



AUSTRALIAN ATOMIC ENERGY COMMISSION
RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

REACTOR HIFAR - THE SAFETY ROD SYSTEM

by

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ABSTRACT

This manual describes the Safety Rod System of the reactor HIFAR.

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Figure 1 Location of Controllers, Reactor HIFAR

Figure 2 Operating Range of Safety Rods

Figure 3 Safety Rod Assembly

Figure 4 Gear Box and Motor for Safety Rod

1. INTRODUCTION

This manual, describing the safety rods, is one of a series on the control, instrumentation and safety circuits of the reactor HIFAR with titles as in Appendix 1. The general reference is AAEC/M1 'Reactor HIFAR: An Introduction to the Guard and Safety Circuits'.

2. THE SAFETY ROD SYSTEM

2.1 General Description

In addition to the six coarse control arms in HIFAR, (AAEC/M30), there are two vertically operating safety rods which guard against an unforeseen gain in reactivity, particularly during a reactor shutdown. They are located just outside the reactor core (Figure 1).

Each rod is capable of inserting $800 \frac{\text{cm}^2}{\text{in}^2}$ of cadmium into the reactor core, corresponding to absorption of approximately 1 per cent of reactivity. Thus the two rods make available approximately 2 per cent of reactivity absorption for a core content of 3.0 kg U-235 and relatively low coarse control arm angles.

A stainless steel cable is connected to each rod and wound around a drum driven by a small constant speed electric motor through reduction gearing, with a magnetic clutch between the cable drum and the motor drive. Each rod is raised to its upper limit by the electric motor drive and then held suspended ready to fall. The magnetic clutch is de-energised to give fast release of the cable drum, freeing the cable and allowing the rod to fall freely in response to the action of the safety circuits. Under gravity it will fall into the reactor in approximately 1.5 seconds. Kinetic energy due to the free fall is absorbed by a retardation cam and spring arrangement operated by projections from the drum face. This also reduces the rate of fall during the last few inches of travel. The safety rod has a collapsible nose to absorb the energy of the fall and prevent excessive damage if the cable should break.

Limit switches at each end of the travel of the safety rod operate indicator lamps in the Control Room and are used in the safety rod circuitry. (See AAEC/M9). A potentiometer in each gearbox gives an instantaneous indication of safety rod position on Panel 3 in the Control Room.

Although the safety rods move in thimbles in the reactor, no special cooling is required because the rods are normally fully out of the reactor and are only fully in while the reactor is in the COMPLETE SHUTDOWN state. The heat generated in each rod is estimated not to exceed 15 watts. The operating range of the safety rods is shown in Figure 2.

If the DROP SAFETY RODS button should be depressed, or either a SCRAM or COMPLETE SHUTDOWN condition is initiated while the reactor is operating, both safety rods will be released to fall into the core.

If the DROP SAFETY RODS button should be depressed or if loss of shutdown margin, that is, greater than 10^4 watts registered on the log power recorder, should occur while the reactor is shut down, both safety rods will be released to fall into the core. Operation of the Master Switch in the Safety Rod Control Unit to the DROP position will also release the rods. In addition, if, while the reactor is shut down, the control instrumentation indicates a condition that would initiate a SCRAM or COMPLETE SHUTDOWN during reactor operation, both safety rods will be released to fall into the core.

The circuits involved for all conditions in which the safety rods would be dropped are described in AAEC/M2, 'Reactor HIFAR, The Scram and Complete Shutdown Circuits' and AAEC/M9 'Reactor HIFAR - Safety Rod Circuits'.

The main features in the design of the safety rod control circuits were:

- (a) that each rod should be controlled independently by a separate mechanism,
- (b) that the rods be required to have two rest positions only:
 - (i) completely down, that is, in the core, and
 - (ii) up, that is, withdrawn from the core, and
- (c) that either rod should be held in the UP position only if its magnetic clutch is energised.

Under normal conditions both safety rods will be completely withdrawn from the core. It is essential that both rods be in this position before making any changes which might affect the state of the reactor. The associated circuits provide electrical interlocks to prevent any movement of any control element unless the safety rods are withdrawn. However, it should be noted that it has not been practicable to include any positive interlock to prevent interference with the reactor fuel elements when the safety rods are down.

Complete information about the design of a safety rod, the actuating mechanisms, the performance data of components and other relevant points is given in 'Design Summary for Control System, Reactor E443 - Safety Rods' by H.M. Hobson Ltd., Wolverhampton, U.K. (1957).

