APPENDIX

U.S. NUCLEAR REGULATORY COMMISSION
REGION IV

Inspection Report: 50-285/93-25

License: DPR-40

Licensee: Omaha Public Power District
Fort Calhoun Station FC-2-4 Adm.
P.O. Box 399, Hwy. 75 - North of Fort Calhoun
Fort Calhoun, Nebraska

Facility Name: Fort Calhoun Station (FCS)

Inspection At: FCS, Blair, Nebraska

Inspection Conducted: November 19-22, 1993

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DETAILS

1 INTRODUCTION (93800)

The NRC has established a policy to provide for the timely, thorough, and systematic inspection of significant operational events at nuclear power plants. This includes the use of an Augmented Inspection Team (AIT) to determine the causes, conditions, and circumstances relevant to an event and to communicate it's findings, safety concerns, and recommendations to NRC management. In accordance with NRC Inspection Manual Chapter 0325, an AIT was dispatched to the Fort Calhoun Station (FCS) on November 19, 1993, to review the circumstances surrounding the uncontrolled control element assembly (CEA) movements that occurred on CEAs 31 and 18. (Note: The terms "CEA" and "rod" are used interchangibly throughout this report.)

1.1 General Description of the Rod Control System

The rod control system consisted of 37 Control Element Drive Mechanisms (CEDMs) powered by 120 VAC. These CEDMs move 49 CEAs through a rack and pinion gear assembly. There also were four nontrippable full length CEAs. The total time to move a CEA from fully inserted to the fully withdrawn position of 126 inches is approximately 3 minutes. The system also contained other components consisting of clutches powered by 48 VDC power which, when interrupted, caused the trippable CEAs to drop into the core and motor brakes on the CEDMs that were powered by their own power supplies. The power supplies were ungrounded and did not have ground detection capability.

Rod position indication was provided by a number of systems. The primary indication system was the seven synchros (one for each group) that provided an analog display of CEA position for the CEA selected. The secondary indication system was the Secondary Control Element Assembly Position Indication System (SCEAPIS), which is a computer driven system that received inputs from magnetic reed switches. The SCEAPIS could display all the group positions simultaneously or all the CEAs within a group simultaneously. The third position indication system that was available was from the Emergency Response Facility (ERF) computer. This system received its inputs from the synchros and could provide indication of all CEAs simultaneously. A fourth rod position indication system was a light system called the core mimic. This system was powered by a 28 VDC supply through limit switches mounted on each CEDM. This system provided indication of rod bottom (green light), rod full out (red light), rod normal operating region (white light), and either a blue or amber light specifying other rod limits depending upon the rod group (See Figure 1).

1.2 General Description of Events

On November 13, 1993, the FCS was in a refueling condition, Mode 5, with all CEAs inserted to the bottom, and all rod bottom lights lit. The licensee was conducting a surveillance test on the SCEAPIS. The purpose of this test was to verify that SCEAPIS would cause a rod block by introducing a simulated signal into the SCEAPIS computer to simulate all CEAs out and a CEA inserted to 8 inches below the other rods. Following this simulation, the rod mode selector switch was placed into the MANUAL INDIVIDUAL position, CEA 30 was selected, and an attempt was made to withdraw CEA 30. As expected, the CEA did not move. The operators then placed the rod block switch in BYPASS, and CEA 30 was withdrawn approximately 2 inches from the bottom position.

After releasing the spring return rod block switch from the BYPASS position, the SCEAPIS was reset to simulate all CEAs out which cleared the rod block condition. Shortly thereafter, a "CONTINUOUS ROD MOTION" alarm annunciated. The operators responded to this alarm by turning the rod mode selector switch to the OFF position as required by the alarm response procedure. This action removed control power to the CEDMs and reset the continuous rod motion alarm. At this time, all rod bottom lights on the core mimic system remained lit.

The operators notified instrumentation and control (I&C) personnel of the continuous rod motion alarm and requested that they investigate the cause of the alarm. Following review of the circumstances relating to the alarm and a review of station drawings, the I&C personnel were unable to determine the cause of the alarm. To further troubleshoot this alarm, the I&C personnel requested that the rod control selector switch be taken out of OFF so that they could time the continuous rod motion alarm. Since this alarm occurred when a continuous rod motion was detected for greater than 32 seconds, the I&C personnel thought that this alarm timing may have changed. Approximately 32 seconds later, the continuous rod motion alarm annunciated and then cleared, and a rod full out light on the core mimic system was noted for CEA 31. It was also noted that the CEA 31 rod bottom light remained lit. Operators immediately checked the primary synchro position indication for CEA 31 and noted that CEA 31 indicated fully withdrawn. They also removed the simulation introduced into the SCEAPIS computer, which had blocked the SCEAPIS position indication function, and noted that the SCEAPIS also indicated that CEA 31 was fully withdrawn.

The operators began manually inserting CEA 31 into the core. When this CEA insertion was halted at 10 inches from the bottom by releasing the rod control joy stick to acknowledge an alarm, the operators noted that CEA 31 began moving outward. The operators immediately turned the Rod Mode Selector Switch to OFF and CEA motion stopped. When the operators recommenced CEA 31 insertion, CEA 31 again began to move out. When a third CEA insertion attempt was made, the CEA fully inserted. After verifying that all CEAs were inserted, the reactor trip breakers were opened.

On November 18, 1993, ground detection troubleshooting activities were being conducted on the rod control system by moving CEAs and monitoring for grounds using a temporary ground detection system. When nontrippable CEA 18 was being inserted into the core, it was noted that the CEA continued to insert into the core after the rod control joy stick was released. Immediately after CEA 18 completed it's movement into the core, all the core mimic system lights went out.

1.3 AIT Formation and Tasks

Region IV, in consultation with the Office of Nuclear Reactor Regulation (NRR) and the Office for Analysis and Evaluation of Operational Data, formed an AIT on November 19, 1993. The AIT, which was led by a section chief from Region IV and which was composed of the FCS senior resident inspector, the FCS project manager from NRR, and an electrical engineer from the Instrumentation and Controls branch of NRR, was sent to FCS to gather information regarding licensee actions and to review plant response to these events. Prior to the assembly of the AIT, a special inspection was being conducted by the senior resident inspector and the electrical engineer from NRR to monitor the licensee's preliminary response to these events. The AIT was fully assembled on site on November 19, 1993 and superseded the special inspection effort.

The AIT tasks, which were specified in a Charter dated November 19, 1993, to Mr. T. F. Stetka from Mr. J. L. Milhoan were:

(1) Develop a sequence of events starting from the discovery of the rod control system problems through the conclusion of the licensee's troubleshooting activities.

(2) Evaluate the adequacy of the response with respect to the "Continuous Rod Motion" alarm. This evaluation should include:

   a. Adequacy of operator response to the alarm (e.g., alarm response procedure used).

   b. Adequacy and thoroughness of I&C troubleshooting activities.

   c. Determine whether there was any outage schedular pressure to continue with the test.

(3) Review the licensee's analysis of the cause(s) of the rod control system problems. Verify that this analysis encompasses the causes for the grounds identified within the rod control system. Include the following in this examination:

   a. Resolution of the "bent" pin in the connector on rod 31 that was discovered early in the outage.

   b. Source of the moisture identified in the rod 31 connector.

   c. Lack of a ground detection system on the rod control system.

(4) Review the history of rod control system operations and maintenance and determine whether similar problems have occurred in the past.

(5) Review the licensee's evaluation of the affect of this event on the following plant conditions:

a. Shutdown conditions.

b. Plant startup.

c. Power operations.

