Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 5.5

Rod Block Monitor System

Table of Contents

List of Tables

List of Figures

5.5 ROD BLOCK MONITORING SYSTEM

Lesson Objectives:

1. State the system's purposes.
2. Explain how the system accomplishes its purposes.
3. Describe the bypasses provided for the system; including parameters, and the reasons bypassing is allowed.
4. Explain the interfaces this system has with the following plant system:
   a. Local Power Range Monitoring System
   b. Recirculation System
   c. Reactor Manual Control System
   d. Average Power Range Monitoring System

5.5.1 Introduction

The purposes of the Rod Block Monitoring (RBM) System are to monitor average power around a selected control rod and to limit control rod movement to prevent local fuel damage. The functional classification of the RBM System is that of a power generation system.

The Rod Block Monitoring (RBM) System consists of two separate and independent channels, A and B. Each channel monitors the local neutron flux during selection and movement of a control rod, and generates a trip signal to actuate rod withdraw blocks when the monitored neutron flux exceeds preset limits.

The RBM accomplishes this function by averaging the selected LPRM inputs (Figure 5.5-1) and applying the resultant signal to trip circuits for comparison with flow biased trip points. LPRM's A and C provide the local neutron flux inputs to RBM channel A, while LPRM's B and D provide inputs to RBM B. This type of arrangement ensures core monitoring overlap between the RBM channels. As long as the selected LPRM average is less than the flow biased trip points, no rod withdrawal blocks will be applied.

5.5.2 Component Description

The major components which makeup the RBM system are discussed in the following paragraphs and are shown in block diagram form in Figure 5.5-2.

5.5.2.1 Selection Matrix

The RBM selection matrix receives a rod select signal from the Reactor Manual Control System (RMCS, Section 7.1). Once the selected control rod signal is received, the selection matrix automatically selects the LPRM detectors adjacent to the control rod selected for movement (Figure 5.5-1). The A and C level LPRM detectors are assigned to RBM channel A while the B and D level LPRM detectors are assigned to RBM channel B. The number of LPRM's providing inputs to the rod block monitor channels is dependent on the location of the selected control rod. The maximum number of LPRM inputs for any one RBM channel is eight. The selection matrix directs the flux amplifier signals from these selected LPRM detectors to the RBM channel A and B circuits in addition to the RBM/LPRM indicators on the reactor control console. The LPRM flux amplifier signals are displayed on the LPRM meters in proper orientation with respect to the selected control rod. The select matrix also provides a gain signal to an amplifier within the count circuit.

5.5.2.2 Count Circuit

The count circuit is provided to ensure that a minimum number of LPRM inputs is being averaged. This number is normally 50% of the maximum inputs per channel. If a control rod is selected with four (4) LPRM strings around it the minimum number of inputs would be four (4) because the maximum number of LPRM's per channel is eight (8). Similarly if a rod is selected with three (3) LPRM strings surrounding it the minimum number of LPRM signals would be three (3). An insufficient number of LPRM input signals, <50%, will produce an inoperative output signal.

5.5.2.3 Averaging Circuit

When a control rod is selected for movement, some of the factors that determine the magnitude of the core power increase include the average core power, the rod's position, the rod's location within the core, the position of the other rods, and the relation of the average local power to the average core power. If the average local power is lower than the average core power, rod withdrawal may cause a larger rate and percent power increase than it would if the local average power were equal to or greater than the average core power (Figure 5.5-4). The RBM is designed to compensate for this difference in rod worth by increasing the gain of the LRPM averaging circuit when the averaging circuit's output is less than the core average as determined by comparison with the companion APRM. The averaging circuit receives the inputs from up to eight LPRM flux signals and averages them to provide a local average power for the area adjacent to the selected control rod. The average local power calculation, comparison, and gain changing are accomplished during the nulling sequence that occurs immediately after a control rod is selected. Once the gain is changed and the RBM average nulls out with the reference APRM, the RBM gain is set and remains fixed until another rod is selected. In cases where the local flux in the region of the selected rod is equal to or greater than the average core power, the RBM averaging amplifier gain is set at unity. The net effect of increasing the RBM gain when a rod in a low flux region of the core is selected is to increase the RBM output, moving it closer to the trip point before rod withdrawal starts. Thus the amount of rod movement allowed, before the rod withdraw block circuit is actuated, is decreased in the case where a rod is liable to have a high worth.

5.5.2.4 Trip Reference Level Select Circuit

This circuit receives five inputs: one from the averaging circuit, one from the null sequence control circuit, and three from; the slope and bias circuit. The inputs from the slope and bias circuit are trip level inputs which are biased by recirculation flow. The formulas for these trips can be found on Figure 5.5-3.

For example, .66(W) + 24, is the first trip level. "W" stands for recirculation loop flow; so at 100% recirculation flow the trip level would be .66 x 100 + 24 or 90% power.

After the signal is nulled by the averaging circuit the trip reference level select circuit will determine which trips will apply. If the initial nulled signal is higher than the first setup level (2% below the first trip level which is at 90%), but lower than the second trip level (99%), then the first trip point will not be affected and the second trip point will be the first trip actuated as power is increased. The circuit will act the same if the initial nulled signal is higher than the second setup level but lower than the third trip level. If the initial nulled signal is higher than the third trip level, a rod block is inserted via the Reactor Manual Control System.

The first two trip levels, if actuated, can be manually set-up with pushbuttons on panel 603. When power as seen by the RBM increases to within ~2% of the selected flow biased trip level, the operator is alerted by a white "push to set-up" light. The operator can push the set-up pushbutton, thereby bypassing this trip level (rod withdrawal block) and automatically select the next higher flow biased trip level. If the operator does not set-up the trip level, a rod withdrawal block will be applied when the flow biased trip level is reached.

Manual set-up can be accomplished only for the first two trip levels. If the third, or highest level, flow biased trip has been selected, a green "set high" light will come on. A rod withdrawal block is applied at this point and this trip level cannot be set-up.

5.5.3 System Features and Interfaces

A short discussion of system features and interfaces this system has with other plant systems is given in the paragraphs which follow.

5.5.3.1 Normal Operation

When the reference APRM channels (C and D) are greater than 30% power and the operator has made a rod selection, the RBM channels perform a nulling sequence. During the nulling sequence, local average power is compared to the core average power and is adjusted to be greater than or equal to the core average power via the gain circuit.

To better understand the operation of the RBM System, assume the following initial conditions:

1. RBM Trip Levels: 57%, 65%, and 73% power.
2. Reference APRM reading of 50% power.
3. Local Average Power signal of 40% power.

Following the rod selection each RBM channel performs a null sequence which determines the gain to be applied to the local average power signal. To increase the local average power from 40% to 50% a gain of 1.25 (50/40) must be applied to the LPRM averaged output signal. After the null sequence has been completed, assume the selected control rod is withdrawn and increases the LPRM flux signals to produce an average of 44%. By multiplying the new LPRM signal by the fixed gain of 1.25, the RBM output would increase to 55% and a push to setup light would illuminate.

Now assume the operator fails to setup the next higher RBM trip level and continues to withdraw the same control rod. When the LPRM's produce an average signal of approximately 46%, the RBM will initiate a rod block (via the RMCS) to prevent further withdraw (1.25 x 46% ~57%). The operator is now forced to setup or select a new control rod for movement.

If the same control rod is to be withdrawn further, the operator must depress both RBM channel push to setup buttons. By depressing both setup buttons the rod block is cleared. The control rod is again withdrawn until the second RBM set point is reached, 65% power. The LPRM average flux signal would be approximately 52% (1.25 x 52% = 65%). At 63% power the push to setup lights would have illuminated again to inform the operator the presence of the second level rod block. If the control rod is still required to be withdrawn per the rod withdraw sequence, the RBM's have to be reset again. Once the RBM's have been reset the operator may continue the rod withdrawal. When the LPRM average flux signal reaches 58% the RBM would indicate 73% which is the third and final level rod block. Assuming that the same control rod requires further movement, the operator must select another control rod and then reselect the previous rod. By performing this evolution the RBM will calculate a new gain for the control rod, and the process continues until the rod is at the required position or the rod block monitor will not allow any further rod movement.

5.5.3.2 System Interfaces

The interfaces this system has with other plant systems are discussed in the paragraphs which follow.

Local Power Range Monitoring System (Section 5.3)

The RBM System receives LPRM inputs from the LPRM assemblies surrounding the control rod selected for movement.

Average Power Range Monitoring System (Section 5.4)

The RBM system uses selected APRM channel output signals for a reference core thermal power.

Reactor Manual Control System (Section 7.1)

The Reactor Manual Control System (RMCS) receives input signals from the RBM system to generate the rod blocks listed in Table 5.5-1.

The RMCS also provides a rod select signal used for the LPRM selection.

Recirculation System (Section 2.4)

The recirculation loop flows provide the total recirculation flow signal (W) used for the flow bias rod block settings.

5.5.4 Summary

Classification - Power Generation System.

Purpose - To monitor average power around a selected control rod. To limit control rod movement to prevent local fuel damage.

Components - Selection matrix; count circuit; averaging amplifier; trip reference level select circuit.

System Interfaces - Local Power Range Monitoring System; Average Power Range Monitoring System; Reactor Manual Control System; Recirculation System.

TABLE 5.5-1 RBM INTERLOCKS AND TRIPS

ALARM or TRIP	SETPOINT	ANNUN-CIATOR	ACTION	AUTO BYPASS
RBM Upscale	.66W + 41 .66W + 33 .66W + 25 % Power	RBM UPSCALE /INOP	Rod Withdraw Block	APRM Reference Low Level (30% Power) or Edge Rod Selected
RBM Downscale	2.5% Power	RBM Downscale	Rod Withdraw Block	APRM Reference Low Level (30% Power) or Edge Rod Selected
RBM INOP	(1)	RBM UPSCALE /INOP	Rod Withdraw Block	APRM Reference Low Level (30% Power) or Edge Rod Selected
APRM Reference Downscale	30% Power			APRM Reference Low Level (30% Power) or Edge Rod Selected
RBM Bypassed	(2) Bypass Switch on Pnl 603			

1. Produced by:
   a. Local panel mode switch not in operate.
   b. Module unplugged.
   c. Less than required number at LPRM imputs.
   d. RBM fails to null.
2. Only one RBM may be bypassed

TABLE 5.5-1 RBM INTERLOCKS AND TRIPS

ALARM or TRIP	SETPOINT	ANNUN-CIATOR	ACTION	AUTO BYPASS
RBM Upscale	.66W + 41 .66W + 33 .66W + 25 % Power	RBM UPSCALE /INOP	Rod Withdraw Block	APRM Reference Low Level (30% Power) or Edge Rod Selected
RBM Downscale	2.5% Power	RBM Downscale	Rod Withdraw Block	APRM Reference Low Level (30% Power) or Edge Rod Selected
RBM INOP	(1)	RBM UPSCALE /INOP	Rod Withdraw Block	APRM Reference Low Level (30% Power) or Edge Rod Selected
APRM Reference Downscale	30% Power			APRM Reference Low Level (30% Power) or Edge Rod Selected
RBM Bypassed	(2) Bypass Switch on Pnl 603			

1. Produced by:
   a. Local panel mode switch not in operate.
   b. Module unplugged.
   c. Less than required number at LPRM imputs.
   d. RBM fails to null.
2. Only one RBM may be bypassed

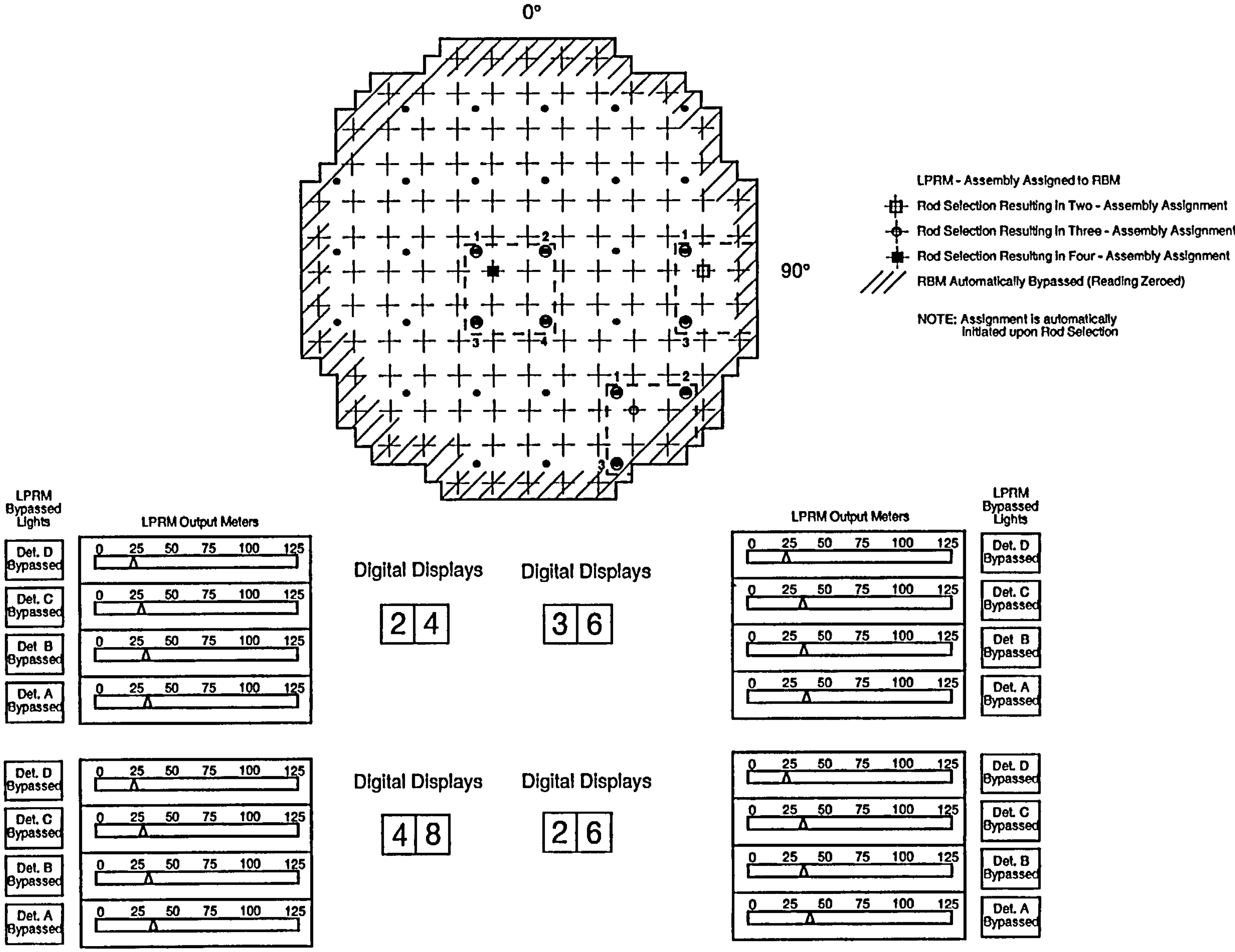


Figure 5.5-1 LPRM Assignment to RBM

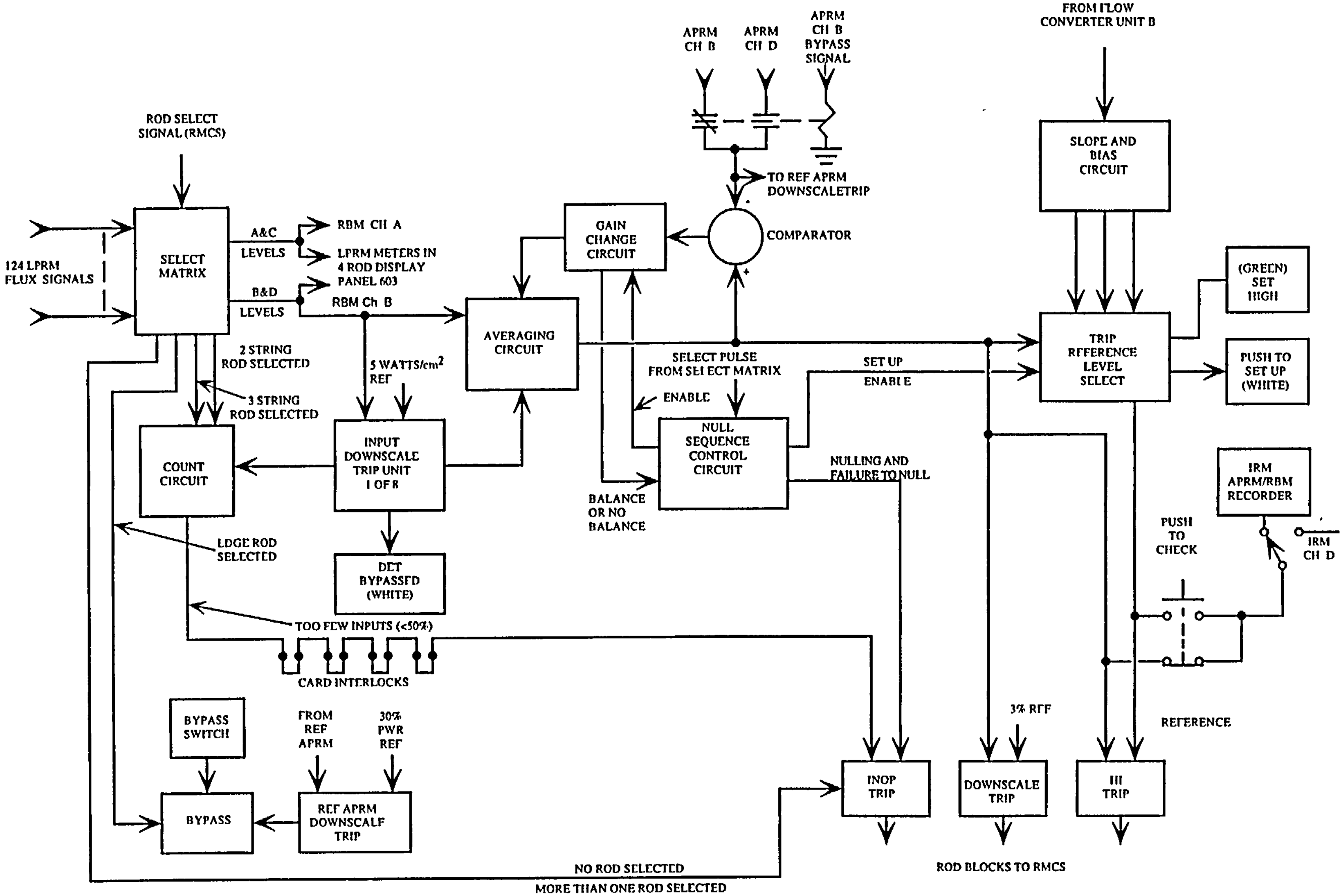


Figure 5.5-2 Rod Block Monitor Channel "B"

1296-5

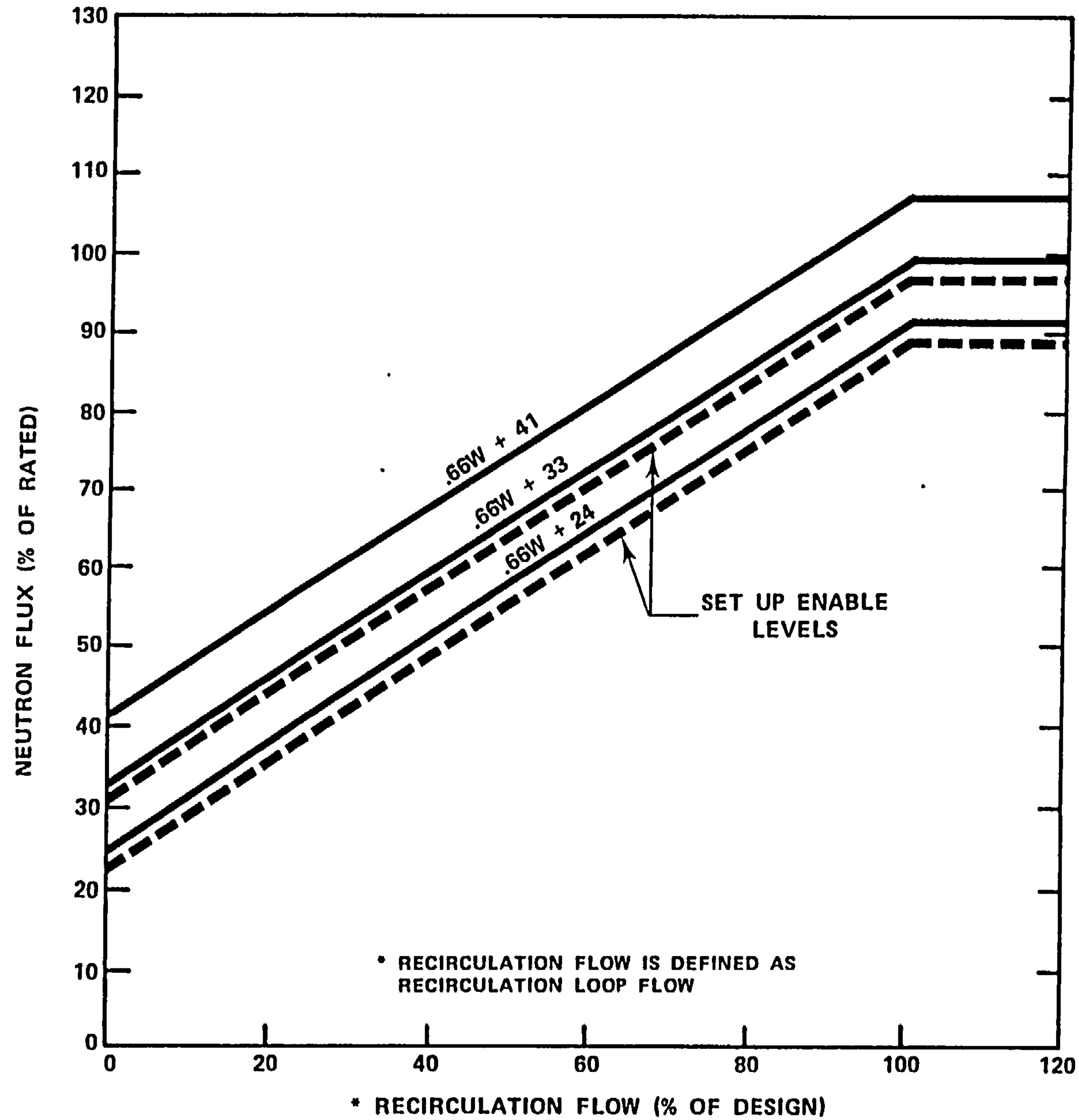
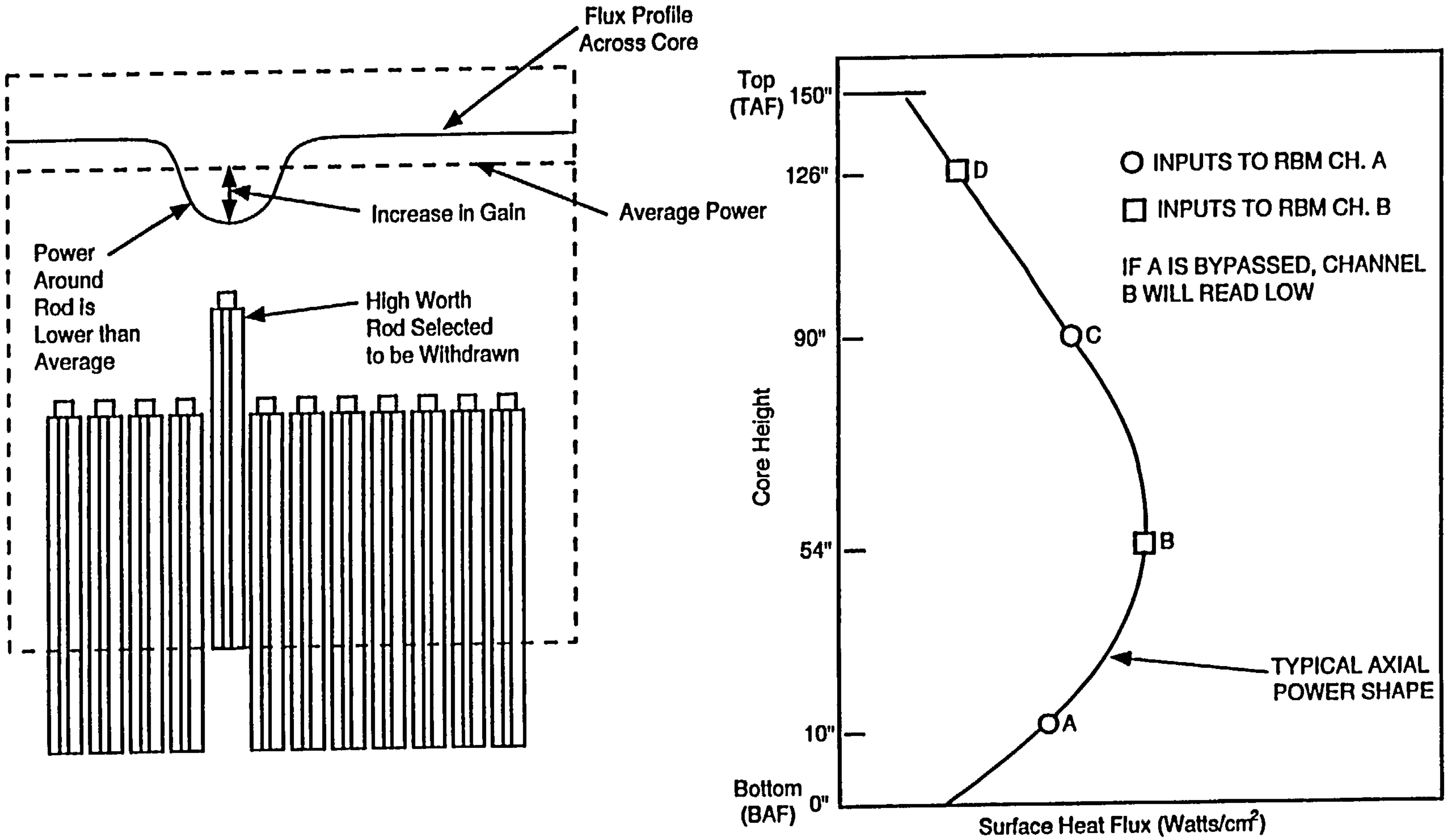


Figure 5.5-3. Graph of RBM Flow Biased Rod Blocks.



LOCAL POWER LOWER THAN AVERAGE

HIGH READING LPRM DETECTONS BYPASSD

Figure 5.5-4 Reasons for Gain Adjust Circuit & LPRM Level Selection

0494

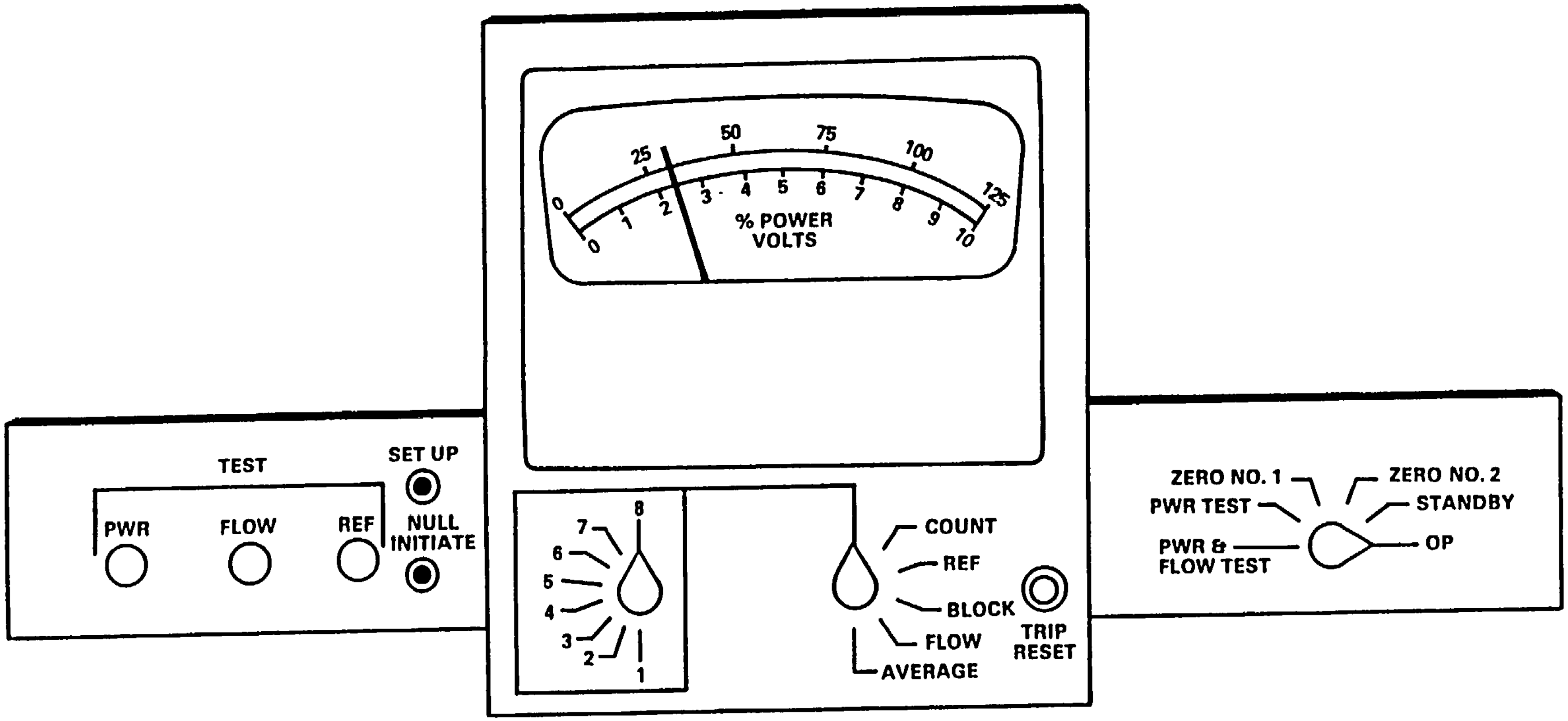


Figure 5.5-5 RBM Meter and Test Switches

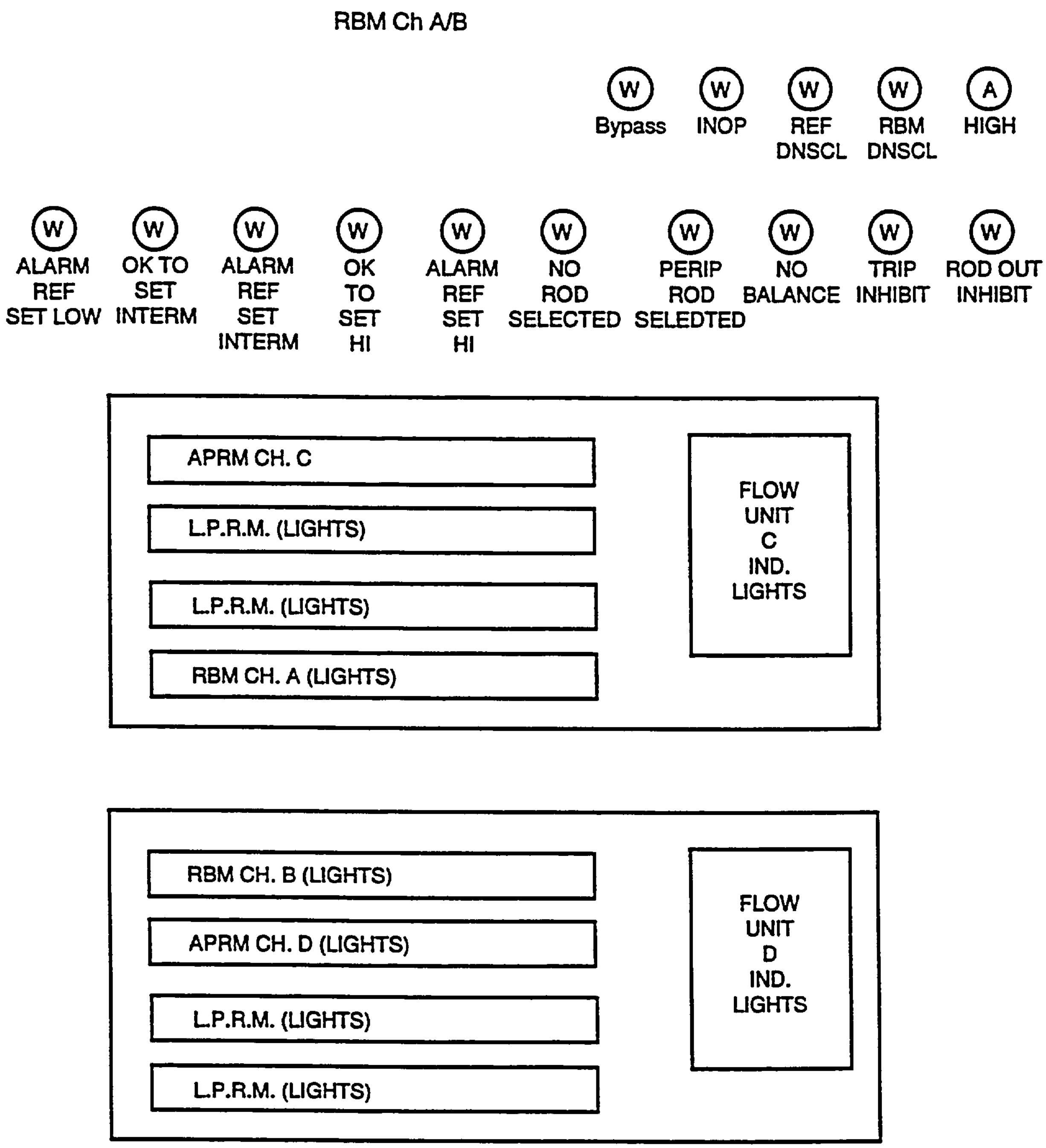


Figure 5.5-6 RBM Cabinet Indicators

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 5.6

Traversing Incore Probe System

List of Figures

5.6 TRAVERSING INCORE PROBE SYSTEM

Lesson Objectives:

1. State the system's purpose.
2. Explain how the system accomplishes its purposes.
3. Explain the interfaces this system has with the following plant systems:
   a. Local Power Range Monitoring System
   b. Process Computer
   c. Nuclear Steam Supply Shutoff System

5.6.1 Introduction

The purpose of the Traversing Incore Probe (TIP) System is to provide a means of obtaining core power distribution.

