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BASIS FOR INSTALLATION OF
RECIRCULATION PUMP TRIP SYSTEM

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GENERAL ELECTRIC

IMPORTANT NOTICE REGARDING

CONTENTS OF THIS REPORT

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TABLE OF CONTENTS

1. INTRODUCTION

The purpose of this document is to describe the basis for the installation, operation, surveillance and testing of the recirculation pump trip (RPT) system at Duane Arnold Energy Center (DAEC).

Significant improvement in the thermal margin of the DAEC can be realized if the severity of the pressurization transients is reduced. The RPT feature accomplishes this objective by rapidly cutting off power to the recirculation pump motors during generator load rejection (turbine control valve fast closure) or turbine trip (stopvalve closure). This results in a rapid reduction in recirculation flow and increases the core void content during the pressurization transients, thereby reducing the peak transient power and heat flux. A more detailed discussion of RPT is included in Section 2.

Basically, the RPT system utilizes pressure switches* installed in the turbine control valves, the position switches* installed in turbine stopvalves and fast-acting breakers. During stopvalve closure or fast control valve closure, redundant breakers between the motor-generator sets and the recirculation pump motors are tripped; this releases the recirculation pumps to coast down under their own inertia. Preliminary analysis indicates that adding the RPT features will result in a significant reduction in ΔCPR** for transients involving stopvalve or control valve closures. Details of the required plant changes to install RPT are included in Section 3.

In order to install the RPT system, it must be shown that the change to the DAEC does not represent an unreviewed safety question. In Section 4, it is shown that the criteria of 10CFR50.59 are satisfied and there are no unreviewed safety questions.

*These are the same switches which initiate scram on control valve fast closure or stopvalve closure. By using the same signal to initiate RPT, the necessary hardware modifications are minimized.
**About 50% for DAEC.

2. EFFECT OF RPT ON PLANT PERFORMANCE

2.1 DYNAMIC CHARACTERISTICS

An inherent design characteristic of the boiling water reactor (BWR) is the relationship of the core average moderator density to neutron moderation, which is represented by a negative void reactivity coefficient. This negative void reactivity coefficient permits load following through control of the recirculation flow without control rod movement. To increase power, core flow is increased, which decreases the void fraction and increases the neutron moderation and reactor power.

The negative void reactivity characteristic of the BWR dictates the necessity for reactivity control during some pressurization transients. For the DAEC, the two most limiting events analyzed in the plant safety analysis are the turbine stopvalve closure (turbine trip) or fast control valve closure (generator load rejection) with assumed bypass failure. In these events, the dome pressure increases rapidly, causing a reduction in the core average void fraction, which increases moderation and results in a positive power increase. This is reflected in decreased margins to pressure and thermal limits.

The physical phenomenon which causes the reduced margins is that the void reactivity feedback, which is due to the pressurization, momentarily can add positive reactivity to the system at a rate faster than the control rods add negative scram reactivity. The rate at which reactivity is added to the core determines the severity of the transient. The scram reactivity depends on the location of the control rods relative to the high flux regions of the core. The minimum scram reactivity occurs at end of cycle when control rods are fully or nearly fully withdrawn from the core. In this configuration, a longer travel time is required for the control rod to reach a high flux region of the core. For this reason, the pressurization transients are more severe near the end of the cycle.

Analyses have shown that pressurization transient severity can be significantly reduced by a rapid reduction in core flow. The rapid reduction in core flow necessary to accomplish this effect can be achieved by the prompt tripping of both recirculation pumps. If the pump trip and coastdown does not occur quickly, the positive void reactivity feedback caused by the pressurization effects will dominate the transient and no margin improvement will be seen from tripping of the pumps. For this reason, the RPT system is made most effective by installing and tripping a line breaker between the recirculation pump-drive motor-generator and the pump motor. Although a motor-generator field breaker trip has cost advantages over a line breaker, the response characteristics from such a trip do not achieve significant improvements in thermal margins. Upon tripping the field breakers, the drive motor-generator continues to momentarily supply some reduced power to the pump motor due to the time required for the generator field and line current to drop to zero. This results in reduced effectiveness of the system.