Include an assessment of the adequacy of the licensee's plans and procedures for mitigating the consequences of a positive reactivity addition event.

(6) Examine licensee root and contributing cause determination as well as the specific licensee corrective actions that have been taken or planned.

(7) Determine if this event or similar events are bounded by the present accident analysis.

2 AIT INSPECTION

The licensee typically formed a Special Work Action Team (SWAT) when problems arose during the outage which needed special attention. A SWAT was formed by plant management following the occurrence of these events and was formalized when the licensee was notified that an AIT would be dispatched. The inspection effort began with a briefing by the licensee's SWAT. The briefing included the licensee's investigation into the events and their findings to date. The AIT found this briefing to be comprehensive and highly beneficial.

The AIT inspection included a review of plant logs, numerous interviews with personnel, a review of plant procedures and maintenance records, a review of pertinent vendor information, observations of ongoing maintenance and testing activities, a review of the accident analyses, and a review of the design criteria.

2.1 Sequence of Events

The AIT developed the following sequence of events based upon review of the licensee's documentation, personnel interviews, and briefings by the SWAT. Times marked with an asterisk are approximations.

November 13, 1993

- I&C personnel set up test equipment to perform surveillance on the SCEAPIS. They simulated 50 percent power and all CEAs at 125 inches. A Group 4 shutdown CEA was simulated to be more than 8 inches below the other CEAs.

- 10:00 p.m.* An operator attempted to move CEA 30, but it would not withdraw, as was expected, due to the rod block function.

•10:00:16 p.m. An operator held the rod block switch in BYPASS. (CEA 31 began to withdraw without operator action. This movement was undetected by control room personnel.)

•10:00:19 p.m. An operator withdrew CEA 30 to 1.89 inches. The operator attempted to return CEA 30 to original position, but it would not move since it was below it's lower electrical limit. (CEA 31 continued to withdraw undetected. CEA 31 moved whenever the operator put the rod block switch in BYPASS in order to move CEA 30.)

•10:00:21 p.m. "ROD POSITION DEVIATION LOW LIMIT" alarm recorded by the alarm printer. Since the alarm was already lit at beginning of the test and did not have reflash capability, there was no audible or visual indication of the alarm. Personnel did not look at the printer output. (CEA 31 at 4.36 inches and withdrawal still undetected.)

•10:00:26 p.m. "ROD POSITION DEVIATION LOW-LOW LIMIT" alarm recorded by the alarm printer. Since the alarm was already lit at beginning of the test and did not have reflash capability, there was no audible or visual indication of the alarm. Personnel did not look at the printer output. (CEA 31 at 8.12 inches and withdrawal still went undetected.)

(CEA 31 raised approximately 65 inches while the operator had the Rod Block Switch in BYPASS.)

I&C technicians simulated all CEAs at 125 inches. This bypassed the rod block circuitry. (CEA 31 withdrew whenever the rod mode selector switch was not in the OFF position.)

"CONTINUOUS ROD MOTION" alarm was received. Operator returned the rod mode selector switch to OFF. Operators did not verify, by the use of other CEA position indications, that CEA motion other than CEA 30 had occurred.

Operators noted on the core mimic system that all green rod bottom lights were lit, but also observed that the white light was lit for CEA 30. Both lights should not have been lit simultaneously. (Later, it was speculated that the white light was probably for CEA 31 and not CEA 30.)

I&C technicians reviewed electrical diagrams to determine the cause of the alarm. Their conclusion was that the test should not have resulted in the rod motion alarm.

I&C requested the operators to perform troubleshooting by timing when the continuous rod motion alarm was received.

•10:33:59 p.m. Operator moved the rod mode selector switch from the OFF position and started timing. (CEA 31 resumed withdrawal motion, but still was undetected.)

The "CONTINUOUS ROD MOTION" alarm was received. The core mimic system red light indicated CEA 31 to be fully withdrawn and the green rod bottom light remained lit. The operators now realized that CEA 31 had been withdrawing during the test. One I&C technician believed that the "up arrow" associated with Group 4 flashed on and off as CEA 31 reached it's full out position. The Group 4 control board red rod deviation light was also lit. (Note: There is some question as to whether the "up arrow" light and the rod deviation light were lit during the rod motion due to the shorts and grounds later discovered.)

The operator used the primary synchro position indication by selecting CEA 31 on the Group 4 individual CEA selection switch to verify that CEA 31 was fully withdrawn. The operator also checked all other CEA positions and verified that no other CEAs were withdrawn.

The operator began to drive CEA 31 into the core.

•10:35:58 p.m. CEA 31 at 121.59 inches.

When CEA 31 was approximately 10 inches from the bottom, the operator stopped rod movement to acknowledge the continuous rod motion alarm. CEA 31 began to withdraw. Operator went to OFF on the Rod Mode Selector Switch.

Shift supervisor directed the operator to continue inserting CEA 31.

When operator resumed driving in CEA 31, it began withdrawing instead. Operator went to OFF and rod motion stopped.

Operator attempted to drive CEA 31 in and it began inserting.

•10:40:39 p.m. CEA 31 at 6.64 inches.

•10:40:44 p.m. CEA 31 at 2.79 inches.

•10:47 p.m.* Reactor tripped to assure no further rod motion.

<u>November 13-18, 1993</u>

The licensee performed troubleshooting activities to determine the cause of the event. The licensee's initial determination was that multiple electrical grounds on the rod control system were the cause. The licensee continued to investigate the source of the grounds.

November 18, 1993

- The licensee was performing Surveillance Test Procedure IC-ST-CEA-0002, "Functional Test of SCEAPIS Rod Block Actuations." Temporary ground detection equipment was installed to search for grounds.
- The operator had moved 48 of 49 CEAs to a height of 5 inches, and then reinserted them to a height of 2 inches with no indication of grounds.
- The last CEA (CEA 18) which is one of four nontrippable CEAs, was raised 5 inches. Upon reinsertion, I&C technicians noted a ground indication.
- The operator was requested to withdraw and reinsert CEA 18 again to verify the ground. A ground indication again was noted.
- When the operator released the rod control joy stick with CEA 18 at 2 inches, it was noted that the CEA continued to insert all the way into the core.
- Power was lost to the Core Mimic.

November 18-23, 1993

- The licensee continued troubleshooting activities to determine the root cause of both events and perform corrective actions.

2.2 Response to the Continuous Rod Motion Alarm

The AIT interviewed the shift supervisor, licensed operator, and the two I&C technicians that were present during the event. These interviews provided additional insight into the November 13 event progress.

The same shift supervisor, during the prior week, deferred this surveillance test due to the integrated leak rate test being performed. On the night of November 13, 1993, the shift supervisor was concerned about performing the test since containment integrity was not available. After discussions with the I&C technicians, the Outage Control Center, and the safe shutdown advisor, it was determined that no CEA motion would occur other than the one CEA being tested. Since the tested CEA would be raised only 1 to 2 inches, the shift supervisor concluded that it would be acceptable to perform the surveillance test.

Prior to the start of the test there were other surveillance tests being performed, but the shift supervisor indicated that they did not have an affect upon the decisions made during the test. However, the shift supervisor did consider these other tests to be a distraction.

Prior to the start of the test, the ERF computer scanning capability for CEA 26 was defeated because this CEA was causing spurious alarms. This action caused the rod position deviation low limit and rod position deviation low-low limit alarms to annunciate and remain annunciated when the test started. The shift supervisor determined that, since the test would only require 1 to 2 inches of rod motion, this alarm would not be expected to occur and, therefore, was not necessary, and the test could be started.

