SECTION 7

INSTRUMENTATION AND CONTROL

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7.2 REACTOR PROTECTIVE SYSTEM

7.2.1 General

The Reactor Protective System consists of instrument channels, trip units, logic circuitry, and other equipment necessary to monitor selected nuclear steam supply system conditions and to effect reliable and rapid reactor shutdown if any one or combination of conditions deviates from a preselected operating range. The system functions to protect the reactor core.

7.2.2 Design Bases

The Reactor Protective System was designed under the following bases to assure adequate protection for the reactor core:

a. Instrumentation conformed to the provisions of the proposed IEEE Standard for Nuclear Power Plant Protective Systems (IEEE 279, August 1968).

b. No single component failure can prevent safety action.

c. Four independent measurement channels, each complete with sensors, sensor power supply units, amplifiers, and bistable modules were provided for each parameter.

d. The channels are provided with a high degree of independence by separate connection of the sensors to the process systems. Separate raceways are used to segregate cable systems.

e. The four measurements channels provide trip signals to four independent trip paths.

f. A trip signal from any 2 trip units monitoring the same parameter causes a reactor trip.

g. When one of the four channels is taken out of service for maintenance, the protective system logic can be changed to a two-out-of-three coincidence for a reactor trip by bypassing the out-of-service channel.

h. The protective system AC power is supplied from four separate instrument buses.

i. Open circuiting, or loss of power supply for the channel logic, initiates an alarm and a channel trip.

j. All measurement channels and trip logic matrices assume the deenergized state to provide a tripping function.

k. The Reactor Protective System can be tested with the reactor in operation or shutdown.

l. A manual trip, independent of the automatic trip system, is provided.

m. Trip signals are preceded by alarms to alert the operator of undesirable operating conditions in cases where the operator could avert a reactor trip by taking timely corrective actions.

n. The Reactor Protective System components are independent of the Power Range Monitor control channels.

The Reactor Protective System (RPS) is shown in Figures 7.2-1 and 7.2-2. It consists of four channels of instrumentation. Each channel monitors 12 safety parameters, each parameter input is derived from a isolated instrument channel. Each parameter operates a two out of four coincidence logic matrix to maintain OR remove power from the Control Element Drive Mechanism (CEDM) clutches. Individual channel trips occur when the measurement reaches a preselected value. A typical measurement channel functional diagram is shown in Figure 7.2-3. The channel trips are combined in six two-out-of-four matrices. Each individual measurement channel has inputs to three of the six logic matrices. The logic matrix trip relays are deenergized when two channels of the same measurement channel trip. Each two-out-of-four logic matrices provides trip signals to the interposing relays which in turn cause a direct trip of the contactors in the a-c supply to the CEDM clutch power supplies. Any one of the six logic matrices will deenergize the 4 clutch power supplies. The logic matrices are arranged in a one-out-of-six logic configuration. The clutch power supply DC outputs are ungrounded.

Reactor trip is accomplished by de-energizing the magnetic clutch holding coils and releasing the control element assemblies (CEA's) to drop into the core. The four non-trippable full length CEA's are not equipped with magnetic clutches (see Section 3.7.2).

The Reactor Protective System meets or exceeds the requirements of IEEE 279 with the following qualifications: During periodic testing of the low reactor coolant flow trip channels, the channel under test is bypassed for a brief period of time. That bypass causes the low flow trip logic to revert from 2 of 4 coincidence to 2 of 3 coincidence. While the bypass is in effect, a single incident could inhibit trip action of two channels, thereby making the low flow trip unavailable. The required incident would be failure of instrument tubing on the low pressure side of selected differential pressure (reactor coolant) flow measuring devices.

The exception to the single failure criterion stated above is considered acceptable because the required single failure is improbable, and further, it must occur during brief periods when a low flow trip channel is bypassed.

7.2.3 Reactor Protective System Actions

Rapid reactor shutdown is effected on the conditions described in the following sections; the reactor trip and pretrip setpoints are listed in Table 7.2-1.

Table 7.2-1- " Reactor Trip and Pretrip Setpoints"

No.	Reactor Trip	Pretrip Setpoint	Trip Setpoint
TU-1	High Power Level (E)	104.9% (of rated power)	≤107.0% (of rated power)
TU-2	High Rate-of-Change of Power (A)	1.5 decades/min	2.6 decades/min
TU-3	Low Reactor Coolant Flow (B)(F)	97% (of 4 pump flow)	≥95% (of 4 pump flow)
TU-4/5	Low Steam Generator Water Level	40.2% of narrow range scale	31.2% of narrow range scale (Top of feedwater ring:4'-10" below normal water level and power level)
TU-6	Low Steam Generator Pressure(C)	≤600 psia	≥500 psia
TU-7	Steam Generator Differential Pressure	≤100 psid	≤135 psid
TU-8	High Pressurizer Pressure	≤2300 psia	≤2350 psia
TU-9	Thermal Margin/Low Pressure (B)(F)	(1750 psia to 2400 psia +50 psi)	1750 psia to 2400 psia (dependant on the reactor coolant temperature and axial shape index) see COLR
TU-10	Loss of Load (D)		
TU-11	High Containment Pressure (G)	--	≤5 psig
TU-12	Axial Power Distribution (D)	(Variable Ratio) See COLR	(Variable Ratio) See COLR

A Inhibited above 15% and below 10^{-4}% rated power.

B Inhibited below 10^{-4}% rated power (if bypass switches are in the "Bypass" position).

C Inhibited when pressure is below pretrip setpoint (if bypass switches are in the "Bypass" position).

D Inhibited below 15% power.

E Setpoint cannot be set greater than 10% above measured power whenever reactor power is greater than 10% of rated power.

F For physics testing at power levels less than 10^{-1}% of rated power the low reactor coolant flow and thermal margin/low pressure trips may be bypassed until their reset points are exceeded if automatic bypass removal of 10^{-1}% of rated power is operable.

G Bypass allowed for containment leak test.

7.2.3.1 High Rate-of-Change of Power

An anticipatory trip in the event of a high rate-of-change of reactor power is provided to protect the reactor against an uncontrolled CEA withdrawal or boron dilution incident while the reactor is critical below 15% Rated Power.

The rate-of-change power is monitored at start-up by four neutron flux wide range monitor channels, as shown in Figure 7.2-4. Each channels uses a dual, wide-range fission chamber, covering a range greater than ten decades. The wide range is effected by using a combination of counting and mean square voltage techniques which also provide good rejection of background gamma signals to provide an operating range from start-up to full power. A channel trip is initiated if the rate-of-change of reactor power exceeds 2.6 decades per minute (dpm). The rate-of-change-of-power trip signal for each channel is automatically bypassed below 10^{-4} percent and above 15 percent power.

A rate-of-change pretrip is also provided which develops a CEA Withdrawal Prohibit (CWP) action. Above 10^{-4} percent power, if the rate-of-change of power for any two trip units exceeds the pretrip setpoint, a CWP alarm will be initiated and the withdrawal of all regulating CEA's will be inhibited.

7.2.3.2 High Power Level

A high power reactor trip (neutron flux) is provided to prevent damage to the fuel cladding resulting from some reactivity excursions too rapid to be detected by pressure and temperature measurements. RCS T_{HOT} and T_{COLD} signals (delta T power) are also provided as a measure of reactor power to the high power level trip unit in addition to the neutron flux signal.

The high power trip setpoint is a variable setpoint with a minimum of 19.1 % and a maximum of 107.0% rated power. The setpoint can be no more than 10% above measured power.

Operator action is required to increase the setpoint as plant power is increased and the setpoint automatically decreases as measured power decreases.

An alarm is provided to apprise Operators of the approach to the trip setpoint and of the need to reset the setpoint margin. A pretrip alarm is also provided to annunciate the continued approach to the trip setpoint.

7.2.3.3 Low Reactor Coolant Flow

This reactor trip is provided to ensure core protection in the event of a low flow condition.

The flow signal for each channel is developed by summing the output of 4 differential pressure transmitters. The transmitter sensing lines are located between each cold leg and its respective hot leg. Each channel signal is a input used in determining the total coolant flow through the reactor.

Refer to Figure 7.2-5.

A channel trip is initiated when the summed flow value falls below a preselected value. A key-operated bypass switch allows this trip to be bypassed for subcritical testing of control element drive mechanisms. The trip bypass is automatically reset above 10^{-4} percent power.

Pretrip alarms are initiated if the RCS flow decreases below the pretrip setpoint.

7.2.3.4 Low Steam Generator Water Level

An abnormally low or decreasing steam generator water level indicates a loss of steam generator secondary water inventory; if not corrected, this would result in a loss of capability for removal of heat from the reactor coolant system.

A channel trip signal is initiated by independent downcomer level differential pressure transmitters on each steam generator. Audible and visible pretrip alarms are actuated to provide for annunciation of approach to reactor trip conditions.

7.2.3.5 Low Steam Generator Pressure

An abnormally high rate of steam flow from either steam generator (e.g., that which would occur as the result of a steam line break) would be accompanied by a marked decrease in steam pressure. To mitigate the consequences of a steam line break, a reactor trip is initiated by low steam generator pressure.

Four narrow range pressure transmitters on each steam generator provide input to the Reactor Protective System to initiate reactor trip if either steam generator pressure drops below a preselected value. Pretrip alarms are actuated if the pressure in either steam generator falls below the pretrip setpoint.

A key-operated bypass switch allows this trip to be bypassed below pretrip setpoint during controlled plant cooldown. This trip bypass is automatically reset when the trip unit pretrip alarm condition is reset.

7.2.3.6 High Pressurizer Pressure

A reactor trip for high pressurizer pressure is provided to prevent excessive blowdown of the reactor coolant system by relief action through the pressurizer safety or power-operated relief valves.

The trip signals are derived from four independent narrow range pressure transducers measuring the pressurizer pressure. A typical channel diagram is shown in Figure 7.2-3.

A channel trip is initiated if the pressurizer pressure exceeds a nominal value of 2350 psia. This signal also opens the power-operated relief valves.

Pretrip alarms are initiated if the pressurizer pressure exceeds a nominal value of 2300 psia.

7.2.3.7 Thermal Margin/Low Pressure Trip

The Thermal Margin/Low Pressure Trip (TM/LP) is provided to prevent exceeding the Safe and Acceptable Fuel Design Limit (SAFDL) on DNBR by working in combination with the variable high power trip, the axial power distribution trip, the Rod Block System and the LCOs. The maximum radial power peak that can be carried up to the variable high power trip limit in the event of a design basis Anticipated Operational Occurrence (AOO) is factored into the thermal margin LSSS. The radial power peak that is allowed at any steady-state or transient core power is specified through the power dependent insertion limit (PDIL).

The TM/LP trip operation is as follows:

The TM/LP trip system monitors core power, axial shape index, reactor coolant inlet temperature and reactor coolant system pressure. The variable low pressure trip limit (P_{var}) is calculated from the following equation for comparison with the measured reactor coolant system pressure.

$$P_{var} = [\alpha \cdot A1(\gamma)B \cdot PF(B)] + [\beta \cdot Tin] + \gamma$$

where:

Y	is measured axial shape index
B	is measured core power
Tin	is measured reactor inlet temperature,
α, β	and γ are constants, and
PF(B)	is a function that defines the variation in overpower with core power.
A1(γ)	is a function that defines the variation in overpower with axial shape index.

The signal representing core power (B) is the auctioneered highest of the neutron flux power and the delta-T power. This signal is used to calculate PF(B) for a measured core power value.

The internal tilt, Y, is calculated in the axial power distribution (APD) calculator of the RPS and this signal is monitored by the TM/LP calculator which calculates A1 (Y) which adjusts P_{var} for variations in axial peaking.

The variable low pressure trip limit (P_{var}) is calculated and compared to a fixed low pressure trip limit (P_{min}). The auctioneered highest is selected as the trip limit (P_{trip}). P_{trip} is then compared with the measured primary pressure (P) and a trip signal is generated when the two are equal. A pre-trip alarm signal is also generated when the measured primary pressure is equal to the pre-trip setting $P_{trip} + \Delta P$.

The fixed low pressure trip limit (P_{min}) is provided to trip the reactor in the event of a rapid depressurization of the reactor coolant system (i.e., loss of coolant accident).

7.2.3.8 Loss of Load

The loss of load channel trip is generated when its associated turbine stop valve comes off its open seat. The loss of load trip is an anticipatory trip and is not required for reactor protection. This trip is not designed to the basis listed in Section 7.2.2, to the extent that it does not meet in full the requirements of IEEE 279.

7.2.3.9 Manual Trip

Two manual reactor trip methods are provided to permit the operator to trip the reactor. One manual trip method opens the same contactors as the Reactor Protective System. The second manual trip method is independent of the contactor trip, tripping the reactor via a shunt trip on the molded case circuit breakers feeding the clutch power supplies.

7.2.3.10 Axial Power Distribution Trip

The axial power distribution trip (APD) is provided to ensure that excessive axial peaking will not cause fuel damage.

The maximum radial power peak that can be carried up to the variable high power trip limit in the event of a design basis AOO is factored into the axial power distribution LSSS. The radial power peak that is allowed at any steady-state or transient core power is specified through the Power Dependent Insertion Limit (PDIL).

The APD trip operation is as follows:

The signal representing core power (Q) is the auctioneered highest of the neutron flux power and the delta-T power. The signal representing the axial power distribution is the measured axial shape index (Y_I), calculated from the excore detector signal and adjusted for shape annealing. The measured axial shape index and power level constitute an ordered pair (Q, Y_I) which is compared to a programmed trip setting, activating a trip signal whenever the ordered pair exceeds the trip setting.

The pretrip setpoint is 0.03 ASI units from the trip setpoint.

Figure 7.2-9 shows a block diagram of a typical channel.

7.2.3.11 Containment High Pressure

A reactor trip on containment high pressure is provided to assure that the reactor is shutdown simultaneously with the initiation of the safety injection system. The setting of this trip is identical to that of the containment high pressure signal which initiates Engineered Safeguards system operation. The channel trip is initiated by its associated containment pressure channel.

Measurement display and recording of containment pressure are continuous in the control room, independent of the RPS system. Pressure reading capability to three times the containment design capacity is available, independent of the RPS system.

7.2.3.12 Asymmetric Steam Generator Transient

A reactor trip is provided on high differential pressure between the two steam generators to protect against a loss of load to one steam generator (e.g., inadvertent closure of an MSIV, inbalance of feedwater flow between the 2 steam generators, or a loss of steam line integrity) which could lead to an asymmetric steam generator transient.

Pressure signals used for a low steam generator pressure trip are also used for the input to the steam generator differential pressure trip unit.

No operational bypass is provided for this trip function.

7.2.4 Signal Generation

Four instrument channels are used to generate the signals necessary to initiate the automatic reactor trip action. The signal cable routing and readout drawer locations are separated and isolated to provide channel independence.

7.2.4.1 High Rate-of-Change of Power

Each of the wide range logarithmic channels obtains a signal from one of the four dual fission chamber detectors located in the biological shield around the reactor. The outputs are amplified and carried to the signal processing drawer in the control room. A rate of change of power signal is developed in the drawer and provided as an input to the high rate-of-change trip unit.

7.2.4.2 High Power Level

The signal for each of the four power range safety channels is obtained from one of the four detector assemblies located in the biological shield around the reactor. Each assembly consists of two uncompensated ion chambers stacked vertically to monitor the full length of the core. The d-c current signal from each ion chamber is fed directly to the control room drawer assembly. The ion chambers cover the range from 0.1 percent to 200 percent power (see Figure 7.2-8).

The reactor power signal that is monitored by the trip unit is the higher of the NI power signal and a thermal power signal (Delta-T). The Delta-T signal is derived from temperature measurements of inlet and outlet reactor coolant loops.

7.2.4.3 Flow, Water Level, Pressure and Thermal Margin

The flow, water level, pressure and thermal margin trips are each actuated from signals generated by separate sets of transmitters. Flow is measured by monitoring the pressure difference across the steam generator. Steam generator water level and pressure are monitored in each steam generator.

The reactor coolant system pressure is measured in the pressurizer. The pressurizer high pressure and the thermal margin trips use the same reactor coolant system pressure signals.

Temperature measurements are taken from the reactor hot leg and cold leg piping in each loop and combined with coolant pressure and axial shape index to ensure adequate thermal margin.

Thermal wells, or piping and connections for these transmitters are separated and isolated to provide independence.

Each transmitter provides a ungrounded current loop output (see typical loop, Figure 7.2-3) to signal receivers and/or bistable trip modules.

7.2.4.4 Trip Modules

The trip modules have three isolated outputs which feed the logic matrices. Additional outputs feed the pretrip alarm and if applicable, the trip alarm and the plant computer. Provisions were also made for test inputs to the trip modules for normal protective system testing and are described in Section 7.2.6. The protective system outputs referred to here are connected into logic matrices as shown in Figure 7.2-2.

7.2.5 Coincidence Logic Matrices

Refer to Figure 7.2-2 for the following discussion.

The RPS has four separate channels having twelve trip units per channel. Each of the twelve trip units serves to monitor a different plant parameter. There are four trip units for each plant parameter monitored, one per channel.

There are six logic trip matrices (AB, BC, BD, AC, CD, and AD). For matrix AB, the normally open contact from the channel A trip unit 1 relay 1 (A1-1) is connected in parallel with the channel B trip unit 1 relay 1 (B1-1).

Each trip unit contains three sealed trip relays which have a single-pole, double-throw (SPDT) contact. The normally open contact from channel A trip unit 1 relay 1 (A1-1) is connected in parallel with the normally open contact from channel B trip unit 1 relay 1 (B1-1). This is similarly done for the twelve contact combinations A1-1 through A12-1 and B1-1 through B12-1 and these twelve parallel combinations are connected in series to form a logic ladder. The trip unit relays are energized in a reset condition, thus the normally open relay contacts are closed. The AB logic ladder serves to control four Matrix relays which are energized in the reset condition. The three trip unit trip relays from the four channels are used to make six logic matrices in the same fashion as the AB matrix.

A normally open contact from each of the four matrix relays are connected in series with a normally open contact from the corresponding relays of the other five matrices to form four trip paths. A contact from one of the manual trip switches and the coil of an interposing relay are in series with the six matrix relay contacts for each of the four trip paths. Under normal operating conditions the four interposing relays are energized. A normally open contact from each of the interposing relays serves to control an M-contactor.

The four M-contactors are combined into pairs with the contacts of each pair connected in series. The series contacts of the two pairs serve to supply AC power to the CEDM clutch power supplies. The CEDM clutches are separated into two groups. The clutches in each group are supplied by parallel pairs of low voltage, d-c power supplies which are fed by an ungrounded supply via contacts from the two pairs of M-contactors. The parallel CEDM clutch power supplies assure that the inadvertent loss of one supply source will not deenergize the clutches.

If one of the trip modules is to be removed for maintenance, the logic may be changed from a two-out-of-four trip to a two-out-of-three trip by the operation of the manual bypass switch (shown on the output of the trip modules, Figure 7.2-3). A different bypass switch key is used for each of the 12 trip units. Only one key is provided for the trips for any one variable to ensure that only one of a group of four could be bypassed at one time.

Certain trips may be inhibited when outside of selected operating ranges. These trips are High Power Rate of Change, Low Reactor Coolant Flow, Low Steam Generator Pressure, Thermal Margin/Low Pressure, Loss of Load, and Axial Power Distribution. The High Power Rate of Change Trip is automatically inhibited below 10^{-4} % power and greater than 15 percent power. Loss of Load and APD trips are automatically inhibited below 15 percent power. These inhibit signals are generated within each channel by the nuclear instrument drawers thus maintaining channel separation. Low Reactor Coolant Flow trip, and the Thermal Margin/Low Pressure trips are manually bypassed by a single key operated switch. The Delta T power signal is also blocked by this bypass switch. This bypass is automatically removed at greater than 10^{-4} power. Both Low Steam Generator Pressure trips are manually bypassed by a single key operated switch. This bypass is automatically removed for each steam generator when that individual generator's steam pressure increases to the pretrip alarm point.

7.2.6 Testing

Provisions were made for periodic protective system testing. These tests cover the trip paths from the sensors to the final outputs to the CEDM clutches.

During reactor operation the measuring channels are checked by comparing the outputs of similar channels and cross-checking with related measurements. Where applicable, the trip modules are tested by means of a digital voltmeter, noting the signal level, and initiating a test input which is also indicated on the voltmeter. This provides the necessary overlap in the testing process and also enables the test to establish that the trip can be effected within the required tolerances. The test signal is connected to the trip module at the signal input and applied by depressing the manual test switch. Trip action (opening) of each of the trip module relays is indicated by individual lights on the front of the trip module. Where applicable, the pretrip alarm action is indicated by a separate light.

Auxiliary Trip Units are tested by operating the appropriate input contact.

The sets of logic trip relays at the output of each logic matrix are tested one at a time. The test circuits in the logic permit only one logic ladder to be opened and one set of relays to be held at a time; the application of hold power to one set denies the power source to the other sets. In testing a logic trip set (e.g., AB) a holding current is initiated in the test coils of the logic trip relays by turning the matrix relay trip test switch to "off" and depressing the matrix logic AB test pushbutton switch. Operation of the channel trip select switch deenergizes a parallel pair of module trip relays. With the ladder logic relay contacts open, the logic trip relays may be deenergized one at a time (by rotating the matrix relay trip test switch) to initiate a half-trip. Indicator lights on the trip relay coils and on the clutch power supply feeders provide verification that coil operation and half-trip conditions have occurred.

The following indications are available to the operator during test or maintenance of the RPS. By procedure, only one of four channels will be tested at one time.

a. General

All parameters that initiate protective actions in the RPS do so through their Auxiliary and Bistable or Auxiliary Trip Units (BTU) (ATU). There are four trip units for each parameter. When a protective action has been initiated, the trip units will indicate this action with a "trip" light and will annunciate the trip condition on the main control board.

b. Trip Inhibit Panel

The trip inhibit panel provides an inhibit of the trip functions of the Auxiliary and Bistable trip units, it does not inhibit annunciation or indication. During test, the following indications are provided:

1. Inhibit keys in the key locks; a separate key for each of the 12 channel trip units with only one set of keys for all four channels. The key cannot be removed in the "INHIBIT" position.

2. A light on the panel indicates the inhibit condition for each trip unit.

c. Power Range Nuclear Instrumentation Drawers

1. "HV" bistable trip lamps indicates a low output of the high voltage power supply or a test switch out of the normal operation position.

2. A trip condition of the High Voltage bistable causes a trip of the associated BTUs unless inhibited.

3. A trip condition of the High Voltage bistable is annunciated on the main control board.

4. Indication is also provided to indicate power on, rod drop bistable alarm, subchannel A or B deviation alarm, and power level bistable trip.

d. Wide Range Nuclear Instrumentation Drawers

1. The red "CHANNEL IN TEST" lamp provides indication of test switches out of the normal operation position.

2. The red "NON-OP" lamp provides indication of a fault with power supplies or test switches out of the normal operation position for the respective channel.

3. Annunciation on the main control board is provided for a inoperative condition.

4. Indication is also provided to indicate power on and power level 1 and 2 bistable trip.

e. Reactor Protective System Calibration and Indication Panel (RPSCIP)

The RPSCIP provides test signals at any one bistable trip unit. Only one channel can be in test at any time. This is accomplished by pushbutton interlock requiring the operator to continuously hold the pushbutton. Test of one channel deenergizes test power to the other channels. The RPSCIP also provides a means of testing the Thermal Margin (ΔT)/Low Pressure calculator using the following:

1. A "Δ-T NOT SELECTED" light indicates when the RPSCIP meter input switch is not in the Delta-T power position.

2. A "Δ-T TEST" light will indicate the input of a simulated Delta-T signal.

3. "VOPT RESET" light indicates an approach to the high power trip setpoint.

4. "Δ-T POWER BLOCK" indicates that Delta-T power block is in place due to the Zero Power Mode Bypass switch.

5. "NUCLEAR PWR - ΔT PWR" deviation meter indicates the magnitude of difference between the nuclear power and Delta-T power signals.

6. RPSCIP Digital Volt Meter (DVM) displays a selectable variable. The variables that may be selected via a rotorary meter input selector switch are: ΔT PWR, $T_{COLD\ CAL}$, P_{VAR}, Nuclear Pwr, T_{COLD}, T_{HOT}, P_{TRIP}, $P_{PRE\ TRIP}$, Aux, PRETRIP S. P., TRIP S. P.

7. NUCLEAR PWR CALIBRATE, ΔT PWR CALIBRATE and T_{COLD} CALIBRATE potentiometers.

8. Trip unit trip test potentiometers and trip test input pushbutton.

9. The RPSCIP Digital Voltmeter displays values representative of the positive and negative low voltage power supply voltages and the low voltage ground potential.

f. Auxiliary Logic Assembly

The Auxiliary Logic Assembly provides means for bypassing protective action on the following parameters:

Low Flow

Thermal Margin/Low Pressure

Low Steam Generator Pressure

These bypasses are performed by key operated switches, one for parameters low flow and thermal margin, called zero power mode bypass switch, and one for low steam generator pressure, called steam generator low pressure bypass switch.