The functional classification of the TIP System is that of a power generation system.

The Traversing Incore Probe (TIP) System, illustrated in Figure 5.6-1, consists of four independent neutron detection units. Each unit contains a miniature fission chamber (probe) connected to a flexible drive cable that is driven by a motor operated drive mechanism. Operation of the drive mechanism causes the fission chamber to be inserted or retracted from the reactor core within individual TIP guide tubes. Each TIP unit uses an indexing device to route the detector to the desired LPRM assembly which houses the TIP guide tube.

The 31 LPRM assemblies are divided between the four TIP machines with one common LPRM assembly connected to all four TIP's for cross calibration of the TIP's. The output signal from a TIP channel may be used to plot an axial flux profile on an X-Y recorder and/or provide a flux distribution signal into the process computer for LPRM calibration data.

5.6.2 Component Description

The major components of the TIP System are discussed in the paragraphs that follow.

5.6.2.1 TIP Detector Assembly

The TIP detector is a miniature fission chamber having characteristics similar to a LPRM detector (Figure 5.6-2).

The detector is constructed of titanium, and has an internal coating of greater than 90% enriched uranium U^{235}. The detector is pressurized with argon gas at 91.5 cm Hg. The active portion of the detector assembly is about .2" outer diameter by 1" long and is capable of operating in the neutron flux range of 2.8×10^{13} n/cm^2/sec (nv) to 2.8×10^{14} n/cm^2/sec (nv) with the applied voltage adjusted for operation in the ionization region of the gas amplification curve. The detector signal cable, which is an integral part of the mechanical drive cable, is a triaxial cable 0.256 inch in diameter and 140 feet long. The outer sheath of the drive cable is constructed in a helical array to facilitate coupling with the motor drive mechanism. This helical wrap of carbon steel provides a low friction means of driving the detector and also protects the signal cable. This cable is lubricated with molydenum disulfite, a dry lubricant. Table 5.6-1 summarizes design parameters of the TIP detector and drive cable.

5.6.2.2 Drive Mechanism

The drive mechanism provides the means of positioning the TIP detector at the desired location within the LPRM assembly. The drive mechanism is located outside of the drywell in the TIP room in the Reactor Building. The TIP drive cable is connected to a takeup reel assembly within the mechanism.

The reel assembly is bolted to the platform of the drive mechanism enclosure and consists of one fixed drum and two drums that rotate. The helically wrapped triaxial drive cable is wound on one of the rotating drums (takeup reel). A standard triaxial cable is distributed between the other two drums through a spring loaded pulley arrangement. The two cables are joined by an adaptor cable with two three pin connectors located on the out board disc of the takeup reel.

As the helical cable is inserted in one of the guide tubes, the standard cable is transferred from one drum to the other, and vice versa, during the withdrawal cycle. This operation causes a rotary-to-linear motion transfer to be accomplished and an electrical path is completed between the detector and a fixed connector without the use of the slip rings or other methods that result in relatively high signal loss.

The drive motor and control circuit components are mounted on the front bracket of the drive enclosure. The motor is an AC constant speed induction type. A transistorized control unit drives the eddy current clutch to provide high speed (60 ft./min.) or low speed (7.5 ft./min.) cable drive. The clutch shaft is connected through a gear reducer to the output load shaft. The load shaft drives a hobbed wheel in the cable drive box through a friction slip clutch. The hobbed wheel engages the drive cable helix and moves the drive cable in the forward or reverse direction at the discretion of the operator. The motor is equipped with a fail safe friction brake to prevent inertial overshoot. If the input commands are valid, the motor starter and clutch (speed control) circuits are controlled by the console operator.

Interlock circuits and strategically located sensors protect the equipment in case of an invalid command (refer to indexer mechanism description). Brake release is automatic when forward or reverse cable drive is selected. The shaft of the friction slip clutch passes through the drive box housing and is chain and sprocket coupled to a counter and to a 40 turn potentiometer. The counter drives a four digit numerical display that indicates the detector position in inches. The counter also supplies digital signals, corresponding to the detector position, to the control console, located in the TIP control and monitoring instrument panel. The potentiometer supplies a detector position analog voltage to the console used to drive the X-axis of the X-Y recorder and provides information to the process computer.

5.6.2.3 Shear Valve

The TIP shear valve includes an explosive squib which can be detonated to cut the TIP cable and seal off the reactor side of the guide tube (Figure 5.6-3). Operation of the squib valve is remote manual and should only be actuated if drywell isolation is required and normal ball valve operation is blocked.

5.6.2.4 Ball Valve

The ball valve assembly includes a solenoid operator which is controlled automatically by detector position or manually by the operator. Automatic closure is initiated when the detector is retracted to the chamber shield, and automatic opening when the detector leaves the shield.

5.6.2.5 Indexing Mechanism

The indexing mechanism, Figure 5.6-4, is situated between the stationary TIP guide tubes going to the reactor vessel and the drive mechanism. The indexing mechanism allows interchangeability between the 10 channels available for detector traverse. Position number 10 of each indexer, connected to a 4-way connector (Figure 5.6-5) permits all four TIP detectors to scan (one at a time) one common centrally located LPRM assembly. This provides a means to cross-calibrate all four TIP detectors during any phase of normal reactor operation. The movable guide tube is locked in the selected position and held in proper alignment by a gear arrangement.

An AC motor is used to drive the gear arrangement and the movable guide tube. The motor requires no brake, since the small inertia can be immediately overcome by load dampening. Two limit switches located inside the indexer are part of the gear drive motor control circuit. These switches provide signals to protect the indexer and TIP cable via system interlocks. A limit switch actuates when the detector (or cable) is in the indexer to prevent rotating the mechanism. Selection of a common TIP channel automatically locks out the selection of that same channel on the other 4 indexing mechanisms.

A proximity sensor is mounted on the end of the indexing mechanism, directly on top of the guide tube. The sensor drives a proximity switch located on the drive mechanism enclosure. The switch contact signals the drive control unit when the detector enters or leaves the indexing mechanism. An adjustable time delay is set to provide the proper withdrawal time to move the detector from the sensor point to the storage location for a given TIP speed.

5.6.2.6 Drive Control Unit

The operation of the probes is controlled from the four drive control units, Figure 5.6-6. Both automatic and manual modes of operation can be initiated and monitored from these units. Selection of the LPRM string to be traversed is also made at each drive control unit by a 10 position channel selector switch. The face of each drive control unit provides the operator with a visual display of various TIP System parameters. These parameters include detector position in inches from a selected reference point, drive speed, direction of detector travel, mode of operation, LPRM string selected, travel limits within the core, indexing mechanism alignment status and detector in shield indication. The drive control units are contained in the TIP control and monitoring instrument panel located in the control room.

5.6.2.7 Flux Probe Monitor

The flux probe monitor, Figure 5.6-7, which is located in the TIP control and monitoring instrument panel, houses the four flux amplifiers, four ion chamber power supplies, a calibration unit, and two low voltage power supplies (required to operate the flux amplifiers and calibration unit). The flux probe monitor powers the detector, amplifies the flux signal, and transmits the signal to the process computer and/or the X-Y recorder.

5.6.2.8 Valve Control Unit

The valve control units, Figure 5.6-8, are also located in the TIP control and monitoring instrument panel. The three units house the control and indicating circuits for the shear valves, ball valves and nitrogen purge system. Fuse indication for the Primary Containment Isolation System containment isolation bus is also shown.

5.6.2.9 X-Y Recorder

The X-Y recorder (Figure 5.6-9) operates during the core traverse cycle and plots a graph (Figure 5.6-10) of flux density versus detector position. The X-axis of the plotting pen is driven by the 40-turn potentiometer and the Y-axis is driven by the output of the flux amplifier. The X-Y recorder is located in the TIP control and monitoring instrument panel.

5.6.2.10 TIP Purge System

To prevent rusting of the drive cable and deterioration of the guide path lubricant and cable insulations (due to high humidity), the guide tubes and indexing mechanisms normally are constantly purged by nitrogen and the drive mechanisms by dry air. Nitrogen to the indexing mechanism passes through a purge assembly which reduces the nitrogen pressure and regulates nitrogen flow to a maximum of 140 SCF per day. A pressure control valve mounted on each indexing mechanism regulates the incoming pressure which establishes the environment inside the indexer. The guide tubes are purged via the indexing mechanisms.

Each drive mechanism is purged with dry air from the Control Air System.

The air pressure is reduced to 5 psig and flow is controlled to each drive mechanism at 1.5 SCFH.

5.6.3 System Features and Interfaces

A short discussion of system features and interfaces this system has with other plant systems is given in the paragraphs which follow.

5.6.3.1 Shielding Provisions

Because of the internal uranium oxide coating of the fission chamber detector, it becomes highly radioactive after only a short exposure to neutron flux. Shielding is provided at the TIP detector storage position to minimize radiation levels in the TIP equipment room.

The chamber shield includes limit switches which actuate status lights on the drive control unit. Additional logic signals are provided to inhibit or permit drive unit operation.

5.6.3.2 System Operation

The TIP system is normally utilized for one or more of the following reasons:

1. To verify an LPRM reading.
2. To obtain an axial flux profile printout on the X-Y plotter to verify flux shapes.
3. To calibrate the LPRM's.

The TIP System serves as an analytical device and, therefore, is not in continuous operation. When the need for a traverse is determined, the TIP units can be operated in automatic or manual mode.

Automatic Mode

When a TIP unit is operated in the automatic mode, the channel select switch is placed at the appropriate position. When the indexing mechanism is in the correct position, (aligned to the appropriate guide tube) the ready light illuminates. The automatic scan is now initiated by actuating the automatic start switch. When the automatic start switch is actuated, the drive mechanism is energized and drives the detector from its start position toward the indexer at a slow insertion speed of 7.5 ft./min., and the forward light comes on, indicating the probe is moving towards the core.

As the detector leaves its storage position, it actuates a proximity switch that causes the in-storage shield light to extinguish. The detector passes into the indexer and is guided into the selected guide tube assembly. The traversing speed is now automatically increased to 60 ft./min. until the detector reaches the bottom of the core. At that point, the drive traverse and the detector is driven up into the core at slow speed until the preprogrammed core top limit is reached at which time the detector stops. As the detector enters the core, the incore indicating light illuminates.

If the process computer is ready to accept data, the scan light on the drive control module illuminates. The automatic start button is again depressed, initiating slow speed detector withdrawal, causing the reverse light to illuminate, and at the same time dropping the X-Y recorder pen to the paper to begin the flux plot, Figure 5.6-6. The flux level is plotted only on the withdrawal portion of the traverse to ensure the drive cable is under tension to prevent effects of cable buckling (during insertion) on the accuracy of the trace. When the detector reaches the pre programmed core bottom, the in-core light extinguishes and the drive mechanism shifts to fast speed until the detector is within the index mechanism. The speed then shifts to slow. The detector continues at slow speed and stops at position 0001, which is approximately 17 inches behind the indexing mechanism. If no additional scans are to be performed at this time, the detector is retracted to its storage position inside the shield chamber by placing the system in manual reverse. This retracts the detector through the proximity switch, which lights the in-shield light and stops the drive mechanism.

Manual Mode

The manual mode of operation is very similar to the automatic mode except that two different modes are provided: manual forward and manual reverse. When the system is placed in the manual forward mode, the detector is driven into the core in the same manner as in automatic operation. The detector remains at the core top until the system is placed in the manual reverse mode of operation, at which time it is withdrawn until it reaches the storage position in the shield chamber. When the system is operated in the manual mode of operation, the detector can be stopped at any time, or its direction of travel can be changed by changing from manual forward to manual off, or to manual reverse, as desired.

Manual Drive

The third mode of operation, manual drive, permits the electric motor in the drive mechanism to be disconnected from the detector drive, and a hand crank substituted to provide driving power. This method of operation is used primarily for probing the guide tube runs to determine the distance to the end of the guide tube so that the core top limits can be programmed. These limits are peculiar to each drive mechanism and each detector channel.

Thus, replacement of the detector drive cable or guide tubing normally necessitates reprogramming all of the core top and bottom limits.

5.6.3.3 System Interlocks

The interlocks provided in the TIP System operate to prevent damage to the TIP detector and drive cable and isolation.

During a TIP traverse, the detector operates in low speed from the storage position until it has passed the indexer to minimize detector damage should the indexing mechanism movable tube alignment not be exact. The TIP detector also operates in low speed in the core region to provide sufficient time for the process computer to process the data from the TIP System and also provide adequate response time for the operator to stop the traverse and prevent detector damage should a malfunction occur in the TIP controls while the detector is in the core region.

The TIP System contains interlocks to prevent attempting simultaneous traverse of the common channel. If any TIP unit is selected to or is traversing the common channel, no other indexing mechanism is allowed to rotate to align to that channel when selected. An interlock is also provided to prevent repositioning of a indexing mechanism while either the TIP detector or drive cable are located within the mechanism.

Proximity switches are provided on the TIP unit guide tubes located just inside the drywell which (after a time delay based on detector speed) stop the detector in the storage position during detector withdrawal after all TIP traverses are complete. This interlock ensures the detector will be located in its shield chamber for the protection of personnel during times when the TIP System is not in use. The TIP detector automatically stops at the core top limit during either an automatic mode or manual mode traverse to provide the operator with control of when the TIP trace commences.

The TIP detector automatically retracts to the shield and the ball valves close on high drywell pressure.

5.6.3.4 System Interfaces

The interfaces this system has with other plant systems are discussed in the paragraphs which follow.

Local Power Range Monitoring System (Section 5.3)

The TIP System is used to calibrate LPRM System detectors. The TIP tube is housed in the LPRM assembly.

Emergency AC Power System (Section 9.2)

The Emergency AC Power System provides 480 VAC power to the detector drive mechanism motors and 120 VAC instrument bus power to the drive control units, flux probing monitor, and X-Y recorder.

Process Computer (Section 6.1)

The TIP System provides raw data about core power distribution to the process computer. The TIP units are mathematically normalized to a uniform output by the process computer.

Nuclear Steam Supply Shutoff System (Section 4.4)

The Nuclear Steam Supply Shutoff System provides a TIP detector withdrawal signal and a ball valve closure command when high drywell pressure is sensed.

5.6.4 BWR Differences

The major differences between TIP Systems at different BWR facilities is the number of TIP probes and drive units the facility has. These numbers are a function of core size. TIP System operation and system interlocks also vary depending on the type of containment at a given facility.

5.5.4.1 Instrument Tubes

New BWR plants utilize a redesigned instrument tube. In the old instrument tube design, the TIP tube, through which the TIP traverses, was placed to the side of the instrument tube. Also in the old cylindrical instrument tubes, a bowing problem was experienced. In the new design, the instrument tubes are square, and the TIP tube is placed in the center where the TIP traverses equidistant from each four corner rod. In addition, the square tube has no tendency to bow or deflect.

5.5.4.2 Gamma TIP

Analytical and experimental investigations over the past several years have shown that the neutron TIPs indicate radial power asymmetries for core locations where the actual power distribution is symmetric. The apparent asymmetries recorded by the neutron detectors can be attributed to sensitivity of the detector response to water gap variations caused by random detector positioning in the LPRM and variable LPRM positioning in the water gap. A small variation in water gap dimensions can cause a significant change in neutron TIP readings. However, gap size variation has very little effect on gamma TIP readings. Asymmetries may result in erroneous readings causing unnecessary conservative or nonconservative thermal limits which may reduce reactor operating flexibility and, on occasion, can actually limit reactor power below full power.

The gamma TIP is a direct replacement for the currently used neutron TIP. These TIPs are interchangeable and compatible with the existing guide tubes, drive machines, and indexers. The neutron TIP detector has an outside diameter of 0.207 inch and a length of 2.348 inches. The gamma TIP has a larger diameter and a longer length. The gamma TIP has a longer conical cap which accounts for the longer length of the gamma TIP detector. These slight changes are within minimum radius of curvature of the guide paths and do not affect operation in the existing guide paths. Operating plants which have installed prototype or pilot production gamma TIP Systems are experiencing TIP asymmetry improvements of 11 to 56%. Five percent improvements in the minimum critical power ratio (MCPR) are typical following gamma TIP installation.

5.6.5 Summary

Classification - Power generation system

Purpose - To provide a means of obtaining core power distribution.

Components - Detector assembly; drive mechanism; shear valve; ball valve; indexer mechanism; drive control unit; flux probing monitor; X-Y plotter; purge system.

System Interfaces - LPRM System; Standby Auxiliary Power System; Process Computer; Primary Containment Isolation System.

TABLE 5.6-1 TIP DETECTOR AND DRIVE CABLE CHARACTERISTICS

Detector

Construction material	Titanium
Coating material (neutron sensitive)	Uranium
Insulating material	Forsterite
Filling gas	Argon
Outside diameter	0.180 inch
Active length	1.0 inch
Neutron sensitivity in BWR	4.8×10^{-18} amp/nv ± 50%
Gamma sensitivity	3×10^{-14} amp/R/h max
Neutron flux operating range	2.8×10^{13} to 2.8×10^{14}
Life (defined as 50% reduction in neutron sensitivity)	10^{21} nvt
Operating voltage (detector polarizing)	100 vdc
Resistance - Collector - to shaft at 100 vdc at room temperature and at 50% relative humidity	1×10^{9} ohms (minimum)

Detector Drive Cable

Type	Triaxial
Helical wrap	Carbon Steel
Sheath	Stainless steel
Inner conductor	Stainless steel (tungsten carbide coated)
Insulating material	Magnesia
Length	140 feet
Outside diameter	0.256 (+0.00/-0.002) inc
Operating environment relative humidity temperature	Less than 50% 6080 F
Exposure life	Not less than 10^{19} nvt