The first indication to personnel that something was abnormal was when the continuous rod motion alarm was received. The operator noted that a white light and a green light (rod bottom light) were lit for CEA 30 on the core mimic system. It was speculated that this light may have been for CEA 31 since these two indications are next to each other. Although the white and green lights should not be lit simultaneously, the operators felt that there was a limit switch setting problem and did not pursue this anomaly. When the continuous rod motion alarm was received, the operator turned the rod mode selector switch back to OFF per the requirements of the alarm response procedure.

The operators and the I&C technicians agreed that the alarm was unexpected. The test was suspended and the I&C technicians reviewed wiring diagrams to determine whether actions they had taken could have resulted in the alarm. They concluded that the surveillance test should not have caused the alarm. The alarm should be received when there is continuous rod motion for greater than 32 seconds. However, the I&C technicians thought that there may have been a problem associated with taking the rod mode selector switch out of OFF. The I&C technicians felt that the timing associated with continuous rod motion may have started when the selector switch was removed from the OFF position which was not normal. By design, the timing sequence should only start when rod motion occurs. In order to test this theory, the operator removed the rod mode selector switch from OFF and started timing. The operator did not take any actions that could cause rod movement during this timing period. At approximately 32 seconds, the continuous rod motion alarm was received, immediately cleared, and all four lights on the core mimic system for CEA 31 were lighted. The operator went to the OFF position on the rod mode selector switch and checked the primary synchro position indication for CEA 31, which indicated that it was fully withdrawn. The I&C technician removed the test signal from the SCEAPIS and noted that it also indicated that CEA 31 was fully withdrawn. When it was confirmed that CEA 31 had withdrawn, the shift supervisor made all nonessential personnel leave the control room.

The shift supervisor directed the operator to drive CEA 31 into the core. The continuous rod motion alarm was received, and the licensed operator stopped rod motion at approximately 10 inches from the bottom to acknowledge the alarm. At this time, CEA 31 started to move out. The rod mode selector switch was placed in OFF, and the rod motion stopped. Again the shift supervisor directed the operator to insert CEA 31. The CEA started to move out instead of in. Again the operator placed the rod mode selector switch in OFF and rod motion stopped.

The operator was then able to drive CEA 31 to the bottom. The rod mode selector switch was placed in OFF, and no further CEA motion occurred. The shift supervisor then decided to trip the reactor in order to prevent any further CEA motion.

2.2.1 Adequacy of Operator Response to the Alarm

The AIT determined that the operators did follow the requirements of Annunciator Response Procedure ARP-CB-4/A8, "Annunciator Response Procedure A8 Control Room Annunciator A8," in that the rod mode selector switch was placed in the OFF position. However, the operators did not consider the alarm as being valid. If they had considered the alarm valid, they could have checked the other available rod position indications and would have determined that CEA 31 had withdrawn. In addition, the alarm printer, which was near the main control panel, had printed that CEA 31 reached positions of 4 inches and 8 inches from the bottom. The printout from this printer was not checked until CEA 31 had fully withdrawn. The AIT determined that the alternate indications were not utilized, since the operators did not expect other CEA movement, and that the operators exhibited an over reliance on a favorite indication.

In addition, the shift supervisor's decision to start the test with the rod position deviation low limit and rod position deviation low-low lights illuminated appeared to be proper assuming a properly operating rod control system. This was based on the operator's knowledge that no other rod movement should occur during the 1- to 2-inch movement of the selected CEA. However, making this alarm function unavailable masked the problem and prevented the CEA movement from being detected earlier. Alarm Response Procedure ARP-CB-4/A8 would have directed the operators to identify the mispositioned CEA had these alarms annunciated.

2.2.2 Adequacy and Thoroughness of I&C Troubleshooting

The AIT determined that the I&C technicians realized that an anomaly occurred during the test which needed to be resolved. The technicians performed a proper review to conclude that the anomaly should not have been caused by the test. They had no reason to believe that grounds and shorts existed in the rod control system.

The I&C technicians and the operators were performing troubleshooting activities when CEA 31 moved to the fully withdrawn position. This troubleshooting included timing of the continuous rod motion alarm to determine whether moving the rod mode selector switch from the OFF position started the timing sequence in lieu of starting the timing sequence when actual rod motion occurred.

The AIT determined that the I&C technicians performed proper troubleshooting activities. However, like the operators, they did not feel that rod motion, other than that for CEA 30, had occurred. Thus, they also did not take advantage of the other available rod position indications.

2.3 Analysis of the Rod Control System Problems

2.3.1 Rod Control System Power Supply Grounding

The CEDMs had a 120 VAC power supply to power the motors for CEA movement and a 28 VDC power supply for rod position indication through limit switches. Both these systems were of the ungrounded type with no ground fault detectors. All the other AC and DC circuits, including the 4160 VAC, 480 VAC, 120 VAC, and 125 VDC power, control, and instrumentation circuits (including safety and nonsafety related circuits) were also ungrounded but do have ground fault detectors installed to provide both alarms and ground indicating lights in the control room.

In most nuclear plants the 480 VAC and 120 VAC safety- and nonsafety-related circuits are grounded and all DC circuits are ungrounded and monitored with ground fault detectors. Ungrounded AC circuits are susceptible to abnormal excessive voltages that can damage multiple equipment. The most effective way to overcome this limitation is to ground the AC systems. However, in a grounded system, upon the occurrence of a ground fault, the circuit's protective device (e.g., a circuit breaker) will immediately isolate the faulty circuit, resulting in loss of the circuit and its associated equipment. The use of ungrounded systems overcomes this limitation and, with the use of a ground detector, also prevents the generation of excessive voltages by grounding the system through a grounding resistor with a resistance value that is less than the per phase leakage capacitance of the system.

An ungrounded AC or DC system can operate indefinitely with a single ground as long as there is no malfunction in the system. However, multiple grounds can bypass system contacts or switches in the circuits, resulting in the unexpected operation or shutdown of equipment. As the result of this potential, it is desirable to isolate every ground in an ungrounded system as soon as they are identified. The NRC issued Information Notice (IN) 88-86, "Operating with Multiple Grounds in Direct Current Distribution Systems," on October 21, 1988, and Supplement 1 to this IN on March 31, 1989. This IN provided information regarding the effects of multiple grounds on DC systems which included unexpected equipment operation and equipment failure to operate. Furthermore, IEEE Standard 946-1992, "IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations," provides detailed guidance on this subject, specifically on the requirements for ground detectors. The ground detectors selected should be designed to prevent generation of overvoltages in ungrounded circuits and have no effect on pick-up or drop-out of any equipment or protective devices.

2.3.2 Analysis of the Electrical Faults

During surveillance tests conducted between November 13 and 23, 1993, the licensee identified electrical faults within the rod control system. These faults consisted of both grounds and short circuits.

2.3.2.1 Electrical Faults Affecting CEA 31 Operation

The following electrical faults were identified in the control circuitry that affected the operation of the CEDM for CEA 31 (See Figure 2):

- A jumper wire between the 120 VAC and 28 VDC system. This jumper was installed between terminals L-13 and L-16 located in the main control board. This jumper was apparently installed during plant construction and was shown on plant wiring diagrams. The licensee could not determine the purpose of this jumper and considered it to be a design error. This jumper provided the electrical connection fault that, when combined with the multiple grounds, was needed to cause uncontrolled operation of the CEDM.