1. The keys cannot be removed in the "BYPASS" condition.

2. The bypass is annunciated on the main control board.

3. Indicator lamps on the Auxiliary Logic Assembly indicate when the bypass functions are in effect.

4. Automatic removal of the bypass is provided. Removal is indicated by the above mentioned lights being deenergized.

g. Automatic bypassing of the Loss of Load and High Power Rate of Change RPS Trips is provided. Those bypasses are annunciated on the main control board and are indicated by a light on the nuclear instrument drawers.

h. Logic Test Module

The logic test module provides a means of testing of the "2 of 4" coincidence logic ladders. Power is supplied through these ladders to the coincidence logic trip relays K(AB)1 through K(AB)4, etc.

1. Only one coincidence logic ladder (matrix) can be in test at one time due to pushbutton interlock.

2. A channel test switch selects which protective action parameter to simulate. Simulation of the trip for that parameter will be indicated by the trip relay lights on the parameter trip unit.

3. A matrix relay test switch selects the coincidence logic relay (K(AB)1 through K(AB)4, etc.) that is to be tested. A "DROPOUT" light indicates that the selected relay has deenergized.

4. A "Hold" light indicates the application of hold voltages to secondary coils on the coincidence logic relays.

Based on the above indications available during test and maintenance, the Reactor Protective System complies with Sections 4.13 and 4.19 of IEEE-279.

7.2.7 Effects of Circuit and Component Failures

The protective system was designed and arranged to perform its function with single failures. Some of the faults that were considered during the system analysis, and the effects thereof, are described in the following sections.

7.2.7.1 Analog Portion of System

a. A loss of signal in a channel initiates channel trip for all trips except high rate of change of power, high power level and high pressurizer pressure; open circuit of the signal leads has the same effect as a loss of signal.

b. Shorting of the signal leads to each other has the same effect as a loss of signal. Shorting the leads to an ungrounded voltage source has no effect since the signal circuit is ungrounded.

c. Single grounds on the signal circuit have no effect.

7.2.7.2 Logic Portion of System

a. Inadvertent operation of the Matrix Relays in the matrices can be identified by the indicating lights.

b. Shorts across the matrix relay contacts are detectable in the testing process. Testing is accomplished by successive opening of the matrix relay contacts associated with each trip function.

c. Shorting of the matrices to an external voltage has no effect since the matrix is ungrounded. The testing process serves to verify proper operation, thus would detect accidental application of potential to the matrix should it have an adverse impact.

d. The logic matrices are each supplied from two power sources. Loss of one power source has no effect. Loss of power to a logic matrix initiates a trip condition.

e. Failure of one set of matrix trip relays to deenergize has no effect since there are five redundant sets of matrix trip relays remaining, any one of which when deenergized, will trip the reactor.

f. The failure of the M contactor in the power supply circuit has no effect since either of the two relays in series can deenergize the clutch power supplies.

g. Single grounds in the M contactor relay circuits have no effect since the circuit is ungrounded; an isolating transformer is provided. Local ground detectors also indicate accidental grounds. Double grounds cause the circuits to fail in the safe direction.

h. The two AC circuits supplying power to the clutch power supplies are fed from isolation transformers with a center tap grounded through a resistance to ensure that single grounds cannot prevent system action. The circuit has a local ground detection system. The supply transformer center tap ground is used in a ground detection system to identify local ground and shorts around the M contactor contacts when the relays are deenergized.

i. The DC clutch power supply circuits are ungrounded so that an inadvertant ground on one side of the power supply will not affect its operation. The clutches are powered from two seperate power supplies to prevent inadvertent rod insertion due to a power supply failure. The clutch power supply current output is continuously indicated on the clutch power supply drawers.

7.2.8 Power Sources

The AC power for the Reactor Protective System M coil circuits and the Clutch Power Supplies are supplied from four independent 120V AC Instrument Buses. The M1 and M2 coils and clutch power supplies 1 and 3 are supplied from either Bus A or Bus B (selectable). The M3 and M4 coils and clutch power supplies 2 and 4 are supplied from either Bus C or Bus D (selectable). Each bus is supplied from the station battery distribution system through an inverter to ensure an uninterrupted, transient-free source of power.

The distribution circuits from the instrument buses are provided with circuit protective devices to ensure selective fault isolation.

7.2.9 Physical Separation

The locations of the sensors and the points at which the sensing lines are connected to the process loop have been selected to provide physical separation of the channels, thereby precluding a situation in which a single event could remove or incapacitate a protective function. The process transmitters, which are located inside the containment and which are required for operation following a design basis accident (DBA), are rated for the intended service in the DBA environment.

The Reactor Protective System cabinet cables are arranged in accordance with Section 8 of the USAR to minimize the likelihood of common event failures. This includes separation at the containment penetration areas.

In the control room, the four nuclear instrumentation and protective system trip channels are located in individual compartments. Mechanical and thermal barriers between these compartments reduce the possibility of common event failure. Outputs from the components in this area to the control boards are buffered so that shorting, grounding, or the application of the highest available local voltages do not cause channel malfunction.

7.2.10 Adjustments

Adjustments to the Reactor Protective System to permit special plant operations are made at the front of the protective system cabinets by means of selector switches. There are two such switches for each safety channel. The two switches are as follows:

1. Each Reactor Protective System channel is provided with a low reactor coolant flow trip and the thermal margin/low pressure trip bypass switch to permit zero-power testing without normal flow or pressure. The bypass is automatically removed above 10^{-4}% rated power.

2. Each RPS channel is provided with a bypass switch for the Steam Generator Low Pressure Trip which is used during a controlled plant cooldown. The bypasses are automatically removed in the range of 550 psia to 600 psia.

A CEA drop test panel is provided which includes a switch for each CEDM. These switches interrupt power to individual CEDM clutches while simultaneously starting a timing device to measure CEA drop time. Interruption of a clutch power supply is indicated on the CEA drop test panel.

Use of either of the protective system adjustment switches or the CEA drop test panel switches is intended during the shutdown condition only.

7.2.11 Diverse Scram System

7.2.11.1 General

The Diverse Scram System (DSS) has been designed and installed to meet the requirements of 10 CFR 50.62, Requirements for Reduction of Risk from Anticipated Transient without Scram System (ATWS) Events for Light Water-Cooled Nuclear Power Plants. The DSS provides an independent means of initiating a Reactor Trip. The DSS uses components that are diverse, independent, and separate from the Reactor Protective System to initiate a Reactor Trip for anticipated operational occurrences which result in an overpressurization of the Reactor Coolant System. The DSS reduces the probability of a Reactor Coolant System Overpressurization from an Anticipated Transient Without Scram (ATWS) Event.

7.2.11.2 Design Bases

The NSSS Design Limits for the Fort Calhoun Plant provide the bases for the design of the Diverse Scram System. In addition to this, the system conforms to the requirements of IEEE 279-1968 wherever feasible. The following bases were used in the design of the system:

A. Instrumentation that conforms to the provisions of the IEEE Standard for Nuclear Power Plant Protective Systems.

B. No single component failure can prevent the safety action.

C. Four independent measurement channels complete with sensors, sensor power supply units, amplifiers, and bistables are provided for the actuation parameter.

D. The channels are provided with a high degree of independence by separate connection of the sensors to the process system and of the channels to instrument power supply buses. Separate raceways are used to segregate cable systems.

E. The four measurement channels provide trip signals to independent trip paths.

F. A trip signal from any two-out-of-four protective channels causes a reactor trip.

G. The system A-C power is supplied from separate instrument buses.

H. Loss of power supply for the channel logic initiates a channel trip.

I. The system can be tested with the reactor in operation or shutdown.

J. Provisions are made for manual bypass of individual channels. Indication is continuously and automatically indicated in the control room when a channel is in bypass.

K. Once initiated, the protective action at the system level goes to completion. Return to operation should require deliberate operator action.

L. The DSS provides the operator with accurate, complete, and timely information pertinent to its own status.

M. The system assumes a two-out-of-three logic when a channel is deliberately placed in bypass.

N. Provisions are made at the channel level for trip and bypass of individual channels.

O. Matrices may be tripped or bypassed without the installation of electrical jumpers.

P. The system reverts to one-out-of-three logic when a channel is placed in trip.

7.2.11.3 Diverse Scram System Actions

The Diverse Scram System monitors pressurizer pressure and is composed of four independent instrument loops, each having a pressure transmitter and a bistable trip unit. The bistable trip unit output contacts are configured into two independent two-out-of-four logic matrices. Each matrix has a lock-out relay which, when energized, deenergizes the undervoltage trip coils on the reactor trip breakers. The DSS initiates a reactor trip when pressurizer pressure reaches 2450 psia. A pre-trip setpoint at 2400 psia is provided to warn operators that a reactor trip is imminent. The DSS design permits on-line testing at the system and channel levels. Provisions are also made for bypassing either a single matrix or a single channel. The DSS may be tripped at either the system or channel levels.

7.2.11.4 Effects of Circuit and Component Failures

The Diverse Scram System is designed and arranged to perform its function even with a single failure in the system. Some of the faults and their effects are described below. These are typical of the faults that are considered during the system analysis.

In the analog portion of the system.

1. A loss of signal in either channels A or B of the system is detected by a loss of indication in the control room.
2. Shorting of the signal leads to each other has the same effect as a loss of signal. Shorting of single leads to a voltage source has no effect since the signal circuit is ungrounded.
3. Single grounds on the signal circuit will have no effect.
4. Open circuit of the signal leads has the same effect as a loss of signal.

In the logic portion of the circuit:

5. Inadvertent operation of the relay contacts in the matrices can be identified by the matrix supervisory lights.
6. Shorting of the DSS Matrix pairs in the matrices will activate the trip circuitry which can not be reset until the shorted contact pair is cleared.
7. Shorting of a logic matrix to ground has no effect and will be indicated by a ground detection circuit in each matrix.

   Shorting of the matrices to an external voltage has no effect since the matrix is ungrounded. The testing process will indicate accidental application of potential to the matrix.
8. The logic matrices will each be supplied by two separate power sources. Single loss of power source has no effect. Loss of power to a logic matrix initiates a trip condition.

7.3 ENGINEERED SAFEGUARDS CONTROLS AND INSTRUMENTATION

7.3.1 Design Bases

The Engineered Safeguards control and instrumentation system was designed to actuate Safeguards and essential support systems automatically. Means for manual operation are also provided. The system includes control devices and circuits for automatic initiation, control, supervision, and manual test of the Engineered Safeguards systems described in Section 6, the containment isolation system described in Section 5.9.5, and the emergency diesel-generator units described in Section 8.4.

The Engineered Safeguards controls and instrumentation system is an integral part of the Fort Calhoun Station's Engineered Safeguards described in Section 6. For more supporting details of components, the Technical Specifications, the CQE Manual, the EEQ manual, and the Regulatory Guide 1.97 Responses should be consulted.

The control system is a Class 1 protection system designed to satisfy the criteria of IEEE 279, August 1968.

a. The functional requirements of IEEE 279, August 1968, were met by the use of duplicate channels, provision for testing maintenance and repair, channel supervisory lamp indications and provision for manual operation.

b. The physical requirements of IEEE 279, August 1968, were met by the use of separate, segregated routing of each channel via trays and conduit. Redundant control and instrument power supplies are provided (two, independent d-c control systems, and four, separate vital a-c buses, see Sections 8.3.4 and 8.3.5);

c. Instruments, controls and electric cables were designed, specified, and tested to function in the DBA environment of pressure, temperature and humidity, where required, (see Section 1.4.8).

d. Manual blocking of reactor coolant low-pressure signals when the system is intentionally depressurized (at shutdown) is alarmed and automatically reset on return to the operating pressure range.

With minor exceptions, the Safeguards control system has no function during plant operation at power and will operate only in the event of an accident, during and after plant shutdown, or when under test.

The control system was designed and installed as two, independent, functionally redundant systems called the "A" train and the "B" train.

These trains are segregated physically and electrically throughout the installation. Cross connections between trains are held to the unavoidable minimum, and such connections are buffered and arranged to prevent communication of faults. In each train, the logic basis for initiation signals is two-out-of-four, with the exception of containment radiation high which is one-out-of-two.

Automatic sequencers for starting Safeguards pumps, fans and support auxiliaries are duplicated in each of the A and B trains.

Each of the four sequencers operates with a separate control power source and distribution system. Any one sequencer operating alone automatically actuates minimum Safeguards.

Means are provided to supervise the availability and operating status of Safeguards equipment, power and control power supplies, and the automatic control systems, and also to test Safeguards and supporting equipment and the major parts of Safeguards systems while the plant is operating at power. Complete system tests (with the exception of full containment spray) are feasible when the plant is shutdown.

A labeling program is provided to identify safety-related equipment. All instrument lines originating from the reactor coolant system terminate at transmitters inside the containment.

Most instrument lines that connect directly with the containment atmosphere also terminate at transmitters inside the containment. The exceptions are:

a. Sensing lines to radiation elements RM-050, RM-051 and RM-052 - These lines are each protected by two automatically operated isolation valves, one inside of containment and one outside, as required by the then applicable General Design Criterion No. 56.

b. Four sensing lines to containment pressure instruments - Safeguards initiating devices are connected to these lines. Each of these lines is protected by a remotely operated valve and a locally operated valve, both located outside containment. The remotely operated valve is not automatically operated since closing this valve would take an engineered safeguard instrument channel out of service. Automatic closing of all four valves would cause the loss of all containment pressure sensors. For the same reason, no valves are provided inside the containment.

c. Two sensing lines for measuring hydrogen concentration inside the containment - These lines are protected by remotely operated valves inside and outside the containment.

Initiating signals are logically combined to effect the required responses of Safeguards and support systems as shown in Figure 7.3-2 and as discussed below.

In every instance, two identical actuation signals are developed and applied separately via the functionally redundant A and B control trains.

7.3.1.1 Safety Injection Actuation Signal (SIAS)

SIAS is the key signal at a loss-of-coolant accident, initiating the basic functions necessary to re-cover and cool the core with borated water, isolate containment, and control the containment atmosphere temperature and pressure via the two containment air filtering and cooling units.

The principal operations which occur coincident with a SIAS include:

a. Containment isolation;

b. Auto-start of diesel-generators DG-1 and DG-2;

c. Sequential starting of Engineered Safeguards equipment (except the containment spray pumps and the two containment atmosphere cooling fans).

If acceptable voltage is available at 4160-volt buses 1A3 and 1A4 from their normal off-site power source, the 161-kV system, Safeguards loads are started automatically and sequentially in groups with minimum initial delay; the composition of load groups, order of connection, and time intervals are shown in Figure 8.4-2. In this case, the diesel-generators are not connected to buses 1A3 and 1A4, but are run in reserve.

If the voltage on bus 1A3 or 1A4 is less than a predetermined value, both buses are disconnected from the normal supply, unneeded loads at 4,160 and 480-Volts are disconnected from the system automatically as the diesels run up, and, when the diesel-generator speed and voltage reach operating range, the generator circuit breakers are closed and the Safeguards loads connected sequentially.

7.3.2 Safeguards Actuation Signals

The Safeguards signals logic is shown in Figure 7.3-1. Safeguards actuation signals result from the logical combination of initiating signals each of which is derived from a departure from the normal operating range of one of the following critical parameters:

a. Reactor coolant pressure (low-low) - PPLS;

b. Containment internal pressure (high) - CPHS;

c. Containment atmosphere radionuclide content (high), see Section 11.2.3 - CRHS;

d. Borated water tank level (SIRW tank low-low) - STLS.

Initiating signals are logically combined to effect the required responses of Safeguards and support systems as shown in Figure 7.3-2 and as discussed below. In every instance, two identical actuation signals are developed and applied separately via the functionally redundant A and B control trains.

7.3.2.1 Auto-start of Diesel-Generators

Automatic starting of diesel-generators DG-1 and DG-2 is initiated by either a PPLS or a CPHS. If acceptable voltage is available at 4160-V buses 1A3 and 1A4 from their normal 161-KV off-site power source, the diesel-generators are not connected to buses 1A3 and 1A4 but are run in reserve. A PPLS or a CPHS also initiates load shedding of selected 4160 Volt and 480-Volt loads (see Section 7.3.2.3).

If the voltage on either bus 1A3 or 1A4 is less than a predetermined value, the bus with inadequate voltage is disconnected from its normal sources. Motors and nonessential auxiliaries (i.e. lighting transformers) directly connected to that 4,160-Volt bus or to 480-Volt switch gear buses supplied by that bus are disconnected from the system as the associated diesel runs up, and when the diesel-generator speed and voltage reach operating range, the generator circuit breaker is closed automatically.

The automatic starting of a diesel-generator, the load shedding of direct connected motors, and the connection of the diesel-generator to bus 1A3 or 1A4 all occur upon loss of voltage of that bus regardless of the presence or absence of Safeguards actuation signals. As discussed in Section 8.4.1.2, the diesel-generators will not operate in parallel, (there being no bus-tie breaker between 4.16-kV buses 1A3 and 1A4 and interlocks prevent interconnection at the 480-Volt level), to ensure the two systems supplying Safeguards are independently operated.

7.3.2.2 Sequential Starting of Engineered Safeguards Equipment

If acceptable voltage is available at 4,160-Volt buses 1A3 and 1A4 from their normal off-site power source when a PPLS or a CPHS signal occurs, Safeguards loads are started automatically and sequentially in groups with minimum initial delay. The composition of load groups, order of connection, and time intervals are shown in Figure 8.4-2.

The load connection sequence is the same whether off-site normal or on-site emergency power supply is used. When a diesel is used there is an additional delay after the initiating Safeguards signal before load sequencing is started. The delay provides time during which the unit is run up and direct connected motor loads are shed.

If load sequencing is started on off-site power and that supply fails, the diesels (idling in standby) are automatically run up to operating speed, loads are shed, and load sequencing repeated to restart loads.

As shown in Figure 8.4-1, all Component Cooling Water Pumps, Raw Water Pumps, Charging Pumps, and Containment Air Recirculation and Cooling Unit Fans are included in the basic sequence of loads automatically started in response to a DBA that actuates both PPLS and CPHS. These components have both normal and emergency functions. In the emergency mode all available units in these categories are started; unneeded units may be subsequently shutdown manually by the operator.

7.3.2.3 Safety Injection Actuation Signal (SIAS)

An A and a B SIAS are derived from pressurizer low-low pressure (PPLS) or containment high pressure (CPHS) signals because either condition is symptomatic of significant coolant loss. In either case the logic basis is two-out-of-four. Pressurizer signals are produced by four pressure transmitters. Containment high pressure signals are produced by eight pressure switches, arranged in two sets of four, one for the A train and one for the B train.

To avoid initiating safety injection when the reactor system is depressurized intentionally, the PPLS control circuits must be blocked. Blocking is manual, alarmed while in effect, and is automatically reset when the reactor coolant pressure enters the operating range.

The passive, pressurized accumulator driven safety injection system described in Section 6.2.2 does not depend on SIAS for initiation, but simply on a drop in coolant pressure to a nominal 240 psig.

In addition to initiating safety injection, SIAS also initiates shedding of selected non-essential loads supplied from 480-Volt motor control centers and shedding of complete 480-Volt motor control centers serving loads which are not essential to support Safeguards system.

7.3.2.4 Containment Spray Actuation Signal (CSAS)

Containment spray operation is initiated by the same basic signals as safety injection, but in a different logic combination. CSAS results from coincidence of pressurizer pressure low-low and containment pressure high, both on a two-out-of-four basis. CSAS, in accordance with the sequencer time delay, starts SI-3A/B/C and VA-7C/D. The spray header valves are interlocked so that one valve will open if one pump starts. The second valve (HCV-344) will open only if SI-3B and SI-3C start.

During normal plant operations, the Containment Spray System is maintained in a standby status with all its components aligned for emergency operation. For emergency operation, all three spray pumps are started by the containment spray actuation signal (CSAS) via the sequencers. If normal power sources are lost and one emergency diesel generator fails to start, at least one spray pump is started by the sequencers. With only one spray pump operating, the spray header valves are interlocked to allow one spray header operation to protect the pump motor.

When the SIRWT level drops to 16 inches above the bottom of the tank, a recirculation actuation signal (RAS) (see Section 7.3.2.7) switches the spray pump suction from the SIRWT to the containment building sump.

7.3.2.5 Containment Isolation Actuation Signal (CIAS)

An A and a B CIAS are derived from the same logical combination of PPLS or CPHS which initiates SIAS. Thus, a pressurizer low-low pressure or containment high internal pressure initiates repositioning of isolation valves as discussed in Section 5.9.

7.3.2.6 Ventilation Isolation Actuation Signal (VIAS)

A Ventilation Isolation Actuation Signal is initiated by a SIAS or CSAS or Containment Atmosphere Radiation High Signal (CRHS). Thus, in effect, a VIAS will result indirectly from a PPLS or CPHS and directly from a CRHS which could occur with or without the presence of the other initiating signals.

A and B CRHS train signals are derived on a one-out-of-two basis from separate contact outputs from the containment and stack radiation monitors.

VIAS initiates closing of the containment pressure relief, air sample and purge system valves, if open. This action prevents release of significant radionuclides from the containment to atmosphere. An exception to automatic isolation of a containment release occurs in the specific case of containment leak rate testing. The containment may be depressurized through a vent path that does not automatically isolate upon a high radiation condition. Manual action will be required to terminate the release.

VIAS also initiates shedding of the containment purge fans, aligns the control room air conditioning system in the filtered air makeup mode and locks out the third stage cooling to limit diesel generator loading. An override switch is provided to restart the third stage cooling. Additionally, VIAS closes the CCW inlet and outlet valves on the Control Room air conditioning economizers (see Sections 9.10.2.4 and 9.10.4.4). In addition, operation of VIAS will initiate opening of the air supply and exhaust dampers in the safety injection pump rooms in preparation for safety injection pump operation.

7.3.2.7 Recirculation Actuation Signal (RAS)

When the initial source of borated water (the SIRW tank) is nearing depletion, a tank low-low level signal is used to realign the system automatically to draw borated water from the containment sump (see Section 6.2.4.3). The system is also automatically realigned for long-term operation at a reduced flow rate.

The suctions of the high-pressure safety injection pumps and containment spray pumps are diverted to the containment sump and the low-pressure pumps are shut down.

An A and B RAS are derived from SIRW tank low level signals (STLS) occurring with either a PPLS or CPHS. The logic basis for STLS is two-out-of-four obtained from separate sets of four SIRW tank level sensors.

7.3.2.8 Auxiliary Feedwater System

Two auxiliary feedwater pumps and four fail open isolation valves are utilized to automatically remove decay heat from the primary system in the event all main feed pump(s) trip causing a loss of feedwater to the steam generator(s). The auxiliary feedwater automatic initiation logic will supply water to the steam generator(s) provided there is no steam line break associated with that steam generator.

The primary sensing elements to detect the need for auxiliary feedwater are from the steam generator wide range level set points. A depressurized condition of a steam generator is detected from pressure or differential pressure between the two steam generators. An intact steam generator is determined by either the lack of a low pressure condition or by a higher pressure in the intact steam generator than in the ruptured steam generator. If either of these conditions exist coincident with a low water level, then auxiliary feedwater is delivered to the intact steam generator.

Four independent instrumentation and control channels with four safety grade racks and separate A.C. power supplies are provided.

Two racks (channels A and C) are installed in the electrical penetration room and the other two racks (channels B and D) in the switchgear room. Locating the redundant instrument racks in two different fire areas assures continued operation of the AFWS in the event a fire completely destroys one channel.

Four wide range level transmitters and four pressure transmitters are installed on each steam generator.

Contacts from the pressure, level and differential pressure modules combine to form a logic gate which controls the energization of (one channel per steam generator) the Auxiliary Feedwater auto initiation matrix relay.

Each parameter and its associated output relay contacts are alarmed in the control room and indicated in the instrument racks which enables the operator to identify and isolate the operation/malfunction of any channel.

A channel trip or failure is characterized by the de-energization of the bistable and the matrix relays, providing a fail safe configuration.

Trip action is automatic, with automatic reset when the parameter that caused the channel to trip resets.

The auxiliary feedwater system is normally operated in the main control room from panels CB-10, AI-66A and AI-66B unless the control room becomes unavailable due to some emergency. In this case all the operations of the auxiliary feedwater system can be controlled on panel AI-179 in the upper electrical penetration room of the auxiliary building with the exception of the FW-6 control switch, which can be controlled locally.

7.3.2.9 Offsite Power Low Signal (OPLS)

An Offsite Power Low Signal protection scheme is installed on the 4.16 KV buses 1A3 and 1A4 to provide protection during accident conditions. The complete description of this system is included in Section 8.4.3, "Automatic Transfer and Load Shedding Controls".

7.3.2.10 Steam Generator Isolation Signal (SGIS)

Automatic isolation of the steam generators is accomplished to prevent the blowdown of more than one steam generator in the event of a main steam line break (MSLB) outside containment and to limit containment pressurization during an MSLB inside containment.