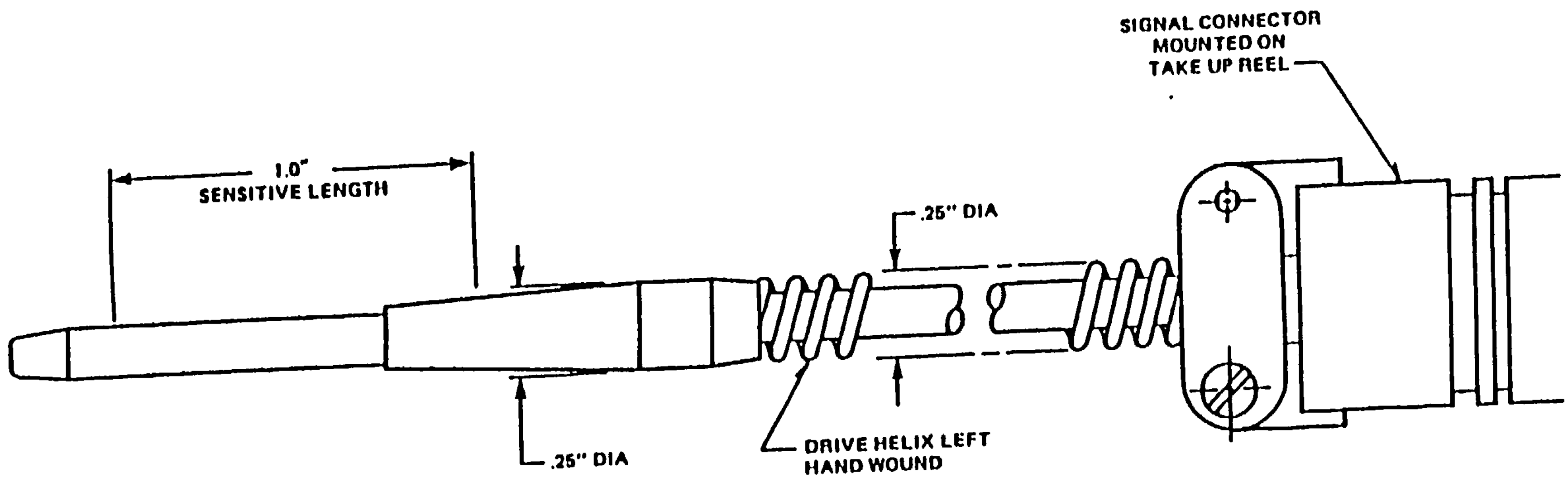


Figure 5.6-2 TIP Detector

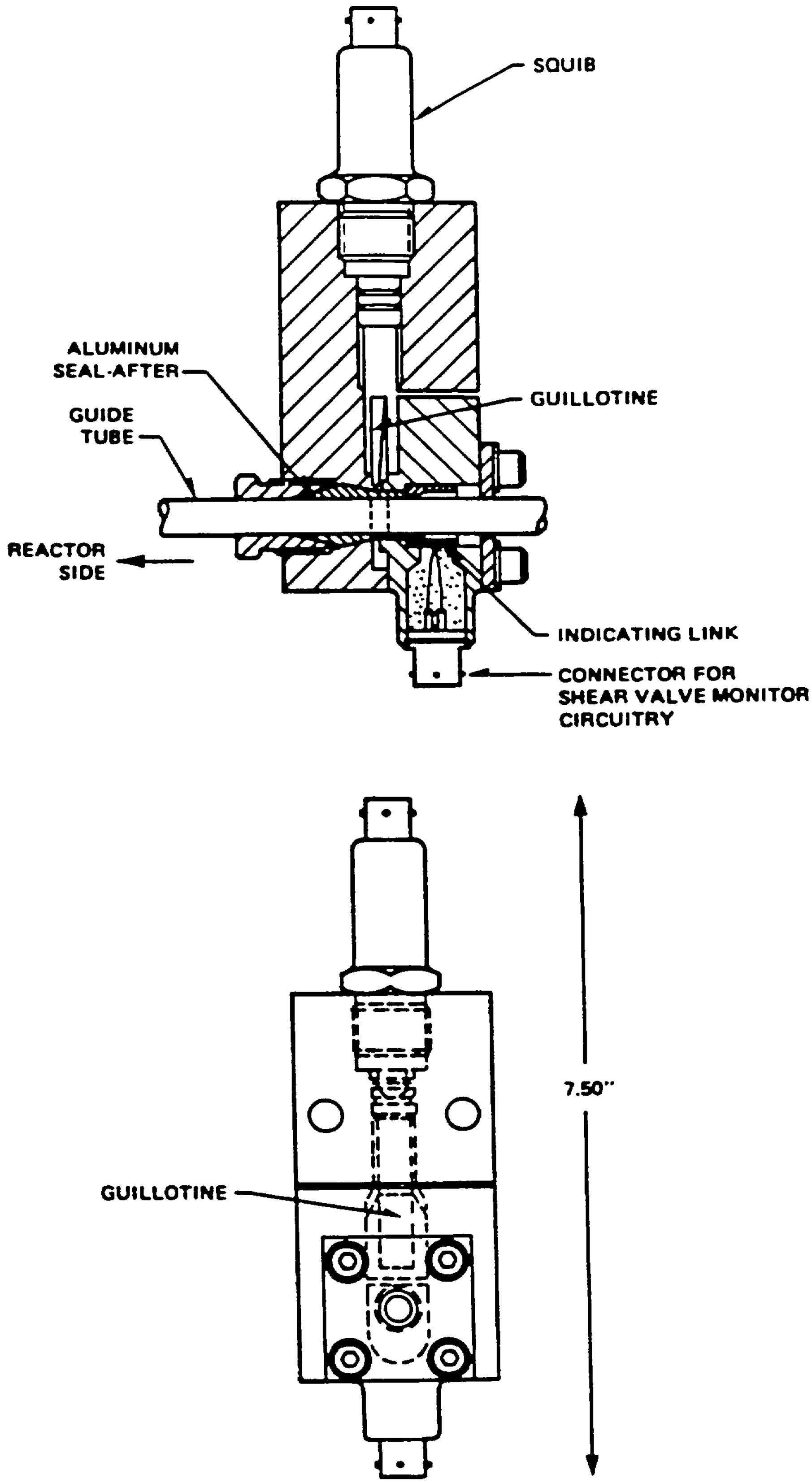


Figure 5.6-3 TIP Shear Valve

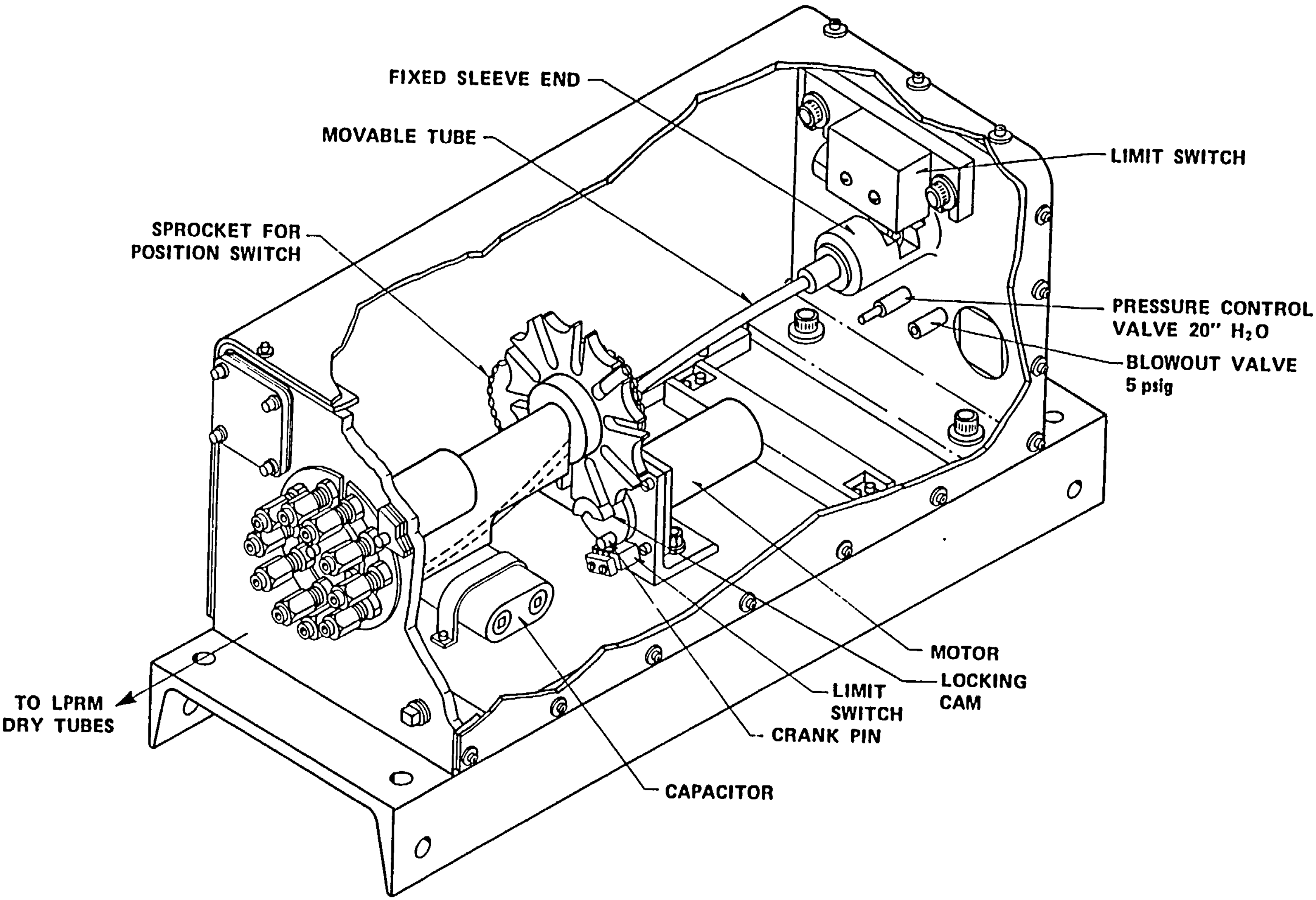


Figure 5.6-4 TIP Indexing Mechanism

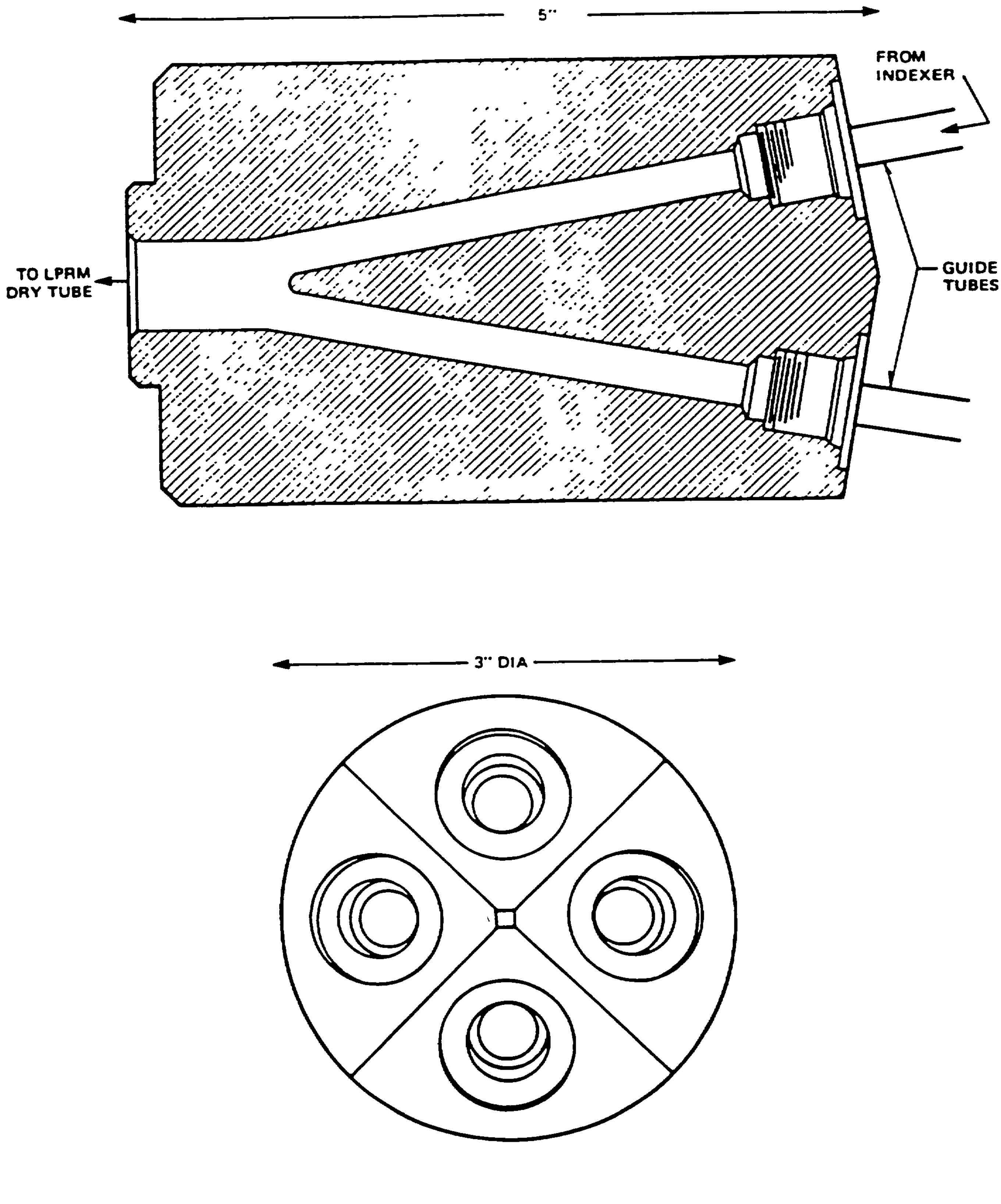


Figure 5.6-5 Four - Way Connector

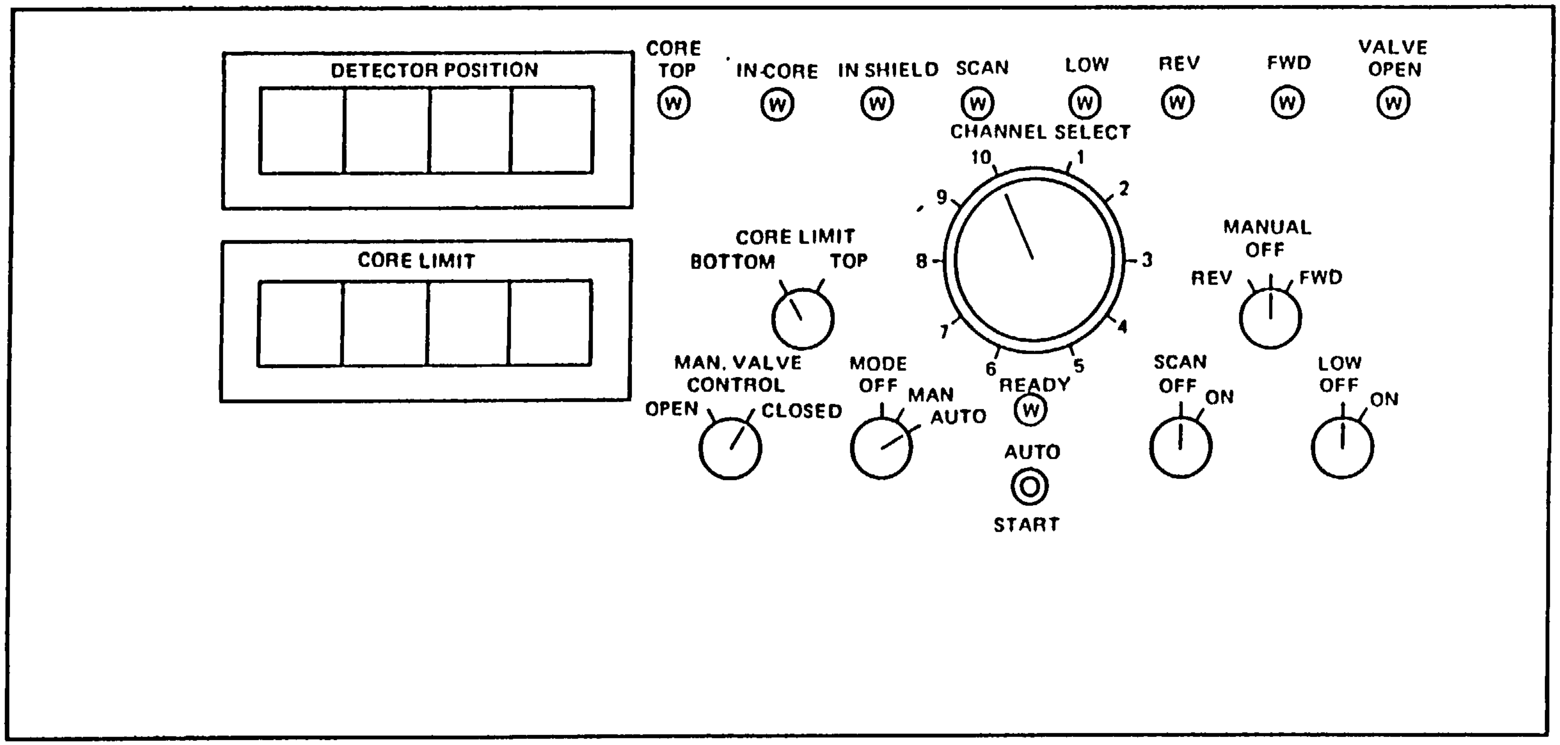


Figure 5.6-6 TIP Drive Control Unit

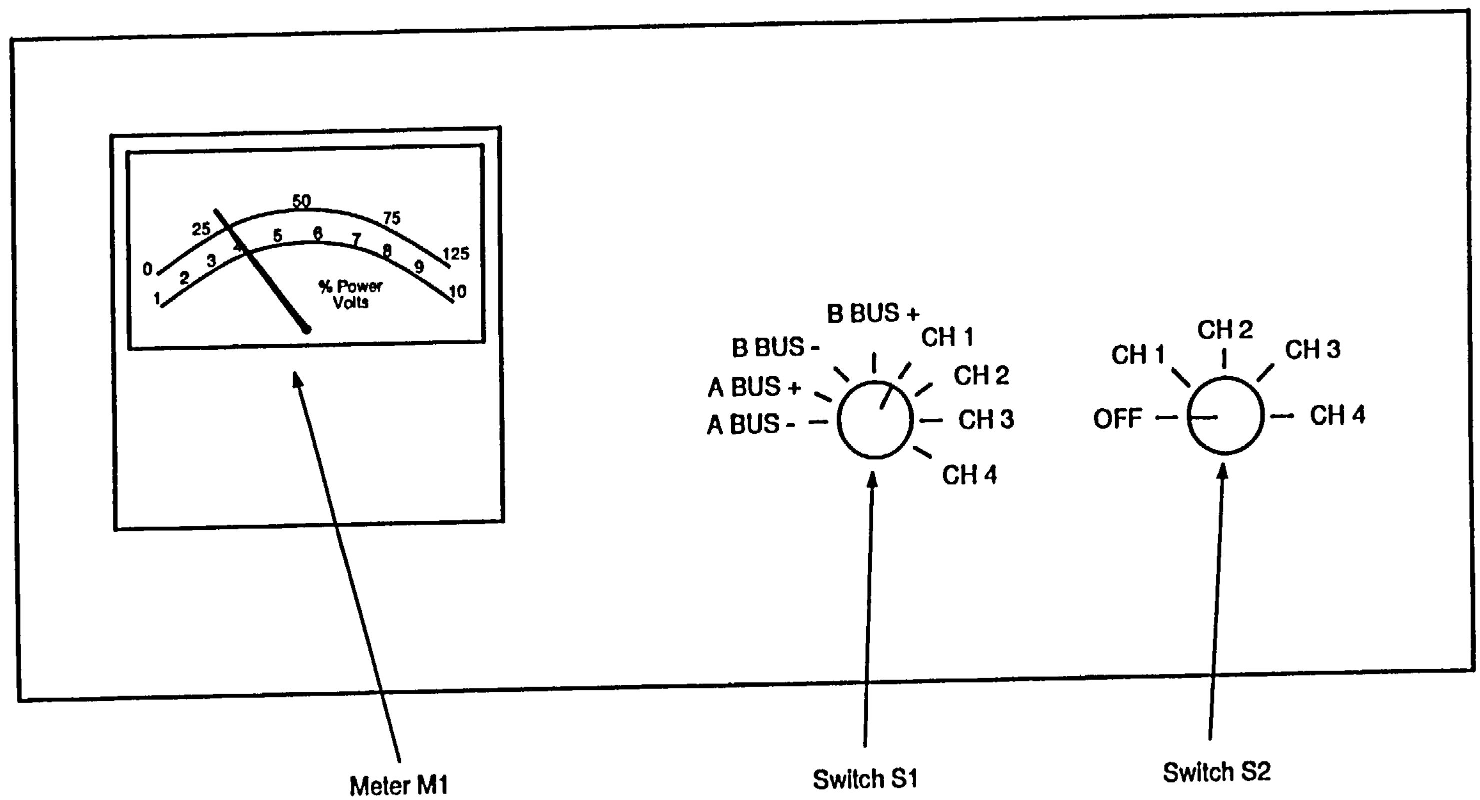


Figure 5.6-7 Flux Probing Monitor

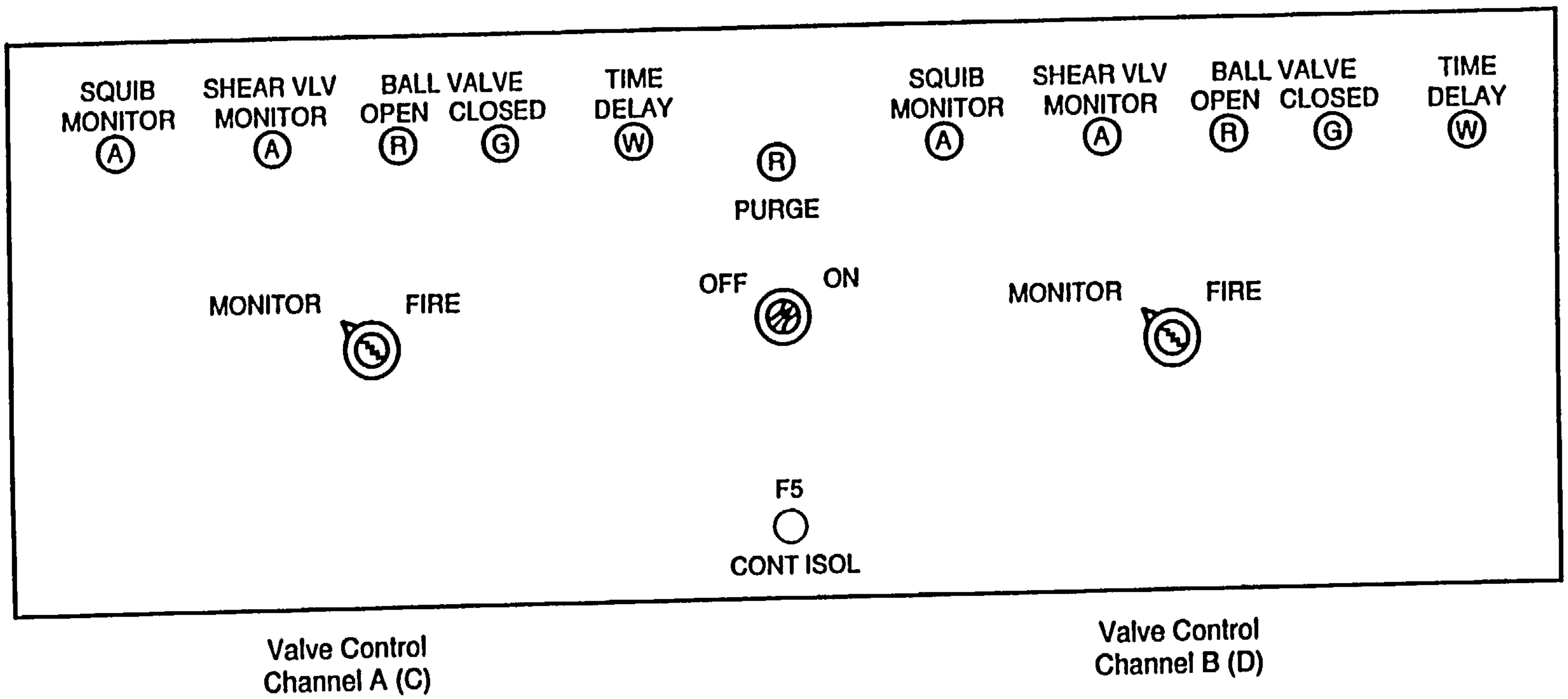


Figure 5.6-8 TIP Valve Control Monitor

0494

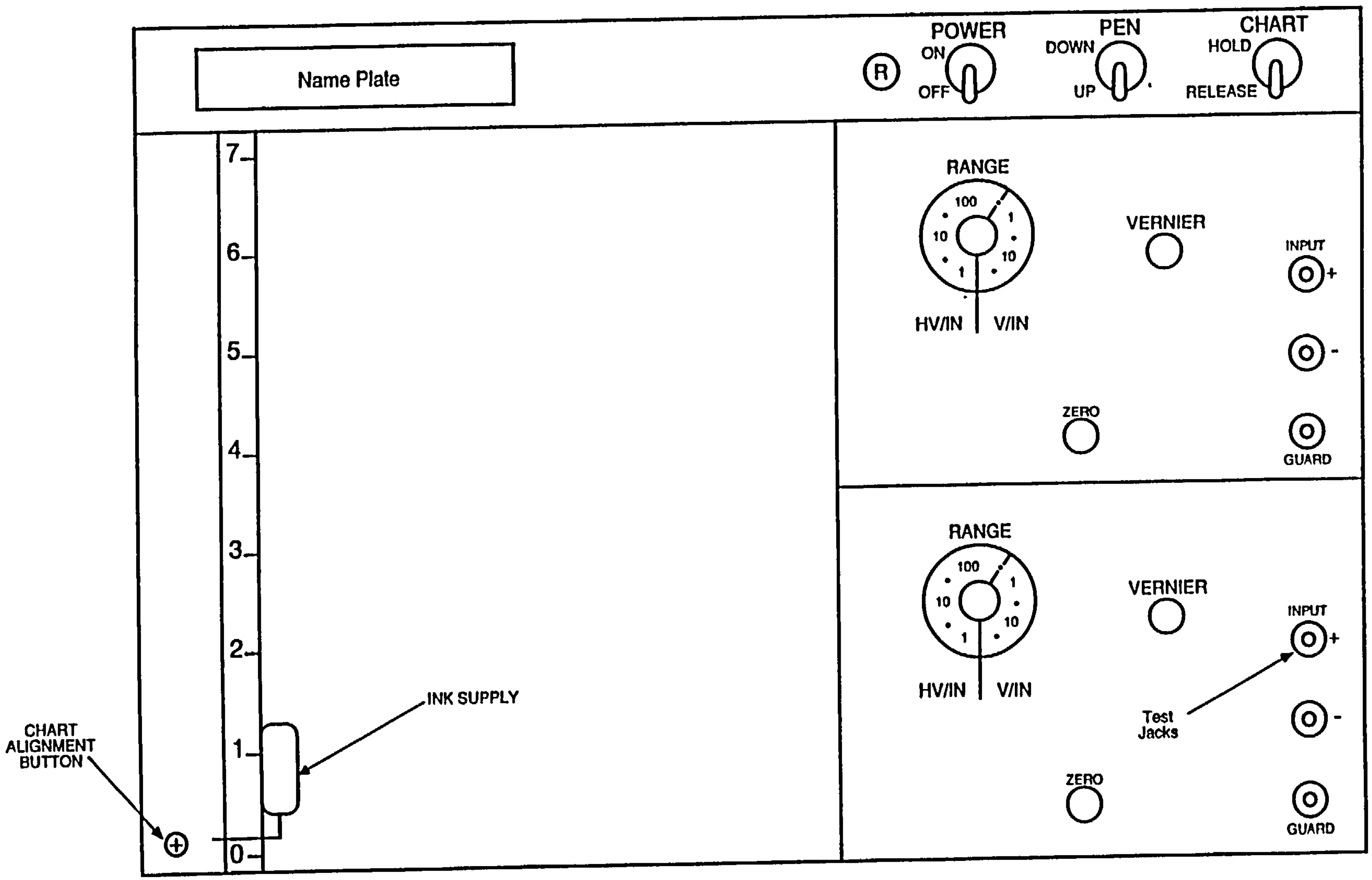


Figure 5.6-9 TIP X-Y Recorder

0494

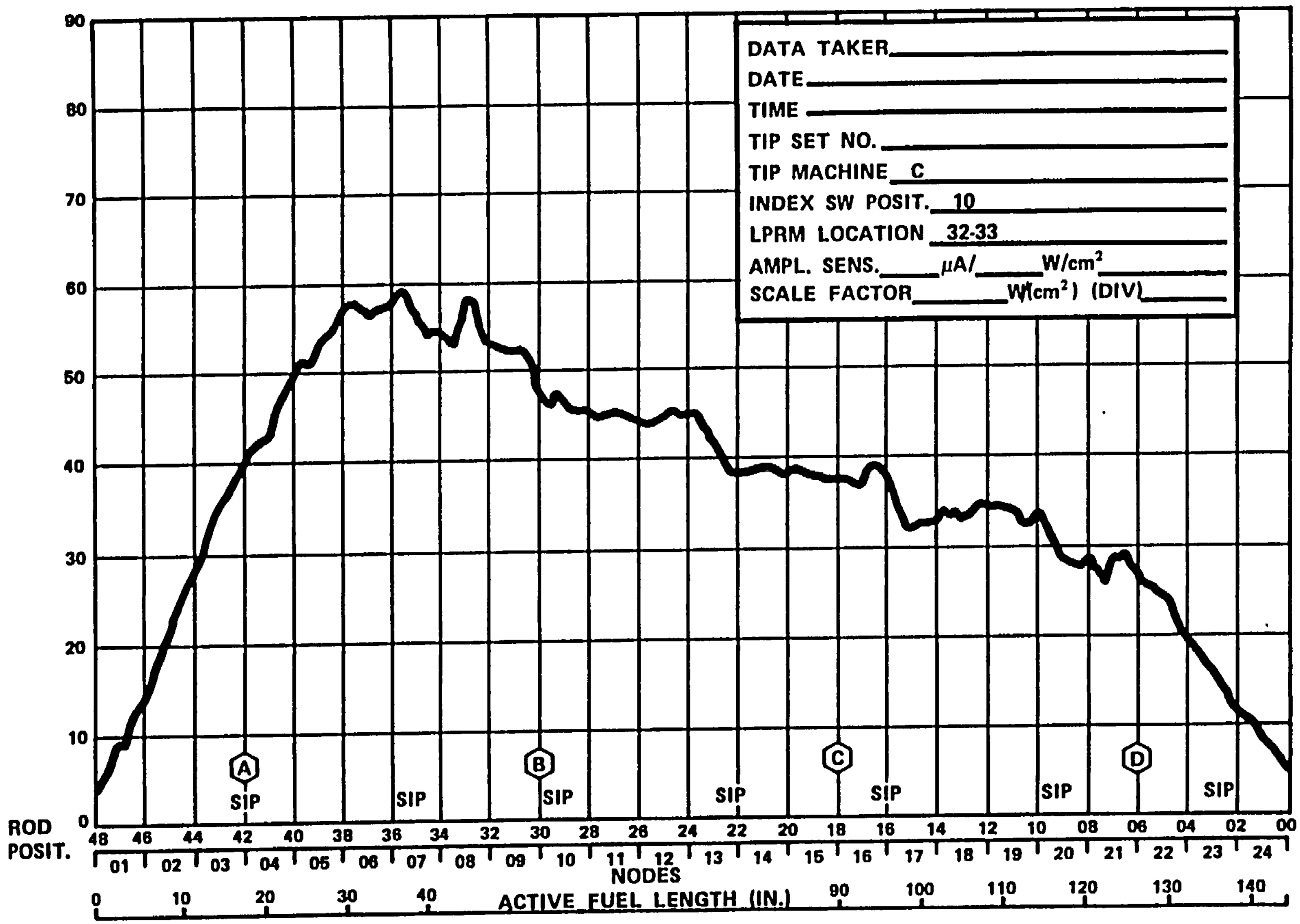


FIGURE 5.6-10 TIP TRACE

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 6.0

Display and Information Systems

Table of Contents

6.0 PLANT INFORMATION SYSTEMS

6.0.1 Introduction

The systems discussed in this chapter have to do with the flow of information associated with operation and management of the plant under normal conditions, abnormal conditions, and emergency conditions. Included in this discussion are systems which provide the operator a tremendous amount of data in various forms, control room equipment which allows the operator to conduct most plant evolutions, remote equipment which allows the plant staff to safely shut the plant down from outside the control room, and equipment which allows the plant staff to respond to emergency conditions. The sections of this chapter are organized in the following manner:

Process Computer System (Section 6.1)
Control Room Design (Section 6.2)
Remote Shutdown System (Section 6.3)
Emergency Response Information System (Section 6.5)

6.0.2 Plant Process Computer System (Section 6.1)

The Process Computer System monitors various plant process variables, provides alarms and messages if limits are exceeded, performs calculations, and provides data to the plant operators in various formats. The process computer also uses 3D Monicore data the provide information necessary form fuel life optimization, and maintaining the fuel thermal power within prescribed thermal limits.

6.0.3 Main Control Room Design (Section 6.2)

The main control room provides the instrumentation, controls and communication systems necessary to operate the plant under all conditions. The control room is designed with as much human factoring as possible to enable the plant staff to response to changing plant conditions as quickly and safely as possible. In the main control room the operating staff is supplied with plant data from analog and digital instrumentation, process computer data, alarm systems, the Emergency Response Information System, and various communications systems. The main control room also has the control and communication systems available for the plant staff to control the various plant systems under almost all plant conditions.

6.0.4 Remote Shutdown System (Section 6.3)

The Remote Shutdown System provides a means for bringing the reactor to a cold shutdown condition, from outside the main control room, should the main control room have to be abandoned.

6.0.5 Emergency Response Information System (ERIS) (Section 6.4)

The Emergency Response Information System helps the operating personnel mitigate the consequences of accidents, transients, and abnormal operating conditions. ERIS supplies graphic information to the operation staff on a large variety of plant variables, this information aids the operations staff in determining overall plant conditions.

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 6.1

Process Computer System

Table of Contents

List Of Tables

List of Figures

6.1 PROCESS COMPUTER SYSTEM USING 3D MONICORE

Learning Objectives:

1. State the system's purpose(s).
2. State how the system accomplishes it's purpose(s).
3. Explain how the process computer can be used to determine plant performance.

6.1.1 Introduction

The functional classification of the process computer system is that of a power generation system.

This chapter discusses both the old process computer system and the computer systems using 3D Monicore. The first sections discuss the older systems while the later sections discuss the 3D Monicore systems.

The purpose of the process computer is to provide on-line monitoring of significant plant process variables, scan the inputs and issue appropriate alarms and messages if limits are exceeded, provide the operator with essential plant performance data, and to provide data necessary for the maintenance of optimum core power distribution, economical utilization of fuel and overall plant operating efficiency.

The Process Computer System provides on-line monitoring of several hundred input points representing significant plant process variables. The system scans digital and analog inputs at specific intervals and issues appropriate alarm indications and messages if monitored analog values exceed predefined limits or if digital trip signals occur. It performs calculations with selected input data to provide the operator with essential plant performance information through a variety of logs, trends, summaries, and other typewriter data arrays. Computer outputs include various front panel displays, and status indications.

The primary function is to perform reactor core calculations and provide the plant operating staff with current core performance information.

The 3D Monicore is a system of computer programs designed to monitor and predict important core parameters. As such it is divided into two major components, the "monitor" and the "predictor". Both components use a three dimensional BWR core simulator called "Panacea." The term Panacea in refers to the computer program that also is known as PANAC09. Panacea calculates the reactor's power, moderator, void, and flow distributions. From these, other parameters such as margin to thermal limits, fuel exposure, and Preconditioning Interim Operating Management Recommendations (PICOMR) envelope data can be determined.

The 3D Monicore monitor is designed to track current reactor parameters automatically or on demand. The predictor runs upon user request. It predicts core parameters for reactor states other than the present one. 3D monicore's accuracy is enhanced by making use of in-core neutron flux measurements. Nodal fit coefficients are calculated such that Panacea calculated, TIP (Traversing In-core Probe) readings are identical to actual TIP readings. These fit coefficients may be utilized for later monitor and predictor cases. The process of calculating and using fit coefficients is called 3D Monicore's "adaptive process". Results of adaptive cases match expected operating parameters more closely than results of standard non-adaptive cases.

Panacea is the calculation core of the process. 3D Monicore programs provide the logic to interface with Panacea, extract outputs from Panacea calculations, and generate reports. 3D Monicore does some minor calculations itself (for example, thermal efficiency). The overall database control is provided by a dynamic database generator called HABITAT. This program provides global configurations of the system. A menu generator program, called Video Terminal Rapport (VTRAP), is provided to enable the user to enter data or select a program to run.

6.1.2 Component Description

The major components of the Process Computer are discussed in the paragraphs that follow.

6.1.2.1 Computer Hardware

A simplified block diagram of the process computer is shown in Figure 6.1-1. Analog voltage and current inputs representing reactor flux levels, flows, pressures, temperatures, and power levels are applied to the analog input scanner. Digital (contact closure) inputs, which include various trips and alarms, TIP system signals, control rod positions, and rod worth minimizer inputs, are applied to the digital input scanner. Pulse inputs for TIP probe positions and gross generator energy are applied directly to the central processor. The central processor performs the calculations required for the program being run, assigns priorities to the various programs and computer functions, and contains a memory unit, which provides for data storage. Computer commands and input data originating from the computer operator's console, computer room console, or the rod worth minimizer components are routed through the central processor.

An analog to digital converter changes the analog inputs into digital inputs for use by the computer. Program messages, logs, etc. are routed to the appropriate output typer. Other outputs from the central processor are distributed by the multiple output controller to controls, indicators and displays on the computer operators console, computer room console, rod worth minimizer panel, TIP system, rod position information system (RPIS) and to the VAX minicomputer.

6.1.2.2 3D Monicore System

3D Monicore operates on the plant's data acquisition system's process computer and the 3D monicore VAX minicomputer. Special application and protocol programs control data flow between the process computer and the VAX. The process computer stores live data needed for 3D Monicore calculations in live memory.

The three types of data scanned are analog, pulse, and digital. Analog inputs indicate continuously varying quantities such as flows, pressures, temperatures, and flux levels. Digital inputs indicate various trips and alarms. Pulse inputs are used with counting devices to represent TIP positions. Programs executed by the process computer control the scanning of input points at specific intervals, the testing of scanned values against predefined limits, and the activation of alarm messages.

6.1.2.3 Core Monitoring Functions

The 3D Monicore System provides a variety of options for monitoring thermal limits, power distribution, and exposure updates. A monitor case automatically executes up to 24 times a day. Users may run additional cases on demand. These manually demanded cases can be either

Table 6.1-3 Terms Used by 3D Monicore

SEQUENCE NUMBER	Refers to the order of this Official 3D Monicore in the day
FPAPDR	Full Power Adjusted Density Ratio
SUBC	Core Inlet Subcooling in BTU/LB
CORE MWD/ST	Average exposure of all fuel in the core
CYCLE MWD/ST	Average exposure added to fuel this cycle
XE WORTH %	Estimate of negative reactivity of Xenon
XE/Rated	Xenon reactivity divided by full power equilibrium xenon
CORE POWER	Reactor power in percent of rated
CORE FLOW	Percent of rated core flow
LOAD LINE	Estimated power if recirculation flow were increased to 100 %
MFLCPR	Limiting multiplier on CPR Operating Limit
MAPRAT	The limiting (minimum) MAPLHGR limit multiplier
MCPRLIM	The uncorrected MCPR Limit used for the limiting bundle
MFLPD	Core maximum ratio of peak pin power to the fuel dependent limit of that bundle
MAPRAT	Core maximum ratio of average nodal power in a node to the fuel, plant ECCS system exposure, power and flow dependent limit of that node
PCRAT	PCIMOR associated variable
SUB RODS	List of control rods with manually substituted positions
CALC SUB FLOW	Value of flow calculated from alternate sensors (% of rated)
FLOW BIAS MEAS	Core flow is measured from sum of jet pump flow signals
FLOW BIAS SUB	Computer calculated from recirculation flow to core flow correlation
FLOW BIAS OPER	Operator supplied value

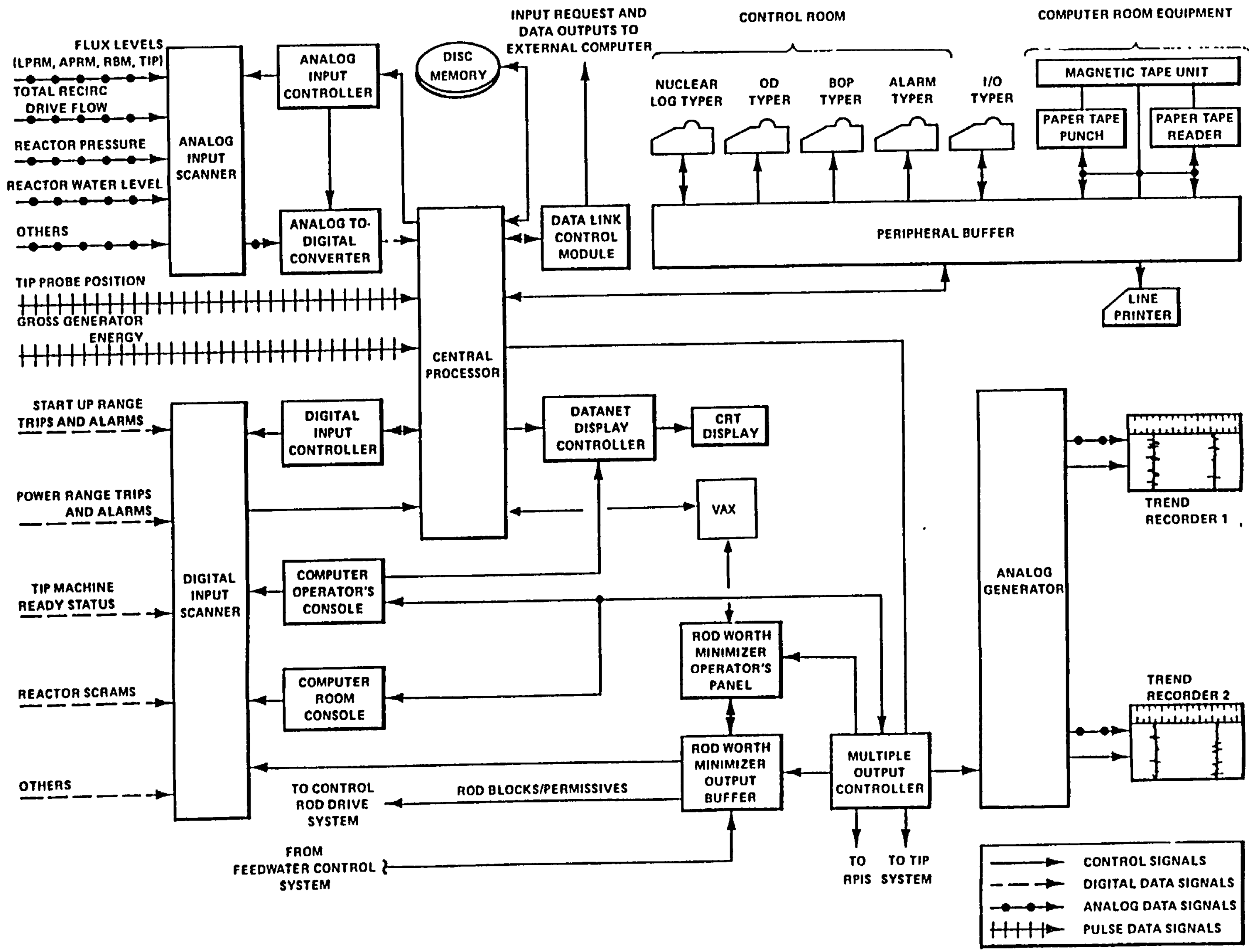
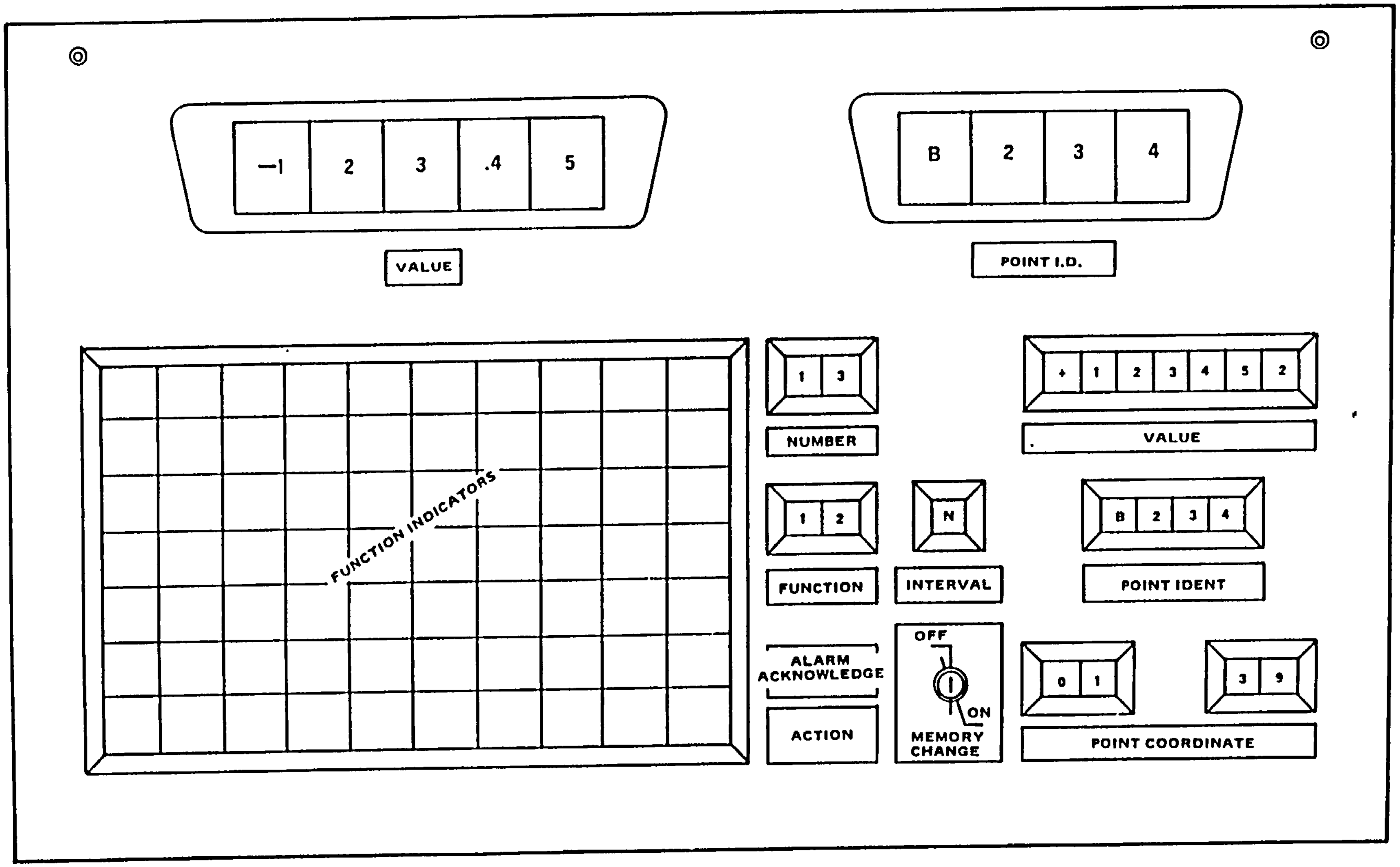


FIGURE 6.1 – 1 PROCESS COMPUTER SIMPLIFIED BLOCK DIAGRAM



6.1-2 Operator Control Panel

```
                                        PLANT NAME            SEQUENCE NO 12
CORE PARAMETERS                         3D MONICORE            7-JUL-1993 12:29 CALCULATED
POWER  MWT            3563.             PERIODIC LOG           7-JUL-1993 12:42 PRINTED
POWER  MWE            1205.                                   CASE ID FMLS1930707122950
FLOW   MLB/HR        86.871            CALC RESULTS           RESTART FRFS1930707120850
FPAPDR                0.909                                   LPRM ABSOLUTE - FULL CORE
SUBC   BTU/LB         24.49            Keff          1.0000
PR     PSIa          1034.3            XE WORTH %    -2.48    LOAD LINE SUMMARY
CORE   MWD/sT       17029.7            XE/RATED       1.01    CORE POWER          99.6%
CYCLE  MWD/sT        5543.6                                   CORE FLOW           83.5%
                                                              LOAD LINE          111.6%
CORRECTION FACTOR:  MFLCPR= 1.017  MFLPD= 1.000  MAPRAT= 0.998
OPTION:   ARTS      DUAL LOOP      MANUAL FLOW   MCPRLIM= 1.190
```

MOST LIMITING LOCATIONS (NON-SYMMETRIC)