- A ground fault, a short, and misadjustment on Limit Switch ZS-31/4 for the CEDM. A microswitch contained within this limit switch was found to be shorted between Terminals 7, 8, and 9 and grounded. The licensee considered the short and grounding to be caused by the presence of a "white" substance within the switch. The licensee speculated that the "white" substance was a boron residue that could have come from wetting the switch. This switch wetting could have been the result of leaks on the reactor head, while coming out of past refueling outages, that sprayed the CEDM. The short caused the abnormal condition of both the green rod bottom light and the white normal operating region light on the core mimic system to be on at the same time. The ground fault provided a path that could cause the CEDM withdrawal contactor coil, RA-31, to be energized.

- A ground fault on Limit Switch ZS-30/4 for the CEDM for CEA 30. The cause for this ground fault could not be determined. This ground fault provided a circuit path that could cause the CEDM withdrawal contactor coil, RA-31, to be energized.

- A ground fault in Limit Switches ZS-31/1 and ZS-31/2 for the CEDM. These limit switches, located in the same vicinity as Limit Switch ZS-31/4, also contained moisture which contributed to the ground fault condition. As discussed for limit switch ZS-31/4, the moisture was probably the result of spraying the CEDM. This ground fault (and the one in the CEDM connector discussed below) provided the other side of the circuit path that was needed to keep coil RA-31 energized.

- A ground fault in the connector for the CEDM. This connector contained moisture and was in the same vicinity as the CEDM limit switches. Again, this moisture was probably the result of spraying the CEDM. Personnel that worked near the reactor vessel head during the refueling outage were interviewed and the source of the moisture could not be definitely determined.

2.3.2.2 Electrical Faults Affecting CEA 18 Operation (See Figure 3)

The licensee identified a pin-to-pin short within the patch panel connector for the CEA 18 CEDM. The connector on this patch panel, which was located in the containment, was not disturbed during refueling outages and was probably last connected during plant construction.

The pin-to-pin short was caused by loose wire strands that caused a short between terminal pins "W" and "F." This short connected the CEDM insertion contactor coil LP-18 to a 48 VDC clutch coil supply. Even though this CEDM is nontrippable and does not utilize a clutch coil, the 48 VDC power was available in the connector. This connection combined with the temporary ground detection system that was installed to test for grounds during rod control system testing, provided a circuit path that kept Coil LP-18 energized.

Subsequent testing performed by the licensee indicated that this coil, once energized, would maintain its contacts closed with a voltage as low as 2 to 4 volts. Calculations performed by the licensee indicated that this coil would have a voltage of approximately 4.6 volts across it due to this combination of the pin-to-pin short and the temporary ground detection system. Therefore, when CEA 18 was being inserted with the temporary ground detection system installed, the conditions were suitable for the contactor to remain energized and the CEA to continue its insertion after the operator released the rod control joy stick.

2.3.3 Additional Rod Control System and Rod Position Indication Anomalies

2.3.3.1 CEDM Connector Bent Pin

When the licensee was inspecting the CEDM connectors prior to reinstallation, a bent pin was identified in the CEA 31 CEDM. The licensee straightened the bent pin and dispositioned the connector to use as is. The licensee determined that this bent pin had no effect on the CEDM operation and did not cause any of the observed grounding conditions.

2.3.3.2 CEA 31 Movement Reversal

Following the withdrawal of CEA 31, the operators attempted to insert the CEA. When two insertion attempts were made, the CEA withdrew instead of inserting. The licensee investigated this occurrence and determined that this anomalous motion was caused by the interlock between the "in" and "out" CEDM motor contactors. If the operator placed the rod block bypass switch in BYPASS prior to moving the rod control joy stick to the insert position, the "out" contactor (due to the electrical fault) would be energized first and, because of the interlock, prevent the "in" contactor from being energized. As a result, the CEA would move out instead of in, regardless of the joy stick position. Conversely, if the rod control joy stick was placed in the "insert" position prior to the rod block bypass switch being placed into the BYPASS position, the "in" contactor would be energized first and prevent the "out" contactor from being energized. As a result, the CEA would insert as demanded by the rod control joystick.

2.3.3.3 Loss of the Core Mimic System Lights

Immediately following the anomalous operation of CEA 18, the core mimic system lights were lost. The licensee's investigation determined that this circuit was designed for protection by 10 ampere fuses in each leg of the circuit. When the fuses were checked following the light failure, a 3 ampere fuse was found to be installed in one of the legs. The licensee speculated that, during troubleshooting activities, the 10 ampere fuses were removed while grounding checks were made. Following completion of these activities, apparently a 3 ampere fuse was erroneously installed in the circuit in lieu of the correct 10 ampere fuse. As the result of this error, the 3 ampere fuse failed on an overload condition. The licensee concluded that the incorrectly sized fuse was the cause for the core mimic system light failure and that this occurrence was not connected to any of the other problems identified with the rod control system.

2.4 <u>Rod Control System Operations and Maintenance History</u>

The FCS rod control system was installed as part of the original design of the plant, with the exception of the rod block system, which was installed in December 1975 as part of Facility License Amendment 8.

The licensee's review of operations and maintenance history for similar problems revealed that there had only been two events identified for inadvertent CEA movement other than dropped CEAs. In 1989, approximately 1 year after rod sequencing control was transferred to the ERF computer system, CEA Groups 2 and 3 sequenced in with Group 4. The programming error was caused by the programming being done in accordance with the computer's technical manual. The problem was intermittent in that it only had an effect when CEAs were moved. The programming error was corrected.

In 1986, CEA 26 drifted in when a frayed wire caused a short across the brake coil contact which energized the coil and released the brake.

There have been four dropped CEAs. Two (CEAs 28 and 25) in 1974, one (CEA 24) in 1982, and one (CEA 35) in 1992. There are ongoing corrective actions to monitor the clutch coil impedance and resistance for predicting replacement, as all these CEA drops were caused by failure of the clutch coils.

There were no past problems associated with grounds on the drive or position indication systems.

Numerous reactor coolant system and component cooling water leaks were identified on the head. Almost all of these were found during hot or cold hydro inspections. Only one leak was noted as getting a CEDM wet. In 1988, an autoclave gasket leak soaked the CEDM for CEA 31 and it was cleaned up. The licensee suspects that the white material found on and in the limit switches was from this leak.

2.5 Effect of Event on Various Plant Conditions

An unplanned or uncontrolled withdrawal of a CEA group would result in the addition of positive reactivity. The effects of this event are bounded by Updated Safety Analysis Report (USAR) Section 14.2, "Control Element Assembly Withdrawal Incident."

2.5.1. Effect During Power Operations

During power operations, the CEAs would normally be operated in a fully withdrawn position. The power dependent insertion limit (PDIL) is a variable limit that ensures sufficient shutdown margin is available at any power level. Operators perform boron adjustments to maintain the CEAs above the PDIL. The rod block system prevents any CEA from being inserted beyond the PDIL. A withdrawal of a group of CEAs would result in an increase in reactor power. If the CEAs were not fully withdrawn, and if such operation was not abated by operator action, the reactor would trip on a variable high power trip, which has a setpoint of 10 percent above the existing power level. The trip at full power has a setpoint of 107 percent.

2.5.2 Effect During Plant Startup

Prior to startup, all CEAs would be inserted, and the reactor coolant system borated such that the reactor would have at least a 5 percent shutdown margin even with all CEAs withdrawn. Operators achieve criticality by either withdrawing all CEAs and diluting the reactor coolant system, or by withdrawing Shutdown Groups A and B, diluting, and then withdrawing the remaining CEAs. During the latter method of going critical, the reactor would be vulnerable to premature criticality after the shutdown groups are withdrawn and when dilution is occurring. If an uncontrolled group withdrawal did occur at startup, the reactor would trip on the variable high power trip. In addition a startup rate trip would trip the reactor. This startup rate trip has a setpoint of 2.6 decades per minute and is in effect from 10-4 percent power (administratively critical) to 15 percent power.