Isolation is accomplished by automatic closure of the main feedwater isolation valves (HCV-1385 and HCV-1386), the backup feedwater valves (HCV-1103 and HCV-1104) the feedwater bypass valves (HCV-1105 and HCV-1106), and the main steam isolation valves (HCV-1041A and HCV-1042A) and bypass valves (HCV-1041C and HCV-1042C).

An A and B SGIS (see Figure 7.3-1) are derived from a logical combination of containment pressure high (CPHS) or low steam generator pressure (SGLS) because either condition is symptomatic of an MSLB. The initiating signals are both derived from a two-out-of four logic basis. The combining logic for SGIS is arranged such that either channel of SGLS or CPHS will initiate both SGIS trains.

The division of valves between SGIS channels (and redundant relays in each channel) ensure that no single active failure can prevent the isolation of at least one steam generator.

7.3.3 Engineered Safeguards Control Panels AI-30A and AI-30B

7.3.3.1 General

Two functionally redundant Safeguards control trains, A and B, are provided to ensure high reliability and effective in-service testability. The A and B trains were designed for individual reliability and maximum attainable mutual independence both physically and electrically.

Either train, operating alone, can automatically actuate minimum Safeguards and essential supporting systems.

As reflected by Figures 7.3-1 and 7.3-2, A and B train segregation begins at the contact inputs to the trains. Such contacts, primary sensor or transmitter outputs, are arranged in individual A and B train logic matrices which produce Engineered Safeguards actuation signals. Physical and electrical segregation of the trains is carried out to remote A and B auto-start relays of the individual Safeguards loads. Contacts on A and B relays are wired in parallel into circuit breaker control circuits to ensure automatic start on demand.

Engineered Safeguards control panels AI-30A and AI-30B, installed in the control room, house the bulk of the control equipment for the A and B trains, respectively. Devices not installed in the panels include primary sensors and transmitters, individual equipment control circuits, and load auto-start relays.

Panel assemblies AI-30A and B are separate structures. They are installed in the control room to provide direct access by the plant operators and a favorable, controlled environment at all times. Control devices are conventional control switches, lamp indicators, time delay relays, and electro-magnetic relays. Each panel assembly is subdivided into separate enclosures as identified in Table 7.3-1. Also tabulated are the relationships of each panel section to the A and B control trains, and to the control power system. In the table, each horizontal line represents a steel partition, provided to segregate control subsystems. Control power buses are carried across the top of the panel assemblies and each is in a separate enclosure and insulated throughout.

Table 7.3-1 - "Control Panels AI-30A and AI-30B" Control and Test

Panel Assembly	Panel Section	Function	Control System	Control Power System
AI-30A	DG-1	Diesel-Generator DG-1	A	D-C 1
		Control and Test	B1	D-C 2
	S1-1	Load Sequencer S1-1	A	D-C 1
	S1-2	Load Sequence S1-2	B1	A-C 2
	Safeguards Panel A	Logic processing of A contact inputs to	A	D-C 1
		produce A and A1 (backup) actuation signals	B1	D-C 2
AI-30B	Safeguards Panel B	Logic processing of B contact inputs to	B	D-C 2
		produce B and B1 (backup) actuation signals	A1	D-C 1
	S2-2	Load Sequencer S2-2	A1	A-C 1
	S2-1	Load Sequencer S2-1	B	D-C 2
	DG-2	Diesel-Generator DG-2	B	D-C 2
		Control and Test	A1	D-C 1

As indicated by Table 7.3-1, A train signals are developed within panel assembly AI-30A, and A signals are used as primary initiation signals in that panel, with B signals as backup; the reverse is true for AI-30B. Signals indicated as backup are buffered from primary signals.

7.3.3.2 Diesel-Generator Panel Sections

Panel sections DG-1 and DG-2 are associated with emergency diesel-generators DG-1 and DG-2, respectively. These sections provide facilities for automatic start, manual operation, supervision of the availability and operating status of the engine, generator and auxiliary systems, and testing of the units. Additionally, a wattmeter, ammeter, volt-meter and frequency meter for each diesel are installed on the main electrical control board, panel CB-20 (see Section 7.6.2).

Display Section

The section consists of a main annunciator with light and reset button. This annunciator indicates the status of the diesel as a unit with window engraving suitable for distant viewing to alert the control room operator to off-normal conditions. In this event an audible alarm sounds. The cause of trouble would, in most cases, be indicated by the lower group of modules each consisting of four indicating lamps. These modules indicate off-normal conditions for all auxiliaries associated with the diesel and include nameplate engraving for each quadrant for close viewing.

Master Control and Test Section

This is primarily a test section consisting of three basic areas as follows:

a. Relay area: This includes all relays, including both manual and self reset, which initiate auto-start idling and full speed of the diesel, the protection override and the auto-close relays for the diesel breaker; additional relays for time delay and load shed trip are also included.

b. Instrument area: This includes three ammeters, three voltmeters and a frequency meter for the diesel.

c. Master control area: The primary purpose of this area is to permit testing of the diesel, the load shed, the breaker protection override and the breaker auto-close circuits (see Section 7.3.4.2).

7.3.3.3 Automatic Load Sequencer Sections

As indicated, automatic load sequencers are duplicated in each of panel assemblies AI-30A and AI-30B, and thus there is a total of four sequencers. Since the arrangement is functionally symmetrical for AI-30A and B, only the former is described in detail.

Automatic sequencers or S1-1 and S1-2 have identical functions; they operate independently on an or logic basis to energize those Safeguards and support system loads supplied directly from 4,160-Volt bus 1A3, and through load centers connected to bus 1A3 (see Figure 8.4-1 for bus arrangements and load lists).

Essential independence of sequencers S1-1 and S1-2 is provided by means of the following:

a. Separate panel section enclosures;

b. Different, redundant, initiation signals: Operation of S1-1 is initiated by directly wired A signals from Safeguards panel A; operation of S1-2 by B1 (buffered B) signals developed in Safeguards panel B;

c. Different control power: S1-1 is associated with d-c system number 1; S1-2 with a-c power system number 2, supplied via an inverter from d-c power system number 2;

d. Separate remote auto-start relays: S1-1 with a d-c relay for each Safeguards pump and fan; S1-2 with a corresponding a-c auto-start relay.

Sequencers S1-1 and S1-2 use different methods for achieving auto-start sequence timing. S1-1, associated with a d-c control-power system, uses a time delay relay for each Safeguards pump or fan; the relays independently time out starting with the A train initiation signal. Sequencer S1-2, associated with a-c control, has solid state timers, started by a B1 (buffered B) signal.

Any one sequencer (S1-1, S1-2, S2-1, or S2-2), operating alone, starts minimum Safeguards. Operation of one category S1 and one category S2 sequencer starts all Safeguards.

The following general description of the sequencer front panel arrangement applies to all as they are similar. The display section is the upper part of the panel and the timer and relay section and master control and test section and auto-start output section are below.

Display Section

This section provides a main annunciator with light and acknowledge button. This annunciator indicates the status of the sequencer with nameplate engraving suitable for distant viewing to alert the control room operator to any off-normal condition. In the event of trouble an easily identifiable audible alarm sounds. A lower group of modules each consisting of four lightable quadrants or indicating lamps indicates the status of each item of the Safeguards(s) equipment and also indicates whether power is available at the buses and whether the 480-Volt bus-tie breakers are open or closed. Modules representing Engineered Safeguards indicate status by both pattern and color as follows:

a. The lower left hand corner of a module lights up in green whenever particular Engineered Safeguards equipment represented by that module is disconnected from its sequencer.

b. The upper left hand corner of a module lights up in amber when the sequencer timer is in the "auto" or "Ready to time out" mode. When the sequencing begins, the light goes off.

c. The upper right hand corner of a module lights up in amber whenever an associated timer initiates a signal to automatically start particular Engineered Safeguards equipment represented by that module.

d. The lower right hand corner of a module lights up in amber whenever particular Engineered Safeguards equipment represented by that module successfully starts in response to a signal initiated by its associated timer.

Relay Area

This initiates those relays which initiate starting of the sequencers.

Test Area

This covers all necessary switches for simulating sequencer autostart signals and for connecting the output of the sequencer into the plant computer. In this manner the computer provides a record of time sequence operation of all timers associated with the sequencer.

Sequencer Area

This area comprises all timers required for sequential starting of Engineered Safeguards. Each timer is individually adjustable.

Auto-Start Output Switch Area

This consists of groups of individual on-off switches which connect or disconnect each individual items of the Engineered Safeguards equipment from its associated timer. Thus, if for any reason a pump has to be disconnected from the auto-start system, this can be accomplished by turning its isolation switch to the off position. These switches are key operated.

7.3.3.4 Supervision of Circuits and Devices

General

Supervisory circuits are used to provide a continuous check of the condition of circuits which form an essential part of the Engineered Safeguards control. The supervisory circuits detect and indicate an open circuit, short circuit and loss of circuit power supply. When the circuit under supervision is triggered by the closure of an initiating contact, the supervisory circuit also detects the closure of the initiating contact. Conversely, this feature also serves as an indication should the contact fail to reset on demand. Supervision is confined to the following categories of circuits:

a. Circuits which are essential parts of the control and are such that the loss of control potential, or the occurrence of open or short circuits would not otherwise be evident to the operator;

b. Derived circuits which cannot be readily tested as part of a regular system or unit test during plant operation at power.

Based on the above criteria, supervisory circuits are provided for:

a. A and B Safeguards initiation trains for:

    1. Pressurizer low pressure (PPLS);

    2. Containment high pressure (CPHS);

    3. Safety injection and refueling water tank low level (STLS);

    4. Containment radiation high (CRHS).

b. Steam generator low steam pressure (trains A and B);

c. Safeguards actuation circuits A, A1, B and B1 for SIAS, CSAS, VIAS, CIAS and RAS within panels AI-30A and AI-30B (see Figure 7.3-2);

d. Diesel and sequencer actuation circuits within panels AI-30A and AI-30B.

Supervisory Wiring Techniques

Wiring is designed and installed to ensure that the circuit under supervision is given maximum coverage as discussed below.

a. Matrix circuits: To give end-to-end short circuit, open circuit, and loss of power supervision, a combination of supervisory lamp(s) is employed (for a typical example see Figure 7.3-3). The supervisory lamp is a low current type connected in series with the initiating relay and continually energized under normal circuit conditions. On loss of supply the lamp deenergizes. To give open circuit, short circuit or "contact sticking" indication, supervisory lamps are connected across initiating contacts. For maximum circuit coverage, supervisory lamps are wired back as close as possible to the supervised device. The lamps are normally lit. Various combinations of lamps would be extinguished under fault conditions depending upon the nature of the fault.

b. Non-matrix circuits: The series and series-parallel actuation circuits within panels AI-30A and AI-30B are simpler than the matrix circuits; adequate supervision is achieved using a series supervisory lamp only. Again the wiring is so arranged that maximum possible supervision coverage is obtained.

Supervisory Alarms and Indication

The supervisory lamps associated with the Safeguards initiation and buffered channels are all mounted on the fronts of panels AI-30A and AI-30B. The eight main signals and buffered backup signals are A, A1, B and B1 for PPLS, CPHS, STLS, and CRHS (see Figure 7.3-2).

The A and B1 train supervisory lamps are displayed on AI-30A, the B and A1 train lamps on AI-30B.

The four load sequencer auto-start actuation circuits (one per sequencer) and the four diesel auto-start actuation circuits (two per diesel) are supervised. The supervisory alarms are displayed on annunciators on the associated sequencer and diesel panel sections of AI-30A and AI-30B.

7.3.4 Equipment and System Test and Maintenance

7.3.4.1 General

Periodically the performance of the Safeguards trains and the emergency power supplies must be verified. To assure the four safety injection tank isolation valves identified as HCV-2914, 2934, 2974 and 2954 cannot inadvertently close during normal operation, positive measures are taken to ensure the valves remain open. Low pressure safety injection flow is assured at all time through FCV-326.

It is necessary to determine that all system elements perform in the required manner, and to find and immediately correct any performance deficiencies. Periodic tests also have the function of exercising equipment in all categories.

The most significant tests would be of the entire train, initiated by perturbing the monitored plant variables that would initiate Safeguards operation in actual accidents. In practice, of course, this is not feasible; train tests must be performed with the plant in service, and plant shutdown and equipment damage must be avoided. Test circuits are designed, therefore, for testing the system in overlapping sections, using the feasible minimum of bypassed and blocked actions.

7.3.4.2 Test Sections

Testing of Safeguards controls and emergency power supplies falls into four main categories:

a. Safeguards initiation and actuation circuits;

b. Load auto-start sequencers;

c. Diesel-generators;

d. Other system components.

Safeguards Initiation and Actuation Circuits

Great care must be taken during the testing of these circuits to ensure that:

a. No circuit is actuated that will trip the plant; most containment isolation valves are in this category;

b. No circuits are activated that could damage system components or other equipment;

c. The testing circuitry or procedure does not reduce the availability or effectiveness of the Safeguards system below an acceptable level.

All Safeguards systems are basically actuated by the action of four relays in panel AI-30A (86-A/PPLS, 86-A/CPHS, 86-A/STLS, 86-A/CRHS) and four relays in panel AI-30B (86-B/PPLS, 86-B/CPHS, 86-B/STLS, 86-B/CRHS), (see Figure 7.3-2). The signals that actuate the above four relays in AI-30A are called the A train signals, and the signals which actuate the above four relays in AI-30B are called the B train signals.

The test circuits are designed to energize, one at a time, all eight of the above relays by simulating the effect of an incoming A or B train signal. A key operated test switch is provided with each relay circuit. This test switch has a contact which is in parallel with the initiation logic matrix. Thus, closure of the test switch on 86-A/PPLS simulates the effect of two-out-of-four logic pressurizer low pressure signals in train A only.

Test keys are provided which are normally in a special lock located on panel AI-30A and AI-30B. Removal of the keys is annunciated.

Certain relays (CPHS and PPLS) when energized, automatically cause their associated diesel and associated sequencer to start. The operator has the option of blocking the output from the sequencer by operating the sequencer output isolating switches.

Only one sequencer panel is taken out of service by means of the isolating switches at one time. The three others remain in service.

Automatic Load Sequencers

Two automatic load sequencers are provided in each of panels AI-30A and AI-30B (see Figure 7.3-2). The pair of sequencers in each panel have identical functions but operate independently.

Sequencers can be isolated one at a time and functionally tested as an individual sub-system, or not isolated and tested as part of the system. Supervision is provided to verify each automatic response and alarms indicate blocking of an individual Safeguards auto-start circuit.

Successful sequencer load starting operations are also indicated by lights, one associated with each connected load to make it easy to spot failures to start, and are logged by the computer.

Diesel-Generators

Panel sections D-1 and D-2, of panels AI-30A and AI-30B, respectively, provide for automatic start, manual operation, supervision of availability and operating status, and test of the diesel-generator units. Performance can be verified from panel sections D-1 and D-2 for:

a. Diesel-generator unit, including auxiliaries;

b. Diesel-generator automatic starting controls;

c. Automatic load-shedding circuits;

d. Diesel circuit breaker and automatic breaker closing circuits.

Test switches are installed on each panel section, D-1 and D-2. These switches test the performance of the auto start circuits, automatic diesel breaker closing circuits and automatic load shedding circuits.

7.3.4.3 Periodic On-Line Testing

The following methods of periodic on-line testing of the four basic Engineered Safeguards circuits are provided.

a. Testing Containment Pressure High (CPHS)

Each of the four redundant pressure sensing lines can be isolated and tested individually by closing its isolation valve and pressurizing its line via the test valve through to the pressure switches. The three remaining pressure sensing lines are operable during the test.

The "A" train lockout relays on panel AI-30A can be initiated by test switch TS-A/CPHS and the subsequent circuits can be tested right down to the sequential start of the Safeguards motor. During the test the Safeguards motors will still operate automatically in the event of a real accident via signals from the "B1" train.

Upon completion of the "A" train test, a similar test can be run for the "B" train.

b. Testing Pressurizer Pressure Low (PPLS)

Each of the four redundant current loop circuits that senses pressurizer low pressure can be tested individually. A plug-in test resistance can be inserted at the meter relay A/PIA-102Y, B/PIA-102Y, C/PIA-102Y or D/PIA-102Y to simulate a low pressure condition. The remaining loops are operable during the test.

The lockout relays, etc., associated with this circuit can be tested in a similar manner to that described for the containment pressure high circuitry.

c. Testing Containment Radiation High (CRHS)

The three process radiation monitoring channels (containment, stack and swing channel) that trigger the Radiation High Safeguards system (CRHS initiating VIAS) can be tested individually by operating the check source pushbutton located in the control room.

A test switch is provided on each sequencer panel to trip the CRHS lockout and verify isolation of containment ventilation isolation valves, switch the control room air conditioning system to the "filtered air make-up" mode of operation, and limit the Control Room Air Conditioner to 2/3rd capacity.

d. Testing Safety Injection and Refueling Water (SIRW) Tank Low Level (STLS)

Each of the four redundant level pressure sensing lines for A train can be tested individually by closing its isolation valve and bleeding off air through the test connection until its pressure switch operates.

The three remaining level pressure sensing lines are operable during the test.

The "A" train lockout relay on panel AI-30A can be initiated by test switch TS-A/STLS and its operation observed.

Upon completion of the "A" train test, a similar test can be run for the "B" train.

The following methods for periodic on line testing of the two Safeguards actuation relay operations requiring coincident accident conditions are provided.

a. Testing Containment Spray (CSAS)

The "A" train lockout relays on AI-30A can be initiated by test switches TS-A/PPLS and TS-A/CPHS and the subsequent circuitry can be tested right down to the opening of the spray valves. A test switch is provided on each sequencer panel to trip the CSAS Lockout and verify proper sequencer function for the containment spray pumps and containment cooling fans. The spray pumps and containment cooling fans are not started on this test, but will still operate automatically in the event of a real accident via signals from the "B1" channel.

Upon completion of the "A" train test, a similar test can be run for the "B" train.

b. Testing Recirculation (RAS)

The "A" train lockout relays on AI-30A can be initiated by test switches TS-A/PPLS and TS-A/STLS and the circuitry tested right down to the operation of the recirculation valves. The test is then repeated for the CPHS and STLS coincident combination using test switches TS-A/CPHS and TS-A/STLS. During both tests the redundant recirculation system will still operate automatically in the event of a real accident via signals from the "B" train.

Upon completion of the "A" train tests, similar tests can be run for the "B" train.

All ESF channels are fully annunciated and indicated in the control room whenever they are taken off their normal standby mode for purposes of test or maintenance.

All wiring associated with the individual matrix circuits is continuously supervised by means of indicating lights. Testing of individual channels is indicated by the extinguishing of the associated matrix light(s).

Isolation of the CPHS pressure sensing tubing by means of the isolating valves is alarmed on AI-30A/B.

Testing of meter relays, which are the signal processors for PPLS signals, is achieved by inserting a plug-in test resistance at each relay. The test plugs are under administrative control. Operation of a meter relay is annunciated and indication by the individual matrix lamps is also provided on panel AI-30A/B.

If a meter relay is taken out of circuit for any reason, this fact is annunciated by means of the contact opening alarm on panel CB-1/2/3 annunciator.

A blocking circuit is provided for the PPLS matrix system. Whenever the blocking circuit is initiated, an alarm is sounded.

The containment high radiation system is tested by means of remotely controlled check sources which are operated by individual pushbuttons at the radiation panels (AI-33A and AI-33B). Additionally, test switches are provided on AI-30A and AI-30B which may be used to trip CRHS.

Operation of all associated lock-out relays are also annunciated on AI-30A&B.

The operation of the actuation relay on each sequencer panel is alarmed. In addition, the operation of individual output circuits is fully indicated. Means are provided for isolating a complete sequencer or any individual output circuit using key operated isolation switches. In all cases this isolation function is alarmed.

Similarly, on the diesel panels key operated mode switches are provided which isolate the diesel auto start or the diesel breaker auto close circuitry. Operation of these switches is alarmed.

In addition, diesel and diesel breaker test switches are provided and operation of these switches is alarmed and indicated.

Certain groups of safety related equipment are controlled from other panels within the control room (i.e., AI-43A, B, CB-1, 2, 3, CB-4, AI-44). Since operation of this equipment would cause the plant to shutdown, means are provided to block the test signals originating from the safeguard panels. In all cases, operation of the blocking device is alarmed.

NOTE: Circuitry is arranged such that testing is performed on an "A" or "B" train basis. Receipt of a "real" signal during test will initiate necessary Safeguards via the redundant train.

Control Switches for motor operated Safeguards devices have positions to disable the circuit during periods of maintenance, etc.

Safety related motor operated valves give an alarm condition in the control room due to the loss of power or whenever their thermal overload operates.

All ESF channel matrices are separately indicated in the control room. If an accident condition occurs then it can be determined which matrix initiated the protective action. These matrices actuate lock-out relays which remain locked out even after the accident signal is removed. They can only be reset by manually operating the relay reset handle. Lock-out relays associated with each train are separately annunciated when operated.

7.3.5 Failure Analysis

7.3.5.1 General

A principal design objective for Engineered Safeguards systems is to ensure an acceptable level of performance in the presence of any credible failure. Careful consideration has been given, therefore, to the effects of control failures on system performances. The minimum level of Engineered Safeguards performance acceptable for the design basis accident (DBA), termed minimum Safeguards, is discussed in Sections 6 and 14.

Control failures are discussed in general order of increasing impact on Safeguards systems performance. Failures involving power supply are treated briefly in this section but are discussed in detail in Section 8.

7.3.5.2 Single Failures-No Loss of Performance

Duplication of essential control functions in the segregated A and B control trains permits identification of certain categories of random, single failures that reduce control function redundancy but have no effect on Safeguards systems performance. With reference to Figure 7.3-2, these categories are:

a. Blown fuse;

b. Inoperative relay, any type;

c. Inoperative load sequencer;

d. Open circuit;

e. Short circuit;

f. Ground.

In these categories single failures are restricted to either the A or B train; resulting loss of control function in one train is backed up by the redundant train. Thus, the A and B trains are considered independent for such faults. The worst cases with respect to loss of control function involve single failures leading to loss of parts of the control power supply system, as summarized in Table 7.3-2.

Table 7.3-2 - "Effects of Control Power Failures on Safeguards Operation"

		Loss of Safeguards Performance	
Fault	Resultant Failure	Control System	Overall Operation
Single, D-C/A-C Inverter, Main, Cable or Bus	A-C Instrument Bus A A-C #1 (Panel AI-30B)	A-C Sequencer S2-2	None
	A-C Instrument Bus B A-C #2 (Panel AI-30A)	A-C Sequencer S1-2	None
	A-C Instrument Bus C	None	None
	A-C Instrument Bus D	None	None
Single D-C Feeder or Bus	D-C # 1 (Panels AI-30A & AI-30B)	A and A1 Signals D-C Sequencer S1-1	None
	D-C # 2 (Panels AI-30A & AI-30B)	B and B1 Signals D-C Sequencer S2-1	None
	D-C Main Bus #1	A-C Inst. Buses A and C AC #1 (Panel AI-30B) A-C Sequencer S2-2	None
	D-C Main Bus #2	A-C Inst. Buses B and D AC #2 (Panel AI-30A) A-C Sequencer S1-2	None

The general arrangement of a-c and d-c control power systems is shown in Figure 8.1-1 and the design is discussed in Section 8.3.

7.3.5.3 Single Failure-Acceptable Loss of Performance

Failures that reduce the availability of power supplies for operation of Safeguards and support systems have no effects on the control system, but directly reduce Safeguards performance. Single failures in this category are summarized in Table 8.4-3 and discussed in Section 8.3 and 8.4.

The worst-case single failure of this type, an unclearable fault on 4.16-kV bus 1A3 or 1A4, reduces Safeguards availability to minimum Safeguards.

7.3.5.4 Precautions Against Failures with Unacceptable Consequences

Random Multiple Failures

As discussed above, system redundancy provides for acceptable levels of Safeguards performance with single failures. Provisions are made for immediate detection and alarm of such a failure to permit immediate repair and prevent cascading of single failures.

The design features adopted to minimize the probability of an undetected failure, and to facilitate maintenance, include:

a. Control device and circuit supervision (see Section 7.3.3.4);

b. Facilities for in-service testing of components and virtually complete Safeguards trains (see Section 7.3.4);

c. Distinctive visual identification of Safeguards control systems throughout the installation.

Every effort is given to attaining maximum coverage by the supervisory system, and supervision is supplemented by periodic component and system tests. Distinctive marking of Safeguards control devices and circuits is intended to expedite fault finding and repair, and prevent mistaken or inadvertent disturbance of the system.

Non-Random Multiple Failures

Failures in this category include multiple performance failures with a single cause. The plant tests that preceded operation were designed to uncover design deficiencies, which, if found, are corrected. The test program included imposition of faults and induced malfunctions on the Safeguards control systems. However, it is possible that a group of identical components could have a common weakness evident only under extreme conditions. A prudent counter measure is use of diversity of principle among redundant devices. This has been applied to the generation of initiation signals and the implementation of automatic load sequencing.

