U. S. NUCLEAR REGULATORY COMMISSION
REGION III

Report No. 50-255/89033(DRP)

Docket No. 50-255 License No. DPR-20

Licensee: Consumers Power Company
212 West Michigan Avenue
Jackson, MI 49201

Facility Name: Palisades Nuclear Generating Plant

Inspection At: Palisades Site, Covert, Michigan
Wyle Laboratories, Norco, California

Inspection Conducted: November 23-30 and December 6-9 and 15, 1989

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1/8/90
Date

Inspection Summary

Inspection on November 23-30 and December 6-9 and 15, 1989 (Report No. 50-255/89033(DRP))

Areas Inspected: Special unannounced team inspection to review an inadvertent depressurization event on November 21, 1989, which resulted in a reactor trip and safety injection actuation from hot standby. The causes appeared to be due to a single train of pressurizer power operated relief valve and motor operated block valve irregular operation. The Inspection Team evaluated: valve design, operation, and testing; procedures; operator actions and training; and, because the root causes of the event were not evident from inspection, a consultant was retained to observe dynamic (full flow) testing of the valves.

Results: The inspection disclosed weaknesses in the licensee's integration of design and testing activities. A potentially serious event was precipitated by a valve's characteristic design response to certain test conditions, but the personnel conducting the test were completely unaware of this characteristic. The root causes of the second opening of the pressurizer power operated relief valve (PORV) and the PORV block valve failure to close during the event could not be determined by either inspection or test. The licensee will meet with NRC Region III to discuss the corrective actions to prevent recurrence of this type event.

AUGMENTED INSPECTION TEAM REPORT

U.S. NUCLEAR REGULATORY COMMISSION

REGION III

PALISADES NUCLEAR PLANT DEPRESSURIZATION

REACTOR TRIP/SAFETY INJECTION FROM HOT STANDBY

NOVEMBER 21, 1989

INSPECTION REPORT NO.

50-255/89033

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DETAILS

1. Event Summary

The Palisades Nuclear Plant completed an October/November 1989 maintenance and surveillance outage during which the licensee replaced the Power Operated Relief Valves (PORVs) and PORV block valves by removal of both the original pair of valves and welding in new valves. Target Rock supplied the relief valves and Rockwell-Edwards supplied the block valves, which they equipped with Limitorque motor operators. Post modification testing was to include an inspection of the welds in the section of piping between the block valves and their respective PORVs. This was scheduled to coordinate with the system hydrostatic test at the completion of the outage.

On November 21, a primary coolant system (PCS) hydrostatic test pressure of 2154 psi (at normal operating temperature) was obtained. Per the normal startup procedure, both block valves were closed, isolating their respective relief valves from PCS pressure. Both PORVs were also closed. The Turbine Generator and Reactor Protection systems had been reset and the control rod shutdown banks were withdrawn for a pre-startup control rod test. At 2:25 a.m, the control rod test was suspended, and block valve MO-1042A was opened. The associated PORV (PRV-1042B) immediately opened also, starting a PCS depressurization. The PORV stayed open for about 34 seconds and depressurized the PCS to around 1670 psi. This caused a Reactor trip (due to Thermal Margin Low Pressure) and a Turbine Generator trip.

The PORV reseated: approximately 2 minutes later, it opened a second time for about 14 seconds. The second opening caused an additional PCS depressurization to about 1565 psi and a safety injection signal (SIS) resulted. The operators reported several attempts to close the block valve during this time, but stated that they were not successful until after the PORV reseated for the second and last time. The plant was then stabilized in hot shutdown.

The licensee subsequently declared an Emergency Plan Unusual Event (UE) at 3:05 a.m., because a PORV had been challenged. The UE was secured at 3:34 a.m. The Licensee reported the event as required by 10 CFR 50.72 and a 10 CFR 50.73 written report is anticipated.

During conference calls conducted on November 21 and 22, the licensee briefed NRC (Region III and Headquarters) personnel on the event and on potential courses of action. The licensee stated that the unit would be taken to cold shutdown to repair and trouble shoot the valves, but first, a safe means was needed to open a block valve without challenging the associated PORV. This would enable use of the PORV in its design function of establishing the required low temperature overpressure protection (LTOP) during the cooldown.

Region III established an Augmented Inspection Team (AIT), in coordination with the Office of Nuclear Reactor Regulation (NRR) to review the events associated with the Palisades power operated relief and block valve irregularities. The Team consisted of the SRI from D.C. Cook (Team Leader), RI from Palisades, and electrical and valve specialists from Region III and NRR.

The Team Charter (Attachment 1) included: validation of the events sequence; determination of apparent equipment irregularities; assessment of recent valve design changes and testing; and, review of operator training and performance. Concerning the first item of the Charter, a detailed, annotated sequence of events is included as Attachment 2 to this report. Some Team members began chartered activities on November 23, with the entire complement on site by November 24. Persons contacted in the course of Team activities onsite are listed on Attachment 3. The first order of business was monitoring licensee actions to safely achieve cold shutdown.

To enable the plant to be taken from hot to cold shutdown, the licensee generated a special operating procedure and a temporary modification to the block valve control circuitry to allow opening a block valve while minimizing the probability and impact of another inadvertent PORV opening. The Inspection Team reviewed: Temporary Modifications (TM) No. 89-087 and No. 89-088; Safety Review No. SE-791-02, Revision B; Work Request No. 140706; and Drawing No. E-242 Sheet 4, "Schematic Diagram Volume Control Shutdown Cooling & Pressure Relief Motor Operated Valves," Revision 16 (see Charter, Item 5). The Team also discussed the event and operation of the block valves with cognizant plant electrical maintenance personnel.

a. Review of TM 89-087, TM 89-088, and Drawing No. E-242, verified that removing the seal-in feature on the block valve opening cycle would give the control room operator better control over the block valve. This would allow the operator to stop the valve as it opens and immediately reclose it if a problem developed. The operator could also "bump" the valve off its seat to allow a more gradual pressurization of the pipe between the block valve and the PORV; and to reduce the probability of inadvertent PORV actuation.

b. Review of Safety Review SE-791-02, indicated that the temporary modification to the block valves did not involve an unreviewed safety question.

