GENERAL ELECTRIC

NUCLEAR ENERGY
ENGINEERING
DIVISION

GENERAL ELECTRIC COMPANY, P.O. BOX 460, PLEASANTON, CALIFORNIA 94566

August 14, 1980

Mr. Darrell G. Eisenhut, Director
Division of Project Management
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: Reliability and Response Action Time For The General Electric Test Reactor (GETR) Scram System - License TR-1 - Docket 50-70

Dear Mr. Eisenhut:

Attached are responses to questions raised in a meeting on July 30, 1980 with members of the NRC staff.

Included is a discussion of the reliability of the General Electric Test Reactor scram circuitry. This equipment is redundant, fails safe upon the loss of power, is frequently tested, and has an excellent record of performance.

Also enclosed are the data which show that the scram action time is in advance of consequential accelerations due to seismic events.

Very truly yours,

R. W. Darmitzel

R. W. Darmitzel, Manager
Irradiation Processing Operation

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attachments

AFFIRMATION

The General Electric Company hereby submits the following information:

(1) Discussion on the Reliability of the Scram Circuitry

(2) Discussion on How the Scram System Operates in Time to Complete the Necessary Scram Action Before Consequential Accelerations are Reached

To the best of my knowledge and belief, the information contained herein is accurate.

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R. W. Darmitzel, Manager
Irradiation Processing Operation

Submitted and sworn before me this 14th day of August, 1980,

Virginia C Casquero, Notary Public in and for the County of Alameda, State of California.

Comment 1: Discuss the reliability of the scram circuitry.

The system requirement for safe shutdown of the reactor for a large seismic event is to scram the reactor and open the emergency cooling automatic valves and the Fuel Flooding System admission valves. The reactor seismic shutdown (scram) is initiated by pendulum switches set to trip at a level of about a Modified Mercali IV (0.01g-0.03g). This scram of the reactor and opening of the necessary valves is accomplished in a short enough time to be in advance of significant earthquake-produced motions. (See response to Comment 2.) Analysis has shown the control rods will stay in the core; and tests have been performed that demonstrate the required valves will remain open through the maximum postulated seismic event. The scram and valve opening circuitry, therefore, are needed prior to significant earthquake motions, but not during or after the maximum postulated seismic event.

Reliability of the scram and valve opening circuitry will be discussed in the context of redundancy, power loss, historical experience and the frequent system and component tests that are performed. These will be discussed in turn in the following sections; the system is described first as an aid in the discussion.

A. Description

The GETR scram circuitry is described in the GETR Safety Analysis Report (submitted August 24, 1977), and the pertinent parts of that document are attached as Appendix A for convenience. Scram of the GETR control rods is produced by interruption of control rod latch magnet current.

The block diagram for this system that includes the sensor that produces a scram for seismic events is shown in Figure 1. The scram system is actuated by either one of two pendulum-type seismic switches. Each switch actuates when the pendulum moves 0.71 mm in any horizontal direction, which corresponds to about a Modified Mercali IV value (0.01g-0.03g). When actuated, each switch sends a signal to separate thyratron tubes, each of which drives separate relays. These relays drive the seismic relays (latching). In turn, each seismic relay (latching) sends two scram signals to the process scram logic and to each of two separated, redundant Fuel Flooding System control units. The process scram logic consists of process relay contacts connected in one out of two (or two of three) configurations. The associated relays are energized during normal operation. A seismic trip will de-energize relays 3-1 and 3-2. These relays send signals to the three reactor protection system logic elements, and to the relay scram logic as shown. The relay scram logic system directly interrupts the control rod magnet circuit and sends a scram signal to the protection system logic elements. The logic elements trip their associated power switches when any one of the three input signals calls for a scram. When any two of three power switches indicate a scram, the magnet circuit is interrupted. Thus, control rod latch magnet current is interrupted either directly via the relay scram logic system or by action of the logic elements and power switches.

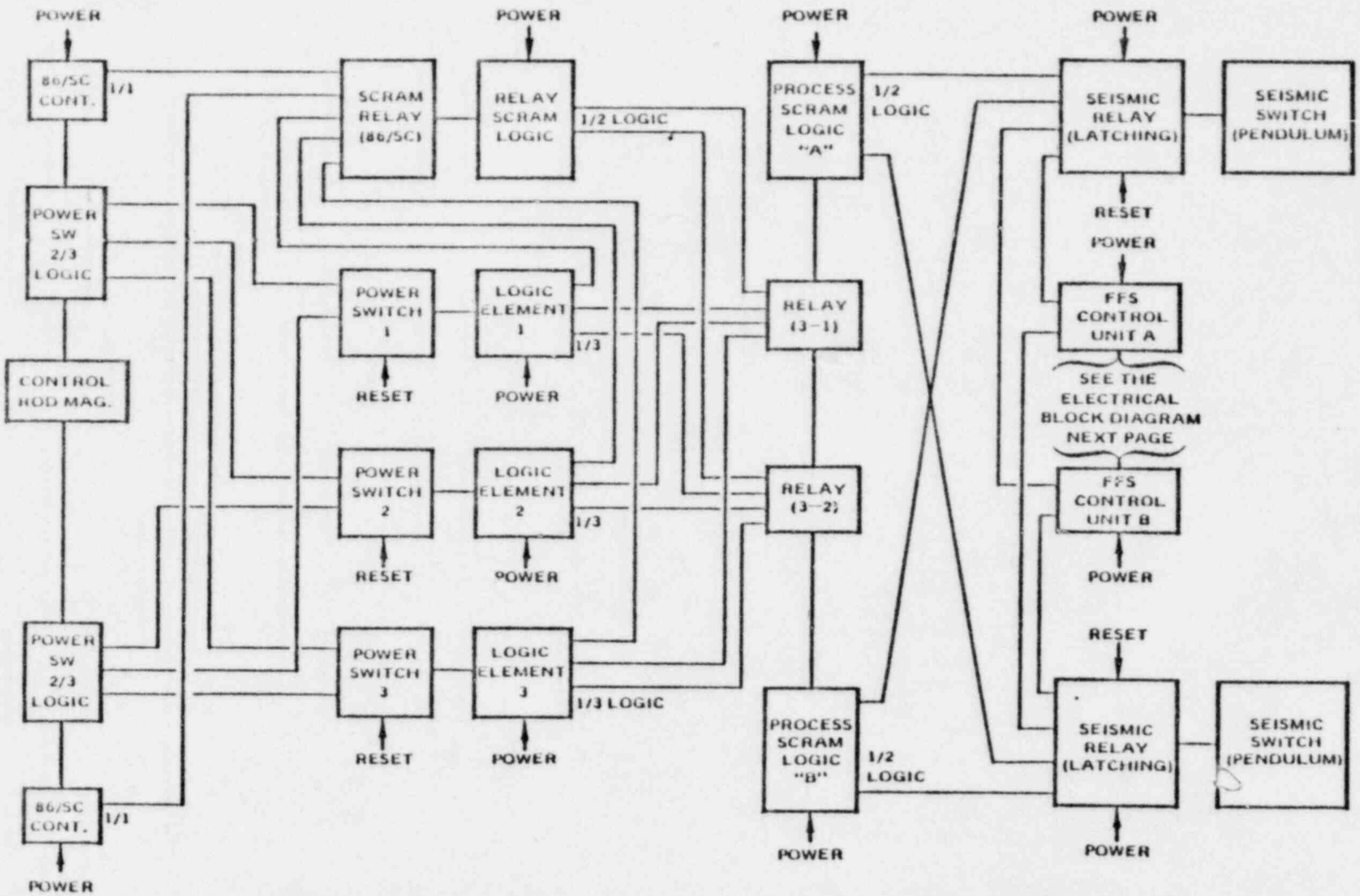

FIGURE 1. MODIFIED SEISMIC SYSTEM BLOCK DIAGRAM

A. Description - continued

A scram signal from the seismic relay (latching) causes the Fuel Flooding System (FFS) control units to trip and in turn send signals to open each of two redundant FFS admission valves, the emergency cooling automatic valves, and to operate the pressurizer isolation valve and nitrogen supply valve (see Figure 2). The control units lock in the trip condition until individually manually reset. Both control units are protected by fuses to fail safe in the event of excessive electrical load anywhere in the system. The actuation system is designed to fail safe on loss of power.

