7.7 REACTOR MANUAL CONTROL SYSTEM

7.7.1 Power Generation Objection

The objective of the Reactor Manual Control System is to provide the operator with the means to make changes in nuclear reactivity so that reactor power level and power distribution can be controlled. The system allows the operator to manipulate control rods.

7.7.2 Safety Design Basis

1. The circuitry provided for the manipulation of control rods shall be designed so that no single failure can negate the effectiveness of a reactor scram.

2. The Reactor Manual Control System shall act to limit the worth of individual control rods in conjunction with the rod worth minimizer system such that a postulated rod drop accident will not result in fuel pellet power density greater than 280 calories per gram (consult UFSAR Section 14.6.2 for additional information regarding control rod drop accident initial conditions and assumptions including the velocity limiter and RPS 120% flux trip functions).

3. The Reactor Manual Control System shall be designed to inhibit control rod withdrawal in time to prevent local fuel damage as a result of erroneous control rod manipulation (consult UFSAR Section 14.4.2 for additional information regarding erroneous control rod manipulation definitions).

4. The Reactor Manual Control System shall be designed to inhibit rod movement whenever such movement would result in operationally undesirable core reactivity conditions or whenever instrumentation (due to failure) is incapable of monitoring the core response to rod movement.

7.7.3 Power Generation Design Basis

1. The Reactor Manual Control System shall be designed to inhibit control rod withdrawal following erroneous control rod manipulations so that Reactor Protection System action (scram) is not required.

2. To limit the potential for inadvertent rod withdrawals leading to Reactor Protection System action, the Reactor Manual Control System shall be designed in such a way that deliberate operator action is required to effect a continuous rod withdrawal.

3. To provide the operator with the means to achieve prescribed control rod patterns, information pertinent to the position and motion of the control rods shall be available in the control room.

7.7.4 Description

7.7.4.1 Identification

The Reactor Manual Control System consists of the electrical circuitry, switches, indicators, and alarm devices provided for operational manipulation of the control rods and the surveillance of associated equipment. This system includes the interlocks that inhibit rod movement (rod block) under certain conditions. The Reactor Manual Control System does not include any of the circuitry or devices used to automatically or manually scram the reactor; these devices are discussed in Subsection 7.2, "Reactor Protection System." Nor are the mechanical devices of the control rod drives and the Control Rod Drive Hydraulic System included in the Reactor Manual Control System; these mechanical components are described in Subsection 3.4, "Reactivity Control Mechanical Design."

7.7.4.2 Operation

7.7.4.2.1 General

Control rod movement is accomplished by admitting water under pressure from a control rod drive water pump into the appropriate end of the control rod drive cylinder. The pressurized water forces the piston, which is attached by a connecting rod to the control rod, to move. Three modes of control rod operation are used: insert, withdrawal, and settle. Four solenoid-operated valves are associated with each control rod to accomplish the actions required for the various operational modes. The valves control the path that the control rod drive water takes to the cylinder. The Reactor Manual Control System controls the valves.

Two of the four solenoid-operated valves for a control rod are electrically connected to the insert bus. When the insert bus is energized and when a control rod has been selected for movement, the two insert valves for the selected rod open, allowing the control rod drive water to take the path that results in control rod insertion. Of the two remaining solenoid-operated valves for a control rod, one is electrically connected to the withdraw bus, and the other is connected to the settle bus. The withdraw valve that connects the insert drive water supply line to the exhaust water header is the one that is connected to the settle bus. The remaining withdraw valve is connected to the withdraw bus. When both the withdraw bus and the settle bus are energized and when a control rod has been selected for movement, both withdraw valves for the selected rod open, allowing control rod drive water to take the path that results in control rod withdrawal.

The settle mode is provided to insure that the control rod drive index tube is engaged promptly by the collet fingers after the completion of either an insert or withdraw cycle. During the settle mode, the withdraw valve connected to the settle bus is opened, or remains open, while the other three solenoid-operated valves are closed. During an insert cycle, the settle action vents the pressure from the bottom of the CRD piston to the exhaust header, thus gradually reducing the differential pressure across the drive piston of the selected rod. During a withdraw cycle, the settle action again vents the bottom of the CRD piston to the exhaust header, while the withdraw drive water supply is shut off. This also allows a gradual reduction in the differential pressure across the control rod drive piston. After the control rod has slowed down, the collet fingers engage the index tube and lock the rod in position.