The following single causes of multiple failures that could negate the effectiveness of redundant controls have been considered:

a. Environmental factors;

b. Maintenance mistakes such as maladjustment of a group of similar, redundant devices;

c. Design weakness of similar components;

d. Component or channel interdependence.

The systems design considers the adverse environmental conditions of the design basis accident, earthquake, tornado, missiles, radiation, temperature and humidity.

With respect to fire damage, provisions were directed toward prevention and control and were subject to review and approval by the Nuclear Energy Property Insurance Association (NEPIA). Provisions include:

a. Exclusive use of thermosetting cable insulation systems, subject to flame-resistance qualification tests (see Section 1.4.8.2);

b. Use of non-combustible construction materials;

c. Careful attention to cable routing, segregation by function, ventilation, and cable tray loading;

d. A full coverage, zoned, fire detection system (see Section 9.11);

e. Automatic fire doors, and fire fighting equipment.

In view of the above, the occurrence of an uncontrolled fire within the plant is extremely unlikely. However, should one occur in a sensitive area, such as the control or cable spreading room and if at the same time Safeguards operation were required, manual control would be necessary (see Section 7.3.6).

Procedural and design precautions against maintenance errors include those enumerated and discussed above, briefly:

a. Written maintenance procedures;

b. Adequate circuit monitoring by means of supervisory devices;

c. Adequate in-service test facilities and procedures;

d. Distinctive visual identification of control devices and circuits.

In addition, the control devices selected are of types widely used and proved in power plant service, and, as far as feasible, are standardized for the plant by manufacturer and model.

Provisions are included to protect the Safeguards control system against the effects of abnormal power supply voltage transients. Safeguards control power is drawn only from the four ac instrument buses, and the two dc control systems, as shown in USAR Figure 8.1-1. Each of the four ac instrument buses is supplied via an independent inverter from the dc main buses, and therefore, does not depend directly on the 60 Hz auxiliary power system for supply. Inverters are thus buffered by the dc system from the plant auxiliary power supply system with respect to normal voltage transients. Inverter frequency is synchronized to system frequency. On loss of the synchronous reference source each inverter individually reverts to an internal frequency reference.

Voltage on the dc control power buses is stabilized by the batteries and by the design of the battery chargers. Therefore, voltage transients on the 60 Hz supply system cannot be reflected in the dc system.

7.3.6 Control Provisions Outside Control Room

In case of a fire, in the cable spreading room or control room, or if any other event leaves the control room untenable, the plant can be safely shutdown using the guidance provided in an Abnormal Operating Procedure that address the consequences of a fire.

7.4 REGULATING SYSTEMS

7.4.1 Reactor Coolant Pressure Regulating System

7.4.1.1 Design Bases

The reactor coolant pressure regulating system maintains system pressure within specified limits by the use of pressurizer heaters and spray valves. Pressurizer pressure sensors provide input to the system.

A high pressurizer pressure indication functions to open the pressurizer spray valves on a proportional basis, thereby reducing pressure. A low pressurizer pressure indication functions to energize heaters on a proportional or group basis to increase pressure. An increase in pressurizer level energizes the backup heaters; a low pressurizer water level indication de-energizes all heaters.

Two channels of control are provided and the controlling channel is selected by a switch. Manual control of the heaters and spray may be selected at any time.

7.4.1.2 System Design and Operation

Two independent pressure channels provide suppressed range (1500 to 2500 psia) signals for control of the pressurizer heaters and spray valves. The output of either controller may be manually selected to perform the control function. During normal operation, a small group of heaters is proportionally controlled to maintain operating pressure. If the pressure falls below the proportional band all of the heaters are energized. Above the normal operating range the spray valves are proportionally opened to increase the spray flow rate as pressure rises. A small, continuous flow is maintained through the spray lines at all time to keep the pipes warm and reduce thermal shock as the control valves open and to ensure that the boric acid concentration in the coolant loops and pressurizer is in equilibrium.

Output from the two pressure control channels are recorded in the control room and provide independent high and low alarms.

Two independent level channels provide pressurizer level signals for two specific functions:

a. A low level signal from either channel de-energizes all heaters;

b. A high level signal from the controlling channel energizes the backup heaters.

The control and alarm pressure setpoints are shown in Figure 7.4-3.

7.4.1.3 System Evaluation

Two independent channels are available for automatically regulating the pressurizer heaters and spray valves. Either channel may be used to control the pressure in the system, and the output from both channels is recorded in the control room. Independent high and low pressure alarms are provided.

The system also allows the operator to manually bring certain selected backup pressurizer heaters into service from the control room without having to reset the accident signal lockouts.

7.4.2 Pressurizer Level Regulating System

7.4.2.1 Design Bases

Pressurizer level is maintained by the action of the chemical and volume control system (see Section 9.2). The level setpoint is programmed as a function of coolant average temperature (T_{avg}). A low level signal functions to reduce letdown flow proportionally and to start the two non-operating charging pumps sequentially. A high level indication functions to increase letdown flow proportionally by opening the letdown control valves and stopping all but one charging pump and energizing the backup pressurizer heaters. There are two independent automatic control channels with channel selection by means of a manual control switch. Automatic control is normally used during operation but manual control may be utilized at any time.

7.4.2.2 System Design and Operation

The operating level of the pressurizer is programmed as a function of power to accommodate plant load changes and transients to minimize the changes in reactor coolant system volume (see Figure 7.4-4).

The level programmer establishes a program level which is directly proportional to coolant average temperature, over the operating range of T_{avg}. The average temperature signal used by the level programmer is the signal used by the reactor regulating system.

The level controller compares the measured and programmed level signals and generates a proportional signal for regulating the letdown control valves. In addition, the level controller functions to start or stop additional charging pumps at low or high level setpoints and deenergizes or energizes the backup pressurizer heaters on low or high levels. The outputs of either of two automatic control channels may be selected by the operator for level control in addition to manual control.

Controller action and program level are described in Sections 4.3.7 and 9.2.2.2.

7.4.2.3 System Evaluation

Two separate level control systems are provided with redundant level transmitters and controllers. The controllers are located in the main control room. Both automatic and manual control of level is provided. Three charging pumps and two letdown control valves provide redundant means of increasing or decreasing reactor coolant system inventory. The variable pressurizer level control program maintains the proper coolant inventory as required during plant load changes.

The level control channels also act to energize the pressurizer heaters on high level and shutdown the pressurizer heaters on low level to prevent energized heater uncovery.

7.4.3 Feedwater Regulating System

7.4.3.1 Design Bases

The feedwater regulating system maintains steam generator downcomer level within acceptable limits by positioning the feedwater regulating valves supplying each steam generator (see Figure 7.4-5).

Automatic control of feedwater is provided when the plant is above 15 percent power. Steam flow, feedwater flow and downcomer level are used in a three-element controller on each steam generator to maintain the preset level during steady state and transient operation.

Manual control of feedwater flow may be selected by the operator at any time. In the event of a reactor/turbine trip the feedwater regulating valves are automatically ramped down to the approximately 8 percent open position (approximately 11% of full flow); this is adequate for decay heat removal through the turbine bypass valve at normal reactor coolant operating temperatures.

7.4.3.2 System Design and Operation

Automatic Mode

The two steam generators are operated in parallel. Each steam generator has a three-element controller using feedwater flow, steam flow (corrected for pressure) and downcomer level as input. The output of each controller provides a pneumatic signal to position the respective feedwater regulating control valve. Two overrides are provided:

a. Upon turbine trip, the feedwater control valves are automatically closed to obtain a linear ramp to decrease valve position to approximately 8 percent open within approximately 20 seconds following the trip.

b. When an abnormally high steam generator level is sensed by an independent downcomer level sensor, a signal is sent to close the associated feedwater control valve and a control room alarm is annunciated.

Manual Mode

The manual control of the feedwater regulating system must be selected by the operator when plant power is below 15 percent. When in manual control, the operator in the control room can:

a. Position each feedwater regulating control valve;

b. Open or close each feedwater stop valve;

c. Position each feedwater bypass regulating valve.

Auxiliary Feedwater Flow

The operator can at any time control operation of the two auxiliary feedwater pumps and position each auxiliary feedwater regulating valve (see Section 9.4).

7.4.3.3 System Evaluation

Conventional three-element, feedwater control is used with fail as-is feedwater control valves. Manual override of the automatic control is always available. Remote manual bypass valves and manual feedwater stop valves provide backup for feedwater valve failure (see P&ID 11405-M-253).

7.4.4 Steam Dump and Bypass System

7.4.4.1 Design Basis

The steam dump system (see Section 10) provides a means of dissipating excess nuclear steam supply system (NSSS) stored energy and sensible heat following a turbine trip without lifting the safety valves. Steam is discharged from the main steam lines to the condenser via the steam dump and bypass valves. The steam dump and bypass valves are sized to prevent the steam generator safety valves from opening following a turbine trip at full load. In automatic, the steam flow is initially regulated by the dump and bypass valves in response to the average reactor coolant temperature and after T_{avg} is reduced the steam bypass valve is controlled based on steam generator pressure.

7.4.4.2 System Design

A block diagram of the steam dump and bypass system is shown in Figure 7.4-6.

The system includes the following inputs:

a. T_{avg} (from reactor regulating system);

b. Steam header pressure;

c. Turbine trip (contacts in steam dump permissive switch);

d. Loss-of-condenser vacuum (contacts).

Outputs of the system are:

a. Steam dump valve position signal;

b. Turbine bypass valve position signal.

7.4.4.3 Operation

The steam dump controller generates a suppressed range signal proportional to (T_{avg} - 532°F); the signal characteristics are shown in Figure 7.4-6. Upon receipt of a turbine trip signal via the steam dump permissive switch, this signal is supplied to open the steam dump valves and is an input to the turbine bypass auctioneering unit to simultaneously open the bypass valve. The position of the steam dump and bypass valves is proportional to the signals supplied to them, providing controlled relief of excess pressure.

Should reactor power be sufficiently high at trip, the steam dump quick-opening override bistable causes the dump and bypass valves to open immediately.

The steam dump valves close proportionately as T_{avg} is reduced. The valves close completely at 535°F; they remain closed unless T_{avg} increases again to more than 540°F.

The steam bypass pressure controller generates a suppressed range signal proportional to secondary pressure over the approximate range of 895 to 905 psia (corresponding to fully closed and fully open bypass valve).

An auctioneering unit transmits the signal from the steam dump controller or the steam bypass pressure controller, whichever is greater, to the turbine bypass valve positioner. Loss of condenser vacuum prevents the bypass valve from opening.

The operator may control reactor coolant temperature during plant cooldown by manually controlling the position of the steam dump and bypass valves.

7.4.4.4 System Evaluation

Automatic or manual control of the steam dump and bypass valves is provided in the main control room. Control panel lights indicate valve position.

Inadvertent opening of the dump valves is prevented by interlocks requiring that the turbine has been tripped before the dump valves can be opened automatically. Excessive reactor coolant system cooldown by the dump valves when in automatic control is prevented by a narrow-range temperature signal which has a minimum output corresponding to approximately 515° F.

7.4.5 Turbine Runback

7.4.5.1 System Operation

Automatic turbine runback has been discontinued. Manual control is now used to reduce turbine power in the event of a dropped CEA and the associated reduction in core power. This allows the operator to maintain a balance between the reactor and turbine power as the system is brought down.

7.4.6 Turbine-Generator Control System

7.4.6.1 Design Basis

The turbine-generator control system (also see Section 10.2.4) is the means by which the turbine-generator is made to meet the electrical load demand placed upon it. The turbine control valves are normally manually positioned, in addition the turbine first-stage pressure, turbine speed, and electrical load are used as the control indices.

7.4.6.2 System Design and Operation

The turbine-generator control system (or electrohydraulic control system) controls steam flow to the turbine. The control system consists of the following four parts:

a. Solid state controller and operator's panel;

b. Steam valve servo-actuator assemblies;

c. High pressure oil supply system;

d. Emergency trip or protection system.

The electronic controller performs basic analog computations on reference signals and turbine feedback signals and generates an output to the actuators.

The operator's panel contains pushbuttons and switches which are used to change the reference input to the controller to vary the speed or load. Indicators provide continuous monitoring of steam admission valve position, load limit setting and control signal.

The servo valves position the governing valves by directing the flow from the high pressure oil system to the actuators.

The turbine-generator electrical trip system is arranged such that all electrical trip signals close contacts in the 24-Volt dc system which energizes the master trip relay. Should the turbine be tripped by other than an electrical trip signal, the system monitors emergency trip system oil pressure, energizing the master trip relay on low pressure.

A loss of load reactor trip results from a turbine-generator trip at power levels greater than 15%.

The turbine-generator unit is controlled from the operator's panel (see Section 7.6.2). The panel shows which devices are controlling the turbine-generator system. The controller computes signals to position the stop and control valves. As the speed reference is changed during startup, the speed transducer signal is compared with the reference speed setting. The difference or speed error then sets the position of the throttle valve servo-actuator. The stop valve servo-actuator or the control valve servo-actuator changes the steam flow to the turbine depending on whether the turbine is at low speed or approaching rated speed. The result is a change in turbine speed. Turbine speed is detected by the speed transducer and is compared with the reference speed setting. Load reference changes are made manually as the first stage pressure is compared with load reference setting.

Manual control provides a control valve position only.

The turbine-generator control system is composed of solid state devices and servo-amplifiers which generate current, voltage and pulse-type signals.

All turbine valves can be tested and/or exercised while the turbine is operating under load. Only one main stop valve may be tested at one time.

7.4.6.3 System Evaluation

The electrohydraulic control system used is a conventional control system of a type with many unit-years of operating experience. The system has been refined and has proved to be very reliable.

7.4.7 Reactor Regulating System

7.4.7.1 Present Status

The reactor regulating system was designed to automatically control reactor power by positioning the control rods in response to turbine demands. This system has been disconnected at its input to the rod drive control system. Reactor power is controlled by manual withdrawal or insertion of the control rods and manual regulation of the boron concentration in the primary coolant (chemical shim).

The indication and alarms related to the system remain available for use in the control room. These parameters are:

a. T_{ref}, T_{avg}, ΔT for loops 1 and 2 to recorders.

b. CEA automatic withdrawal prohibit.

c. Deviation alarms (T_{avg1} - T_{avg2}; T_{avg1} - T_{ref1}; T_{avg2} - T_{ref2})

The two T_{avg} (selectable) signals are still used as part of the pressurizer level setpoint analog program.

Inputs to the system are:

a. Nuclear power

b. Loop 1 T_{ave}, Loop 2 T_{ave}

c. First stage turbine pressure

7.4.7.2 System Design

Figure 7.4-1 provides a block diagram of the system. The T_{ref} signal is based on turbine first stage pressure, where first stage pressure is a linear function of load.

The 2 channels are selectable (however, the actual control is disconnected).

7.5 INSTRUMENTATION SYSTEMS

7.5.1 Process Instrumentation

7.5.1.1 Design Bases

The non-nuclear process instrumentation measures temperatures, pressures, flows and levels in the reactor coolant system, secondary systems and auxiliary systems. Process variables required for startup, operation and shutdown of the plant are indicated, recorded and controlled from the control room. Other instrumentation which is used less frequently or which requires a minimum of operator action is located near the equipment. Alternate indicators and controls are located at other locations than the main control room to allow reactor shutdown should the main control room have to be evacuated (see Section 7.6).

Four independent measurement channels are provided to monitor each process parameter required for the reactor protective system. Redundant channels are provided for engineered safeguards action to meet the single-failure criterion. The four independent channels provide sufficient redundancy to ensure system action and to allow each channel to be tested during plant operation.

Two channels are provided to monitor parameters required for critical control functions such as Pressurizer Pressure and Pressurizer Level. These channels and associated sensors are independent of the Reactor Protective System, with the exception of the T-121H channel which receives an isolated input signal from the B/T-122H channel.

Redundant subcooled margin monitors are provided to give a continuous indication of margin to saturated conditions. Each of the monitors utilizes two hot leg temperatures, two cold leg temperatures, and a pressurizer pressure signal to calculate the subcooled margin. In addition, the Safety Parameter Display System (SPDS) provides a similar function plus two additional subcooled margins using other temperature signals are calculated.

7.5.1.2 System Description

The process instrumentation described below is associated with the reactor protective, reactor control, reactor plant controls, or reactor instrumentation:

Temperature

Temperature measurements are made with precision resistance temperature detectors (RTD's) which provide a signal to the remote temperature indicating control and safety devices.

The following is a brief description of each of the temperature measurement channels:

a. Hot leg temperature: Each hot leg contains seven temperature measurement channels. Four of these channels provide a narrow range hot leg temperature signal to the thermal margin/low pressure trip circuits and to subcooled margin monitors. Two wide range channels provide signals to the QSPDS for indication and subcooled margin monitoring. The other hot leg temperature measurement channel provides a signal to the loop T_{avg} and W summing computers in the Reactor Regulating system. Channel T-121H receives an isolated T_{hot} signal from channel B/T-122H. The five narrow range hot leg temperatures are indicated on the control panel. A high temperature alarm from each control channel is provided to alert the operator to a high temperature condition.

b. Cold leg temperature: Each cold leg branch contains four temperature measurement channels. Two of the narrow range channels in each branch provide a cold leg temperature signal to the thermal margin/low pressure trip circuits and to the subcooled margin monitors. These channels also provide cold leg temperature indication on the control panel. One wide range channel provides a cold leg temperature signal to the QSPDS for its subcooled margin monitoring function.

The other cold leg temperature measurement channel in one branch of each loop provides a signal to the loop T_{avg} and W summing computers; the remaining cold leg temperature channel provides a signal to the plant computer and is an input to the low temperature/over pressure PORV reduced pressure protection scheme.

c. Loop average temperature: Each loop is provided with an average temperature summer. The T_{avg} summer receives inputs from the control channel hot leg temperature detector and the cold leg temperature detector and provides an average temperature output to the reactor regulating system and to a recorder. Channel T-121H receives an isolated T_{hot} signal from channel B/T-122H. The temperature recorders are equipped with two pens. One pen records the average temperature and the other pen records the programmed reference temperature signal (T_{ref}) corresponding to turbine load (first stage pressure).

d. Loop differential temperature: The loop differential temperature is computed from the control channel hot leg temperature detector signal and the cold leg temperature detector signal. Channel T-121H receives an isolated T_{hot} signal from channel B/T-122H. Each loop differential temperature is recorded in the main control room.

e. There are two subcooled margin monitors, each with a backup channel. The first is a stand alone type using narrow range temperature signals and a pressurizer pressure signal to calculate subcooled margin. The second is the subcooled margin monitor function of the QSPDS. It uses wide range temperature signals and a pressurizer pressure signal to calculate subcooled margin.

Four resistance-thermometer elements, not associated with the reactor protective, reactor control or reactor plant controls, are provided within the containment for temperature indication during DBA and post-DBA conditions. The temperature elements were designed for service at 500°F and 4000 psia.

Additional temperature indication is provided by the Core Exit Thermocouples (CET's) located in the in-core instrumentation (ICI) assemblies.

Level

Reactor vessel water level is provided by the Heated Junction Thermocouple (HJTC) probes. Two probes in the reactor vessel measure the coolant inventory and provide an indication of the collapsed liquid level between the fuel alignment plate and the top of the head. This indication is provided on both the Qualified Safety Parameter Display System (QSPDS) and on the plant Safety Parameter Display System (SPDS).

The HJTC probes contain eight sensors each at varying levels in the reactor vessel. Each sensor senses the existence or absence of coolant at a particular level and the QSPDS microprocessor translates this information to an indication of level of water in the vessel.

Pressure

Pressure is measured by two pressure control channels which are recorded in the control room and provide independent high and low alarms. The transmitter produces a dc current output that is proportional to the pressure sensed by the instrument. The dc current outputs are used to provide signals to the remote pressure indicating, control and safety devices.

The following is a brief description of each of the pressure measurement channels:

a. Pressurizer pressure (protective action): Four pressurizer pressure transmitters provide independent, narrow range, pressure signals. These four independent pressure channels provide the signals for the reactor protective system high pressure trip and the variable thermal margin/low pressure trip. The channels also provide the low-low pressure signal to initiate safety injection. All four pressure channels are indicated in the control room and high, low, and low-low alarms are annunciated.

b. Pressurizer pressure (protective action): Four pressurizer pressure transmitters in the Diverse Scram System provide independent, high range, pressure signals. These four independent pressure signals are inputs to the Diverse Scram System high pressure trip. Of the four channels, two provide pressure indication in the control room.

c. Pressurizer pressure (control action): Two independent pressure channels provide suppressed range signals for control of the pressurizer heaters and spray valves. The output of either controller may be manually selected to perform the control function.

   The Power Operated Relief Valves are actuated by the high primary system pressure reactor trip signal.

Pressurizer Level

Level is sensed by level transmitters which measure the pressure difference between a reference column of water and the pressurizer water level. This pressure difference is converted to a dc current signal proportional to the level of water in the pressurizer. The dc current outputs of the level transmitters provide signals to the remote level indicating control and safety devices.

Two independent pressurizer level transmitters provide signals for use by the chemical and volume control charging and letdown system. In addition, signals are provided for pressurizer heater override control. These level transmitters are calibrated for steam and water densities existing at normal pressurizer operating conditions.

Each of the two pressurizer level control channels provide a signal for level recorders in the control room. These recorders are two-pen recorders, with one pen recording actual level as sensed by the level control channel and the other pen recording the programmed level set point signal from the reactor regulating system.

Subcooled Margin

The redundant stand alone Subcooled Margin Monitors are an on-line microcomputer-based system which uses reactor coolant process signals to provide a continuous indication of the margin from saturation conditions. These SMM's receive their inputs from hot leg temperature, cold leg temperature and pressurizer pressure loops

The (narrow range) temperature and pressure analog signals are converted to digital signals. These signals are interfaced to a microcomputer. The microcomputer contains steam tables and interpolation routines for which a saturation temperature and pressure are calculated.

By comparing the saturation temperature and pressure to the actual coolant temperature and pressure, a margin from saturation is calculated. Either the temperature or pressure margin can be displayed on the digital panel meter. The margin is also compared to a setpoint for a low margin alarm.

In addition to the above-described Subcooled Margin Monitor with the narrow hot and cold leg temperature input ranges, additional subcooled margin indications are available as part of the Safety Parameter Display System (SPDS). The SPDS performs a subcooled margin calculation similar to the one described above using wide range hot and cold leg temperatures and the same pressure signals as above. A block diagram of the wide range Subcooled Margin Monitor is shown in Figure 7.2-6a. In addition, the SPDS performs two additional subcooled margin calculations. These additional calculations are based on representative Core Exit Thermocouple (CET) temperature, and upper head temperature as sensed by the reactor vessel level Heated Junction Thermocouple (HJTC) probes. All three calculations share the same pressure inputs.

Flow

An indication of reactor coolant flow is obtained from measurement of the pressure drop across each steam generator. The pressure drop is sensed by differential pressure transmitters which convert the pressure difference to dc currents. The dc currents provide a signal to the remote flow indicating and safety devices.

Eight independent differential pressure transmitters are provided in each heat transfer loop to measure the pressure drop across the steam generators. The outputs of one of these from each branch are summed to provide a signal of flow rate through the reactor core, which is indicated and supplied to the reactor protective system for loss-of-flow determination. The differential pressure sensed by each transmitter is indicated in the control room. The arrangement of the flow transmitters is shown in Figure 7.2-5.

Four additional differential pressure transmitters across the reactor coolant pumps and four across the reactor loops furnish additional readings for periodic reevaluation and systems calibration.

7.5.2 Nuclear Instrumentation

7.5.2.1 Design Bases

Ten channels of instrumentation are provided to monitor the neutron flux. The system consists of four wide range logarithmic channels, four power range safety and two power range control channels. Each channel is complete with separate detectors, power supplies and amplifiers to provide independent operation. The operating capability of the ten monitoring channels is greater than 10 decades of neutron flux and, as such, is more than adequate to monitor the reactor power from shutdown through startup to 200 percent of full power. Channel range, sensitivity and overlap are shown in Figure 7.2-8.

The neutron flux detectors are located in instrument thimbles in the biological shield around the reactor vessel. The power range control channel detectors are placed 180 degrees apart. The power range safety channel detectors are placed in thimbles approximately equally spaced around the reactor vessel as shown in Figure 7.5-1.

7.5.2.2 System Description

The nuclear instrumentation system consists of ten independent channels.

Installation

The nuclear instrumentation signal processors are located in the control room (see Section 7.6.2). Four cabinets designated as AI-31A, AI-31B, AI-31C and AI-31D each house one power range safety channel and one wide range logarithmic channel. Two additional Power Range Monitors located in the adjacent cabinet, AI-31E, provide control channel power level signals to the Reactor Regulating System. Mechanical and thermal barriers between the cabinets reduce the possibility of common event failure. The detector cables are routed separately from each other. This includes separation at the containment penetration areas. The nuclear detector locations are shown in Figure 7.5-1.