Each FFS admission valve is supplied service air pressure through a three-port, solenoid-operated valve as shown in Figure 3. When the solenoid-operated valves are energized, air pressure is supplied to the admission valve operators to shut the valves against spring pressure. If electrical power is removed from a solenoid-operated valve, it will reposition to vent air pressure from the admission valve operator allowing the admission valve to open by spring pressure. The actuation system is fail safe on loss of air pressure. The emergency cooling automatic valves and the pressurizer valves are also controlled by solenoid-operated valves and fail safe on loss of air pressure.

The safety system power busses are alternating current, ungrounded, with ground detectors indicated on the control console in the control room.

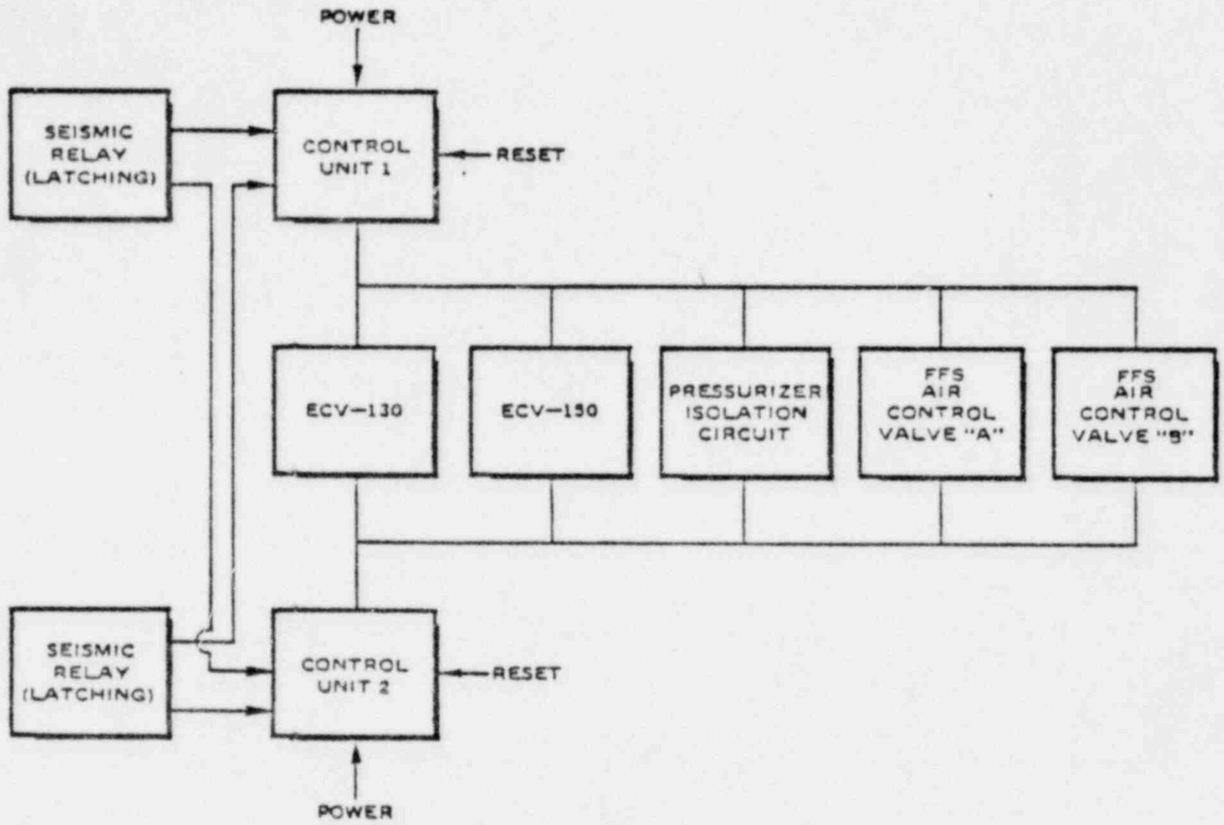

FIGURE 2. ELECTRICAL BLOCK DIAGRAM

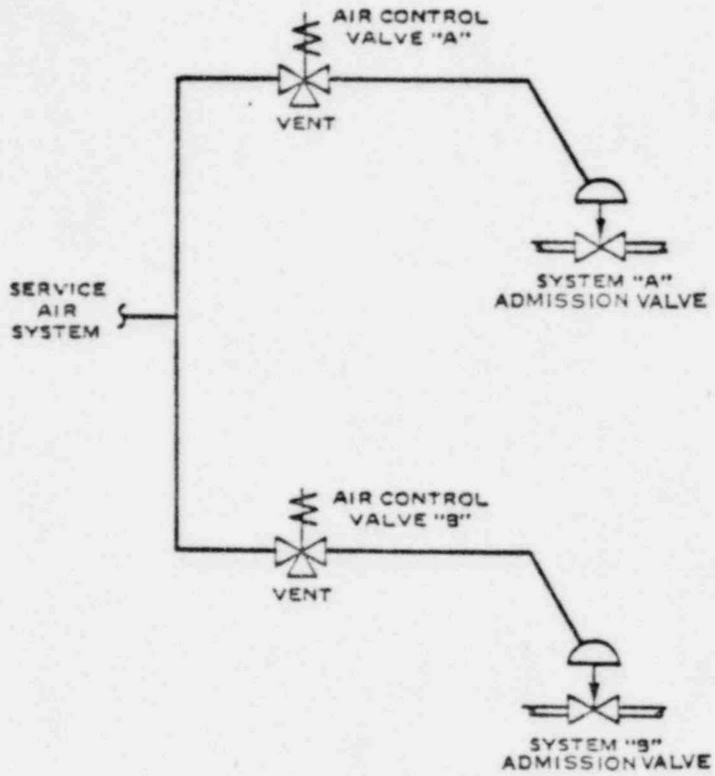

FIGURE 3. AIR CONTROL CIRCUIT
(For the fuel flooding system water admission valves.)

B. <u>History</u>

A brief examination of the historical record was made to determine the number of operations of the GETR scram system and certain of the sensors (seismic switch) which cause scram.

A single cycle (a cycle is of five weeks average duration) review was made to determine the split between the number of process scrams and those produced by the nuclear instrumentation. For example, the 86/SC relays operate only for process sensor scrams, and the power switches and logic units operate on all scrams. A more comprehensive review of twenty-one cycles was made for the approximate two-year period before October, 1977. It was in this review that the process scram system or representative portions of it were made to function 1,791 times. Extrapolating these data to the full 18 years of GETR operation, much of the process scram system (specific components are noted in Section C) was operated as many as 14,000 times. The seismic switches were not tested as frequently (approximately 180 times in 18 years) but have operated properly on all occasions when required. It should be noted that the logic elements and power switches were installed and operated for 11 years before October, 1977, and are estimated to have operated 8,500 times based on the above information.

The scram system has operated properly for all the occasions (test and actual) in which a reactor scram was required.

C. <u>Redundancy and Fail Safe on Loss of Power</u>

Subsystems contained in the seismic scram and emergency cooling trip system and fuel flooding system are:

1. Power Switch
2. 86/SC (Relay Scram)
3. Logic Element
4. Process Scram Logic
5. Seismic Amp and Follower Relay Seismic Relay (Latching)
6. Seismic Switch
7. FFS Control Unit

All the above systems and subsystems except the FFS control unit, which is new, have been repeatedly tested or otherwise made to function over the 18 years of operation of the General Electric Test Reactor (the logic elements and power switches have been installed 11 years); and not one failure to operate or place the reactor in a safe condition has been observed. The character of the redundancy and fail safe nature of these subsystems are discussed below.

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C. Redundancy and Fail Safe on Loss of Power - continued

1. Power Switch

There are three separate, identical redundant power switches whose output contacts are connected in a two-out-of-three twice configuration. The control rods will scram on loss of power to any two of the three power switches because the relay contacts within the power switch open on loss of power. This places the reactor in a safe condition in the event of a seismic occurrence. These three power switches each have been operated more than 8,500 times over the past 11 years, and there has not been one unsafe failure. The power switches are in the control room under the surveillance of the reactor operator.