The RPT system is required only if all four stop or control valves close. If one steamline remains open (i.e., if the control and stopvalve in that line do not close), the RPT initiation is not required.

2.2 THERMAL LIMITS CONSIDERATIONS

The minimum critical power ratio (MCPR) is established such that the most severe abnormal operational transient is expected to subject less than 0.1% of the fuel rods to boiling transistion. This is known as the General Electric Thermal Analysis Basis (GETAB). GETAB statistically correlates the calculated fuel cladding integrity safety limit MCPR as the condition which, if exceeded, less 0.1% of the fuel rods may experience boiling transition. This valve is incorporated into the plant technical specifications. An operating limit MCPR is established such that the most severe abnormal operational transient will not result in violating the safety limit. The difference between the actual plant operating critical power ratio (CPR) and the operating limit MCPR is a measure of the thermal margin. Table 2-1 defines MCPR and shows its relationship to the expected fuel performance (i.e., thermal margin) and the technical specification safety limit. An operating CPR higher than the operating limit MCPR indicates greater margin in that the fual is operating further away from the onset of boiling transition.

If the normal operating CPR at the licensed power level cannot be maintained above the operating limit MCPR, a plant derate will be imposed to assure that the resultant change in CPR from a worst-case abnormal operational transient will not decrease the MCPR below the safety limit. A reduction in severity of the worst transient allows a reduction in the operating limit. For the DAEC, either a turbine or generator trip without bypass is the limiting thermal event near EOC. The RPT system will provide improved thermal margin for these limiting events.

2.3 OVERPRESSURE PROTECTION CONSIDERATIONS

The basic pressure limitation is the ASME vessel overprotection limit, which limits the peak vessel pressures to less than 110% of the vessel design limit of 1250 psig. Compliance to the vessel design pressure limit is demonstrated by an analysis of the main steam isolation valve (MSIV) closure with indirect scram event (conservatively neglecting the direct scram from position switches on the isolation valves). This margin is met by installation of an appropriate number of safety/relief valves. The RPT system has no effect on this analysis because it is not initiated during this event.

Table 2-1

PLANT THERMAL PERFORMANCE RELATIONSHIPS

DEFINITIONS

Boiling Transition (BT) = the point at which the mode of boiling rapidly oscillates between nucleate and film boiling. This results in an abrupt decrease in heat transfer efficiency.

$$\text{Critical Power Ratio (CPR)} = \frac{\text{Bundle Power for Onset of Transition Boiling}}{\text{Actual Bundle Power}}$$

Minimum CPR (MCPR) = the CPR for the limiting fuel bundle in the General Electric Thermal Analysis Basis (GETAB) requires that, for transients caused by single operator error or equipment malfunction, more than 99.9% of the fuel rods in the core would be expected to avoid boiling transition.

Steady-State Operating Critical Power Ratio

"Operating Thermal Margin"
Margin Between Minimum Steady State CPR and Operating MCPR Limit

Operating Limit Minimum Critical Power Ratio (Tech. Spec.)

Margin for Limiting Abnormal Operational Transient

Fuel Cladding Integrity Safety Limit (Tech. Spec.)

3. RECIRCULATION PUMP TRIP SYSTEM

3.1 SYSTEM DESCRIPTION

The RPT system utilizes hydraulic pressure switches (sensors to detect the fast closure of the turbine control valves), position switches (sensors to detect closure of the turbine stopvalves), relays, logic, and fast-acting circuit breakers. In order to satisfy the single-failure criterion, the RPT logic feature consists of two almost-identical divisions in a two-out-of-two configuration such that either is capable of causing fast opening of independent redundant circuit breakers in the supply circuit of each recirculation pump motor. The RPT logic is diagrammed in Figure 3-1.

The operation of any RPT sensor (pressure switch or position switch from any of the four turbine control valves or any of the four turbine stopvalves) causes an electromagnetic relay to de-energize. The relay contacts are combined with contacts from an Operating Bypass and contacts from a manual bypass switch to provide power to the breaker trip coils. The trip coils provide the necessary force to open the circuit breakers. The breakers are designed to interrupt load within 135 milliseconds of the switching event. The operating bypass disables the RPT system when the turbine first-stage pressure is below about 30%, as is done for the turbine inputs to the scram system. The manual bypass switch ("out-of-service") allows each RPT division to be disabled for maintenance purposes.