Inspection Team members attended the Plant Review Committee meeting on the temporary modification and special procedure on November 24, 1989, and observed implementation of these activities on November 25. The actions were successful; PRV-1043B was unisolated and placed in service for LTOP and the plant safely achieved cold shutdown on November 26, 1989.

2. Operator Actions

At the time of the event, approximately 2:25 a.m. on November 21, 1989, the Palisades Control Room was staffed with two licensed Reactor Operators; designated Control Operator No. 1 (CO-1) and Control Operator No. 2 (CO-2) by the licensee. Present in the Shift Supervisor's office were the Shift Supervisor (SS) and the Shift Engineer (SE), both holders of Senior Reactor Operator licenses. A normal complement of auxiliary operators was onsite; they were responding to an unannounced fire drill in the condensate pump area and were not materially involved in the depressurization event and its immediate aftermath. The CO-2 was performing a routine startup test of the control rod interlocks. Several control rods had been tested when the request was received (through the SS and the CO-1) to open valve MO-1042A, one of the Power Operated Relief Valve (PORV) block valves. This valve had previously been closed (along with the other motor operated PORV block valve, MO-1043A) as specified by the startup procedure. The change in valve position required an administrative control device, called a special valve lineup, to ascertain the acceptability of changing the valve to an off-normal position. The SS verified the special valve lineup sheet included the opening of the PORV block valves; other valves had also been repositioned.

The following discusses the observations and actions of the operators, as described in subsequent interviews and statements prepared for the post trip review (see AIT Charter, Item 6). These interviews yielded quite consistent descriptions for all events witnessed by more than one person. Where there was only one observer, the narrative so indicates.

> The CO-2 turned the handswitch for valve MO-1042A to "OPEN". Within a couple of seconds, as expected, the red "OPEN" indicating light above the handswitch illuminated, so both the red and green (CLOSED) lights were lit. Almost simultaneously, the associated PORV (valve PRV-1042B) opened as well. PORV open alarms were received and primary coolant system (PCS) pressure began a very rapid drop, as shown on a front-panel LED readout. PORV design and behavior are discussed further in another section of this report. One or both control operators called out that the PORV was open, which caused the SS and SE to enter the control room. The CO-2 reversed the block valve handswitch to the CLOSED position and held it there (it would otherwise spring-return to neutral) but he knew the valve had a "seal in" circuit and had to stroke fully open before it could be closed. A full stroke consumes approximately 18 seconds. He believed he saw the block valve reach OPEN (red light only) then return to red/green, indicating it had begun to close. He stated he continued to hold the handswitch to "CLOSE", for what seemed an equivalent time as the OPEN stroke. He then released the switch (still showing red/green) and checked various plant parameters. Glancing back at the block valve, he observed it OPEN (red light only), so he gave it another CLOSE signal and observed concurrent red/green lights. By this time, a reactor trip had occurred, and the CO-2 left the block valve handswitch to perform associated "immediate actions".

The CO-1 was likewise performing his "immediate actions". Only the CO-2 indicated he saw the block valve OPEN twice. The CO-1, the SS and the SE all stated they did not see the valve fully open. The design of the valve would not permit closure without it first being fully open once, barring some electrical problem. No such problem could be subsequently identified in multiple tests performed by the licensee, some of which were witnessed by a member of the Inspection Team. Therefore, it appears likely that the valve did fully open at least once. It is less certain that the block valve was fully open only once. The datalogger shows a continuous "NOT CLOSED" entry for nearly three-and-one-half minutes. The timing, the design and the post-event checkouts seem to exclude the possibility the valve moved in the OPEN direction other than in the initial, approximately 18 second interval. The reactor trip occurred at 24 seconds after the block valve first indicated "NOT CLOSED", around 26 seconds after the initial OPEN signal from the handswitch. This is insufficient time for this valve to come fully open (about 18 seconds), then close for an approximately equivalent time (another 18 seconds), be unobserved briefly, found OPEN again (another 18 seconds) and reinstructed to CLOSE. That would require around 60 seconds.

At the time the CO-2 left the block valve, it was indicating red/green concurrently. Sufficient time had passed (at least 30 seconds) to provide confidence that if the valve was moving, it was moving in the CLOSED direction. This is supported by repeated subsequent observations that the valve always showed red/green until it finally showed green (closed) only. When opened, the block valve moves until stopped by a limit switch. When closed, the valve moves until stopped by an overtorque condition, presumably from the valve disc driving into the seat. Any other cause of indicated overtorque (friction, obstruction, torque switch maladjustment) would cause a closing valve to stop in place, where it would remain until the torque switch cleared and the handswitch was operated again. Additional details of block valve design and operation are discussed in Paragraph 3.

The reactor trip "immediate actions" are memorized checks performed by both the CO-1 and the CO-2. These checks consume about a minute or so, barring complications, and involve movement around and behind some of the control panels. During this process on November 21, or perhaps slightly before it began, the PORV reclosed at about 34 seconds into the event. All control rods had tripped as designed. No significant abnormalities were evident. Both operators stated the CO-1 first identified the PORV had closed. PCS pressure stabilized and began to return toward a "normal" pressure above 2000 psig, from approximately 1670 psig. The more formal, routine post-trip checkoff was underway when the PORV opened again. Neither operator recalled operating any controls coincident with this event.

The second PORV-open cycle was quicker, lasting only about 14 seconds, but reducing PCS pressure below the 1605 psi setpoint for safety injection actuation signal (SIS). The SIS immediately sequenced and loaded all required safety equipment onto its respective emergency bus. This depressed bus voltage and resulted in both emergency diesels starting; however, offsite power remained in service so neither diesel loaded to its bus. The effect of SIS on the emergency electrical systems is discussed in greater detail in Paragraph 5.

Another CLOSE signal was given to the block valve. This time the CO-1 operated the control and the valve finally closed about 26 seconds (more than a normal full-stroke time) after the PORV had closed. This ended the event.