2.2 Details of Main Components (See Figures 3 and 4)

2.2.1 Safety rod and thimble

A safety rod consists of a cylindrical cadmium absorber housed vertically between two concentric stainless steel sheathing tubes with a cable attachment plug fastened two thirds of the way down the bore of the inner sheath. The cadmium and sheathing slide up and down in an aluminium thimble guided by the central, stainless steel, lower end of the shield plug assembly. The upper end of the shield plug assembly is made of heavy iron-shot concrete held within a steel tubular container. The cadmium portion is 30 inches long, 0.080 inch thick and formed from a sheet 4.88 inches wide. The cadmium area provided by the two safety rods in the effective core depth of 24 inches is 1512 cm^2 . The stainless steel cable connecting the safety rod to the winding drum is pre-stretched.

The thimble (or static sleeve container) has 4 parts; the locating adaptor, the upper static sleeve, the lower static sleeve and the locating pin assembly. These are welded together to form a closed thimble.

The shield plug assembly also contains the shield plug cap which forms the base for the pulley bracket mounting and houses the CO₂ purging channel and the helium leak test probe channel. A square section seal on the upper shoulder of the lower shield plug is loaded by cable tension pulling the upper face on to the seal.

2.2.2 Motor and gearbox

The two gear boxes are mounted under a channel structure in the gallery at the top of the reactor, and are installed in diagonally opposite positions outside the biological shield.

Each gearbox comprises a small synchronous motor which drives the cable winding drum through two worm/wormwheel sets and one set of spur reduction gears. A branch drive of 3 spur gears actuates the limit switch operating cams which cause the motor to cut out at top rod position and also operate the light indicators when the rod is below the 54 inch down position. After 59.06 inches total fall (and assuming no cable break) the lower edge of the cadmium is 5.06 inches below the bottom of the reactor core. The rod is then at the lowest IN position. The duplicated lower limit switches act when the lower edge of the cadmium is level with the bottom of the reactor core.

For full lift, the rod is raised to its top OUT position when the lower edge of the cadmium is at heavy water level (that is, 59 inches below the datum level of the master plate above the top shield). When the rod reaches this outer position one of the three up limit switches operates to cut out the motor.

The branch train primary shaft also drives a linear wound potentiometer, which operates indicators in the safety rod control unit in the Control Room.

The motor speed and overall reduction gearing is arranged so that the rod is withdrawn from the IN position to the OUT position in 8.21 minutes.

The rod starts to be arrested after a free fall of 46 inches, is decelerated for approximately the next 13 inches to the extreme down position (without cable break) and is finally brought to rest by compression springs housed in the gearbox, at 54.06 inches nominal DOWN position. The inertia of the winding drum is overcome by these springs in the gearbox and this tends to prevent slackening of the cable.

The magnetic clutch is housed within the winding drum and is a 50 volt d.c. plate type which gives a minimum holding load of 50 lb tangential to the drum rim. A transmission sleeve is driven by the clutch and drives both the cable drum and the transmission shaft to the limit switch and position indicator branch gear train. This arrangement permits axial movement of the cable drum relative to the transmission shaft to monitor the line of action of the cable.

Towards the end of the winding drum axial travel, a stop on its forward face engages with a stop on the retardation cam at a point where the rod is 8 inches from its final position. The retardation cam is then driven around and lifts a steel roller which is bearing against it and which is spring loaded by a cast iron lever with two pairs of concentric springs attached to its outer end. This arrangement absorbs the energy of the fall and the rotational inertia of the system as well as controlling the deceleration forces.

2.2.3 Limit switches and safety rod position

The following is a summary of the relation of the limit switches to the safety rod position:

Position	Distance of Safety Rod Fall (inches)	Length of Safety Rod in Core (inches)
Fully up (safety rod against shield plug)	0.1	—
Clutch slipping (cable drum on upper stop in gearbox)	—	—
Third top microswitch operates to cut motor	0.6	—
First two top microswitches operate	0.6	—
Retardation cam engages	46.0	16
Bottom two microswitches operate	54.0	24
Final rest position	54.06	24
Extreme down position (broken cable)	59.06	24
Position at maximum height of bounce	50.56	17.56

The incorporation of the limit switches in the associated circuits is described in AAEC/M9.