A fast closure sensor (pressure switch) from each of two turbine control valves provides input to one RPT division; sensors from the other two turbine control valves provide inputs to the second RPT division. Similarly, a position switch for each of two turbine stopvalves provides input to one RPT division; sensors from the other two stopvalves provide inputs to the other RPT division. For each RPT division, the sensor relay contacts are arranged to form a two-out-of-two logic for the fast closure of control valves and a two-out-of-two logic for the stopvalves. The relays are fast acting, highly reliable, low maintenance elements already in use in the RPS. The operation of either logic will actuate the RPT feature.

The trip logic, trip circuits and closing mechanisms for each RPT division are powered by a separate 125V DC battery. A 30 amp master series fuse is used to provide protection for all circuits. Also, 15 amp fuses are used to provide protection for the remote closing function and the red circuit breaker closed status lamp supervision. Additional 15 amp fuses are used to protect the local closing function, and 10 amp fuses are used to protect the elevating function (Figure 3-1). A power available indicating relay with test switch to annunciate the loss of trip circuit power will also be included. In addition, the status of the 30 amp fuse is indicated by the red circuit breaker closed status lamp located in the control room. This lamp also signals the condition of the trip coil by means of a trickle current through the coil.

Provision has been included for control room annunciation of the bypass of the RPT system below 30% power (as indicated by turbine first-stage pressure) by changing the RPS bypass alarm window from "control valve fast closure and stopvalve scram bypass" to "control valve fast closure, turbine stopvalve scram and recirculation pump trip bypass".

The two divisions of the RPT feature will be physically and electrically independent. There is one interconnection between the RPT and a nonsafety system. When the RPT is tripped, auxiliary relay contacts feed the control circuits of the motor-generator sets to de-energize them. This interlock is adequately isolated such that no credible failure can prevent proper action of the RPT.

Although the purpose of the RPT is to mitigate a core-wide pressurization transient, the desired thermal margin advantage can be realized only if the initiating events are sensed on an anticipatory basis, rather than monitoring pressure directly. The use of pressure switches to sense the loss of hydraulic control fluid pressure to each control valve is adequate to anticipate fast closure of those valves. Similarly, position switches set at $\geq$ 90% open will anticipate closure of the turbine stopvalves. The RPT is not given credit for any other initiating events.

Each RPT system may be manually bypassed by use of a keyswitch ("out-of-service"), which is administratively controlled. Both the manual bypasses and the operating bypass (<30% power) are annunciated automatically and distinctively in the control room.

Unlike the scram system, the RPT system is not fail-safe, (i.e., does not go to tripped state upon loss of electric power). The sensor relays will go to the tripped state on loss of power, but the RPT circuit breakers are "power-on-to-trip". For the 4160V circuit breaker, electric power is required to operate the trip coil. For this design, the logic circuits and trip coils operate on 125 Vdc. A single Class 1E battery provides the 125 Vdc for each RPT system.

If battery power is lost, this results in an out-of-service condition for that division. This is similar to placing that division in test. For either case, the technical specification dictates the time allowed before the division must be returned to service or have the reactor power reduced. A loss of battery power condition is annunciated in the control room.

To be effective, the RPT must be initiated virtually immediately. Manual initiation of a prompt trip of the recirculation pumps at any reasonable point after the time when automatic action should have occurred will not have a significant improvement on the situation. The power to the motor-generator sets can be tripped manually from the control room. Therefore, provision for manual initiation of the EOC RPT feature is unnecessary. Following RPT, the tripped circuit breakers must be manually closed before resuming power operation.

The most severe postulated failure of the system would be the failure of one of the four turbine control valves or turbine stopvalves to close (thus, not providing an actuation signal to the one RPT division) with simultaneous failure of the bypass valves to open during testing (or failure of the other RPT division). However, in this case, the open line to the turbine would, in effect, be acting as a bypass. The pressurization transient analyses with bypass provide a conservative estimate of the effect of failure of one or more turbine stop or control valves to close. The results of the pressurization transient with bypass (or with one or more stop or control valves open) and without RPT indicate that the transient is not limiting.

