found from

$$\frac{P_2}{P_1} = \frac{100}{0.1} = 10^3 = \exp\left[0.8/T\right]$$

or

$$T = 0.116 \text{ sec}$$

A positive reactivity of 0.8% would be required to place the reactor on such a period.

TABLE 9-2

TWENTY-FOUR HOUR INTEGRATED DOSES IN THE MEZZANINE LAB

CAVALIER Power History Prior to Loss of Water	Integrated Dose R
1000 hours at 10 watts	0.32
1 hour at 100 watts	0.26
2 hours at 100 watts	0.43

In the calculations for Tables 9-1 and 9-2, the 7-Group, time dependent, fission product gamma-ray data of Perkins and King were used. [6].

An analysis was run to determine the effects of a ramp insertion from below the sensitive range of log power channel. Since criticality is expected to occur at approximately 10^{-3} watts, the ramp insertion was commenced there. The average reactivity addition rate for this analysis was 1.075×10^{-4} $\Delta K/K$/sec.

The results of the analysis are shown in Figure 9.1. Power level reaches the sensitive range of the log power channel in approximately 42.5 sec. The period at this time is about 4 sec. resulting in an immediate scram. Assuming it takes 0.8 sec. to terminate the transient with the rods, the peak power is 0.14 watts. The total reactivity addition at the time of the scram is 0.45% which is well below the limiting value given above.

With the minimum sensitivity of 0.1 watts and the period scram setpoint of 5 sec., the log power channel is effective in terminating the transient well before the 100w safety limit is reached even for transients starting in the source range.

9.3.1 Ramp Reactivity Insertions

The most probable form of power excursion for a system like the CAVALIER is that resulting from a ramp-like insertion of reactivity due to a rod, or rods, being inadvertently withdrawn from the core. Since normally such transients would be terminated by period and level trips, calculations were done assuming failure of level trip signals. The results of the reactivity transients are evaluated in terms of the radiation dose at the top of the Moderator Tank, and as can be seen from Table 9-3, the consequences of the transients analyzed are negligible. No reactor damage would be expected at the peak power reached, 2.2 kilowatts.

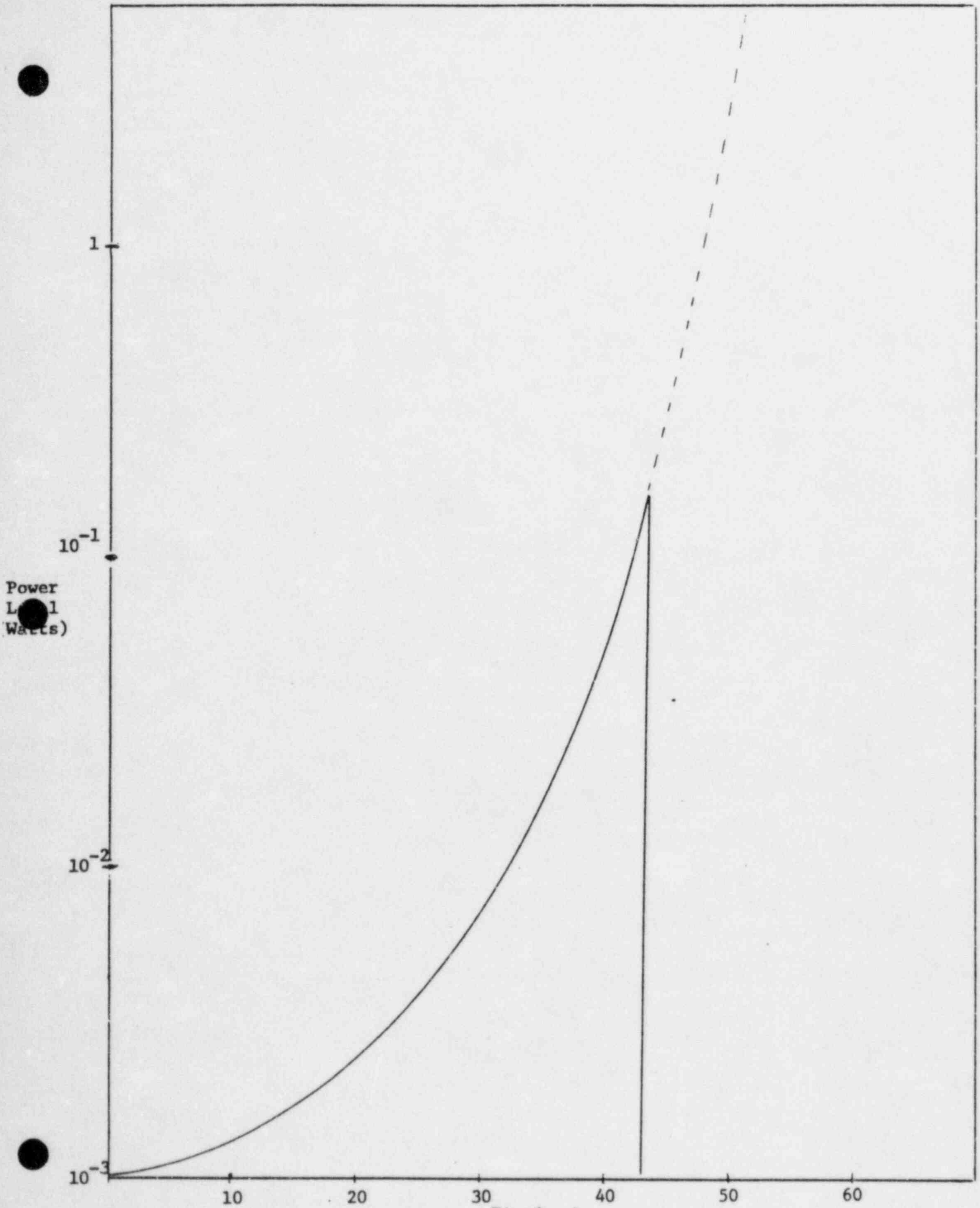


Figure 9.1
Ramp Insertion Rate of 1 x 10^{-4} ΔK/K/Sec.

The analysis was performed assuming the reactor was at 100 watts when the transient began. Ramp insertion rates were calculated assuming one rod to be worth 3 percent and having a withdrawal rate of 3.74 in/min. Although a rod is approximately 27-inches long, only 24-inches is inserted in the core. For conservatism, it was assumed that the first 5-inches of a withdrawn rod has essentially no worth due to the differential rod worth. Under these assumptions, the constant withdrawal of one rod represents a ramp insertion rate of about 10^{-4} $\frac{\Delta k}{k}$/sec. If two rods were constantly withdrawn, the ramp rate is 2×10^{-4} $\frac{\Delta k}{k}$/sec.

Calculations were made for ramp insertions of 1×10^{-4} $\frac{\Delta k}{k}$/sec, and 2×10^{-4} $\frac{\Delta k}{k}$/sec, and the resulting reactor power profiles shown in Fig. 9.2. For the smaller ramp, the power reaches 2200 watts before the 5-second period scram. In the second case, the period reaches 5-seconds at 550 watts. By integrating the curves, the total integrated power released during these transients was determined. From this, the dose at the top of the Moderator Tank was calculated for each case, and results are shown in Table 9-3.

9.4 Large Reactivity Excursions

As shown in the proceeding sections, there is no significant hazard associated with a loss of water, or with reasonable rates of ramp-reactivity insertion. In this section a limiting case of large step insertion of reactivity will be evaluated for the CAVALIER system.

As a result of the excess reactivity limit of 1.6 percent $\Delta k/k$, and the CAVALIER design features which preclude the addition of reactivity by dropping elements into or along side the core, the maximum amount of excess reactivity that could possibly be inserted as a step would be

TABLE 9-3

DOSE FROM RAMP INSERTIONS

Ramp Insertion	1×10^{-4} $\frac{\Delta k/k}{sec}$	2×10^{-4} $\frac{\Delta k/k}{sec}$
Initial Power	100 watt	100 watt
Peak Power	2200 watt	550 watt
Integrated Power	0.02 Mwt-sec	0.004 Mwt-sec
Dose*	1.1 mRad	0.22 mRad

*Dose calculated assuming 0.36 Mwt-sec equals 20 mRad at the top of the Moderator Tank.

1.6 percent $\Delta k/k$ or \$1 super prompt (for β_{eff} = 0.008). Information gained in the SPERT, reactor transient, tests indicate that such an addition of excess reactivity would produce a nuclear excursion having a total energy release about 10 MW-sec (9,500 Btu).

In this section a justification for using SPERT results is presented and the consequences of a 10 MW-sec nuclear excursion are analyzed.

9.4.1 Equivalence of CAVALIER and SPERT-1 Cores

The SPERT-1 Test Series, Runs 22-54, were made using plate type, U-Al alloy fuel elements which were quite similar to the fuel elements of CAVALIER and UVAR. In Table 9-4, a comparison of several parameters of the elements which make up the two reactors is made. Also a calculation has been made of the total energy release from CAVALIER (UVAR) using an experimentally determined prompt, negative feedback coefficient of -2.710^{-5} $\Delta k/k/^{o}F$ (7,8). The calculated value of energy release was 23 MW-sec for a \$20/sec assembly rate, which corresponds to an experimentally determined value of 31 MW-sec for an equivalent reactivity insertion to SPERT (α = 313 sec^{-1}).

TABLE 9-4

CAVALIER-SPERT FUEL ELEMENT COMPARISON

Parameter	CAVALIER (UVAR)	SPERT Du 12/25 Core
Fuel Plates per Element	12	12
Uranium Enrichment	>90%	>90%
Clad-Meat-Clad, Dimension, mils	15-20-15	20-20-20
Between-Plate Watergap, mils	211	179
Fuel Material	U-Al	U-Al

9.4.2 Energy Release Considerations

The SPERT tests for excursions having energy releases in the range cf 10 MW-sec showed some fuel plate buckling and rippling that might be deleterious to continued use of the fuel, but there was no melting or fission product release apparent. In modeling to estimate the effects of a 10 MW-sec release from CAVALIER it has been conservatively assumed that 60 percent of the energy is produced in the central region of the core, making up one third of the total fuel and water volume.

Under this assumption, the energy release first will cause temperature of the metallic fuel (~30 lbs. Al) in the central region to rise adiabatically to about 1000°F, well below the aluminum melting point of 1220°F. The heat in the central portion of the core will then be transferred to the adjacent water. Assuming no water flow during this heat addition process, the water at the center (~30 lbs.) will be raised to the boiling temperature, and enough energy will remain to produce about 2.4 pounds of steam. The local pressures initially associated with the steam formation will be high, but will quickly be relieved by condensation and coolant expansion and, according to the SPERT data, cause little fuel damage. This amount of steam, at atmospheric pressure would occupy 65 ft^3. The area in which the reactor will be located has a volume of about 6500 ft^3, thus the maximum pressure rise due to steam formation and release would be 0.01 atm.

9.4.3 Direct Radiation to Operators During Excursion

During the peak flux portions of a reactivity excursion, the Moderator Tank water would still be in place, providing shielding to operators of the CAVALIER. The total radiation dose at the top of the tank for a 10 MW-sec can be determined by relating steady state operations to this energy release. The dose rate at the top of the tank is 20 mR/hr for a reactor power level of 100 watts, and thus and hour's worth of operation (3.6×10^{-1} MW-sec) yields an integrated dose of 20 mR. A 10 MW-sec power pulse would then deliver 28 times as much radiation, for a total dose of ~600 mR, at the tank top. The integrated dose would be about one fourth of this at the operator's position.