2.5.3 Effect During Shutdown Conditions

At shutdown conditions, the reactor coolant system would have enough negative reactivity from boron (1900 ppm) to prevent going critical even with all CEAs fully withdrawn.

2.5.4 Procedures for Mitigating Event Consequences

Abnormal Operating Procedure AOP-02, "CEA and Control System Malfunction," provides operator instructions to recover from an unplanned or uncontrolled CEA withdrawal. The operators did enter this procedure on November 13, 1993.

The AIT reviewed this abnormal operating procedure to ensure that it would provide sufficient instructions for plant conditions ranging from shutdown to power operations. The AIT determined that Procedure AOP-02 would mitigate the consequences of the addition of positive reactivity from an uncontrolled CEA withdrawal event.

Annunciator Response Procedure ARP-CB-4/A8, "Annunciator Response Procedure A Control Room Annunciator A8," provides direction for the operator response to CEA control anomalies. This procedure provides guidance for the annunciation of the rod position deviation low limit, the rod position deviation low-low limit, and the continuous rod motion alarms. The AIT determined that Procedure ARP-CB-4/A8 would probably provide sufficient early recognition of an uncontrolled CEA motion event so that operators could react and mitigate the situation prior to the occurrence of safety system challenges.

The AIT also noted that Procedure ARP-CB-4/A8 would have directed the operators to locate the withdrawn CEA during the November 13 event if the rod position deviation low limit and rod position deviation low-low limit annunciator lights had reflash capability and had not been lit prior to the start of the surveillance test. The procedure's direction to respond to the Continuous Rod Motion alarm was not fully adequate in that, while it required operators to cease CEA motion, it did not direct the operators to locate the CEA that had moved.

2.6 Root Cause, Contributing Causes, and Corrective Actions

2.6.1 Root Cause

The licensee determined that the root cause of the event was the lack of a ground detection system for the power supplies in the Rod Control System. The lack of a ground detection system allowed for undetectable multiple grounds to develop over the 20 years of operation. These grounds resulted in the abnormal CEA operation. In addition, the lack of the ground detection system and the occurrence of the multiple grounds essentially invalidated the advantage of having an ungrounded supply system.

2.6.2 Contributing Causes

A contributing cause was the electrical connection between the 120 VAC rod control power supply and the 28 VDC power supply used for the core mimic system. This wiring deficiency, which apparently had existed since original construction, provided an electrical path that allowed a ground on the 28 VDC circuit and a ground on the 120 VAC circuit to allow power to be applied to the withdrawal contactor coil, RA-31, for the CEA 31 CEDM. This electrical connection was not part of the design basis for the rod control power supply.

Another contributing cause was that neither the surveillance test nor the annunciator response procedure (ARP) required verification of all CEA positions following any abnormalities. In addition, the surveillance test did not provide any precautions to alert operators that the rod block would be removed from service during the test which could allow a CEA to withdraw.

2.6.3 Corrective Actions

The licensee consolidated the causes of the event into 4 areas. The first area indicated that the problem was not anticipated in design. Although the ungrounded power supply was used to prevent abnormal operation under a single ground situation, equipment was not provided to monitor for the existence of a ground. Installation of a continuous ground detection circuit similar to that on the power supplies would have allowed for identification of such abnormalities in the rod control and indication power supplies.

The second area indicated that the situation was not covered by procedure. The surveillance test did not require verification of all CEAs upon indication of any abnormalities. Additionally, the surveillance test did not specify that the rod block would be removed during the test.

The third area indicated that there was an over-reliance on a favorite indication. The operator did not use all available indication to determine CEA position.

The fourth area indicated that the drawing reviews were not adequate. The wiring drawings specifically indicated the hard wire connection between the 28 VDC core mimic system power supply and 120 VAC CEDM power supply. The reviews did not identify this deficiency. This discrepancy has probably existed since initial construction.

On the basis of the events that occurred on November 13 and 18, the licensee identified the following corrective actions that were implemented and committed to complete these actions prior to their restart from the refueling outage:

- Troubleshoot, identify, and eliminate all grounds in the rod control, core mimic, and rod block systems. Remove the hardwired connection between the 120 VAC and 28 VDC power supplies.
- Install a permanent ground detection system on the rod control and core mimic systems.
- Perform comprehensive testing of the rod control, core mimic, and rod block systems.

- Have the Nuclear Safety Review Group (NSRG) conduct an independent review of the troubleshooting and testing activities.

- Have a shutdown safety advisor conduct an independent assessment to confirm the adequacy of operator and I&C technician actions during the CEA withdrawal event of November 13, 1993

- Review all other ungrounded power supply systems to ensure that these systems are provided with ground detection systems.

- Conduct a formal safety assessment to confirm that the event was bounded by the safety analysis and that the present design meets the current licensing basis. This includes an evaluation by Combustion Engineering (CE) of the safety and operational significance of any malfunctions resulting from multiple grounds, including low resistance and high resistance grounds. It also includes an assessment of the effect of multiple smart grounds that result in bypassing redundant rod block contacts. This action was completed prior to the AIT exit meeting that was conducted on November 22, 1993.

- Conduct a review of 1993 Refueling Outage Modifications and Maintenance for possible linkage to this event. This review will include work rela... to the multiple grounds and the moisture intrusion into the connector.

- Perform an initial update of the Nuclear Network that will include the details surrounding these events and the root causes of the events.

- Review plant records to determine if any similar occurrences of uncontrolled rod motion had occurred.

- Complete a root cause analysis (RCA) to identify root cause for the November 13, 1993, event and identify corrective actions to preclude similar events.

- Reinforce to all operations personnel that all instrumentation indications will be considered valid unless it is proven that the instrument indication is invalid. In addition, all operating shifts will receive training regarding the events, the revised procedures, and the new ground detection system prior to assuming their watch standing duties.

- The annunciator response procedure (ARP-CB-4/A8) for the continuous rod motion alarm will be revised. This revision will insure that CEA positions are verified using all available indications after the rod mode selector switch is placed in the OFF position.

- Revise Surveillance Procedure IC-ST-CEA-0002 by adding a precaution to insure that containment integrity is established whenever more than one CEA is to be moved.

- Revise surveillance procedures involving CEA movement to require that the primary synchro CEA position indicating system is operable, that alarms are capable of alerting the operators to CEA mispositioning, and that CEA positions are displayed on the ERF computer screen during testing activities. This revision will include a requirement that CEA positions be verified at selected procedural steps to insure that they are as expected.

The licensee proposed other corrective actions to resolve those issues identified during its investigation of the event. These corrective actions include the following:

- A calculation will be completed that will demonstrate the sensitivity of the newly installed ground detection system on the rod control and the core mimic systems.

- A signoff and inspection criteria will be considered for the procedures used for disconnecting and reconnecting CEDM cable connectors. The licensee is also considering ensuring that only properly qualified electricians either perform or directly supervise the removal or installation of the CEDM cables.

- Procedure OP-2A will be revised to require a reactor trip if a reactivity anomaly which results in an increasing count rate or reactor power level is observed.

- Standing Order O-1 will be revised to add a statement to the annunciator response section emphasizing that all alarms are to be treated as valid unless proven otherwise and that alarms directly associated with safety functions must be fully understood prior to continuing with other plant activities.