2.2.4 Control unit and position indicators

The safety rod control unit, located on Panel 3 in the Control Room contains the DROP – RAISE – HOLD switch known as the Reactor Master Switch, and which is common to both safety rod circuits for simultaneous operation.

The safety rod control unit also contains for each rod:

- (a) A meter position indicator operating from the linear wound potentiometer driven by gearing from the winding drum shaft in the gearbox. Its range of –10 to +150 cm (63.0 in) covers the complete travel of the rod including overshoot of the rod following its free fall from the UP position.
- (b) Lamp indication as follows:
 - UP – operated by an upper limit switch
 - DOWN – operated by a bottom limit switch
 - RISING – controlled by an appropriate motor relay.
This lamp is also referred to as an IN TRANSIT lamp and operates only as its rod is being withdrawn from the core.

Additional shutdown lamps are provided in the Control Room on Panel 5 and the Trip Annunciator Panel to show when both rods are not completely withdrawn from the core.

3. CONTROL

3.1 Operation

Detailed operation of the circuits associated with the Safety Rod System is given in AAEC/M9.

In operation the two rods are controlled in parallel, although the control circuits remain independent of each other so that any fault in one circuit does not invalidate safety action by the other.

The clutch circuit of each rod is established via relay contacts and switches which require certain conditions to be satisfied before either safety rod can be raised.

These conditions are:

- (a) All COMPLETE TRIP guard conditions must be safe and the guard circuit monitoring relays X-P1, X-P2, X-Z1 and X-Z2 must be energised.
- (b) The safety rod release relay B3-B must be energised.
- (c) All the coarse control arms must be in the down position.
- (d) Lockout Switch No. 2 must be in the operational position.
- (e) Initially the safety rod itself must be down. (This condition is included to check that nothing has prevented the free and complete drop of the safety rod on a previous occasion).

If the above listed conditions are realised then the operation of the Master Switch in the safety rod control unit on Panel 3 into the RAISE position completes the circuits to the electromagnetic clutches.

The conditions which must be satisfied to hold the safety rods up depend on the position of the Master Switch as discussed in AAEC/M9.

3.2 Maintenance

Each safety rod mechanism can be tested separately by using a maintenance switch installed next to each unit. The maintenance switches are operated by HIFAR key No. 3 which, under operational conditions, is trapped in lockout Switch No. 2.

If, when the reactor is shut down, the Lockout Switch No. 2 is rotated to the position labelled SAFETY RODS the key can be withdrawn and used in conjunction with either of the Safety Rod Maintenance Units in the reactor gallery. Provided both safety rods are already up, it is then possible to lower or raise either safety rod, one at a time, from the reactor gallery adjacent to the appropriate safety rod gear box.

4. ACKNOWLEDGEMENT

This manual includes material from a draft prepared by the late G. Page.

APPENDIX

REACTOR HIFAR – LIST OF INSTRUMENTATION MANUALS

EXPLANATORY NOTE

The status of titles that have not been issued at June 1969 is indicated by the following marks:

- * In draft form
- * Not issued
- Title and serial number cancelled.

- M1 Introduction to HIFAR Guard and Safety Circuits
- M2 Complete Shutdown Circuits
- M3 Trip Circuits
- M4 Control Reversal Circuits
- M5 Warning Circuits
- * M6 Primary Search Unit
- M7 Start Guard Circuits
- * M8 Flux Trip Circuits
- * M9 Safety Rod Circuits
- * M10 Coarse Control Arm Circuits
- M11 Fine Control Rod Circuit
- M12 Dump Valve Circuit
- M13 Main Heavy Water Pump Circuit (S1)
- M14 Shutdown Heavy Water Pump Circuit (S2)
- * M15 Liquid Level Pump Circuits (S3 and S4)
- * M16 Main H₂O Pump Circuits (S6)
- * M17 H₂O Shutdown Circuits (S8)
- * M18 Cooling Tower Fan Circuits (G8)
- * M19 Shield Cooling Pump Circuits (S7)
- M20 Experimental Pump Circuits (S9)
- M21 Fine Control Rod Pump Circuits (S14)
- * M22 Miscellaneous Circuits
 - 24V circuits 4-LLA-10 circuit
 - 50V d.c. circuits 4-L-15 circuit
 - 240V circuits Panel N
- M23 Trip and Warning Alarm Circuits
- * M24 Ventilation Flow Diagram Circuit
- * M25 Main Flow Diagram and Cooling Tower Lamp Circuits
- * M26 Annunciator Lamp Circuits
- * M27 Fault Analysis Lamp Circuits
- * M28 Principles of Operation of the Nucleonic Instruments