9.4.4 Fission Product Release

The SPERT results showed that for excursions of the order of 10 MW-sec there was no release of fission products. However, in order to obtain a complete assessment of the hazards potential related to the operation of the CAVALIER, calculations have been performed to determine exclusion area doses as a result of fission product releases, making the following grossly conservative assumptions;

Reactor History: 2-years at 10 watts, plus a 10 MW-sec excursion

Fraction of Fission: Products Airborne:

50% iodine isotopes,

100% noble gas isotopes,

1% solid fission products.

The inventory of airborne radioisotopes present in the Student Laboratory immediately after their release is given in Table 9-5. The fourth column of the Table shows the isotope inventory associated with long-term operation at 10 watts, and the fifth column the total inventory, long-term plus those isotopes produced in a 10 MW-sec excursion. Note that the 10 MW-sec excursion yields by far the greatest

TABLE 9-5

AIRBORNE RADIOISOTOPE INVENTORIES

Isotope	Half-Life	Gamma Ray Decay Energy, MeV	Long Term 10-Watt Inventory Ci	Total Inventory, Long Term + 10 Mw-sec. Initial Ci	Total Inventory, Long Term + 10 Mw-sec. 2-hr. Avg. Ci
I-131	8.1 d	0.4	0.14	0.27	0.27
I-132	2.3 h	2.2	0.19	16.0	12.0
I-133	21.0 h	5.2	0.29	2.8	2.8
I-134	53.0 m	2.4	0.36	74.0	39.0
I-135	6.7 h	1.6	0.26	7.7	6.9
Xe-133M	2.3 d	0.23	0.014	0.32	0.32
Xe-133	5.27 d	0.081	0.57	1.1	1.1
Xe-135M	15.0 m	0.53	0.16	115.0	22.0
Xe-135	9.2 h	0.24	0.54	12.0	11.0
Xe-138	17.0 m	0.9	0.48	324.0	72.0
Kr-83M	1.86 h	0.041	0.049	4.9	3.5
Kr-85M	4.4 h	0.18	0.11	7.3	6.1
Kr-87	76.0 m	1.1	0.22	32.0	20.0
Kr-88	2.8 h	1.9	0.30	22.0	16.0
Solids		~0.7	0.39	73.0	30.0

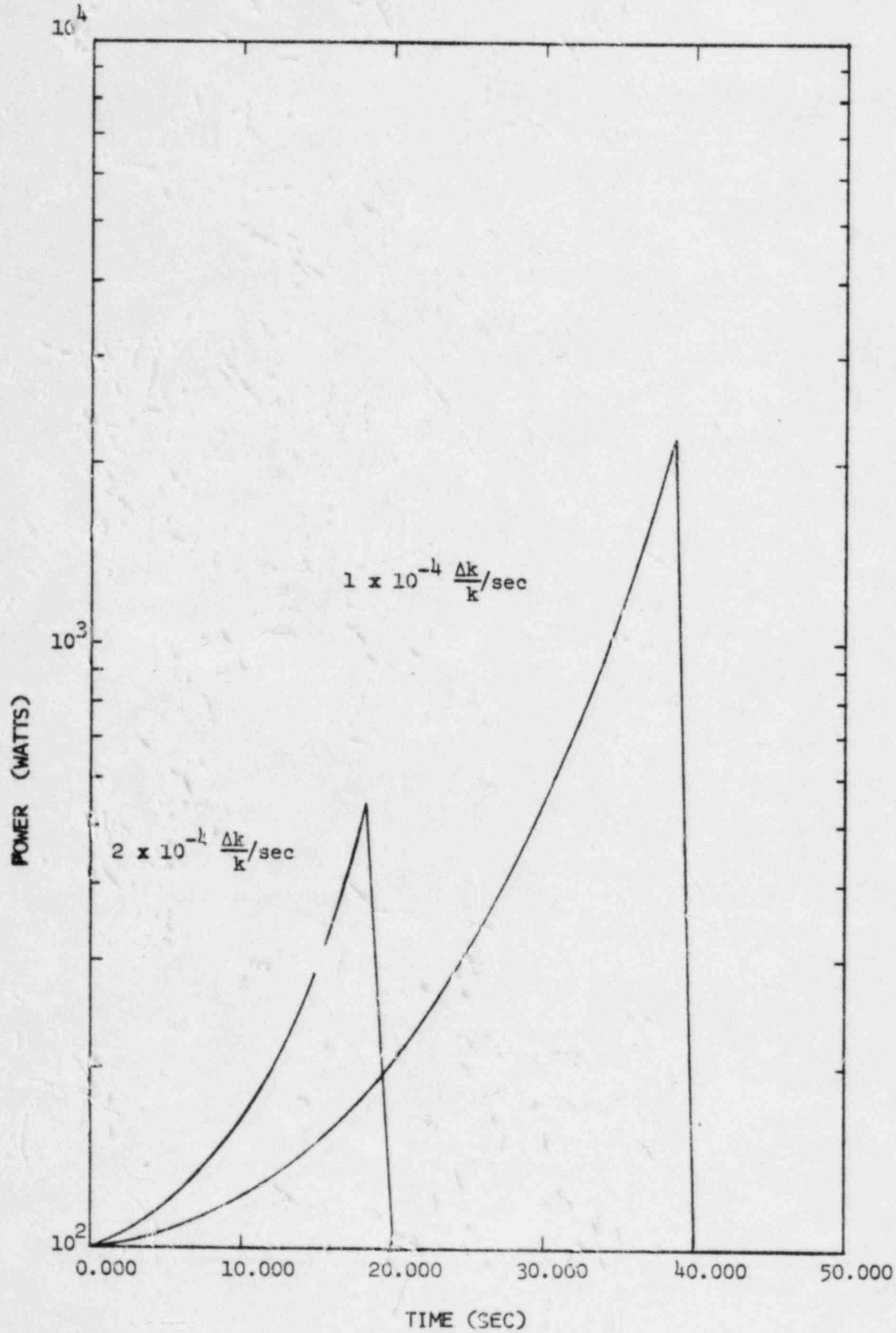


Fig. 9.2 Ramp Insertions Terminated by a Five-Sec Period Scram

portion of the inventory. Also shown is the 2-hour average value inventory, which accounts for decay of the shorter-lived isotopes, and which was used to calculate 2-hour doses.

Dose calculations were made using the conservative meteorology model of TID-14844 [9], and a building wake factor ($\frac{cA}{\pi}$, of 16.7 [10]. The latter assumes a value of $c = \frac{1}{2}$, and the smallest possible building areas, that associated with the west end of the building, 105 m^2. The apparent building area looking from the south is about 600 m^2. A ground release, and ground receptor were postulated, and essentially all of the radioactive material was assumed to be released from the Student Laboratory in a period of two hours. The assumption is conservative and maximizes the 2-hour dose. A 40 meter exclusion distance (site boundary) was assumed. No 30-day doses are presented, but because of the short release time of material from the building, the 30-day and 2-hour doses at any position are nearly equal.

Radioiodine doses to the thyroid are calculated as in TID-14844. Whole body doses at the exclusion distance were determined by assuming a multiple line-source model for the plume. No air shielding was accounted for, and the dose point was taken to be at the center of a symmetric, elongated cloud.

A summary of the results of dose calculations is given in Table 9-6. The table indicates that the 2-hour doses at the site boundary are low, and are in fact within the limits of 10 CFR-20, averaged over a period of a year. The initial thyroid dose rates to persons in the Student Lab are high, but the whole body dose rates are not, and if persons in the area left immediately the consequences of an accident of this magnitude would not be sufficient to cause major physiological damage.

TABLE 9-6

RADIOLOGICAL CONSEQUENCES OF AIRBORNE FISSION PRODUCTS

Condition	Dose Rate or Dose
2-Hour Doses at 40 M Site Boundary - Exclusion Distance:	
Whole Body	0.093 rad
Thyroid, inhalation	0.230 rad
Initial Dose Rate to Persons in the Student Laboratory:	
Whole Body	2 rad/min
Thyroid, inhalation	350 rad/min
2-Hour Dose to Persons in Laboratory above CAVALIER after 10-Mw-Sec Excursion. Assumes at least 1-ft of Water remains above core:	
Whole Body	~8 rad

9.4.5 Discussion of Large Reactivity Excursion

We have investigated the effects of a large reactivity excursion, and have pessimistically associated with the excursion a far greater-than expected release of airborne radioactivity. Our results indicate that the consequences of such an incident to persons off-site would be within the limits of 10-CFR-20. Under these conditions, the dose rates to persons actually in the Student Laboratory with the reactor would be high, but even these individuals, if they were to leave quickly, would not receive a medically significant exposure.

This analysis has been presented to show that the hazards potential of the CAVALIER system, even under extreme conditions, is well within normally accepted limits for public safety.

9.4.6 Additional Shutdown Mechanism

9.4.6.1 Background

When the original application for a license to operate the CAVALIER reactor was being reviewed (1974), the NRC staff proposed the following incredible situation. The maximum allowable excess reactivity (1.6% $\Delta k/k$) is suddenly added to the reactor and the entire safety system fails rendering the reactor incapable of being shut down. It was pointed out that the shim rod magnet power is provided by two separate solid state relay units, each of which supplies two rods. All trip signals are supplied to the mixer driver-solid state relay chains, which in turn also send trip activation signals to each other. There are redundant safety channels which derive trip activation signals from reactor power and period. All safety system channels are tested prior to reactor operation and the shim rods are driven over most of their range during operation. Finally a frequent, if not normal mode of reactor shutdown is the intentional activation of one of the safety channels, resulting in a full test of the trip system including rod insertion. Under these conditions of reactor design and operation it appears incredible that a failure mode could exist that would render the safety system inoperable. If no shim rod action is considered after the insertion of 1.6% $\Delta k/k$ the reactor would eventually reach an operating mode in the megawatt power range in which the excess reactivity would be compensated for by moderator temperature and density effects. The ultimate shutdown mechanism in this unrealistic situation would be by cumulative temperature effect such as water loss by boiling. The radiation levels in the CAVALIER operating area and adjacent laboratory areas would be in the order of 10 R/hr if the reactor were allowed to operate at a power level sufficient to compensate for a 1.6% $\Delta k/k$ reactivity insertion. These levels are not so high as to preclude safe evacuation of the effected areas and possibly some remedial action.

The decision was made, however, to install a new system capable of shutting down the reactor independent of the safety system. The system is known as the "Alternate Reactivity Insertion System" (ARIS).