The SS subsequently chose EOP-4.0, "Loss of Coolant Accident Recovery", to verify plant status and stabilize in a safe condition. The Inspection Team considered this a prudent, correct choice.

In addition to conducting interviews with the operating shift crew, the Inspection Team reviewed applicable procedures and instructions, logs, and training records (see Charter, Item 4) in order to assess operator performance.

a. Training Factors

Two types of training, germane to the event, were provided to the involved shift crew. Classroom training specific to the PORV and block valve modification was accomplished under Lesson Plan IE 890303. Facility Changes FC-791 (replacement of PORVs and block valves with new) and FC-809, (new PORV actuation and control circuits) were each described. System functions, normal operation and failure consequences were discussed. An exercise challenged the trainees to determine Low Temperature Overpressure Protection (LTOP) system operability requirements. The classroom training emphasized the LTOP function of the system. The Inspection Team found no classroom training involving either operation of the plant with the block valve open, or opening the block valve while at high pressure.

The second type of training consisted of review of proposed revisions to procedures, an activity accomplished by a "Required Reading" assignment as on-the-job training (OJT). The procedures affected by the new PORV and block valve were reviewed by the Inspection Team. None contemplated changes to the operating mode previously practiced; namely, the block valves were to be closed as part of disarming LTOP during heatup.

b. Procedures

Plant procedures relating to normal startup and operation, and to arming and disarming the LTOP system, (Charter, Item 3) were reviewed by the Inspection Team. At the completion of the outage, the licensee began an orderly plant heatup to hot shutdown using General Operating Procedure (GOP)-2. Steps 2.29 and 2.41 established the conditions that subsequently led to the inadvertent opening of the PORV.

Step 2.29 disarmed the LTOP system by reference to System Operating Procedure (SOP)-1, "Primary Coolant System." Section 7.1.4.0, of SOP 1, closed the two block valves (MO-1042A & MO-1043A), placed HS-105A & HS-105B in defeat and placed the PORVs (PRV-1042B & PRV-1043B) to the closed position. This was done when the cold leg temperature was between 385 degrees Fahrenheit and 430 degrees Fahrenheit. Thus, normal plant procedures isolated the PORVs before significant plant pressurization as part of "disarming" the LTOP system.

Step 2.41 of GOP 2 required performance of a PCS leak test (if the PCS was opened) per RO-70F or SOP 1, Attachment 2. The Operations Administrative Support Supervisor (an individual holding an active SRO license) chose SOP 1, Attachment 2, which established a test pressure of 2150 psi and a temperature of 532 degrees Fahrenheit or greater. The attachment does not normally require valve manipulation. However, Temporary Change Notice (TCN-0-89-286) was made to Attachment 2 and established a special valve lineup for VT-2 examinations during the PCS Hydrostatic test. The lineup was written by the Operations Administrative Support Supervisor and contained the valve manipulations necessary to expose the PORV modification (FC-791) to hydrostatic pressure. The lineup was written by reviewing the Repair/Weld Inspection Cards (RIC) for the applicable work order (WO-24903975), which implemented FC-791. The RIC specified a hydrostatic test pressure of 2135 psi and a temperature of 500 degrees Fahrenheit or greater. The "C" shift (4:00 p.m. to Midnight) Operations crew performed the special valve lineup on November 20, 1989, except for manipulation of the two PORV block valves. The following "A" shift crew subsequently opened one block valve (MO-1042A) and precipitated the event of interest in this report.

The Inspection Team reviewed the valve lineup implemented by TCN-0-89-286. Plant Administrative Procedure 4.02, "Control of Equipment Status" at paragraph 8.0.b, established the requirements for special valve lineup sheets which alter an existing mode of operation or which manipulate systems in a manner not covered by an SOP. Paragraph 8.0.b required: Shift Supervisor approval of the lineup; that the lineup be implemented by a Temporary Change Notice; that the Temporary Change Notice not become permanent; and, system restoration be specified on the special lineup sheet. The Temporary Change Notice and the special valve lineup complied with these administrative requirements. As discussed previously however, the position of the PORV block valves is controlled by paragraph 7.1.4.0 of SOP 1 and step 2.29 of GOP 2, prior to full heatup and pressurization. Manipulation of the block valves, thereafter, alters the purpose and scope of those procedures. This means manipulation of the valves by a special valve lineup and Temporary Change Notice was not the correct mechanism. Manipulation of the PORV block valves, after heatup, involved a procedure revision, which required a safety evaluation pursuant to 10CFR50.59. This is discussed further below.

c. Assessment

The Palisades Plant operators were not trained for the condition of operating the plant with the PORV block valves open, nor were they trained concerning the potential consequences of opening the block valves at high PCS pressure. Once the event began, reported and recorded operator actions were apparently without error and were prudent.

The Palisades Plant procedures intended for the PORV block valves to be closed prior to significant PCS pressurization as part of disarming LTOP and did not address plant operation thereafter with the block valves open. No reviewed, approved procedure existed for opening the block valve at high PCS pressure.

Opening the PORV block valve MO-1042A at a high PCS pressure constituted a change to the intent of a plant procedure (SOP-1) which was reviewed and approved pursuant to Technical Specification 6.8.1.a. As such, accomplishing this action as a "temporary change" is contrary to Technical Specification 6.8.3.a, which permits only such temporary changes as do not affect the intent of the original procedure; this appeared to be a Violation. The NRC resident inspector office was assigned to further review and to initiate any appropriate regulatory action on this matter.

The Inspection Team did not consider this apparent violation as a root cause of the event. Further, it was not obvious that processing the required procedure revision (or preparing a special procedure) and performing a 10 CFR 50.59 safety evaluation would have necessarily prevented the event.

One potential violation and no deviations, unresolved or open items were identified.