(continued)

APPENDIX (continued)

- M29 The Control Room
- M30 The Coarse Control System
- M31 The Fine Control System
- M32 The Safety Rod System
- M33 Fine Control Drive System
- M34 Leak Detectors
- * M35 Modifications for Low Power Operation
- * M36 Recorders
- M37 Physical Instrumentation of HIFAR
- * M38 Ionisation Chambers and Health Monitors
- M39 Test Schedule for Guard, Safety, and Interlock Circuits

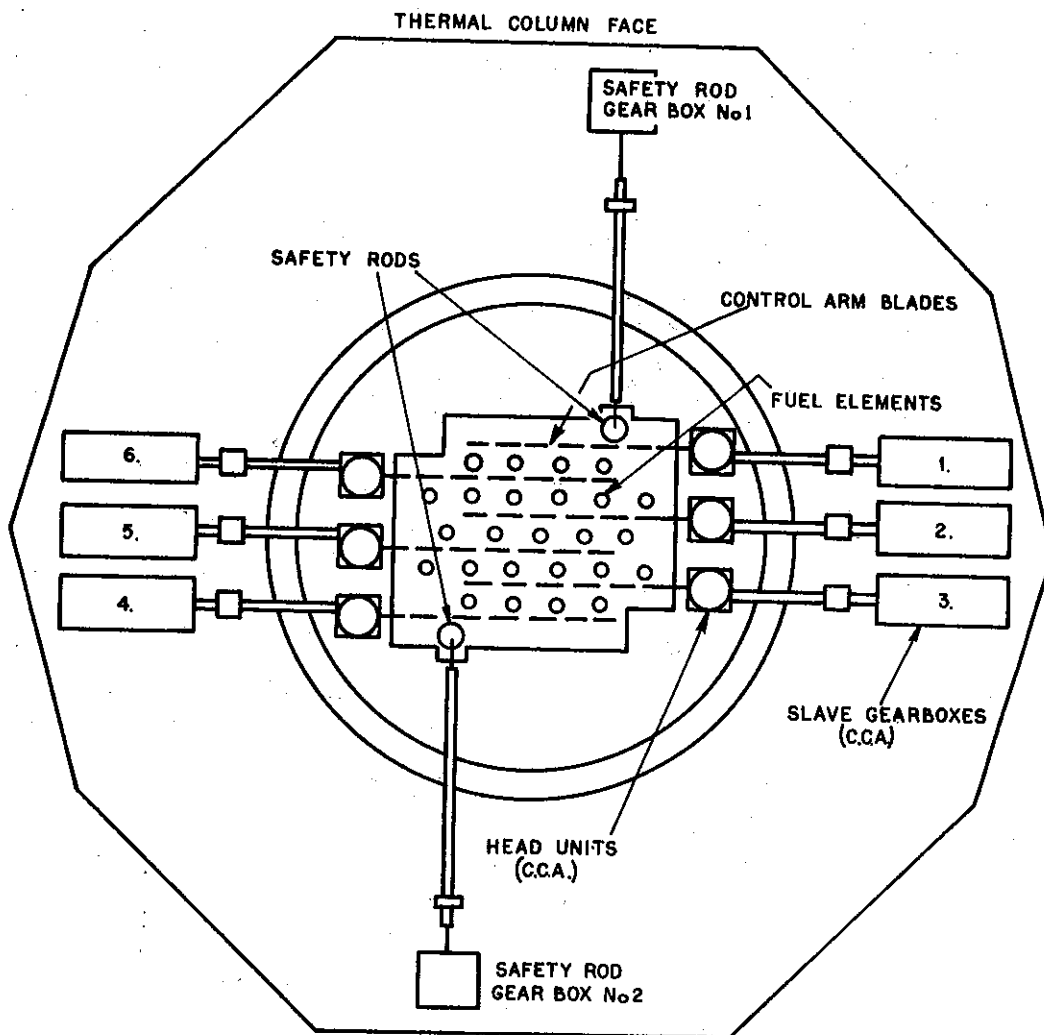
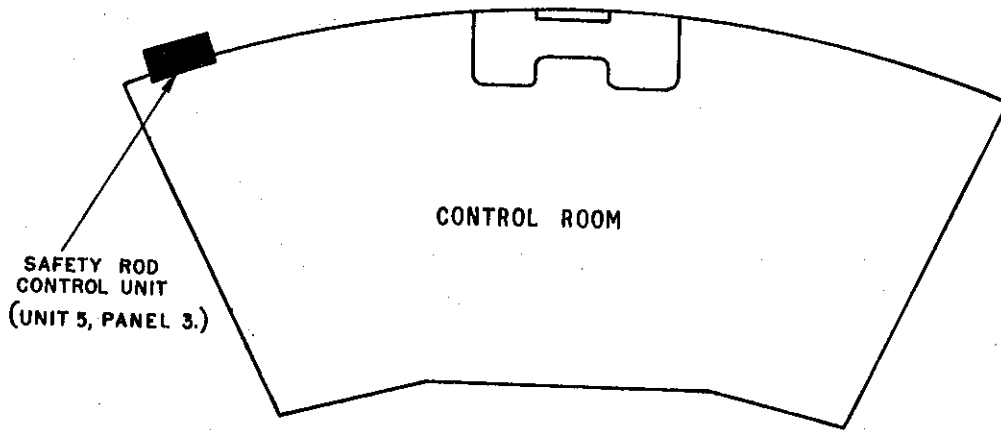


