KANSAS GAS AND ELECTRIC COMPANY

GLENN L. KOESTER
VICE PRESIDENT - NUCLEAR

November 13, 1984

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Mr. R.P. Denise, Wolf Creek Task Force
Reactor Projects Branch 2
U.S. Nuclear Regulatory Commission
Region IV
611 Ryan Plaza Drive, Suite 1000
Arlington, Texas 76011

KMLNRC 84-196
Re: Docket No. STN 50-482
Subj: Final 10CFR50.55(e) Report - Pressurizer Power Operated Relief Valves (53564-K155)

Dear Mr. Denise:

The attachment to this letter provides the final report submitted pursuant to 10CFR50.55(e) concerning the pressurizer power operated relief valves (PORV) at Wolf Creek Generating Station (WCGS). This matter was initially reported by Mr. H.K. Chernoff of Kansas Gas and Electric Company (KG&E) to Mr. John Boardman of the Nuclear Regulatory Commission, Region IV, on October 11, 1984.

Kansas Gas and Electric's plans for resolution of the pressurizer PORV preoperational test discrepancies will be provided to the NRC under separate cover by November 19, 1984.

If you have any questions concerning this matter, please contact me or Mr. Otto Maynard of my staff.

Yours very truly,

Kent R Brown

for Glenn L. Koester
Vice President - Nuclear

GLK:jlh
xc:RCDeYoung
PO'Connor (2)
HBundy

Attach.

IE-27

WOLF CREEK PRESSURIZER POWER OPERATED RELIEF VALVES (PORV)

Safety Evaluation Summary

The Wolf Creek PORV's failed to close during a specific preoperational test. This safety evaluation summary report is intended to define the conditions under which the valve malfunctioned; describe the reason for the failure to close; explain the corrective action that was taken; and provide assurance of valve operability.

Introduction

The Wolf Creek pressurizer power operated relief valves (PORVs), manufactured by Garrett, are 3" x 6" and are solenoid operated. They are intended to control pressurizer pressure to a value below the fixed high-pressure reactor trip setpoint for a 40% load rejection assuming failure of the pressurizer spray system. They also provide a safety grade means for reactor coolant system depressurization to achieve cold shutdown. Additionally, they serve as part of the cold overpressure mitigation system (COMS).

The PORVs are not required to open in order to prevent overpressurization of the reactor coolant system for the loss of load event discussed in the Overpressure Protection Report. The pressurizer safety valves perform this function assuming pressurizer spray and PORVs fail to operate.

The PORVs are electrically actuated valves which respond to a signal from the pressure sensing system or to manual control. They are provided with Class 1E direct position indication in the main control room. For each valve there are indication lights and alarms that are activated by stem-actuated limit switches.

Figure 1 shows the functional schematic of the PORV. The mode of operation of the valve is as follows:

The valve is a line-pressure actuated, solenoid-controlled, relief valve of the caged-plug type. The schematic diagram of Figure 1 shows the unit with the solenoid de-energized and the valve closed. Inlet pressure (either vapor or water) flows into the valve inlet connection and is ported through the solenoid seat to the actuator head chamber of the valve. Inlet pressure is also ported underneath the piston and through the cage holes to surround the plug. The forces tending to hold the valve closed include the pressure in the actuator head chamber acting on the entire piston area and the actuator spring load. Inlet pressure also acts on the annular area beneath the piston (and outside the seat diameter) in a direction to open the valve. Since the annular area is less than the total piston area, the closing force predominates and the plug is held down against the seat with a force equal to the value of inlet pressure multiplied by the seat area.

When the solenoid is energized, the magnetic force acts on the solenoid armature to move the ball from the vent seat (as shown) to the opposite seat, thus sealing off inlet pressure from the actuator head chamber. At the same time, the actuator head pressure is vented to discharge through the vent seat of the solenoid. With the actuator head chamber now at discharge pressure, inlet pressure acting on the annular area is sufficient to overcome the actuator spring load. The plug moves away from the seat in the direction to open the valve.

As the valve opens, pressure inside the cage builds up underneath that portion of the plug exposed to discharge pressure. Because of the pressure drop through the cage flow holes, this pressure is less than inlet pressure but higher than the discharge pressure. The large seating force that exits when the valve is closed is thus turned into an opening force, causing the plug to move to the full-lift position.

When the solenoid is de-energized, the ball moves back to the seat as shown, sealing off the path to discharge and repressurizing the actuator head chamber with inlet pressure. With the plug in the full-lift position, the opening force consists of inlet pressure acting on the annular area and cage pressure acting on the base of the plug. The closing forces (consisting of inlet pressure in the actuator head chamber and the actuator spring load) overcome the opening forces and cause the plug to move toward the seat. Discharge pressure drops to a minimum as the valve reseats, and the valve is once more held in the closed position by a force that is equal to inlet pressure multiplied by the seat area.

Discussion of Valve Malfunction

It was in the closing mode, described above, in which the valves malfunctioned. Specifically, the valves were being operated in the manual mode, discharging steam, and being held open for a period of approximately 32 seconds. Prior to opening the valve, the inlet piping (consisting of approximately fourteen feet of vertical downward run loop seal) was filled with cold water as were the valves themselves. The valves are located in a compartment which is below the top of the pressurizer. This location away from the top of the pressurizer results in valves being substantially colder than if they were at the top of the pressurizer. Valve ambient temperature at Wolf Creek is approximately 90 degrees fahrenheit.

The preoperational test itself required approximately 32 seconds of continuous operation to achieve pressure relief of 200 psi. The purpose of the test is to verify valve stroke time and leakage after the valve has been opened for more than two seconds. This test simulates certain conditions which may be encountered during plant operation such as loss of load. The valve equipment specification contains requirements such as: valve cycle time; discharge fluid rates; number of design cycles; etc. These design requirements are adequate to assure that the valve will perform its intended function.