The arrangement of control rod selection pushbuttons and circuitry permits the selection of only one control rod at a time for movement. A rod is selected for movement by depressing a button for the desired rod on the reactor control bench board in the control room. This bench board is shown in Figure 7.7-2. The direction in which the selected rod moves is determined by the position of a switch, called the "rod movement" switch, which is also located on the reactor control bench board. This switch has "rod-in" and "rod-out-notch" positions and returns by spring action to the "off" position. The rod selection circuitry is arranged so that a rod selection is sustained until either another rod is selected or separate action is taken to revert the selection circuitry to a no-rod selection. Initiating movement of the selected rod prevents the selection of any other rod until the movement cycle of the selected rod has been completed. Reversion to the no-rod-selected condition will not occur until any moving rod has completed its movement cycle unless control circuit power is lost or the settle bus is de-energized. Selection of the EMERG ROD IN position on the CRD NOTCH OVERRIDE switch on the reactor control bench board de-energizes the settle bus and allows selection of another control rod prior to completion of the control rod movement cycle.

7.7.4.2.2 Insert Cycle

The following is a description of the detailed operation of the Reactor Manual Control System during an insert cycle. The cycle is described in terms of the insert, withdraw, and settle buses. The response of a selected rod when the various buses are energized has been explained previously.

A three-position rod movement switch is provided on the reactor control bench board. The switch has a "rod-in" position, a "rod-out-notch" position, and an "off" position. The switch returns by spring action to the "off" position. With a control rod selected for movement, placing the rod movement switch in the "rod-in" position and then releasing the switch energizes the insert bus for a limited amount of time. Just before the insert bus is deenergized, the settle bus is automatically energized and remains energized for a limited period of time after the insert bus is deenergized. The insert bus timer setting and the rate of drive water flow provided by the control rod drive hydraulic system determine the distance traveled by a rod. The timer setting results in a one-notch (six-inch) insertion of the selected rod for each momentary application of a rod-in signal from the rod movement switch. Continuous insertion of a selected control rod is possible by holding the rod movement switch in the "rod-in" position.

The CRD NOTCH OVERRIDE switch also can be used to initiate insertion of a selected control rod. This switch has an EMERG ROD IN, OFF, and NOTCH OVERRIDE position and spring returns to the OFF position. Holding this switch in the EMERG ROD IN position continuously energizes the insert bus causing a continuous insertion of the selected control rod.

7.7.4.2.3 Withdraw Cycles

The following is a description of the detailed operation of the Reactor Manual Control System during a withdraw cycle. The cycle is described in terms of the insert, withdraw, and settle buses. The response of a selected rod when the various buses are energized has been explained previously.

With a control rod selected for movement, placing the rod movement switch in the "rod-out-notch" position energizes the insert bus for a short period of time. Energizing the insert bus at the beginning of the withdrawal cycle is necessary to allow the collet fingers to disengage the index tube. When the insert bus is deenergized, the withdraw and settle buses are energized for a controlled period of time. The withdraw bus is deenergized prior to the settle bus, which, when de-energized completes the withdraw cycle. This withdraw cycle is the same whether the rod movement switch is held continuously in the "rod-out-notch" position or released. The timers that control the withdraw cycle are set so that the rod travels one notch (six inches) per cycle. An interlock is provided in the withdraw circuitry to deenergize the control circuit and prevent rod withdrawal if the withdraw bus timer fails to deenergize the withdraw bus after the specified time period.

A selected control rod can be continuously withdrawn if the rod movement switch is held in the "rod-out-notch" position at the same time that the CRD NOTCH OVERRIDE switch is held in the "notch-override" position. With both switches held in these positions, the withdraw bus is continuously energized.