- Lessons learned from this event will be included in future training classes. This will include additional training on CEA position indication as part of the biennial licensed operator requalification training program. This training will also encompass any new procedural changes that have been made as the result of these events.

- The performance of maintenance and testing activities affecting safety functions and requiring a high level of attention during an outage will be evaluated to determine the feasability of restricting the performance of these activities to between 2:30 a.m. and 6 a.m. These activities could include testing of CEAs, shutdown cooling evolutions, and monitoring of reactor coolant system level during filling or draining evolutions. These activities are more likely to be completed successfully when fewer distractions are present in the control room. Another consideration that will be examined will be to place administrative restrictions on the number of activities or personnel in the control room at any one time.

- Evaluate what improvements can be made to protect the CEDM cable connectors against water intrusion.

2.7 Accident Analysis Bounding Review

The USAR provided an analysis for several accidents involving the CEAs. One analysis described in Section 14.2 involved a CEA withdrawal incident. This accident assumed that a sequential CEA group withdrawal event occurred due to a failure in the rod control system or by operator error. The rod block system, which was installed after Cycle 1, has eliminated the possibility of an out-of-sequence bank withdrawal or a single CEA withdrawal due to a single failure.

There are two major initial conditions which were examined, hot full power (HFP) and hot zero power (HZP). During HFP, all CEAs, except Group 4, which was limited to 75 percent withdrawn by the power dependent insertion limits (PDIL), were fully withdrawn. During HZP, Groups 1 and 2 were fully out, while Group 3 was at 20 percent withdrawn, which was also based on the PDIL, with critical boron concentration, 532°F reactor coolant temperature, and the reactor critical. The analysis assumed that the group withdrawal from HFP was mitigated by a high power trip at 112 percent of rated thermal power. For the HZP, the reactor trip was initiated by the variable high power trip at 28 percent (20.0 percent plus 8 percent uncertainty) of rated thermal power.

Protection at full power was maintained by the response of the reactor protection system (RPS) which provides automatic reactor trip on high power level. In addition, protection was also provided by the initial steady state thermal margin which was maintained by adhering to the Core Operating Limits Report (COLR) regarding the departure from the nucleate boiling ratio (DNBR) margin. The zero power case for Cycle 15 results in a minimum DNBR of 5.84. The analysis also showed that the peak linear heat rate (LHR) achieved was within the acceptable limit.

The CEA withdrawal incident, when initiated at either HFP or HZP, did not lead to a DNBR or an LHR which would violate the design limits.

The November 13, 1993, event was less limiting than the corresponding USAR accident because: (1) only one CEA, CEA 31, withdrew, while all the rest of the CEAs were on the bottom, and (2) the boron concentration was at 2100 ppm, which was greater than the required refueling boron concentration. The additional boron resulted in 7.81 percent additional shutdown margin over the 5 percent refueling requirement with all CEAs out. Thus with CEA 31 withdrawn and all other CEAs on the bottom except the nontrippable CEAs, the shutdown margin was 16.88 percent. Therefore, the event that occurred was bounded by the present analysis in the USAR.

Another analysis in USAR Section 14.5 involves the malpositioning of the nontrippable CEA's. The analysis was based on a dropped CEA which is bounded by Section 14.4, "Control Element Assembly Drop Incident." Section 14.4 describes a CEA dropping into the core initially at 100 percent of rated thermal power and the analysis showed that the LHR and DNBR would not be exceeded. The event on November 18, 1993, involved the driving into the core of CEA 18 from 2 inches withdrawn to the bottom with all other CEAs on the bottom and, therefore, was bounded by the present analysis in the USAR.

The licensee had CE perform an evaluation in support of FCS's action plan for the November 13, 1993, event. This included an identification of the worst case scenaric within the approved licensing basis of the Rod Control System, confirmation that rod block circuitry cannot be defeated because of multiple grounds in the rod control system, and confirmation that, in the worst case, multiple grounds can result in sequential group withdrawal. CE's evaluation concluded that there were no credible combination of ground faults which could have defeated the rod block circuitry for events initiated above $1E^{-4}$ percent reactor thermal power, and CEA-related events not addressed by the rod block were analyzed in the accident analysis in the USAR. For events below $1E^{-4}$ percent reactor thermal power, shutdown boron concentration was administratively maintained until both shutdown groups were fully withdrawn. It was, therefore, concluded that this event was of no safety significance.

The CE evaluation also analyzed the rod block system which had contacts located on both sides of the power to the CEDM starter. This configuration was reviewed in the original Safety Evaluation Report for the rod block circuit in License Amendment 8. This arrangement eliminated the possibility of a double ground fault from one 120 VAC line to a point downstream of the rod block contacts, but upstream of the motor starter, such that the block would be defeated. Also, with the two sets of rod block contacts, another ground between the second set and the motor would cause the motor to be shorted to ground, thus preventing motor operation (See Figure 2).

3 FINDINGS AND CONCLUSIONS

The AIT had the following findings and conclusions:

- The AIT's evaluation of the licensee's response to the event indicates that the response was adequate and in accordance with the plant's procedures. The team noted, however, as discussed in this report, that the was evidence of a lack of attention to detail by the operators during their response.

- The AIT noted that the I&C troubleshooting was also not as comprehensive as it could have been. The fact that the continuous rod motion alarm was not thoroughly investigated by reviewing all available information is an example of a less than fully comprehensive review.

- The AIT concluded that, prior to and during the performance of the surveillance test conducted on November 13, 1993, there was no pressure either on the operators or the I&C technicians to complete the test to meet the outage schedule.

- The AIT conducted a thorough review of the licensee's analysis of the causes of the rod control system anomalies. The team concurred with the licensee's conclusions that the uncontrolled movement of CEA 31 was caused by a combination of grounds in the system combined with the short connection between the rod control system and core mimic system power supplies. The team also concurred with the licensee's findings and resolutions regarding the CEDM connector bent pin, the unexpected movement of CEA 18, and the loss of the core mimic system lights.

- The AIT noted that the licensee has been unable to positively identify the reason for the moisture in the cable connector and limit switch on the CEDM for CEA 31. However, the team considered the licensee's corrective actions to be adequate.

- The AIT concurred with the licensee's conclusions that the root cause of this event was the lack of a ground detection system on the rod control system. If such a system had been present, it is likely that this event could have been prevented.

- The AIT's review of the history of operations and maintenance on the rod control system indicated that there was no evidence that such a condition had occurred in the past.

- The AIT determined that, while the licensee's present plant procedures were adequate for mitigating the consequences of a positive reactivity addition event, enhancements were needed to address uncontrolled CEA motion events. The team noted that the licensee's procedure enhancements should improve the identification and response to such events. The team noted that training packages were developed for plant operators that included the revised procedures and information regarding the new ground detection system, including necessary procedure changes. The team also noted that operators on watch have received training in these changes and that other operators will be trained on the content of these packages prior to assuming their watch.

- The AIT concluded that this event and similar events are bounded by the licensee's accident analysis.

- The AIT reviewed the licensee's preliminary analyses of the root and contributing causes of this event and concurred with the findings and conclusions. The team considered the proposed corrective actions to be thorough and complete.

4 EXIT MEETING

A public exit meeting was conducted on November 22, 1993, with the personnel listed in Attachment A. During this meeting, the team leader summarized the scope and findings of this inspection as delineated in this report. The licensee acknowledged the inspection findings and did not express a position on the inspection findings documented in this report. The licensee did not identify as proprietary any information used in the performance of this inspection.