3. PORV Block Valve MO-1042A

a. Design/Application

The Inspection Team reviewed design change documentation (see Charter, Item 7) associated with the newly installed block valves. The review included portions of Facility Change (FC) No. 791, "Pressurizer Valves Replacement Project," Revision 2, Specification No. SP-MP-8304-001(Q), "Replacement Power Operated Relief Valves," Revision 0 and No. SP-MP-8304-002(Q), "Replacement Power-Operated Relief Valves," Revision 0; Report No. MP12-1141, "Third Party Qualification Review of Replacement valves For Palisades Nuclear Power Plant," dated August 27, 1989; Technical Report No. TR-7258-1, "Palisades Pressurizer Valve Project Third-Party Qualification Review," dated August 24, 1989; and Safety Review No. SE-791-01 "Palisades Pressurizer Valves Replacement Project," Revisions C, D, and E.

(1) The team concluded that FC-791 and the Safety Evaluation of the conceptual design were acceptable; however, in general both only considered the use of the PORVs and the block valves for use during Once Through Cooling (OTC) and Low Temperature Over Pressure (LTOP) operation.

(2) Hydro testing of the modified relief system from the pressurizer to the PORVs was required by paragraph 4.1.17.3 of the Design Plan; however, the Safety Evaluation did not address that this test would be performed after heat up (2154 psig). Opening the block valves after achieving Hot Standby is an action not described by the plant's procedures, as discussed above (Paragraph 2.c), and could be classified a "special test". Failure to perform a Safety Evaluation prior to performing a special test is a potential violation of 10 CFR 50.59. This potential Violation is, in effect, another way of approaching the issue of review/approval of an unusual plant configuration identified as a potential Violation in Paragraph 2.c above. As noted above, the NRC resident inspection office will evaluate the matter further and make a specific recommendation concerning any enforcement action deemed appropriate.

(3) The specifications for the PORVs and the block valves were acceptable; however, they too were concerned mainly with their operation during OTC and LTOP, even though the block valve specification required the block valve to be qualified to close against a differential pressure of 2500 psig.

(4) The unique operating characteristics of the Target Rock Valves when being subjected to high differential pressures (discussed in Paragraph 4.c, below) were not considered in the FC-791 design.

In the Palisades design, two PORVs (PRV-1042B and 1043B) are attached to the pressurizer with each relief line having a motor-operated block valve (MO-1042A and 1043A). During power operations, the block valves are closed, as stated in the FSAR. The PORVs are used during shutdown conditions for low temperature overpressure protection. The original lines and valves were too small for a single line to accommodate post-accident "feed and bleed." This method of core cooling relies on the safety injection pumps to supply water to the reactor coolant system, while core heat is removed by rejecting water from the relief lines. To enable each relief line to have adequate capability, the licensee modified the lines by increasing their size from 2.5 to 4 inches and by installing larger PORVs and block valves. This modification was in response to Item II.D.1 of NUREG-0737. The modification also improves the low temperature overpressure protection capacity of the relief lines.

In designing the modification, the licensee provided the design specifications for the block valves to Edward Valve (a subsidiary at that time of Rockwell International). The design specifications included, among other things, differential pressure conditions, system pressure and temperature conditions, valve opening and closing times, and environmental conditions. Edward Valve selected each PORV block valve to be an Edward 4 inch "Equiwedge" type gate valve with a Limitorque SMB-00-25 motor operator. Based on the licensee's design specifications, Edward Valve calculated and set the torque switch settings before delivery to the licensee. The licensee reviewed the sizing calculations as provided by Edward Valve. The licensee indicated that this procedure is typical for its purchase of MOVs.

b. Testing

Testing of the block valves was reviewed by the Inspection team (see Charter, Item 3) including vendor test data. The block valves were tested by the supplier for opening against full differential pressure. The valves were reportedly not tested for closure under full flow conditions because of the absence of a suitable test facility. They were considered capable based on a "reference" test of a three inch valve, along with calculational modeling.

Following installation, the licensee performed post-maintenance testing of the block valves under no load conditions. During testing of MO-1043A for its open stroke, the motor was burned out when the limit switch failed to trip the motor. The cause was traced to the failure of the supplier to install a "pin" in the assembly. This was corrected and the motor was replaced. Block valve MO-1042A was inspected and found to contain the required pin. The Licensee had a Valve Operator Test and Evaluation System (VOTES) diagnostic analysis performed on each MOV to verify that the torque switches tripped at the expected thrust values. This VOTES testing was performed at a zero differential pressure condition. The VOTES testing also provided additional information such as indication of the accuracy of packing load assumptions. Although not previously the case, the current block valves are classified as ASME Section III, Class 1 and are included in the inservice testing program for Section XI of the ASME code.

With respect to the licensee's maintenance program for MOVs, the licensee had a list of the required thrust values for each safety-related MOV. Following a maintenance activity that might affect MOV operation, the licensee has a VOTES diagnostic analysis performed to determine that the MOV is delivering the expected thrust. Verifying thrust empirically means the licensee relies very little on the value of the torque dial indicator setting. On the other hand, reduction in available thrust margin could result from changes in packing load, and this needs to be monitored. This was discussed with licensee representatives.

c. Event Behavior/Anomalies

Following the modification to install the larger PORVs, block valves, and piping, the licensee attempted to perform a hydrostatic test of the new installation. As part of this test, the licensee opened block valve MO-1042A at 2:25 a.m., on November 21, 1989, with pressure at 2154 psi. Immediately after initiating the opening of MO-1042A, the PORV in that line (PRV-1042B) opened and began sending steam to the quench tank. Upon recognizing that the PORV was open, the control room operator turned the block valve hand switch to the close position. The block valves, however, had a seal-in circuit that required the valve to stroke fully. Therefore, the control room operator could not begin closing the MOV until it had opened fully.

The computer printout data indicate that the MOV remained "not closed" from 02:25:50 to about 02:29:18. Because the data are obtained from a full-stroke switch, the actual valve disk position is not known. During that three minute and 28 second interval, the pressurizer pressure dropped rapidly for about 34 seconds (while the PORV was also open), began to slowly recover for two minutes and 10 seconds, then dropped rapidly for 14 seconds when the PORV opened again, and finally began to recover. Full closure of the MOV was not indicated until 26 seconds after the pressurizer pressure began to recover after the final PORV reclosure.