7.7.4.2.4 Control Rod Drive Hydraulic System Control

Two motor-operated pressure control valves, two air-operated flow control valves in parallel with only one operating, and four solenoid-operated stabilizing valves in parallel with only two operating are included in the Control Rod Drive Hydraulic System to maintain smooth and regulated system operation (see Subsection 3.4, "Reactor Control Mechanical Design"). The motor-operated pressure control valves are positioned by manipulating switches in the control room. The switches for these valves are located close to the pressure indicators that respond to the pressure changes caused by the movements of the valves. The air-operated flow control valve is automatically positioned in response to signals from an upstream flow measuring device. The stabilizing valves are automatically controlled by the action of the energized insert and withdraw buses. The drive water pumps are controlled by switches in the control room. Each pump automatically stops upon indication of low suction pressure.

7.7.4.3 Rod Block Interlocks

7.7.4.3.1 General

To achieve an operationally desirable performance objective, where most failures of individual components would be easily detectable or would not disable the rod movement inhibiting functions, the rod block logic circuitry is arranged as two similar logic circuits. Most common connection points that would, after failure, allow rod withdrawal under rod block conditions are eliminated. The two circuits are energized when control rod movement is allowed. Rod block contacts are normally closed, and rod block relays are normally energized. Each of the two similar circuits receive input trip signals from a number of trip channels. Three rod withdrawal block signals are associated with the two rod block circuits. Either of the two circuits can provide a separate rod block signal to the rod control circuitry. The individual signal from each circuit is called an "annunciating rod block control," because, when tripped, an annunciator is lighted and a buzzer is sounded in the control room to indicate the block signal. The third rod block signal is obtained by combining the outputs of the two similar logic circuits, the rod worth minimizer output (see Subsection 7.16, "Process Computer System"), and the rod block monitor outputs. This third signal is called the "nonannunciating rod block control," because, when tripped, the rod block condition is indicated in the control room by light indicator only. The two "annunciating rod block controls" are always placed in pairs in the rod control circuitry, while the "nonannunciating rod block control" is used independently. Both the two "annunciating rod block controls" and the "nonannunciating rod block control" must be in the permissive state for control rod withdrawal to be possible. A failure of any one of the three rod block controls cannot prevent the remaining parts of the rod block circuitry from initiating a rod block.

When in the tripped state, the "nonannunciating rod block control" prevents the withdraw movement of a selected rod by opening the rod control circuit that is used to energize the withdraw bus. The "annunciating rod block controls" prevent the withdraw movement of a selected rod in a similar manner, but the rod control circuit is opened at a location different from that affected by the "nonannunciating rod block control." The rod block circuitry is effective in preventing rod withdrawal, if required, during both normal (notch) withdrawal and continuous (notch override) withdrawal. If a rod block signal is received during a rod withdrawal, the control rod is automatically stopped at the next notch position, even if a continuous rod withdrawal is in progress.

The components used to initiate rod blocks in combination with refueling operations provide rod block trip signals to these same rod block circuits. These refueling rod blocks are described in Subsection 7.6, "Refueling Interlocks."

7.7.4.3.2 Rod Block Functions

The following discussion describes the various rod block functions and explains the intent of each function. The instruments used to sense the conditions for which a rod block is provided are discussed later.

a. With the mode switch in SHUTDOWN, no control rod can be withdrawn. This enforces compliance with the intent of the SHUTDOWN mode.

b. The circuitry is arranged to initiate a rod block regardless of the position of the mode switch for the following conditions:

    1. Any average power range monitor (APRM) upscale rod block alarm. The purpose of this rod block function is to avoid conditions that would require Reactor Protection System action if allowed to proceed. The APRM upscale rod block alarm setting is selected to initiate a rod block before the APRM high neutron flux scram setting is reached.

    2. Any APRM inoperative alarm. This assures that no control rod is withdrawn unless the average power range neutron monitoring channels are either in service or properly bypassed.

    3. Either rod block monitor (RBM) upscale alarm. This function is provided to stop the withdrawal of a control rod so that local fuel damage does not result from a localized power excursion.

    4. Either RBM inoperative alarm. This assures that no control rod is withdrawn unless the RBM channels are in service or properly bypassed.

       The RBM inoperable functions are 1) local RBM chassis mode switch not in operate, 2) less than the required number of LPRM inputs for the rod selected, 3) module unplugged (loss of input power), 4) self-test detected critical fault, and 5) RBM fails to null.

    5. Any recirculation flow signal upscale or inoperative alarm. This assures that no control rod is withdrawn unless the recirculation flow functions, which are necessary for the proper operation of the APRMs are operable.