3.2 DIFFERENCES BETWEEN DAEC RPT AND BROWNS FERRY UNIT 1 (BF1) RPT

The differences between the DAEC RPT system and the BF1 system are summarized below.

1. The DAEC RPT system utilizes a single 125V DC battery for each division (i.e., two batteries total) for the required power supply to the trip logic, trip coil and closing circuits. Alternate power supplies are not available because DAEC is a single plant site.

   The BF1 RPT system utilizes a single 250V DC battery for each division but has available alternate power supplies from BF2 and BF3.

   A single power supply for each division for DAEC is considered adequate for the following reasons: failure of the single DAEC power supply would be, in effect, the same as failure of the 35 amp trip circuit fuse on BF1, which on BF1 would result in failure of the trip circuit regardless of the number of power supplies. Either a fuse failure on BF1 or a power supply failure on DAEC would result in an out-of-service condition for that division, which is the same as placing that division in test or in "inop". For this condition, the technical specification allows 72 hours to have the division back into operation or power must be reduced.

2. DAEC uses a single 30 amp fuse for all circuit breaker control functions with separate 10 amp and 15 amp branch fuses for the elevating mechanism, the local closing circuit, and the control room closing and red light supervision circuit. BF1 uses 10, 35, and 6 amp branch fuses for the closing circuits and elevating mechanisms, trip logic and trip coil, and indicating lights.

Circuit overloads are most likely to occur in the mechanical functions of elevating and closing. Since these functions are protected in the DAEC design by branch fuses, such failure would not affect the trip circuit, which is protected by the 30 amp fuse mentioned above. Failure of the 30 amp fuse is annunciated by a special "RPT Power Not Available" annunciator and the red circuit breaker closed status lamp, both located in the control room.

3. The DAEC system uses circuit breaker status lamps in both the control room and the breaker cabinet. These lamps are wired through the closing circuit 15 amp branch fuse so that smaller sized wiring can be used to connect the status lamps. The local status lamps for BF1 are wired to the 35 amp trip circuit fuse requiring heavier wiring.

   In addition, the red lamp in the control room is also used to indicate trip coil continuity for the DAEC system.

3.3 RPT SYSTEM TESTING

3.3.1 Testability

The system is designed so that it may be tested during plant operation from sensor device to final actuator logic. One stopvalve or control valve can be closed and system status tested by observing relay contact status and logic test light status without causing RPT operation. The entire logic and input sensors of one division may be tested without tripping the pumps by placing that division bypass switch briefly in the "inop" position for the duration of the test; the test is initiated either by closing the two stopvalves assigned to that division to the 10% closed (90% open) position, or by tripping the two appropriate control valve fast closure pressure switches.

Successful completion of the test is indicated by annunciation of "RPT initiate" as the annunciation relays are energized. During this brief interval, the redundant RPT division is, of course, continuously available to perform its safety function. Circuit breakers shall be tested as per the plant technical specifications.

3.3.2 Initial Testing

A comprehensive functional test of the RPT system is performed to confirm the correct installation of the integrated system prior to startup. This testing includes a check of all relay logic combinations and several breaker trips.

The startup testing is performed in two parts. A turbine trip from low power with RPT initiation is done to establish that the delay time, from beginning of turbine valve motion to the RPT breaker trip, is less than that assumed in the transient calculations. Secondly, a two-pump trip (RPT) is performed from full flow to measure the actual flow coastdown. From these tests, the system response, consisting of coastdown time and delay time, is confirmed to be less than that assumed in the transient calculations.

3.3.3 Periodic Testing

3.3.3.1 Once Per Cycle Breaker Functional Tests

The RPT breakers will be tested by manually completing the existing logic which will result in tripping both breakers. This procedure tests the trip coils which would be called upon in the event of RPT actuation.

3.3.3.2 Monthly Logic Testing

The RPT monthly logic testing is done in parallel with the monthly RPS surveillance. The two RPT divisions are functionally tested individually in order to provide RPT capability during the test period.