2. 86/SC (Scram Relay)

There are two separate, identical redundant scram relays (86/SC). Their output contacts are connected in a one-out-of-two configuration. The control rods will scram on loss of power to either of the scram relays because the contacts open on loss of power. The 86/SC relays are in the control room under the surveillance of the reactor operator. The two scram relays have been operated more than 11,500 times over the past 18 years, and there has not been one unsafe failure.

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C. Redundancy and Fail Safe on Loss of Power - continued

3. Logic Element

There are three separate, identical redundant logic elements. Loss of power to any two of the three logic elements will cause the scram of the control rods because the input power is coupled through the logic element (i.e., if there is no input voltage, there is no output voltage to the power switch). This then places the reactor in a safe condition. The logic elements are in the control room under the surveillance of the reactor operator. The three logic elements have been operated at least 8,500 times over the last 11 years. There has not been even one unsafe failure.

4. Process Scram Logic

There are two separate, identical redundant process scram logic blocks and associated relays. Loss of power to the process scram logic will cause the control rods to scram because the relay contacts open on loss of power. This places the reactor in a safe condition. Process scram relays are in the control room under the surveillance of the reactor operator. The process scram logic and relays have been operated more than 11,500 times over the last 18 years of operation. There has not been one unsafe failure.

C. Redundancy and Fail Safe on Loss of Power - continued

5. Seismic Relay (Latching)

There are two separate, identical redundant seismic relay (latching) subsystems. Loss of power to either one of the seismic relays will cause the control rods to scram because the relay contacts open on loss of power, the depressurization of the reactor, and the initiation of the Fuel Flooding System. This reaction would place the reactor in a safe position. Both of the two seismic switches have been tested more than 192 times and have been operational for 18 years, and there has not been even one unsafe failure.

6. Seismic Switch

There are two separate, identical redundant seismic switches. There is no power to the passive seismic switch. Both of the two seismic switches have been tested at least 192 times and have operated for the past 18 years, and there has not been one failure.

7. FFS Control Unit

There are two separate, identical redundant control units. Loss of electrical power to only the control unit would cause reactor depressurization and scram and the initiation of fuel flooding. The two redundant control units are new. They each contain only one relay. It has been seismically qualified and has a mean time between failure of 1×10^6 hours, a reliability adequate for the GETR safety system.

D. <u>Surveillance of Equipment Needed for Safe Shutdown of the GETR</u>

If a large seismic event were to occur, the safe shutdown of the GETR requires the following reactor systems:

1. Seismic Scram and Emergency Cooling Trip System
2. Reactor Control Rods
3. Fuel Flooding System

Surveillance testing associated with these systems is described below.

1. <u>Seismic Scram and Emergency Cooling Trip System</u>

The reactor seismic scram and emergency cooling trip system consists of the sensors and circuitry to detect a seismic event and to initiate 1) a rapid shutdown and depressurization of the reactor, and 2) opening of the Fuel Flooding System admission valves.

In-service surveillance of the reactor seismic scram and cooling trip system consists of the following:

a. The seismic sensors are each functionally tested prior to every reactor cycle startup (average 5 weeks). The test consicts of manually tripping the sensor and verifying loss of control rod magnet power, opening of the Fuel Flooding System admission valves and the emergency cooling automatic valves, and closure of the required pressurizer valves. This test is performed with alternate halves of the redundant circuit in bypass each time. Redundant circuit components, therefore, are checked every other cycle.

D. Surveillance of Equipment Needed for Safe Shutdown of the GETR

1. Seismic Scram and Emergency Cooling Trip System - continued

b. The scram circuit is activated by numerous sensors besides the seismic switches. Testing of the scram circuitry which involves tripping any sensor and verifying control rod(s) drop or loss of control rod magnet current (in the event the control rods are not raised) is performed as a minimum as follows:

(1) Each reactor scheduled cycle or midcycle shutdown the control rods are scrammed after manually driving the rods to 12 inches.

(2) Each reactor startup for low power testing, the scram circuitry is tested eight times.

(3) Each startup following a midcycle refueling outage, the scram circuitry is tested approximately 16 times. These tests are performed with half of the redundant circuit bypassed.

(4) Each startup following a cycle refueling outage, the scram circuitry is tested approximately 33 times. These tests are performed with half of the redundant circuit bypassed.

(5) Approximately 20 actual scrams per year can be expected.

c. The seismic sensors are calibrated annually.

d. The emergency cooling automatic valves provide rapid depressurization of the primary system. In-service surveillance consists of a functional test every reactor shutdown. The valves are verified to open when the primary pump is shut down. Prior to each cold reactor startup, the valves are tested by tripping open five times each.

D. Surveillance of Equipment Needed for Safe Shutdown of the GETR

1. Seismic Scram and Emergency Cooling Trip System - continued

e. The primary pressurizer safety related valves include the valve which isolates the pressurizer from the primary system and the valve which isolates the nitrogen supply from the pressurizer. In-service surveillance of these safety-related valves consists of a functional test as described in paragraph 1.d. above, and an annual leak test of the primary isolation valve.

f. The emergency cooling check valves open the primary system to the pool and provide the inlet path for makeup water from the Fuel Flooding System. In-service surveillance consists of testing the check valve disc assembly for freedom of motion and measuring the amount of disc travel. These tests are performed prior to every reactor cold startup.

2. Control Rods

The control rods assure rapid shutdown of the reactor. In-service surveillance of the control rods consists of the following tests and checks prior to every reactor cold startup:

a. Rod scram checks are performed where each control rod is raised one at a time and scrammed by tripping a different scram sensor for each rod.

b. A latch integrity test is performed to verify the three control rod components are properly latched. After the control rod components are installed and engaged to the drive, an upward vertical force is applied which exceeds the weight of the components. Improperly latched components will separate.

D. Surveillance of Equipment Needed for Safe Shutdown of the GETR

2. Control Rods - continued

c. Visual inspections of control rod components are performed at the following frequencies:

(1) Poison sections each time the poison section is removed from the core.

(2) Fuel followers prior to initial installation.

(3) Shock sections and guide tubes at least once every 15 months.

(4) All components when removed from the pressure vessel.

(5) Accessible parts of the control rod drives by mechanical technicians quarterly.

(6) The water retaining boundary of the control rod drive is inspected prior to every reactor cycle startup.

d. Drop times for each control rod are measured and recorded after replacement, disassembly or maintenance on any control rod component or the control rod drive or at least once per operating cycle. Drop times are measured both with and without the primary system pressurized and water circulating.

e. Preventive maintenance is performed on each control rod drive unit at least every 15 months. Preventive maintenance involves disassembly, inspection and rebuilding of the drive by a qualified technician.

f. The control rod bank reactivity worth is routinely checked at least annually.

D. Surveillance of Equipment Needed for Safe Shutdown of the GETR - continued

3. Fuel Flooding System

The Fuel Flooding System assures a long-term supply of cooling water to irradiated fuel at the GETR. The surveillance program for the Fuel Flooding System (FFS) components consists of the following tests and inspections.

a. Continuous In-Service Surveillance

Continuous in-service surveillance of the FFS will consist of the following:

(1) Monitoring admission valve position. The admission valve position, in conjunction with the periodic tests performed, will indicate whether or not water is flowing in the system.

(2) Monitoring reservoir water level. Monitoring the reservoir level will assure an adequate supply of water is maintained. If the water level should drop below the minimum allowable level, an alarm will activate and immediate action will be initiated to refill the low reservoir.

(3) Monitoring critical point temperatures. Monitoring the water temperature at critical points in the system will assure the system water does not freeze sufficiently to reduce system flow. Temperatures below the freezing point of water are rarely attained and never sustained. Nevertheless, the FFS will utilize insulation (possibly heat tape) and the relative shallow ground frost line to assure that ice formation in the system will not inhibit water flow. Monitoring water temperature, however, will allow corrective action, such as turning on heaters or

D. Surveillance of Equipment Needed for Safe Shutdown of the GETR

3. Fuel Flooding System

a. Continuous In-Service Surveillance - continued

....initiating water flow, in the event that water temperatures approach freezing.