6. (Deleted).

7. Scram discharge volume high water level. This assures 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.

8. Scram discharge volume high water level scram trip bypassed. This assures that no control rod is withdrawn while the scram discharge volume high water level scram function is out of service.

9. Rod worth minimizer (RWM) function of the process computer system initiates a rod insert block, a withdrawal block, or a rod select block. The purpose of this function is to reinforce procedural controls that limit the reactivity worth of control rods under low power conditions. The rod block trip settings are based on the allowable control rod worth limits established for the design basis rod drop accident. Adherence to prescribed control rod patterns is the method by which this reactivity restriction is observed. Additional information of the rod worth minimizer function is available in Subsection 7.16, "Process Computer System."

10. Rod position information system malfunction. This assures that no control rod can be withdrawn unless the rod position information system is in service.

11. Rod movement timer switch malfunction during withdrawal. This stops control rod withdrawal and assures that no control rod can be withdrawn unless the timer is in service.

c. With the mode switch in RUN, only the following conditions initiates a rod block:

1. Any APRM downscale alarm. This assures that no control rod will be withdrawn during power range operation unless the average power range neutron monitoring channels are operating correctly or are correctly bypassed. All unbypassed APRMs must be on scale during reactor operations in the RUN mode.

2. Either RBM downscale alarm. This assures that no control rod is withdrawn during power range operation unless the RBM channels are operating correctly or are correctly bypassed. Unbypassed RBMs must be on scale during reactor operations in the RUN mode.

3. Any Oscillation Power Range Monitor (OPRM) alarm. The OPRM alarm is only enabled in the region of the power/flow map where the OPRM scram trip is enabled.

d. With the mode switch in STARTUP or REFUEL, the following conditions initiate a rod block:

1. Any source range monitor (SRM) detector not fully inserted into the core when the SRM count level is below the retract permit level and any intermediate range monitor (IRM) range switch on either of the two lowest ranges. This assures 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.

2. Any SRM upscale level alarm provided IRMs are below Range 8. This assures that no control rod is withdrawn unless the SRM detectors are properly retracted during a reactor startup. The rod block setting is selected at the upper end of the range in which the SRM is designed to detect and measure neutron flux.

3. Any SRM downscale alarm provided IRMs are below Range 3. This assures that no control rod is withdrawn unless the SRM count rate is above the minimum prescribed for low neutron flux level monitoring.

4. Any SRM inoperative alarm provided IRMs are below Range 8. This assures that no control rod is withdrawn during low neutron flux level operations unless proper neutron monitoring capability is available in that all SRM channels are in service or properly bypassed.

5. Any intermediate range monitor (IRM) detector not fully inserted into the core. This assures that no control rod is withdrawn during low neutron flux level operations unless proper neutron monitoring capability is available in that all IRM detectors are properly located.

6. Any IRM upscale alarm. This assures that no control rod is withdrawn unless the intermediate range neutron monitoring equipment is properly upranged during a reactor startup. This rod block also provides a means to stop rod withdrawal in time to avoid conditions requiring Reactor Protection System action (scram) in the event that a rod withdrawal error is made during low neutron flux level operations.

7. Any IRM downscale alarm except when range switch is on the lowest range. This assures 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 upranges the IRM too far for the existing flux level; thus, the rod block ensures that the intermediate range monitor is onscale if control rods are to be withdrawn.

8. Any IRM inoperative alarm. This assures that no control rod is withdrawn during low neutron flux level operations unless proper neutron monitoring capability is available in that all IRM channels are in service or properly bypassed.

7.7.4.3.3 Rod Block Bypasses

To permit continued power operation during the repair or calibration of equipment for selected functions which provide rod block interlocks, a limited number of manual bypasses are permitted as follows:

1 SRM channel,
2 IRM channels,
1 APRM channels, and
1 RBM channel.

The permissible IRM and APRM bypasses are arranged in the same way as in the Reactor Protection System. The IRMs are arranged as two groups of equal numbers of channels. One manual bypass is allowed in each group. The groups are chosen so that adequate monitoring of the core is maintained with one channel bypassed in each group. In Unit 1, the same type of grouping and bypass arrangement is used for the APRMs. The arrangement allows the bypassing of one IRM and one APRM in each group. In Unit 2 and Unit 3 there are four APRM channels, each receiving input from LPRM detectors covering the entire core. The channels are arranged so that adequate monitoring of the core is maintained with one channel bypassed.