Functional Description

Ten channels of instrumentation are provided to monitor the neutron flux. The system consists of wide range logarithmic channels, power range safety and power range control channels. Each channel is complete with separate detectors, power supplies, amplifiers, and bistables to provide independent operation. The operating capability of the ten monitoring channels is greater than 10 decades of neutron flux and is more than adequate to monitor the reactor power from shutdown through startup to 200 percent of full power.

Four wide range logarithmic channels monitor the flux from source level to above full power. The flux signals, obtained from dual fission chambers, are amplified and transmitted to the signal processors located in the control room. Audible count rate signals are available in the control room. In addition to the information on the neutron flux, these channels provide a rate-of-change-of-power signal to the reactor protective system for CEA withdrawal prohibit or reactor trip.

Four channels are designated as power range safety channels and provide power level signal outputs to the reactor protective system. These channels operate from 0 to 200 percent of full power. These four channels contain detectors composed of dual section ion chambers which monitor the full axial length of the reactor core at four circumferential positions. They can also detect axial flux tilt.

Two separate power range control monitors, which are identical to the power range safety monitors, provide reactor power signals to the reactor regulating system. The channel output is a signal directly proportional to reactor power from 0 to 200 percent.

The gain of each channel is adjustable to provide a means for calibrating the output against a plant heat balance. Each channel provides a power reference signal to one of the independent reactor regulating system channels.

7.5.2.3 Design Criteria

The system was generally designed in accordance with the criteria of IEEE 279, August 1968. In areas not covered or specifically identified by the criteria, the following criteria were used:

a. The nuclear instrumentation sensors are located so as to detect representative core flux conditions;

b. Multiple channels are used in each flux range;

c. The channel ranges overlap sufficiently to ensure that the flux is continually monitored from source range to 200 percent of rated power;

d. The power range safety channels are separate from, and independent of, the control channels;

e. Each of the four power range safety channels is physically segregated from the others. Each of the four startup and logarithmic channels is physically segregated from the others;

f. Power is supplied to the system from four separate ac buses. Loss of one bus trips one safety channel and one startup or logarithmic channel;

g. Loss of power to channel logic results in a channel trip;

h. All channel outputs are buffered so that accidental connection to 120-Volts ac, or to channel supply voltage, or shorting individual outputs has no effect on any of the other outputs.

7.5.2.4 Wide Range Logarithmic Channel Description

The four (4) wide range nuclear instrumentation channels provide relative indication of the neutron flux level at the detector assemblies and the measure of the rate of change of neutron flux from source level to above 100% of full power. Dual fission chambers are used to detect the neutron flux. The signal from the fission chambers is provided to an amplifier assembly where the signal is amplified with some conditioning. The monitor in the main control room provides further processing of the detector signal into parameter signals.

The monitors provide indication of source range level (CPS), wide range level (% power) and rate of change of power (DPM). These signals are provided as outputs for remote indication. LED lamps provide status indication of the two internal adjustable bistables, A/C power, Channel in Test, and a channel fault condition. The rate of change of power signal is utilized as an input to a trip unit within the Reactor Protective System (RPS). The RPS trip unit pretrip signal provides an input to the CEA Withdrawal Prohibit function. The source range level signal is provided as an input to the Audio Countrate drawer.

The two adjustable internal wide range monitor bistables monitor the wide range power level signal. One bistable serves to enable Zero Power Mode Bypass for the Reactor Protective System (RPS) and to disable the rate of change of power signal provided to the RPS. The second adjustable bistable provides a contact input to the SCEAPIS for lower power cutout and annunciation input.

Any one of the four (4) channels of wide range nuclear instrumentation can be selected on the Audio Countrate drawer as the input to the Audio Countrate circuitry. The Audio Countrate drawer contains a local speaker and provides an output to a remote speaker in containment.

Channel D of wide range nuclear instrumentation provides input signals to a separate monitor at the alternate shutdown panel location (AI-212) (Section 7.6.4). This monitor and associated amplifier assembly are isolated from the main control room signal processor to provide independence in the event of a main control room fire.

7.5.2.5 Power Range Safety Channel Description

The four power range channels measure flux linearly over the range of 1 percent to 200 percent of full power. The detector assembly consists of two uncompensated ion chambers for each channel. One detector extends axially along the lower half of the core while the other, which is located directly above it, monitors flux from the upper half of the core. The upper and lower sections have a total active length of 12 feet. The dc current signal from each of the ion chambers is fed directly to the control room drawer assembly without preamplification. Integral shielded cable is used in the region of high neutron and gamma flux.

The signal from each ion chamber (sub-channel) is fed to an independent amplifier. Within each channel the outputs of the two amplifiers are indicated and averaged. The averaged output of the two amplifiers forms the channel output and feeds remote recorders, bistables and the reactor protective system. In addition, each of the four channel outputs is averaged in a comparator averager module to form an overall average of the four power range safety channels. This overall average is compared to each ion chamber sub-channel output to provide a deviation signal. When this deviation reaches a manually adjustable setpoint, an alarm will annunciate on the main control board.

The 1.0 to 200 percent full scale output is always fed to a recorder and to the bistable which is used by the reactor protective system to disable the wide range logarithmic channel rate trip above 15 percent full power. The summing circuit also has an X2 gain selector switch which disconnects the input of one ion chamber and doubles the gain for the other ion chamber in order to allow full scale power indication with one inoperative ion chamber.

The 1.0 to 200 percent full scale signal is also fed to a CEA drop detection circuit which compares the present value of the signal with the time delayed (5 to 15 seconds) signal level.

Channel calibration and test is accomplished by an internal current source which checks amplifier gain and linearity. A check of the high flux trip setpoint is provided by a current signal which is added to the normal detector output.

Each power range channel contains two bistables. One, previously mentioned, disables the rate of change of power trip signal, as well as enables the axial power distribution trip and the loss of load trip signals; the other, a failure monitor, initiates an alarm on decrease of detector voltage, drawer calibration, or removal of any of the drawer modules. The condition of each bistable is shown by a front panel light.

7.5.2.6 Power Range Control Channel Description

The power range control channels are identical to the power range safety channels. They are located on the reactor protective system nuclear instrumentation cabinet AI-31E in the main control room. These power level signals are connected only with the reactor regulating system and to remote meters.

7.5.3 CEA Position Instrumentation

7.5.3.1 Design Bases

There are 41 control element drive mechanisms (CEDM's). Four are spares. The remaining 37 control element drive mechanisms (CEDM's) are each equipped with two indication systems to provide the operator with position information. The primary and secondary CEA position sensing systems are separate and independent.

The primary CEA position indication system utilizes the output of a synchro transmitter geared to the clutch output shaft. CEA position is displayed visually at the main control panel. One position indicating meter is provided for each group; any CEA within the group may be selected for monitoring. The position of all CEA's may be printed by the plant computer printer on demand at any time. CEA position information is also used to initiate alarms when limiting conditions are approached, to provide contact closures for sequencing and control, and to monitor for an alarm position deviation between individual CEA's within a group. During a drop test, the system measures and records the time for a CEA to reach the 90 percent inserted position after the clutch is released.

The secondary CEA position system utilizes the output of a voltage divider network controlled by a series of reed switches. The reed switches are actuated by a permanent magnet attached to the rack assembly. Position information is supplied to a cathode ray tube position indicator for simultaneous viewing of all CEA group positions. Individual control rod groups are displayed when selected by the operator. During a rod drop test, the system measures and records the time for a CEA to reach the 90 percent inserted position after the clutch is released.

7.5.3.2 Primary Position Indication System Description

The primary CEA position sensing system determines CEA position by use of synchros. Outputs are provided for visual display and for CEA control. The systems major components are:

a. Thirty-seven CEA position synchro transmitters;

b. Seven visual displays, one for each group, and each with one switch to select any CEA within a group. The displays are synchro receiver indicators and are driven directly by the selected synchro transmitter;

c. The plant computer and its output printer. The computer receives information directly from the synchro transmitters and is fully independent of the visual displays.

The synchro transmitter for each CEA is geared to the CEA drive shaft below the CEA clutch. Synchro output is transmitted to the display receivers and independently to the plant computer which scans and converts synchro outputs into inches of CEA withdrawal. The resolution of this system is approximately $\pm$0.5 inch.

The operator has two means of determining CEA position from the primary CEA position sensing system:

a. Seven visual displays (dials) are mounted above the CEDM controls on the main control panel. There is one display for each group; a selector switch at each display allows the position of any CEA in that group to be indicated. Should any CEA's within the group deviate in position more than a preset amount from any other in the group, a deviation alarm alerts the operator. The out-of-limits CEA can be identified by observing the printout or by checking the position of each CEA within a group by the visual displays.

b. A printer connected to the MODCOMP computer can be used to print out any or all positions either hourly or upon request by the operator.

7.5.3.3 Secondary Position Indication System

The secondary position sensing system measures CEA position by use of magnetic reed switches actuated by a permanent magnet attached to the rack assembly. Simultaneous visual display of all CEA groups is provided by a cathode ray tube position indicator. Indication of individual control rod position is provided on the cathode ray tube display when a particular control rod group display is selected by the operator. The secondary position sensing system is mechanically and electrically isolated from the primary position sensing system. The resolution of the secondary system is approximately ±2 inches.

The system contains:

a. Thirty-seven reed switch/resistor assemblies;

b. The cathode ray tube display unit and associated electronics.

An assembly containing a number of series resistors to form a voltage divider network with reed switches connected at each junction is attached to the CEA extension housing. A voltage is applied to the network; output voltage depends on which reed switches are closed in the voltage divider. A magnet on top of the CEA extension actuates the reed switches as the CEA moves. Overlap between adjacent reed switches is provided. The output is a voltage directly proportional to CEA position.

The outputs from all assemblies are sent to the cathode ray tube display unit. This unit is completely independent of the primary position system.

The Secondary Position Indication System monitors control rod position and reactor power and initiates alarms when the following abnormal CEA configurations are detected:

a. CEA Deviation

b. CEA Regulating Group Overlap

c. CEA Regulating Group Out-of-sequence withdrawal/insertion

d. CEA Insertion to the Pre-Power Dependent Insertion Limit

e. CEA Insertion to the Power Dependent Insertion Limit

f. Regulating Group Withdrawal Prohibit (ISH)

g. Shutdown Group Insertion Permissive (IRG)

The Secondary Position Indication System also performs a rod drop timer function and initiates the actuation of the Rod Block System.

7.5.3.4 Rod Block System

The rod block system is automatically initiated by the Secondary Position Indication System to inhibit all CEA motion in the event a Limiting Condition for Operation (LCO) on CEA insertion, CEA deviation, CEA overlap or CEA sequencing is approached.

The installation of the rod block system ensures that no single failure in the control element drive control system (other than a dropped CEA) can cause the CEA's to move such that the CEA insertion, deviation, sequencing or overlap limits are exceeded. Accordingly, with the rod block system installed, only the dropped CEA event is considered an Anticipated Operational Occurance (AOO) and factored into the derivation of the Limiting Safety System Settings and Limiting Conditions for Operation.

7.5.4 In-Core Instrumentation

7.5.4.1 Design Bases

The primary function of the in-core instrumentation is to provide measured data which may be used in evaluating the neutron flux distribution in the reactor core. This data may be used to evaluate thermal margins and to estimate local fuel burnup.

The bases for the design of the in-core monitoring system are as follows:

a. Detector assemblies are installed in the reactor core at selected locations to obtain core neutron flux and coolant temperature information during reactor operation in the power range;

b. Flux detectors of the self-powered type, with proven capabilities for in-core service, are used;

c. The information obtained from the detector assemblies is used for fuel management purposes and to assess the core performance. It will not be relied on for automatic protective functions;

d. The output signal of the flux detectors is calibrated or adjusted for changes in sensitivity due to emitter material burnup;

e. Each detector assembly is comprised of four local neutron flux detectors stacked vertically for axial monitoring, and one thermocouple at the assembly outlet.

Axial spacing of the detectors in each assembly and radial spacing of the assemblies permit representative neutron flux mapping of the core and monitoring of the fuel assembly coolant outlet temperatures.

7.5.4.2 System Description

The in-core instrumentation system consists of 28 fixed in-core detector assemblies inserted into selected fuel assemblies. Each assembly contains four rhodium detectors, and one thermocouple. Outputs may be read on the terminals and printers in the control room. These units with their cabling are contained inside an Inconel sheath.

Assemblies are inserted into the core through six instrumentation ports in the reactor vessel head. Each assembly is guided into position in an empty CEA tube in the center of the fuel assembly via a fixed stainless steel guide tube. The seal plug forms a pressure boundary for each assembly at the reactor vessel head as does the Gralock adaptor hub to the reactor vessel flange assembly.

The neutron detectors produce a current proportional to neutron flux by a neutron-beta reaction in the detector wire. The emitter, which is the central conductor in the coaxial detector, is made of Rhodium 103 and has a high thermal neutron capture cross section. The rhodium detectors are provided to measure flux at four axial locations in the fuel assemblies.

The data from the detectors are read by the Emergency Response Facilities (ERF) plant computer which scans all assemblies and prints out the data periodically or on demand. The computer continually computes integrated flux at each detector to update detector sensitivity factors to compensate for detector burnout.

7.5.4.3 ICI Requirements for Monitoring Technical Specifications

On July 16, 1993, the USNRC issued a Final Policy Statement on Technical Specification Improvements for Nuclear Power Reactors. The Final Policy Statement contains four criteria which can be used to determine which constraints on the design and operation of nuclear power plants are appropriate for inclusion in the plant's Technical Specifications. The ICI System does not meet any of those four criteria. Subsequently, on February 10, 1995, OPPD requested the elimination of Technical Specification 2.10.3 and the relocation of the Technical Specification limitations on the use of the ICI System to the Fort Calhoun Station Updated Safety Analysis Report (USAR). The USNRC issued a Safety Evaluation Report (SER), dated June 26, 1995, approving OPPD's request (Reference Amendment No. 167). The SER stated that in order to change the requirements concerning the number and location of functional detectors, a successful 10 CFR 50.59 safety evaluation with a rigorous evaluation and justification is required. The following considerations must be included in a 10 CFR 50.59 evaluation if changes to the ICI System requirements are proposed:

1) How an inadvertent loading of a fuel assembly into an improper location will be detected,

2) How the validity of the tilt estimates will be ensured,

3) How adequate core coverage will be maintained,

4) A list of the measurement uncertainties and why the added uncertainties are adequate to guarantee that measured peak linear heat rates, peak pin powers radial peaking factors, and azimuthal power tilts will meet TS limits, and

5) How the ICI System will be restored to at least 75 percent prior to the beginning of a new cycle.

The following information represents the ICI requirements for measuring Technical Specification values:

The ICI System shall be operable with either:

1) At least 75% of all incore instruments and a minimum of two incore detector strings per full axial length quadrant whenever the ICI System is used to monitor the intergrated radial peaking factor (F_R^T), the total peaking factor (F_Q^T), the radial power distribution, the peak linear heat rate, and the azimuthal power tilt, or

2) At least 28% but less than 75% of all Incore Detector Strings and:

   - At least two Incore Detector Strings are operable per Axial Quadrant whenever the ICI System is used to monitor the integrated radial peaking factor (F_R^T), the total peaking factor (F_Q^T), the radial power distribution, the peak linear heat rate, and the azimuthal power tilt, and

   - An increase of 1% to the total uncertainties applied to the integrated radial peaking factor (F_R^T), and the total peaking factor (F_Q^T), (Reference 7.7.16), and

   - The frequency of determining total integrated and planar radial peaking factors is changed to a minimum of once every 15 days.

An operable in-core instrument shall consist of three or more operable rhodium detectors.

A quadrant symmetric in-core instrument location consists of a location with a symmetric counterpart in any other quadrant.

Following each fuel loading:

- The ICI System must have at least 75% of the in-core instruments operable, and

- The initial measurement of the linear heat rate, F_r^T and azimuthal power tilt shall consist of the first full core power distribution calculation based on in-core detector signals made at a power level greater than 40 percent of rated power.

For recalibration of the ex-core detectors, a minimum of four in-core instrument locations at each detector level (or a total of 16 detectors) with at least one location in the center seven rows of fuel assemblies and at least one location outside the center seven rows of fuel assemblies shall be operable.

With the ICI System inoperable, do not use the ICI System for 1) recalibration of the ex-core detector inputs to the axial power distribution trip calculator, and 2) monitoring of peak linear heat rate and radial power distribution.

The linear heat rate shall not exceed the limits of the Allowable Peak Linear Heat Rate vs. Burnup Figure provided in the COLR when the following uncertainties are appropriately applied:

- A flux peaking augmentation factor as shown in Technical Specification Figure 2-8,

- A measurement calculational uncertainty factor of 1.062 for more than 75% of the ICIs operable and 1.072 for between 75% and 28% of the ICIs operable,

- An engineering uncertainty factor of 1.03,

- A linear heat rate uncertainty factor of 1.002 due to axial fuel densification and thermal expansion, and

- A power measurement uncertainty factor of 1.013 at 100% power, 2.1% at 65% power and 5% below 30% power (Ref. 7.7.17).

A statistical combination of the above uncertainties (SCU) yields a 1.09 multiplier for more than 75% of the ICIs operable and a 1.11 multiplier for between 75% and 28% of the ICIs operable to the peak linear heat rate measurement. This SCU analysis (Ref. 7.7.18) considered the effects of a variable power measurement uncertainty and fuel rod bowing effects on peak linear heat rate.

7.5.5 Plant Computer (ERF System)

7.5.5.1 Design Bases

The Emergency Response Facilities (ERF) System is used to monitor and log plant parameters and equipment status, to perform some secondary plant performance calculations and to provide the primary Safety Parameter Display System (SPDS).

The principal purpose and function of the SPDS is to aid the control room personnel during abnormal and emergency conditions in determining the safety status of the plant and in assessing whether abnormal conditions warrant corrective action by operators to avoid a degraded core. A Human Factors Maintenance Plan has been and will continue to be used for SPDS display formats and techniques.

The computer is not part of the Reactor Protective System. The function of the computer is to assist the operator in optimizing plant performance and assimilate plant data. The computer provides both a record of the operation of the plant and a means of readily providing the operator with information of the following type:

a. The current status of certain plant switches, relay contacts, values, or plant parameters;

b. The displayed value or trend of selected plant parameters or calculated values;

c. Post-trip review of selected plant analog parameters.

7.5.5.2 System Description

The computer is a real time digital processing system which collects and organizes plant data for reference and display in the Control Room, Technical Support Center (TSC) and in the Emergency Operations Facility (EOF). The ERF computer is a distributed MODCOMP based system which consists of dual processors for data acquisition and dual processors which serve as the host for the system.

User interaction with the computer is through the host. The arming plans are established through user interface to the host. Display selections and other system options are made through the host user interface. The host controls storage of on-line history files, audit trails, and transient data files. It performs other system functions, such as initial program loading for the Data Acquisition System (DAS), security protection, and communication with external data systems.

The system provides supplementary information for assistance in plant operation and provides logic for automatic identification and alarm of off-normal conditions.

The computer interfaces with the Inadequate Core Cooling Instrumentation (ICCI) System via fiber optic data links. The ICCI System provides numerous channels of measurement data and valve position indication to the computer data base for processing and display.

The system scans numerous analog inputs (flow, temperature, pressure and level), and digital inputs (including the position of valves, relay contacts, circuit breakers and switches). It provides indication and alarm of off-normal conditions on the system terminals and printers.

An analog input can be simultaneously selected for direct observation on a two pen recorder; two such recorders are provided.

The plant design includes sufficient instrumentation to permit safe operation of the plant at all times, irrespective of computer availability.

The SPDS displays and software also reside in the system. The variables displayed on the SPDS screens were chosen to aid operators in the diagnosis and mitigation of transients and accidents. The parameters necessary for evaluation of the events of the Emergency Operating Procedures and their Safety Function Status Checks are located on these 7 mid-level screens or the associated screens available from these displays. The parameters included for display are consistent with those contained in References (1) and (2) and are grouped under the EOP Safety Functions as listed below:

a. Reactivity Control

b. Vital Auxiliaries

c. RCS Inventory Control

d. RCS Pressure Control

e. Core Heat Removal

f. RCS Heat Removal

g. Containment Integrity

7.5.5.3 Terminal/User Interface Description

The system contains numerous terminals to provide communication between the user and the computer. The computer executes various functions in response to commands entered at the terminals.

7.5.5.4 Program Functions

<u>Scanning and Display</u>

The computer system checks digital inputs from valves, relay contacts and position switches and initiates an alarm in the event of an improper change in status.

The system also checks analog inputs for the following:

a. Operability of sensors and instrument transmitters. Signal in proper range.

b. Comparison of sensor output to alarm setpoints for alarm initiation.

The SPDS software takes information supplied by plant sensors and uses it to develop mid- and top-level graphic displays that provide an indication of the plant safety functions. Selected combinations of plant sensors and computed parameters are used to drive the mid-level bar graph displays. This information is then further processed into a top-level display which serves as an "annunciator" for the safety functions and their alarms.

<u>Calculations</u>

The system performs functions necessary for conversion of inputs to engineering units and preparation of some plant performance calculations (linearization of thermocouple inputs, square root extraction, integration and averaging).

The system also detects flux tilting factors by using the out-of-core nuclear instruments. This program calculates a single magnitude and angle for the excore Quadrant Power Tilt Detection System. The program has logging capabilities which include an hourly and demand log of tilt (%), angle in degrees and harmonic indexes for safety channels A through D and control channels A and B. Vector averaging is also included on these logs for the detectors.

R0002X	Control A Linear
R0002Y	Control A Linear
R0002X	Control B Linear
R0002Y	Control B Linear

The computer performs functions necessary for conversion of inputs to engineering units and preparation of the plant performance calculations, e.g., linearization of thermocouple inputs, scale factoring, zero-suppression, square root extraction, integration and averaging.

A heat balance is performed by computing the enthalpy rise in the steam generator secondary side, correcting for blowdown and stored heat in the steam generator. The reactor thermal output is computed by summing the thermal outputs from each of the steam generators (secondary side), correcting with programmed constants to compensate for the heat input from reactor coolant pump and pressurizer operation and for losses, e.g., heat losses to ambient. Finally, an on-line comparison is made between the calculated reactor output and all four power range nuclear instrument channels. Alarms are initiated if the relative readings differ by more than a predetermined percentage of indicated full power.

The calculated thermal output of the two steam generators is summed, and the fraction of the total output contributed by each steam generator is computed to obtain a thermal tilting factor.

Performance Logging

The computer system logs the position of all CEA'S and alarms the deviation in position of an individual CEA within a group. The integrated power history for each CEA in specified core axial intervals is also logged.

A plant performance log is automatically printed out each hour. The data logged normally includes the plant operating parameters such as temperature, pressure and reactor coolant flow, and computed values of reactor thermal output and steam generator output. A selected log of these items is also printed out daily.

CEA Position

The plant computer functions include:

a. Monitoring the CEA synchros and checking the CEA position against limiting positions;

b. Initiating alarms and interlocks under certain limiting CEA positions (CEA's at upper and lower stops, regulating and shutdown CEA insertion limit alarm);

c. Providing contact outputs under other CEA positions (these outputs are used as permissive conditions in the sequencing controls);

d. Checking positions of all CEA's within a given group for deviations in position, and alarming if the deviations exceed a preset value;

e. Printing out all CEA positions hourly;

f. Calculating the CEA drop time.

In-Core Instrumentation

The in-core flux detectors are scanned, corrected for background and sensitivity factors, and converted into thermal neutron flux and power readings. These data are available for display when it has been requested and are logged automatically. The system also collects in-core data and operating parameters (power levels) required for offsite fuel management studies.

Sequence-of-Events Monitoring

The Sequence-of-Events (SOE) hardware and software are used to provide event sequencing of selected digital inputs. The SOE log which prints automatically to a preselected device provides one of the tools for determining that the plant can be restarted safely.

The SOE System monitors inputs from the Reactor Protective System (RPS) trip units and from the diesel safety panels (AI-30A and AI-30B) which perform the automatic load sequencing for the Engineered Safety Features (ESF) equipment.

Emergency Response Data System

The Emergency Response Data System (ERDS) hardware and software is used to provide a data link with the NRC. The data link provides pre-selected plant parameter information to the NRC when an emergency classification is declared in accordance with 10 CFR 50, Appendix E, Section VI. The ERDS is manually initiated. Once the link is established no additional manual actions are required.

7.5.5.5 MINI-CECOR/BASSS

MINI-CECOR is a NRC approved computer program installed on the Plant Computer System, which synthesizes three-dimensional assembly and peak pin power distributions from fixed in-core detector signals. These distributions are useful for monitoring reactor operation with respect to Technical Specification and COLR limits.

In-core detector signals and general plant operating data are input to MINI-CECOR via the Plant Computer System. Detailed three-dimensional assembly burnup distributions are input from an exposure computer file. General reactor data, configuration, fuel characteristics and geometry data are input from a geometry file. Using all of this data, the signals are synthesized into three-dimensional assembly and peak pin power distributions. Power to signal ratios convert the in-core signals (from instrumented assemblies) to assembly powers, while coupling coefficients translate signals from instrumented assemblies to uninstrumented assembly powers.