3.3.3.2.1 Control Valve Logic - Each control valve is individually closed. RPT relay contact status lights are checked. In addition, the response time of the turbine control valve fast closure pressure switches is measured as per Table 4.1-2 of the Technical Specifications.

3.3.3.2.2 Stopvalve Logic - The four stopvalve pairs that drive the autoscram channels are closed until they pick up the 10% closed switches. Two of the above combinations also complete the RPT logic, as evidenced by the energization of test coil C71A-K23A(B), which alarms as the "RPT initiate" annunciator. It is necessary to place the individual RPT division in "bypass" briefly to prevent actual tripping of the recirculation pumps. At least one RPT division will always be in service.

3.4 RPT TECHNICAL SPECIFICATION SURVEILLANCE REQUIREMENTS

The plant technical specifications require that both divisions be individually functionally tested monthly. If the test period for one RPT division exceeds two consecutive hours, the divisions will be declared inoperable. If both RPT divisions are inoperable or if one RPT division is inoperable for more than 72 consecutive hours, an orderly reduction to below the RPT bypass or until the operating MCPR is below the MCPR limit without RPT. The RPT breakers are tested once during each operating cycle.

3.5 CONFORMANCE TO IEEE STANDARDS AND REGULATORY REQUIREMENTS

The RPT system was designed to comply with IEEE Standards 279, 323, and 338 and General Design Criteria 13, 19 through 24, and 29 of 10CFR50, Appendix A.

The system is designed to meet the single-failure criterion such that any single trip channel (sensor and associated equipment) or system component or power supply failure shall not prevent the system from performing its intended safety function. Electromechanical relays used as the logic elements within the system and the system logic are failsafe (i.e., actuate on loss of electrical power). The RPT system is designed to accomplish the desired function with a minimum effect on plant availability. The system logic is designed such that it will not cause the inadvertent trip of more than one pump given a single component failure in the system. Each trip division shall be clearly identified to reduce the possibility of inadvertent trip of the recirculation pump during routine maintenance and test operations. Redundant circuits in each division (sensors, wiring, relays, power supplies, circuit breakers, etc.) are electrically, mechanically, and physically independent so that they cannot be disabled by a single event.

Relays used by the RPT Logic are of a failsafe logic (i.e., actuate on loss of electrical power to individual relays). However, loss of control power to a particular RPT Division will result in the failure of that individual division. Therefore, individual RPT divisions are not considered entirely "failsafe". However, each RPT division is supplied from one division of two separate Class 1E Battery systems.

Control Room annunciators are provided to identify the tripped portions of RPT in addition to the instrument channel annunciators associated with the RPS described in the FSAR. These same functions are connected to the process computer to provide a typed record of the system status.

Annunciation is also provided to indicate that part of a division is not operable. The system has annunciators, lighting and sounding whenever one trip division is bypassed. Indicator lights are provided for logic tests.

All bypass and inoperability indicators, both at the division level and the component level, will be grouped for operational convenience. As a result of design, preoperational testing and startup testing, no erroneous bypass indication is possible. These indication provisions serve to supplement administrative controls and aid the operator in assessing the availability of component and system level protective actions.

The annunciator initiation signals are provided through isolation devices and can in no way prevent protective actions. Testing will be included on a periodic basis when equipment associated with the indication is tested.

Either RPT division may be bypassed independently from the control room using a keylock switch. RPT protection for both pumps is preserved with one division in bypass.

The control room is a restricted area controlled by card-key access to authorized personnel. Also, the RPT System out-of-service annunicators in the main control room would alert the unit operator to unauthorized bypassing of the RPT logic.

The EOC-RPT system conforms to IEEE 279-1971, except for Section 4.17, which covers manual trip feature. This is discussed further in Section 3.0.