In addition to assuring operability through equipment specification requirements, considerable testing has been performed on these valves. This testing includes preoperational tests at other foreign and domestic plants and the following successful tests at Wolf Creek. At Wolf Creek, tests performed in the automatic mode, during which the valve remained open for a period of approximately two seconds, were successful. Additionally all Wolf Creek testing performed without a cold loop seal was completed successfully. Further, a number of isothermal tests have been performed on the Garrett Power Operated Relief Valves. These include the EPRI Safety and Relief Valve Test Program, and Garrett operability tests. In these tests, the valves closed as required.

When the valves failed to close when signaled after the discharge period of approximately 32 seconds, the motor-operated block valves, which are installed upstream of the PORVs and whose function is to preclude the loss of reactor coolant if a leak should develop in a PORV, were closed. Closing of the PROVs was observed to occur simultaneously with block valve closure. This occurred because the head actuator chamber (which was isolated) was at approximately 500 psig, the normal discharge pressure. Closure of the block valve reduced inlet pressure. Since the active area above the piston is three times greater than that below the piston, the 500 psig was sufficient to overcome the falling inlet pressure.

Summary of Investigation

The postulated causes for the valve malfunction considered were: solenoid failure, plug to cage binding, and failure to get required fluid pressure to actuator head chamber. Proper solenoid operation was verified. The fact that the valve operated as designed in the automatic mode and inspection of the valve internals showed no evidence of binding (i.e., gouging etc.), eliminated the binding supposition. Therefore, there was strong indication that the third postulated cause, that of failure to get required fluid pressure to the actuator head chamber, was the source of the malfunction. By reviewing the valve design in conjunction with detailed manufacturing drawings it was determined that differential thermal expansion between the valve cage and the valve body bore in which the cage is housed, would cause the cage-to-body annulus to be reduced in size even to a point of total closure. This annulus serves as a path for inlet fluid to travel to the solenoid port and eventually to the actuator head chamber as defined previously. To verify this supposition, a subsequent manual test, similar to the tests in which malfunction occurred, was performed with the valve body heated to 228 degrees fahrenheit. The valve functioned as required providing strong support to the premise that differential thermal expansion was the cause of the malfunction. It should be noted that by heating the valve body to 228 degrees fahrenheit the valve body bore was increased by six mils which results in an additional annular clearance under the flow conditions.

In review of the valve manufacturing drawings, it was determined that the maximum and minimum radial annular clearance at ambient temperature when the parts (valve body and cage) are machined to within specified tolerances are nine and six mils (0.009 - 0.006) respectively with diametral clearance being eighteen to twelve mils (0.018 - 0.012).

Based on the information from the testing described above and the small manufacturing tolerances, an analysis was performed to determine the effects of differential temperature on the valve body and cage. Figure 2 is a plot of the results and shows that for 100 degrees fahrenheit of temperature differential the annular gap is reduced by approximately three and one half mils (.0035). This is based on the expansion of the cage with no expansion of the valve body. By heating the valve in the successful test, approximately six mils (0.006) annular clearance was added due to the thermal expansion of the valve body at its initial condition of 228 degrees fahrenheit.

This phenomenon was then analyzed to determine the effects of gap closure on fluid flow with a homogeneous flow model. The results substantiate the heated test results and the differential expansion premise. Specifically, for all relief conditions, the minimum annular diametral gap between the body and the cage necessary for the PORV to function properly is 1.12 mils. With the valve starting cold (90 degrees fahrenheit) and suddenly exposed to high pressure steam (650 degrees fahrenheit) it will take 5.75 seconds for the annular orifice gap to be reduced from 15 mils to 1.12 mils. In 7.47 seconds, the annular orifice is completely closed off. If the annular orifice gap started out at 18 mils, it would take approximately 9 seconds for the gap to be reduced to 1.12 mils. By 11 seconds, the 18 mil gap would be completely closed. In this analysis the cage expands as a function of time and temperature and the thermal expansion of the valve body during these time intervals is negligible.

Corrective Action Taken

The valves under discussion were disassembled and dimensions of the body bore I.D. and cage O.D. were taken. This showed that the diametral annular clearances at ambient temperature were nominally 15 mils and 18 mils for the two valves. A field change notice (FCN) was prepared to machine the cages to an O.D. of 4.55 to 4.57 inches, thereby providing a final diametral annular clearance of 114 mils and 111 mils respectively. This action was taken with full cognizance and technical support/assurance by the valve designer/manufacturer (Garrett) and Westinghouse.

In designing the valve to meet the specification requirements, the designer kept the annular clearance small so that it would serve as a filter to prevent any debris that may be entrained in the fluid from fouling the three-way ball valve of the solenoid. However, the valve manufacturer (Garrett) has determined that the clearance provided by this design need not be this small. Garrett has also confirmed that the machining to resize the cage is a product improvement.

Summary and Conclusion

The Wolf Creek pressurizer PROVs failed to close after a discharge of water followed by steam which was conducted manually for an extended period of time. The cause of this malfunction was determined to be differential thermal expansion (valve body to cage) resulting in a restriction of an essential fluid flow path to the valve actuator head assembly. Identification of the cause of the malfunction is supported by testing in other operating modes, successfully repeating the failed test with reduced differential temperatures, and a detailed engineering analysis.

A valve modification, specified by Westinghouse and concurred with by Garrett (the valve designer/manufacturer) has been made which corrects the malfunction without having any deleterious effects on valve function.

Based on the information contained herein and supporting documentation, it is concluded that the Garrett pressurizer power-operated relief valves will function under all design conditions.