(4) Monitoring heat tape. The FFS piping outside of the containment building and above ground may be heated with heat tape to additionally prevent system water freezing. The status of the heat tape, if used, will be monitored so that immediate action may be initiated to remedy a malfunction.

b. Periodic In-Service Surveillance

Periodic in-service surveillance of the FFS will consist of the following:

(1) Instrument and Control Test. The instrument and control portion of the FFS will be functionally tested on an approximate annual frequency. This test will check the system from the seismic switch input to the activation of the admission valves. This test will also check the operability of the continuous surveillance instrumentation, any interlocks in the FFS and all redundant components.

(2) Instrument and Control Calibration. Level and thermal (if used) switches will be calibrated on an approximate annual frequency.

(3) Water Flow. System water flow will be measured on an approximate annual frequency. Water flow will be verified to be within acceptable limits.

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D. Surveillance of Equipment Needed for Safe Shutdown of the GETR

3. Fuel Flooding System

b. Periodic In-Service Surveillance - continued

(4) Water Quality. The reservoirs will be filled with filtered potable water. Water samples will be analyzed periodically for water quality.

(5) Admission Valve. Each admission valve will be functionally tested at least once every reactor operating cycle (average five weeks) and visually inspected for proper operation and anomalous conditions.

(6) Siphon Breaker. Each siphon breaker device will be functionally tested on an approximate annual frequency.

(7) Automatic Valve Preventive Maintenance. The FFS automatic valves will be rebuilt on a 10-year frequency.

(8) Reservoir Water Sample. Reservoir water samples will be analyzed when the tanks are initially filled, one month after filling, six months after filling, and annually thereafter. Acceptance criteria is not yet established but will be based on trends rather than quantitative criteria.

(9) System Visual Inspection. During the flow test described in (3) above, the FFS line will be visually inspected for leaks from the automatic valve to the pool and canal. The FFS lines in the reactor pool will be visually inspected for good condition as part of the Supervisor's Final Core and Pool Inspection Checklist. This inspection will be performed before every reactor cold startup.

D. Surveillance of Equipment Needed for Safe Shutdown of the GETR

3. Fuel Flooding System

b. Periodic In-Service Surveillance - continued

A monthly visual inspection will be performed on the rest of the FFS. The inspection will include general condition, proper connections, water leakage, and other anomalous conditions which could potentially affect the system. Areas to be inspected include the reservoirs, reservoir end walls, reservoir hoses and valve pit, level instrumentation, hose trench, containment building valve panel, penetration, pipe line to the pool and canal, anti-siphon valve, throttle valves and shutoff valves.

(10) Standpipe Pneumatic Test. The reactor emergency cooling valve standpipes will be capped biennially and pneumatically pressure tested with the reactor emergency cooling valves closed. This test assures that the standpipes do not leak and primary water will be maintained above the core in the unlikely event that the pool were to be drained.

(11) Standpipe Inspection. The standpipes and connected FFS hose in the pool will be visually inspected annually to verify good condition and proper connections.

(12) Sample sections of Fuel Flooding System supply line hose will be buried in a similar manner as the supply line. These samples will be inspected annually and tested biennially. The test will be performed by an independent testing laboratory and will consist of pressurizing the hose to the design pressure and applying an axial load until a leak develops which causes the internal pressure

D. Surveillance of Equipment Needed for Safe Shutdown of the GETR

3. Fuel Flooding System

b. Periodic In-Service Surveillance - continued

....to decay. Acceptance criteria have not been established but will be based on the load required to pull the hose out of the trench. Previous tests demonstrate that the axial failure load (i.e., load which causes onset of leakage) exceeds a five meter pull-out load by a factor of six.

(13) Sample sections of the water reservoir material will be exposed to the same environmental conditions as the reservoirs. These samples will be inspected and tested for tensile strength annually. Acceptance criteria have not been established but will be based on the stresses in the reservoirs experienced during the postulated seismic event. It has been determined that the tensile strength exceeds the postulated seismic event stresses by more than a factor of three.

(14) It is anticipated that existing unused pipe penetrations through the containment building will be used for the FFS lines. This FFS pipe-containment building barrier interface will be tested periodically as part of the annual containment building leak test.

(15) Written procedures will be prepared for 1) operator response to abnormal conditions as indicated by continuous in-service surveillance instrumentation, and 2) all tests, checks, inspections and corrective or preventive maintenance. All written procedures will receive appropriate review and approval as required by the GETR SAR and Technical Specifications.

E. Conclusions

A majority of the GETR scram circuitry (excluding only the sensors and interconnecting wiring) is in a small control room, manned continuously by a reactor operator. Abnormal conditions, such as fire, are readily detected and actions quickly taken to place the reactor in a safe condition or control the fire. Physical damage would be necessary to short redundant channels; and not only is this also observable by the reactor operator but also likely to produce a scram since any of a number of relay openings will interrupt control rod magnet power.

The scram circuitry consists of separate, redundant units which fail safe on the loss of power. This is also true of the emergency cooling automatic valves and the Fuel Flooding System control units and admission valves.

The scram circuitry has been repeatedly tested or otherwise made to function over the 18 years of operation of the General Electric Test Reactor, and not one failure to operate has been observed. The protracted record of successful operation of this system demonstrates in a unique way its outstanding reliability.

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APPENDIX A

REACTOR SCRAM SYSTEM

(From GETR Safety Analysis Report, NEDO-12622) pump on the portable mix tank cart pumps the resin slurry to the demineralizer. Resin transfer valves RST-171, -164, -165, -166, -129, and -915 are automatic isolation valves described in Section 4.2.5. System demineralizers are described elsewhere in Section 4.7. Tank 114 is an 1800 gal capacity painted carbon steel tank rated at 50 psig at 150°F.

After radioactive decay in tank 114, the resins may be flushed to containers for radioactive waste disposal. Flushing resins from tank 114 is performed by pressurizing the tank with air to force the resin and water slurry through a pipe to the loading station. Resins are loaded into sealed 55 gal drums or larger containers capable of being placed in a cask. Water is decanted at the loading station. A permanent radiation monitor is located at the loading station with a local and control room alarm. Resins from the tank farm demineralizers do not contain significant radioactivity and may be flushed directly from the demineralizer to the loading station.

4.8 INSTRUMENTATION AND ELECTRICAL SYSTEMS

4.8.1 Reactor Scram System

4.8.1.1 General Introductory Description

The instruments in the reactor scram system cause automatic loss of power to the scram magnets which allows the insertion of the six control rods and shutdown of the reactor if pre-established limits are exceeded on pre-determined parameters. Any one of the six control rods contains sufficient negative reactivity to shut down the critical reactor if the rod is inserted. A loss of power to any one of the six magnets is sufficient to shut down the reactor.

The scram system is separated into six parts; each part will be described in the following sections. The six parts fit together to make up the scram system as shown in Figure 4–80. The parts or individual systems comprising the scram system monitor selected parameters pertinent to safe reactor or experiment operation, such as, reactor flux level and primary coolant flow. There is a pre-determined trip level on each of the selected parameters. The trips are monitored by the scram actuator (which includes logic elements, power switch, and the magnet power supply). The logic element determines whether a scram is warranted.