MFLCPR	LOC	MFLPD	LOC	MAPRAT	LOC	PCRAT	LOC
0.874	21-40	0.905	19-50- 4	0.892	41-12- 4	0.998	19-34-16
0.861	25-36	0.897	49-42- 5	0.889	51-22- 5	0.997	41-32-13
0.846	27-34	0.884	51-40- 5	0.887	49-42- 5	0.997	27-14-16
0.846	25-38	0.875	21-52- 4	0.878	51-44- 5	0.996	37-40-16
0.845	35-40	0.872	51-44- 5	0.878	21-10- 4	0.996	33-32-18
0.844	29-34	0.871	17-52- 5	0.871	17-10- 5	0.996	27-40-16
0.839	27-30	0.864	43-36- 5	0.863	43-26- 5	0.996	13-48-15
0.837	23-36	0.858	53-42- 5	0.852	51-26- 5	0.996	27-42-16
0.834	37-42	0.855	19-54- 4	0.849	43-44- 5	0.996	47-34-16
0.833	21-36	0.851	51-26- 5	0.837	39-40- 9	0.996	21-40-17

```
SEQ. A-2     C=MFLCPR D=MFLPD M=MAPRAT P=PCRAT *=MULTIPLE

59
 L
55                      12
51               D
 L
47          32    08    38    08    32
43
 L
39          08    C34   08    34    08
35                P
 L
31    12    38    08    36    08    38    12
27
 L
23          08    34    08    34    08
19
 L
15          32    08    38    08    32
11                             M
 L
07                      12
03       L     L     L     L     L     L     L
   02 06 10 14 18 22 26 30 34 38 42 46 50 54 58
```

CORE AVE AXIAL

NOTCH	REL PW	LOC
	0.197	25
00	0.436	24
02	0.672	23
04	0.839	22
06	0.921	21
08	0.946	20
10	0.991	19
12	1.005	18
14	1.037	17
16	1.098	16
18	1.129	15
20	1.136	14
22	1.174	13
24	1.210	12
26	1.211	11
28	1.220	10
30	1.253	09
32	1.254	08
34	1.228	07
36	1.248	06
38	1.246	05
40	1.202	04
42	1.098	03
44	0.845	02
46	0.406	01

CORE AVERAGE RADIAL POWER DISTRIBUTION

RING #	1	2	3	4	5	6	7	8
REL PW	1.011	1.251	1.162	1.212	1.106	1.149	1.014	0.652

Ffigure 6.1-3 LPRM Adaptive Monitor Case Output (Sample Output)

```
                                                                    PAGE   2
PLANT NAME           INSTRUMENT READINGS/STATUS      SEQUENCE NO 12
                      CALIBRATED LPRM READINGS        7-JUL-1993 12:29 CALCULATED
                                                      7-JUL-1993 12:42 PRINTED
57D               38.5  42.6  29.8                   CASE ID FMLS1930707122950
  C               47.9  43.4  41.6                   LPRM ABSOLUTE - FULL CORE
  B               51.5  44.3  46.0
  A             D 44.5  36.1   0.0
                                                        FAILED SENSORS:
49D  27.2  44.3  53.0  53.6  47.5  37.9                 LPRM (  2 SIGNAL FAILED)
  C  42.9  66.3  63.5  65.5  60.2  58.8                   3209C 4057A
  B  49.1  72.4  67.8  69.5  67.4  66.2                 LPRM (  0 PANACEA REJECTED)
  A  44.0  60.1  57.2  49.3  68.4  55.2                 OTHER SENSORS (  1 TOTAL)

41D  42.4  52.9C 57.9  57.0  55.4  47.7  30.8             2-CRD FDW TEMP (F)
  C  60.7  65.2P 76.6  66.4  71.5  60.6  41.1           SUB RODS
  B  69.2  70.5  79.4  68.5  76.8  67.6  44.9             NONE
  A  70.1  60.9  58.0  51.9  58.1  66.7  40.5
                                                        T = TIP RUN RECOMMENDED
33D  50.8  56.7  58.4  57.4  54.9  52.8  41.5           C = MFLCPR LOCATION
  C  58.2  73.1  69.5  73.3  64.2  66.0  42.0           M = MAPRAT LOCATION
  B  63.6  78.6  71.4  75.5  67.8  69.7  43.1           D = MFLPD LOCATION
  A  55.9  58.2  56.2  54.0  54.1  52.6  35.9           P = PCRAT LOCATION
                                                        * = MULTIPLE LIMIT
25D  46.1  54.8  57.7  58.8  56.8  52.5  37.7
  C  61.2  65.8  75.6  71.2  75.0  63.0  47.5
  B  66.4  71.0  79.5  73.3  78.8  66.4  50.3
  A  63.9  59.4  57.2  56.8  60.5  61.6  46.6

17D  36.0  47.4  54.7  57.6  51.9  44.8
  C  57.0  67.0  65.7  73.4  64.8  67.0
  B  66.2  73.1  70.6  77.4  69.3  72.9
  A  67.3  61.1  58.6  54.8  62.4M 62.4

09D        36.3  46.6  51.2  42.2  26.7
  C        57.2  61.1   0.0  61.0  41.4
  B        67.1  66.2  62.2  68.9  47.1
  A        67.4  64.6  53.5  71.0  44.0

      08    16    24    32    40    48    56

     CORE SUMMARY
  CORE POWER     99.6%    CALC SUB FLOW      84.1%   DP MEAS PSI                15.51
  CORE FLOW      83.5%    OPER SUB FLOW      -1.0%   DP CALC PSI                20.20
  LOAD LINE     111.6%    FLOW BASIS         MEAS    FEEDWTR FLOW MLB/HR        15.35

     APRM CALIBRATION
               A       B       C       D       E       F       G       H
  READING    99.1    99.4    99.6    99.5    99.5    99.5    99.3    99.0
  AGAF      1.005   1.001   1.000   1.001   1.000   1.001   1.003   1.006

     TIP RUNS RECOMMENDED
  STRINGS:         NONE
```

Figure 6.1-4 LPRM Adaptive Monitoring Case (continued)

```
                                                                          PAGE    1

                                        PLANT NAME
                                        3D MONICORE          18-JUN-1993 14:44 CALCULATED
                                        FAST LOG             18-JUN-1993 14:44 PRINTED
                                                             CASE ID FFLS1930618144400
                                                             RESTART FFLS1930618143115

                                 CORE POWER 100.0%
                                 CORE FLOW   83.5%
                                 INITIATED BY: USER REQUEST

                                          VALUE      LOCATION
                                 MFLCPR   0.883      21-22
                                 MFLPD    0.960      41-12- 4
                                 MAPRAT   0.938      41-12- 4
                                 PCRAT    1.002      53-22- 9

OPTION:  ARTS         DUAL LOOP      MANUAL FLOW   MCPRLIM=
CORRECTION FACTOR:    MFLCPR= 1.017  MFLPD= 1.000  MAPRAT= 1.000

SEQ. A-2    C=MFLCPR D=MFLPD M=MAPRAT P=PCRAT *=MULTIPLE


59
  L
55                      12
51
  L
47          32    08    38    08    32
43
  L
39          08    34    06    34    08
35
  L
31    12    38    06    36    06    38    12
27
  L
23          08   C34    06    34    08    P
19
  L
15          32    08    38    08    32
11                              *
  L
07                      12
03      L     L     L     L     L     L     L
   02 06 10 14 18 22 26 30 34 38 42 46 50 54 58
```

Figure 6.1-5 Fast Periodic Report (Sample Format)

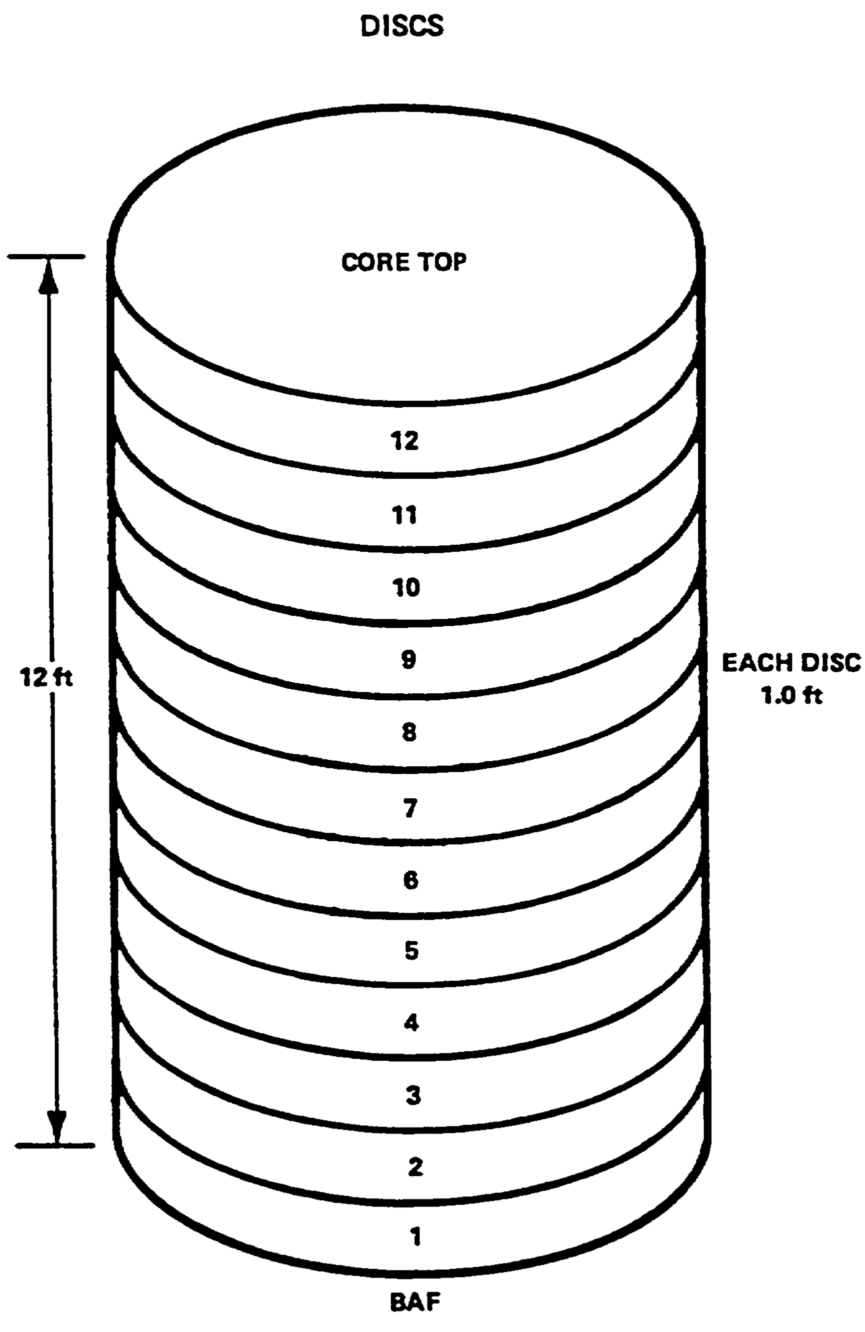


Figure 6.1-6 Core Axial Array Definition

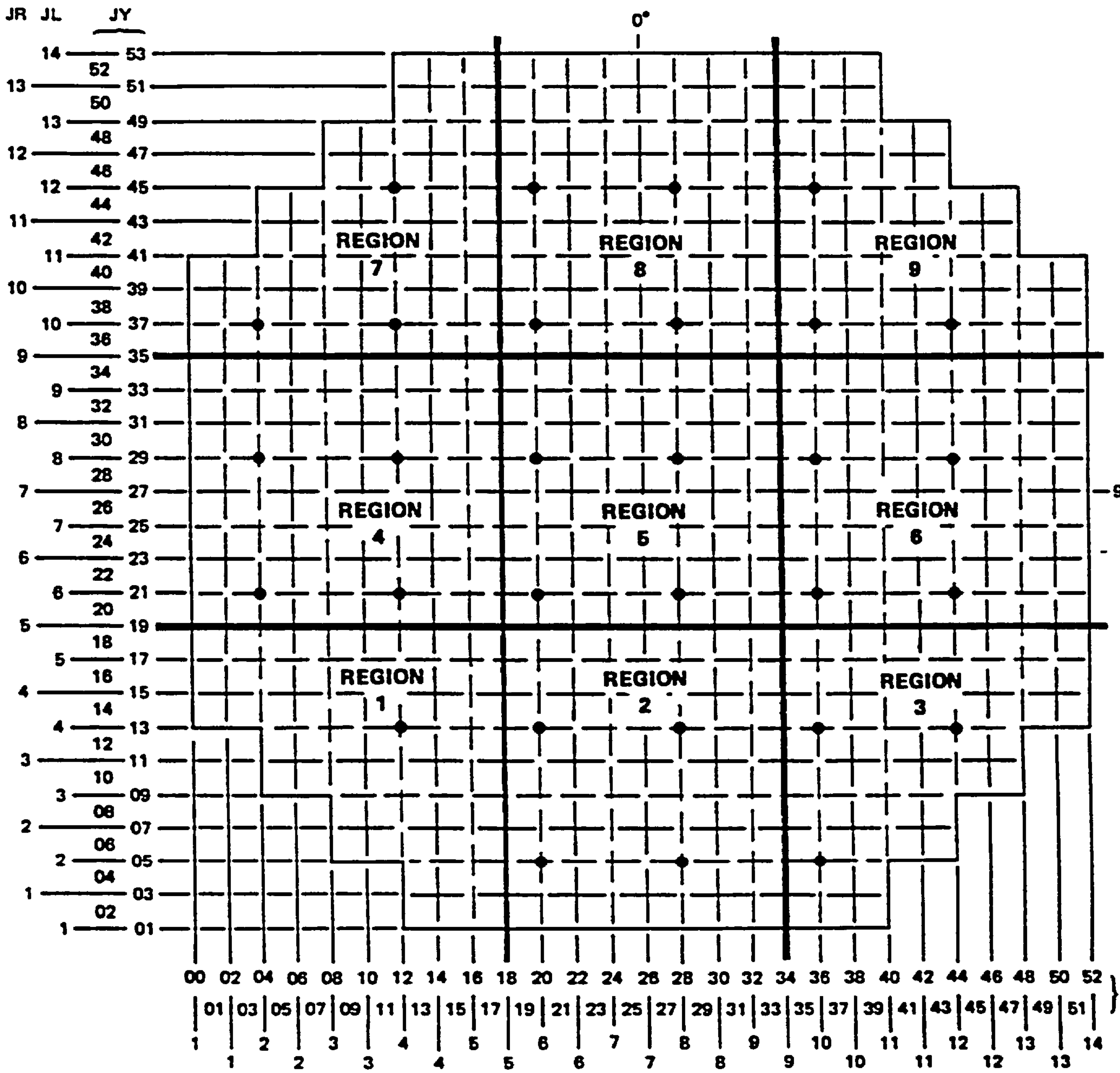


Figure 6.1-7 Core Region Array Definition

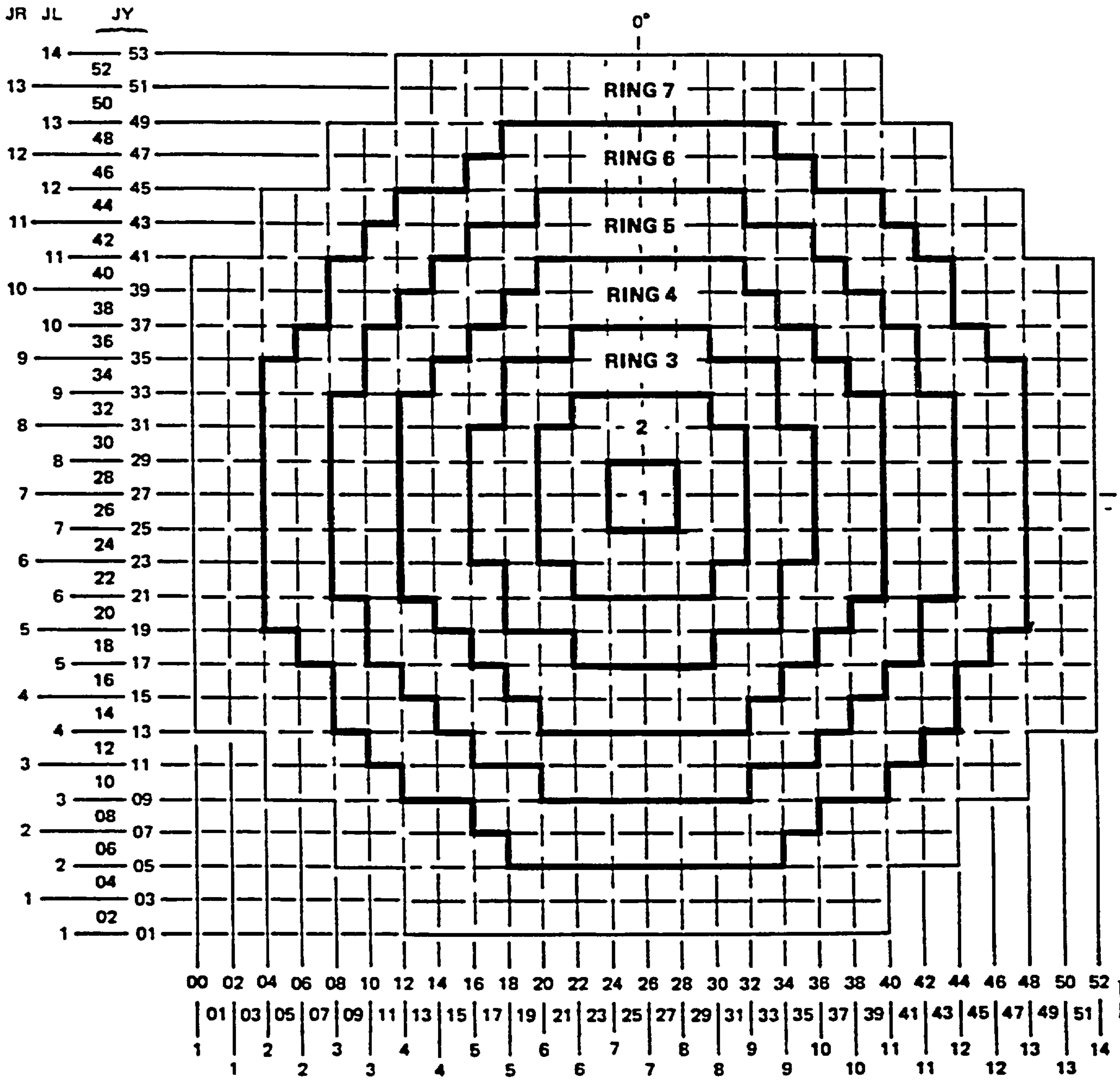


Figure 6.1-8 Core Ring Array Definition

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 6.2

Control Room Design

Table of Contents

List Of Figures

6.2 CONTROL ROOM DESIGN

Lesson Objectve

Show a basic knowledge of the control room design.

6.2.1 Introduction

The plant control room (Figure 6.2-1) supplies information, data and control hardware needed to operate the plant in a safe, efficient and reliable manner. The control room is the main point of control for all modes of plant operation and integrates instrumentation systems, control systems, display systems and data processing systems.

6.2.2 Component Description

The main control room is a centralized area for providing control and information for the operation of the plant. Control is provided through the use of pushbuttons, control switches, and both automatic and manual controllers. Information is provide by the use of recorders, displays, process computer, communication systems as well as digital and analog indicators.

Their are several major areas of the main control design which are discussed in the following paragraphs.

6.2.2.1 Human Factors Criteria

All facets of the main control roo design have been subjected to a process of research, testing and design to comply with with applicable human factors. As a result the instruments, displays, alarms and controls are grouped by functional area and frequency of use. This helps reduce the possibility of operator error during control operations.

6.2.2.2 System Integration

The control room design integrates the primary system, nuclear steam supply shut off system, balance of plant systems and emergency systems, to give the operator an effective human to machine interface. This type of integration is consistent for all the plant systems and aids the operator in the process of making and implementing decisions regarding plant operations.

6.2.2.3 Power Supplies

Power supplies are arranged to the control room to provide for system separation and redundancy. No single failure in the power supply system will result in degradation of the control room functions, except for non-essential systems whose failure will not decrease the plants abilty to operate or shutdown safely.

6.2.2.4 Control Panels

The control panels in the main control room are designed to meet the seismic requirements of the 10CFR's and are arranged to give the best possible access to the operator for control manipulation as well as for monitoring of displays and instrumentation.

Primary Control Panel

The primary control panel is the location for all controls, displays, recorders and instumentation necessary for the power operation from hot standby to full power. This includes controls and instrumentation for the reactor systems, main turbine control, main steam system, condensate system, emergency core cooling systems and emergency diesels. The reactor display and control rod controls are located in the center of the panel with the other systems to either side.

The systems controls, displays and intrumentation are integrated into a unified arrangemnet to optimize operator understanding of the plant status while minimizing the movements required for plant control.

Auxiliary Panels

The auxiliary panels located in the main control room contain all the controls, displays and instrumentation less frequently used. The controls, alarms and instrumentation systems are generally associated with support systems, area radiation monitoring systems, process radiation monitoring systems and control panels for the neutron monitoring systems. Access to the auxiliary panels is arranged to allow the operator the ability to operate controls from these panels while still in visual control with the primary control panel.

6.2.2.5 Other Equipment

Also located in the control room is the control console for the process computer. which gives the operator a wide range of information on the reactor operation, heat balance and plant status.

There is a work station for both the operator and supervisor in the control room. Each of these stations have telephone and paging capabilities in addition to the communication sets located a various positions near the control panels.

Plant procedures and drawings are kept at a location in the control room to give the operator access to this information without the need to leave control area, this allows the operator to have visual contact with the control panels while researching system procedures or drawings. Also located at the operators station are the controls to activate the various plant alarm systems such as the site evacuation alarm.

6.2.3 System Interfaces

The equipment in the main control room interfaces with most of the plant systems, subsystems and support systems.

6.2.4 Summary

Purpose: To supply information and control needed for the safe, effecient and reliable operation of the plant.

Components: Control panels, operators work station, and the process computer.

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 6.3

Remote Shutdown System

Table of Contents

List of Figures

6.3 REMOTE SHUTDOWN SYSTEM

Learning Objectives

1. State the system's purpose(s).
2. State how the system accomplishes its purpose(s).
3. Explain how control is transferred from the Main Control Room to the Remote Shutdown System.

6.3.1 Introduction

The purpose of the Remote Shutdown System is to provide remote control outside the main control room for placing the reactor in a cold shutdown condition.

The Remote Shutdown System is designed to control the required shutdown systems from outside the Main Control Room irrespective of control panel problems in the Main Control Room. The design of the system ensures that no common points of vulnerability are created by the utilization of the Remote Shutdown System.

The design bases for establishing the functional requirements to provide hot shutdown capability from the Remote Shutdown Panel and local control points are:

a. Inaccessibility of the Main Control Room does not occur simultaneously or subsequent to an accident condition other than a loss of off site power. The period of inaccessibility is assumed to be no longer than one week.

b. The Main Control Room control boards remain operable, and all automatic systems continue functioning during and subsequent to Main Control Room evacuation.

c. A communication network is provided between local control points and the Remote Shutdown Panel.

d. Transfer of control for equipment to the Remote Shutdown Panel (RSP) is annunciated in the Main Control Room.

The Remote Shutdown System (RSS) provides control for the systems needed to shutdown the reactor to cold shutdown condition from outside the Main Control Room in an orderly fashion, through the use of suitable procedures. Normal cooldown is accomplished by controlling the various components utilized during a normal reactor cooldown operation from the Main Control Room. Cooldown can also be accomplished from the RSP when feedwater is unavailable, and the reactor is isolated from its normal heat sink (the main condenser).

Figure 6.3-1 shows all the various components that can be controlled from the RSP, and the RSP instrumentation and indicators. Each component that can be controlled from the RSP has associated with it a control switch and a Remote Shutdown Transfer Switch (RSTS). Each component has its own control switch, but a RSTS can be used for more than one RSP component.

When the Reactor Core Isolation Cooling System or the Residual Heat Removal System is being controlled from the RSP, these systems will not automatically initiate into emergency mode if a Loss-Of-Coolant Accident (LOCA) occurs. The Remote Shutdown System is not designed to be operated coincident with a LOCA condition.

Basically the RSP is placed into operation when the Main Control Room becomes untenable. The operator manually scrams the reactor and evacuates the Main Control Room. If time permits the RSP should be manned first with a licensed operator. If it was not possible to manually scram the reactor prior to evacuation, the reactor may be scrammed by opening breakers on the Reactor Protection System distribution panels. Reactor pressure should be controlled by the Electro-hydraulic Control System with the turbine bypass valves. If the Main Steam Isolation Valves close then the Safety/Relief Valves (SRVs) should control reactor pressure. The operator will transfer control to the RSP by placing all of the RSTSs in the EMERGENCY position.

The RSP will be enclosed to protect the panel from "missiles", etc. The RSP access door will be key locked and interlocked so when the door is opened an annunciator, "RSPS ENCLOSURE ACCESSED" will alarm in the Main Control Room..

6.3.2 Component Description

The Remote Shutdown Panel is the only major component of the Remote Shutdown System.

6.3.3 System Features and Interfaces

The components that makeup the Remote Shutdown Panel are discussed in the following paragraphs.

6.3.3.1 Remote Shutdown Transfer Switches

Remote Shutdown Transfer Switches are provided to transfer control of the affected component from the main control room to the Remote Shutdown panel. In order to control the component from the RSP it's associated transfer switch must be placed in the "EMERG" position. This transfers control power from the control room to the RSP. This action will interrupt control power to the Main Control Room for the associated component and will also result in the following annunciator on the RSP: "RSDS TRANSFER SWITCH IN EMERGENCY".

6.3.3.2 Valve Control Switches

The valve control switches are maintained contact switches with two positions (Open and Close). Each valve has a red light for the open position and a green light for the closed position with both lights being illuminated in intermediate positions.

6.3.3.3 Pump Control Switches

The pump control switches are maintained contact switches with three positions of "Stop-Normal-Start". Each pump has a red light for the run position and a green light for the stopped position. As with most motor control switch indicating lights the red and green lights are associated with the motor breaker and not the actual control switch position.

6.3.3.4 RCIC Controls and Indicating Lights

The RCIC has several controls and indicating lights on the RSP, which allows for operation of the RCIC System from the RSP. There are amber indicating lights for the following functions: RCIC Turbine Bearing Oil low Pressure, RCIC Turbine End Oil Temperature High, and Turbine Tripped. The controls consist of : valve control switches, RCIC flow controller, RCIC lube oil cooling water PCV controller, and RCIC turbine trip push button.

6.3.3.5 Interlocks

All interlocks that originate at relays and switches in the Main Control Room are bypassed when the Remote Transfer Switches are in the "EMERG " position. Significant interlocks that are bypassed are :

a. RCIC will not auto initiate on low level.

b. All RCIC interlocks are bypassed except turbine trips.

c. All RCIC isolation signals are bypassed.

d. RCIC minimum flow valve will not operate automatically.

e. Low Pressure Coolant Injection (Loop B) will not auto initiate.

f. All Loop "B" Residual Heat Removal System and Loop A Shutdown Cooling suction valves interlocks are bypassed.

Interlocks which originate at the switchgear will remain in effect.

6.3.3.6 System Interfaces

The following systems can be controlled from the RSP:

a. Residual Heat Removal System

b. Reactor Recirculation System

c. Reactor Core Isolation Cooling System

d. Fuel Pool Cooling System

f. Service Water System

g. Reactor Building Closed Cooling Water System

h. Instrument and Service Air

I. Safety / Relief Valves (SRV's)

6.3.4 Summary

The Remote Shutdown System is designed to control the required shutdown systems from outside the Main Control Room in the event evacuation is necessitated. The transfer switches on the RSP allow transfer of component control from the Main Control Room to the RSP. When control is transferred to the RSP the operator must be aware that most interlocks and trips are no longer in the circuitry and it is up to the operator to ensure that proper operating conditions and limitations are met while operating the system.

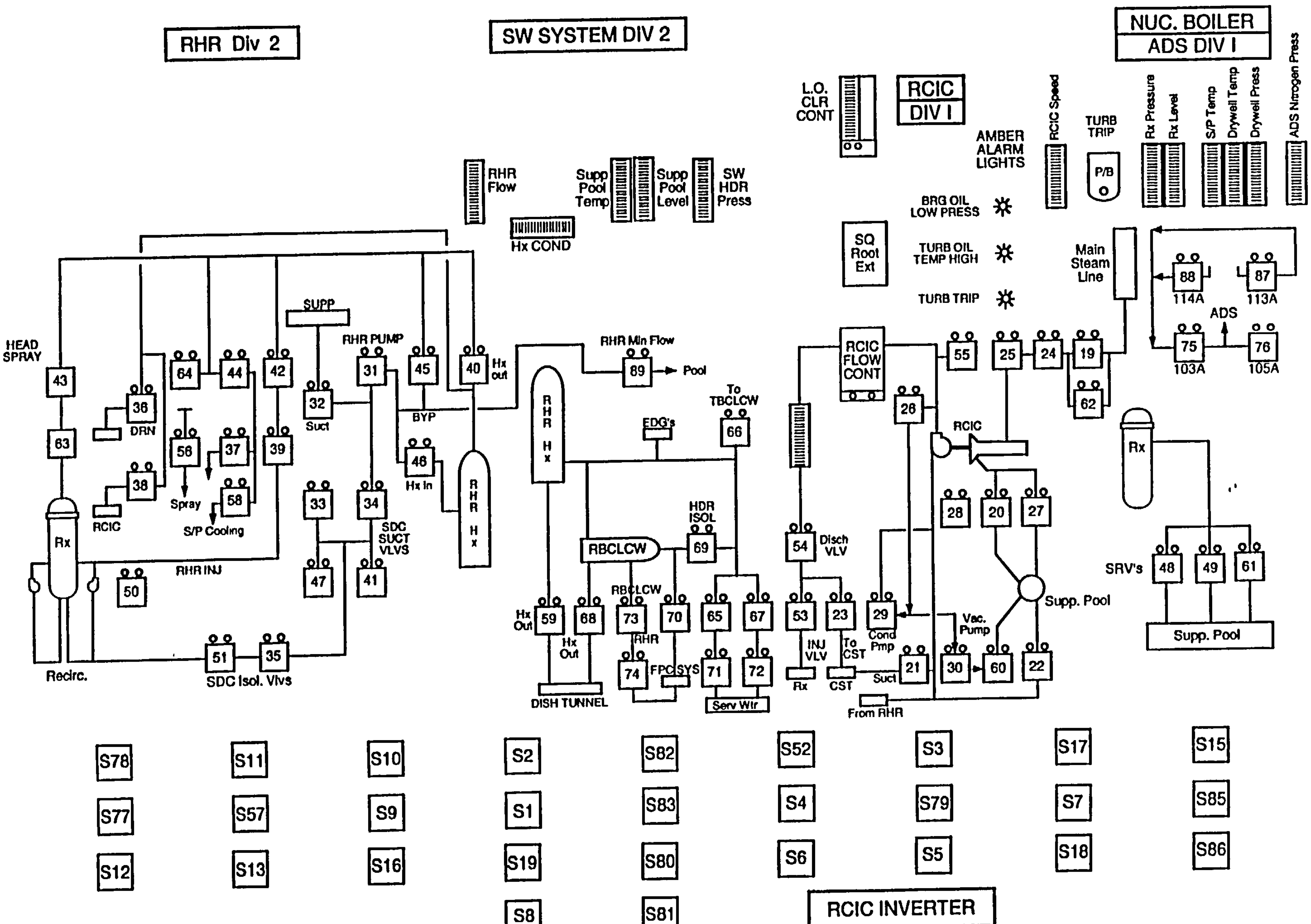


Figure 6.3-1 Remote Shutdown Panel

0294

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 6.4

Emergency Response Information System

Table of Contents

List of Figures

6.4 Emergency Response Information System

Lesson Objectives:

1. State the system's purpose.
2. Explain how the system accomplishes its purpose.

6.4.1 Introduction

The purpose of the Emergency Response Information System (ERIS) is to improve the control room response to operational transients in a boiling water reactor. ERIS will also aid operators in detecting abnormal operating conditions, assessing the safety status of the plant, executing the corrective actions, and monitoring the plant response. The design of the ERIS displays is such that they provide the operators with information necessary to utilize the Emergency Procedure Guidelines (EPG's).

Following the Three Mile Island incident, the Nuclear Regulatory Commission established a requirement that control room operators be aided by a system that would combine critical plant parameters in a new Safety Parameter Display System (SPDS). The SPDS would aid the control room operator during abnormal and emergency conditions in the following areas:

1. Determining the safety status of the plant.

2. Mitigating the effects of abnormal transients to avoid a degraded core.

The use of the SPDS can be particularly important during anticipated transients and the initial phase of an accident.

The General Electric Company has developed the Emergency Response Information System (ERIS) to meet the requirements of the SPDS.

6.4.2 System Description

The ERIS is an integrated system that gathers the required plant data, stores and processes that data, generates visual displays for the operator and other personnel who need plant status information, and provides printed records of transient events. The basic components of ERIS are the Data Acquisition System, the Central Processor Unit, and the Graphic Display Console (Figure 1).

The Data Acquisition System (DAS) interfaces with existing plant sensors or devices, converts the acquired signals to digital data, and performs some pre-processing of the data before passing it on to the Central Processors.

The Central Processor Unit (CPU) is a computer module that accepts data from the Data Acquisition System, stores the data, performs calculations, validates the information, and generates displays according to the programmed formats.

The Graphic Display Console (GDC) contains one or more cathode-ray tubes and their associated keyboards. The cathode-ray tubes generate a variety of graphic real-time displays that are available on command from the keyboards. The displays are capable of showing ciritical plant parameters such as water levels, temperatures, pressures, flows and status of pumps, valves, and other equipment.

The ERIS consists of two major subsystems: Real Time Analysis and Display (RTAD) and Transient Recording and Analysis (TRA).