9.4.6.2 ARIS Description

The alternate reactivity insertion system consists of a covered tank with sight-glass, a manually operated 2 inch gate valve, a small leak detection trap, and 2 inch piping and fittings. The tank contains a solution of boric acid (H_3BO_3) and Borax ($Na_2B_4O_7.10H_2O$). A 2 inch pipe leads from the tank to the bottom of the CAVALIER moderator tank. A diagram of the system is shown in figure 9.3. An operator noting the failure to scram situation would open the valve allowing the borated solution to flow by gravity into the moderator tank. An amount of

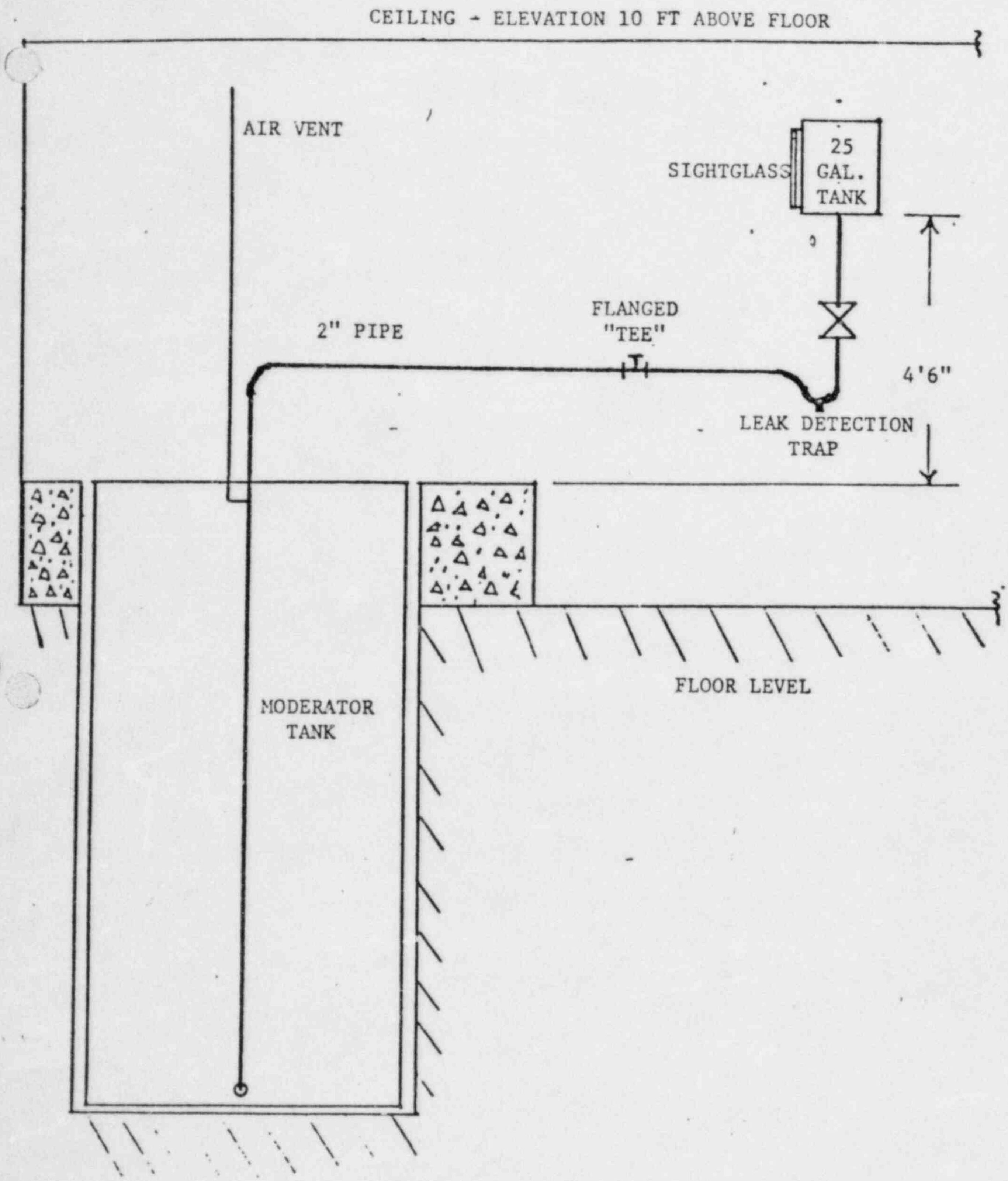


FIGURE 9.3 ALTERNATE REACTIVITY INSERTION SYSTEM

solution sufficient to overcome 1.6% $\Delta k/k$ excess reactivity in the core would flow into the tank in less than one minute.

The small leak detection trap, in which any leakage through the normally closed valve would be noticeable before it could enter the moderator tank, is included to preclude reactivity changes in the CAVALIER system resulting from boron solution leaks that would not be noticed by inspection of the sight glass. Such leaks could cause inadvertent fluctuation with reactivity of the CAVALIER system.

The boron solution contains 0.144 lbs./gallon of boron, an amount that will remain in solution throughout a temperature range of 60^{o}-85^{o}F. The CAVALIER control room is kept within the range. With this concentration a volume of 21.5 gallons of solution leads to a negative reactivity addition of 3.2% $\Delta k/k$ when the solution is uniformly mixed with the water in the moderator tank. The same reactivity addition will result from a volume of 24 gallons of solution at a concentration of 0.129 lb./gallon of boron which is considered the minimum requirement of the system. The ARIS tank normally contains 25 gallons of solution at a concentration of 0.144 lb./gallon of boron. Introducing the poison at the bottom of the moderator tank would produce an even stronger negative reactivity effect in the core area immediately after system initiation.

The system flow characteristics are based on a minimum gravity head in the tank of 4.6 feet (or 2 psi) above the top of the moderator tank. For a 2 inch line, taken as 200 feet long to account for pressure losses in the pipe run, bends, and other flow restrictions, the initial flow rate into the moderator tank from the boron tank (assuming the boron tank is 18 inches high) is 39 gallons/min., Thus the entire 25 gallon poison solution would flow into the moderator tank in well less than 2 minutes, and an amount sufficient to add a negative reactivity greater than 1.6% $\Delta k/k$ will flow into the tank in less than 1 minute.

To reduce the likelihood of an inadvertent system initiation the ARIS valve has a lock on the valve hand wheel which can be engaged when the reactor is shutdown and no licensed operator is present. The valve is unlocked prior to any reactor operation.

REFERENCES

1. Quarles, L.R. and W.P. Walker, "A Hazards Summary of the Proposed Research and Training Reactor," UVAR-3, submitted March 14, 1957 to USAEC-DRL.

2. Meem, J.L., "The University of Virginia Reactor, Description and Operation," UVAR-8, submitted Sept. 23, 1958 to USAEC-DRL.

3. Meem, J.L., "Revised Safety Analysis Report in Support of Ammendment to License R-66 for Two Megawatt Operation, University of Virginia Reactor," UVAR-18, Pt. I, submitted October 1970 to USAEC-DRL.

4. Egen, R.A., et al., "Hazards Summary Report for the VMR Critical Assembly Experiments," p. 20, BMI-1445, June 10, 1960.

5. Thompson, T.J. and J.G. Beckerly, "The Technology of Nuclear Reactor Safety, Vol I Reactor Physics and Control," pp. 683-684, MIT Press, Cambridge, Mass. (1964).

6. Perkins, J.F. and R.W. King, "Energy Release from the Decay of Fission Products," Nuc. Sci. Engr. 3, 726 (1958).

7. Palabrica, R. DeJ., "Determination of the Temperature Coefficients of Reactivity of a Reactor by Analysis of its Response to a Ramp Input," unpublished Doctor Dissertation, University of Virginia (June, 1968).

8. Obeid, M. and A.C. Lapsley, "Determination of the Lumped Heat-Transfer and Reactivity Coefficients of a Research Reactor," J. of Nuc. Energy, 23, pp. 191-181 (1969).

9. DiNunno, J.J., et al., "Calculations of the Distance Factors for Power and Test Reactor Sites," TID-14844, 1962.

10. Slade, D.H., Edt., "Meteorology and Atomic Energy, 1968," pp. 111-113, USAEC - TID-24190, July, 1968.

1982-83
Financial Report

University of Virginia

Financial Summary

Current Fund Revenues	1982-1983
Educational and General	$ 186,000,000
Hospital Operations	131,000,000
Auxiliary and Independent Operations	31,000,000
Total	$ 348,000,000
Current Fund Expenditures and Mandatory Transfers	
Educational and General	$ 177,000,000
Hospital Operations	126,000,000
Auxiliary and Independent Operations	28,000,000
Total	$ 331,000,000
Fund Balances at June 30, 1983	
Current Funds	
Unrestricted	$ 31,000,000
Restricted	27,000,000
Loan Funds	15,000,000
Endowment and Similar Funds	226,000,000
Plant Funds	328,000,000
Total	$ 627,000,000

1982-83

Tuition and Fees	In-State	Out-of-State
University Division		
Arts & Sciences - Undergraduate	$1,350	$3,276
Graduate	1,350	3,276
Graduate Business (MBA)	2,566	5,466
Law	2,088	4,588
Medicine	3,946	8,146
Room and Board	2,180	2,180

UNIVERSITY OF VIRGINIA
FINANCIAL REPORT 1982-83

October 21, 1983

To the President and Board of Visitors
of the University of Virginia:

We are pleased to submit the annual financial report of the University of Virginia for the fiscal year ended June 30, 1983. The financial statements are presented in conformance with the American Institute of Certified Public Accountants' Audit Guide for Colleges and Universities.

The State Auditor of Public Accounts conducted the audit of the University for the fourth consecutive year. The Auditor's opinion on the financial statements appears on page 9. We again wish to acknowledge the contributions of the State Auditor and the University's Internal Audit department to the financial report.

Respectfully submitted,

Peter L. Munger
Assistant Vice President
for Finance

Ray C. Hunt, Jr.
Vice President for Business
and Finance

Year in Review

The University felt the impact of a depressed economy when the Commonwealth of Virginia cut state appropriations previously budgeted for 1983 operations. State appropriations to the University Division for educational and general programs were reduced by approximately $3.8 million or 5%. At the same time, 1983 state guidelines required that students pay a greater share of their cost of education. Of the 18% increase in tuition and fees charges, 11% was due to the shift in the amount paid by students versus state appropriations and other income.

As of June 30, 1983 the University had received $76.7 million in gifts and pledges as part of a three-year $90 million capital campaign announced in December 1981. Although 85% of the total goal was reached by June 30, 1983, certain goal areas were below target and will be emphasized during the coming year.

Plans for a $187 million replacement hospital were unveiled during 1982-83. The project includes a new 445-bed facility and renovation of the existing facility to house an additional 218 beds. A vendor was selected during 1982-83 to provide new financial systems for the hospital with implementation of patient accounting scheduled for the fall of 1983. Although a vendor was chosen for the patient care portion of the Hospital Information System, contract negotiations had not begun by year-end.

ADMISSIONS STATISTICS UNIVERSITY DIVISION	1982-83	1981-82	1980-81	1979-80	1978-79
Offers as a percentage of applications (Fall Semester)					
Undergraduate	37.1%	39.6%	39.6%	39.2%	42.2%
Graduate and First Professional	32.1%	34.2%	33.3%	37.9%	36.2%
Enrollment as a percentage of offers (Fall Semester)					
Undergraduate	61.1%	60.9%	61.0%	62.5%	58.9%
Graduate and First Professional	54.0%	54.6%	53.4%	53.9%	52.5%

Demand for the University's academic programs is evidenced by the accompanying admissions statistics. Offers as a percent of applications, at 37.1% and 32.1% for undergraduates and graduates respectively, were the lowest in five years.

Enrollment in the University Division during 1982-83 was slightly greater than the 16,400 enrollment plan limit approved by the Board of Visitors.

