AEOD ENGINEERING EVALUATION REPORT*

UNIT: Edwin I. Hatch Unit 2
DOCKET NO.: 50-366
LICENSEE: Georgia Power Company
NSSS/AE: General Electric/Southern Company Services and Bechtel

EE REPORT NO. AEOD/E414
DATE: May 31, 1984
EVALUATOR/CONTACT: P. Lam

SUBJECT: STUCK OPEN ISOLATION CHECK VALVE ON THE RESIDUAL HEAT REMOVAL SYSTEM AT HATCH UNIT 2

EVENT DATE: October 28, 1983

SUMMARY

On October 28, 1983, the isolation check valve on a 24-inch low pressure coolant injection line of the residual heat removal system at Edwin I. Hatch Unit 2 was found open and could not be closed. An immediate investigation by the licensee determined that the valve was being kept open by the attached air actuator. A subsequent investigation by the licensee determined that the check valve had been held open by the air actuator for over four months. During this period, the plant had operated at substantial power levels. The principal cause for this event was a maintenance error on the air actuator involving the backward reconnection of the two air supply lines to the actuator. The pneumatic pressure reversal which resulted caused the actuator to hold open the check valve. Inadequate post-maintenance testing of the valve was considered to be an important secondary factor which allowed the initial error to go undetected. A lack of adequate surveillance of the valve and air actuator control room position indications was considered to be a third contributing factor.

This event is judged to be significant in terms of reactor safety because the open check valve substantially degraded the high-pressure/low-pressure isolation arrangements provided between the reactor coolant system and the low-pressure residual heat removal system. The inadvertently opened valve thereby significantly increased the likelihood of an interfacing loss-of-coolant accident during the four-month period. While studying the Hatch event, another event report was found for the Pilgrm Nuclear Power Station in which a significant degradation in the high-pressure/low-pressure isolation arrangements for the high pressure coolant injection system occurred. The cause of that event was also traced to multiple operator (human) errors. In light of the potentially severe consequence of the Hatch event and the significant contribution of human errors to the degradation of the isolation barriers between the high-pressure reactor coolant system and low-pressure systems in both events, it is suggested that the Office of Inspection and Enforcement consider issuing an Information Notice for these occurrences. It is also suggested that an industry group, such as the Institute of Nuclear Power Operations, consider evaluating what constitutes good industry practice and procedures for disabling testable check valve air actuators and their associated position indications when flow testing is performed in accordance with ASME Section XI.

*This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

DISCUSSION

1. Event Description

On October 28, 1983, with the plant in cold shutdown, personnel at Hatch Unit 2 discovered during valve operability testing that isolation check valve 2E11-F050B on the residual heat removal (RHR) system "B" train was open and could not be closed (Ref. 1). The valve was found being held open by its air actuator because its air supply lines were connected backwards. A subsequent investigation by plant personnel (Ref. 2) revealed that the check valve had been open since June 7, 1983. During this four-month interval the plant had operated at close to full power.

Isolation valve 2E11-F050B is a swing-type testable check valve manufactured by the Rockwell International Company. It has an air actuator controlled by a four-way solenoid pilot valve manufactured by the Automatic Switch Company (ASCO). The air actuator for check valve 2E11-F050B is of the rotary-type. The valve, its actuator and the solenoid valve are situated on the 24-inch low pressure coolant injection (LPCI) line inside the primary containment structure. The valve provides the first of two isolation boundaries between the high-pressure reactor coolant system (RCS) and the low-pressure RHR system. Upstream of the check valve and located immediately outside containment is a normally closed motor-operated injection gate valve. The outboard valve opens automatically on an accident signal when pressure in the RCS falls below the low pressure permissive setpoint. The injection valve is the second and last isolation boundary between the RCS and the RHR system piping.

The air actuator for the isolation check valve 2E11-F050B is used by the licensee (Georgia Power Company) to perform inservice testing of the valve during cold shutdown. Prior to a test opening via the air actuator, the bypass valve on the 1-inch line around the check valve is opened to equalize the pressure on both sides of the disk of the 24-inch check valve. When the remote test push button is depressed, power is supplied to the solenoid pilot valve causing the pilot valve to shift. This in turn causes the actuator rod to rotate from its neutral position. When the actuator rod reaches its 150-degree position, it engages the check valve disk via a disk pin. Further rotation of the actuator rod lifts the disk from the valve seat. The actuator rod will rotate another 30 degrees to its 180-degree position where it will stop. The limit switch on the actuator gives an indication of actuator travel (the full 180 degrees from neutral) via a light on the control panel in the control room. A proximity switch tripped by a ferrous cam connected to the valve disk gives an indication of disk position (open) via another light on a control panel in the control room. The isolation check valve which provides the first of two isolation boundaries between the RCS and the RHR system is a safety-related component, while its air actuator and the pilot solenoid valve are not classified as safety-related.