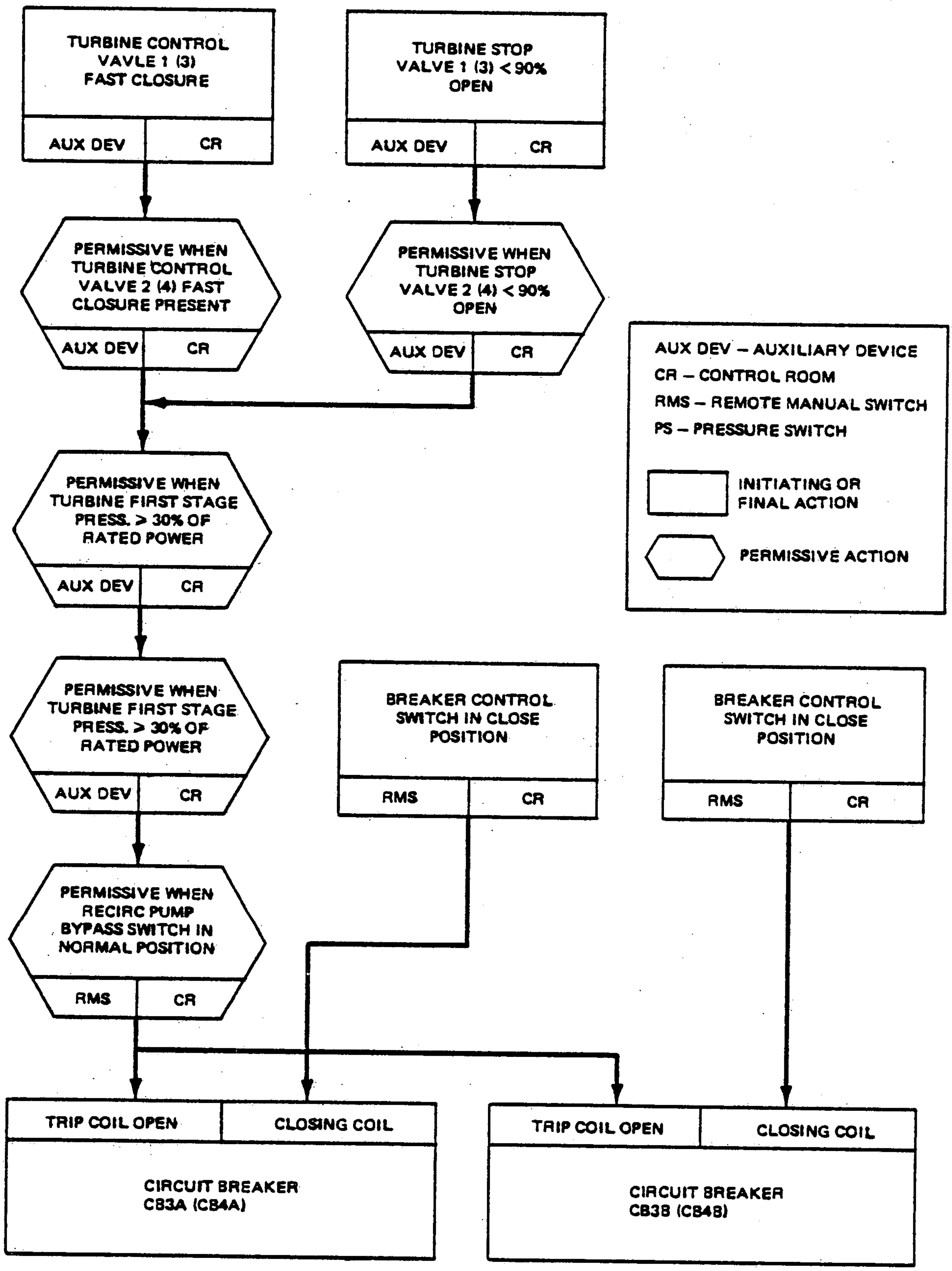

Figure 3-1a. Recirc Pump Trip System A Logic Diagram Typical for System B Except as Shown ( )