FALL ENROLLMENT (FTE)	1982-83	1981-82	1980-81	1979-80	1978-79
University Division					
Undergraduate	11,486	11,261	11,098	11,062	10,838
First Professional	1,584	1,618	1,591	1,567	1,542
Graduate	3,621	3,513	3,513	3,430	3,360
Total	16,691	16,392	16,202	16,059	15,740
Continuing Education Division	1,713	1,984	1,785	1,835	1,663
Clinch Valley College	873	805	836	829	765

DEGREES AWARDED	1982-83	1981-82	1980-81	1979-80	1978-79
Undergraduate	2,734	2,583	2,599	2,492	2,442
First Professional	491	521	486	490	490
Graduate	1,408	1,350	1,375	1,355	1,362
Total	4,633	4,454	4,460	4,337	4,294

Financial Highlights

Current Funds

EDUCATIONAL AND GENERAL

Summary of Activity

REVENUES (in millions of dollars)	1982-83		1981-82		1980-81		1979-80		1978-79	
	$	%	$	%	$	%	$	%	$	%
Student Tuition and Fees	36.9	19.8	30.4	18.0	27.3	17.6	24.2	17.3	22.7	18.0
State Appropriations	77.3	41.6	72.0	42.5	67.2	43.3	59.2	42.2	54.6	43.3
Government Grants & Contracts	37.4	20.1	39.3	23.2	40.5	26.1	36.1	25.7	31.0	24.6
Private Gifts & Grants	16.2	8.7	12.1	7.1	9.3	6.0	8.2	5.9	7.4	5.9
Endowment Income	8.2	4.4	7.1	4.2	6.2	4.0	4.6	3.3	5.2	4.1
Sales and Services, Other	10.1	5.4	8.4	5.0	4.7	3.0	7.9	5.6	5.2	4.1
Total	186.1	100.0	169.3	100.0	155.2	100.0	140.2	100.0	126.1	100.0

EXPENDITURES AND MANDATORY TRANSFERS (in millions of dollars)	1982-83		1981-82		1980-81		1979-80		1978-79	
	$	%	$	%	$	%	$	%	$	%
Instruction	72.8	41.1	64.7	39.5	58.9	39.1	52.5	39.6	48.6	41.1
Research	31.2	17.6	28.8	17.6	26.2	17.4	22.8	17.2	19.6	16.6
Public Service	3.3	1.9	4.5	2.7	6.1	4.0	5.5	4.1	5.2	4.4
Academic Support	24.5	13.8	21.9	13.4	18.2	12.1	16.8	12.7	14.6	12.3
Student Services	7.3	4.1	6.8	4.1	5.9	3.9	5.0	3.8	4.7	4.0
Institutional Support	12.9	7.2	12.7	7.8	12.1	8.0	10.5	7.9	8.9	7.5
Operation & Maintenance of Plant	13.8	7.8	13.8	8.4	12.6	8.4	11.1	8.4	9.3	7.9
Scholarships & Fellowships	11.5	6.5	10.6	6.5	10.6	7.1	8.3	6.3	7.3	6.2
Total	177.3	100.0	163.8	100.0	150.6	100.0	132.5	100.0	118.2	100.0

Educational and general revenues and expenditures are those which are directly or indirectly in support of the University's primary program areas of instruction, research and public service. The chart above shows 1983 educational and general revenues exceeding expenditures by $8.8 million, representing a 60% increase over the previous year.

Tuition and fees revenue increased by more than 21% while state appropriations increased by only 7%, which reflects the state plan for students to pay a larger portion of their educational costs. The amount of educational and general revenue from government grants and contracts declined for the second consecutive year. The decrease was due primarily to a reduction in government support of public service programs. The University's use of private gifts and endowment income has grown by almost 100% during the past five years, demonstrating the importance of private donations in supporting the University's programs.

Total educational and general expenditures for 1983 exceed 1982 by 8.2%, the smallest increase in the past four years. The percentage of total expenditures for instruction was greater than last year while the percentage of total expenditures for support and service declined. These two changes result from improved productivity in the support areas and a successful energy savings and physical plant program. Research and financial aid expenditures, as a percent of total, remained constant between 1983 and 1982. The lack of external support for public service has caused a continued decline in the amount expended for this program.

The University began recording accrued sick and annual leave in 1982 to comply with the Financial Accounting Standards Board (FASB) Statement No. 43. Only the increase in accrued leave from 1982 is included in expenditures for 1983.

SPONSORED PROGRAMS

Awards

(in millions of dollars)	1982-83		1981-82		1980-81		1979-80		1978-79	
	$	%	$	%	$	%	$	%	$	%
Research	34.7	79.4	32.9	74.3	31.5	69.6	29.2	65.0	25.3	69.3
Training	3.8	8.7	3.1	7.0	4.5	9.9	5.4	12.0	4.5	12.3
Student Support	3.0	6.9	3.5	7.9	3.9	8.6	3.9	8.7	1.0	2.8
Other	2.2	5.0	4.8	10.8	5.4	11.9	6.4	14.3	5.7	15.6
Total	43.7	100.0	44.3	100.0	45.3	100.0	44.9	100.0	36.5	100.0

Sponsored Program awards, which are not included in revenues until expended, decreased by 1% to $43.7 million in 1982-83. The dollar totals include amounts awarded for both direct and indirect costs. A 4.2% decrease in federally-funded programs was partially offset by a 17.4% increase in non-federal awards. Federal awards for 1982-83 still accounted for 85% of total awards versus 87% for 1981-82. The University is actively seeking non-federal sources for research and training to offset reduced federal expenditures for such sponsored program activities. This effort parallels that of the University's development campaign and should result in increased funding from private sources in future years.

Awards for research were $34.7 million or 79.4% of the total, an increase of 5.5%. Awards for training programs in 1982-83 were $3.8 million, an increase of 23%. Approximately 47% of the dollar value of awards were to the Medical Center, while 24% and 16% were to the College of Arts and Sciences and the School of Engineering and Applied Science, respectively.

AUXILIARY OPERATIONS

Summary of Revenues and Expenses

(in millions of dollars)	1982-83		1981-82		1980-81		1979-80		1978-79	
	REV	EXP	REV	EXP	REV	EXP	REV	EXP	REV	EXP
	$	$	$	$	$	$	$	$	$	$
Food Services	14.9	14.5	14.1	13.4	12.1	11.5	10.3	10.0	9.2	9.0
Residential Facilities	6.6	5.0	5.9	5.1	5.3	4.6	4.8	4.3	4.8	4.4
Athletics	4.2	3.6	3.9	3.6	2.9	2.8	2.7	2.3	1.8	2.0
Other (Bookstore, Student Health)	9.4	8.1	8.3	7.3	7.6	6.6	7.6	6.5	6.0	5.2
Gross Activity	35.1	31.2	32.2	29.4	27.9	25.5	25.4	23.1	21.8	20.6
Less Recoveries	5.0	5.0	4.8	4.8	3.8	3.8	4.1	4.1	3.7	3.7
Total	30.1	26.2	27.4	24.6	24.1	21.7	21.3	19.0	18.1	16.9

The activities included in auxiliary operations are self-supporting. The operations are an integral part of the University and contribute directly to the residential and educational environment by delivering essential services to students, faculty, staff, alumni and guests. Recoveries represent intra-university sales.

The University houses approximately 5,200 graduate and undergraduate students in some 39 residential units, placing families and single students in apartments and dormitories. Food service includes contract and cash operations, vending, concessions, catering, specialty shops and central support services, such as a bakery and a meat department. Students may enter a food contract plan or dine at one of several non-contract food service facilities. Among parking and transportation services are provision of some 10,000 spaces for students, faculty, staff and visitors; registration of approximately 15,000 cars; and operation of a bus charter service, a motor pool and an 18-bus transportation system carrying more than 13,000 passengers each day. Other auxiliary activities include intercollegiate athletics, student health services and the bookstore.

HOSPITALS

Summary of Activity

(in millions of dollars)	1982-83	1981-82	1980-81	1979-80	1978-79
	$	$	$	$	$
Revenues	130.5	115.7	95.7	86.8	77.6
Expenditures	126.4	112.8	97.7	81.1	71.0
Revenues less expenditures	4.1	2.9	(2.0)	5.7	6.6
Patient Days	208,900	200,800	201,200	207,500	219,400

The Main Hospital discharged 24,275 patients during 1982-83, an increase of 1,911 discharges over 1981-82. Total patient days, exclusive of nurseries, were 191,638, an increase of 6% over the 1981-82 total of 181,049. The average daily census increased from 496 in 1981-82 to 526 during 1982-83. Average length of stay decreased slightly during 1982-83 to 8.4 days from 8.8 days in the previous year. Reflecting its role as a comprehensive teaching facility, the Hospital discharged 17,577 patients who reside in areas other than Charlottesville and Albemarle County and 2,316 of these patients were from other states.

A total of 111,317 outpatient clinic visits were recorded in the Hospital and Primary Care Center Clinics during 1982-83, excluding the Emergency Room. This represented an increase of 16,994 visits over the previous year, an increase of 18%. Emergency Room visits decreased slightly, from 37,579 in 1981-82 to 37,139.

The Blue Ridge Hospital generated 17,323 patient days during the 1982-83 year, a decrease from the 19,830 patient days generated the prior year. Reflecting its changing role, Tuberculin patient days dropped dramatically from 12,607 in 1981-82 to 5,547 in 1982-83, a 56% drop. Geriatric/Oncology and Medicine patient days for 1982-83 were 6,159, an increase of 4,548 patient days over 1981-82. This trend is expected to continue into 1983-84 and should offset the loss in Tuberculin patient days.

Loan Funds

Summary of Student Loans Outstanding

(in millions of dollars)	1982-83		1981-82		1980-81		1979-80		1978-79	
	$	%	$	%	$	%	$	%	$	%
Federal Loan Programs	13.8	92.0	13.1	93.0	12.4	93.2	11.5	93.5	9.4	86.2
Other Loans	1.2	8.0	1.0	7.0	.9	6.8	.8	6.5	1.5	13.8
Total	15.0	100.0	14.1	100.0	13.3	100.0	12.3	100.0	10.9	100.0

Default Rates:

	1982-83	1981-82	1980-81	1979-80	1978-79
	%	%	%	%	%
NDSL	9.4	8.8	8.9	9.3	9.2
HPSL	9.9	6.1	9.9	N/A	N/A
NSL	7.3	6.4	18.5	N/A	N/A

On June 30, 1983, more than $15.0 million in loans were outstanding, in support of 9,283 present and former University students. This balance represents an increase of approximately 6% over the previous year and 38% over four years ago. There were 3,677 new loans and additions to existing loans totalling $3.5 million.

More than 91% of all loans outstanding have been made through federal loan programs, particularly the National Defense/Direct Student Loan (NDSL), Health Professions Student Loan (HPSL), and Nursing Student Loan (NSL) programs. In general, the federal programs provide for repayment of loans within 10 years. Special cancellation benefits are available to those engaged in certain specified types of employment.

The method of calculating the default rate for the HPSL and NSL programs has materially changed in 1982-83 and accounts for the increase in the current year default rates.

Federal guaranteed student loan funds (GSL) received directly by students are not included in University Loan Funds.

The chart above depicts the growth during the last five years in the aggregate dollar amount of loans outstanding. The amount of new loans granted during 1982-83 was slightly more than the previous year, reflecting an increase in nonfederal (University) loan support. An ongoing collection effort included the litigation of 134 loans.