FIGURE 1. LOCATION OF CONTROLLERS, REACTOR HIFAR

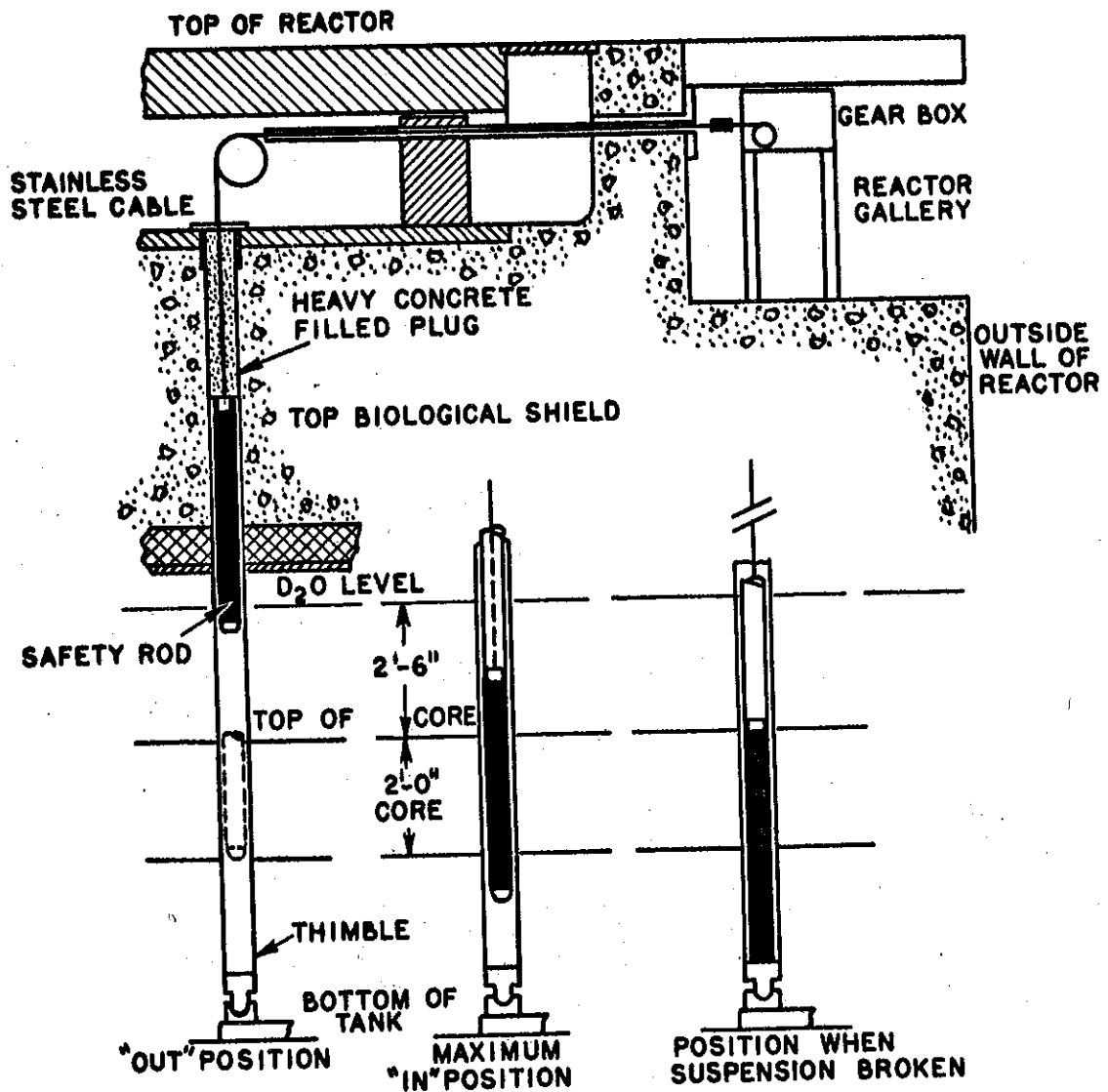