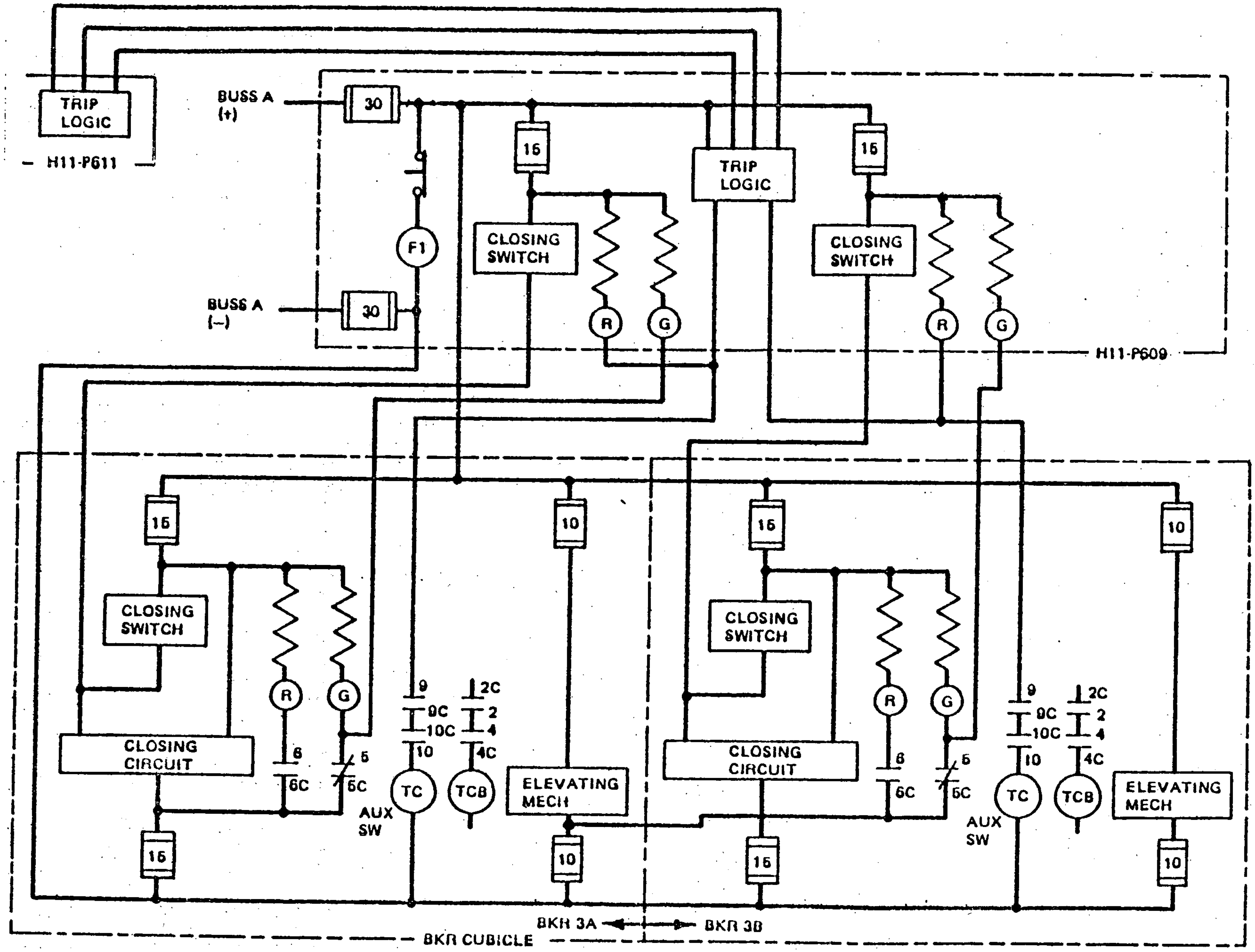

Figure 3-1b. Duane Arnold EOC-RPT (Div I)

4. CONFORMANCE TO 10CFR50.59

The criteria of 10CFR50.59 provide the basis for making changes to a plant as long as there are no unreviewed safety questions or technical specification changes. A proposed change deemed to involve an unreviewed safety question if the probability of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated in the safety analysis report may be increased; or if a possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report may be created; or if the margin of safety as defined in the basis for any technical specification is reduced. As discussed below, all of these criteria are satisfied by the installation of the RPT system at the DAEC.

As previously described, the severity of events considered in the safety analysis report are reduced by the installation of the RPT System. There is no potential for a new type of event being created which is more severe than those already analyzed. Therefore, it can be concluded that there is no unreviewed safety question.

As described in Section 2, the purpose of the RPT system is to permit a reduction of the MCPR operating limit in the plant technical specifications. Thus, a technical specification change is necessary at the time that credit is taken for the RPT.