Endowment and Similar Funds

Market Value

(in millions of dollars)	1982-83		1981-82		1980-81		1979-80		1978-79	
	$	%	$	%	$	%	$	%	$	%
Corporate Stocks	136.8	60.5	96.6	62.6	125.3	69.7	96.9	68.1	76.7	65.1
Bonds	27.8	12.3	19.6	12.7	18.6	10.4	11.2	7.9	14.4	12.2
Mortgages	21.8	9.6	21.7	14.1	20.0	11.1	16.8	11.8	13.8	11.7
Other	39.7	17.6	16.3	10.6	15.8	8.8	17.4	12.2	12.9	11.0
Total	226.1	100.0	154.2	100.0	179.7	100.0	142.3	100.0	117.8	100.0

Per Share Values

	1982-83	1981-82	1980-81	1979-80	1978-79
	$	$	$	$	$
Consolidated Endowment Fund					
Market value per share	408.97	285.32	347.27	277.82	236.27
Earnings per average share	17.98	17.12	12.89	12.00	11.61
Eminent Scholars Fund					
Market value per share	124.15	96.94	108.16	108.25	103.38
Earnings per average share	9.45	9.15	9.04	8.28	6.83

Total Returns

	1982-83	1981-82	1980-81	1979-80	1978-79
	%	%	%	%	%
Consolidated Endowment	50.7	(13.1)	29.6	23.1	15.6
Eminent Scholars Endowment	39.3	(2.1)	8.3	12.7	10.5
S&P 500	61.2	(11.7)	20.4	17.1	13.7
Lehman Brothers/Kuhn Loeb Bond Index	29.1	11.9	(8.5)	(1.0)	7.1
Consumer Price Index	2.4	7.1	9.6	14.3	10.9

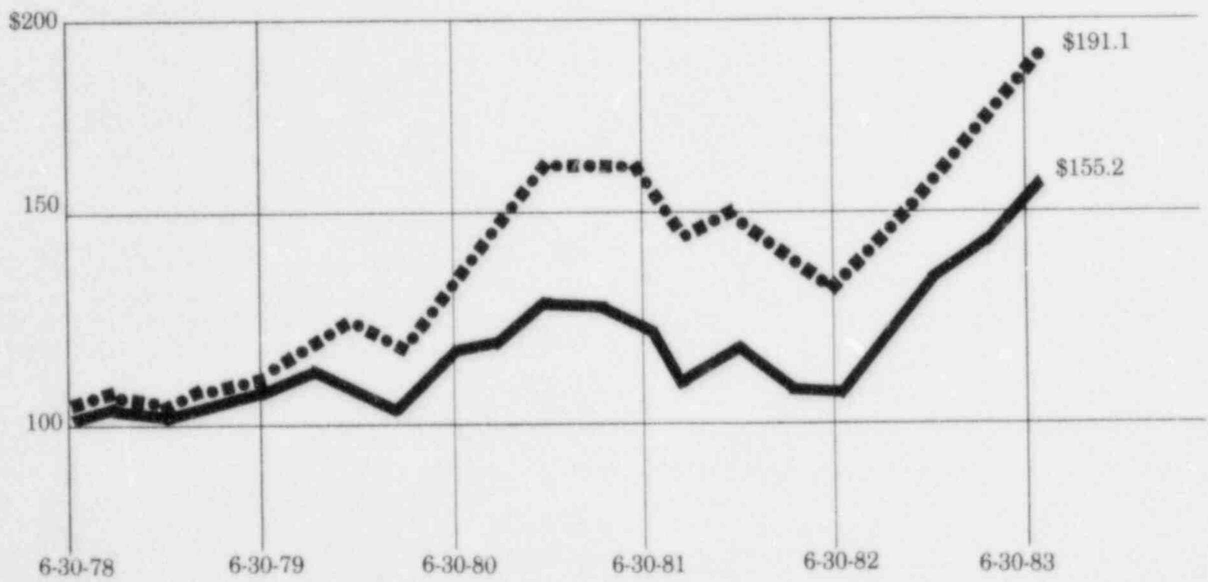
Precipitated by an easing of credit by the Federal Reserve Board and led by rapidly rising bond prices, a dynamic bull market in equities began in August 1982. This trend continued throughout the period ended June 30, 1983. The stock market, as measured by the S&P 500 Index, rose 61.2% during the fiscal year, the most rapid rise in the postwar period. The bond market likewise registered a healthy 29.1% return as measured by the Lehman Brothers/Kuhn Loeb Index. The fiscal year ending June 30, 1983 also was an exceptional one for the University's endowment, which grew from $154 million to $226 million, a 47% increase for the period. More than 90% of that growth was attributable to capital appreciation which resulted largely from the University's continued commitment to equities. Gifts and additions to quasi-endowment of approximately $7.0 million accounted for the remainder. The tables above provide a five-year historical perspective of the market value and asset mix of the University's endowment, as well as the share value and income per share and performance for the two pooled endowments.

The University of Virginia's endowment, most of which is managed by external investment counsel, is divided into four major categories: the Consolidated Endowment Fund, the Eminent Scholars Endowment Fund, Other University Administered Funds, and Funds Held by Trustees and Affiliated Foundations. Gifts to the University's endowment are added to one of the first three categories based on donor designations or determinations by the Board of Visitors. Funds in the fourth category are managed by designated trustees and foundations and are not the University's responsibility.

The **Consolidated Endowment Fund**, the largest of the four groups, had a market value of $202 million on June 30, 1983. The consolidated fund is pooled for investment purposes with earned income distributed annually to participating University accounts on a share basis. The primary investment objective of the fund is to achieve a long-term average annual total return equal to the rate of inflation plus the average level of spending of endowment income. In addition, income is targeted to grow on a per share basis at a rate of at least 4% annually.

Since the revision of investment guidelines four years ago, the 20.2% total return on the Consolidated Endowment has exceeded the 8.5% rate of inflation, as measured by the Consumer Price Index plus spending of 4% to 5%. A shift in asset mix out of equities and into bonds in spring 1981 and the exceptional yields available in the bond markets have resulted in a significant increase in income per share in the last two years. Should this trend continue, the Finance Committee of the Board of Visitors may consider measures to bring income growth back in line with the 4% objective.

CONSOLIDATED ENDOWMENT FUND AND MARKET INDEX*
CUMULATIVE RETURNS FIVE YEARS ENDED JUNE 30, 1983
BASE: JUNE 30, 1978 = $100



*Comprised 75% S&P 500/ 25% Lehman Brothers/Kuhn Loeb Index

The Finance Committee believes that the best way to meet the investment objective is to commit some 75 percent of the total market value of the Consolidated Fund to equity investments. Though equity returns may fluctuate in any given period, the Finance Committee has a long term orientation and currently believes that the potential principal appreciation and yield from equities will exceed those available from fixed income instruments. The graph above plots the cumulative returns of the Consolidated Endowment Fund versus a market index comprised 75% of the S&P 500 and 25% of the Lehman Brothers/Kuhn Loeb Bond Index. The fund continues to outperform the market over the long term.

The **Eminent Scholars Fund** also is a pooled endowment, the income from which is used to provide salary supplements above base State salaries to distinguished scholars holding endowed professorships. Income used for supplements each year is matched by the Commonwealth of Virginia. The fund had a market value of $16.7 million at June 30, 1983. The fund continues to be the beneficiary of generous gifts which added some $1.7 million to this balance over the past year.

The primary investment objective of the fund, unlike that of the consolidated fund, is to emphasize income rather than total return. The goals are to meet spending requirements of 6% to 7% of the market value of the fund and to increase participation by the Commonwealth. The total return on the fund has averaged 13.6% over the past four years. Income per share for 1982-83 was $9.45, a modest increase over 1981-82. The fund continues to produce an income flow above spending levels due to the exceptional yields prevalent in the bond market during the past several years.

Funds Administered by the University separate from the pooled accounts include contributions with limited marketability or donor restrictions or those with purposes inconsistent with either of the pooled funds. Whenever possible, these funds are transferred to the pooled accounts.

Trustee-held Funds, for which the University is the income beneficiary, totaled more than $53 million at June 30, 1983 and each year contribute income of more than $2 million to academic programs and student aid. In addition, certain endowments are held by affiliated foundations, which exist for the benefit of the University. Distributions from these affiliated foundations are treated as gift income at the time of receipt. Neither trustee-held funds nor funds held by affiliated foundations are included in the University's financial statements.

Plant Funds

Investment in Plant

(in millions of dollars)	1982-83		1981-82		1980-81		1979-80		1978-79	
	$	%	$	%	$	%	$	%	$	%
Land, Improvements & Buildings	231.3	71.1	205.3	69.9	193.0	69.7	179.2	70.5	179.9	94.1
Equipment	94.2	28.9	88.6	30.1	83.8	30.3	75.1	29.5	11.2	5.9
Total Investment in Plant	325.5	100.0	293.9	100.0	276.8	100.0	254.3	100.0	191.1	100.0
Plant Indebtedness	36.0	11.1	31.0	10.5	28.9	10.4	31.5	12.4	30.1	15.8
Net Investment in Plant	289.5	88.9	262.9	89.5	247.9	89.6	222.8	87.6	161.0	84.2

During 1982-83, total expenditures for plant additions consisting of equipment, renovations and improvements, totaled $37.9 million which represents a $15.3 million increase compared to the 1981-82 total of $22.6 million. Net additions to plant charged to current funds in 1982-83 increased to $16.2 million from $11.2 million during 1981-82.

Total plant fund long-term indebtedness, primarily related to plant used for auxiliary enterprises and the replacement of telephone equipment, amounted to $52.0 million at June 30, 1983. This represented a significant increase from the $33.1 million outstanding at June 30, 1982. The increase results from the issue of $5.8 million of bonds related to auxiliary enterprises and $15.0 million of notes related to various capital projects including the acquisition of property and scientific equipment as well as construction of student housing.

The above table presents summary information on investment in plant for the past five years. During that period, the total investment in plant has increased approximately 45% (excluding the $46.5 million increase due to the initial inventory of equipment as of June 30, 1979) while indebtedness has increased by approximately 20%. This indicates that the University has funded large amounts of plant expansion from sources other than debt.

The most significant project completed during 1982-83 was the replacement of the University's telephone system. The project involved the acquisition of a computerized branch exchange telephone system. In addition, 7,200 telephone instruments were purchased to replace leased equipment.

As in the past, the areas of emphasis for future plant expansion will include research space and student housing. Currently under construction are three student housing projects, Alderman-Stadium Road, Faulkner and Sprigg Lane, that will provide space for almost 1,000 students. The Medical Research Building and Engineering Research Building are currently under construction while planning has begun for the Gilmer Hall Addition.

Below is a list indicating the status of major capital outlay projects.

MAJOR CAPITAL OUTLAY PROJECTS

	Completion Date	Cost (in Thousands)
Major Projects Completed During 1982-83		
Clinch Valley College Student Union Building	November 1982	$ 1,981
Food Services Central Support Facilities	August 1982	1,923
Modernization of Central Telephone System	August 1982	9,386
Newcomb Hall Addition — Phase I/Peabody Renovations	July 1982	2,031
Sprinkler/Smoke Detector System — Medical Center	April 1983	1,879
Major Projects in Progress at June 30, 1983		
Alderman/Stadium Road Housing	August 1984	$13,615
Birdwood Golf Course	November 1984	1,810
Children's Rehabilitation Center Addition	June 1984	1,620
Engineering Research Building	December 1984	2,912
Faulkner Housing	December 1983	3,107
Medical Research Building MR-4	August 1983	2,047
Newcomb Hall Addition Phase II	February 1984	2,768
Sprigg Lane Housing	January 1984	1,825
Major Projects Approved for Planning at June 30, 1983		
Gilmer Hall Addition		$ 8,088
Scott Stadium Athletic Facility		2,899
Sponsor's Hall Addition		2,120

Commonwealth of Virginia

AUDITOR OF PUBLIC ACCOUNTS

P. O. Box 1295
Richmond 23210

Charles K. Trible
Auditor

October 21, 1983

The Honorable Charles S. Robb
Governor of Virginia

The Honorable Hunter B. Andrews
Chairman, Joint Legislative Audit
and Review Commission

The Board of Visitors
University of Virginia

Gentlemen:

We have examined the balance sheet of the UNIVERSITY OF VIRGINIA as of June 30, 1983, and the related statements of changes in fund balances and current funds revenues, expenditures and other changes for the fiscal year then ended. Our examination was made in accordance with generally accepted auditing standards and, accordingly, included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying financial statements present fairly the financial condition of the University of Virginia as of June 30, 1983, and the changes in fund balances and current funds revenues, expenditures and other changes for the fiscal year then ended, in conformity with generally accepted accounting principles and the Code of Virginia on a basis consistent with that of the preceding year.