These bypasses are effected by positioning switches in the control room. A light in the control room indicates the bypassed condition.

An automatic bypass of the SRM detector position rod block is effected as the neutron flux increases beyond a preset low level on the SRM instrumentation or when the IRMs are on range 3 or above. The bypass allows the detectors to be partially or completely withdrawn as a reactor startup is continued.

An automatic bypass of the RBM rod block occurs whenever the power level is below a preselected level or whenever a peripheral control rod is selected. Either of these two conditions indicates that local fuel damage is not threatened and the RBM action is not required.

The rod worth minimizer rod block function is automatically bypassed when reactor power increases above a preselected value in the power range. It may be manually bypassed for maintenance at any time. If control rods are to be manipulated while the rod worth minimizer function is manually bypassed, a second licensed operator will be present in order to verify control rod movement.

7.7.4.3.4 Arrangement of Rod Block Trip Channels

The same grouping of neutron monitoring equipment that is used in the Reactor Protection System is also used in the rod block circuitry. One half of the total numbers of APRMs, IRMs, SRMs, and RBMs provides inputs to one of the rod block logic circuits, and the remaining half provides inputs to the other logic circuit. In Unit 1, one recirculation flow converter provides a rod block signal to one logic circuit; the remaining converter provides an input to the other logic circuit. The flow converter comparator provides trip signals to each flow converter trip circuit. In Unit 2 and Unit 3, each APRM receives recirculation loop A and B flow signals from a pair of differential pressure transmitters and calculates total recirculation flow. The APRM provides an alarm and control rod block on recirculation flow upscale conditions. In addition to the arrangement just described, both RBM trip channels (Unit 1) provide input signals into a separate circuit for the "nonannunciating rod block control." Scram discharge volume high water level signals are provided as inputs to both rod block logic circuits. Both rod block logic circuits sense when the high water level scram trip for the scram discharge volume is bypassed. The rod withdrawal block from the rod worth minimizer trip affects a separate circuit that trips the "nonannunciating rod block control." The rod insert block from the rod worth minimizer function prevents energizing the insert bus for both notch insertion and continuous insertion.

The APRM rod block settings are varied as a function of recirculation flow such that the ratio of percent power to percent flow equals 0.61 when both reactor recirculation loops are in operation. The radio is reduced to 0.55 for a unit in single loop operation. The reason for this difference in the rod block settings is that operation in the MELLLA+ domain is prohibited unless a unit has both recirculation loops in service.

Analyses show that the settings selected are sufficient to avoid both Reactor Protection System action and local fuel damage as a result of a single control rod withdrawal error. Mechanical switches in the SRM and IRM detector drive systems provide the position signals used to indicate that a detector is not fully inserted.

Additional detail on all the Neutron Monitoring System trip channels is available in Subsection 7.5, "Neutron Monitoring System." The rod block from scram discharge volume high water level utilizes two nonindicating switches installed on the scram discharge volume.

7.7.4.4 Instrumentation

The operator has three different displays of control rod position:

a. Full rod status display,

b. four rod display, and

c. process computer.

These displays serve the following purposes:

a. Provide the operator with a continuously available, presentation of each control rod's status,

b. Provide continuously available warning of an abnormal condition,

c. Present numerical rod position for each rod, and

d. Log all control rod positions on a routine basis.

The full rod status display is located on the upper vertical section of the reactor control board in the control room. It provides the following continuously available information for each individual rod:

a. Rod position, digital and fully inserted (green),

b. Rod position, digital and fully withdrawn (red),

c. Rod identification (coordinate position, white),

d. Accumulator trouble (amber),

e. Rod scram (blue), and

f. Rod drift (red).

Also dispersed throughout the display in locations representative of the physical location of LPRM strings in the core are LPRM lights as follows:

a. LPRM low flux level (white), and

b. LPRM high flux level (amber).