BASSS (Better Axial Shape Selection System) calculates thermal margin using the output of MINI-CECOR and actual plant conditions to gain operating margin. Specifically, BASSS uses power level, rod insertion, and unrodded radial peaking factors to produce DNB limits as a function of axial shape index (ASI) and power. BASSS then selects the most appropriate ASI and power combinations for the current conditions and produces the maximum allowable amount of operating margin for those conditions.

7.5.6 Inadequate Core Cooling Instrumentation

7.5.6.1 Design Bases

The Inadequate Core Cooling Instrumentation (ICCI) system is used to monitor selected plant parameters and equipment status to detect the approach to, existence of, and recovery from an inadequate core cooling situation. The safety grade processing and display of this information is performed by the Qualified Safety Parameter Display System (QSPDS). The QSPDS also provides safety grade processing and display of selected Regulatory Guide 1.97 variables and accident monitoring instrumentation. The QSPDS serves as a safety grade to non-safety grade isolator for transmission of these class 1E signals to the ERF computer system.

7.5.6.2 System Description

The ICCI system is comprised of the following major pieces of equipment (see Figure 7.5-2):

a. Heated Junction Thermocouple Probe (HJTC). The HJTC's (two redundant sensors) provide an indication of liquid inventory in the reactor vessel above the core. It uses heated and unheated thermocouple junctions at discrete elevations in the reactor vessel to detect the presence of liquid. When the liquid level drops below the heated junction, the less favorable heat transfer characteristics result in an increased temperature of the heated junction without a corresponding change in the temperature of the unheated junction. The temperature difference between the heated and unheated junctions is used as an indication of liquid level by indicating whether or not the thermocouple is uncovered.

b. The 28 Core Exit Thermocouples (CET's) are situated at selected locations in the reactor vessel within each in-core instrument (ICI). The CET's are located above the core and provide an indication of the temperature of the coolant as it leaves the active core region.

c. The HJTC and CET signals are transmitted in containment via mineral insulated (MI) cables. The MI cable is a silicon dioxide insulated multi-conductor stainless steel sheath cabling which is hermetically sealed through an all-welded construction technique. A grounded copper inner sheath is used to block electromagnetic interference. The cables are terminated in multi-pin connectors. The MI cables carry the signals from the instruments to the electrical penetrations.

d. The Qualified Safety Parameter Display System (QSPDS) provides the signal processing and display for the ICCI variables. The QSPDS utilizes a micro-processor based design for the signal processing equipment in conjunction with a display having alphanumeric representation and associated keyboard for each of the two channels. Each channel accepts and processes input parameter signals and transmits its output to the plasma display unit (PDU), an alphanumeric display device. In addition, each channel transmits its output to the ERF computer system.

7.5.6.3 Program Functions

The QSPDS displays, in converted engineering units, all ICCI inputs. These variables are arranged on various display pages, grouped by common critical functions. A hierarchy of displays is utilized to facilitate ease of use and to direct the operator to the pertinent pages which may be in an alarm status.

In addition to the display of the ICCI input variables, the QSPDS also performs the following functions:

a. Bad Data Checking

b. Range Checking

c. Alarm Setpoints and Deadbands for Variables

d. Calculation of Derived Variables:

- RCS Saturation margin
- Representative CET Temperature
- CET Saturation Margin
- Reactor Vessel Level
- Upper Reactor Head Temperature
- Highest/Next Highest CET per Quadrant

e. Flagging of Suspect Calculations

f. Control of Power to HJTC Heaters

g. Transmission of Data to the ERF Based Computer (including the SPDS)

In addition to the ICCI variables, the QSPDS accepts, processes, displays and transmits to the ERF computer other Reg. Guide 1.97 variables. These include both analog (e.g., steam generator levels and pressures) and digital (i.e., critical containment isolation valve positions) indications.

7.5.6.4 Testing

The ICCI and QSPDS computer displays are verified by checking the values against hand calculations using standard steam tables. The HJTC vessel inventory is verified by hand calculations. The Core Exit Thermocouple readings are checked for validity.

7.6 OPERATING CONTROL STATIONS

7.6.1 General Layout

Most of the operating control stations described in Section 7.6 are, in whole or in part, associated with Engineered Safeguards Control and Instrumentation Systems. Some panels are solely devoted to Engineered Safeguards equipment, while others contain both Engineered Safeguards and non-Engineered Safeguards equipment. See Section 6.1.2.3 for definition of Engineered Safeguards control and instrumentation systems. For more supporting detail of the Engineered Safeguards components housed in the various control panels, the design documents, Technical Specifications, CQE Manual, EEQ Manual and Regulatory Guide 1.97 Responses should be consulted.

Normal plant control, including startup, shutdown and normal operation, is handled in the control room. This room is located in the northeast corner of the auxiliary building at elevation 1,036'-0". The room is adjacent to the operating floor of the turbine building.

Other control functions are handled at the following locations:

a. The waste disposal system is controlled from panels AI-100, AI-102, and AI-103, located in the auxiliary building on the north side at elevation 989'-0".

b. A local control station, panel AI-179, for the steam driven auxiliary feedwater pump and associated valves is located in the auxiliary building in the upper electrical penetration room. This panel is used to control the steam generator level if the control room cannot be occupied and auxiliary feedwater is required.

c. Local control stations for the diesel-generators, panels AI-133A and AI-133B, are installed in the diesel-generator rooms. The diesel-generators can be started locally and controlled from these panels in the event that the control room cannot be occupied. Diesel-generator loads can be controlled from switchgear and control centers under such circumstances.

d. The auxiliary building area ventilation air temperatures are controlled at local panels adjacent to the air handling units.

e. Air compressors are controlled from a local panel. This panel includes sequencing controls.

f. The following local panels provide for operation of steam plant equipment:

1. Condenser backwash (AI-123);
2. HP heater drains (AI-121);
3. Screen wash (AI-120);
4. LP heater drains (AI-122);
5. Stator winding cooling and hydrogen control cabinet (AI-134);
6. Alternate shutdown panel (AI-185).

The turbine can be tripped at the turbine standard.

g. The demineralized water plant is controlled from panel AI-104, located in the turbine building plant area.

h. The vacuum deaerator in the demineralized water system is located in the auxiliary building and is controlled from panel AI-105 which is near the deaerator at elevation 1,025'-0".

i. Control of reactor coolant system chemistry (i.e., demineralizers in service and pH chemical addition) is local.

j. The sampling system panels are local to the sampling equipment; these panels are described in Section 9.13.

7.6.2 Main Control Room

The location of the main control room is shown in P&ID 11405-A-8. This location places the control room in an area designed as Class I with regard to seismic disturbances and tornadoes. It also provides easy physical access to the turbine room and the reactor plant. The plant has been laid out to minimize the length of cable run to the switchgear. A cable spreading room is located directly underneath the control room. The arrangement inside the control room is shown in Figure 7.6-1.

The main control board is a duplex benchboard. The equipment requiring the most immediate attention from the operator is located near the center, with those items less likely to require his attention located toward the edges. Panel CB-4, located in the corner of the L, is the reactivity control panel. The primary and secondary CEA position indicators are here, along with the CEDM controls. Controls for boric acid concentration are also located on this panel.

Directly to the right of panel CB-4 is panel CB-10/11, which contains steam generator, turbine, and other steam plant controls. Directly adjacent to panel CB-4, are the controls used to regulate the steam generators, to establish equilibrium conditions in the reactor coolant system and steam generators while going critical, and to operate the auxiliary feedwater and steam dump and bypass systems. This area includes steam generator level indicators, auxiliary and main feed pump and condensate controls and supervisory instruments, and steam dump valve controls. This grouping allows the operator to concentrate his attention on a relatively small portion of the control board during plant startup and following a plant trip. Further to the right, on the same board, are the turbine operation and supervisory instrumentation. The plant electrical output is regulated from this part of the control panel.

Reactor plant and auxiliary controls are on panel CB-1/2/3, located to the left of panel CB-4. Immediately next to panel CB-4 are the reactor coolant system controls and supervisory instruments, including reactor coolant loop flow and temperature indicators. Next are the pressurizer controls and supervisory equipment, including pressure and level indicators and controls, and relief and spray valve switches and controls. Next in order are the chemical and volume control system controls. Normally, this system operates automatically. The operator can override automatic operation if necessary. Next in sequence are the controls for the shutdown cooling system. This system is used only during shutdown and refueling and is manually controlled. The left-hand third of this panel is occupied by the component cooling and raw water system controls. These systems also operate automatically, and the operator can override the automatic controls. The controls located here govern pump operation and the valves which determine the flow paths used by the coolant. The latter capability is given the operator so that he can maintain control of the system in the event of malfunctions. System trimming, to meet flow requirements, is controlled from panel AI-45, behind the main control board.

The extreme right-hand end of the main control board is formed by the electrical panel CB-20. The electrical distribution system within the plant and the electrical connections between the plant and external electrical systems are controlled here. Synchronization of the generator is controlled from the area of the board adjacent to the turbine board. Once set up, this board requires minimal operator attention during normal plant operation.

Computer "desks" are arranged in the area directly before the main control boards. These desks include the operator's console with equipment and user terminals for communication with the computers and provision for writing areas.

A row of panels across the room from the main control board, contains the nuclear instrumentation system and safeguards controls. These are described in order from left to right looking at the panels.

On the left are panels AI-43A and AI-43B, the containment isolation panels. Each panel is in two sections. They incorporate position indicating lights for all containment isolation valves and control switches for all isolation valves which do not have control switches elsewhere in the control room. If a valve fails to close upon the containment isolation signal the operator can remote-manually close the valve from their panels. If a given line has two isolation valves, one is on each panel. A description of the containment isolation system is contained in Section 5.9.5. Containment isolation is a part of Engineered Safeguards as defined in Section 6.

Panels AI-30A and AI-30B are the Engineered Safeguards control panels; these panels are described in Section 7.3.3.

Next in line is the reactor protective system nuclear instrumentation panel, AI-31A through E. Each channel of nuclear instrumentation is equipped with a power level indicator.

The last cabinets in this line are the radiation monitoring panels AI-33A, B, and C. These panels have alarms, indicators, and recorders for the radiation monitors.

Panels AI-65A & B and AI-66A & B, located in the N. corner of the Control Room are Post Accident Monitoring Panels and are instrumented to annunciate, monitor and record conditions of post accident reactor coolant gas valves and positions, containment sump and containment levels, Diverse Scram System, and auxiliary feedwater pumps and valves. Controls for the monitored systems are also provided.

Two rows of panels behind the main control board contain instruments and controls which require only occasional supervision and auxiliary equipment (e.g., power supplies) which must be convenient to other equipment in the control room but require no operator attention. The functions of these panels include component and raw water systems controls, auxiliary building ventilation and purge systems controls, fire detection and lighting.

Panels AI-106A and AI-106B are the control room air conditioning system control panels and are located out of the main operating area along the south wall of the control room. These panels contain controls and instrumentation for the control room air conditioning units, emergency filtration units, and the control room iodine monitor. These systems are designed to require minimal operator attention. These panels are part of the Engineered Safeguards.

7.6.3 Radioactive Waste Disposal System Control Panels

The radioactive waste disposal system is controlled by a combination of automatic, remote-manual, and local operations. Remote-manual operations are conducted from panel AI-100 located in the auxiliary building at elevation 989'-0" near the processing equipment. The panel also contain supervisory instrumentation for the automatic functions and annunciators.

Panel AI-100 is used to control the following functions:

a. Water transfer from the waste holdup tanks, hotel waste tanks, and spent regenerant tanks to the inlet treatment header or monitor tanks;

b. Treated water from the monitor tanks to the overboard header or for further treatment;

c. Gaseous waste release to the ventilation discharge duct.

In cases where redundant components are provided, selection of the equipment to be used is made from the panel. Equipment which is supervised from this panel, and normally operated automatically, can also be operated manually from this panel as follows:

1. Gas decay tanks;
2. Waste gas compressors;
3. Waste holdup recirculation pump;
4. Auxiliary building sump tank and pumps;
5. Spent regenerant tank pumps;
6. Waste filters (no controls);
7. Spent resin tank;
8. Containment sump pumps.

The portions of the liquid and solid radwaste processing system in the Radioactive Waste Processing Building are controlled from local panels near the mobile process equipment. Because of the nature of this equipment, each system has its own unique controls.

7.6.4 Miscellaneous Local Control Stations

As far as possible, the control of plant systems is concentrated in the control room. The auxiliary feedwater system can also be operated from an alternate shutdown panel located elsewhere. The diesel-generators can also be controlled from panels located in the diesel-generator rooms. As described previously the waste disposal system is controlled from outside the control room; other panels, described below, have also been found desirable to control local functions. The local panels are:

a. Auxiliary feedwater regulating panel (AI-179): This panel displays the water level in each of the steam generators and contains controls for the auxiliary feedwater containment isolation valves, the turbine driven auxiliary feedwater pump steam supply valves and the associated safety class pump recirculation valves. The panel also contains a master transfer switch to transfer control of the auxiliary feedwater system from the control room to this point. These panels are part of the Engineered Safeguards.

b. Diesel-generator panels (AI-133A and AI-133B): These panels (see Section 7.3.6) include master switches which disconnect all external sources of supply from the station bus, shed all non-essential loads, disconnect all engine and generator protective devices except overspeed trip and isolate control from the safeguards panels, AI-30A and AI-30B. Operation of the master switch allows local operation of the diesel breaker emergency switch to connect the generator to the station bus. Each diesel- generator is also provided with an integral panel which permits starting the unit and isolating control of the engine from the control room. These panels are part of the Engineered Safeguards.

c. Temperature control panels for the auxiliary building ventilation systems: The panels contain controllers only (see Section 9.10.2.1); thermostats are located elsewhere.

d. Vacuum deaerator control panel (AI-105): This equipment normally operates automatically; the panel contains supervisory equipment.

e. Air compressor control panel: The air compressors run automatically; the panel includes unloading controls, supervisory instrumentation, and an operation sequence switch.

f. Condenser backwash panel (AI-123): This panel contains circulating water valve controls. An operator periodically reverses flow through each condenser shell in turn for a short period to dispose of debris in condenser tubes and at the tube inlets. The panel is in the turbine room at the basement level.

g. HP heater drain panel (AI-121): This panel contains level controllers for feedwater heaters 5 and 6. The equipment operates automatically. The panel is in the turbine room at the basement level.

h. LP heater drain panel (AI-122): This panel contains level controllers for feedwater heaters 1, 2, and 3. The equipment operates automatically. The panel is in the turbine room at the basement level.

i. Screen wash panel (AI-120): This panel contains screen controls, screen wash pump controls, circulating water pump discharge valve controls and supervisory instruments for this equipment. The circulating water pump and circulation pump discharge valve controls duplicate functions on the main control board.

j. Stator winding cooling and hydrogen control cabinet (AI-134): This panel includes annunciators and other instruments and controls for operating and monitoring the stator winding cooling water system. It also incorporates a flowmeter, pressure indicator, and other instruments, controls, and alarms for the generator hydrogen cooling system.

k. Alternate Shutdown Panels: Alternate Shutdown Panels (ASP) AI-185 and AI-212 have been installed next to the auxiliary feedwater panel AI-179 in the electrical penetration room at Elevation 1013'-0". These panels are part of the Engineered Safeguards.

The following instruments and controls are provided on these panels:

- Primary Loop Hot Leg Temperature Indicator
- Primary Loop Cold Leg Temperature Indicator
- Volume Control Tank Level Indicator
- Pressurizer Level Indicator
- Control Switch "Open-Close" with one set of indicating lights for HCV-239
- Open/Close indication for: HCV-240, PCV-103-1, PCV-103-2 and TCV-202
- Control Switch "Close-Trip" with one set of indicating lights for CH-1B
- Wide Range Neutron Flux Monitor

7.6.5 Features Which Enhance Safe Operation

All panels and consoles are enclosed. Panels within the control room are individually air cooled where required. All cables enter from the cable room below; the sleeves between the cable room and control room are sealed. A fire originating outside the control room could not spread to the control room through the duct system or cable sleeves. Further, since combustible materials are excluded from the control room as far as practical, the danger of fire in the control equipment is minimized.

Safety circuits have redundant channels. Two channels are generally provided for actuating circuits such as containment isolation valve closure signals. Four channels are provided for sensing circuits such as pressurizer level. Inside the panels, equipment in each channel is separated from adjacent channels by metallic separators to minimize the possibility that damage to one channel could cause damage to another channel serving the same purpose.

In some cases, such as the containment isolation valve panel, (AI-43A and AI-43B), two sections are provided, one for instruments and devices in each channel.

The panels are arranged to minimize the span of attention required from the operator so that he can better monitor plant conditions. Items most likely to require frequent or immediate attention are grouped toward the center of the panel and equipment requiring less frequent attention toward the ends of the panel. For example, reactivity control is close to the middle. The electrical distribution equipment is at one end. Items which are likely to need attention, at the same time or in succession, are grouped together as much as possible. For example, the steam dump valve controls which are used to stabilize reactor coolant parameters after plant heatup is completed are adjacent to the CEA controls which are used when the reactor is made critical. Such grouping minimizes the likelihood of operator error.

7.6.6 In-Plant Communication System

The in-plant communication system comprises two separate systems, a GAI-Tronics Transistorized Communication (GTC) system and a sound-powered, telephone system. The dial telephone system is not a plant-wide system and is not intended for in-plant communication. The dial telephones each have individual numbers and are connected to the District's internal telephone system and the local telephone company exchange.

OPPD's 800 Mhz radio communication trunking system has been expanded to Fort Calhoun and is available to various groups at the plant. This system is not considered a plant wide system.

The basic GTC system is made up of handsets which have a local speaker amplifier and are distributed at strategic locations throughout the plant. Jack stations are also located in containment for use with portable handsets and amplifiers.

Two single channel sub-systems complement the basic three channel system. As an aid to fuel handling operations, handsets at the fuel pool area and the refueling crane inside the containment permit intercommunication between these areas and the control room. Certain handsets in the control room are, therefore, equipped with an additional channel. The GTC system is supplied from the 120-Volt instrument ac system (see Section 8.3.5).

The sound-powered telephone system is provided to facilitate maintenance and to back up the main electronic system. Sound-powered telephone jacks are distributed throughout the plant at certain GTC system locations. Portable handsets and portable headsets are provided. The system has two channels to provide the facility for two separate conversations utilizing up to the total number of handsets and headsets available.

7.6.7 Off-site Communication

Off-site communication comprises five separate systems, a dial telephone system connected to the District's internal telephone system and the local telephone company in Blair and Omaha; dedicated leased telephone lines for various functions; a microwave transmission system; 800 Mhz two way radio system and backup radio systems (Washington County Sheriff contact and emergency 800 Mhz radio communication backup with all OPPD's power plants) provided in case of failure of telephone and/or radio system.

7.6.8 Alternate Shutdown Capability

Alternate shutdown capability is provided for use in the event of an accident situation which renders the control room uninhabitable. Located in the auxiliary building the alternate shutdown panels contain the necessary instrumentation and control equipment to allow the operator to safely bring the plant to hot shutdown status and maintain that status until sufficient corrective measures can be taken to allow and maintain a cold shutdown.

SECTION 8

ELECTRICAL SYSTEMS

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The following figures are controlled drawings and can be viewed and printed from the listed aperture card.

8.2 NETWORK INTERCONNECTIONS

The station output is supplied to the 345-kV transmission system through the substation located at the plant site. Figure 8.2-1 is a one-line diagram of the transmission system in the vicinity of the plant site.

8.2.1 Distribution of Station Output

The generator output is fed through a two-winding 22-345-kV delta-wye transformer to a breaker and a half scheme in the switchyard. Three 345 kV transmission lines connect the on-site switchyard to Omaha; Lincoln, via the Lincoln Electric System (LES) Wagener Substation; and Sioux City, via the Mid-American Energy, Inc. Raun Substation. Each of the three 345-kV lines connected to the on-site substation has sufficient capacity to carry the station output.

The plant substation is arranged as a breaker and a half scheme and includes high speed relaying for line and bus protection. Primary relaying protection of the transmission lines is accomplished via power line carrier relaying. Secondary relaying using telephone pilot wire relaying was also installed to ensure protection.

Line design exceeds the requirements of National Electric Safety Code for heavy loading district, grade B construction. The line design was based on calculated lightning performance of less than one outage per hundred miles per year.

A detailed stability analysis involving the Fort Calhoun Power Station for the summer of 1971 conditions was conducted by OPPD in 1968. In representing the 345 kV system associated with the Fort Calhoun unit, the major portion of the bulk transmission system in seventeen states was included. In order that the system investigation would represent the most severe conditions, the maximum tolerable power transfer (1100 megawatts south to north) was represented in the Mid-Continent Area Power Pool (MAPP) (formerly Mid-Continent Area Power Planners) system as a predisturbance condition.

The study was conducted using the Westinghouse Dynamic Stability Program. The major generating units in the MAPP area were represented in detail complete with generator electrical constants, turbine-generator inertia constants, excitation system description and electrical constants, and speed-governor description and control constants.

Since previous studies had indicated that the system may not go unstable until after the second or third oscillation, a five second study duration was utilized to ensure that the most severe oscillation was included.

Both three-phase and single line to ground faults were examined as follows:

1. Primary clearing with reclosing into a permanent fault.

2. Breaker failed to operate at the fault location and the fault is finally cleared by back-up operation tripping an additional line.

3. The Fort Calhoun unit was tripped by a back-up relay.

Conclusions from this study indicate that a three-phase fault at the Fort Calhoun substation with a stuck breaker at Fort Calhoun which allows the unit to feed the fault for thirteen cycles and is then cleared by back-up relaying will not cause the remainder of the system to become unstable.

The effect of a trip of the largest unit in the MAPP system at the time, the 800 MWe NPPD Cooper Station Unit No. 1, was investigated by Stone & Webster, consulting engineers, in 1967. The investigation considered disturbances during 1000 megawatt power transfers both north and south. Conclusions indicated the system to be stable for all conditions of load transfer.

Subsequent studies by the MAPP Reliability Studies Task Force have simulated various conditions for the 1982 and 1986 summer seasons. Although these were not thorough studies of the area around Fort Calhoun, they were intended to locate the most severe "probable and extreme" disturbances, as defined by MAPP, within the power pool. None of the disturbances simulated resulted in a complete collapse of the system, causing loss of station power at the Fort Calhoun Station.

The results of these stability studies indicate that neither the loss of the Fort Calhoun Station unit nor the loss of the largest unit in the MAPP system will adversely affect the remainder of the transmission system. The two sources of off-site power, the 161 kV line and the 345 kV system, will remain intact.

The 345 kV and the 161 kV lines entering the switchyard from the north and west are widely separated except for two 345 kV/161 kV crossings west of the switchyard (see Figure 8.2-2).

The 345-kV substation switching power (breaker control and operation) is provided by one of two batteries.

Each battery is connected to a battery charger fed from the switchyard 13.8 KV distribution system in normal and emergency operation. This is the normal layout for all OPPD transmission and distribution substation service.

The 161 KV substation uses two batteries in an arrangement similar to the 345 KV substation where both the normal and emergency battery charger power feed are from the switchyard 13.8 KV distribution system.

The 345 kV and 161 kV lines from the switchyard to the plant were located as far apart as possible. Those points of minimum separation, including one crossing, were established by the location of the transformers, and by the orientation of equipment in the switchyard.

In all, 345 kV line 3423 crosses 161 kV line 1587 at one location. OPPD records show that of fifty-five crossings of transmission lines, i.e., 345/161 kV and 161/69 kV, in operation at the time of the study, no major line failures had occurred at the points of crossing. The fact that the 345 kV towers have been designed to withstand 1.7 times the wind loads of our conventional 161 kV double circuit steel tower line, plus a special one inch radial ice loading design, further demonstrates the improbability of a failure at one of the 345 kV/161 kV crossings at the Fort Calhoun site. Should a failure of either a conductor or shield-wire on the 345 kV line occur the 161 kV line breakers would trip, thus preventing damage to electrical equipment.

8.2.2 Station Service Power Supply

Power for the 4.16-kV station auxiliary system is available from two separate systems, either of which has sufficient capacity for all of the auxiliaries. One source is the generator 22-kV bus, tapped between the generator disconnect switch, DS-T1, and the 22-345 kV generator transformer; the other source is the 161 kV system which is normally connected to both the OPPD generating system in Omaha and generating system in Sioux City. Each of these two sources feeds the station auxiliaries through two transformers.

Backup auxiliary power is provided by backfeeding from the 345 kV system via the main transformer and the 22-4.16 kV auxiliary transformers following a generator trip and manual opening of generator disconnect switch DS-T1. DS-T1 current interrupting capacity limitations require that interlocks be provided to prevent switch opening unless the 345 kV generator circuit breakers have tripped, generator excitation has been removed, and the generator bus is deenergized, the isolated phase bus forced air cooling system has been shut down, and the four 4.16-kV bus breakers associated with the 22-kV supply are open.