Sincerely,

Charles K. Trible

AUDITOR OF PUBLIC ACCOUNTS

Balance Sheet
As of June 30, 1983
With Comparative Figures for 1982

ASSETS

	1983	1982
CURRENT FUNDS		
Unrestricted:		
Cash and Temporary Investments	$ 14,221,020	$ 19,063,749
Accounts Receivable—Hospital, less allowance for doubtful accounts and contractual adjustments of $12,603,000 in 1983 and $8,064,000 in 1982	26,896,103	23,863,554
Estimated Amounts due from Third Party Payors (Note 2)	2,270,355	2,052,759
Accounts Receivable — Other, less allowance for doubtful accounts of $146,000 in 1983 and $110,000 in 1982	1,363,203	1,125,343
Interest Receivable	940,989	927,083
Inventories	4,634,209	4,058,717
Prepaid Expenses	671,847	1,177,820
Loans Receivable from Investment in Plant (Note 8)	1,516,051	2,171,446
Due from Current Restricted Funds	1,362,131	1,337,123
Due from Loan Funds	57,865	
Due from Endowment and Similar Funds	52,099	54,418
Total Unrestricted	53,985,872	55,832,012
Restricted:		
Cash and Temporary Investments	28,512,458	24,194,324
Interest Receivable	68,384	
Grants and Contracts Receivable	2,925,564	4,012,814
Prepaid Expenses	171,541	112,599
Due from Endowment and Similar Funds	101,133	110,486
Total Restricted	31,779,080	28,430,223
TOTAL CURRENT FUNDS	$ 85,764,952	$ 84,262,235
LOAN FUNDS		
Cash and Temporary Investments	$ 1,083,584	$ 768,215
Notes Receivable, less allowance for doubtful notes receivable of $1,408,000 in 1983 and $1,243,000 in 1982	13,604,878	12,980,971
Due from Current Restricted Funds		101,790
TOTAL LOAN FUNDS	$ 14,688,462	$ 13,850,976
ENDOWMENT AND SIMILAR FUNDS		
Cash and Temporary Investments	$ 2,507,702	$ 1,738,978
Investments at Market Value (Note 4)	232,964,257	164,892,886
Interest Receivable	590,193	
Loans Receivable from Investment in Plant (Note 8)	2,554,218	2,818,350
Due from Unexpended Plant Funds (Note 4)	11,782,413	2,067,223
Due from Investment in Plant (Note 4)	10,717,587	5,432,777
TOTAL ENDOWMENT AND SIMILAR FUNDS	$ 261,116,370	$ 176,950,714

LIABILITIES AND FUND BALANCES

	1983	1982
CURRENT FUNDS		
Unrestricted:		
Accounts Payable and Accrued Expenses	$ 5,477,267	$ 5,745,452
Collateral Deposits on Securities Loaned to Brokers	4,000,000	
Deposits and Deferred Revenues	3,081,210	2,472,936
Advance from Treasurer of Virginia (Note 7)	570,500	570,500
Accrued Leave (Note 6)	8,318,974	7,543,635
Due to Unexpended Plant Funds	1,870,494	537,334
Due to Reserve for Renewals and Replacements	79,115	79,115
Fund Balance	30,588,312	38,883,040
Total Unrestricted	53,985,872	55,832,012
Restricted:		
Accounts Payable and Accrued Expenses	980,285	666,558
Grant and Contract Prepayments	2,200,803	3,115,014
Accrued Leave (Note 6)	363,656	383,952
Due to Current Unrestricted Fund	1,362,131	1,337,123
Due to Loan Funds		101,790
Fund Balances	26,872,205	22,825,786
Total Restricted	31,779,080	28,430,223
TOTAL CURRENT FUNDS	$ 85,764,952	$ 84,262,235

	1983	1982
LOAN FUNDS		
Accounts Payable	$ 531	$ 569
Due to Current Unrestricted Fund	57,865	
Fund Balances:		
U.S. Government Grants Refundable	12,133,813	11,540,236
University Funds—Restricted	2,496,253	2,310,171
TOTAL LOAN FUNDS	$ 14,688,462	$ 13,850,976

	1983	1982
ENDOWMENT AND SIMILAR FUNDS		
Collateral Deposits on Securities Loaned to Brokers	$ 3,550,305	$ 8,138,800
Notes Payable (Note 8)	15,000,000	7,500,000
Bonds Payable (Note 8)	14,109,424	6,919,443
Investments Held for Foundations	2,235,131	
Due to Current Unrestricted Fund	52,099	54,418
Due to Current Restricted Funds	101,133	110,486
Fund Balances:		
Endowment	82,927,052	56,854,146
Term endowment	707,258	911,417
Quasi-endowment—Unrestricted	71,235,290	47,074,970
Quasi-endowment—Restricted	71,198,678	49,387,034
TOTAL ENDOWMENT AND SIMILAR FUNDS	$ 261,116,370	$ 176,950,714

Balance Sheet (Continued)
As of June 30, 1983
With Comparative Figures for 1932

ASSETS

	1983	1982
LIFE INCOME FUNDS		
Investments at Market Value (Note 4)	$ 606,903	$ 272,103
TOTAL LIFE INCOME FUNDS	$ 606,903	$ 272,103
PLANT FUNDS		
Unexpended:		
Cash and Temporary Investments	$ 31,302,248	$ 16,371,929
Appropriations Receivable	9,241,254	5,480,732
Accounts Receivable	93,236	295,548
Due from Current Unrestricted Fund	1,870,494	537,334
Total Unexpended	42,507,232	22,685,543
Renewals and Replacements:		
Cash and Temporary Investments	11,457,801	3,537,896
Due from Current Unrestricted Fund	79,115	79,115
Total Renewals and Replacements	11,536,916	3,617,011
Retirement of Indebtedness:		
Cash and Temporary Investments	1,016,427	313,065
Investments with Treasurer of Virginia	2,118,668	2,092,754
Prepaid Expenses	10,587	20,625
Total Retirement of Indebtedness	3,145,682	2,426,444
Investment in Plant:		
Land	10,890,963	8,817,870
Land Improvements	24,508,397	14,743,526
Buildings	180,263,191	162,612,872
Equipment	94,202,800	88,558,385
Construction in Progress	15,600,348	19,206,652
Total Investment in Plant	325,465,699	293,939,305
TOTAL PLANT FUNDS	$ 382,655,529	$ 322,668,303
AGENCY FUNDS		
Cash and Temporary Investments—Health Services Foundation	$ 1,649,075	$ 1,847,574
Cash and Temporary Investments—Other	1,947,042	545,934
TOTAL AGENCY FUNDS	$ 3,596,117	$ 2,393,508

LIABILITIES AND FUND BALANCES

	1983	1982
LIFE INCOME FUNDS		
Fund Balances	$ 606,903	$ 272,103
TOTAL LIFE INCOME FUNDS	$ 606,903	$ 272,103
PLANT FUNDS		
Unexpended:		
Accounts Payable	$ 2,774,005	$ 1,077,682
Bonds Payable (Note 8)	4,262,194	
Security Deposits	50,000	50,000
Due to Endowment and Similar Funds (Note 4)	11,782,413	2,067,223
Fund Balances	23,638,620	19,490,638
Total Unexpended	42,507,232	22,685,543
Renewals and Replacements:		
Accounts Payable	470	47,070
Fund Balances	11,536,446	3,569,941
Total Renewals and Replacements	11,536,916	3,617,011
Retirement of Indebtedness:		
Fund Balances	3,145,682	2,426,444
Total Retirement of Indebtedness	3,145,682	2,426,444
Investment in Plant:		
Installment Purchases Payable (Note 8)	1,033,842	657,127
Advance from Treasurer of Virginia		2,018,500
Bonds Payable (Note 8)	19,575,640	16,925,903
Loans Payable to Current Unrestricted Fund (Note 8)	1,516,051	2,171,446
Loans Payable to Endowment and Similar Funds (Note 8)	2,554,218	2,818,850
Due to Endowment and Similar Funds (Note 4)	10,717,587	5,432,777
Capitalized Lease Purchases Payable (Note 8)	561,543	1,012,105
Net Investment in Plant	289,506,818	262,902,597
Total Investment in Plant	325,465,699	293,939,305
TOTAL PLANT FUNDS	$ 382,655,529	$ 322,668,303
AGENCY FUNDS		
Deposits Held in Custody for Others—Health Services Foundation	$ 1,649,075	$ 1,847,574
Deposits Held in Custody for Others—Other	1,947,042	545,934
TOTAL AGENCY FUNDS	$ 3,596,117	$ 2,393,508

The accompanying Notes to Financial Statements are an integral part of this statement.

Statement of Changes in Fund Balances
For the Year Ended June 30, 1983

	Current Funds		
	Unrestricted	Restricted	Loan Funds
Revenues and Other Additions:			
Unrestricted Current Fund Revenues	$ 296,515,404		
State Appropriations—Restricted		$ 1,829,463	
Federal Grants and Contracts—Restricted		35,253,552	
State Grants and Contracts—Restricted		377,299	
Local Grants and Contracts—Restricted		118,921	
Private Gifts, Grants and Contracts—Restricted		16,830,269	$ 254
Endowment Income		8,987,455	65,043
Interest on Loans Receivable			238,123
U.S. Government Advances			500,326
Expended for Plant Facilities (including $15,598,501 charged to Current Fund)			
Retirement of Indebtedness			
Unrealized Gain on Investments			
Realized Gain on Investments			
Other Sources		696,014	
TOTAL REVENUES AND OTHER ADDITIONS	296,515,404	64,092,973	803,746
Expenditures and Other Deductions:			
Educational and General Expenditures	126,242,456	51,093,169	
Auxiliary Enterprise Expenditures	24,362,191		
Hospital Expenditures	126,249,181	165,665	
Independent Operations Expenditures	825,542		
Indirect Costs Recovered		8,022,316	
Loan Cancellations and Write-Offs			249,322
Administrative and Collection Costs			64,645
Expended for Plant Facilities (including $1,082,608 Not Capitalized)			
Retirement of Plant Facilities (Note 10)			
Retirement of Indebtedness			
Interest on Indebtedness			
Refunded to Grantors			
TOTAL EXPENDITURES AND OTHER DEDUCTIONS	277,679,370	59,281,150	313,967
Transfers Among Funds:			
Mandatory:			
Debt Service and Other	(2,220,187)	(55,600)	55,600
Non-mandatory:			
Debt Service and Other	(2,083,748)	(127,187)	
(To)/From Other Funds	(22,826,827)	(582,617)	234,280
TOTAL TRANSFERS	(27,130,762)	(765,404)	289,880
Net Increase (Decrease) for the Year	(8,294,728)	4,046,419	779,659
Fund Balance at Beginning of Year	38,883,040	22,825,786	13,850,407
Fund Balance at End of Year	$ 30,588,312	$ 26,872,205	$ 14,630,066

	Endowment and Similar Funds	Life Income Funds	Plant Funds			
			Unexpended	Renewals and Replacements	Retirement of Indebtedness	Investment In Plant
			$ 6,514,578			
	$ 3,697,844	$ 241,677	925,098			
			452,095			
						$ 30,059,329
						2,940,062
	48,455,941	29,690				
	16,420,128	63,433				
			116,658	$ 80,653	$ 507,494	
	68,573,913	334,800	8,008,429	80,653	507,494	32,999,391
			14,789,967	**753,469**		
						6,395,170
					2,940,062	
					1,542,524	
			76,317			
			14,866,284	753,469	4,482,586	6,395,170
					2,220,187	
			(196,342)	(66,866)	2,474,143	
	3,266,798		11,202,179	8,706,187		
	3,266,798		11,005,837	8,639,321	4,694,330	
	71,840,711	334,800	4,147,982	7,966,505	719,238	26,604,221
	154,227,567	272,103	19,490,638	3,569,941	2,426,444	262,902,597
	$ 226,068,278	$ 606,903	$ 23,638,620	$ 11,536,446	$ 3,145,682	$ 289,506,818

The accompanying Notes to Financial Statements are an integral part of this statement.