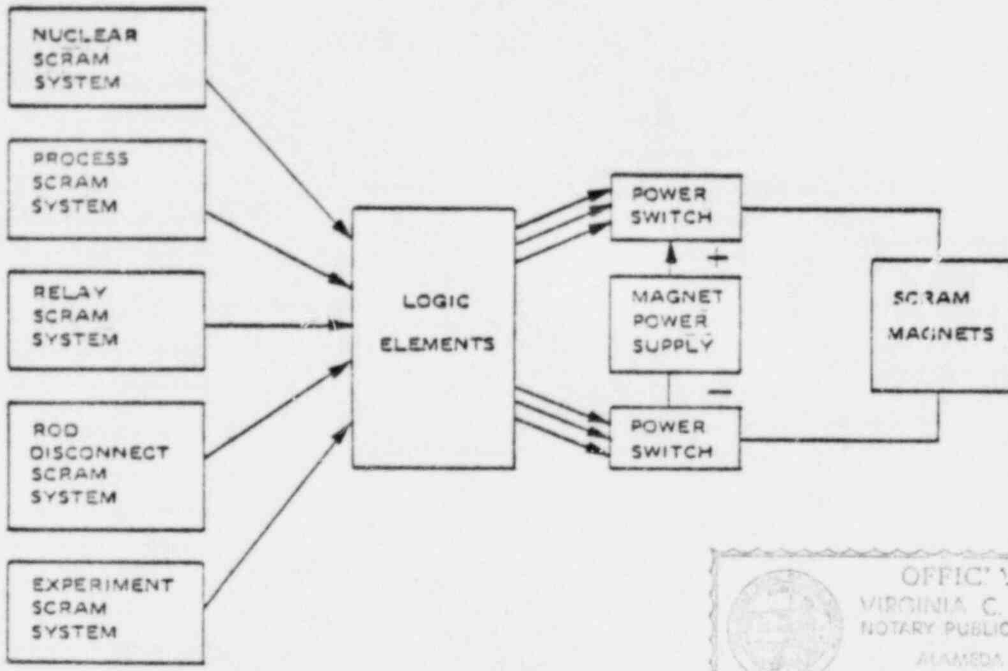


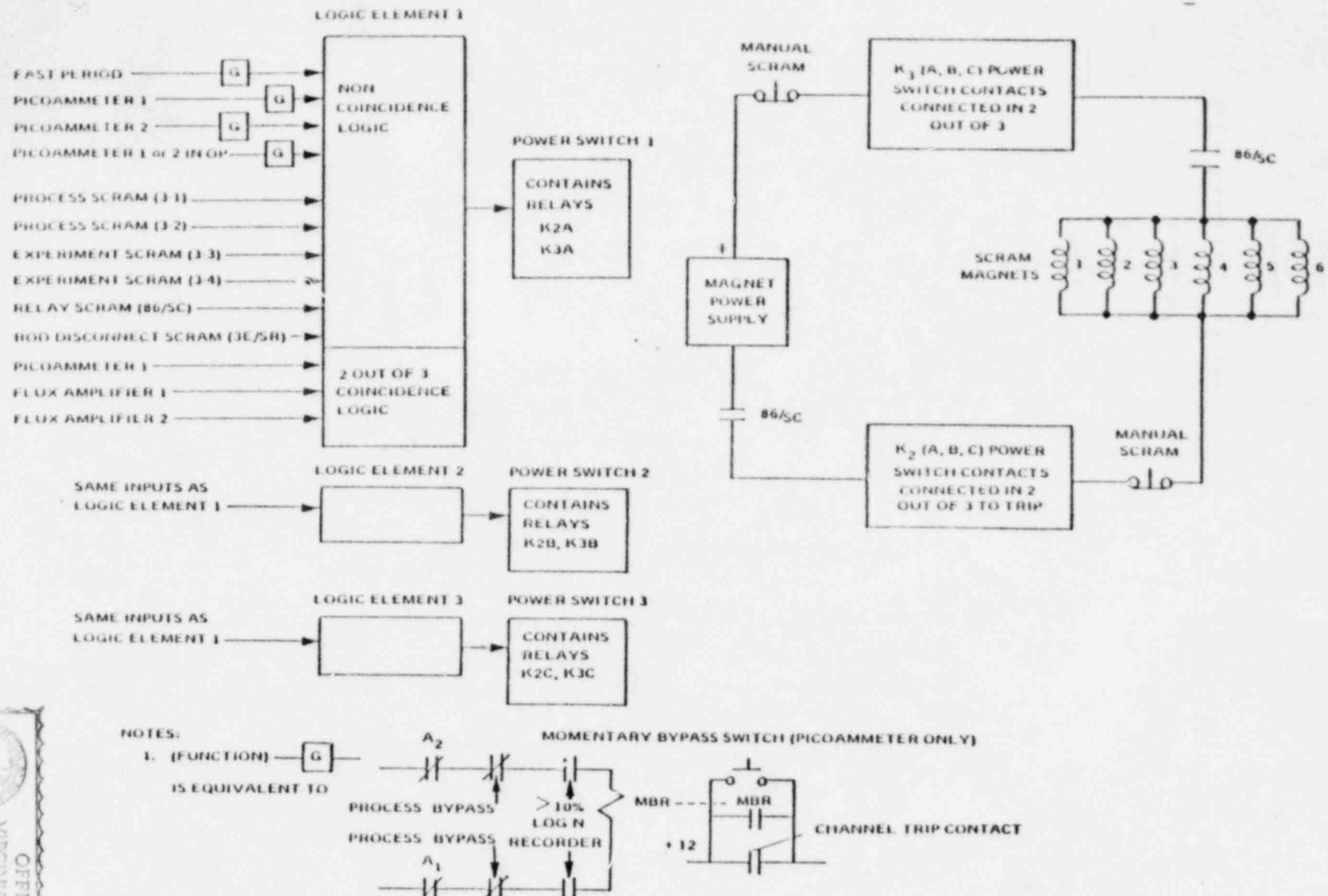
FIGURE 4–80. FUNCTIONAL BLOCK DIAGRAM OF SCRAM SYSTEM

The control rods are held out of the core by the power that is applied to the scram magnets through the power switches. If a scram is called by the logic elements, the power switches de-energize, remove power from the scram magnets and cause the rods to drop into the core and shut down the reactor.

4.8.1.2 Scram Actuator including Control Logic

The scram actuator (Figure 4–81) consists of three logic elements, three power switches, a bypass circuit, a magnet power supply, and six scram magnets. The inputs to the three logic elements are the nuclear instrument scram system, process scram system, experiment scram system, relay scram system, and the rod disconnect scram system.

Twelve volts on the input to the logic element is required to satisfy the nontrip condition, so on those input lines with G boxes, either a no-trip signal on the channel or an energized MBR relay or a channel bypass will put 12 V on that channel's input to the logic element to satisfy the nontrip condition. Any noncoincidence input to the logic element not being a nominal 12 V (actually 6 ± 1.5 is the trip point) constitutes a tripped logic element. Any 2-out-of-3 inputs to the coincidence input to the logic element, not being a nominal 12 V also satisfies the requirements to trip the logic element. A tripped logic element l



2. A_1 A_2 ARE THE PICOAMMETER RANGE SWITCHES. SWITCH CONTACTS ARE OPEN $\leq 10^{-3}$ RANGE.
3. PROCESS BYPASS SWITCH CONTACTS ARE CLOSED IN THE NORMAL POSITION – OPEN IN BYPASS.
4. THE 10% POWER (LOG N RECORDER) SWITCH CONTACTS ARE CLOSED > 10% REACTOR POWER.
5. THE MAIN BYPASS RELAY IS ENERGIZED – BYPASSING THE LOGIC ELEMENT INPUT WHEN THE SWITCH CONTACTS IN 2, 3, 4 ARE ALL CLOSED.

FIGURE 4-81. SCRAM ACTUATOR BLOCK DIAGRAM will de-energize power switch 1; also, a tripped logic element 2 will de-energize power switch 2, and a tripped logic element 3 will de-energize power switch 3. The contacts of the power switches are connected in a 2-out-of-3 logic configuration twice. The K2 relay contacts connected in a 2-out-of-3 logic configuration are connected between one side of the power supply and the scram magnets; the K3 relay contacts are connected in a 2-out-of-3 logic configuration connected between the other side of the magnet power supply and the scram magnet coils. The power switches are then in the redundant logic configuration of 2-out-of-3 twice, or in other words if any two of the three power switches de-energizes or the magnet power supply fails, the scram magnet coils will de-energize, the rods will drop into the core and scram the reactor.

The three logic elements and their associated power supplies within the logic element block (Figure 4-30) are:

1. *Logic Elements.* The logic element performs coincidence and noncoincidence logic functions on input signals. The logic element can accommodate six signals (two sets of three) as coincidence logic inputs, and 12 signals as noncoincidence logic inputs. Normal input levels are 12 V nominal.

   Depending on the input signal levels, the logic element provides either a 16 Vdc or less than 1 V output. For the output level to be 16 V, all the noncoincidence logic inputs, and at least two out of each set of three coincidence inputs, must be greater than 6 V. If any one of the noncoincidence, or any two in the same set of coincidence input levels, drops to less than 6 V, the output signal drops to less than 1 V. An external power supply is used to supply 24 Vdc operating voltage to the logic element. The output signal of the logic element is used to control a power switch, which, in turn, controls current to the control rod magnets.