The RTAD subsystem provides for the function of automatic reporting and display of real-time plant parameters for current user requests. The RTAD includes the following functions:

a. Initial data processing
b. Display processing
c. Editing capabilities
d. Graphic display package.

The TRA subsystem provides for the function of normal and high speed data acquisition, real time and historical transient analysis, and printing/plotting of the transient data.

The control room operator will, in all likelihood, most frequently use the Real Time Analysis and Display subsystem. The TRA subsystem will be most used by plant engineering staff to analyze specific plant transients. As a result, the discussion in this course will be limited to the RTAD subsystem.

The General Electric Company provides two design alternatives for the ERIS. One is called Basic ERIS and the other is called Enhanced ERIS.

The Basic ERIS displays a limited number of CRT formats, two-dimensional plots and trend plots on the cathode-ray tubes. It also provides the hard copy (print/plot) of limited transient data. Major functions of the Basic ERIS are as follows:

a. Critical parameter validation.
b. Display of a few emergency response CRT displays
c. Real-time and historical trend plots
d. Two-dimensional plots
e. Sequence of events resolution
f. Transient data recording and generation of associated hard copy
g. Post event analysis.

The Enhanced ERIS performs all the functions provided by the Basic ERIS. In addition, it can accommodate a larger number of process inputs and has the capability to display additional preformatted displays on the CRT. The extra displays provide additional information so that plant conditions can be more quickly assessed and abnormalities more easily diagnosed. Major functions of the Enhanced ERIS design include those listed above as well as the following emergency response functions:

a. Heat balance for RPV and Containment
b. Site wind rose maps for radiation release assessment
c. Valve status
d. Emergency Procedure Guidelines (EPG) contingency displays
e. Process and Area radiation monitoring
f. One-line electrical and piping diagrams.

The Enhanced ERIS design also provides additional data logging and plotting functions.

The discussion in this course will be limited to the Basic ERIS design.

6.4.3 Component Description

As previously stated, the ERIS has three basic components: the Data Acquisition System, the Central Processor Unit, and the Graphic Display Console.

6.4.3.1 Data Acquisition System (DAS)

The purpose of the Data Acquisition System is to gather data (in the form of electrical signals) from field instrumentation and put it into a form that the Central Processor Unit can use efficiently.

Analog and digital signals from various plant sensors and devices are sampled periodically by the DAS. The rate of signal sampling varies, depending upon the signal. Typical rates utilized are 100 sps (samples per second) for monitoring turbine bypass and control valves, 20 sps for process flow, 50 sps for neutron flux and vessel pressure, and 1 sps for temperatures. The specific sampling rates used will be programmed into a plant's ERIS.

The DAS then digitizes the analog signals and performs some pre-processing on both the analog and digital signals. This pre-processing includes such functions as sequence of events resolution and data compression.

The data is then multiplexed and sent, as needed, to the Central Processor Unit for use.

6.4.3.2 Central Processor Unit (CPU)

There are two main functions served by the Central Processor Unit in connection with ERIS: one involves Transient Recording and Analysis and the other is associated with Real Time Analysis and Display. As it performs the TRA function, the CPU receives all the data collected by the DAS and stores it. For post-event analysis, the processor then retrieves stored data and performs necessary computations or formatting to provide outputs as requested by personnel. Outputs will include sequence of event data and time-history plots of plant parameters throughout the event of interest.

For the RTAD function, the processor retrieves portions of the data collected by the DAS and performs the necessary computations to convert this data to parameters which appear on the display formats. Where possible, it also performs calculations to provide validation of all displayed parameters. In connection with RTAD, the processor also stores data which can be retrieved to provide trend display information.

6.4.3.3 Graphic Display Console (GDC)

The Graphic Display Console contains one or more sets of the following combination of equipment: cathode-ray tube (CRT), keyboard, and microcomputer. In other words, each ERIS CRT has its own keyboard and microcomputer. The combination of CRT, keyboard and microcomputer is collectively referred to as an Intelligent Display Terminal (IDT). It is possible, through the addition of hardware, to align the configuration such that two or more CRT's can be individually accessed from the same keyboard.

The microcomputer serves as the interface between the CRT/keyboard and the CPU. Display formats are contained within the memory of the microcomputer. When display of a particular format is desired, the microcomputer notifies the host CPU of the format to be displayed and then displays background (non-variable) data on the CRT. The host CPU then transmits the dynamic data to the IDT. The IDT displays the data, in appropriate form, on the CRT.

The keyboard has both function keys and standard alpha-numeric keys. The user can call up any color graphic display through the proper use of the keys. The function keys are labeled and each can have a particular display assigned to it.

6.4.4 System Features

A short discussion of system features and interfaces this system has with other plant systems is given in the paragraphs which follow.

6.4.4.1 Normal System Operation

The Basic ERIS is capable of displaying CRT formats and two-dimensional plots. It also provides trend plots and transient recording for various analog and digital variables. The displays provided in the Basic ERIS are of four types: Emergency Procedure Guideline (EPG) displays, 2-D plots, critical plant variables display, and trend plots. The first three types of displays are mainly real-time displays where the emphasis is on displaying the current plant status. The trend plots, on the other hand, are essentially historical displays where the emphasis is on displaying the most recent trends.

A list of the formats provided by Basic ERIS is provided on the plant's "Format Menu" (Figures 2a and 2b). Any format can be accessed by entering its number in the lower left corner of the menu. Certain formats can be directly accessed if they have been assigned to specific function keys; this assignment is identified on the menu also. For example, referring to Figure 2a, format 111 (Critical Plant Variables) can be directly accessed by depressing the number 15 function key on the keyboard.

6.4.4-2 General Description of Information

The information contained on the ERIS displays falls into four general categories: analog values, limit tags, event status, and system status.

Analog Values

Analog information is presented in the form of trend plots, values and bar graphs. The form of the presentation is dependent upon the control parameter and the display. For example, in Figure 3, RPV water level is shown on a trend plot. There is a bar graph to the right of the trend line and a digital readout of the value of water level above the trend plot; these two highlight and pinpoint the current value of water level.

The trend line tracks the value of the control parameter, and its color is the same as the color coding used for the bar graph. Whenever the control parameter is "bad data", the trend line will not be plotted and the digital readout will consist of asterisks. The trend line, however, will continue to scroll with time.

The horizontal scale of the trend plots is time. For full-page trend plots, the scale represents the most recent thirty minutes; for the smaller plots such as shown in Figure 3, the scale represents the most recent ten minutes (except for RPV temperature which has a thirty-minute scale). The control parameter being displayed is on the vertical scale (level, pressure and temperature in Figure 3). The control parameter may have more than one vertical scale, selectable by the operator by depressing the "SCALE UP" and "SCALE DOWN" buttons on the keyboard. If there is more than one trend plot on a display, the operator can select which trend plot he/she wishes to rescale.

Limit Tags

A control parameter may have up to five limit tags associated with it, each corresponding to a process limit. The process limits are of two types: dynamic limits and static limits. Dynamic limits are limits which functionally depend on other control parameters; as a result, their values may change with time. Static limits are limits which remain constant with time. In addition, the process limits fall into two categories: upper limits and lower limits. Upper limits are limits which call for or allow for operator actions when the limits are exceeded from below; lower limits are limits which call for or allow for operator actions when the limits are exceeded from above.

The process limits further belong to two classes: alarm limits and permissive limits. Each alarm limit may be in one of five states: inactive, safe, caution, alarm and bad data; the corresponding colors are blue, green, yellow, red, and magenta, respectively. Each permissive limit may be in one of three states: inactive, active and bad data; the corresponding colors are blue, white and magenta, respectively.

As a process alarm limit is approached, it changes from "safe" to "caution" to "alarm"; the border around the limit tag correspondingly changes from green to yellow to red. The "alarm" state is reached when the value of the control parameter reaches the limit specified for a particular limit tag. A limit tag will change state from "safe" to "caution" before reaching its limit; the difference between the point where the state changes from "safe" to "caution" and the point when the limit is reached (the "alarm" state) is called the process limit offset. For example, the SCRAM LO limit tag associated with RPV water level shown in Figure 3 has a limit of 10" and a limit offset of 5". Consequently, the limit tag will be in the "safe" condition (green) anywhere above 15". When RPV level decreases to 15", the limit tag changes state to "caution" (yellow); at 10", it changes to the "alarm" state (red).

A line (tail) connects each limit tag to the bar graph at the point which corresponds to the value of the process limit. The tail appears in the same color as the color coding used for the limit tag.

On the trend plot there will be a limit line displayed for each dynamic limit associated with the control parameter, if the limit's value is on-scale. The limit line will track the value of the associated dynamic limit when it is on-scale, thereby providing the operator with a reference limit point when evaluating plant conditions. The color of each limit line will be the same as the color coding used for the corresponding dynamic limit tag. Whenever the limit is "bad data", the limit line will not be plotted.

In Figure 3, RPV Level has three limit tags associated with it. These process limit tags are static limits, and two (SCRAM LO and TAF) are lower limits while the third (TRIP HI) is an upper limit. RPV Pressure has 4 limit tags, two dynamic (POOL LD and HEAT CAP) and two static (SRV LIFT and 100% BPV).

A list of control parameters monitored by the Basic ERIS and their associated limit tags and typical limit offset values is given in Table 1.

Event Status

The status of particular plant events (e.g., SRV operation and diesel generator operation) is indicated on certain displays. Event indications are separated into groups and each group is displayed alongside the associated control parameter, wherever possible. Referring to Figure 3, the status of five events is being displayed: diesel generator operation, SRV operation, MSIV operation, group isolation, and scram status.

Each event indication may be in one of five states: inactive, safe, caution, alarm, and bad data. The corresponding color coding is blue, green, yellow, red, and magenta, respectively. A change in the status will be quickly identified by a change in the color of the border and a change in the wording within the border. The lettering remains white in all states except "bad data", when it will also be magenta.

The events monitored and displayed by the Basic ERIS are listed in Table 2, along with their different states. The exact meaning of each state will be discussed later.

System Status

The status of particular plant systems is indicated on certain displays. The system status region, shown on the left in Figure 3, has up to four columns, in addition to the system identification column. Each system status may be in one of four states: inactive, active, flow, and bad data. The corresponding color coding is blue, white, green, and magenta, respectively. A change in system status will be indicated by a change in border color and a change in the wording within the border. The lettering remains white in all states except "bad data", when it will be magenta and white.

A list of the systems whose status is displayed by the Basic ERIS is given in Table 3, along with a list of the system parameters monitored. System status logic will be discussed in detail later.

6.4.4.3 Color Coding

There are seven colors used for the ERIS displays: red, yellow, green, white, cyan, blue, and magenta. The CRT's utilize a black background for the displays, which accentuates the individual colors. Each color has its own meaning, which aids the user in prioritizing the information on a particular display.

Red

Red is an attention-getting color associated with danger. It generally indicates an unsafe condition, danger, that immediate operator action is required, or that a critical parameter value is out of tolerance. Red is reserved for indication of exceeding a limit or that commanded safety functions have not been achieved. Red is used in a display as a thick border surrounding white letters and/or numbers, as well as for limit and trend lines and bar graphs.

Yellow

Yellow is an attention-getting color associated with caution. It generally indicates a potentially unsafe condition, caution, that attention is required, or that a marginal parameter value exists.Yellow is reserved for indication of approaching limits or marginal parameter status. When used with analog data (such as RPV level), yellow indicates data of marginal validity. Yellow is used in a display as a thick border surrounding white letters and/or numbers, as well as for limit and trend lines and bar graphs.

Green

Green is a nonattention-getting color associated with satisfactory conditions. Green is generally indicative of safe conditions, that no operator action is required, or that a parameter value is within tolerance. It is reserved for indication of safe limits and parameter status indication when safe or satisfactory conditions exist. When used in connection with system status, green indicates the presence of flow in the system Green is used in a display as a thick border surrounding white letters and/or numbers, as well as for limit lines. It is also used to track actual plant conditions on the two-dimensional (2-D) plots.

White

White is a nonattention-getting color. It is used for lettering and numbers, and also for labels, coordinate axes, dividing lines, or structural features. White is also used as a border in connection with system status.

Cyan

Cyan is a nonattention-getting color which can be used in conjunction with white to provide some amount of non-critical discrimination (e.g., demarcation lines or brackets). Cyan also indicates that a measured parameter is corrected and validated for present plant conditions. Cyan is used in a display as a thick border surrounding white letters and/or numbers, as well as for trend lines and bar graphs.

Blue

Blue is a poor contrast on the black background, so it is not used for attention-getting purposes or for information-bearing data. Blue is reserved for labels and other advisory type messages, and it generally indicates an inactive condition. Blue is used in a display as a thick border surrounding white or blue letters and/or numbers.

Magenta

Magenta is a harsh, attention-getting color. It is reserved for use as indication of invalid data status or system failures. Magenta is used in a display as a thick border surrounding magenta or white letters and/or numbers.

Color Gun Status

The ERIS uses three colors - red, blue, and green to make all of the colors needed for each display. For instance, yellow is formed by the combination of blue and green. The status of the three color guns appears in the lower right corner of each display. If a gun fails (i.e., the color disappears on the display), then the color gun status for that color will disappear.

Date and Time

The current calendar date and time of day is also shown in the lower right corner of each display, along with the plant name. The time is expressed to the nearest second.

6.4.5 System Interfaces

Interfaces the Emergency Response Information System has with other plant systems are discussed in the paragraphs which follow.

Emergency AC Power System (Section 9.2)

The EACPS provides reliable power to the Emergency Response Information System.

6.4.6 Summary

Classification - Power generation system.

Purpose - To help the control room personnel mitigate the consequences of accidents and respond to abnormal operating conditions.

Components - Data Acquisition System, Data Processing System, Graphic Display Console, ERIS displays.

System Interfaces: EACPS, Control Room Design, all systems with parameters monitored by ERIS.

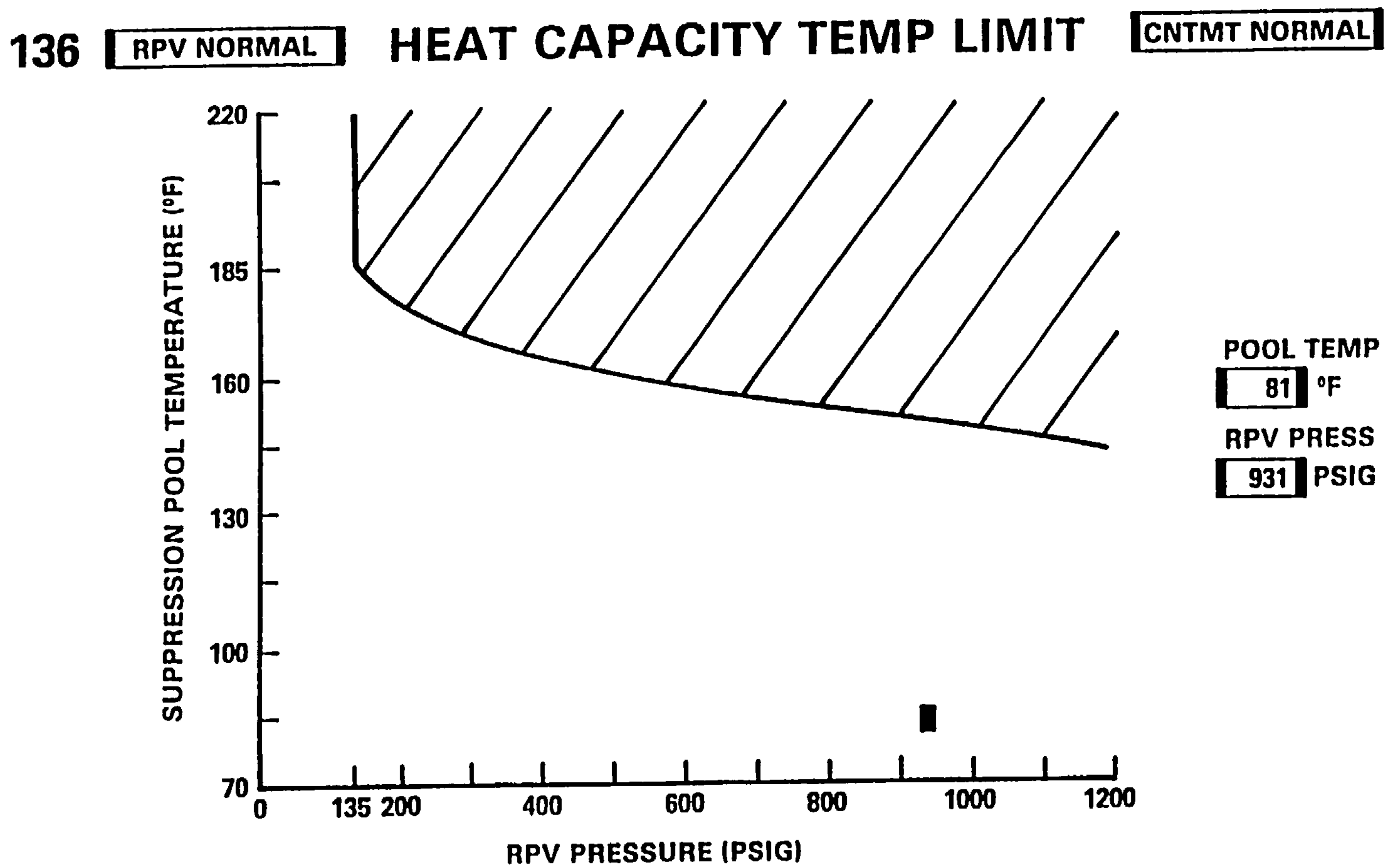


Figure 6.4-2 2-D Plot Display

105 RPV NORMAL

2-D PLOT MENU

CNTMT NORMAL

FORMAT NO.	2-D PLOT FORMAT TITLE	STATUS
132	SUPPRESSION POOL LOAD LIMIT	NORMAL
134	HEAT CAPACITY LEVEL LIMIT	NORMAL
136	HEAT CAPACITY TEMPERATURE LIMIT	NORMAL
138	RPV SATURATION TEMPERATURE	NORMAL
140	PRIMARY CONTAINMENT PRESSURE LIMIT	NORMAL
142	PRIMARY CONTAINMENT DESIGN PRESSURE	NORMAL
144	PRESSURE SUPPRESSION PRESSURE	NORMAL
146	MAXIMUM CORE UNCOVERY TIME LIMIT	---------

Figure 6.4-3 2-D Plot Menu

0694

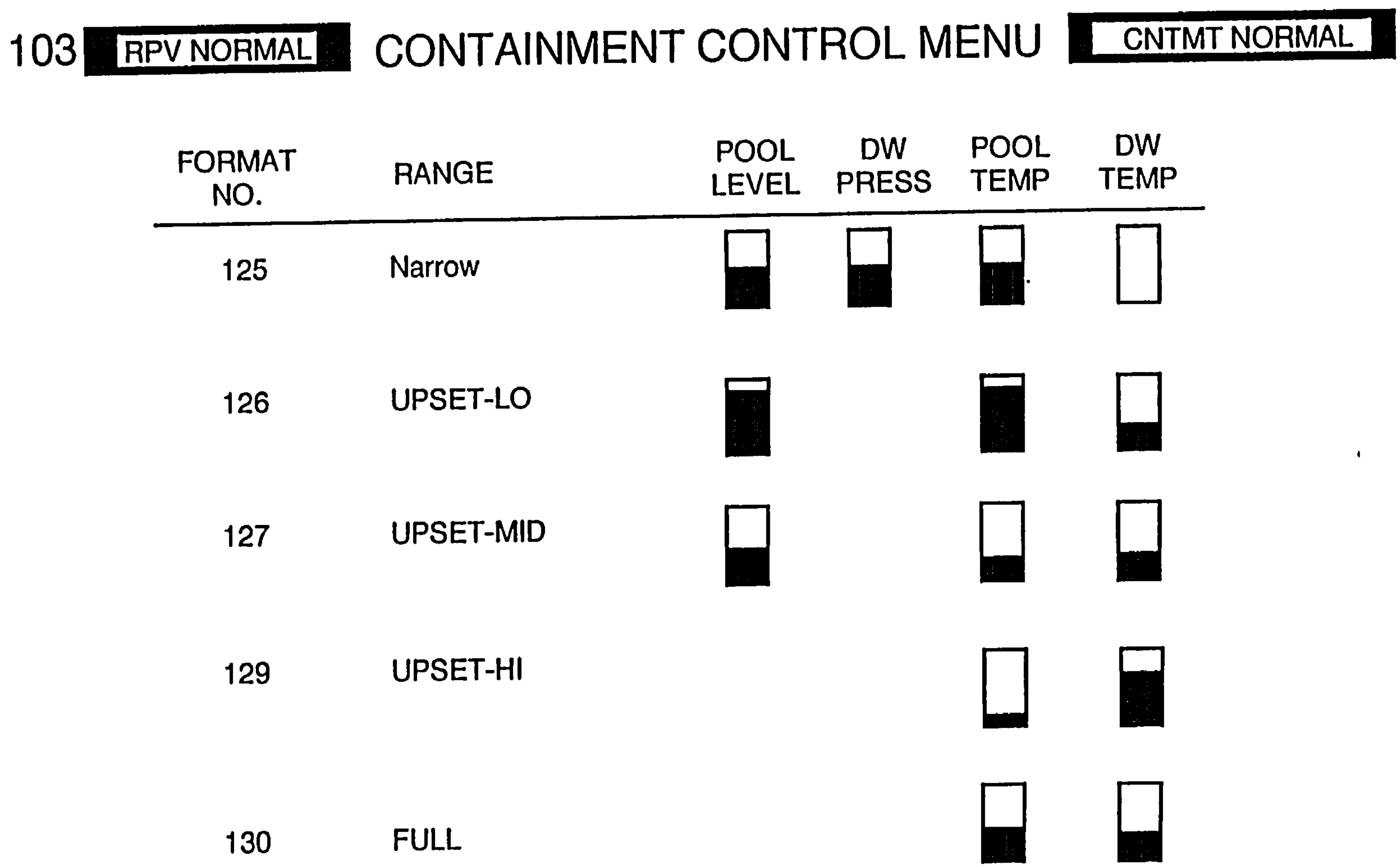


Figure 6.4-4 Containment Control Menu

0694

107 RPV NORMAL

TREND PLOT MENU

CNTMT NORMAL

FORMAT NO.	PARAMETER	FORMAT NO.	PARAMETER
148	RPV WATER LEVEL	153	SUPPR POOL LEVEL
149	RPV PRESSURE	154	DRYWELL PRESSURE
150	REACTOR POWER	155	SUPPR POOL TEMP
151	RPV TEMPERATURE	156	DRYWELL TEMPERATURE

Figure 6.4-5 Trend Plot Menu

101 RPV NORMAL

RPV CONTROL MENU

CNTMT NORMAL

----- FORMAT NO. ----				
RX POWER	RPV TEMP	RANGE	RPV LEVEL	RPV PRESS
114	119	NARROW		
113	128	WIDE		
115	121	FUEL ZONE		
116	122	SHUTDOWN		
117	123	FULL		

Figure 6.4-6 RPV Control Menu

0694

Format Menu

NO.	Format Title	ASGN
101	RPV Control	PF1
103	Containment Control Menu	PF2
105	2-D Plot Menu	PF3
107	Trend Plot Menu	PF4
111	Critical Plant Variables	PF15
113	RPV Control WR/PWR	PF16
114	RPV Contorl NR/PWR	
115	RPV Control FZR/PWR	
116	RPV Control SDR/PWR	
117	RPV Control FR/PWR	
119	RPV Contorl NR/TEMP	
120	RPV Control WR/TEMP	
121	RPV Control FZR/TEMP	
122	RPV Control SDR/TEMP	
123	RPV Control FR/TEMP	
125	CNTMT Control NR	
126	CNTMT Control UPSET/LR	
127	CNTMT Control UPSET/MR	PF17
129	CNTMT Control UPSET/MR	
130	CNTMT Control FR	
132	Suppr Pool Load Limit	
134	Heat Capacity Level Lim.	
138	RPV Saturation Temp	
140	Primary CNTMT Press Limit	
142	Primary CNTMT Desing Pr.	
146	MAXD Core Uncover Time	
148	RPV Water Level	PF18
149	RPV Pressure	PF19

Format NO: ( )

Figure 6.4-7 ERIS Format Menu

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 7.0

Reactivity Control Systems

Table of Contents

List of Figures

7.0 REACTIVITY CONTROL SYSTEMS

The systems described in this chapter are used to control the core reactivity under normal, abnormal, and emergency conditions. The systems used to control core reactivity are shown in simplified form in Figure 7.0-1.

7.0.1 Reactor Manual Control System (Section 7.1)

The Reactor Manual Control System provides rod movement control signals to the control rod drive system, to vary core power level and power distribution.

7.0.2 Recirculation Flow Control System (Section 7.2)

The Recirculation Flow Control System provides a means for control of core power level, over a limited range, by controlling recirculation system flow, which in turn determines the flow rate of water through the reactor core.

7.0.3 Reactor Protection System (Section 7.3)

The Reactor Protection System automatically initiates a rapid reactor shutdown (scram) by inserting control rods, to preserve the integrity of the fuel cladding and reactor coolant pressure boundary.

7.0.4 Standby Liquid Control System (Section 7.4)

The Standby Liquid Control system injects a neutron absorbing poison solution into the reactor vessel to shutdown the reactor, independent of any control rod movement, and maintain the reactor subcritical as the plant is cooled to maintenance temperature.

7.0.5 Rod Worth Minimizer (Section 7.5)

The Rod Worth Minimizer (RWM) serves as a backup to procedural controls to limit control rod worth during startup and low power operation. This helps limit the reactivity addition rate in the event of a control rod drop accident.

7.0.6 Rod Sequence Control System (Section 7.6)

The Rod Sequence Control System (RSCS) is a backup system to the Rod Worth Minimizer. It independently imposes restrictions on control rod movement to mitigate the effects of a control rod drop accident.

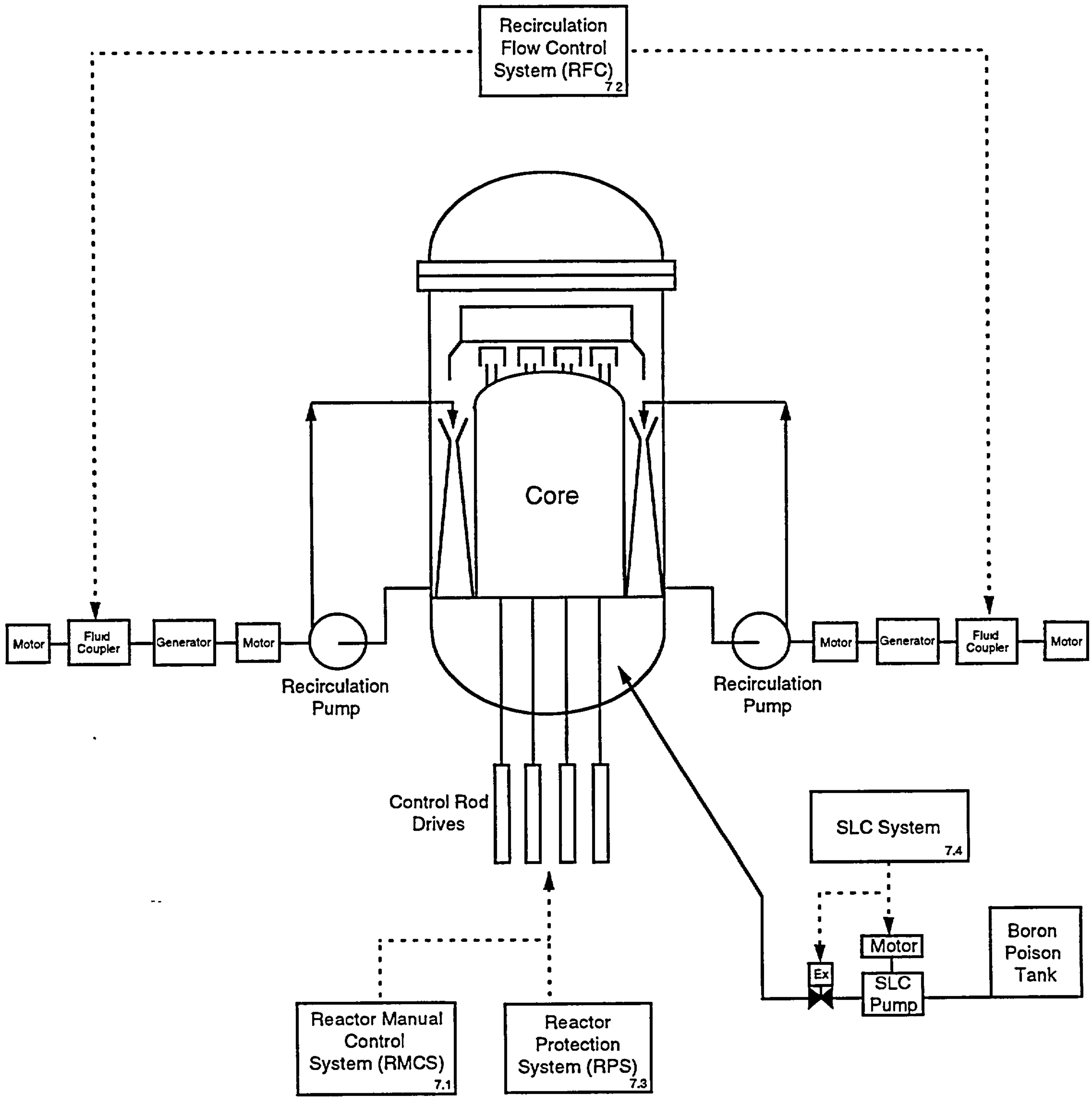


Figure 7.0-1 Simplified BWR Reactivity Control Systems

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 7.1

Reactor Manual Control System

Table of Contents

List of Tables

List of Figures

7.1 Reactor Manual Control System

Learning Objectives:

1. State the system's purposes.
2. Explain the uses of the Rod Motion Control Pushbuttons.
3. Explain how control rod motion is achieved.
   a. Insert
   b. Withdraw
   c. Continuous withdraw
   d. Continuous insert
4. List and describe the two types of rod blocks.
5. Explain how control rod position is measured.
6. Explain how this system interfaces with the following systems:
   a. Control Rod Drive System
   b. Recirculation System
   c. Neutron Monitoring System
   d. Rod Worth Minimizer

7.1.1 Introduction

The purposes of the Reactor Manual Control System (RMCS) are:

1. To provide control signals to control rod drive system for normal rod movement.

2. To prevent control rod movement during potentially unsafe conditions.

The Reactor Manual Control System provides the means for the operator to move control rods to change core reactivity so that reactor power level and power (neutron flux) distribution can be controlled.

The functional classification of the RMCS is that of a power generation system.

The RMCS (Figure 7.1-1) consists of the electronic circuitry, switches, indicators and alarm devices necessary for manipulating the control rods in and out of the core, and for the surveillance of the associated equipment. To prevent inadvertent operator errors, reactor core performance and control rod positions are constantly monitored by system components that either give an alarm demanding operator attention or else completely block control rod movement until the error has been corrected. The RMCS includes interlocks that inhibit control rod movement under certain plant conditions, but does not include any of the circuitry or devices used to scram the reactor either automatically or manually.

The RMCS is a special purpose, fixed program computer that operates in a mode which transmits information in the form of digital signals over single conducting path shared cable. The information is assembled into data words that are directed to parts of the system where they result in some required action or display of system status. The RMCS's signals are generated in duplicate by two separate and independent channels. The duplication minimizes or prevents a fault inspired command that could result in improper or unwanted control rod movement. The two independently generated signals are compared to ensure identical commands were generated. If the two signals are not identical an alarm is sounded along with indication to alert the operator of the comparison discrepancy.

7.1.2 Component Description

The major components of the RMCS are discussed in the paragraphs that follow.

7.1.2.1 Rod Select Module

The Rod Select Module is located in the center of the reactor control panel and is illustrated on Figure 7.1-2. The Rod Select Module contains the pushbutton array with which the operator chooses the control rod he desires to move and two identical transmitter cards. One transmitter card scans the pushbutton array, senses any button depressed by the operator, and codes that button's coordinates into an identification number for transmission. The second transmitter card does an identical operation using the second contact pair in the button and a second independent lamp. If the system is working correctly, two lamps will light under the button selected. The rod motion request and system status selections are assembled into the REQUEST word and transmitted to the Rod Drive Control System, Rod Position Information System, and the Neutron Monitoring System.

Rod Motion Switches

The rod motion switches, shown in Figure 7.1-2, consists of four control pushbuttons. These pushbuttons are the insert, withdraw, continuous withdraw, and continuous insert controls. The insert pushbutton, when momentarily depressed, causes the selected rod to insert one notch. When the insert pushbutton is depressed and held in that position, continuous control rod insertion results as permitted by the activity control module until the pushbutton is released.

The withdraw pushbutton, when depressed, causes the selected rod to withdraw one notch. When the withdraw pushbutton is held depressed along with the continuous withdraw pushbutton, the selected rod is continuously withdrawn as permitted by the activity control analyzer. The continuous withdraw pushbutton does nothing if it is the only button depressed.

The continuous insert pushbutton, when depressed, causes continuous insertion of the selected rod independent of the normal rod motion timing circuits. No settle function is included with the continuous insert pushbutton which allows the selection of another control rod without the wait for the driving rod to settle. This type of feature would be helpful when the control rods need to be inserted in as little time as possible without using the scram function of the Reactor Protection System.

Rod Drift Test and Reset Pushbuttons

If any control rod is detected at an odd position, and is not actively being moved with the rod timing circuit, a rod drift alarm for that control rod will illuminate. Along with the individual rod drift alarm light, a common audible and visual alarm will actuate and alert the control room operator of unrequested rod movement. During normal rod movement, the drift alarm is bypassed on the selected rod while the automatic sequence timer is cycling. The rod drift test pushbutton is provided to reset the drift alarm, not the drift condition.