ATTACHMENT A

The AIT contacted the following personnel during this inspection. In addition to these personnel, the AIT contacted other licensee personnel during this inspection.

1 OPPD PERSONNEL

*R. Andrews, Division Manager, Nuclear Services
*G. Cavanaugh, Licensing Engineer
*J. Chase, Manager, Fort Calhoun Station
*G. Cook, Supervisor, Station Licensing
J. Connolley, Lead System Engineer
J. Cook, Shift Supervisor
*M. Frans, Supervisor, System Engineering
*S. Gambhir, Division Manager, Production Engineering
*J. Gasper, Manager, Training
*W. Gates, Vice President, Nuclear
*J. Herman, Supervisor, Nuclear Licensing
*R. Jaworski, Manager, Station Engineering
*W. Jones, Senior Vice President
L. Kusek, Manager, Nuclear Safety Review Group
*S. Lee, Secretary
*T. Patterson, Division Manager, Nuclear Operations
*F. Petersen, President
*R. Phelps, Manager, Design Engineering
*H. Sterba, Division Manager, Corporate Communications
*J. Tills, Supervisor, Operations
*G. Williams, Supervisor, Media Relations

2 NRC PERSONNEL

*S. Bloom, Project Manager, NRR, Fort Calhoun
*J. Gilliland, Public Affairs Officer, Region IV
*T. Gwynn, Deputy Director, Region IV, Division of Reactor Projects
*C. Hackney, Regional State Liaison Officer, Region IV
*A. Howell, Deputy Director, Region IV, Division of Reactor Safety
*S. Mazumdar, Electrical Engineer, NRR
*R. Mullikin, Senior Resident Inspector, Fort Calhoun

3 OTHER PERSONNEL

*J. Anderson, Reporter, Omaha World-Herald
*I. Cohen, Member, CLEAN/SIERRA CLUB
*T. Coleman, Jr., Homeowner, Fort Calhoun, Nebraska
*C. Griffin, Reporter, KETV
*B. Jensen, Reporter, WOW

*Denotes personnel that attended the exit meeting.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
611 RYAN PLAZA DRIVE, SUITE 400
ARLINGTON, TEXAS 76011-8064

ATTACHMENT B

NOV 19 1993

Docket: 50-285
License: DPR-40
CAL 4-93-~~322~~014

Omaha Public Power District
ATTN: T. L. Patterson, Division Manager
Nuclear Operations
Fort Calhoun Station FC-2-4 Adm.
P.O. Box 399, Hwy. 75 - North of Fort Calhoun
Fort Calhoun, Nebraska 68023-0399

SUBJECT: CONFIRMATORY ACTION LETTER

Pursuant to a telephone conversation on November 19, 1993, between Terry L. Patterson, Division Manager, Nuclear Operations, and T. P. Gwynn, Acting Director, Division of Reactor Projects, it is our understanding that Fort Calhoun Station will not proceed beyond operational Mode 3 until you have met with the NRC staff to review the results of your efforts to identify and correct the condition that is causing unexpected movement of control element assemblies and the NRC staff is satisifed with your immediate corrective actions.

Pursuant to Section 182 of the Atomic Energy Act, 42 U.S.C. 2232, and 10 CFR 2.204, you are required to:

1. Notify me immediately if your understanding differs from that set forth above; and

2. Notify me in writing when you have completed the actions addressed in this Confirmatory Action Letter.

Issuance of this Confirmatory Action Letter does not preclude issuance of an order formalizing the above commitments or requiring other actions on the part of the licensee. Nor does it preclude the NRC from taking enforcement action for violations of NRC requirements that may have prompted the issuance of this letter. In addition, failure to take the actions addressed in this Confirmatory Action Letter may result in enforcement action.

The responses directed by this letter are not subject to the clearance procedures of the Office of Management and Budget as required by the Paperwork Reduction Action of 1980, Pub. L. No. 96-511.

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter and its enclosures, if any, will be placed in the NRC Public Document Room.

Sincerely,

James L. Milhoan
James L. Milhoan
Regional Administrator

cc:
LeBoeuf, Lamb, Leiby & MacRae
ATTN: Mr. Michael F. McBride
1875 Connecticut Avenue, NW
Washington, D.C. 20009-5728

Washington County Board
of Supervisors
ATTN: Jack Jensen, Chairman
Blair, Nebraska 68008

Combustion Engineering, Inc.
ATTN: Charles B. Brinkman, Manager
Washington Nuclear Operations
12300 Twinbrook Parkway, Suite 330
Rockville, Maryland 20852

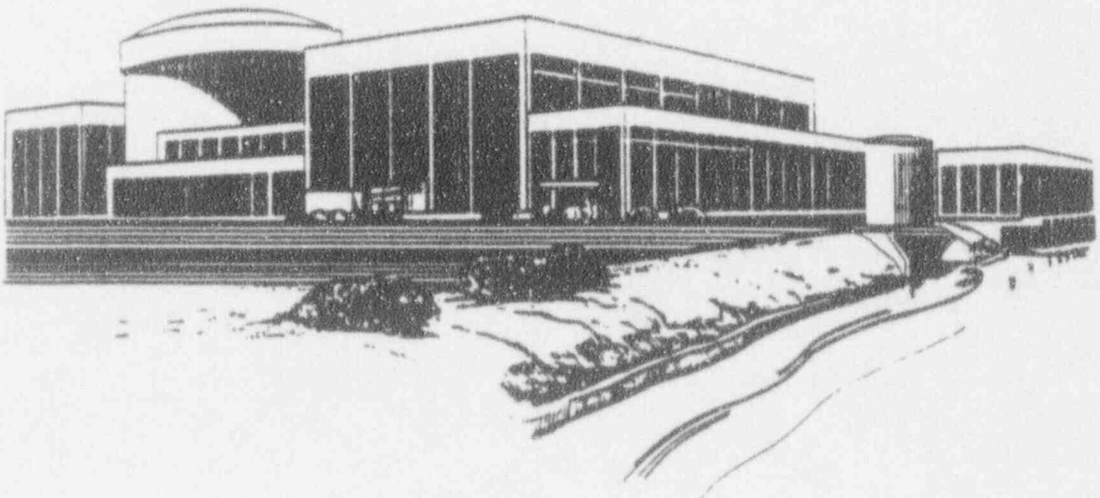
Nebraska Department of Health
ATTN: Harold Borchert, Director
Division of Radiological Health
301 Centennial Mall, South
P.O. Box 95007
Lincoln, Nebraska 68509-5007

Fort Calhoun Station
ATTN: James W. Chase, Manager
P.O. Box 399
Fort Calhoun, Nebraska 68023

ATTACHMENT C

NRC BRIEFING ON CEDM

TROUBLESHOOTING AND CORRECTIVE ACTIONS



NOVEMBER 22, 1993

AGENDA

NRC BRIEFING ON CEDM TROUBLESHOOTING AND CORRECTIVE ACTIONS

• INTRODUCTIONS	W. G. GATES
• SYSTEM DESCRIPTION	T. L. PATTERSON
• SEQUENCE OF EVENTS	J. W. TILLS
• SAFETY SIGNIFICANCE	T. L. PATTERSON
• ROOT CAUSE ANALYSIS AND CORRECTIVE ACTIONS	S. K. GAMBHIR
• CLOSING COMMENTS	W. C. JONES

SYSTEM DESCRIPTION

- Four sub-systems associated with the CEA drive function:
  - Clutch Coil Power Supply System
  - Rod Drive Control System
  - CEA Position Indication Systems
  - Rod Block System

- There are 37 CEDMs divided into 7 separate groups which move 49 CEAs.