   The logic element is composed of two noncoincidence logic boards, two coincidence logic boards, and an auxiliary component board. The five circuit boards are interconnected (Figure 4-32).

   Nine input signals are applied to noncoincidence logic board A, and three input signals are applied to noncoincidence logic board B. Six input signals from the coincidence logic boards are also applied to noncoincidence logic board B. The coincidence logic boards each receive three input signals.

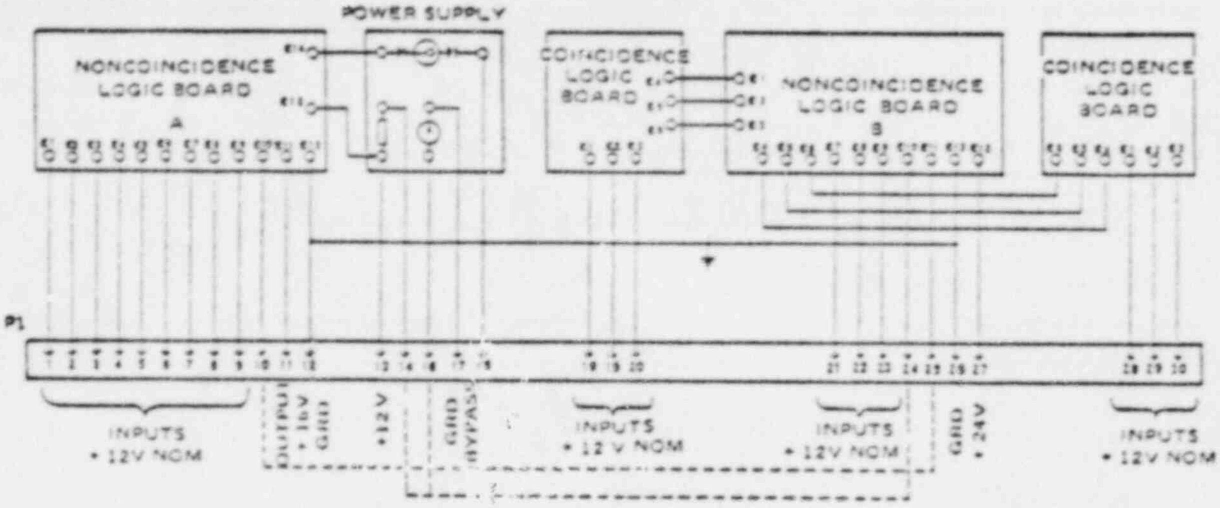
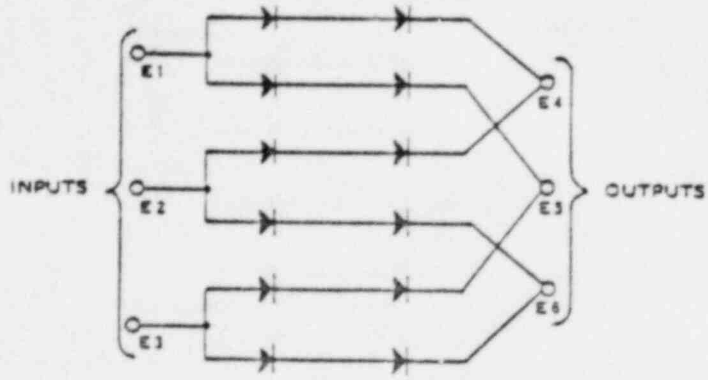


FIGURE 4–82. LOGIC ELEMENT, ELEMENTARY DIAGRAM

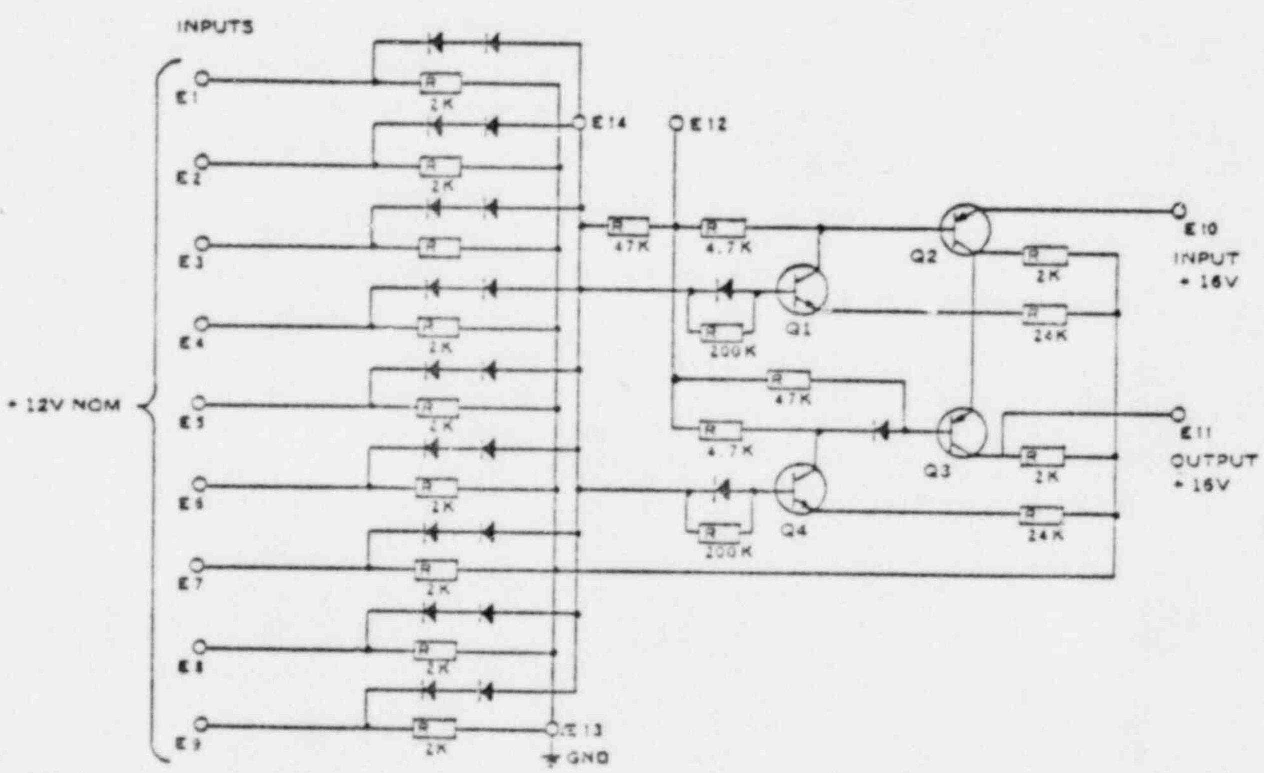
2. *Noncoincidence Logic Circuit.* The noncoincidence logic circuit (Figure 4–83) is designed for fail-safe operation. Any failure or malfunction will cause the output voltage to drop to less than 1 V (safe condition) rather than allow continued operation with 16–V output (potentially unsafe condition). The decrease in voltage is accomplished by the designed redundancy of circuit operation. The safety and redundancy features of the circuit include:

   a. Series input diodes for each input line.
   b. Duplicate operation by transistors Q1 and Q4.
   c. Series output transistors Q2 and Q3. An additional safety feature in the output circuit is provided by diode CR20. The diode prevents high voltage from being applied to the output in the event of a base-collector short in Transistor Q3.

3. *Coincidence Logic Circuit.* The coincidence logic board contains a 2-out-of-3 circuit (also shown in Figure 4–83). Positive input levels are applied to terminals E1, E2, and E3, and passed through diodes to output terminals E4, E5, and E6. The diodes are cross-connected so each output terminal can receive voltage from two different input terminals. Therefore, if only one input level drops to zero, all three outputs will remain at the positive level. When any two input levels drop to zero, the level at the corresponding output terminal also will drop to zero.