Testing of the drift circuity is performed by depressing the test pushbutton while performing a rod movement. The drift alarm then actuates when the control rod passes an odd position reed switch.

7.1.2.2 Rod Drive Control Cabinet

The Rod Drive Control Cabinet is the heart of the Rod Drive Control System. The cabinet contains four major sections. At the top of cabinet are two identical Activity Control Sections.

In the middle is an Analyzer section and below it is the Power section.

All incoming signals enter the cabinet in duplicate, with one member of each pair connected to each of the Activity Control sections. In the Activity Control section the signals are processed in duplicate and the results sent to the Analyzer section. In the Analyzer section the inputs are checked to ensure that the signals are identical, and if they are, one signal is sent on to the transponders and the other signal retained as a reference. If the signals do not agree, the error is noted and the system tries again. The trials continue until agreement is found or until an error count limit is reached and the system is disabled and the fault annunciated.

The Power section contains the power module which is capable of disconnecting the power to the system should the self test subsystem in the analyzer determine that some malfunction has occurred.

Each Activity Control section is in an electrically isolated box, as is the Analyzer section. The separate boxes make it highly unlikely that the failure of a single component in one section would produce a failure in the others.

7.1.2.2.1 Activity Control Module

The Activity Control Module receive selected plant status data, operator requests from the Rod Select and Rod Motion switches, and rod position data from RPIS. If conditions allow, the activity control module generates the rod motion command and HCU identification signal to send to Analyzer.

Selected plant status data includes inputs from the Neutron Monitoring System, Scram Discharge Instrument Volume, Recirculation System flow converters, Rod Worth Minimizer, Rod Position Information System, and the Refueling and Service Platform.

The Activity Control Module consists of two identical control sections. Each of the Activity Control sections contain an activity control card, rod motion timer card, and an input isolator card.

Input Isolator Card

The input isolator card electrically isolates the signals coming from outside the cabinet.

Activity Control Card

The main function of the Activity Control Card is to monitor the present state of the plant to determine if rod motion requested is permissible. If the requested rod motion is permissible, the activity control card will start its associated rod motion timer card. The timer card cycles through a fixed pattern of timing signals to cause rod motion. The activity control card will add the command code from the rod motion timer card to the rod identity and transfer this combination of signals as a COMMAND word to the analyzer card. A similar process occurs in the other activity control section.

Rod Motion Timer Card

The rod motion timer card produces a precise sequence of time intervals, spanning about 10 seconds, designed to move a control rod one notch. Moving a rod IN requires a different sequence of intervals than moving a rod OUT. Circuitry contained in the timer card prevents trying to move a rod and IN and OUT at the same time, in addition to preventing the timing sequence from being interrupted.

7.1.2.2.2 Analyzer

The Analyzer contains an analyzer card and a fault map card whose function is to compare the data from the two channels of the Activity Control Modules and to generate command signals to appropriate equipment if the two signals are identical. If the two signals differ in any way, the analyzer produces a rod block signal and illuminates the activity control disagree light on the operators center control room panel. If both signals agree, the analyzer stores one signal and transmits the other as a command word to the Branch Junction Modules (BJM). The command word contains a HCU identification signal and the signals to operate the directional control valves in the control rod drive system. In addition, the analyzer sends information to the Rod Status and Motion Display for the appropriate status displays.

Analyzer Card

The analyzer card is the master control element in the system. It compares the signals from the two activity control sections for equivalency before using them to control the rest of the system. It also causes the system to process operator REQUEST words, SCAN words, and SELF TEST words in an alternating predetermined sequence. Acknowledge words being returned to the cabinet from the transponders are received by the analyzer and compared to the expected response to determine if an error has occurred. If so, the analyzer will remember the error and continue with the program. If a sufficiently large number of errors are found, appropriate indicators will light on the fault map (indicating the BJM or transponder in fault) and the system will stop.

Fault Map Card

The fault map card contains an array of light emitting diodes laid out as a map of the reactor core. Should the self test program discover a fault associated with any of the transponders, it will light the corresponding spot on the fault map. The fault map card also contains two counters, the scan ident counter and test ident counter.

The scan ident counter advances one count at a time and sends a scan request out through the system. When the entire core has been scanned once and is ready to start again, the self test counter advances one step to test a transponder. A new scan then starts and proceeds until the core again has been scanned. When this is finished, a second transponder will be self tested. This process continues until all rods have been checked by the self test program and then it starts all over again. This process is repeated indefinitely.

7.1.2.2.3 Power Section

The power section comprises the AC power junction box through which AC power for the Rod Drive Control System is derived. A power gate controls power to the remote parts of the system and contact power supply.

The power gate consists of two large silicon controlled rectifiers mounted on heat sinks in the Rod Drive Control Cabinet. The purpose of the power gate is to transfer 120 VAC to the array of transponders located on the hydraulic control units.

As long as a signal is received from the analyzer portion of the Rod Drive Control cabinet, the power gate will continue to supply power. If the analyzer encounters a problem in the system, the signal to the power gate is dropped and the two silicon rectifiers turned off, disconnecting all power to the hydraulic control unit clusters. This action prevents failures in the system from causing a control rod to move.

7.1.2.3 Branch Junction Modules

The Hydraulic Control Units (HCUs) are arranged in two banks, one on the east side and one on the west side of the reactor building. Each bank is comprised of five clusters consisting of six to fifteen HCUs. Each cluster contains one Branch Junction Module (BJM), for a total of ten clusters and ten BJMs. The first BJM in the bank receives the command word from the analyzer and passes it on, until all five BJMs in each bank are linked together. The BJMs also receive power for the directional control valve solenoids from the power module and distribute it to the HCUs.

The Branch Junction Module is an enclosure mounted at the end of a cluster of hydraulic control units. The Branch Junction Module serves as:

- a mechanical termination point for cables arriving from the control room and adjoining branch junction modules,
- a housing for voltage regulating transformer,
- and as a mounting place for a branch amplifier card.

The branch amplifier card contains a power supply and logic circuitry for the following functions:

- Receive command words and transmit them to the down stream branch junction modules.

- Receive acknowledge words from the downstream branch junction modules.

- Merge acknowledge words originating within its hydraulic control unit cluster and transmit them to the upstream branch junction module or Rod Drive Control Cabinet.

- Sense the phase and magnitude of the AC power supplying its HCU cluster and adds this data to the acknowledge words originating with the cluster.

7.1.2.4 Hydraulic Control Unit Transponder

The transponders (one per HCU) contain logic circuits that decode the command signals and compare the rod identity address with their own identity address. If the identities match, the HCU responds to the operation action code to insert or withdraw the control rod. The transponders acknowledge the command signal by sending a signal back to the Analyzer. This acknowledge signal is made up of the identity address of the HCU responding, the operation currently being performed, the status of scram valves, scram accumulator, and the individual rod scram test switches on the HCU. This information is compared to the original command by the Analyzer. If the identity and operation codes do not agree, the operation is terminated, and the condition is annunciated. When an HCU responds to a command, insert or withdraw directional control solenoid valves open and close according to the timing sequence. As the rod moves, its position is transmitted via the Rod

Position Information System (RPIS) to the various displays. This is known as the operator follow (OF) mode of operation.

7.1.2.5 Display Memory Module

The display memory module receives multiplexed information from the Analyzer and Rod Position Information System. The information is used to control the full core display and the 4-rod display indication. In addition the display memory module routes scram time test information from the HCUs to a multipoint scram time recorder.

7.1.2.6 Test Signal Generator

When the control room operator requests conrol rod motion by using the appropriate pushbuttons. Normal rod movement command is in what is called the operator follow (OF) mode. The Analyzer also has a test signal generator which generates test signals for two more modes of system operation, the scan mode and the self test mode.

The scan mode is a data gathering mode. The test signal generator initiates a rod selection signal and sends it to both activity module channels. Each channel forms a command signal (consisting of only an HCU identity) and sends it along the same path as is used in the operator follow mode. The system processes the command signal as in the operator follow mode. However, the transponder response is different. Selected HCU status data from the transponder is transmitted back to the analyzer comparator as an acknowledgement. The analyzer adds all rod drive system status data to the acknowledge word and retransmits it for display.

The self test mode is a diagnostic and evaluation mode used by the system to detect internal faults. The test signal generator of the analyzer initiates a rod identity and a specific motion control signal which is sent to both channels of activity module where a command signal (motion command and HCU identity) is formed. This command signal is processed exactly as in the two previous modes. Mechanical operation of the HCU directional control valves (DCVs) does not occur, because in actual operation a series of repetitive control signals is needed to allow valve operation (many command signals in series). Electrical operation is verified through the acknowledge word. Discrepancies are annunciated to the operator. A suspected fault causes the system to automatically run a series of rechecks.

In addition to the self test mode, the system can be tested manually through the use of local pushbutton controls to verify the self test function reliability.

7.1.2.7 Rod Position Information System

The Rod Position Information System (RPIS) is used to obtain control rod position data. The position information is provided to the operator, to the Performance Monitoring System (PMS), and to the RMCS display.

For the purpose of providing position information, each control rod drive (CRD) contains a stationary position indicator probe consisting of 53 reed switches. The 25 even control rod notch positions (00-48) are detected by switches spaced at intervals of 6 inches. Halfway between each of the even position switches are 24 additional switches used to determine when the rod is at an odd position. The four remaining switches are used to detect the rod at the full in, full out, overtravel in, and overtravel out positions. When the control rod is stationary or being driven, a magnet attached to the index tube of the CRDM closes a reed switch in the probe assembly, when it passes the vicinity of the reed switch.

7.1.3 System Features and Interfaces

A short discussion of system features and interrelations between this system and other plant systems is given in the paragraphs that follow.

7.1.3.1 Normal Operation

The Reactor Manual Control System, during normal conditions, is continuously cycling through three modes of operation:

- Operator Control Mode (OF)
- Scan Mode (S)
- Self Test Mode (ST)

Once power is applied to the system, the analyzer continually cycles through its prescribed sequence of OF, S, and ST modes which are grouped in a certain testing sequence. The system cycles ST1 - OF - ST2 - OF - ST3 - OF - ST4 OF - ST5 - OF - ST6 - OF - ST7 - OF through seven counts of the test generator. During one operator follow mode, the operator generated demand (if any) is generated, and the self test command is transmitted to the transponders.

After completing seven counts, the test generator then counts eight, whereupon a scan is made of all rods (OF-S-OF-S-OF-S-OF-S). Scanning is performed in a square matrix with the scan progressing from left to right, top to bottom. Following the scan mode, the analyzer now goes back to ST-OF-ST-OF. During this portion of the sequence, the analyzer is receiving the acknowledge words from the HCU that was just tested in the self test mode. This describes a complete test cycle for one rod. Normally three test cycles are conducted for each rod. If errors are encountered, it is possible that up to 14 such tests will be conducted. The normal three test cycles per rod is conducted for all rods, resulting in aproximately 20 seconds to test all rods.

7.1.3.1.1 Operator Control Mode

On the Operator Control Mode the signal starts with the operator, who uses manual pushbuttons to make a rod selection. Then by depressing the appropriate rod motion request button(s), the control rod select multiplexers transform the selection and motion request into two binary request words for transmission to its related activity control. This information will also be used to back light the selected rod's pushbutton and full core display identification, providing the operator with an initial verification that the signal is being processed correctly.

Both Activity Control units receive the request word, sent by its respective multiplexer. In addition, the activity control modules are monitoring plant status for rod block conditions. If plant status is such that rod blocks are not imposed, then the activity control circuitry will initiate operation of the rod motion timer card. This card will produce a fixed (about ten seconds) program sufficient to move a rod one notch in or out when delivered to the appropriate transponder. Both activity control modules then send a combined identification and motion signal to the analyzer.

The command words from each activity control are compared as they enter the Analyzer. If the command words agree in the analyzer, then one of the signals will be transmitted to all of the transponders on the hydraulic control units while the other is retained as a reference command word. If the command words for some reason DO NOT agree, nothing will be transmitted and the operator will receive the "Activity Control Disagree" light in addition to an annuctiator indicating the Reactor Manual Control System is inoperable. This condition will cause the system to stall and must be cleared by using the reset on the analyzer page.

If the signals do agree, one signal is transmitted to the BJMs as the command word while the other is retained as a reference. The selected transponder receives the command word from its BJM and immediate acknowledgement is returned to the analyzer, along with HCU status, via the BJM for comparison. Should this comparison find any discrepancy between the command and activity, or between the identity of the addressed rod and the responding one the analyzer will interrupt its signal and secure power to all HCUs.

If no discrepancies are found, then the transponder will operate the HCU solenoid valves as follows:

Rod withdraw

The rod insert light will illuminate for approximately one second. During this time the 121 and 123 valves are energized to insert the rod. Movement of the rod into the core removes the static load on the collet fingers. Following the small movement in of the control rod, power is remove from the insert direction control valves and supplied to the withdraw directional control valves (120 & 122). This forces the collet fingers against the guide cap, away from the index tube, and also drives the control rod out of the core. When the rod moves to the next notch position the drive signal is removed and the rod is allowed to settle into the notch. The settle function is accomplished by removing power to the 122 valve and leaving the 120 valve open for approximately 6 seconds.

Rod insertion

Rod insertion is the same as the initial portion of the withdrawal sequence and then accompanied by the settle function.

Continuous withdraw

To continuously withdraw a control rod, both the continuous withdraw and withdraw pushbuttons must be depressed. The sequence is the same as the withdraw sequence above, except the control rods will continue to drive.

Continuous insert

Continuous insert is accomplished by depressing either the insert or continuous insert pushbutton and holding it in the depressed position. The difference between the switches is the continuous in button bypasses the timer function, the control rod will not have to settle and another control rod may be selected immediately with out waiting 6 seconds for the settle function to time out.

7.1.3.1.2 Scan Mode

In the scan mode, the system is being used for gathering data. In this mode, control starts at the analyzer instead of the operator. The analyzer generates a rod identification number and sends it to each of the activity controls in a form known as a mode request. The activity controls intern generate a command word, having no valve control signal associated with it. The transmission path is the same as that described in the operator mode. In addition to its identification, the acknowledge word will contain status data from the HCU:

- Accumulator pressure and level
- Scram test switch position
- Scram valve positions
- Directional control valve status (open/closed)

The analyzer receives the information sent from the transponder and retransmits this information in the form of a status word to the Display Memory Module. The status word will be demultiplexed, stored in memory, and used to illuminate the various display elements of the full core display.

7.1.3.1.3 Self Test Mode

Self test is a diagnosis and evaluation mode, whose control also starts at the analyzer. When called for in the operating cycle, the analyzer generates a rod selection signal and valve control signal. These signals are transmitted as discussed above in the other two modes.

The analyzer is programmed so the valve control signals will cause all four directional control solenoid valves to energize. The solenoids are energized long enough to check for continuity, thus preventing any rod motion. The acknowledge word that returns to the analyzer for comparison is checked to see if the correct transponder replies and the correct driver circuit responds to signals called for.

7.1.3.2 Rod Withdraw Block Functions and Bases

Each of the rod withdraw block functions and the bases associated with these functions are discussed in the paragraphs that follow. Additionally, these rod withdraw blocks are given in Table 7.1-1.

SRM Inoperative Trip

This ensures that a control rod is not withdrawn during low neutron flux level operations unless proper neutron monitoring capability is available and that all SRM channels are in service or are properly bypassed. This rod withdrawal block is automatically bypassed when IRMs are selected to range 8 or above, when the reactor mode switch is in RUN mode.

SRM Downscale Trip

This ensures that a control rod is not withdrawn unless the SRM count rate is above the minimum prescribed low neutron flux monitoring level. The rod withdrawal block is automatically bypassed when IRMs are selected to range 3 or above.

SRM Wrong Position Trip

This ensures that no control rod is withdrawn unless all SRM detectors are properly inserted when they must be relied upon to provide the operator with neutron flux level information.

IRM Upscale Alarm Trip

This ensures that a control rod is not withdrawn unless the IRM equipment is properly up ranged during a reactor startup.

This rod withdrawal block also provides a block of rod withdrawal before reaching an RPS scram setpoint.

IRM Inoperative Trip

This ensures that no control rod is withdrawn during low neutron flux level operations unless proper neutron monitoring capability is available with all IRM channels in service or properly bypassed.

IRM Downscale Trip

This ensures that no control rod is withdrawn during low neutron flux level operations unless the neutron flux is being properly monitored. This rod block prevents the continuation of a reactor startup if the operator up ranges the IRM too far for the existing flux level.

IRM Wrong Position Trip

This ensures that no control rod is withdrawn during low neutron flux level operations unless proper neutron monitoring capability is available with all IRM detectors properly located.

APRM Upscale Alarm Trip

This rod block is provided to avoid conditions that would require action by the Reactor Protection System (RPS) if allowed to continue. The APRM upscale alarm trip setting is selected to initiate a rod block before the APRM upscale scram setpoint is reached. This APRM upscale alarm trip has a fixed setpoint of 12% reactor power when the reactor mode switch is not in the run position. Its setpoint is flow biased by Recirculation System loop flow when the reactor mode switch is in the run position.

APRM Inoperative Trip

This ensures that a control rod is not withdrawn unless the APRM channels are in service or properly bypassed.

APRM Downscale Trip

This ensures that no control rod is withdrawn during power range operation unless the average power range monitoring channels are operating properly or are correctly bypassed. All unbypassed APRMs must be on scale during reactor operation with the mode switch in the run position.

APRM Flow Unit Upscale Trip

This ensures that no control rod is withdrawn during power range operation with the reactor mode switch in the run position unless the recirculation flow units are operating properly. The flow units are necessary to provide the flow biased rod withdraw block and scram trips for the APRM System.

APRM Flow Unit Comparator Trip

This ensures that no control rod is withdrawn with the reactor mode switch in the run position unless the difference between the outputs of the recirculation flow converters is within limits.

APRM Flow Unit Inoperative Trip

This ensures that no control rod is withdrawn with the reactor mode switch in the run position unless the recirculation flow converters are in service.

RPIS Failure Trip

This ensures that rod position indication is available before any control rod can be withdrawn.

Scram Discharge Instrument Volume High Level Trip

This ensures that no control rod is withdrawn unless enough capacity is available in the scram discharge volume to accommodate a scram. The setting is selected to initiate a rod block well in advance of that level which produces a scram.

Scram Discharge Instrument Volume High Level Scram Trip Bypassed

This ensures that no control rod is withdrawn while the scram discharge volume high water level scram function is out of service. This rod block is disabled when the reactor mode switch is in the startup or run positions because the scram cannot be bypassed in that case.

Refueling Interlock Trips

These rod withdraw blocks ensure that no control rod is withdrawn when the fuel in the core might be in an unusual geometry or refueling is in progress.

7.1.3.4 Rod Bypass

Only one control rod can be bypassed at a time and the bypassed control rod CANNOT BE MOVED. The control rod is bypassed using the toggle switches on the analyzer section of the rod Drive Control Cabinet. When a bypassed control rod is selected, the rod bypassed light on the rod control and selection matrix will illuminate.

7.1.3.4 Control Rod Coupling Check

Because of the severe consequences of a rod drop accident, each time a control rod is withdrawn to notch position 48 (full out), a coupling check is performed. To accomplish this check, the operator attempts to withdraw the drive one notch past position 48. If the drive and blade are uncoupled, the control rod drive goes to the overtravel out position, and the operator receives an audible alarm and loss of the digital position display for that control rod. If the control rod blade is coupled to the control rod drive, it is physically impossible for the control rod drive index tube to get into a position that allows the permanent magnet to close the rod position indication reed switch for the overtravel out position. If a control rod is found to be uncoupled, procedures require the operator to insert the rod to attempt to couple it.

7.1.3.5 System Interfaces

A short discussion of interrelations between this system and other plant systems is given in the paragraphs that follow.

7.1.3.5.1 Control Rod Drive System (Section 2.3)

The RMCS controls the direction control valves (DCVs) to direct the hydraulic water forces of the Control Rod Drive Hydraulic (CRDH) System to cause control rods to move. The RMCS controls the CRDH System stabilizing valves to allow constant flow through the CRDH System even during rod motion. The reed switches within the control rod drive mechanism (CRDM) are used by the Rod Position Information System. The scram discharge instrument volume has level instrumentation which causes a rod withdraw block if the instrument volume is partially full.

Various CRDH System parameters are displayed on Rod Interface System equipment.

7.1.3.5.2 Source Range Monitor System (Section 5.1)

The SRM System provides upscale, inoperative, downscale, and wrong position trips which cause rod withdraw blocks.

7.1.3.5.3 Intermediate Range Monitor System (Section 5.2)

The IRM System provides upscale, inoperative, downscale, and wrong position trips which cause rod withdraw blocks.

7.1.3.5.4 Local Power Range Monitor System (Section 5.3)

The LPRM System provides local power level indication around a control rod selected for movement.

7.1.3.5.5 Average Power Range Monitor System (Section 5.4)

The APRM System provides APRM upscale (fixed and flow biased), inoperative, and downscale trips and APRM flow unit upscale, comparator difference, and inoperative trips which cause rod withdraw blocks.

7.1.3.5.6 Control Room Design (Section 6.3)

The operator control module (OCM), auxiliary select module (ASM), and rod display module (RDM) are located in the central section of the Main Control Console.

120V AC Power System

The RMCS is supplied 120 VAC uninterruptible power from divisions 1 and 2.

Refueling and Vessel Servicing System (Section 12.3)

The RMCS has various interlocks with the refueling equipment.

7.1.6 Summary

Classification - Power generation system

Purpose - To provide the means for operator execution of control rod movements to change core reactivity so that reactor power level and power (neutron flux) distribution can be controlled and to limit the reactivity worth of any control rod to reduce the effects of a rod drop accident or rod withdrawal error

Components - Rod Interface System (ASM, OCM, RDM), Rod Action Control System (rod pattern controller, rod motion inhibit logic, valve control and timing circuit), Rod Gang Drive System (analyzer, HCU transponders, test signal generator), Rod Position Information System

System Interrelations - CRD System, Main Steam System, SRM System, IRM System, LPRM System, APRM System, Control Design, Essential AC Power System, Refueling and Vessel Servicing System

Table 7.1-1 Control Rod Blocks

Function	Setpoint	Bypassed
RDCS Activity Disagree	Outputs from Activity Controls A & B do not match	Never
RDCS Analyzer Failure	Command and Acknowledge words disagree	Never
RDCS Inoperative	Routine System Self Testing Response Failure	Never
Recirc Flow Unit High	$\leq$ 108/125 of Scale	Never
Recirc Flow unit Inop	$\leq$ 10% mismatch between flow units, Switch out of operate, or module unplugged	Never
Scram Instrument Volume Hi	$\leq$ 18 gal of water (30.5 inches)	Never
Scram Inst. Vol. Switch	In Bypass	Never
Rod Select Power Off		Never
Rod Block Monitor Hi	Flow biased $\leq$ .66W + (25, 33, 41)	<30% or Edge rod sel.
Rod Block Monitor Inop	Switch not in op, Module unplugged, Nulling, <50% inputs, or > 1 rod selected	<30% or Edge rod sel.
Rod Worth Minimizer	Insert or Withdrawal Blocks	> 20% Stm. Flow
NMS	Insert or Withdraw Blocks	
Refueling Platform	Withdraw Blocks	