SAFETY SIGNIFICANCE

- Conservative shutdown margin maintained at all times.

- Comprehensive testing program of Rod Drive Control System, Rod Block System and CEA Position Indication System prior to startup.

- Mode of operation limits potential risks.

- Design basis analysis margins assured at all times.

- PRA model confirms RPS protects fuel for all CEDM withdrawal scenarios.

ROOT CAUSE/GENERIC IMPLICATIONS ANALYSIS

SUMMARY OF EVENTS:

1. Unexpected withdrawal of control rod #31.
2. Unexpected insertion of control rod #18.
3. Loss of power to the lights which indicate CEA position.

PROBLEMS IDENTIFIED DURING TROUBLESHOOTING:

1. Ground due to moisture in connector for control rod #31.
2. Ground due to faulty microswitch for control rod #30.
3. Fault due to short on wiring for control rod #18.
4. Hardwire connection between Rod Drive Control System & CEA Position Indication System.
5. Incorrect fuse found in CEA Position Indication System.

ROOT CAUSE/GENERIC IMPLICATIONS ANALYSIS

ROOT CAUSE:

Lack of ground detection system.

CONTRIBUTING CAUSES:

1. Alarm Response Procedure weakness.
2. Surveillance Test Procedure weakness.
3. Moisture intrusion in connector for control rod #31.

GENERIC IMPLICATIONS:

1. Ungrounded control system with no ground detection system.
2. Procedural weaknesses.

CORRECTIVE ACTIONS

1. Developed a 15 point corrective action plan.

2. Completed rigorous troubleshooting of the system, eliminated all grounds.

3. Removed hardwired connection between Rod Drive Control System and CEA Position Indication System.

4. Conducted a root cause analysis.

5. Installed ground detection system on the Rod Drive Control System, CEA Position Indication System, and Rod Block System.

6. Procedures associated with annunciator response and surveillance tests have been/will be upgraded.

7. Comprehensive testing of the Rod Drive Control System, CEA Position Indication System and Rod Block System will be completed prior to startup.

8 Completed formal safety assessment to confirm that the event was bounded by safety analysis.

9. Evaluated other ungrounded control systems.

10. Independent review was conducted by our Nuclear Safety Review Group.

11. Precautions will be added to procedures to ensure proper handling of CEA drive packages during the next refueling outage.

Figure 1

CAM OPERATED CORE MIMIC LIGHTS

FUNCTION / ROD GROUP	UPPER ELECTRICAL LIMIT (UEL)	UPPER ROD STOP (URS)	SHUTDOWN ROD EXERCISE LIMIT	NORMAL OPERATING REGION	LOWER ELECTRICAL LIMIT (LEL)
SHUTDOWN RODS	RED		BLUE	WHITE	GREEN
REGULATING RODS	RED	AMBER		WHITE	GREEN
NON-TRIPPABLE RODS	RED	AMBER		WHITE (WHEN MOVING)	GREEN

RED R.S. *>126"	BLUE P.C. >120"
GREEN L.S. <4"	WHITE L.S. >4"

SHUTDOWN CRDM'S

RED L.S. >126"	AMBER P.C. >125"
GREEN L.S. <4"	WHITE ** ROD MOVING L.S. >4"

REGULATING AND NON-TRIPPABLE CRDM'S

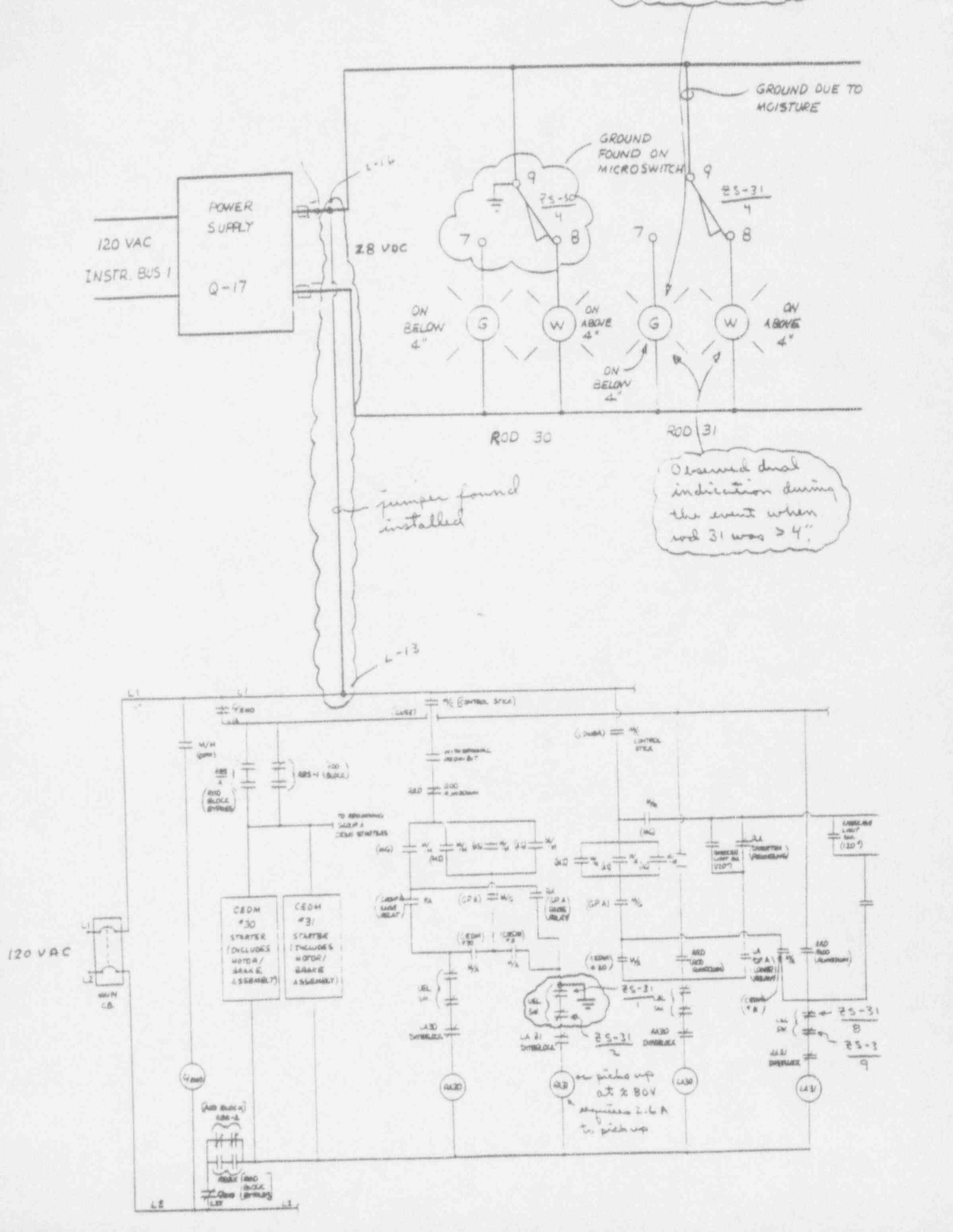
* REED SWITCH ACTUATED

** NON-TRIPPABLE MOTION CIRCUIT

RDCAMOPR

Figure 2

CEA 31 Rod Control Circuitry
Showing Electrical Faults



CEA 18 Rod Control Circuitry Showing Electrical Fault

Figure 3