A separate, smaller display is located just below the large display on the vertical part at the bench board (see Figure 7.7-2). The information presented on this display includes the LPRM values for each of the detector arrays surrounding the rod selected (see Figure 7.7-4). Since each detector array contains four sensors in a vertical column and since there can be a maximum of four detector arrays surrounding a rod, sixteen meters are installed. Four rod position modules are between the LPRM indicators. [On Unit 2, operator display assemblies (ODAs) provide LPRM indications, and the four rod position displays are located below the ODAs.] These four modules will display rod position in two digits and rod selected status (white light, off or on) for the four rods located within the LPRM detector arrays being displayed. The rod position digital range is from 00 to 48, with 00 representing the fully in position, and 48, fully out; each even increment (e.g., 00-02, equals six physical inches of rod movement). The four rod display allows the operator to easily focus his attention on the core volume of concern during rod movements.

Control rod position information is obtained from reed switches in the control rod drive that open or close during rod movement. Reed switches are provided at each three-inch increment of piston travel. Since a notch is six inches, indication is available for each half-notch of rod travel. The reed switches located at the half-notch positions for each rod are used to indicate rod drift. Both a rod selected for movement and the rods not selected for movement are monitored for drift. A drifting rod is indicated by an alarm and red light in the control room. The rod drift condition is also monitored by the process computer.

The status color statements are integrated with the position numeral statement. See Figure 7.7-2.

Reed switches are also provided at locations that are beyond the limits of normal rod movement. If the rod drive piston moves beyond the fully withdrawn position, an alarm is sounded in the control room. The overtravel alarm provides a means to verify that the drive-to-rod coupling is intact, because, with the coupling in its normal condition, the drive cannot be physically withdrawn to the overtravel position. Coupling integrity can be checked by attempting to withdraw the drive to the overtravel position and observing that the overtravel alarm does not annunciate.

The process computer receives position indication from each rod and is capable of displaying and printing control rod position information.

All displays are essentially independent of one another. Signals for the rod status display are hard-wired from the rod position information system cabinet (RPISC) buffer outputs, so that a signal failure of other parts of the RPISC will not affect this display. Likewise, the computer could conceivably fail and the rod status and rod position displays will continue to function normally.

The following control room lights, alarms, and indications are provided to allow the operator to know the conditions of the Control Rod Drive Hydraulic System and the control circuitry:

a. Stabilizing valve selector switch position,

b. Insert bus energized,

c. Withdraw bus energized,

d. Settle bus energized,

e. Withdraw permissive,

f. CRD Notch override emergency in direction,

g. Pressure control valve position,

h. Flow control valve position,

i. Drive water pump low suction pressure (alarm only),

j. Drive water filter high differential pressure (alarm only),

k. Charging water (to accumulator) high pressure (alarm and indication),

l. Control rod drive temperature (alarm only),

m. Scram discharge volume not drained (alarm only), and

n. Scram valve pilot air header low pressure (alarm only).

Additional instrumentation provided for the Reactor Manual Control System is presented in Table 7.7-1. Many of these Reactor Manual Control System indications are displayed on the Main Control Room Panels.

7.7.5 Safety Evaluation

The circuitry described for the Reactor Manual Control System is completely independent of the circuitry controlling the scram valves. This separation of the scram and normal rod control functions prevents failures in the reactor manual control circuitry from affecting the scram circuitry. The scram circuitry is discussed in Subsection 7.2. Because each control rod is controlled as an individual unit, a failure that results in energizing of any of the insert or withdraw solenoid valves can affect only one control rod. The effectiveness of a reactor scram is not impaired by the malfunctioning of any one control rod. It can be concluded that no single failure in the Reactor Manual Control System can result in the prevention of a reactor scram, and that repair, adjustment, or maintenance of reactor Manual Control System components does not affect the scram circuitry. This meets safety design bases 1 and 2.

The rod block monitor limits local power spikes due to rod withdrawal. This meets safety design basis 3. The logic and instrumentation used in the reactor manual control system is designed to prevent rod movement in the event that one channel of a required protective function becomes inoperable. This meets safety design basis 4.

7.7.6 Inspection and Testing

The Reactor Manual Control System can be routinely checked for proper operation by manipulating control rods using the various methods of control. Detailed testing and calibration can be performed by using standard test and calibration procedures for the various components of the reactor manual control circuitry.