The disconnect switch DS-T1 has a Kirk Key interlock and is actuated in one of three ways: electrically from the Control Room, electrically from local controls, or manually with a removable hand crank.

To further ensure switch reliability, DS-T1 is normally exercised following each generator trip or generator shutdown, and the contacts are normally inspected before the switch is reclosed.

The adequacy of the switch design was demonstrated by magnetizing current interruption, voltage impulse, current impulse, and heat run factory tests.

Should loss of offsite power occur during a DBA, bus undervoltage relays together with auxiliary relays will operate to:

a. Trip Engineered Safeguards and trip other, nonessential loads.

b. Bring the Diesels from "Idling" to Full Speed and Voltage.

c. Reset the four Engineered Safeguards Sequencers.

Diesel Generator Breaker closure on buses 1A3 or 1A4 will cause the associated timers on the Sequencers to begin to time out and restart the first group of safeguards loads.

Protective relays will operate through lockout relays to disconnect buses 1A3 and 1A4 from the faulted offsite power source. With no voltage on buses 1A3 and 1A4, completion of 4.16-kV load shed, and proper voltage and speed at the diesels, the diesel breakers will close automatically to restore power to the buses.

Normal protective trip devices for the diesel engine and generator are bypassed except for the overspeed trip.

A 13.8 kV emergency power system is available from the 13.8 kV Distribution system to allow for plant shutdown in the event that the normal plant power supply, including the emergency diesel generators, is lost.

8.3 STATION DISTRIBUTION

8.3.1 4.16-kV System

8.3.1.1 Design Bases

The 4.16-kV system was designed to function under the design accident and environmental conditions defined in Section 8.1.1, and to satisfy the following performance criteria:

a. Meet load demand for plant operations at power, including starting of the largest motor with other normally operating motors running and loaded, with any one of the four 4.16-kV supply transformers out of service;

b. Obviate plant trip in the event supply fails to buses 1A3 and 1A4;

c. With two diesel-generators but no outside power available, start and operate the full complement of Engineered Safeguards; if only one diesel-generator is available, start and operate at least minimum Engineered Safeguards;

d. Satisfy the single failure criterion.

8.3.1.2 Description and Operation

General

The 4.16-kV system comprises four, outdoor transformers; nonsegregated bus duct supply connections separately routed to each of the four main buses; two diesel-generators for emergency supply; and supply-bus, and load-feeder circuit breakers. The arrangement of these elements is shown in USAR Figure 8.1-1.

Buses 1A1 and 1A2, which supply only loads at 4.16-kV are normally connected to unit auxiliary transformers T1A-1 and T1A-2, respectively; these transformers are supplied at 22-kV from the generator main leads. Buses 1A3 and 1A4 are connected to, respectively, house service transformers T1A-3 and T1A-4 for normal supply, and diesel-generators D-1 and D-2 for emergency supply. Transformers T1A-3 and T1A-4, if energized, are supplied from the 161-kV system.

Buses 1A3 and 1A4 supply plant 4.16-kV loads and all 480-Volt loads through three, double-ended 480-Volt load centers, each with three bus sections.

The double-ended 480-Volt load centers permit feeding of the 480-V station auxiliary loads from either bus 1A3 or 1A4. The systems associated with bus 1A3 and 1A4 are operated as separate systems. Interlocks prevent interconnection of these systems at the 480V level.

Buses 1A3 and 1A4 also supply all Engineered Safeguards, directly or through the 480-Volt load centers. The systems associated with buses 1A3 and 1A4 are operated as separate systems, between which redundant Engineered Safeguards are so divided that minimum Engineered Safeguards are connected to each system.

Station lighting transformers T1C-3A and T1C-4A can be fed from either bus 1A3 or 1A4. Normally T1C-3A is fed from bus 1A3 and T1C-4A is fed from 1A4. Special situations may require that both transformers be fed from the same bus. Interlocks on the feeder breakers make this possible without compromising 1A3 and 1A4 redundancy.

As arranged, 4.16-kV buses 1A1 and 1A3, have access to either the generator auxiliary transformer (T1A-1) or the house service transformer (T1A-3), while 4.16-kV buses 1A2 and 1A4 have access to either the other generator auxiliary transformer (T1A-2) or the other house service transformer (T1A-4).

Interlocks prevent connection of a 4.16-kV bus to both transformers (except temporarily for manual, hot bus transfer) to avoid the condition where the available short circuit current is in excess of the interrupting capacity of the 4.16-kV circuit breakers. Either both generator auxiliary transformers or both house service transformers have the capability of carrying the full station service load. Under normal conditions the load is divided between the two transformer systems (two 22-kV/4.16-kV and two 161-kV/4.16-V transformers).

An automatic bus transfer scheme between the two transformer systems as summarized in Table 8.4-3 is provided.

Two transfer modes are provided:

a. Fast transfer (break before make limiting the bus dead-time to within motor Volts per Hertz-V/Hz limits) provided that before the failure the sources' frequency was in acceptable limits and the voltage phase difference was within the acceptable range;

b. A slow transfer is based on load shed of selected 4.16-kV rotating loads and the decay of bus residual voltage to a safe value before re-energization.

Slow transfer operates in the event that fast transfer fails or when fast transfer is blocked because of source frequency or excessive voltage phase-angle difference.

The 4.16-kV Switchgear is rated at 5-kV, 250 MVA interrupting, metal clad, with 1200 ampere (load) and 2000 ampere (bus feeder) circuit breakers.

Unit auxiliary transformers T1A-1 and T1A-2 are outdoor units rated for 12/13.44/17.9 MVA, OA/OA/FA, 22-4.16-kV, and have a nominal 6 percent impedance.

The house service transformers ratings are identical except that the voltage rating is 161-4.16 kV and the nominal impedance is 8 percent. With these transformer ratings the plant can be operated at maximum capacity (worst case plant loads) with only two transformers in service.

Relay protection follows standard power plant practices in most respects.

Differential protection is provided for large motors (3500 HP and larger).

Undervoltage relays on the 4.16-kV buses and the 480-V load centers initiate load shedding as the diesel-generators are run-up in preparation for automatic connection of Engineered Safeguards loads.

Plant Startup

For reactor startup and turbine-generator warmup, buses 1A1 and 1A2 are normally fed from T1A-1 and T1A-2, respectively, while buses 1A3 and 1A4 are supplied from the 161-kV system via T1A-3 and T1A-4.

Buses 1A1, 1A2, 1A3 and 1A4 are supplied from the 161-kV system for generator synchronization. Following generator synchronization to the system, buses 1A1 and 1A2 are transferred live, in turn, to transformers T1A-1 and T1A-2, respectively. No other changes are required for operation at power.

Plant Shutdown

Before the generator breaker is tripped, buses 1A1 and 1A2 are respectively transferred live from transformers T1A-1 and T1A-2 to transformers T1A-3 and T1A-4. Following tripping of the generator breakers, the disconnect switch in the generator leads is opened, the 345-kV backfeed established, and normally buses 1A1 and 1A2 are retransferred back to the unit auxiliary transformers.

8.3.1.3 Design Analysis

The four bus arrangement described above is used to provide a flexible reliable power supply in which single failures would not reduce the system below acceptable levels for:

a. Performance of Engineered Safeguards;

b. Reactor protection, with respect to flows of Reactor Coolant, Steam Generator Feedwater, Component Cooling Water, and Raw Water;

c. Protection for other plant systems and equipment.

The worst case single failure in the plant auxiliary power system is a fault on 4.16-kV bus 1A3 or 1A4 that is not cleared automatically and cannot immediately be cleared manually. Such a failure trips the plant and reduces Engineered Safeguards availability to a level approaching minimum Engineered Safeguards. If bus 1A3 is de-energized, its associated 480 volt buses 1B3A, B and C can be energized via the 1A4 side providing proper 480 volt breaker lineups have been performed. Safeguards available and responding to an SIAS when both buses 1A3 and 1A4 are energized by their normal sources, are shown in Figure 8.4-1.

Engineered Safeguards equipment available and nominal automatic response times to a DBA requiring both safety injection and containment spray when both buses 1A3 and 1A4 are energized, are shown in Figure 8.4-1 (the normal operating condition of 480-V bus-tie breakers is used). Engineered Safeguards available upon loss of either bus 1A3 or 1A4 may also be determined from Figure 8.4-1. Adequate Engineered Safeguards are available in either case.

When any 4.16-kV main bus is de-energized by source failure, it is automatically reconnected to an alternate source, or where appropriate, to an emergency source as described in Section 8.4-3.

8.3.2 480-Volt System

8.3.2.1 Design Bases

The system arrangement shown in USAR Figure 8.1-1 is based on maintaining an acceptable performance level for Engineered Safeguards and other plant auxiliaries required for safety and equipment protection, in the event of 480-Volt outages of the following magnitudes:

a. Load center sections connected to 4.16-kV main bus 1A3, or 1A4, as would result from a main bus outage;

b. One, complete, double-ended load center.

8.3.2.2 Description and Operation

The 480-Volt system arrangement is shown in USAR Figure 8.1-1. The main 480-Volt buses comprise three, double-ended load centers, each with three bus sections. The center bus section of each can be tied to either adjacent bus section, but not both if the adjacent sections are energized from their associated 4.16-kV/480-V transformers. This is prevented by electrical control circuit interlocked bus-tie circuit breakers.

Each center bus section is normally connected to the "preferred" adjacent bus section by means of a normally closed bus-tie circuit breaker as indicated in Figure 8.4-1. Thus the center bus sections are each part of one of the two separate systems, starting with 4.16-kV main buses 1A3 and 1A4, between which redundant Engineered Safeguards and other essential auxiliaries are divided. In the event of the loss of either main bus, each de-energized center bus section may be manually transferred to the "alternate" bus section at the discretion of the operator.

Each double-ended load center group is provided with two dc control power feeders, one from each dc system (see Section 8.3.4) and a manual transfer switch to ensure availability of control power.

The six load center transformers are throat-connected, 1000/1,333 kVA, dry-type, AA/FA, 4,160-480-Volt, delta-delta units, and provided with surge protection on the 4.16-kV side. The air circuit breakers are of the stored energy type, rated to interrupt 22,000 Amperes.

Twenty-three motor control centers are contained within the plant. The circuit breakers feeding the motor control centers are rated to interrupt a maximum current of 22,000 Amps.

8.3.2.3 Design Analysis

Nine 480-Volt bus sections, three with access to bus 1A3 for supply, three to bus 1A4, and three to either bus 1A3 or 1A4, permit a distribution of loads (see USAR Figure 8.1-1) that satisfies the single failure criterion with one of the six 4,160-480-Volt transformers out of service. In the worst case with one load center transformer already out of service, the single failure is an uncleared fault on bus 1A3 or 1A4, which could remove from service three additional transformers (a total of four transformers out of service). Under this condition minimum Engineered Safeguards could be operated by manually closing 480-Volt bus-tie breakers to supply as many as six 480-Volt bus sections.

Provision of dual dc control power feed-manual transfer switch for each load center minimizes the consequences of single failure in the dc control power systems.

Selective fault protection is used throughout the 480-Volt system

Available fault current levels are within the circuit breakers' or breaker/starters' interrupting capability.

8.3.3 Control Element Drive Power

8.3.3.1 Design Bases

The control element drive power system is designed as a stable, reliable supply for the control element drive motors.

8.3.3.2 Description and Operation

Two 480-120-Volt, single phase, 60 Hz transformers furnish power for the control element drive system. Selection of the transformer is made through a manual transfer switch on the 120-Volt side. The drive motors are supplied through individual contactors located in the contactor panel and are controlled from the control room.

Each transformer is supplied from a manually controlled circuit breaker in a different motor control center. The motor control centers are supplied with power from different 480-Volt load centers and arranged so that the power for each is fed from a different 4.16-kV Engineered Safeguards bus.

Loss of control element drive power does not affect the CEA position or inhibit the ability to trip the reactor.

Means are provided to interrupt drive power at the contactor panel; use of the interrupt is annunciated in the control room.

8.3.3.3 Design Analysis

Each transformer is sized to operate the CEDM system. To assure reliability, the transformers are supplied from separate buses, each of which can be supplied by a separate emergency diesel-generator. Upon loss of one transformer, the other transformer may be manually placed in service to supply power to the CEDM's. The CEDM drive fails as is on loss of power. A loss of both transformers would not prevent a safe shutdown since the CEA's insert when the clutches are de-energized.

8.3.4 DC Systems

8.3.4.1 Design Bases

The dc systems are designed as the basic sources of energy for plant control and instrumentation in all categories, and to operate without interruption during the accident and adverse environmental conditions listed and referenced as general design bases in Section 8.1.1.

The capacity of the storage batteries in each of the two, independent systems is adequate to supply continuous control power, and instrumentation required for safety for 8 hours without operation of the battery chargers.

8.3.4.2 Description and Operation

The dc systems are diagramed in USAR Figure 8.1-1. Each of the two systems comprises a 58-cell storage battery with each battery rated at a nominal 2062 ampere - hours at the 8-hour discharge rate, a battery charger, main fuses, a main distribution switchboard with circuit breakers and switches, local distribution panels, and feeders. A third battery charger is used as a spare for either system. Spare battery charger dc circuit breakers are interlocked to prevent paralleling main buses.

The battery chargers are solid-state, rated 400 Amperes and are designed for constant voltage operation up to a nominal 380 Amperes and have a current limiting characteristic beyond the nominal 380 Amperes.

The switchboard circuit breakers are rated to interrupt expected fault current. Battery fuses, main panel supply and feeder circuit breakers, and local panel feeder circuit breakers and fuses provide selective fault protection.

The systems are ungrounded and provided with ground detectors and alarms.

During normal operation, the battery charger floats on the bus, supplying dc load demand up to maximum charger capacity, and at the same time keeps the battery fully charged. The battery assists in meeting peak demands greater than charger capacity. The charger is also used for applying an equalizing charge to the battery.

Each of the two dc power supply systems is provided with condition and performance instrumentation in the control room as follows:

On control room dc distribution panels (AI-41A for dc system 1, AI-41B for dc system 2):

a. Battery ammeter (charging current or discharge current);

b. Battery voltmeter;

c. Main dc bus voltmeter;

d. Battery charger, voltmeter and ammeter;

e. Main dc ground indication.

f. Ground Fault Voltmeters

On main control boards:

a. Battery charger failure monitoring annunciator point for:

1. Loss of ac input
2. Low dc output voltage
3. High dc output voltage
4. Charger failure (low output current)

DC System Annunciation.

1. An undervoltage relay monitors the battery and bus voltage and will sound an alarm in the control room on low voltage.

Relays monitor both positive and negative leads for ground and will sound a separate alarm in the control room on detection of a single lead ground.

The battery chargers also have separate voltmeters and ammeters located in the control room indicating their operating condition.

System instrumentation/annunciation, together with administrative control will ensure that any abnormal condition, should it arise, will be detected and corrective action taken.

8.3.4.3 Design Analysis

The effects of failures involving loss of dc on Engineered Safeguards control and operation are considered in Sections 7.3.5.2 and 8.3.5.3 and are summarized in Table 7.3-2.

Each switchgear section is provided with two feeders, one from dc bus 1 and one from dc bus 2, and a manual transfer switch, see Figure 8.1-1. Similar provisions are made for important control panels.

8.3.5 Instrument AC System

8.3.5.1 Design Bases

The ac instrument system is designed to function without interruption in the event of the design accident or adverse environmental conditions cited in Section 8.1.1.

Other design requirements include:

a. System arrangement compatible with basic logic schemes used for the Reactor Protective and control systems, and for actuation of Engineered Safeguards.

b. Inverter voltage regulation and total harmonic content contribution.

c. Inverter synchronous operation with the 480-V system as the reference source with automatic reversion to internal reference if the synchrous reference source is lost (a voltage based transfer to the internal reference).

8.3.5.2 Description and Operation

The ac instrument system is comprised of six separate buses, four of which supply power to safety related instrumentation. Each instrument bus is supplied by a separate solid-state inverter from the dc system. As shown in Figure 8.1-1, instrument buses A, C, and 1 are supplied from dc bus 1 and B, D, and 2 are supplied from dc bus 2.

Safety related inverters A, B, C, and D are rated 7.5 KVA at 0.8 power factor, lagging at 120-volts ± 2 percent, single phase.

Inverters 1 and 2 are rated 10 KVA at 0.8 power factor, lagging at 120-volts ± 2 percent, single phase.

All instrument buses provide annunciation in the main control room upon detection of low bus voltage. Each inverter has its own annunciator point in the control room which is actuated when the inverter is in an off-normal condition.

Instrument buses A and C, supplied from dc bus 1, have a manual bus tie for use only when an inverter is out of service for maintenance. Buses B and D, supplied from dc bus 2, are similarly arranged.

Each of the instrument inverters which supply power to the instrument buses also have a bypass source which supplies power to the bus if there is an inverter failure or inverter maintenance is necessary. In the event of inverter failure, the load on the inverter is automatically transferred to the bypass source. The bypass source is supplied with power from the 480 volt distribution system which is an interruptible source.

In addition to the bypass transformers, inverters 1 and 2 each have a dedicated test transformer which can supply convenience power to instrument buses 1 and 2, respectively, when the normal inverter/bypass power supply is unavailable.

8.3.5.3 Design Analysis

Four instrument buses are used to complement Reactor Protective and Engineered Safeguards initiation logic schemes, which are basically two-out-of-four.

Where inputs to a two-out-of-four logic matrix require ac control or instrument power, each input channel is supplied from a different ac instrument bus.

Where the inputs to such matrices de-energize to trip (characteristic of Reactor Protective logic) failure of one instrument bus trips one input channel to each matrix. Failure of two instrument buses (which can result from a single dc failure) will trip the reactor. Failure of two instrument buses will not prevent safe shutdown of the reactor.

Safety injection and containment spray systems are not actuated by such failures.

Each inverter supplying the instrument buses operates in synchronism with the auxiliary power system to improve accuracy and consistency of timing operations and to avoid the beat frequencies that can occur in a synchronous system. Each inverter reverts to an internal frequency reference when the system reference synchronization voltage source is lost.

The instrument inverters are buffered from plant auxiliary power system faults and voltage disturbances such as commonly occur in starting large motors by the isolation characteristics of the transformers which serve as the alternate power source. The safety related inverters, A, B, C and D also have an internal isolation transformer which is connected between the bypass source and the inverter output to further minimize the possibility of a disturbance being caused on the 120 VAC instrument buses.

8.4 EMERGENCY POWER SOURCES

8.4.1 Diesel-Generators

8.4.1.1 Design Bases

The Diesel-Generators are designed to furnish reliable in-plant ac power adequate for safe plant shutdown and for operation of Engineered Safeguards, when no energy is available from the 345 or 161-kV systems. For adequate reliability two units are provided. One unit is connected to each of the two separate 4.16-kV systems (one system consists of bus 1A3, the second system consists of bus 1A4) between which Engineered Safeguards and other essential auxiliaries are divided (see Figure 8.4-1). The division of loads is such that operation of either system alone provides minimum Engineered Safeguards required for the DBA as discussed in Section 6.

The Diesel-Generators are located in separate rooms. The rooms are separated from each other by a three-hour fire rated barrier and are of a seismic Class I design. The installation is designed to survive without impairment of function, any of the design basis environmental conditions referenced in Section 8.1.1.

8.4.1.2 Description and Operation

There are two diesel-generators similar in design and characteristics. (There are minor differences in the intake damper configuration and only DG-2 is configured to be credited for fire safe shutdown capabilities). Each unit is complete with all auxiliaries necessary for operation and for ensuring quick starts. No auxiliaries are shared, and no energy source external to the units, other than dc control power, is required for starting or subsequent operation. The capacity rating of each unit at 4.16-kV, 0.8 power factor lagging, and 60 Hz, is listed in Table 8.4-1.

Table 8.4-1 - "Diesel-Generator Unit Capacity"

2000 HR KW RATING

2000 HR ENGINE RATING	3950 HP	2946 KW
RADIATOR FAN DRIVE DERATING	-120 HP	-89 KW
GENERATOR COOLING DERATING	-20 HP	-15 KW
GLYCOL SOLUTION COOLING	-180 HP	-134 KW
NET AVAILABLE ENGINE CAPACITY		2708 KW
GENERATOR EFFICIENCY MULTIPLIER		.97
NET AVAILABLE DIESEL GENERATOR CAPACITY		2627 KW*

*The Diesel-Generator available capacity is then further derated based on Turbocharger intake air temperature and engine coolant temperature. If the engine coolant is changed to a treated water mixture the 134 KW derating for glycol coolant need not be applied.

There are engine ratings that exceed the 2000 HR rating in which capacity is increased and the related inspection time decreases. The 2000 HR rating is the design capacity available for operation of Engineered Safeguards.

The generator impedance characteristics and the characteristics of the static exciter and voltage regulator provide adequate voltage for satisfactory starting, acceleration, and continuous operation of sequenced load groups shown in Fig. 8.4-2.

The engines are started with stored pressurized air. Each is provided with duplicate systems, both driven by electric motors and a diesel driven emergency compressor which is capable of charging either the primary or secondary receivers. The primary and secondary air receivers are normally supplied by plant instrument air which is raised in pressure to 240 psig by booster compressors. The emergency compressor uses ambient air in the event that power or the instrument air header is not available. Each of the engine starting air systems has capacity for five starts. Other auxiliaries that are duplicated for each unit include the fuel oil systems between the day tank and engine fuel line, and fuel transfer pumps.

Fuel for both diesels is supplied from a common 18,000 gallon underground storage tank by a separate supply line to each diesel. A minimum of 8,000 gallons of additional fuel is available in the auxiliary boiler underground storage tank should extended operation of the diesels be required.

A minimum of 8,000 gallons of fuel oil is available from the auxiliary boiler underground storage tank for transfer to the diesel generator storage tank to permit operation of a diesel generator for 7 days in the event of an emergency.

Each diesel has two fuel oil transfer pumps mounted on the engine. The pumps transfer fuel oil from the underground storage tank to a 300 gallon wall mounted day tank in the diesel room. Fuel oil is gravity fed from the day tank to a 550 gallon engine base tank. The 550 gallon base tank provides for more than 3 hours of operation of the engine before fuel transfer is necessary.

Power is supplied to the two fuel oil transfer pumps via a 480 volt, 3 phase transfer switch, fed by the station 480 volt auxiliary power system. In the event that both the normal and emergency power supplies are not available to the transfer switch when the engine is running, a manually interlocked breaker will supply power to the pumps from a transformer connected to the diesel generator output. The loss of power to the transfer pumps is annunciated in the control room.

Each transfer pump has a separate MAN-OFF-AUTO control switch and a common pump selector switch which selects one pump as the lead pump with the other pump as backup.

The level in the wall mounted Auxiliary Fuel Tank is maintained by automatic operation of the fuel oil transfer pump in response to low and high level signals. Low or high level in the auxiliary day tank is alarmed in the control room. Low level in the engine base tank is alarmed in the control room.

Immersion heaters are provided to maintain engine jacket water and lubricating oil temperatures at desirable temperatures for quick, reliable starting.

Lubricating oil is circulated in the engine and turbocharger by two electric motor driven pumps to prelubricate the engine to ensure high reliability during fast engine starts.

The radiator type cooling system for each engine is of the completely integral type, requiring no energy sources except the diesel engine itself.

The units are independently and automatically started under emergency conditions as discussed in Section 7.3. Manual starting and control provisions are provided in the control room and at the local control panel near each unit.

The Diesel-Generators cannot be operated in parallel. There is no bus-tie breaker between 4.16-kV buses 1A3 and 1A4, and interlocks prevent the interconnection of the diesels at the 480-Volt level. This provision ensures that under emergency conditions the two systems supplying Engineered Safeguards are operated independently.

Emergency loading of each diesel-generator unit is functionally diagramed in Figure 8.4-2; the control circuits and automatic load sequencer operation are discussed in Section 7.3. The arrangement of the motor control centers supplying Engineered Safeguards and essential loads and the load distribution are shown in USAR Figure 8.1-1.

8.4.1.3 Design Analysis

The capacity of each Diesel-Generator is adequate to support long term operation of minimum Engineered Safeguards.

8.4.2 Station Batteries

8.4.2.1 Design Bases

Station batteries are an emergency source of dc and ac power for instrumentation and control, and are elements of the dc systems generally described in Section 8.3.4.

The battery installation is designed to survive without interruption of output or impairment of function of the environmental design bases cited in Section 8.1.1 for Class 1 seismic.
The capacity of the storage batteries in the two, separate dc systems is adequate for up to 8 hours operation of control and

instrumentation devices required in the event of a DBA, or for reactor shutdown and standby, without battery charger operation. To ensure 8 hours of battery capacity manual actions must be taken to minimize DC system loads. The battery worst case loading schedule assumed during these emergency conditions accounts for operation of the following:

DC Bus #1

1. Emergency Bearing Oil Pumps (including starting transient and subsequent shutdown)

2. Emergency Lighting (a portion is load shed in minutes)

3. Breaker transient loads and DG start attempts

4. Continuous instrument and control loads.

5. Shutdown of nonessential loads.

DC Bus #2

1. Emergency Turbine Seal Oil Pump (including starting transient and subsequent shutdown)

2. Emergency Lighting (a portion is load shed in minutes)

3. Breaker transient loads and DG start attempts

4. Continuous instrument and control loads.

5. Shutdown of nonessential loads.

Analysis has demonstrated that the installed station batteries have adequate capacity to meet the present eight hour load demand and have additional margin to accommodate load growth.