The licensee's documentation indicated that the block valve operated properly during the VOTES diagnostic testing with no differential pressure. The torque switch tripped at the expected value. Therefore, if the thrust calculations were correct, the control room operator should not have required three minutes and 28 seconds to allow the MOV to open fully and then shut the valve. The valve stroke time, during the VOTES testing, was less than 20 seconds.

The AIT reviewer examined thrust calculations provided by the valve supplier. Based on the input parameters given, the expected thrust requirements were independently recalculated. The calculations were found mathematically correct. The motor and actuator sizes met the calculated thrust requirements. The VOTES test documentation indicated that the torque switch settings were consistent with the required thrust calculation at about 12,000 pounds.

One apparent weakness in the licensee's calculations was that the packing load was derived by the valve supplier. That value was 685 pounds. The VOTES testing, however, indicates that the actual value was about 300 pounds higher, close to 985 pounds. This under estimation of packing load slightly reduces the available thrust margin, but this did not appear to be significant to the subject event. The documentation did not indicate that the MOV was evaluated for accommodating stall thrust on the maximum valve thrust rating.

If the MOV was operating as designed and installed, but nevertheless failed to close under design conditions, then an appropriate assumption is that the input parameters into the thrust calculations were incorrect. System pressure, differential pressure, and seat and stem areas were all found to be correct in the calculations. Therefore, a primary candidate for an incorrect value was the valve friction factor. The valve supplier calculated this factor based on sliding friction tests. A normal distribution of friction factors was found and a value of 0.37 selected that predicted that 99 percent of all friction factors would be below this value. It is not clear that this statistical approach is conservative. Further, simple sliding tests are not representative of friction factors where closure is against high flow with a moment exerted on the valve seat. Research and operating experience indicate that a valve friction factor of 0.37 may be only about half of the actual value for similar types of gate valves. An unexpectedly large valve friction factor could result in the torque switch being set too low. For example, increasing the friction factor for this valve to 0.50 would raise the required thrust from about 12,000 pounds to almost 15,000 pounds. Because the SMB-00 actuator has a maximum thrust rating of 14,000 pounds, the adequacy of the actuator would need to be confirmed if the torque switch settings were to be increased.

d. Assessment

After the event, the licensee disassembled the block valve to obtain measurements of the valve and to inspect for conditions that might have caused the inadequate valve performance, such as stem or disc galling, metal-to-metal transfer, or unusual wear patterns. No such conditions were noted that would provide positive proof of a problem. Valve measurements were obtained by the licensee to verify that the tolerances were acceptable.

Stroke testing at static conditions was performed following the event. The block valve was instrumented using the VOTES equipment to evaluate the thrust developed by the operator. This stroke testing did not reveal any problems with the valve. The thrust at torque switch trip (the limit that would halt the valve motion) in the closed direction was 12,363 pounds. This value was greater than the value established by the vendor to ensure valve closure, and was consistent with the pre-event setting.

The AIT Team was unable to absolutely determine the root cause for block valve behavior (see Charter, Item 2) from information available at the plant. To evaluate the operability of the valves, the licensee removed the PORV and the block valve and shipped them to the Wyle laboratories, Norco Facility, for testing. The licensee arranged to have assistance in conducting the tests from Edward Valve, Target Rock, Bechtel/KWU, and Babcock & Wilcox. The tests were observed for the NRC staff by its consultant EG&G, Idaho, which has expertise in the testing of valves under high differential pressure conditions.

The physical arrangement of the PORV and its block valve at the test facility was said to be similar to the actual plant configuration. Because of its small steam supply volume, the test facility could not maintain full system pressure throughout the block valve closing stroke. As will be discussed later, this resulted in an inability of the test facility to fully model the November 21 event.

At Wyle, the licensee performed tests of the block valve for its capability to open or close against various differential pressure conditions. Many of the tests were run to allow independent data collection by Liberty Technology and B&W diagnostic systems. Among the data collected, thrust measurements were taken by means of a VOTES sensor on the valve yoke.

During the testing of the PORV on December 6, the block valve was opened electrically against 575 psig on several occasions. On December 7, the MOV was opened against differential pressures of 1760 psig and 2500 psia. The block valve was closed against differential pressures of 43 psig and 700 psig. A successful seat leakage test of the block valve was performed with system pressure at 2500 psia.

On December 8, the licensee performed four tests aimed at demonstrating the operability of the block valve under differential pressure conditions. Because of the limited volume of the steam supply, the test apparatus was unable to supply full system pressure during the entire close stroke of the block valve. Therefore, the licensee performed closure tests of the block valve from partial open positions. For each of the four tests, the initial system pressure was 2500 psia but dropped to lower values during the closing stroke. In the first test, the block valve was initially positioned at 60% open when the PORV was opened to commence blowdown. The block valve was then given a signal to close. The block valve successfully closed. The final system pressure for that test was 2000 psig. The block valve was jogged open against this pressure. In the second test, the block valve was again initially positioned at 60% open when the blowdown began. The block valve successfully closed. The final system pressure for that test was 2000 psig. The block valve was jogged open against this pressure. In the third test, the block valve was initially positioned at 25% open when the blowdown was begun. The block valve successfully closed. The final system pressure for that test was 2430 psig. The block valve was also jogged open against this pressure. In the last test, the block valve was initially positioned at 100% open when the blowdown was begun. The block valve successfully closed. The final system pressure for that test was 1730 psig.

Because the test facility could not fully duplicate plant conditions, detailed analysis of the results of these tests including the licensee's instrumentation data will be necessary to determine whether the tests were adequate to demonstrate that the block valve will operate under conditions similar to the November 21 event. Further, the reliability of closure tests from partially open positions in demonstrating MOV operability from a full open position will need to be evaluated. In this regard, the nonlinear increase in required thrust during valve closure that has been found in certain valves as part of NRC-sponsored research of high flow conditions may be relevant.

One potential Violation, and no deviations, unresolved or open items were identified.