On June 7, 1983, at the end of a maintenance activity to repair an air leak on the check valve air actuator, the two air supply lines to the actuator were reconnected backwards. That is, the supply line which should have been connected to the right-hand cylinder of the actuator was incorrectly connected to the left-hand cylinder, and vice versa. This error was primarily attributed to the failure to use the check valve maintenance manual which was not available during the repair work (Ref. 3). Without the manual, maintenance personnel installed the two air supply lines to the actuator backwards. The two air suppy lines should have been arranged to physically cross each other on their way from the solenoid valve to the actuator cylinders. Instead they were routed to go straight to the actuator. The installation error caused the check valve actuator (rod) to move to the 180-degree position when air supply pressure was restored to the de-energized solenoid pilot valve. This action opened the check valve.

The error was not discovered by post-maintenance testing even though such testing was recognized by the licensee as a requirement for returning safety-related valves to service. This requirement is stated in ASME Section XI, IWV-3000. In the ensuing four months, during which the reactor was operating at substantial power levels, the open check valve went undetected by plant operating personnel even though valve position and actuator travel indications were provided in the control room.

2. Licensee Corrective Actions

The immediate corrective action taken by the licensee following the discovery of the maintenance error was to correctly reconnect the air supply lines to the check valve air actuator. This placed the valve in its correct normal position (i.e., closed). A subsequent licensee action was to counsel the involved plant personnel on the importance of performing equipment maintenance correctly. Specifically, plant personnel were reminded of the need to perform maintenance according to the valve maintenance manual and to perform thorough post-maintenance testing before returning a valve to service. For the long term, the licensee is considering adopting an alternative testing method for the LPCI isolation check valves (Ref. 4). This alternative test method, which is in accordance with ASME Section XI, IWV-3520 (Ref. 5), allows inservice testing of the isolation check valves to be performed by passing shutdown cooling flow through the valve during each cold shutdown.

3. Safety Significance

This event is judged to be significant because the open isolation check valve substantially reduced the safety margins for preventing an interfacing loss-of-coolant accident (interfacing LOCA) involving the RCS and the RHR systems during the four-month period that the valve was open. The isolation check valve on the 24-inch RHR injection line provides the first barrier to protect the low-pressure RHR system from an interfacing LOCA involving the

RCS (Ref. 6). The second isolation device on the 24-inch LPCI injection line is the normally closed motor-operated outboard gate valve. This gate (injection) valve is designed to open on a LPCI injection signal (i.e., low-low-low vessel water level or the combination of high containment pressure and low vessel pressure) when pressure in the RCS drops to the low pressure permissive setpoint. There is no additional regulatory requirement other than independent diverse interlocks to prevent the gate valve from opening at full differential (reactor) pressure across the disk. Therefore, there is no assurance that the gate valve will not open against full reactor pressure if the independent diverse interlocks fail. Thus, with the isolation check valve open, a postulated failure involving the motor-operated injection valve (e.g., spurious actuation or disk rupture) could allow the discharge of high-pressure reactor coolant into the low-pressure RHR system. The LPCI system is designed for operation in the 450 psig range. It is not designed to withstand the pressure or the dynamic loadings from the discharge of reactor coolant at operating pressure of approximately 1100 psig. Thus high-pressure reactor coolant could fail the low-pressure RHR system piping or lift its pressure relief valves. Such an interfacing LOCA would likely disable at least one train of the RHR system and would certainly bypass the containment.

Since the check valve was being held open by its actuator, its reclosure is not certain for several reasons. First, there are uncertainties in the extent of actuator interference, and in the flow conditions associated with a sudden discharge of reactor coolant. For example, the total flow which would pass through the RHR system relief valve might not result in sufficient differential pressure across the check valve to force its closure. Secondly, if suddenly forced to reclose in response to a very large rupture in the RHR system piping, the valve disk may not survive the dynamic loadings from such a rapid closure. Finally, a check valve held open by its air actuator for a prolonged period of time may increase the likelihood that the check valve will be stuck open from causes not related to the actuator interference which can be, for example, corrosion of the hinge pin or loose part obstruction.

The probability of an interfacing LOCA associated with this event is estimated in Appendix A. There, the probability of a single failure of the motor-operated LPCI injection valve caused by a spurious actuation or a disk rupture was assessed using generic failure data. The extent of credit that could be taken for the held-open check valve to reclose was also discussed. The results indicate that the probability of an interfacing LOCA during a four-month period when a check valve is held open is significantly higher (from one to several orders of magnitude) than that associated with a normally closed check valve. It should be emphasized here that the probability estimates in this evaluation are not intended to give a precise quantification of the likelihood of occurrence of the postulated accident or its associated risks. Instead, they are made to underscore the safety significance of the event and to provide a risk perspective in the discussion.