Statement of Current Funds Revenues, Expenditures And Other Changes For the Year Ended June 30, 1983 With Comparative Figures for 1982

	Year Ended June 30, 1983			Year Ended June 30, 1982*
REVENUES	Unrestricted	Restricted	Total	Total
Student Tuition and Fees	$ 36,902,487		$ 36,902,487	$ 30,441,564
State Appropriations—Hospitals	20,567,530		20,567,530	19,287,290
State Appropriations—Current Operations	75,404,848	$ 1,855,963	77,260,811	72,016,712
Federal Grants and Contracts	7,634,183	29,700,200	37,334,383	38,896,317
State Grants and Contracts	3,054	102,924	105,978	102,982
Local Grants and Contracts	11,825	159	11,984	272,262
Private Gifts, Grants and Contracts	1,059,425	15,119,900	16,179,325	12,069,415
Endowment Income	3,976,016	4,181,668	8,157,684	7,148,135
Sales and Services of Educational Departments	2,273,600		2,273,600	2,465,847
Sales and Services of Auxiliary Enterprises	30,128,170		30,128,170	27,374,748
Sales and Services of Hospitals	109,952,438		109,952,438	96,462,062
Sales and Services to Independent Operations	1,162,748		1,162,748	1,131,757
Other Sources	7,439,080	353,620	7,792,700	5,954,181
Total Current Revenues	296,515,404	51,314,434	347,829,838	313,623,272
EXPENDITURES AND MANDATORY TRANSFERS				
Educational and General:				
Instruction	64,313,517	8,523,280	72,836,797	64,647,068
Research	2,802,727	28,349,299	31,152,026	28,816,179
Public Service	1,443,145	1,895,877	3,339,022	4,510,234
Academic Support	22,038,285	2,511,407	24,549,692	21,915,880
Student Services	7,122,724	200,122	7,322,846	6,835,663
Institutional Support	12,835,769	17,552	12,853,321	12,635,126
Operation and Maintenance of Plant	13,790,200	4,178	13,794,378	13,803,755
Scholarships and Fellowships	1,896,089	9,591,454	11,487,543	10,596,581
Total—Educational and General	126,242,456	51,093,169	177,335,625	163,760,486
Mandatory Transfers for Debt Service and Other		55,600	55,600	37,200
Total—Educational and General Expenditures and Mandatory Transfers	126,242,456	51,148,769	177,391,225	163,797,686
Auxiliary Enterprises:				
Operating Expenditures	24,362,191		24,362,191	22,933,521
Mandatory Transfers for Debt Service	1,795,187		1,795,187	1,688,153
Total—Auxiliary Enterprise Expenditures and Mandatory Transfers	26,157,378		26,157,378	24,621,674
Hospitals	126,249,181	165,665	126,414,846	112,791,529
Independent Operations:				
Operating Expenditures	825,542		825,542	772,499
Mandatory Transfers for Debt Service	425,000		425,000	495,832
Total—Independent Operations Expenditures and Mandatory Transfers	1,250,542		1,250,542	1,268,331
Total—Expenditures and Mandatory Transfers	279,899,557	51,314,434	331,213,991	302,479,220
OTHER TRANSFERS AND ADDITIONS/(DEDUCTIONS)				
Excess of Restricted Receipts over Transfers to Revenues		4,756,223	4,756,223	7,697,063
Refunded to Grantors				(2,894)
Private Clinic Balances to Health Services Foundation				(931,784)
Accrued Leave				(7,927,587)
Non-Mandatory Transfers:				
To Endowment and Similar Funds	(2,537,256)	(727,615)	(3,264,871)	(2,471,288)
To Loan Funds		(234,280)	(234,280)	(166,298)
To Plant Funds	(22,038,332)	(82,896)	(22,121,228)	(7,061,123)
To Current Restricted Funds	(334,987)	334,987		
Net Increase (Decrease) in Fund Balances	$ (8,294,728)	$ 4,046,419	$ (4,248,309)	$ 280,141

*Certain 1982 amounts have been redistributed to conform to 1983 expenditure classifications.

The accompanying Notes to Financial Statements are an integral part of this statement.

Notes to the Financial Statements

Note 1: Summary of significant accounting policies

The accompanying financial statements include the accounts of all organizational units of the University of Virginia including the University Division, the University Hospital, the Blue Ridge Hospital Division, the Division of Continuing Education and Clinch Valley College. The significant accounting policies of the University are as follows:

a. Basis of accounting

The University has adopted the accrual basis of accounting in accordance with the American Institute of Certified Public Accountants' Audit Guide for Colleges and Universities. Accruals for interest on student loans and bond interest payable have not been recorded and are not considered by management to be material. Effective July 1, 1982, the University changed its method of recording endowment investment income to an accrual basis. Prior years' accruals were not considered by management to be material. The University follows the practice of recording gifts and pledges when collected. No value is assigned to art and other collections received as gifts.

Non-faculty salaried employees' attendance and leave regulations make provision for the granting of a specified number of days of leave with pay each year. The amount of leave earned but not taken is recorded on the balance sheet.

b. Fund accounting

In order to ensure observance of limitations and restrictions placed on the use of resources available to the University, the accounts of the University are maintained in accordance with the principles of fund accounting. The accounts relating to specified activities or objectives have been classified into separate funds. Similar funds have been combined for financial reporting purposes.

Within each fund group, fund balances restricted by outside sources are so indicated and are distinguished from unrestricted funds allocated to specific purposes by action of the Board of Visitors. Restricted resources may only be used for the purposes established by the source of such funds.

Restricted gifts, appropriations, endowment income and other restricted sources are accounted for in the appropriate restricted funds. Restricted funds are reported as revenues and expenditures when expended for current operating purposes.

All gains and losses arising from the sale, collection, or other disposition of investments and other noncash assets are accounted for in the fund which owned such assets. Ordinary income derived from investments, receivables, and the like is accounted for in the fund owning such assets, except for income derived from investments of endowment and similar funds, which income is accounted for in the fund to which it is restricted or, if unrestricted, as revenues in unrestricted current funds.

c. Inventories

Inventories are valued at the lower of cost (generally determined on the first-in, first-out method) or market.

d. Investments

Temporary investments and endowment fund investments in corporate stocks and marketable bonds are recorded at market value. Mortgages held for investment by the endowment fund are recorded at book value representing principal amounts due. Investments in real estate (included in "Miscellaneous" in Note 4) are recorded at book value.

e. Net investment in plant

Plant assets are stated at actual or estimated cost at date of acquisition. Construction is capitalized as expended and reflected in net investment in plant. Current fund expenditures of $10,000 or greater for renewals and replacements are capitalized only to the extent that such expenditures represent long-term improvements to properties or significantly enhance the usefulness of the properties.

University Division current fund expenditures for equipment are capitalized when the unit acquisition cost is $500 or greater and the estimated useful life is two years or more. Effective July 1, 1982 the Hospital and Blue Ridge Divisions changed their capitalization limit from $300 to $500. Clinch Valley College current expenditures for equipment are not capitalized. Current fund expenditures for library acquisitions have not been capitalized.

The accompanying financial statements include no provision for depreciation of plant assets.

f. Due to/from other funds

Interfund advances represent the temporary use of current funds pending the receipt of monies from grants, loan agreements or the receipt of pledged gifts from various donors.

g. Funds held in trust by others

Assets of funds held by trustees for the benefit of the University are not reflected in the accompanying balance sheet. The University has irrevocable rights to all or a portion of the income of these funds. However, assets of the funds are not under the management discretion of the University according to the trust agreements. The following table reflects the market value of these funds at June 30, 1983 and 1982, and the amount of income received from their trustees during the years then ended:

	1983	1982
Market value of funds held by trustees for the benefit of the University	$ 53,230,121	$ 38,185,318
Income received from funds held by trustees for the benefit of the University	$ 2,740,003	$ 2,332,750

h. Affiliated Foundations

Assets of affiliated foundations which are separately incorporated and managed by their own boards are not included in these statements. These Foundations are organized as fund-raising activities which either support the University or benefit specific schools. Income received from such foundations is recorded as a gift when received.

The University of Virginia Health Services Foundation, whose Board includes officers of the University, is described in Note 3.

Note 2: Estimated amounts due on settlement with third party payors

The University Hospital provides services to patients under reimbursement agreements with third party payors. Reimbursements under certain agreements are determined on the basis of the cost of providing services to patients covered by these plans, subject to certain limitations, and are subject to audit and retroactive adjustment. Provisions for possible adjustments of cost reports have been reflected in the accompanying financial statements as considered appropriate.

For each of the five years ended June 30, 1982, the Hospital's Medicare and Medicaid cost reimbursement has been subject to a limitation on in-patient general routine service costs arising from the classification as a "non-urban" hospital. During this period, actual costs based on cost reports filed, or adjusted as appropriate, exceed this limitation by an aggregate of approximately $4,800,000 which is not included as a receivable in the accompanying financial statements. The Hospital has submitted a request to the Health Care Financing Administration (HCFA) for relief from such limitations under various exemptions or exceptions as provided by Medicare and Medicaid regulations. The University expects that the request for relief will be approved, in some degree, resulting in the recoveries of certain costs for the fiscal years 1978 through 1982.

Note 3: Health Services Foundation

The University of Virginia Health Services Foundation, a non-profit educational, scientific and charitable organization, was established by the Board of Visitors as of June 30, 1980 to assist the University in providing hospital and medical care services, medical education programs, medical research and programs of public charity at the University of Virginia. Except as noted, the financial statements do not include the assets, liabilities and equity of the Health Services Foundation.

Following is a condensed summary of the financial condition of the Health Services Foundation as of June 30, 1983 and 1982:

Assets	1983	1982
Cash and Investments	$ 14,586,000	$ 13,954,000
Other Assets	11,638,000	9,545,000
Total Assets	$ 26,224,000	$ 23,499,000
Liabilities and Fund Balances		
Liabilities	$ 7,493,000	$ 8,140,000
Fund Balances	18,731,000	15,359,000
Total Liabilities and Fund Balances	$ 26,224,000	$ 23,499,000

The revenues and expenditures for the Health Services Foundation were $52,810,000 and $49,736,000, respectively, in 1983 and $44,241,000 and $44,035,000, respectively, in 1982.

Fund balances of the Clinic-Private Division as of July 1, 1981 totaling $932,000 were transferred during 1981-82 from the University to the Foundation. During 1982-83 and 1981-82 the University acted as fiscal agent for the Foundation and held in custody for the Foundation $1,649,000 and $1,848,000 as of June 30, 1983, and June 30, 1982, respectively.

The Foundation has contracted with the University for the provision of office space and certain administrative services and has reimbursed $97,000 and $114,000, respectively, for these items in 1982-83 and $93,000 and $158,000, respectively, for these items in 1981-82. In addition to the contracted services, the Foundation reimbursed the University for other administrative services of $1,443,000 for 1982-83. The Foundation paid the University of Virginia Hospital $2,764,000 in 1982-83 and $1,076,000 in 1981-82 for costs associated with certain clinical operations. The University of Virginia Hospital has contracted with the Foundation for the provision of supervisory and administrative services. The amounts paid to the Foundation for such services in 1982-83 and 1981-82 were $9,298,000 and $7,292,000, respectively.