4. PORV PRV-1042B

a. Design/Application

The Inspection Team reviewed design change documentation (see Charter, Item 7) associated with the newly installed Power Operated Relief Valves. The Palisades PORV is a Target Rock brand two-stage pilot operated relief valve. It is solenoid actuated to allow for the control of either steam or water flow. When the valve is closed, inlet pressure is transmitted through control orifices in the main piston to a control chamber above the main piston and disc. Pressurization of the control chamber results in balanced forces on the piston and leaves only the force created on the main disc by the inlet pressure; this provides a strong seating force. Additionally, return springs on the pilot and main discs provide an additional seating force.

When the solenoid is energized, a magnetic force is developed and the pilot disc is opened. This closes the control orifices and allows the pressure in the control volume above the piston to vent through the pilot seat to the downstream side of the valve. The resultant loss of control pressure allows the inlet pressure acting on the main piston to move the disc to the open position. The main disc is then held firmly in the open position by a larger magnetic force created by coupling of the upper and lower plungers.

At the top of the valve, a reed switch assembly provides indication of valve position and input to the plant events recorder. The input to the events recorder indicates only that the valve is not closed. The reed switches are actuated by the motion of a magnet assembly through the upper plunger.

PORV closure is accomplished by de-energizing the solenoid. When the solenoid is de-energized, the magnetic opening force is eliminated and the pilot return spring closes the pilot valve, reopening the control orifices. The control pressure then increases until, in combination with the main spring, closing force exceeds the pressure acting on the annular area of the main disc, allowing the PORV to close.

b. Testing

Testing of the PORV was reviewed by the Inspection Team (see Charter, Item 3) including procedure number T-FC791-8304-501Q, Revision 0, "Power Operated Relief Valves." This procedure was approved and released for implementation on October 2, 1989. The testing verified that the relief valve was properly installed and would operate. The stroke times for the PORV were measured to be 0.7 seconds (open) and 0.42 seconds (close). These values for stroke time were less than the design values of less than 2 seconds.

Testing was also conducted to demonstrate operability and to test for degradation of the PORV by functionally checking the PORV through the actuation channel of the LTOP system and verifying valve full open stroke and open stroke time. Response time testing was also performed. The stroke times were taken with the inlet pressurized from 175 to 225 psig and were found to be 1.275 seconds, less than the design value of less than 2 seconds. No problems with these procedures were noted.

c. Event Behavior/Anomalies

During the event, the first opening of the PORV exhibited a characteristic of valve design. The key to valve operation is that the inlet pressure acts on both the top and under sides of the piston (balanced opening and closing forces) and on top of the disc (closing force). Since the piston has a larger cross-sectional area than the disc, opening force will be greater than closing force whenever pressure is acting only on the under side of the piston. A valve of this design would also open, however, if a large and rapid enough transient inlet pressure were applied, sufficient to overcome disc/stem weight and closing spring forces. Therefore, a pressure surge capable of creating a temporary pressure difference of 85 psid, between the inlet area and the control volume (connected through an orifice), would be large enough to open the PORV.

The PORV handswitch was in the "Close" position and there was no electrical signal to open the PORV during the event. Therefore, the pilot disc was seated. With a closed pilot disc, the control orifices were open and inlet area and control volume pressures (above and below the piston) were very low and equalized. When the block valve was opened, steam at approximately 2150 psig very rapidly pressurized the small (approximately one-half cubic foot) inlet area volume. Pressure buildup from the opening of the four inch valve substantially exceeded equalization through the orifices (two bores at 0.060 inches each) to the control volume. Thus, the valve disc lifted. The lift was subsequently computer modeled and found to have been sufficiently rapid that the pilot valve, internal to the main disc, may have been thrown open against its closing spring. This could have delayed pressure buildup in the control volume.

The primary factor in the 34 second duration of the initial PORV opening, however, was found to be condensation in the control chamber. Testing at the Wyle Laboratories Norco facility showed unpowered PORV opening and closing cycles from a few seconds to over 60 seconds, depending on temperature differences among the steam supply, valve inlet, control chamber and outlet. With the PORV mounted vertically, condensation in the control volume apparently drains out of the small orifices very slowly, if at all, such that steam subsequently forced through the orifices is "quenched" and control volume pressure buildup is delayed until the condensate boils off. Computer modeling which incorporated this phenomenon calculated valve opening durations consistent with those observed.

d. Assessment

The team observed the post-event disassembly and inspection of the PORV which the licensee performed to provide information to aid in the root cause analysis.

During the disassembly of the PORV, foreign material was found in the valve that was similar to wood shavings. Additionally, the main disc piston rings were found to have their plating to be flaking off. These conditions, though abnormal, were not believed likely to cause the PORV to operate erratically. No other problems were noted at the time of the inspection. The reed switches on the PORV were verified to be in the correct positions to provide valve position indication. PORV full stroke was also verified during the inspection.

Subsequent testing of the PORV, in tandem with block valve MO-1042A, was performed by the licensee at the Wyle Laboratories Norco, CA. facility. On December 6, 1989, the licensee performed tests on the PORV at 575 psig. The purpose of the test was to open and close the PORV electrically at this system pressure. Both of the tests conducted in this manner were successful. Another type of test was intended to determine if the PORV would pop open following the opening of the block valve. For four such tests, the PORV and its block valve were initially closed. The block valve was then jogged open for 2 to 3 seconds. In each case, the PORV popped open and remained open for intervals of 2-4 seconds, 21 seconds, 64 seconds, and 14 seconds, respectively. After jogging the MOV open and waiting for the PORV to reseat, the MOV was opened fully. The PORV did not spuriously reopen in any of those four tests during the full opening stroke of the block valve.

On December 7, 1989, PORV tests were performed with increased system pressure. First, with the system at 1760 psig and both valves closed, the block valve was jogged open. The PORV popped open briefly and reseated. The block valve was then opened to 50%, closed, and fully opened. The PORV did not pop open during this stroking of the block valve. The licensee then opened the PORV and block valve to blow down the system. Following the blowdown, the licensee closed the MOV but, unknown to the licensee, the PORV apparently failed to fully close. With the system pressure at 2500 psia, the block valve was opened. Pressure fell rapidly through the open PORV. At 700 psig, the licensee closed the block valve. Upon removing the PORV, the licensee found a 0.75-inch metal plate lodged in the PORV. The licensee will need to inspect the PORV and block valve to ensure that the metal plate did not damage the valves.