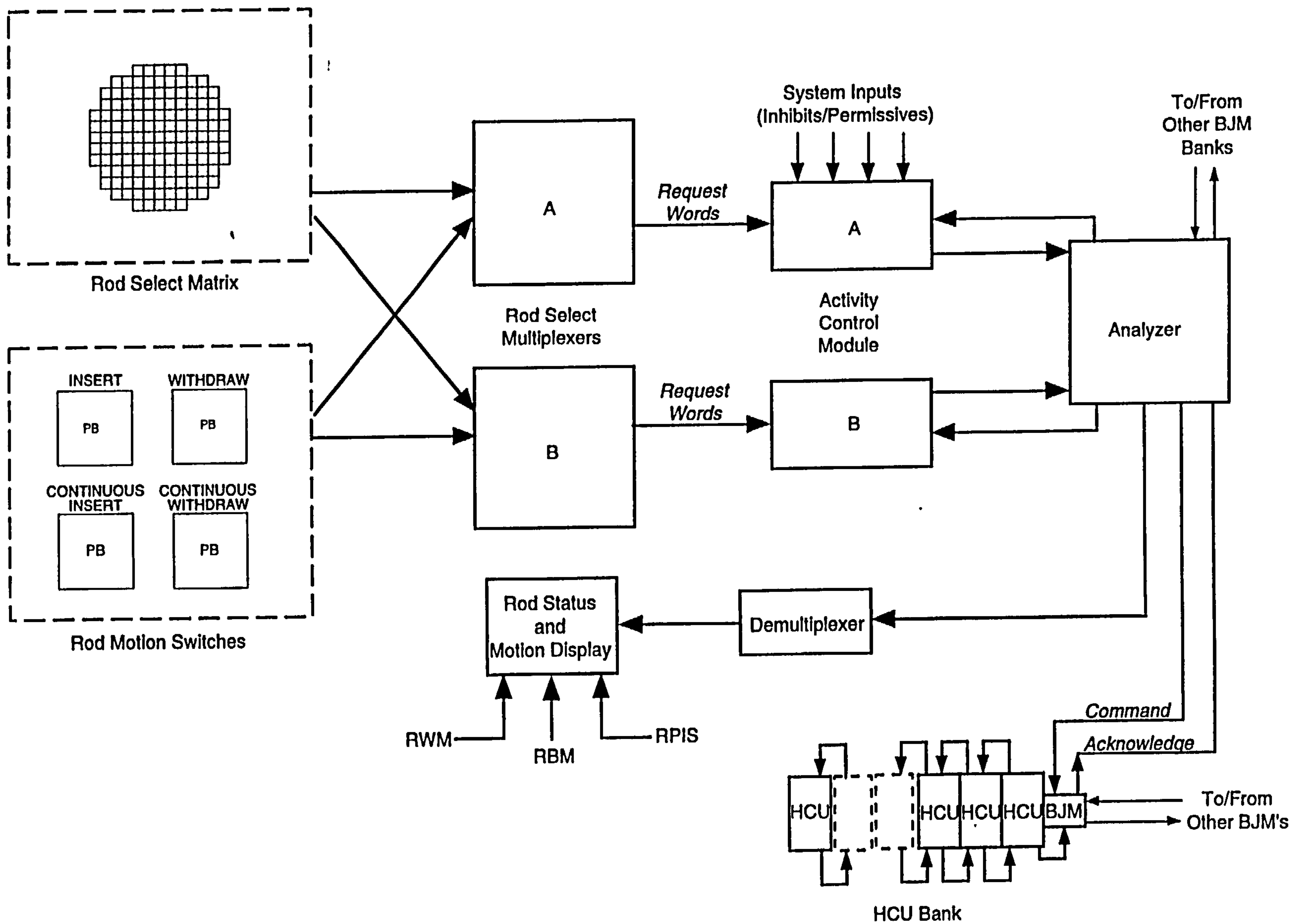


Figure 7.1-1 Reactor Manual Control System

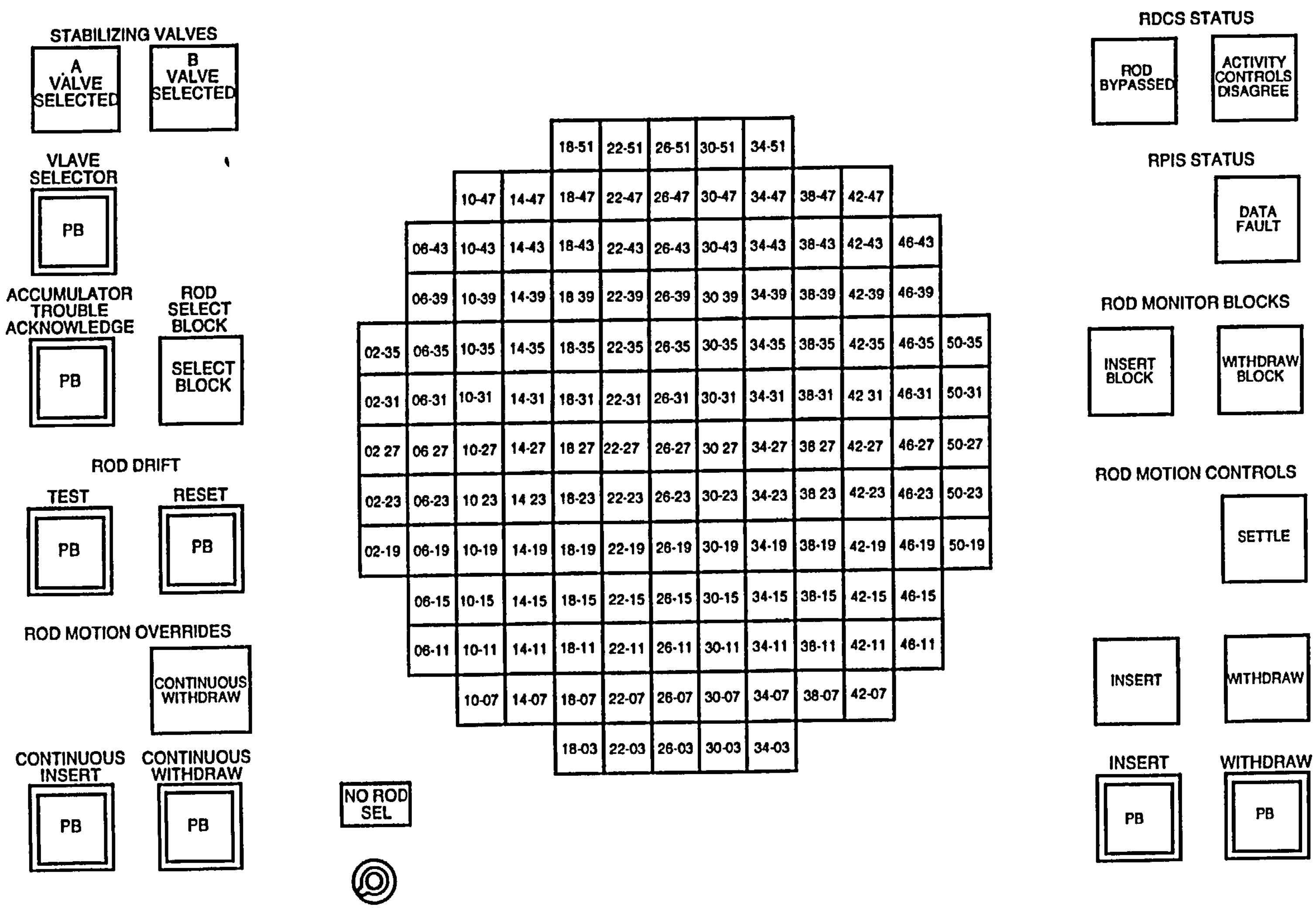


Figure 7.1-2 Rod Control & Selection Matrix

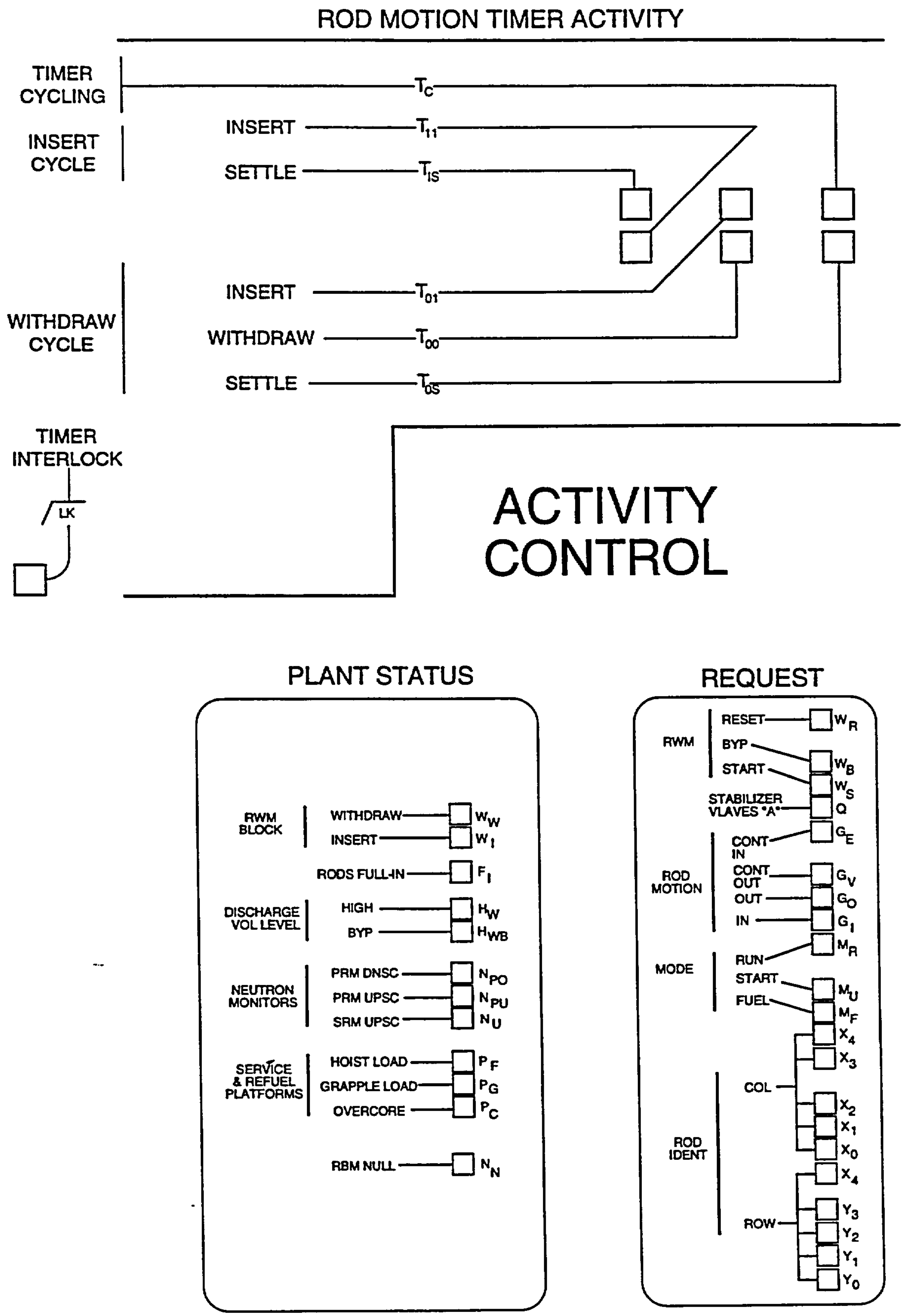


Figure 7.1-3 Activity Control Indicators

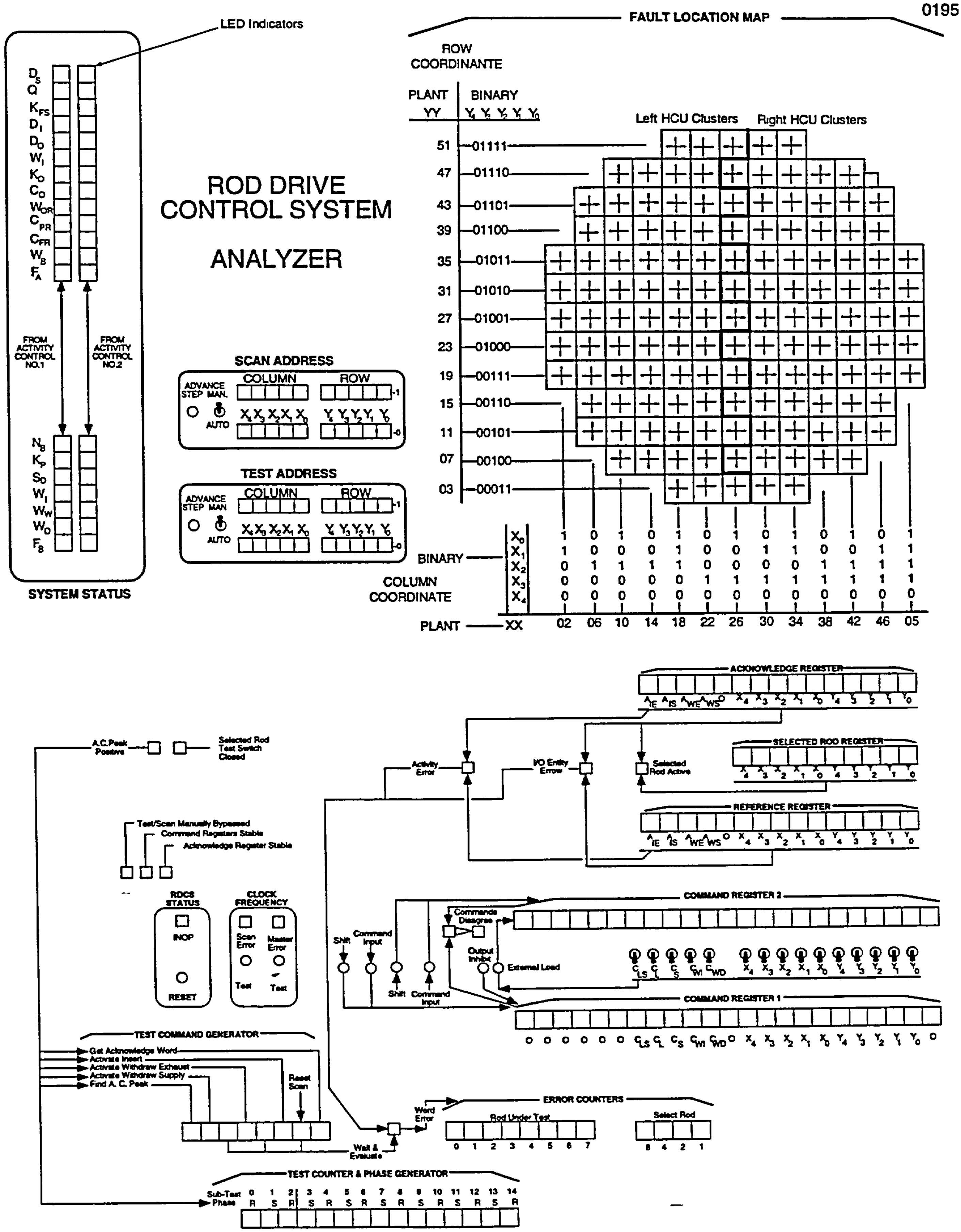


Figure 7.1-4 Analyzer Page Indicators

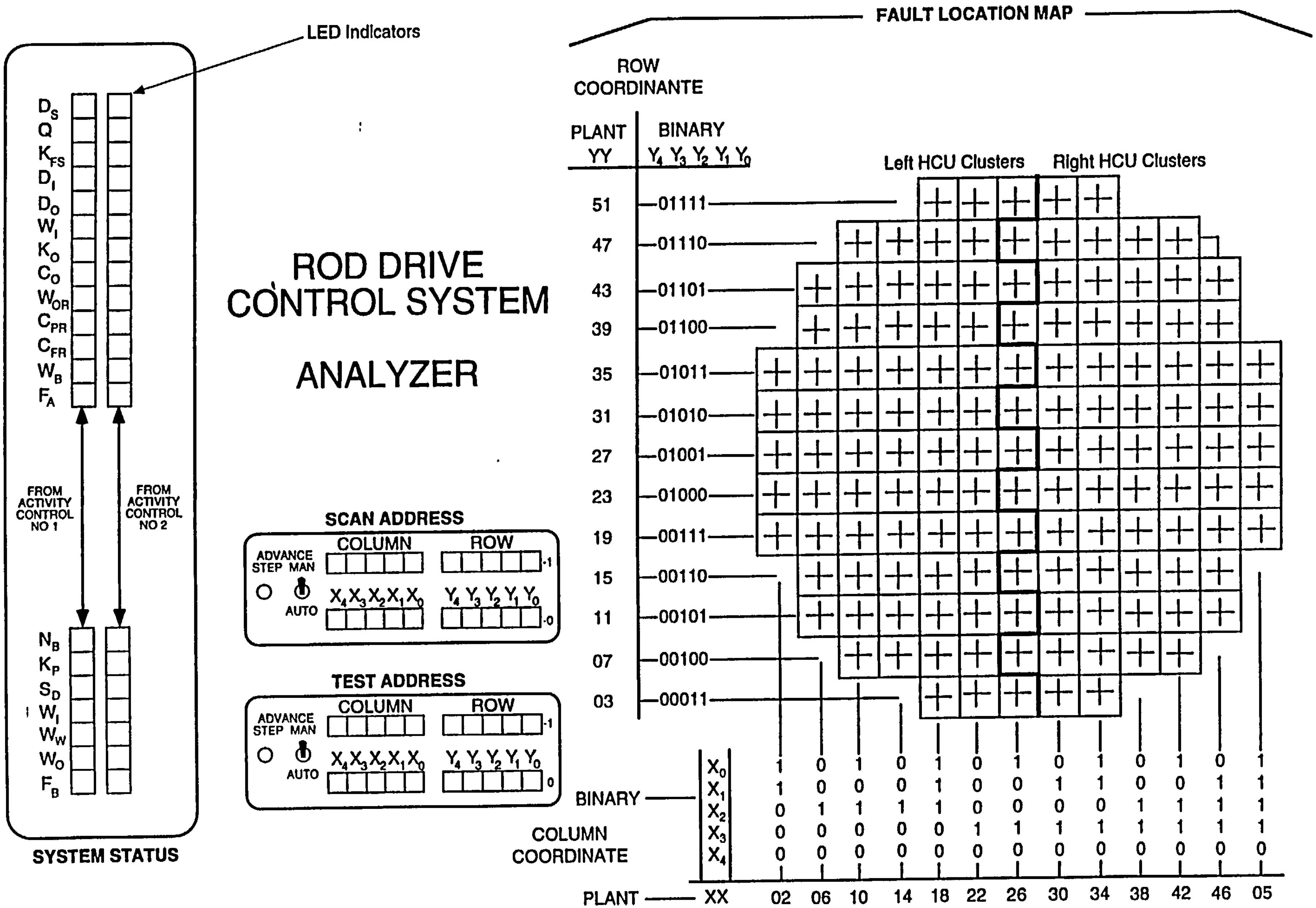


Figure 7.1-5 Analyzer Page - Top Portion

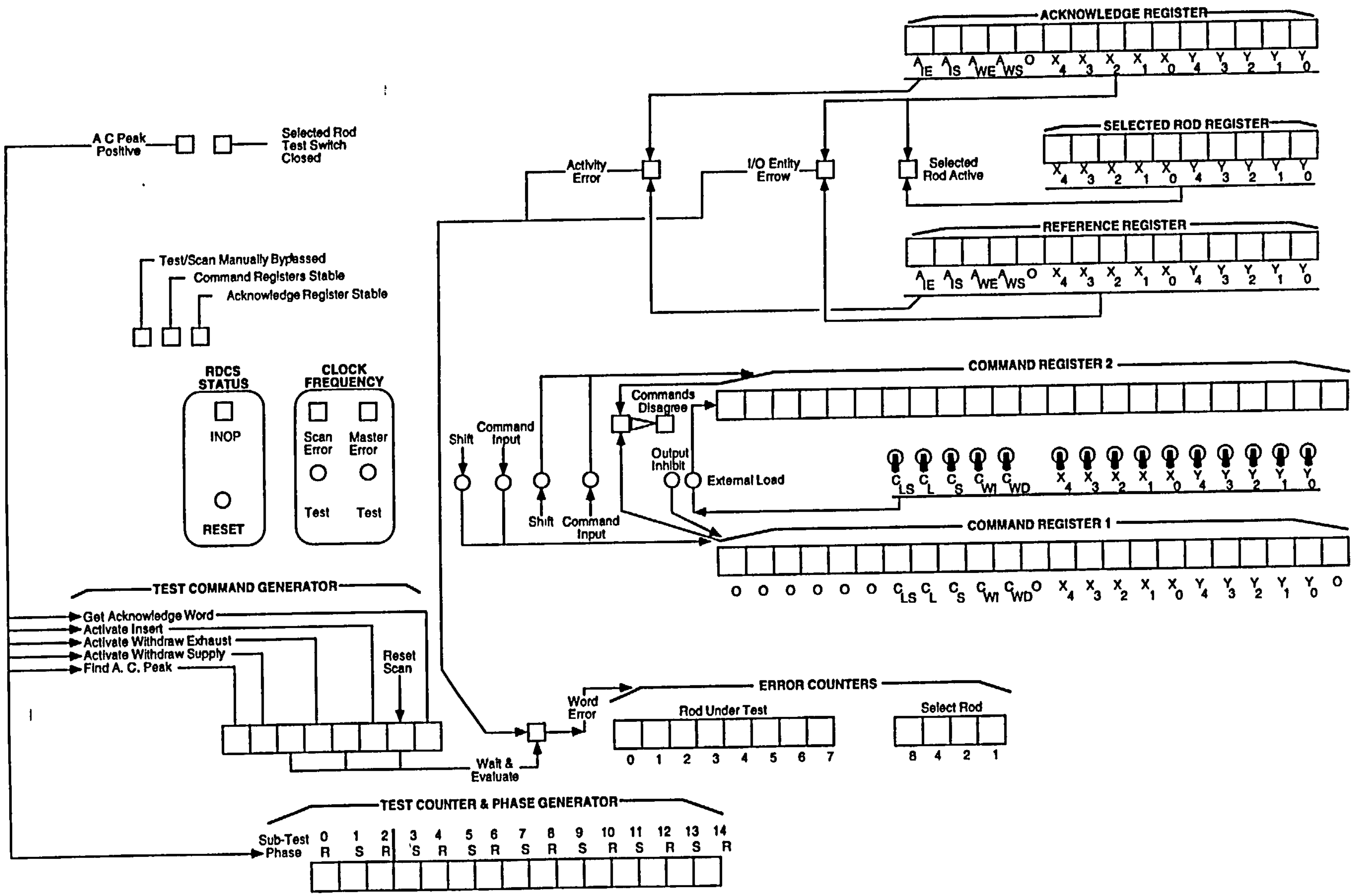
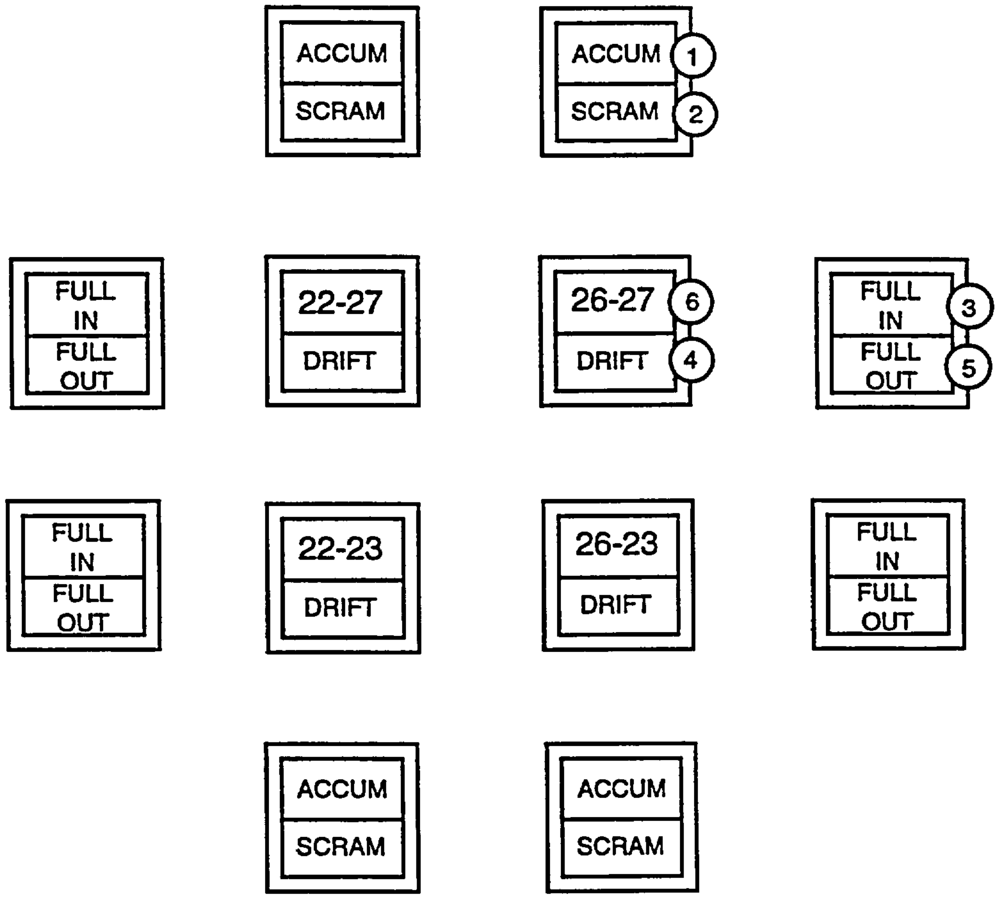


FIGURE 7.1-6 Analyzer Page - Bottom Portion



1. Accumulator trouble (amber lamp)
2. Scram valves open (blue lamp)
3. Control rod full in (green lamp)
4. Control rod drifting when not selected (red lamp)
5. Control rod full out (red lamp)
6. Control rod selected (white lamp)

Figure 7.1-7 Rod Status Display

Boiling Water Reactor
GE BWR/4 Technology
Technology Manual

Chapter 7.2

Recirculation Flow Control System

List of Figures

7.2 RECIRCULATION FLOW CONTROL SYSTEM

Learning Objectives

1. State the System's purpose.
2. Explain how the system accomplishes its purpose.
3. Explain how changing the core flow rate can change reactor power.
4. State the purpose of the major system components.
   a. Master controller
   b. Dual limiter
   c. M/A transfer station
   d. Start signal generator
   e. Minimum speed limiter
   f. Operational limiter
   g. Function generator
   h. Scoop tube
   i. Exciter
   j. Drive motor
   k. Fluid coupler
   l. Generator
   m. Recirculation pump trip breakers.
5. Given a power to flow map, Core Flow and Reactor Power, state if operation is within the allowed operating region.
6. Explain how the system interfaces with the following systems.
   a. Recirculation System
   b. Feedwater Control System

7.2.1 Introduction

The purpose of the Recirculation Flow Control (RFC) System is to control the rate of recirculation system flow, allowing control of reactor power over a limited range.
The functional classification of the RFC System is that of a power generation system.

7.2.2 System Description

The recirculation flow control system consists of two motor driven variable speed generator sets and the speed control logic needed to vary the generator speed. The motor driven variable speed generators provide the power to drive the recirculation pump motors, Figure 7.2-1. By varying the speed of the generator, the recirculation pump speed will then vary.

Changing recirculation flow results in a change in core flow rate and core power. Varying the core flow varies core power, from the effect core flow has on steam voids in the core. The mechanisms controlling reactor power are discussed in Chapter 1.12, Reactor Physics.

7.2.3 Component Description

The major components of the recirculation flow control system are discussed in the paragraphs which follow.

7.2.3.1 Recirculation Motor Generator Set

The recirculation motor generator set (Figure 7.2-2 and 7.2.3) consists of a drive motor, fluid coupler, generator, and the necessary auxiliary components to support motor generator set operation.

Drive Motor

The recirculation motor generator set drive motor is a constant speed 7000 horse power motor. The drive motor supplies the fluid coupler with motive force through a constant speed input shaft. In addition the drive motor provides the motive force for the M/G generator exciter.Drive motor trips are listed below:

7.2 RECIRCULATION FLOW CONTROL SYSTEM

Learning Objectives

1. State the System's purpose.
2. Explain how the system accomplishes its purpose.
3. Explain how changing the core flow rate can change reactor power.
4. State the purpose of the major system components.
   a. Master controller
   b. Dual limiter
   c. M/A transfer station
   d. Start signal generator
   e. Minimum speed limiter
   f. Operational limiter
   g. Function generator
   h. Scoop tube
   i. Exciter
   j. Drive motor
   k. Fluid coupler
   l. Generator
   m. Recirculation pump trip breakers.
5. Given a power to flow map, Core Flow and Reactor Power, state if operation is within the allowed operating region.
6. Explain how the system interfaces with the following systems.
   a. Recirculation System
   b. Feedwater Control System

7.2.1 Introduction

The purpose of the Recirculation Flow Control (RFC) System is to control the rate of recirculation system flow, allowing control of reactor power over a limited range.

The functional classification of the RFC System is that of a power generation system.

7.2.2 System Description

The recirculation flow control system consists of two motor driven variable speed generator sets and the speed control logic needed to vary the generator speed. The motor driven variable speed generators provide the power to drive the recirculation pump motors, Figure 7.2-1. By varying the speed of the generator, the recirculation pump speed will then vary.

Changing recirculation flow results in a change in core flow rate and core power. Varying the core flow varies core power, from the effect core flow has on steam voids in the core. The mechanisms controlling reactor power are discussed in Chapter 1.12, Reactor Physics.

7.2.3 Component Description

The major components of the recirculation flow control system are discussed in the paragraphs which follow.

7.2.3.1 Recirculation Motor Generator Set

The recirculation motor generator set (Figure 7.2-2 and 7.2.3) consists of a drive motor, fluid coupler, generator, and the necessary auxiliary components to support motor generator set operation.

Drive Motor

The recirculation motor generator set drive motor is a constant speed 7000 horse power motor. The drive motor supplies the fluid coupler with motive force through a constant speed input shaft. In addition the drive motor provides the motive force for the M/G generator exciter.Drive motor trips are listed below:

- EOC-RPT
- ATWS-RPT
- Generator Lockout
- UV on 4 kv bus
- Recirc pump discharge valve closed <90 or not open in 3 min.
- Recirc pump suction <90% open
- Lube oil pressure low <30#
- Lube oil temperature high >210°F
- Drive motor breaker trip (86 device)

Fluid Coupler

The fluid coupler consists of an input shaft that is connected to the impeller by a bolting arrangement, a runner that is connected to the output shaft, scoop tube, and the fluid coupler housing that serves to enclose the fluid coupler and act as an oil reservoir (Figure 7.2-4 and 7.2-5)

The fluid coupler transmits a portion of the drive motor torque to the generator shaft. The amount of torque that is transmitted to the generator is determined by the coupling between the drive motor and generator, which is determined by the amount of oil in the fluid coupler. The quantity of oil in the fluid coupler is regulated by the positioning of a device called a "scoop tube". The greater the quantity of oil in the fluid coupler, the greater the coupling between the drive motor and generator. Oil is fed into the circuit continuously by the M/G oil system via drilled passage in the generator shaft. By positioning the scoop tube to remove more oil from the circuit, the generator speed will be reduced due to less torque being transmitted. The drive motor shaft drives an impeller which forces oil against a runner. The runner is attached to the generator shaft. Therefore, the scoop tube position determines the torque transmitted to the generator and thus the generator and recirculation pump speed. The scoop tube locks up on lube oil low pressure or high temperature, undervoltage on drive motor 4kv bus, or speed control signal failure.

Generator

The M/G set generator is a synchronous generator driven at variable speed by the fluid coupler. Its output is wired to the associated recirculation pump motor through the End of Cycle and Anticipated Transient Without Scram recirculation pump trip breakers. Excitation is applied by a voltage regulation system from the exciter mounted on the M/G set drive motor, or from a startup source during M/G set startup. A tachometer generator is mounted on the generator shaft to provide an input to the speed control and voltage regulation circuits.

Generator lockouts are listed below:

- Generator Neutral ground voltage high
- Generator overcurrent
- Generator instantaneous differential overcurrent
- Generator loss of field
- Exciter field undervoltage
- Exciter field overcurrent

Note: on receiving a generator lockout, the drive motor breaker and field breaker open or trip.

7.2.3.2 Oil System

Each recirculation M/G set oil system consists of three ac motor driven pumps, one emergency dc motor driven pump, an oil cooler, and an oil reservoir (Figure 7.2-6). The lower casing of the fluid coupler serves as the system oil reservoir. The oil is normally pumped by two of the ac motor driven pumps through the oil cooler. A portion of the oil flows directly to the fluid coupler for use as working oil for the coupler; the remainder is directed to the M/G set bearings through an oil filter. The oil cooler is cooled by reactor building closed loop cooling water.

Should oil pressure entering the fluid coupler decrease below 30 psig, the standby pump will automatically start to restore pressure. If pressure remains below 30 psig for 6 seconds, the M/G set drive motor breaker and all ac oil pumps will be tripped. The emergency dc motor drive pump will start as pressure drops to 20 psig and supply oil to the fluid coupler bearings.

7.2.3.3 Recirculation Pump Speed Control Logic

Figure 7.2-7 is a simplified block diagram of the recirculation flow control logic. The principle of operation is to set a desired pump speed, measure the actual speed, compare these signals and produce a control signal used to position the scoop tube to obtain the desired pump speed. The components performing this function are discussed in the paragraphs which follow.

Master Flow Controller

The master flow controller provides the means of controlling both recirculation motor generator sets from a single controller.

Normal operation of the master controller is in the manual mode of operation.

By depressing the manual push button a signal is developed and transmitted to the manual-automatic transfer station via a dual limiter.

In the automatic mode of operation the Electro Hydraulic Control (EHC) system provides the desired main generator load demand signal. Only one utility, Commonwealth Edison, is licensed to operated in the automatic mode. All other BWR utilities operate in master manual mode of operation or individual loop control.

Manual-Automatic Transfer Station Controllers

The manual-automatic transfer station controllers provide the means of controlling both motor generator sets independently or as a paired unit. Similar to the master controller, the manual automatic transfer stations contain two modes of operation, manual and automatic. Normal mode of operation for both controllers is automatic.

Speed Limiters

Speed limiters are used in the control logic to limit the maximum and/or minimum speed demand signal according to plant operating conditions.

The output of the master controller is routed through the dual speed limiter which limits the speed demand from the master controller to a maximum of 102.5% of rated speed and a minimum of 45% speed. The output of this dual limiter is routed to the input of each manual-automatic transfer station. The maximum value, of 102%, is based on various limitations such as: generator, drive motor, and pump motor ratings; reactor vessel component stresses at high flow; and setting of K_f factors for minimum Critical Power Ratio limits. The minimum setting is based on the stability of system.

The output of the manual-automatic transfer station controller is routed through two speed limiters. The first of these limiters restrains recirculation pump speed to a maximum of 30% with the pump discharge valve not full open, reactor water level less than 12.5 inches, or feedwater flow less than 20%. This limiter prevents overheating of the recirculation pumps with the discharge valve not full open (low flow conditions) and cavitation problems for the recirculation pumps and jet pumps at low feedwater flow rates (low net positive suction head - NPSH).

The second limiter (operational limiter) restricts the maximum recirculation pump speed demand to less than 45%, which corresponds to approximately 65% reactor power. That restraint ensures a sufficient supply of feedwater is available to the reactor vessel to recover or maintain normal operating level following loss of a feedwater pump at 100% power. This limiter is bypassed whenever level is normal or if all Condensate, Condensate Booster, and Reactor Feed Pumps are in service. Once the operational limiter is in effect, it must be manually reset. The reset is manually performed via a pushbutton on panel 602 next to the manual-automatic stations.

Speed Control Summer

The speed control summer, during normal operation, compares the speed demand signal to the actual generator speed and develops an error signal which is sent to the speed controller. The error signal is limited to about 8% of the control band.

Startup Signal Generator

The startup signal generator provides a signal to the error limiting network to position the scoop tube properly for recirculation M/G set startup. This signal is set for approximately 80% unloaded generator speed to provide adequate breakaway torque for the recirculation pump.

Speed Controller

The speed controller establishes and maintains a speed demand signal in accordance with the error signal received from the speed control summer.

Function Generator

The function generator corrects the speed demand signal from the speed controller to account for the system's non-linearities, providing a linear relationship between the signal input to the master controller and recirculation flow. The function generator output is sent to the scoop tube positioner and signal failure detector.

Scoop Tube Positioner

The scoop tube positioner converts the electrical input signal from the function generator to a mechanical scoop tube position. The positioner compares the input signal to actual scoop tube position as developed by a cam operated position transmitter. The cam is cut to provide a linear function of scoop tube position versus speed. The error signal developed is acted upon by a servo amplifier that controls the direction of rotation of a drive motor. The drive motor in turn rotates a crank arm that is connected to the scoop tube positioning arm. The positioner has both electrical and mechanical high speed stops that limit the maximum torque transferred to the generator, thus limiting recirculation pump speed.

Signal Failure Detector

The normal input-output signal of all of the control devices range from 10 to 50 milliamps. Loss of signal input to the positioner is monitored by the signal failure detector. If the monitored signal decreases to 1 milliamp the scoop tube motor is locked in place by an electrically operated break. This function is referred to as locking up the scoop tube.

Following a scoop tube lockup, the reason for the lockup must be corrected and then the lockup manually reset. Prior to resetting the lockup, the speed demand signal must be matched to the actual scoop tube position to prevent a large process bump when resetting. The operator is provided with a percent speed demand indicator that indicates the difference in speed demand at the speed controller output and generator speed.

7.2.3.4 Generator Voltage Regulation

Voltage regulation is set at a constant 70 volts /Hz. The reference signal used in voltage regulation circuit comes from the generator driven tachometer which provides a signal proportional to speed. The circuit then sets the amount of excitation applied to the generator exciter field. During startup, a 120 VAC source is provided to establish the initial generator output. High voltage at low frequency can cause excessive current with damage to the exciter components from overheating.

7.2.4 System Features and Interfaces

A short discussion of system features is given in the paragraphs which follow.

7.2.4.1 Recirculation Pump Start

Figure 7.2-8 lists the initial requirements and sequence of events occurring on a recirculation M/G set start. The drive motor starts when all of the permissive are satisfied:

- Scoop tube in proper position
- pump not developing a differential pressure
- breaker lockout relays reset
- 6 second time delay is initiated
- field breaker closes

During the time delay, the drive motor and generator are accelerated to approximately 80% unloaded speed. Note on Figure 7.2-7 that when the field breaker is open, the speed control system input to the error limiter is replaced by the signal generator, and the tachometer feedback by the speed controller output. This serves to position the scoop tube to the 80% unloaded position. Excitation is applied from the 120 VAC source to the M/G set exciter 5 seconds after the drive motor breaker is closed.

Thus, when the field breaker closes at 6 seconds after the drive motor breaker closure, the M/G set is accelerated to approximately 80% unloaded speed and fully excited to provide the necessary breakaway torque for the recirculation pump. Once the field breaker is closed, excitation will automatically shift back to the generator output following a 26 second time delay. Since the recirculation pump trip breakers are normally closed, the pump motor is directly tied to the generator output and the recirculation pump starts when the generator field breaker closes.

The 15 second incomplete sequence timer allows time for the pump to rotate and develop greater than 4 psid. As soon as 4 psid is reached, the incomplete sequence timer is deenergized and the timer resets. If the pump does not generate greater than 4 psid in 15 seconds, the incomplete sequence timer trips the generator lockout relay. The lockout relay trips both the drive motor breaker and generator field breaker. When the generator field breaker is closed, the speed control circuits are returned to normal and the M/G set and pump will runback to the limiter value of 30% with the discharge valve closed. The final event that occurs is the jogging open of the recirculation pump discharge valve. If the valve is not fully open within three minutes, the drive motor breaker trips open. This protection is provided to replace the normal minimum flow circuits normally part of the pumping loop for large pumping systems.

7.2.4.2 Power/Flow Map

The power/flow map is a plot of percent core thermal power versus percent of total core flow for various operating conditions. The power/flow map contains information on expected systems performance. A brief description of the curves on the power/flow map, Figure 7.2-9, is given in the paragraphs which follow.

Natural Circulation Line

As reactor power is increased by withdrawing control rods, core flow increases due to the change in moderator density and steam formation (voids) within the core region. The colder (more dense) water in the downcomer region coupled with the less dense water in the core region supports a natural core flow that supplements forced circulation.

30% Pump Speed Line

Startup operations of the plant are normally carried out with both recirculation pumps at minimum speed. Reactor power and core flow follow this line for the normal control rod withdraw sequence with the recirculation pumps operating at approximately 30% speed.

Design Flow Control Line

This line is defined by the control rod withdraw pattern which results in being at 100% core thermal power and 100% core flow, assuming equilibrium xenon conditions. Reactor power should follow this line for recirculation flow changes with a fixed control rod pattern.

Pump Constant Speed Line

This line illustrates the change in core flow associated with a power reduction from 100% power, 100% core flow, while maintaining a constant recirculation pump speed.

Minimum Expected Flow Control Line

This line represents the flow control line for plant startup in which the recirculation pump speed is increased above minimum speed as soon as the 20% feedwater interlock is cleared.

Region of Instability

This area of the Power/Flow Map represents the point(s) where core thermal hydraulic stability problems may exist at all BWRs. Generally, intentional operation in this area is not permitted.

7.2.4.3 Recirculation Pump Trip

An end of cycle - recirculation pump trip (EOC-RPT) circuit provides an automatic rapid trip of the recirculation pumps on a main turbine trip or load rejection, if greater than 30% power. The trip is accomplished by opening the breakers between the pump motor and the variable speed generator. The purpose of the pump trip is to reduce the peak reactor pressure and power resulting from those transients coincident with a failure of the turbine steam bypass valves to ensure the MCPR safety limit is not violated.
The acronym "ATWS-RPT" refers anticipated transient without scram (ATWS) recirculation

pump trip (RPT). If a plant transient were to occur, necessitating a reactor scram, and for some reason the scram function did not occur, then an ATWS event would exist. To lessen the effects of an ATWS event, and get reactor power within the SRV capacity, negative reactivity must be added to the reactor core by another means. The means chosen is to trip the recirculation pumps which rapidly adds negative reactivity due to a sudden increase in steam voiding in the core area as core flow decreases. When reactor pressure reaches 1120 psig or reactor water level decreases to the low-low level setpoint, the recirculation RPT breakers and motor generator set drive motor breaker trips.

7.2.5 System Interfaces

The interrelations this system has with other plant systems are discussed in the paragraphs which follow.

7.2.5.1 Recirculation System (Section 2.4)

The recirculation flow control system regulates the speed of the recirculation pumps. The pump suction and discharge valve are in the start logic.

7.2.5.2 Electro Hydraulic Control System (Section 3.2)

The EHC System can control recirculation flow if the master controller is allowed to be placed in the automatic position.

7.2.5.3 Main Steam System (Section 2.5)

The Main Steam System provides the trip input signals for the EOC-RPT circuit (SVs, CVs and 1st stage turbine pressure).

7.2.5.4 Feedwater Control System (Section 3.3)

The Net Positive Suction Head (NPSH) interlock (<20% total feedwater flow) is provided by the Feedwater Control System. As well as Level 3 and Level 4 inputs into the 45% limiter (ops limiter) and the 30% limiter.

7.2.6.5 Condensate and Feedwater System (Section 2.6)

The Condensate and Feedwater System provides the bypass for the 45% speed limiter (RFPs, condensate booster pumps, and condensate pumps).

7.2.5.6 Reactor Vessel Instrumentation System (Section 3.1)

The Reactor Vessel Instrumentation System provides the reactor vessel high pressure and low-low water level ATWS-RPT signals.

As well as Level 3 and Level 4 inputs into the 45% limiter (ops limiter) and the 30% limiter.

7.2.6 Summary

Classification - Power generation system

Purpose - To control the rate of recirculation system flow, allowing control of reactor power over a limited range.

Components - Motor generator set; speed control logic; RPT breakers.

System Interfaces -Recirculation System; Main Steam System; Feedwater Control System; Condensate and Feedwater System.