FIGURE 2. OPERATING RANGE OF SAFETY RODS

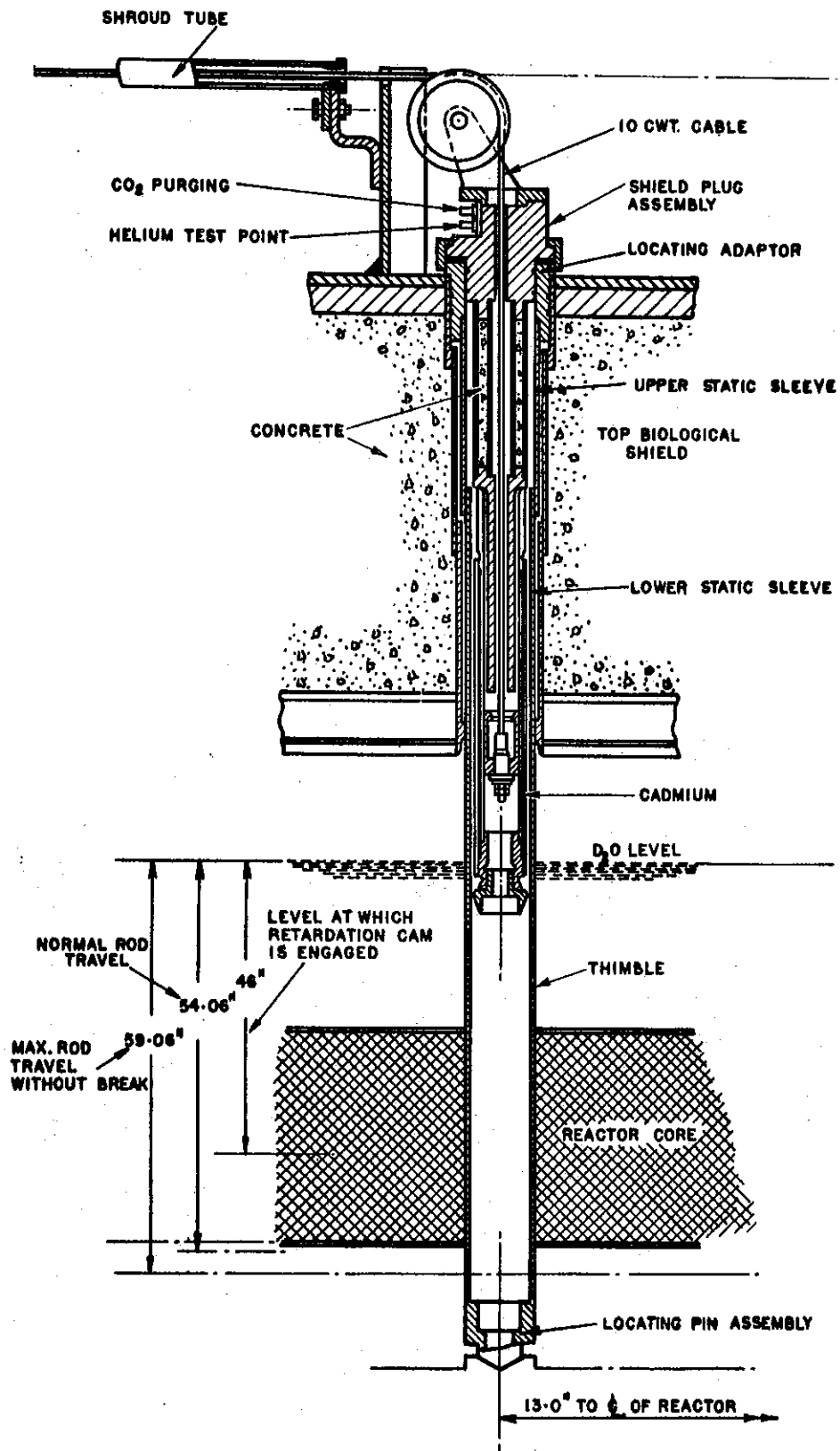


FIGURE 3. SAFETY ROD ASSEMBLY