During the testing of the block valve on December 8, the block valve was jogged open on three occasions with the system pressure at approximately 2200, 2000, and 2430 psig, respectively. In each case, the PORV popped open and then reseated in 3 to 5 seconds.

Through the testing at the Wyle facility, the licensee confirmed that the PORV will pop open if it is subjected to a sudden surge of steam that results when the block valve is opened. The length of the interval during which the PORV remained open ranged from 2 to 64 seconds. This extensive range indicates that the block valve must be capable of closing during full flow through the PORV.

The licensee was unable to duplicate the event at Palisades where the PORV appeared to pop open a second time during the transient. It is not known whether the small steam volume of the test facility was a factor in the inability to cause the PORV to pop open a second time. In any event, the licensee should review the event data to confirm the initial conclusion that the PORV did pop open the second time. If that conclusion is confirmed, the licensee should ensure that the PORV circuitry is correct and that a spurious open signal was not sent to the PORV.

The tests focused on the November 21 event in that steam was the only fluid used during the tests. Therefore, the tests might not be useful in satisfying the requirements of Item II.D.1 of NUREG-0737. For example, the PORV might need to operate with saturated water conditions.

The AI Team concluded that the subject event was precipitated by a predictable response of the Target Rock brand PORV to a sudden inlet pressure increase. Other brands of pilot actuated PORVs have similar design principles and would respond similarly.

It is unclear who may have known about this characteristic of PORV behavior. Those closely involved in setting up and conducting the hydrostatic test did not know. Had they known, they would not have set up the test in the way they did, and the event would not have occurred.

On the recommendation of the valve vendor, the Palisades PORV is being reinstalled rotated some 135-degrees from vertical. This is intended to minimize the collection of condensation in the control volume. Depending on individual valve internal geometry, it is considered probable that pilot actuated valves from other vendors could also be susceptible to prolonged openings in unpowered actuations.

The second PORV opening remained unexplained.

The details of design development, of procurement, of testing, and of procedures and training, all emphasize the new PORVs as a low temperature and low pressure functioning system. The breakdowns in communication among various groups having an involvement in the installation of the new system were not all readily apparent, but several opportunities existed to change the course of events. The licensee decided to investigate these factors and opportunities via the Human Performance Evaluation System (HPES) process developed by the Institute for Nuclear Power Operations (INPO).

Following the HPES evaluation is beyond the scope of the AIT Charter, but the results (findings and corrective actions) will be of interest to NRC Region III, and perhaps others.

No violations, deviations, unresolved or open items were identified.

5. <u>Safety Injection Actuation</u>

Charter Item No. 8 concerns the circumstances surrounding the safety injection and the loading of the safeguards bus, which caused the undervoltage condition and the diesel generator start. The Inspection Team reviewed the event sequence, portions of Facility Change (FC) No. 800, "Offsite Power Reliability Modification," Drawing No. E-1, "Plant Single Line Diagram," and Logic Diagram No. E-17, "2400 Volt Load Shed." This review produced the following information:

a. Two minutes and 58 seconds into the event, PCS pressure fell to 1605 psia which actuated the Safety Injection System (SIS).

b. The large inrush of starting current, due to the actuation of multiple pumps and valves by the SIS, dropped the voltage on the 2400 volt safeguards buses 1C and 1D to approximately 87 percent of normal.

c. The degraded voltage protection relays on the buses started Diesel Generators (DGs) 1-1 and 1-2, since the bus voltage reached the set point of voltage less then 92 percent for greater than one half second.

d. As the SIS pump motors accelerated, the starting currents decreased, and the bus voltages returned to greater than 95 percent in approximately four seconds. This was less than the load shed setpoint of voltage less than 92 percent for greater than six seconds; therefore, these buses remained on off-site power and the diesels were not loaded.

The Inspection Team determined that the SIS, diesels, protection logic, and load shed logic performed as designed.

No violations, deviations, unresolved or open items were identified.

6. <u>Lessons Learned</u>

A significant adverse event occurred at the Palisades plant which was precipitated by a predictable response of a pilot-actuated relief valve to a sudden inlet pressure increase. This valve design characteristic, however, was not generally appreciated, and was certainly unknown to the operations and test personnel directly involved in setting up the test conditions which caused the problem. The test conditions, though unique and not specifically addressed in design documentation, training or procedures, were established routinely.

The event thus emphasized the need for thorough evaluation, understanding, communication and coordination before performing any plant manipulation for the first time, particularly those involving new or modified systems.

This event emphasizes an NRC concern for the ability of MOVs at other plants, not specifically tested under high differential pressure and flow conditions, to operate under those conditions. Although this licensee historically operated with the block valves closed, many plants operate with the valves open. Such plants may need to reexamine the bases for believing that their block valves will operate under design basis conditions. Events have occurred at other plants where MOVs failed to open or close against high differential pressure and flow. The Palisades event is additionally significant in that it resulted in an unisolable (until the PORV closed) loss of coolant event. This event again highlights the need for licensees to implement a program to ensure MOV operability under postulated pressure/flow conditions discussed in Generic Letter 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance."

This licensee completed the Bulletin 85-03 program and performed full differential pressure testing of about 20 of the 24 MOVs within that program. Another 20 MOVs were said to be within the scope of Generic Letter 89-10 for Palisades. Other plants may not have tested their MOVs at full differential pressure to such an extent as this licensee.

7. <u>Management Interview</u> (30703)

The Inspection Team met with licensee representatives on November 30, 1989, and again on December 15, 1989, to discuss the scope and findings of the inspection. In addition, the inspector also discussed the likely informational content of the inspection report with regard to documents or processes reviewed by the inspector during the inspection. The licensee did not identify any such documents/processes as proprietary.