COINCIDENCE LOGIC CIRCUIT DIAGRAM



NONCOINCIDENCE LOGIC CIRCUIT DIAGRAM

FIGURE 4–83. LOGIC CIRCUIT DIAGRAMS

4. *Logic Element Power Supply.* An external power supply furnishes a regulated output of 24 Vdc at a maximum load of 1 A. This voltage is internally regulated to 16 V providing internal power for the logic element and a 16–V output signal to the power switch.

The three power switches within the two blocks (Figure 4–80) are:

1. *Power Switches.* A power switch is a relay-switching unit used in the reactor scram system. A 16–V input signal, which is supplied from the coincidence and noncoincidence logic circuit, provides the primary drive for the power switch. When the input signal is present, two switching relays are energized; when the input signal is less than 1 V, the relays are de-energized. The two relays provide four normally open, and four normally closed contacts through which voltage can be applied, or blocked, to control various functions in the reactor scram system. During normal reactor operation, the relays are energized.

2. *Principle of Operation.* The power switch is normally connected in the reactor scram system with a 16–V input signal applied to connector P1–1 (Figure 4–84). This 16–V signal is indicative of proper operation of various reactor functions which control the power switch. Thus, normally, relays K2 and K3 are held energized by the 16–V input; voltage from P1–1 is applied directly to the coil of K2, and through diode CR1 and resistor R2 to the coil of K3. External signals can be passed through normally-open contacts, or blocked from passing through normally-closed contacts of K2 and K3.

   If an abnormal reactor condition causes the input voltage to drop to less than 1 V, relays K2 and K3 immediately de-energize and cause the relay contacts to return to the de-energized position. Signals that are passed through closed contacts during normal reactor operation are now blocked, and blocked signals are passed.

   Upon restoration of the 16–V input signal, or during initial application of signal, relay K2 immediately energizes and capacitor C1 charges to 16 V through the path provided by resistor R1 and the normally closed contacts of K1. However, relay K3 is prevented from energizing by the voltage drop across R2. To energize K3, RESET switch S1 must be depressed. This action first energizes K1

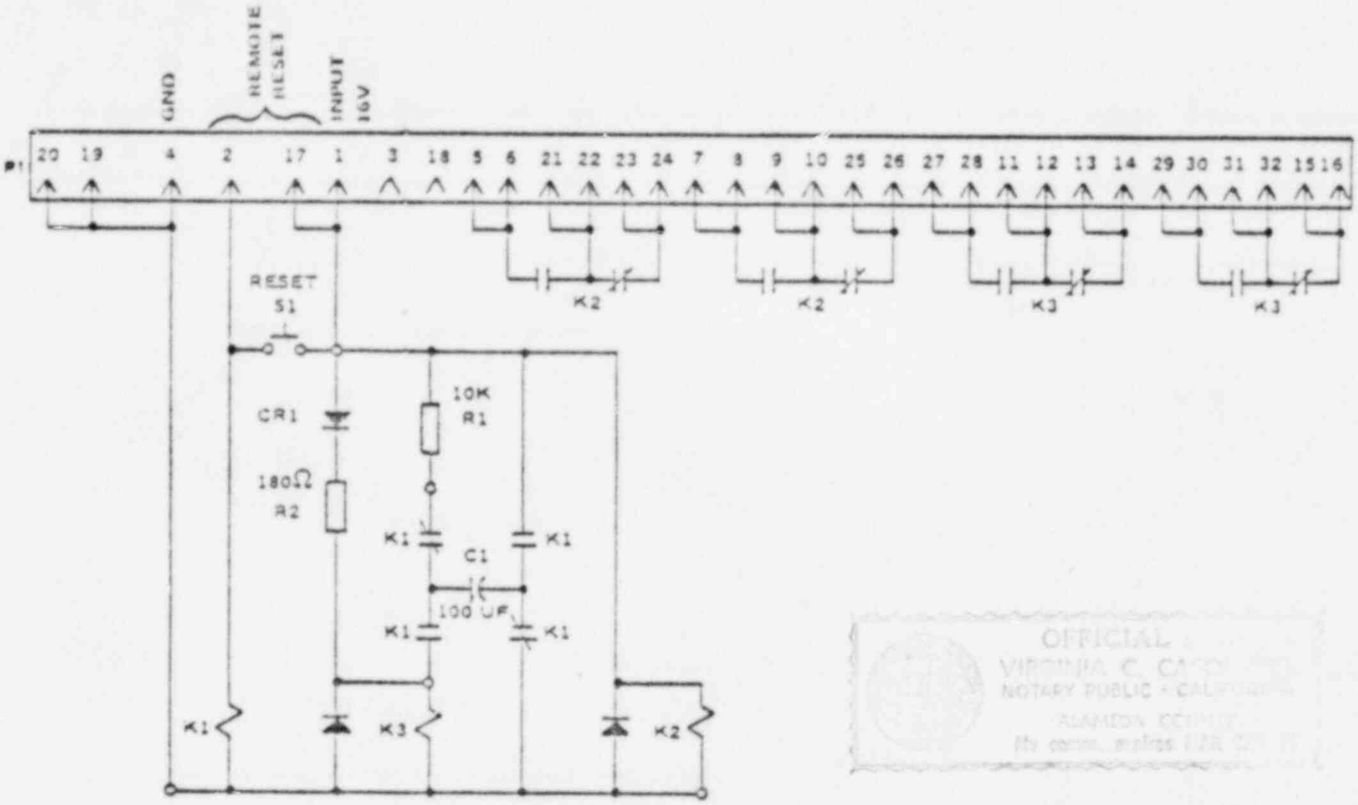


FIGURE 4–84. POWER SWITCH SCHEMATIC DIAGRAM

and closes the normally-open contacts of the relay. The stored charge in capacitor C1 discharges through relay coil K3 and adds to the voltage from R2. This voltage boost is sufficient to energize K3. Once energized, the limited voltage through R2 is sufficient to hold K3 energized, and S1 is released.

The six rod scram magnets, their respective regulators and bypass switches and their power supply in the scram magnet and magnet power supply block (Figure 4–80) are:

1. *Rod Scram Magnet Circuit.* A magnet current regulator panel is located in the control room and consists of a 0 to 150 mA meter and a 0 to 5 kohm potentiometer for each control rod magnet (Figure 4–85). The potentiometer is of the digital indicating type with the settings monitored for possible changes in magnet characteristics. Each magnet is individually fused with a 100 mA fuse, and the current adjusted for a nominal 75 mA on each magnet current meter.

2. *Magnet Circuit Bypass Switch.* There is an administrative controlled magnet circuit bypass switch located in the control room that allows either the K2