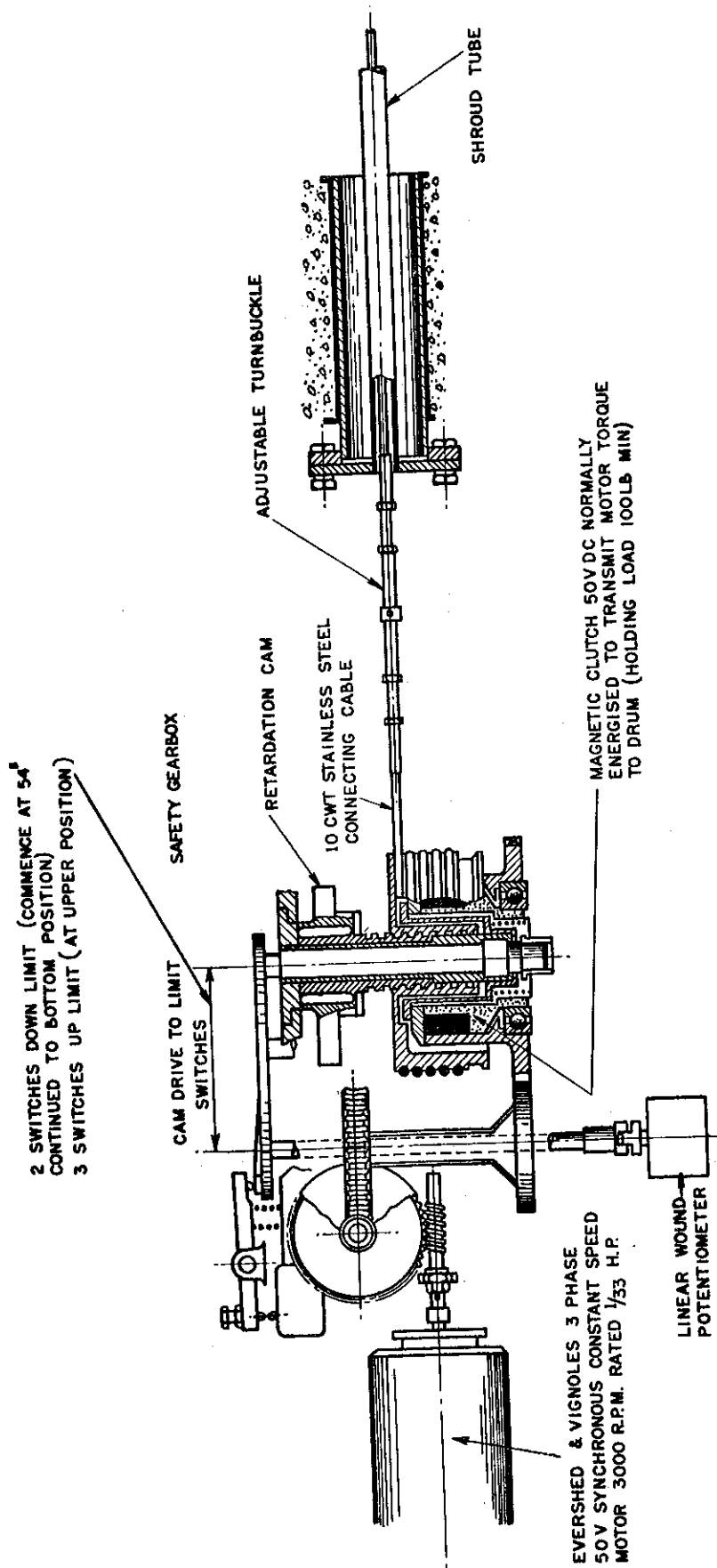


FIGURE 4. GEARBOX AND MOTOR FOR SAFETY ROD