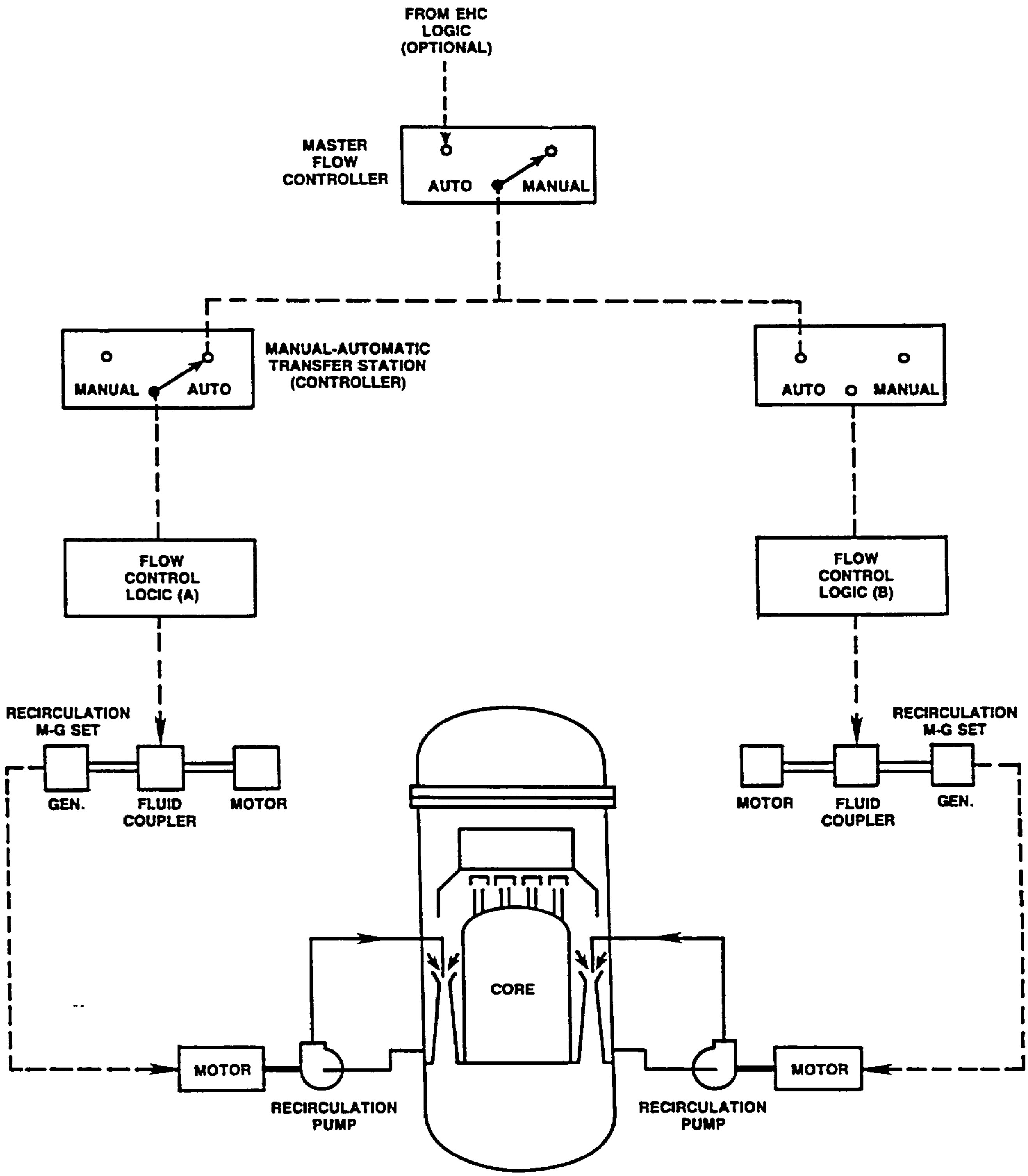


FIGURE 7.2-1 SIMPLIFIED RECIRCULATION FLOW CONTROL LOOP

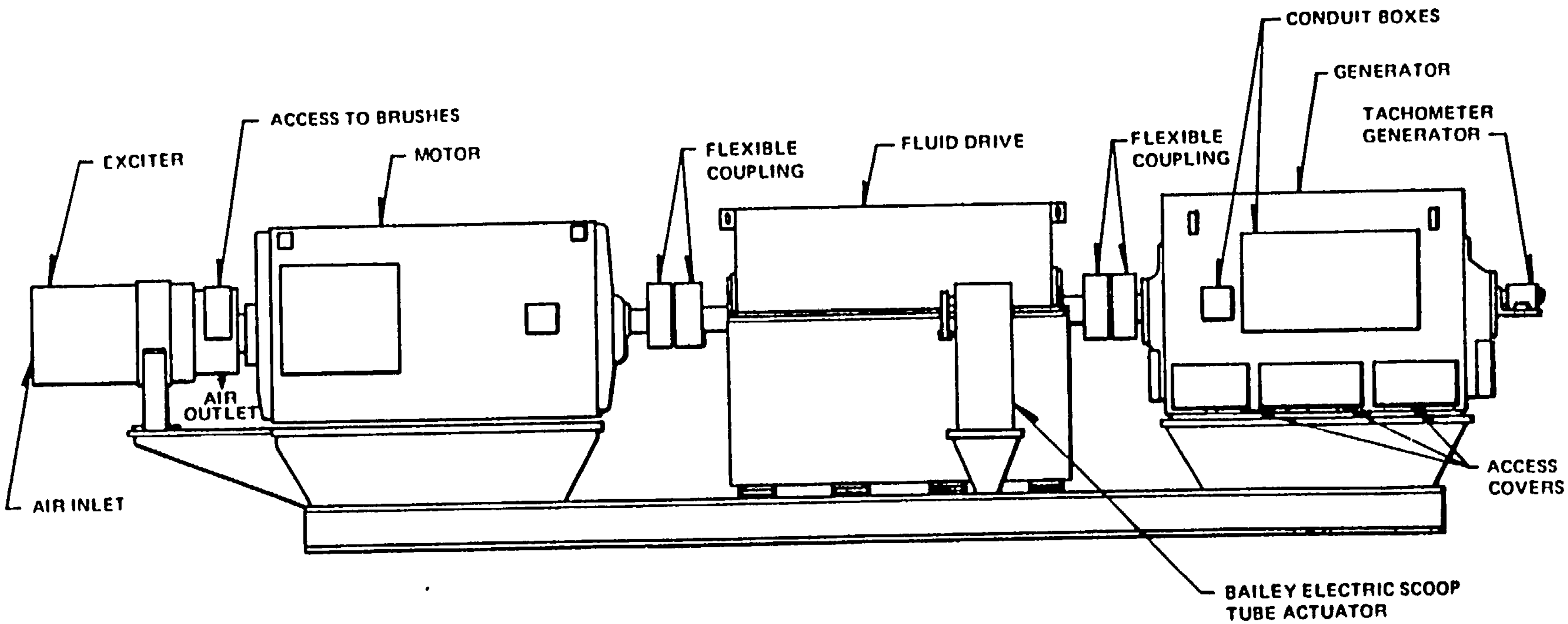


FIGURE 7.2 – 2 RECIRCULATION MOTOR-GENERATOR SET SIDE VIEW

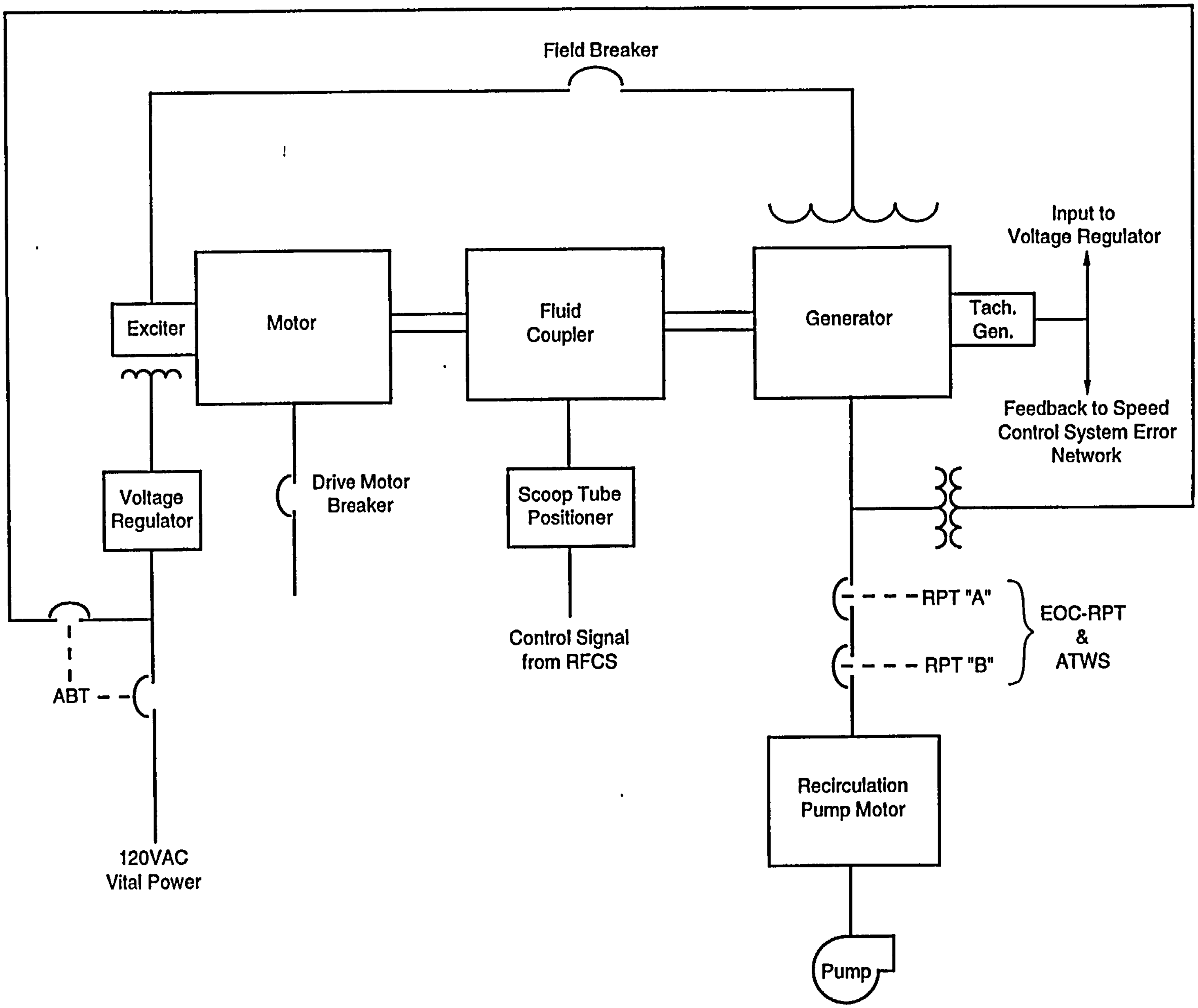


Figure 7.2-3 Recirculation Pump Motor Generator Set Block Diagram

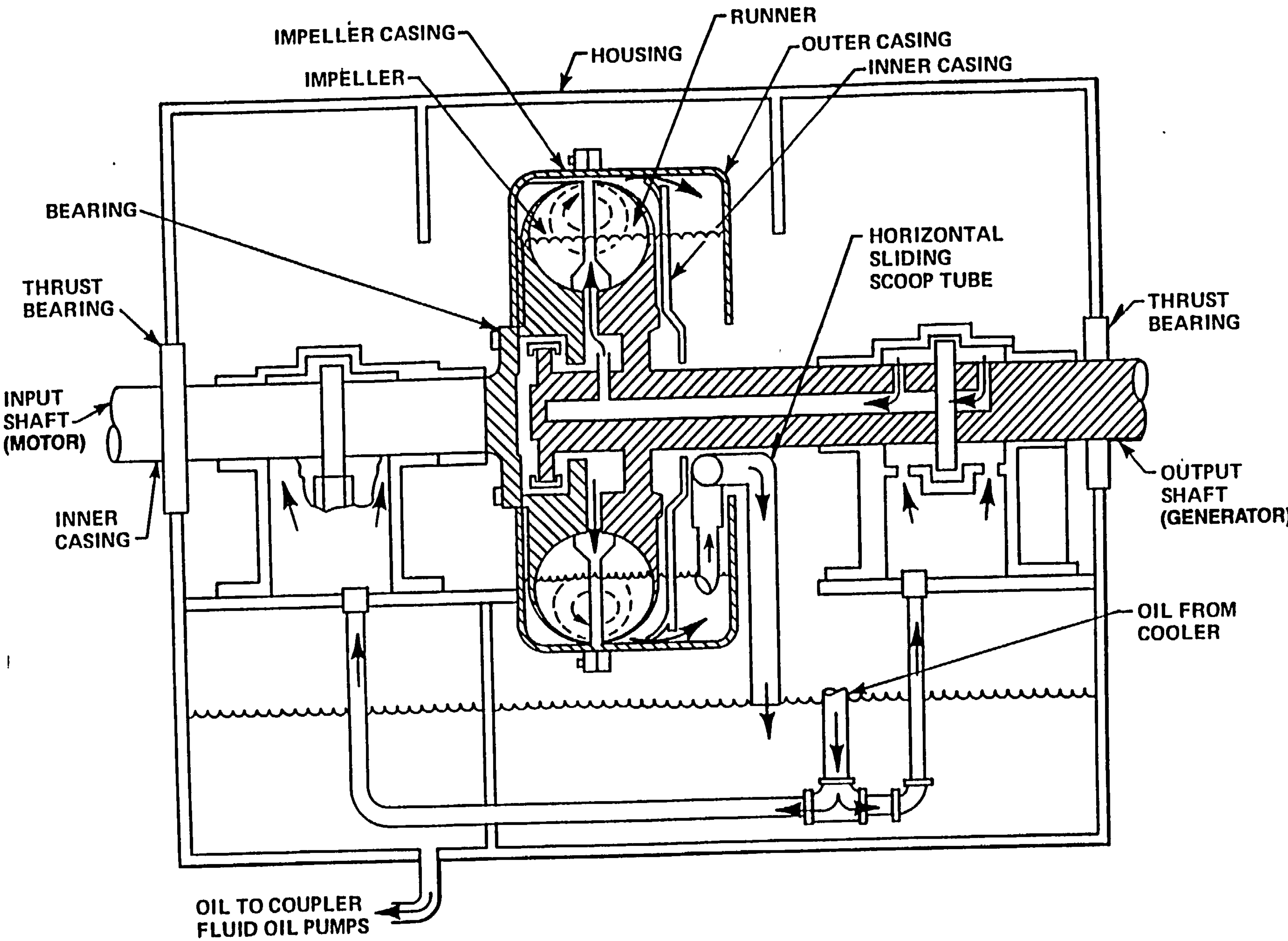


FIGURE 7.2-4 RECIRCULATION M-G SET FLUID COUPLING

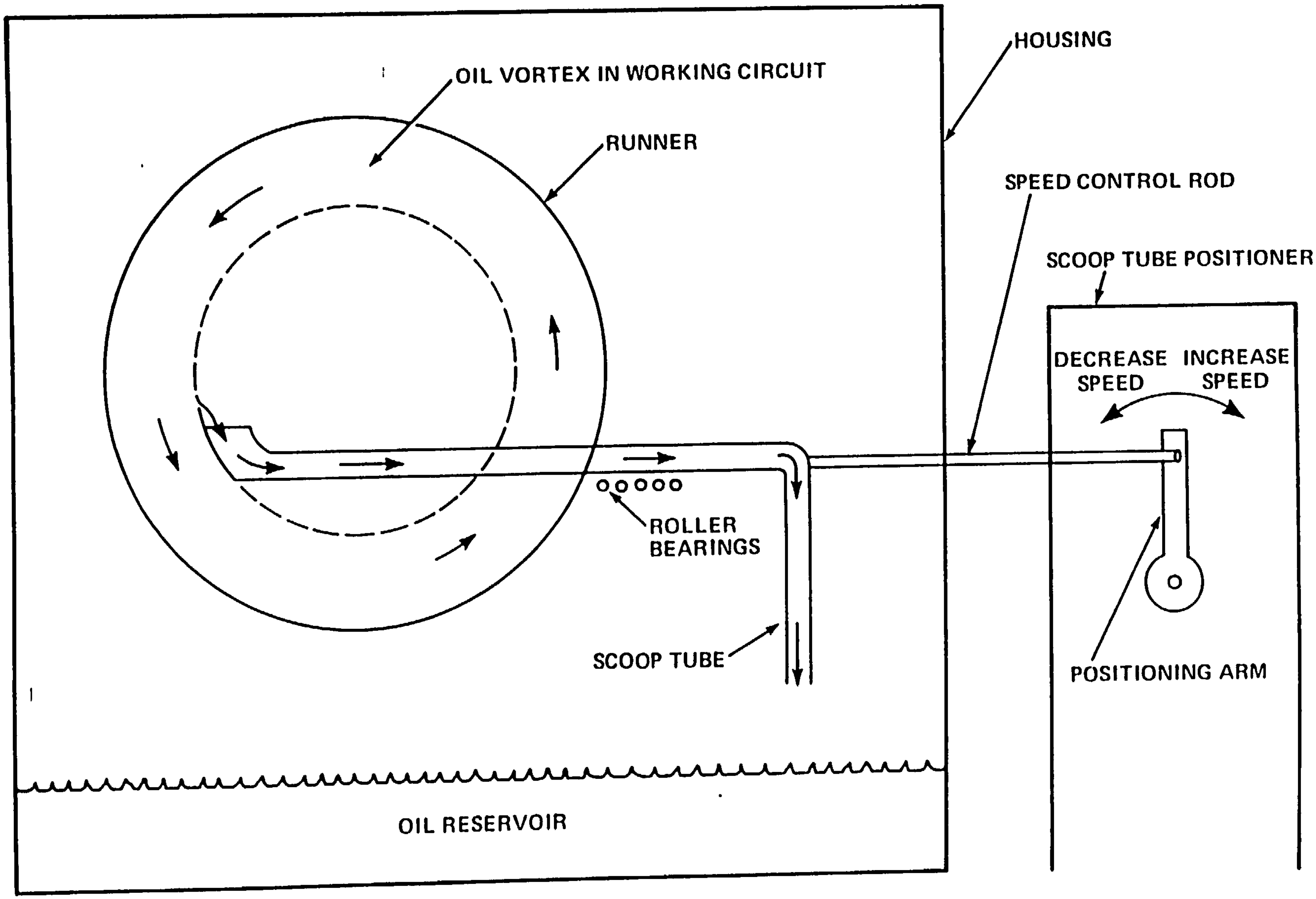


FIGURE 7.2 – 5 FUNCTIONAL DIAGRAM OF SCOOP TUBE ACTION
(VIEW FROM MOTOR END)

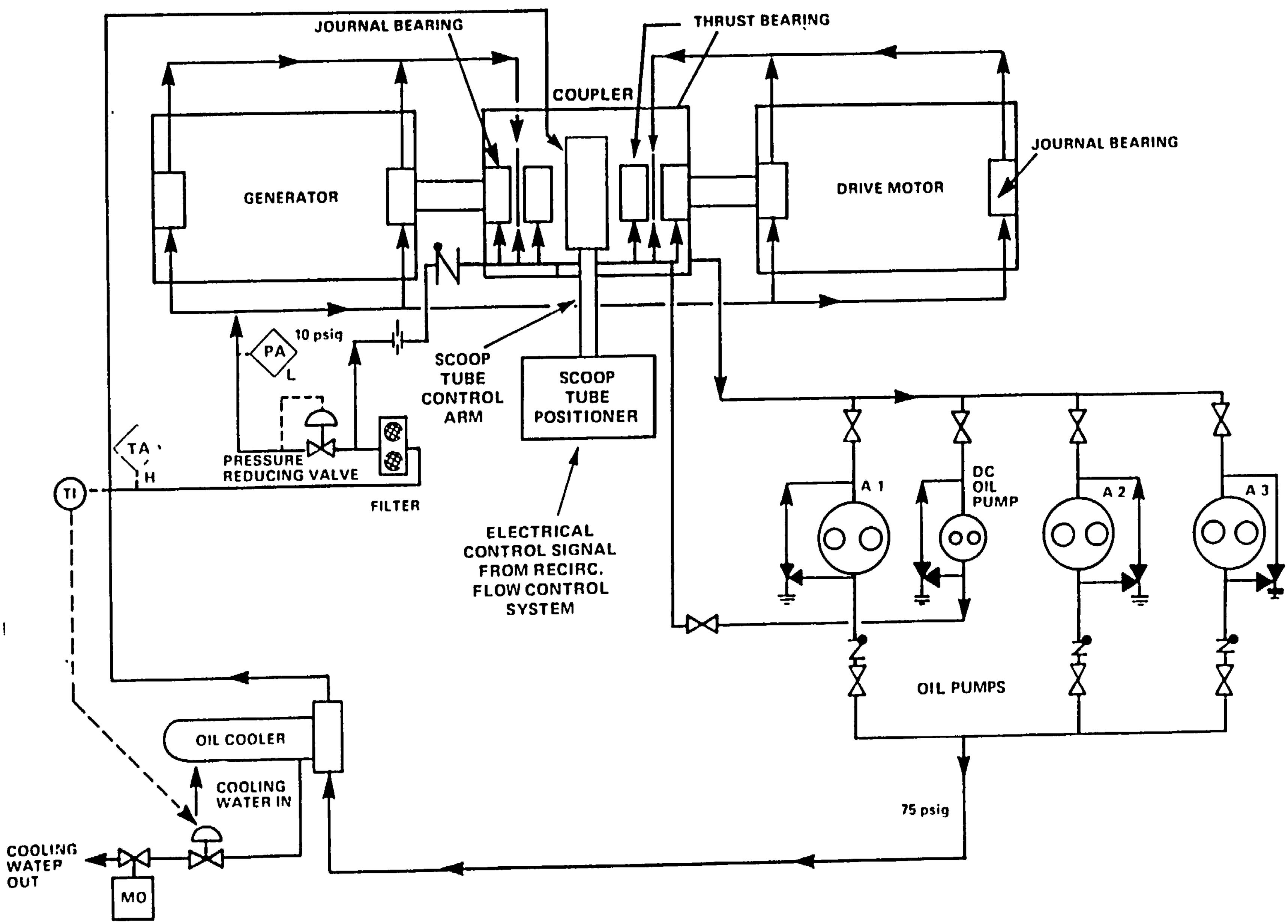


FIGURE 7.2-6 RECIRCULATION MG SET OIL SYSTEM

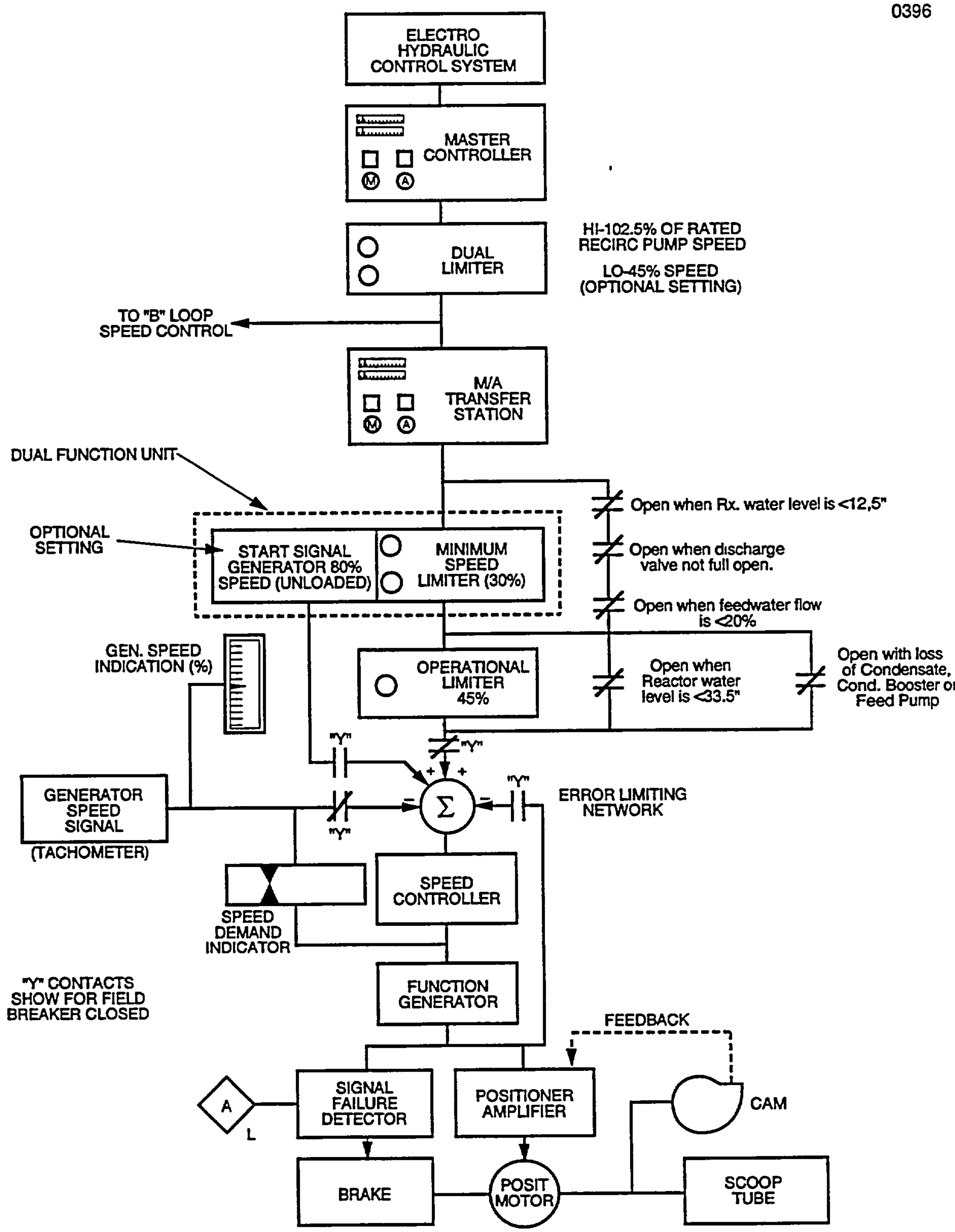


Figure 7.2-7 Recirculation System Flow Control Network (Shown for A loop, TYP. for B)

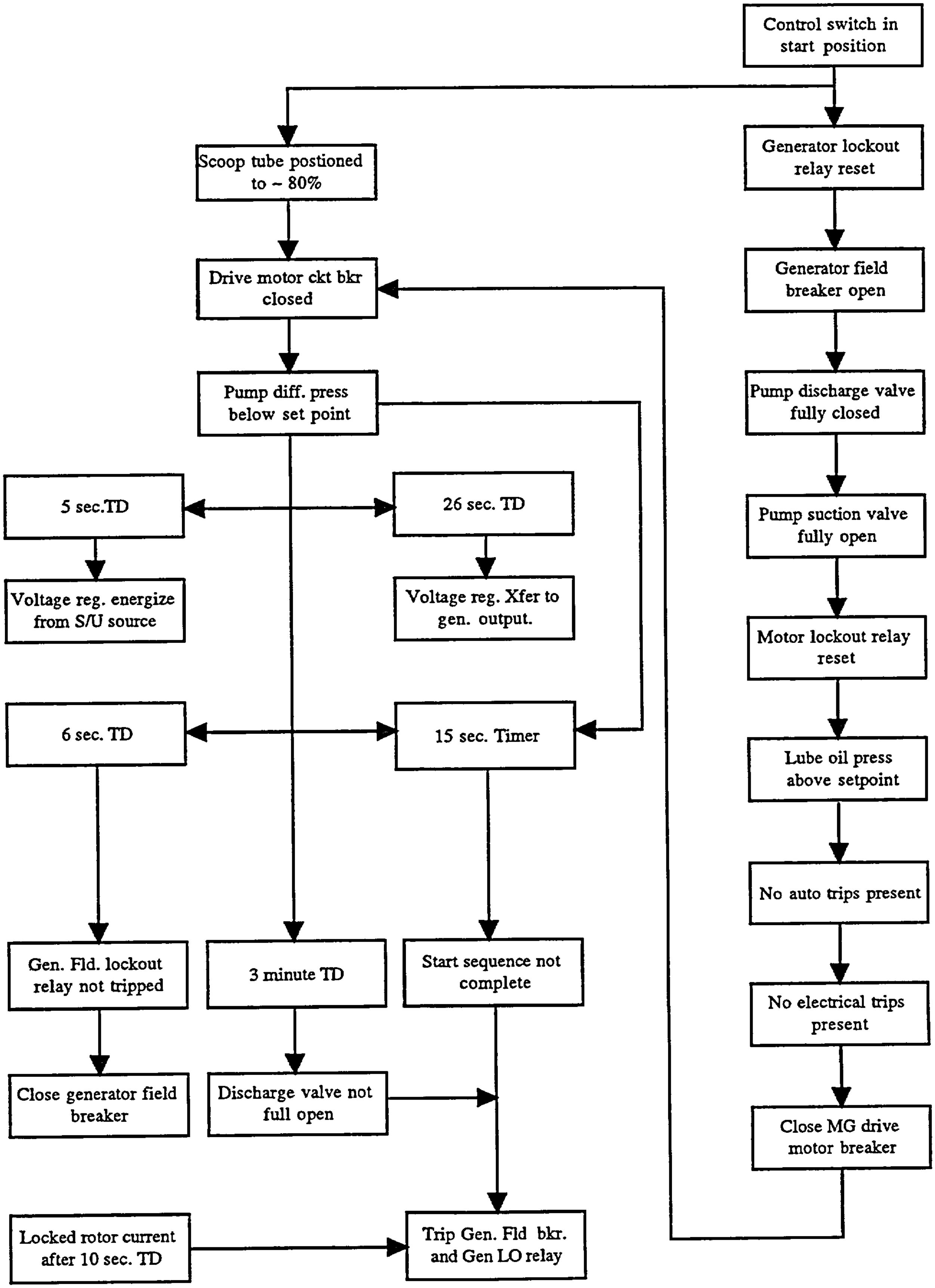


Figure 7.2-8 Recirculation Pump Motor Generator Set Starting Sequence

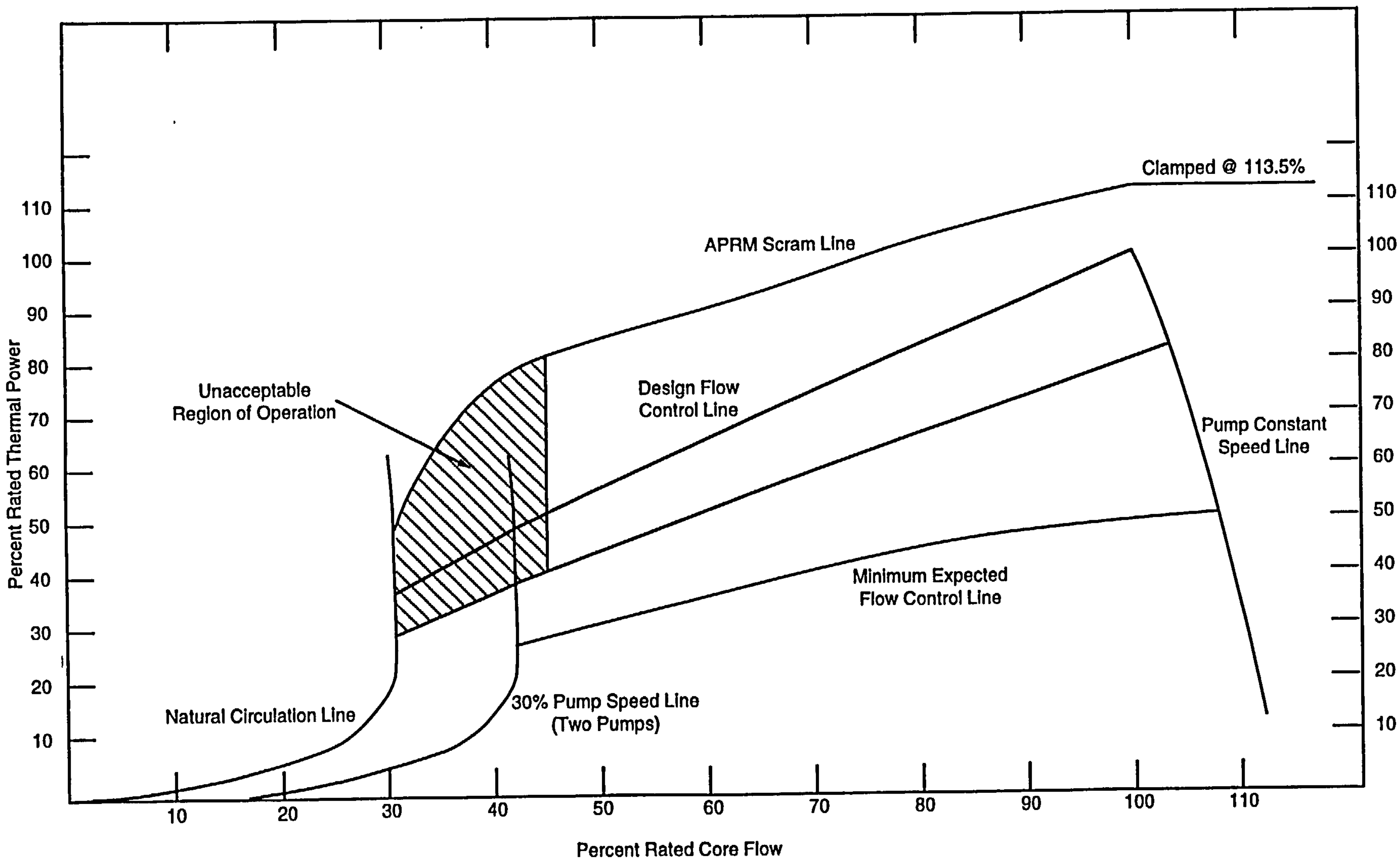


Figure 7.2-9 Power/Flow Map