Note 4: Valuation and performance of endowment and similar funds and life income funds

Investments of endowment and similar funds and life income funds are composed of the following:

	June 30, 1983 Market Value	June 30, 1983 Cost
Endowment and Similar Funds:		
Corporate Stocks	$ 136,832,574	$ 78,650,690
Bonds	27,788,149	27,186,121
Mortgages	28,391,690	28,391,690
Miscellaneous	3,748,445	3,707,592
Cash and Short Term Investments	36,203,399	36,525,428
	$ 232,964,257	$ 174,461,521
Life Income Funds:		
Corporate Stocks	$ 409	$ 1
Bonds	228,243	220,387
Cash and Short Term Investments	378,251	378,251
	$ 606,903	$ 598,639

	June 30, 1982 Market Value	June 30, 1982 Cost
Endowment and Similar Funds:		
Corporate Stocks	$ 96,613,712	$ 83,347,176
Bonds	19,647,320	22,388,830
Mortgages	21,254,256	21,254,256
Miscellaneous	3,758,339	3,737,507
Cash and Short Term Investments	23,619,259	23,618,322
	$ 164,892,886	$ 154,846,091
Life Income Funds:		
Corporate Stocks	$ 75,368	$ 71,987
Bonds	194,785	219,592
Cash and Short Term Investments	1,950	1,950
	$ 272,103	$ 293,529

Included in endowment investments are real estate mortgages amounting to $12,822,185 and $12,466,432 at June 30, 1983 and 1982, respectively, which are held by Virginia National Bank as trustee under a bond indenture agreement related to bonds issued in 1972. These real estate mortgages are pledged as security for the outstanding bonds of $6,609,424 and $6,919,443 at June 30, 1983 and 1982, respectively. Under the terms of the agreement, the principal and interest payments on the mortgages are collected by the trustee and, in turn, used to pay the principal and interest on the bonds outstanding.

The University of Virginia, pursuant to a resolution adopted by the Board of Visitors on March 22, 1980, has issued $7,500,000 in Telephone Bonds of 1983. The proceeds of the sale of the Bonds constitute a part of the University's Endowment Funds. After payment of the cost of issuance of the Bonds, monies were used to purchase a telephone communications system to replace the leased telephone system formerly used by the University in Charlottesville. In order to reimburse the Endowment Fund for the cost of the system, the University has deposited its special obligation promissory note (the "System Note") in the principal amount of $7,500,000 in the Endowment Fund and pledged the System Note to secure the bonds.

The University of Virginia, pursuant to a resolution adopted by the Board of Visitors on January 27, 1983, has issued $15,000,000 in Endowment Fund Demand Revenue Notes of 1983 (the "Capital Projects Loan"). The proceeds of these notes will be used to finance, on a temporary basis, the acquisition, construction and renovation of fixed assets. The Notes are limited obligations of the University and are secured by, and payable exclusively from, the University's Unrestricted Quasi-Endowment Fund.

The major portion of the investments of the endowment and similar funds are pooled under two major funds. The Consolidated Endowment Fund is the general endowment pool for the University. On June 2, 1979 the University adopted an investment objective whereby the average annual return over the long-term would equal the rate of inflation, measured by the Consumer Price Index, plus its average level of spending from endowment income. The average annual return for the Consolidated Endowment Fund was 50.7% in 1983 and (13.1%) in 1982. These percentages have been computed using realized and unrealized gains and losses and endowment income at a weighted average market value.

The Eminent Scholars Fund is the second major pooled fund. The primary investment objective of this fund is to earn a current return which meets current spending requirements and maximizes participation by the Commonwealth of Virginia in the Eminent Scholars Program. A secondary objective is to provide growth in income equal to one-half the inflation rate. The average annual return for the Eminent Scholars Fund was 39.3% in 1983 and (2.1%) in 1982. These percentages have been computed using realized and unrealized gains and losses and endowment income at a weighted average market value.

In both funds, the investment objectives do not anticipate the expenditure of capitalized endowment income.

Both the Consolidated Endowment Fund and the Eminent Scholars Fund are pooled using a market value basis, with each individual fund subscribing to or disposing of units on the basis of the market value per unit at the beginning of the calendar month within which the transaction takes place. A summary of book and market values as of June 30, 1983 and 1982, together with unit value information and earnings per unit for the year then ended for the pooled funds is presented below:

	1983	1982
Separately Invested Funds		
Book value	$ 7,564,384	$ 7,581,388
Unrealized net loss	(306,591)	(977,195)
Market value	$ 7,257,793	$ 6,604,193
Consolidated Endowment Fund		
Book value	$ 146,225,797	$ 124,827,662
Unrealized net gain	55,847,795	11,204,789
Market value	$ 202,073,592	$ 136,032,451
Unit Values		
Number of units outstanding at June 30	494,099	476,774
Book value	$ 295.94	$ 261.82
Unrealized net gain	113.03	23.50
Market value	$ 408.97	$ 285.32
Average number of units outstanding during the year	484,064	466,960
Earnings per average unit outstanding (Exclusive of net gain)	$ 17.98	$ 17.12

	1983	1982
Eminent Scholars Fund		
Book value	$ 13,775,361	$ 11,771,722
Unrealized net gain (loss)	2,961,532	(180,799)
Market value	$ 16,736,893	$ 11,590,923
Unit Values		
Number of units outstanding at June 30	134,815	119,576
Book value	$ 102.18	$ 98.45
Unrealized net gain (loss)	21.97	(1.51)
Market value	$ 124.15	$ 96.94
Average number of units outstanding during the year	125,512	111,455
Earnings per average unit outstanding (Exclusive of net gain)	$ 9.45	$ 9.15

Note 5: Employee benefits

Substantially all full-time faculty and certain administrative staff participate in the University's retirement annuity program through TIAA/CREF Insurance Companies. This is a fixed-contribution program where the retirement benefits received are based upon the employer and employee contributions, plus interest and dividends. Individual contracts issued under the plan provide for full and immediate vesting of both the University's and the participants' contributions. Total pension costs under this plan were approximately $3,880,000 in 1983 and $3,612,000 in 1982.

All other full-time salaried employees are participants in the Virginia Supplemental Retirement System (VSRS). Guaranteed retirement payments under the VSRS plan are based on years of service and achieved salary levels. The employer's cost related to the VSRS retirement program was $6,273,000 in 1983 and $4,472,000 in 1982.

Note 6: Accrued leave

In accordance with Financial Accounting Standards Board (FASB) Statement No. 43, the University has recognized a liability of $8,682,630 for 1982-83 and $7,927,587 for 1981-82 for the amount of sick and annual leave earned but not taken as of June 30 of each year for its non-faculty salaried employees. The amount reflects, as of June 30, all earned vacation leave not taken and the amount payable under the Commonwealth of Virginia's sick leave payout policy upon termination which is the lesser of 25% of sick leave not taken or $2,500 per employee with five or more years of service.

Since the University cannot determine the amount of accrued leave attributable to prior years, the cumulative amount of accrued leave for June 30, 1982 of $7,927,587 is treated as an other deduction in the Statement of Current Funds Revenues, Expenditures and Other Changes for the year ended June 30, 1982. Changes in accrued leave attributable to 1982-83 have been treated as expenditures in the Statement of Current Funds Revenues, Expenditures and Other Changes for the year ended June 30, 1983. The University believes that the liability will be funded from future revenues.

Note 7: Temporary advance from Treasurer of Virginia

Temporary advance authorized by the Treasurer of Virginia to provide interim funding at June 30, 1983:

Current Funds:	
Imprest funds for payroll and other expenditures.	$ 570,500

Note 8: Long-term debt

Long-term debt at the University at June 30, 1983 consists of the following:

Plant Funds:	
Installment purchases payable over varying periods up to five years for the purchase of equipment.	$ 1,033,842
Loans payable to endowment funds represent loans for long-term financing of auxiliary enterprise facilities approved by the Board of Visitors with interest at 6%. Loans are payable over periods established by the Board of Visitors from 3 to 12 years. Repayment terms for loans amounting to $1,679,396 have not been established.	2,554,218
Loans payable to current unrestricted funds represent advances for periods of up to 5 years for construction of several facilities approved by the Board of Visitors with either no interest or a variable rate of one-half of the prime rate plus one-half of 1%.	1,516,051
Commonwealth of Virginia bonds issued by the Treasurer of Virginia pursuant to the provisions of Section 9(c) of Article X of the Constitution of Virginia. This subsection provides that the General Assembly may authorize the creation of debt secured by a pledge of net revenues derived from rates, fees or other charges and the full faith and credit of the Commonwealth, provided that such debt is created for specific revenue producing capital projects of, among others, institutions of higher learning of the Commonwealth. Bonds are payable over periods of 1 to 20 years and bear interest at rates ranging from 3.5% to 12%.	19,480,000
University of Virginia Revenue Bonds are payable over 1 to 9 years, with interest from 3.25% to 3.6%.	3,220,000
Other bonds including $911,000 of the Department of Housing and Urban Development supported issues with interest rates from 2.88% to 6% are payable over periods up to 36 years.	1,137,834
Capitalized lease purchases payable for additions to plant and equipment.	561,543
Endowment Funds:	
Faculty Mortgage Revenue Bonds with interest rates from 4.3% to 5.5%. These bonds are payable in installments to maturity in 1997.	6,609,424
Telephone Bonds of 1983, payable over 1 to 9 years, with interest from 8% to 8.75%.	7,500,000
Capital Projects Loan, with a variable interest rate (one-half of prime plus one-half percent), payable in 1986.	15,000,000
	$ 58,612,912

Long-term debt matures as follows:

1983-84	$ 3,524,373
1984-85	3,507,394
1985-86	18,313,940
1986-87	3,102,605
1987-88	3,233,593
Later Years	26,931,007
	$ 58,612,912

Note 9: Commitments

At June 30, 1983, the University was a party to construction contracts and commitments totaling approximately $32,966,353 of which $13,822,076 has been incurred. Pledges outstanding relating to plant construction aggregated $4,041,963.

The University occupies certain buildings and uses various types of equipment under lease arrangements. Commitments for subsequent fiscal years are as follows:

1983-84	$ 1,845,335
1984-85	1,157,184
1985-86	395,050
1986-87	242,736

The total rental expense for all property and equipment was approximately $4,693,400 and $5,301,130 for fiscal years ended June 30, 1983 and 1982, respectively.

Note 10: Inventory and valuation of hospital building and equipment

A physical inventory of buildings and equipment was conducted as of July 1, 1982 for the Hospital and Blue Ridge Divisions. The inventory was undertaken in order to update existing fixed asset records and establish a detailed information and accounting system.

As of July 1, 1982 the Hospital and Blue Ridge Divisions changed their capitalization limit for equipment from $300 to $500. Fully depreciated equipment costing less than $500 was not inventoried and has been removed from the fixed asset records.

Following is a summary of the adjustments made as of July 1, 1982, to bring balance sheet costs into agreement with supporting inventory records.

Division	Net Decrease in Investment in Plant
Hospital	$ 5,188,775
Blue Ridge	73,208
	$ 5,261,983

CAVALIER Training and Research Reactor
Annual Operating Costs
1984/85 Estimate

Personnel:	
Senior Nuclear Reactor Operator (100%)	$20,117
Nuclear Reactor Operator Supervisor (15%)	4,836
Subtotal	$24,953
Fringe Benefits	6,238
Supplies	2,000
Total Annual Operating Costs	$33,191

Over the next five years these costs will remain consistent. However, they will increase due to (yet to be determined) across the board salary raises mandated by the State of Virginia and price increases of supplies.

Future budgets of the Department of Nuclear Engineering and Engineering Physics will include sufficient funds (as requested by the Department's Chairman and approved by the Dean of the School of Engineering and Applied Science) for safe operation of the CAVALIER or sufficient funds to decommission the CAVALIER.

Signed: Jeanne M. Hammer
Jeanne M. Hammer
Budget Officer
School of Engineering and
Applied Science