ATTACHMENT 1

AUGMENTED INSPECTION TEAM (AIT) CHARTER

PALISADES POWER OPERATED RELIEF VALVE AND BLOCK VALVE FAILURE AND ASSOCIATED REACTOR TRIP AND SAFETY INJECTION EVENT

You and your team are to perform an inspection to accomplish the following:

1. Develop and validate the sequence of events associated with the plant trip and safety injection that occurred on November 21, 1989 including the operation of the block valve and the power operated relief valve (PORV) during hydro testing.

2. Determine the root cause for:

   - the pressurizer block valve failure to fully close after receiving a close signal from the plant operator including the valve control logic adequacy, limit and torque switch setting development and the adequacy of the calculated thrust and torque requirements for operation against expected differential pressures.

   - the opening of the PORV during the initial opening of the block valve and the subsequent (second opening) unexpected cycling of the PORV.

   - the pressurizer block valve remaining open for a period of approximately three and one half minutes.

3. Review the post modification testing of the PORV, the pressurizer block valve and related operational procedures for adequacy.

4. Review the training provided to the operators prior to the implementation of the procedure for the pressurizer block and PORV for adequacy.

5. Review the licensee proposed design change regarding the control circuitry on the block valve including the 50.59 evaluation for adequacy.

6. Interview the plant operator directly involved in the event and determine the adequacy of operator actions.

7. Review the initial design change package including the 50.59 evaluation for adequacy.

8. Review the circumstances surrounding the safety injection and the loading of the safeguards bus which caused the undervoltage condition and the diesel generator start.

ATTACHMENT 2

PALISADES DEPRESSURIZATION - 11/21/89
Sequence of Events

TIME	EVENT TIME (SECONDS)	Description
1:13		The shift was authorized to perform control rod drive interlock testing. To perform this test, the turbine and reactor protective systems were reset and the shutdown control rods were withdrawn.
2:06		PCS was at 2154 psi and normal operating temperature to perform a system hydrostatic test.

Note: The log entries listed above establish the plant conditions that were germane to the event that follows. Other activities were in progress, but did not pertain to the event.

TIME	EVENT TIME (SECONDS)	Description
2:25:50	0	PCS was at 2154 psi, Quench tank was at 0 psig, Quench tank level was at 75.4%, and Pressurizer level was 30.2%

Note: Given subsequent indications, the block valve must have been given an "Open" signal very near this time.

TIME	EVENT TIME (SECONDS)	Description
2:25:52	2	PCS was at 2142 psi, Quench tank was at 1 psig, Quench tank level was at 78.9%, and Pressurizer level was 30.2%. This was the first indication that the PORV and the block valve were open. The reactor operator had opened the block valve in order to pressurize the space between the block valve and the PORV. The operator had no advance information, either by precaution in the procedure or by previous training, that the PORV would open when the PORV was suddenly exposed to pressure.

Note: The operators stated, in written statements contained within the post trip review and during interviews conducted subsequent to this event, that numerous attempts were made to close the block valve.

2:26:16	26	PCS was at 1758 psi, Quench tank was at 4 psig, Quench tank level was at 78.7%, and Pressurizer level was 28.5%. Reactor trip due to activation of Thermal Margin Low Pressure (TMLP).
2:26:26	36	PCS was at 1669 psi, Quench tank was at 5 psig, Quench tank level was at 85.4%, and Pressurizer level was 28.4%. PCS depressurization had stopped, which indicated the PORV was closed. The plant computers indicated the block valve was not closed.

Note: The block valve design contains a "seal in" circuit that requires completion of travel before direction can be changed. As such, a cycle time of almost 40 seconds (20 seconds one way stroke time) was required to close the valve.

2:28:36	166	PCS was at 1738 psi, Quench tank was at 5 psig, Quench tank level was at 83.4%, and Pressurizer level was 29.4%. The plant had recovered to these parameters
2:28:38	168	PCS was at 1734 psi, Quench tank was at 5 psig, Quench tank level was at 83.0%, and Pressurizer level was 29.3%. This was the second opening of the PORV. One of the plant computers indicated that the PORV opened 6 times within 1 second.
2:28:48	178	PCS was at 1605 psi, Quench tank was at 7 psig, Quench tank level was at 86.8%, and Pressurizer level was 29.1%. Safety Injection signal was activated at this time.
2:28:52	182	PCS was at 1565 psi, Quench tank was at 7 psig, Quench tank level was at 86.7%, Pressurizer level was 28.1%. The PORV appears to have seated a second time. The PCS pressure was starting to increase.

2:29:18	208	PCS was at 1583 psi, Quench tank was at 6 psig, Quench tank level was at 85.9%, Pressurizer level was 29.4%. The block valve indicated CLOSED for the first time since the event began.
2:56		Unusual Event declared because the PORV was challenged.
3:05		SIS reset
3:34		License secured from the Unusual Event

Note: Normal operating practice was to heat up (and cooldown) with the PORVs disarmed and the PORV block valves closed, except to provide LTOP protection. This mode of operation was practiced since initial startup. The updated FSAR describes this mode of operation.

ATTACHMENT 3

Persons Contacted

Consumers Power Company

#G. B. Slade, Plant General Manager
#R. M. Rice, Plant Operations Manager
#J. G. Lewis, Technical Director
#R. D. Orosz, Engineering and Maintenance Manager
#W. L. Beckman, Radiological Services Manager
J. L. Hanson, Operations Superintendent
R. B. Kasper, Mechanical Maintenance Superintendent
K. E. Osborne, System Engineering Superintendent
R. M. Brzezinski, I&C Engineering and Maintenance Superintendent
C. S. Kozup, Technical Engineer
#D. J. Malone, Senior Licensing Analyst
R. J. Frigo, Operations Staff Support Supervisor
W. L. Roberts, Plant Projects Supervisor
R. W. Smedley, Staff Licensing Engineer
K. A. Toner, Plant Projects Superintendent
J. P. Pomaranski, Project Manager, ESS Engineering
R. T. Gilmore, Project Manager
#T. S. Palmisano, Administrative and Planning Manager
W. E. Garrity, Engineering Manager, ESS
D. E. Engle, Staff Engineer
P. M. Fitten, Staff Engineer
#R. E. Mc Caleb, Site QA Manager

#Indicates some of those in attendance at the December 15, 1989 Management Interview.