8.4.2.2 Description and Operation

Two storage batteries are provided. Each battery has sufficient capacity to meet the power demands as described in Section 8.4.2.1. Each battery is installed in a separate room for physical segregation and protection; the rooms are separately ventilated. Battery racks are designed to hold the battery cells in position in the event of the maximum hypothetical earthquake. The arrangement of the battery rooms and their ventilation is as shown in Figure 8.4-3.

During normal operation, the batteries share in meeting control power demand only during peaks when the battery charger rating is exceeded; otherwise the battery chargers meet system demand and simultaneously float-charge the batteries to maintain full charge.

8.4.2.3 Design Analysis

During any period that ac auxiliary power is not available from normal sources or the Diesel-Generators, the station storage batteries are the only available source of dc and ac control power. Thus, under such conditions the batteries are relied on for the control power for starting and loading the Diesel-Generators, and for uninterrupted support of Reactor Protective and Engineered Safeguards systems. In the improbable event of a prolonged ac blackout, the batteries are the source of dc and ac control power for shutdown and, safe monitored standby.

To satisfy the single-failure criterion, two batteries, buses, and distribution systems are provided, and design emphasis is given to preserving electrical and physical independence. The batteries are in individual, closed, ventilated rooms. The distribution apparatus is in individual enclosures, and the feeders of the two systems are separately routed. Single failure consequences are summarized in Table 7.3-2.

Engineering and design attention has been given also to eliminating possible sources of systematic multiple failures. Preventive design measures that apply to Reactor Protective and Engineered Safeguards control systems, of which station batteries are an essential element, are discussed in Section 7.3.5.

The batteries are carefully maintained. Particular emphasis is given to keeping batteries fully charged in view of their emergency function as stored energy sources for operation of instruments and controls. Routine maintenance comprises check of electrolyte level and specific gravity, and, when non-uniform voltage among cells reaches a limit recommended by the manufacturer, application of an equalizing charge.

8.4.3 Automatic Transfer and Load Shedding Controls

8.4.3.1 Design Bases

The Fort Calhoun Station protective relaying is designed to maximize the availability of offsite power to the 4.16-kV system.

Automatic control circuits are provided to re-establish supply to any 4.16-kV bus from a redundant (alternate) source on failure of the normally connected (preferred) source. In the event offsite power fails the Engineered Safeguard buses are automatically resupplied from the onsite Diesel-Generators.

Automatic bus 4.16-kV transfers are summarized in Table 8.4-3.

Bus transfers at 4.16-kV are provided to minimize unnecessary plant shutdowns as the result of single failures of basic power sources or supply apparatus in the plant. Automatic transfer of both Engineered Safeguards buses 1A3 and 1A4 to the unit auxiliary transformers on failure of the 161-kV system avoids plant trip.

No automatic bus transfers are provided at the 480-Volt level.

The 480-Volt buses remain connected to the associated 4.16-kV bus and transfer with that bus.

Table 8.4-3 - "Automatic Bus Transfer"

Bus	Automatic Transfer on Failure of Source			Notes
	Preferred	To Alternate	To Emergency	
4.16-kV UNIT BUS	Generator Leads, via:	161-kV System, via:		
1A1	T1A-1	T1A-3	None	Transfer Independently
1A2	T1A-2	T1A-4	None	
4.16-kV House Service Bus	161-kV System, via:	Generator Leads, via:	Diesel Generator	
1A3	T1A-3	T1A-1	DG-1	Transfer Independently
1A4	T1A-4	T1A-2	DG-2	

8.4.3.2 Description and Operation

4,160-Volt Bus Transfer

Identical and independent automatic control circuits are provided for transfer of each of the four 4.16-kV buses from the preferred to the alternate source. The buses are arranged in pairs as shown in Figure 8.1-1. The preferred source for house service bus 1A3 is the alternate source for unit auxiliary bus 1A1, and vice versa. A similar reciprocal relationship applies for house service bus 1A4 and unit auxiliary bus 1A2. Automatic transfers are not provided that would parallel any two supply transformers, which would result in available short-circuit current in excess of the switchgear capacity.

Two modes of automatic transfer from preferred to alternate sources are provided.

a. 'Fast' (instantaneous) when preferred and alternate sources had been in synchronism with acceptably small voltage phase-angle difference. Total transfer time is accomplished within a short enough time to limit the magnitude of the voltage transient to within the stressing limits of the 4.16-kV motors.

b. 'Slow' transfer, when fast transfer is blocked, that depends on decay of bus residual voltage to a safe value and load shed of rotating and if applicable lighting loads for re-energization of the bus.

Fast transfer is initiated by protective relay operation. Completion of the transfer (closure of the supply circuit breaker from the alternate source) is automatically inhibited to prevent equipment damage when rotating equipment is energized by the alternate source or to prevent an attempt to reenergize a faulted condition. The transfer is inhibited by any of the following conditions:

a. Source under frequency or excessive voltage-angle difference (lack of synchronism);

b. No alternate source voltage;

c. Uncleared fault on the transferred bus;

d. Failure of the preferred source circuit breaker to open (alternate source breaker cannot close until a 'B' contact on the preferred source breaker closes).

The fast transfer can also be manually inhibited.

Slow transfer (dead time several seconds) backs up fast transfer when the latter is blocked because of a source synchronism or excessive voltage phase-angle difference. Slow transfer is initiated by bus undervoltage relays; completion of a transfer is automatically inhibited by b, c, and d above. Slow transfer can also be manually inhibited.

In the event of total failure of supply from the generator main leads and the 161-kV system, both 4.16-kV buses 1A3 and 1A4 are disconnected from their normal and alternate supply sources. Load shedding of motor and selected lighting loads connected to 4.16-kV and 480-Volt buses is initiated by undervoltage relays. Diesel-Generators are started, run up to operating speed and voltage, and connected automatically. If no PPLS or CPHS signal exists, reloading of the system is performed manually by the operator in accordance with established emergency procedure. If a PPLS or CPHS signal occurs, additional load shedding of selected 480-Volt motor control center loads is initiated by means of actuation signals SIAS and OPLS. A PPLS or CPHS signal also initiates the loading of Engineered Safeguards by the automatic load sequencers as shown in Figure 8.4-1.

In the event of a PPLS or CPHS, selected vital loads are sequentially and automatically reconnected by the automatic load sequencers. In the event of a PPLS and CPHS, all vital loads associated with the automatic load sequencers are sequentially reconnected.

A 13.8-kV-480V supply provides another source of emergency power in the event that both Diesel-Generators fail; the source of supply is from the 161-kV system, outside the switchyard breakers which feed the plant station service. The 13.8 kV source has adequate capacity to maintain the plant in a safe shutdown condition.

Buses 1A3 and 1A4 (with their associated 480-Volt systems) are connected automatically and independently to emergency sources (diesel-generators DG-1 and DG-2, respectively) in the event of total failure of supply from the generator main leads and the 161-kV system. If a PPLS or CPHS Engineered Safeguards initiating signal occurs at the same time, a total delay of approximately 13 seconds occurs after the diesel auto start signal before load sequencing is started. The 13-second deadband allows the Diesel-Generators to attain operating speed and voltage and the diesel breakers to close automatically and accelerate the dead loads (loads started on Diesel Generator Breaker closure), see Figure 8.4-2.

Load Shedding

Automatic load shedding involves the following methods depending on the load category:

a. The Fort Calhoun Station Electrical Distribution System is equipped with an undervoltage relay protection scheme which is designed to insure that adequate voltage exists on the station buses to permit safe reactor shutdown and maintain the reactor in a safe shutdown condition under all grid conditions. To accomplish this, a Loss of Voltage protection scheme is installed on 4.16 KV buses 1A1, 1A2, 1A3, and 1A4. A degraded voltage protection scheme referred to as the Offsite Power Low Signal (OPLS) protection scheme is installed on the 4.16 KV buses 1A3 and 1A4 to provide protection during accident conditions.

   An undervoltage relay scheme is installed on the 480V buses. This 480V scheme provides motor protection and works in conjunction with both 4.16 KV relay schemes.

   The 480v undervoltage relays are not actuated by the 4.16-kV relays. Load shed initiation is based on the 480V bus voltage.

The loss of voltage scheme operates on a two out of two logic on all four 4.16 KV buses in the event that bus voltage degrades due to degraded grid conditions. The relays act to protect large 4.16 KV motors. If the station bus voltage falls below the relay setpoint, the buses will be load shed. Buses 1A3 and 1A4 will then be reenergized by the Diesel-Generators DG-1 and DG-2 respectively.

The 480V undervoltage relays act (in a two out of two logic) independently to protect the large 480V motors and will, in addition, act to load shed the large 480V loads during the time the Diesel-Generators are accelerating to full speed. The Diesel-Generators may then be loaded manually by the operator to maintain the plant in a safe shutdown condition.

The Offsite Power Low Signal (OPLS) degraded voltage relay system provides undervoltage protection in the event of an accident in which Safety Injection is required. The OPLS lock-out relay is armed if the Safety Injection Actuation Signal (SIAS) is actuated. The OPLS scheme is based on a two out of four logic to actuate. The OPLS setpoints ensure that adequate voltage exists on the 4.16-kV and 480-V voltage levels to insure that the safety related loads which are sequenced on will have adequate voltage to accelerate to rated speed and operate within nameplate voltage limits.

If the grid voltage falls below the OPLS setpoint, the same 4.16-kV relays which are actuated by the loss of voltage scheme will be actuated. This will load shed the 4.16 kV safety buses (done independently) and at approximately the same time the 480V undervoltage relays will load shed the large 480V loads. The OPLS signal also directly (not through an undervoltage relay) load sheds selected nonessential 480-V loads. Since an accident signal is present, the Engineered Safeguards load sequencers will be reset. When the diesel generator has accelerated to full speed and energized the bus, the sequencers will time back out automatically starting necessary Engineered Safeguards loads to maintain the reactor in a safe shutdown condition.

b. In the event of a PPLS or CPHS, the resulting SIAS initiates shedding of selected non-essential waste disposal system loads which are supplied from 480-Volt motor control center. The SIAS actuation signal also initiates shedding of additional selected non-essential loads supplied from 480-Volt motor control centers as well as shedding of complete 480-Volt motor control centers serving loads which are not essential to support Engineered Safeguards systems. The load shed circuitry initiated by the SIAS signals is located in Load Shed panels A1-109A and B (switchgear bay).

8.4.3.3 Design Analysis

Fast (instantaneous) transfers of individual 4.16-kV buses to their assigned alternate sources on failure of the preferred source involve sufficiently short transfer time to avoid loss of auxiliaries, unacceptable motor transient, and unacceptable transients in fluid systems, preventing a plant trip. Fast transfers are possible only if acceptable frequency and phase angle conditions exist between sources to prevent severe voltage and current transients that could cause possible motor over stress and damage. Moreover, protection is provided against transferring a fault to a sound source, or transferring a bus to a dead source.

A slow transfer, backing-up a blocked fast transfer, provides sufficient dead time to avoid possible motor damage. Such transfers do not prevent plant trip, but restore full power supply within several seconds. Slow transfers also are arranged to prevent transfer of a fault or transfer to a dead alternate source.

Transfer of buses 1A3 and 1A4 (or either individually) to emergency sources (diesel-generators DG-1 and DG-2, respectively) is automatic upon loss of power from the generator main leads and the 161-kV system. All loads connected to buses 1A3 and 1A4 are shed except the Low Pressure Safety Injection Pump (if manually started prior to the loss of offsite power) and 4160/480-Volt transformers supplying 480-Volt buses before the diesel-generator breakers can close. All motors connected directly to the 480-Volt buses are also shed before the diesel-generator breakers' closure. Upon breaker closure, the system is reloaded manually if no accident signal is present.

In the event of a PPLS or CPHS, selected vital loads are sequentially and automatically reconnected by the automatic load sequencers. In the event of a PPLS and CPHS, all vital loads associated with the automatic load sequencers are sequentially reconnected.

The diesel generator breaker can close without the low pressure safety injection pump being load shed if the pump was manually started. This can occur when the pump is being tested or the plant is in a condition where shutdown cooling is in service.

8.5 INITIAL CABLE INSTALLATION DESIGN CRITERIA

The following summarizes the cable installation design criteria intended to preserve the independence of redundant Reactor Protective systems and of those systems designed as Engineered Safeguards. The Cable and Conduit Schedule Notes, Figure 8.5-1, provides the standard design criteria for cables and conduits. Deviation from the standard criteria is acceptable provided an analysis has been completed which justified the deviation.

8.5.1 Cable Separation Criteria

Cable separation criteria of redundant Reactor Protective and Engineered Safeguards circuits are as follows:

a. Redundant Reactor Protective and Engineered Safeguard circuits are routed from their sensors to the cable room in separate cable trays, conduits, containment penetrations and junction boxes.

b. Cables are identified according to the notes shown in Figure 8.5-1. These notes ensure segregation of redundant circuits with special emphasis placed on Reactor Protective and Engineered Safeguard circuits. See notes #2, 5, 7, and 15 of Figure 8.5-1.

c. Redundant Reactor Protective and Engineered Safeguard instruments are identified by tag numbers prefixed A, B, C, or D followed by a slash (/) in agreement with the cable prefix.

d. The auxiliary and containment building cable trays are divided into four basic systems. These systems are identified on the drawings as EA, EB, EC, and ED. These designations agree with the cable numbering system as stated in Figure 8.5-1.

   Two tray systems are assigned to each floor with a minimum horizontal separation of 2-3". Where this minimum horizontal separation cannot be maintained suitable metallic barriers are installed.

The cable tray systems are assigned as follows:

Location	Floor Elevation	Tray Systems
Auxiliary Building	971'	EA, EB
Auxiliary Building	989'	EA, EB
Auxiliary Building	1007' to 1013'	EC, ED
Auxiliary Building	1025'	EA, EB
Auxiliary Building	1036'	EC, ED
Containment Building	994'	A - North half EB - South half
Containment Building	1013'	C - South half ED - North half
Containment Building	1045'	o cable trays

Cables to Reactor Protective and Engineered Safeguard equipment whose prefix differs from that of the nearest tray system are routed separately to the matching tray system.

e. The cable spreading room contains the cable tray, conduit, and junction\ box system for the routing of cables to the control boards, auxiliary instrument panels and the ERF computer. In addition, the cable spreading room contains items to support the operation of the plant including such items as fire extinguishers, fire detectors and panels, fire suppression (Halon) for both room 70 and control room walk-in cabinet, emergency lighting and Gaitronics communication, control room sanitary drain, control room air conditioner room floor drains, mechanical equipment drain line and isolation valve, ventilation dampers, 800 mhz radio system junction box JB-622a, electrical power receptacles, condenser vacuum gauge lines, cables abandoned in place, control room delta pressure sensor, and lighting including panel LP-7.

The cable tray and conduit arrangement is shown on Figure 8.5-2. All trays are run in vertical banks with a minimum vertical separation of 12 inches.

Engineered Safeguard cables are separated by metallic barriers right up to the control boards in accordance with note #7 of Figure 8.5-1.

f. The E prefixed cables inside the screenhouse and between the plant building and screenhouse are routed in separate conduits, tray sections, or in separate duct bank conduits (plastic tubes embedded in concrete).

The pull box and manhole layout is as follows:

1. Pull boxes

There are two pull boxes along the outside of the south auxiliary building wall. The pull boxes are divided in sections by asbestos - cement compound plates. One pull box contains EA and EC cables in separate sections, and the other pull box contains EB and ED cables, also in separate sections. In conformance with Note 22 of Figure 8.5-1, a metallic barrier is placed inside each section containing E prefixed cables in order to segregate them from the non-E prefixed cables.

2. Manholes

There is one manhole between the pull boxes and the screen house. The cables are in cable trays and the routing is in conformance with the Cable and Conduit Schedule Notes (Figure 8.5-1). There is a 6" minimum thickness concrete wall separating cable trays with EA and EC cables from cable trays holding EB and ED cables.

The cable tray system in the cable room does not have covers since the installation consists mainly of instrument and control cables, basically 120V AC, 125V DC, or low energy signal and computer control circuits.

There are no 4160V or 480V power cables installed in cable trays in the cable spreading room.

g. The criteria governing the separation of power cables from those used for control and instrumentation are stated in notes #10, 11, 12 and 13 of Figure 8.5-1. In general these cables are grouped in separate trays and the notes in Figure 8.5-1 apply to those areas where physical limitations, etc., preclude this.

h. The intermixing of non-vital cables with Reactor Protective or Engineered Safeguard cables is prohibited by note #22 of Figure 8.5-1.

i. The cable for each redundant sensor of a protection channel is assigned a different prefix (EA, EB, EC, or ED) and is routed separately in accordance with the notes on Figure 8.5-1. If cables of two different protection channels are located in the same area, note #7 of Figure 8.5-1 ensures that only those cables with the same prefix will be grouped together.

8.5.2 Cable Protection Against Missiles

The cable installation design criteria described in USAR Sections 8.5.1, 8.5.3, and 8.5.5 along with the following summary comprise the methods used to ensure that in areas containing high pressure piping or where mechanical damage is possible, such as from missiles generated by rotating equipment, no single credible incident could damage more than one cable raceway of a redundant system. Redundant circuits referred to in this summary are those associated with Reactor Protective and Engineered Safeguards systems.

The methods employed for the protection of these cables are as follows:

a. Each redundant channel is routed in a separate cable tray system.

b. Each redundant channel is routed in separate conduits and junction boxes.

c. Each redundant channel is routed through a separate containment penetration.

d. Only two out of the four redundant cable tray systems are assigned to each floor elevation and these are horizontally separated.

e. Cable trays are installed with covers where required (See USAR Appendix M Section 4).

f. In the auxiliary building main cable tray systems are located in corridors where the amount of rotating equipment is at a minimum.

g. In the containment cable trays are located in protected areas (see USAR Section 5.8.1). When a redundant electrical component is located inside the shield walls surrounding the reactor coolant loops, conduit is used.

8.5.3 Electrical Penetration Separation Criteria for the Containment Building

The separation criteria for the electrical penetrations in the containment building are as follows:

Electrical penetrations are of the canister type. A description of the canister is included in the USAR Section 5.9.3. An arrangement drawing showing the spacing and service of each canister is shown on Figure 5.9-16. This figure shows that separate canisters are assigned for the following class cables and is in accordance with Figure 8.5-1. The platform and floor shown on Figure 5.9-16 exists on both sides of the containment wall.

4160V AC Power A
4160V AC Power B
4160V AC Power C
4160V AC Power D
Power EA (480V, 120/208V and 125 DC)
Power EB (480V, 120/208V and 125 DC)
Power EC (480V, 120/208V and 125 DC)
Power ED (480V, 120/208V and 125 DC)
Power A&C (480V, 120/208V and 125 DC)
Power B&D (480V, 120/208V and 125 DC)
Control EA (125V DC & 120V AC)
Control EB (125V DC & 120V AC)
Control EC (125V DC & 120V AC)
Control ED (125V DC & 120V AC)
Control A&C (125V DC & 120V AC)
Instrumentation EA
Instrumentation EB
Instrumentation EC
Control B&D (125V DC & 120V AC)
Instrumentation EA
Instrumentation EB
Instrumentation EC
Instrumentation ED
Instrumentation A&C
Instrumentation B&D
Coax
EA
Coax EB
Coax EC
Coax ED

Reactor Protective and Engineered Safeguard cables with different prefixes are routed through separate canisters. Cables are routed from the canister in separate tray or conduit in accordance with the cable separation criteria stated in USAR Section 8.5.1.

8.5.4 Cables

Cable criteria are as follows:

a. Cable tray loading is in accordance with notes #17, 18, and 20 of Figure 8.5-1. Note #17 applies to 5 kV power cable only. Note #20 is further described as follows:

1. <u>600 Volt Class E Prefixed Power Cable</u>

   The fill in cable trays shall generally not exceed 40 percent of the rectangular area derived from the height of the cable tray side times the cable tray width. Fill exceeding 40 percent shall be justified by analysis.

   The 40 percent fill is defined as the sum of the cross-sectional areas of all cables in the tray. For triplexed cable only, the cross-sectional area includes the spaces between the three conductors as enclosed in an encompassing circle.

2. <u>600 Volt Class Non-E Prefixed Power Cable</u>

   In general the same criteria as for E prefixed cable shall apply.

3. <u>600 Volt Class E and Non-E Prefixed Control Cable Used For 125 Volt DC and 125 Volt AC Control Circuits</u>

   The fills in cable trays shall generally not exceed a maximum of 50 percent of the rectangular area derived from the height of the cable tray side times the cable tray width. Fill exceeding 50 percent shall be justified by analysis.

   The 50 percent fill is defined as the sum of the cross-sectional areas of all cables in the tray.

b. Cable environmental qualification is described in USAR Section 1.4.8.2 and 1.6.16.

c. Cable splicing in cable trays is used only for connection of incoming and outgoing cables with containment electrical penetration conductors.

d. Cable derating is in accordance with established methods as described in IEEE Publication No. S-131-1 - IPCEA (currently ICEA) Publication No. P-46-426, titled "Power Cable Ampacities - Vol. I - Copper Conductors".

   An ambient temperature of 50° C. is assumed for exposed conduit and cable tray and an ambient temperature of 20° C. is assumed for underground ducts. The maximum allowable continuous conductor temperature is 85° C.

e. As part of the electrical system's design, power cables have been oversized to ensure equipment operability. In general, a 125% full load current criteria per National Electric Code Article 430-22 and derating procedures outlined in "e" above were used.

f. Cable and wireway markings

   1. Generally, whenever a conduit enters or leaves a box or tray, it is marked on each side of the box or at the tray, in accordance with the Cable and Conduit Schedule, with the identifying number of the cable or cables in the conduit run to which they are attached.

   2. Cables are identified with suitable markers in accordance with the identifying number assigned in the Cable and Conduit Schedule.

Engineered Safeguards cables are a subset of Safety Related cables which are identified by an "E" prefix and are separated for easy identification by their distinctive colored jacket or jacket banded with colored tape every three feet as listed below:

Cable Number Prefix	Jacket Color
EA	Red
EB	Green
EC	Yellow
ED	Blue

3. Wires are identified by individual wire numbers or letters at both ends of wires and at terminal boards. Wire identification corresponds to that shown on the elementary and connection diagrams.

8.5.5 Fire Protection Requirements for Cables

a. Flame resistance qualifications

The cables that are installed in trays must meet the flame resistance qualification test described in the USAR Section 1.4.8.2.

b. Temperature monitoring of cables

The conservative approach of cable tray loading and derating procedures, outlined in USAR Section 8.5.4, precludes the necessity of monitoring cable temperatures in trays.

c. Fire detection system, connected to electrical bells and annunciation in the control room is described in USAR, Section 9.11.2.1.

Location of detectors at strategic positions is in accordance with Figures 8.5-4 through 8.5-11.

d. Fire stops

There are fire stops for slots and openings in walls and floors through which cable trays pass.

8.5.6 Process Instrumentation Inside Containment Building

The criteria for the process instrumentation inside the Containment Building were as follows:

a. Process instruments within the containment are located in shielded areas accessible for maintenance.

   Redundant instruments for safety instrumentation are identified by tag numbers prefixed by a capital letter A, B, C, or D followed by a slash(/). Sensing lines to these redundant instruments are run from separate sensing points. Redundant instruments within the containment for a safety channel are located on physically separate racks or on a common rack. However, where these instruments are located on a common rack metal barrier plates are provided to maintain separation between all A/, B/, C/, and D/ instruments and lines. Redundant instrument racks were not placed closer than three feet from each other unless they were separated by a wall or furnished with a metallic plate on their sides.

   Redundant instrument sensing lines were not placed closer than three feet from each other unless they are separated by an adequate shield (steel plate, steel channel, concrete wall, etc.) to protect the lines against mechanical injury. In the case where two redundant sensing lines cross each other the mechanical separation was provided for a radius of at least two feet from the point of crossing.

b. All cable trays in the containment containing redundant instrumentation leads are located in a protected area. This area is outside the concrete shield walls surrounding the reactor coolant loops (see USAR Section 5.8.1). When thermocouples or RTD's are located inside these walls, their cables are routed in conduit.

Cables of redundant instruments are identified in accordance with Figure 8.5-1. To maintain separation, these cables are generally routed in the following manner to the penetration area.

Cables prefixed EA----------	Routed counterclockwise above floor elevation 994'
Cables prefixed EB----------	Routed clockwise above floor elevation 994'
Cables prefixed EC-----------	Routed clockwise above floor elevation 1013'
Cables prefixed ED----------	Routed counterclockwise above floor elevation 1013'