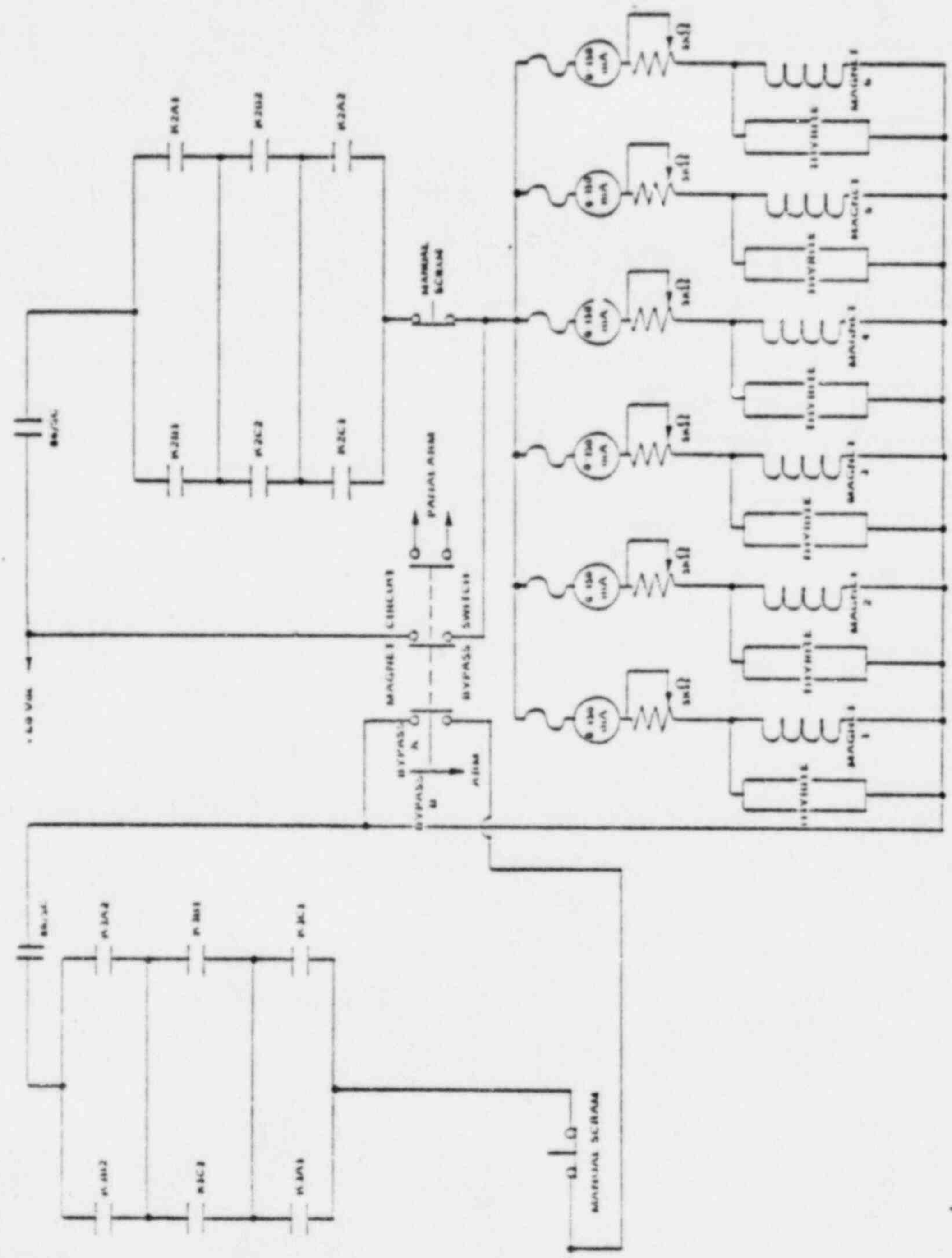


FIGURE 4-85. CONTROL ROD MAGNET CIRCUIT

contacts or the K3 contacts to be bypassed. The bypass is for testing system operability when the reactor is shut down. When the bypass switch is out of the arm position, a Panalarm is initiated.

3. *Magnet Power Supply.* The magnet power supply is a 60-V Dymec supply manufactured by Hewlett-Packard and used to supply current for the control rod magnets. The power supply features a current control that permits adjustment of the output current to the desired value for protection of the control rod magnets and serves as an output current control when the supply is used as a constant current source. Overload protection is provided by a continuously acting constant current circuit which protects the power supply for all overloads, including a direct short placed across the output terminals. The total current and voltage applied to the magnet current regulator are controlled from this power supply. A voltmeter with a nominal operational reading of 60 Vdc and an ammeter with a nominal operational reading of 450 mA are located on the front panel to indicate the total voltage applied and the total current being drawn by the scram magnets. An alarm meter will actuate a low magnet current alarm at 59 Vdc and also start an event recorder.

There is a scram event recorder that is not shown on Figure 4-80; however, for clarity, it is described here as well as in Section 4.8.9 for continuity. The scram event recorder is a dual 20-pen recorder manufactured by Esterline Angus. There are 34 inputs, such as process scram relay trip, picoammeter 1 trip, and rod 1 engaged to the event recorder. The recorders run continuously at a very slow speed until any 1 of the 34 events occur. In the event of a trip, the event recorder runs at high speed for several seconds, therefore, it is easy to distinguish the sequence of events. The sequence of events during a scram is important in diagnosing the cause of scram.

4.8.1.3 Nuclear Scram System

The reactor neutron monitoring system senses neutron flux levels in the pool for visual indication of reactor power level as well as providing trip signals to the reactor protection system when pre-set levels are exceeded. Six independent channels of neutron flux level monitoring instrumentation are provided. The range of each one of these channels and the overlapping range feature is shown on Figure 4-86. A source range monitor is used for the startup range. A Log N instrument which contains period protection is provided which covers the range shown in Figure 4-86. High trips on two picoammeters and the fast

Comment 2: Discuss how the scram system operates in time to complete the necessary scram action before consequential accelerations are reached.

Instrumental acceleration versus time records for a number of earthquakes were examined to determine instrumental acceleration values at times after seismic switch trip of scram action events for safe shutdown of the General Electric Test Reactor (GETR), such as control rod disengagement, reactor shutdown and valve opening. The GETR scram system operates when (among other events) the seismic switches (pendulum type) close at 0.01 to 0.03g. The reactor control rods are disengaged from the drive mechanism 180 milliseconds after either of these two seismic switches make electrical contact. That is, all the electrical and electronic scram circuitry have operated and the control rod magnetic latch circuit has been interrupted and the control rod begun its drop by the end of the 180 millisecond period. The control rod then drops by the forces of gravity and primary coolant flow so as to be fully inserted from a 36-inch withdrawal starting position within 500 milliseconds from the time the control rod is disengaged from the drive. Based on available rod drop data, it is conservatively estimated that within 300 milliseconds from the time the control rod is disengaged from the 36-inch withdrawal starting position, or 480 milliseconds from seismic switch trip, the control rods will be at or below the 12.2-inch withdrawal position whereupon the reactor is assured to be safely shut down. The emergency cooling valves begin to open 190 milliseconds after the seismic switches make electrical contact and require an additional 800 milliseconds to fully open, completing the action in under one second.

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The instrumental acceleration value at 0.5 and 1 second after a recorded value of 0.01 or 0.03g was reached was determined for a number of earthquakes. This was done with a subroutine that examined the computerized earthquake record. These values and the earthquake records from which they were derived are listed in Table 1. Instrumental acceleration values are shown for seismic trips at 0.01 and 0.03g for both 0.5 and 1 second after seismic trip. In addition, to obtain a measure of the instrumental acceleration value soon after the scram circuitry has operated, acceleration values at 0.2 seconds after were obtained for the Helena, Montana, 1935 earthquake. The values obtained of 0.035g and 0.04g after a 0.03g trip are quite low.

It is important to note that the values shown in Table 1 are instrumental values and are, therefore, higher than actual accelerations in the building. Also, the delay produced by the building response time has not been considered and would reduce the accelerations further. Thus, the already low levels are in fact smaller. Scram action is consummated in advance of consequential accelerations.

TABLE 1

Maximum Instrumental Accelerations
Within 0.5 and One Sec. Interval
After Recording 0.01g or 0.03g

Earthquake and Recording Station	Component	Maximum Absolute Horizontal Instrumental Acceleration, g — After recording 0.01g		After recording 0.03g	
		0.5 sec	1.0 sec	0.5 sec	1.0 sec
Imperial Valley El Centro Site 5/18/1940	S90W	0.002	0.05	0.08	0.16
	S00E	0.003	0.07	0.07	0.15
Eureka Earthquake Eureka Fed. Bldg. 12/21/1954	N79E	0.03	0.03	0.10	0.11
	N11W	0.03	0.03	0.04	0.04
Helena, Montana Carroll College 10/31/1935	N00E	0.03	0.04	0.09	0.11
	N90E	0.03	0.04	0.15	0.15
Hollister City Hall 4/8/1961	S01W	0.03	0.04	0.07	0.07
	N89W	0.05	0.12	0.05	0.18
San Francisco Golden Gate Park 3/22/1957	N10E	0.02	0.03	0.09	0.09
	S80E	0.02	0.03	0.11	0.11
Parkfield Array No. 2 6/27/1966	N65E	0.02	0.03	0.08	0.12
Imperial Valley Array 7 10/15/1979	140 degree	0.02	0.04	0.04	0.04
	230 degree	0.02	0.04	0.04	0.07
Imperial Valley Array 8 10/15/1979	140 degree	0.01	0.03	0.05	0.06
	230 degree	0.02	0.04	0.03	0.04
Imperial Valley Array 5 10/15/1979	140 degree	0.02	0.07	0.08	0.11
	230 degree	0.02	0.04	0.07	0.15