A further evaluation of many complex and interrelated events would be required to determine how the accient might actually progress. For example, some of these events are: the availability of the remaining LPCI train and the success criteria for reflooding the core with only two LPCI pumps and the core spray system; the role and adequacy of other means of coolant makeup; the rate of depletion of supression pool inventory; and the extent of adverse environmental impact on vital equipment in the reactor building. An in-depth evaluation of these events is beyond the scope of this report. In any case, regardless of the specific scenario postulated, a blowdown of the reactor coolant system through a 24-inch line into the reactor building at normal operating pressure and temperature would be a serious accident beyond the current plant licensing basis.

4. Occurrence of Similar Events

The potential for a similar event occurring at other boiling water reactors (BWRs) was also assessed. The investigation first determined if other BWRs have similar RCS-RHR system interface configurations to that of Hatch Unit 2. The results of a recently completed study (Ref. 7) by Oak Ridge National Laboratory of light water reactor safety systems were examined. The Oak Ridge study reveals that a large number of BWRs have a similar RCS-RHR system interface configuration to that of Hatch Unit 2 (i.e., an inboard air-operated isolation check valve and a normally closed outboard motor-operated injection valve). The plants found with this configuration include Duane Arnold, Brunswick 1 and 2, Cooper, Dresden 2 and 3, Hatch 1, Fitzpatrick, Monticello, Peach Bottom 2 and 3, Pilgrim, and Quad Cities 1 and 2.

The next step taken in this evaluation was to investigate whether a similar event had occurred at another BWR (i.e., a LPCI isolation check valve that was held open by its air actuator during power operations). A limited survey of BWR Licensee Event Reports using the Sequence Coding and Search System (Ref. 8) was conducted. The results indicate that a similar incident had not previously been reported at another BWR in the past two years. Therefore, although a potential may exist for a similar event at other BWR plants, it is apparently not a frequent event.

A somewhat related event had occurred at Pilgrim on September 29, 1983. This event involved an actual overpressurization of the low pressure pump suction piping of the high pressure coolant injection (HPCI) system during a functional test of the HPCI system logic. The cause of of the Pilgrim event was also traced to personnel errors. The errors consisted of conducting more than one surveillance test at the same time and not ensuring that test prerequisites and initial test conditions for all steps in the test procedure were being met. The personnel errors led to the simultaneous opening of two HPCI pump discharge valves. With both valves open, a partially stuck open downstream testable isolation check valve permitted a sudden pressurization of the low pressure HPCI pump suction piping. This event is similar to the Hatch 2 event in that it also involved the degradation of the high-pressure/low-pressure system isolation valves due to personnel errors.

FINDINGS

The following findings were obtained in this evaluation:

1. The isolation check valve on the RHR system at Hatch 2 was held open by its air actuator for four months. During this four-month interval, the plant had operated at close to full power levels.

2. The occurrence was traced to a series of human errors. The primary cause was a maintenance error consisting of a backward installation of the air supply lines to the attached air actuator. A secondary factor was the failure to discover the mispositioned valve due to inadequate post-maintenance valve testing. A tertiary factor was the lack of adequate surveillance of the control room indications for the air actuator and valve disk positions for the four-month interval when the valve disk was mispositioned.

3. This event involved a significant reduction in the reactor safety margins because the open check valve substantially degraded the RCS-RHR system isolation barriers. This in turn led to a significant increase in the probability of an interfacing LOCA during the four-month period of power operation.

4. A large number of BWRs have a similar RCS-RHR system isolation configuration to that in Hatch 2. These plants incorporate a normally closed (testable) air-actuated inboard isolation check valve and a normally closed outboard injection gate valve on the LPCI injection line. Therefore, these plants may be susceptible to a similar occurrence if the air operator is not disabled during normal power operation.

5. The event at Hatch 2 appears to be unique. An open LPCI testable check valve has not been reported at other plants in the past two years. A related event occurred at the Pilgrim plant which involved the degradation of the RCS-HPCI system isolation barriers. This event was also caused by a series of personnel errors.

SUGGESTED ACTIONS

In light of the severe consequence of an interfacing LOCA and the dominant contribution of human errors to the degradation of the isolation barriers between the high-pressure RCS and the interfacing low-pressure systems, the following suggestions are provided:

1. It is suggested that the Office of Inspection and Enforcement (IE) consider issuing an IE Information Notice to all BWR licensees for this event and another event at Pilgrim involving the degradation of high-pressure/low-pressure system boundaries due to human errors. It is suggested that emphasis be placed on reminding licensees of the potential for isolation check valves to malfunction when the air actuators remain installed and enabled. The information notice should also remind licensees of the important contribution of human errors to the loss of high-pressure/low-pressure system isolation features.

2. It is suggested that an industry group such as the Institute of Nuclear Power Operations or the BWR Owners Group consider defining good practice with regard to deactivating the air actuators of testable isolation check valves if and when the alternative inservice inspection testing is adopted. This alternative is the flow testing of the check valves during cold shutdown according to ASME Section XI, IWV-3520.

   If this alternative of flow testing is adopted, the air-operated actuator of the testable check valve could be deactivated in a way so as not to pose any mechanical interference with the operability of the check valve either in lifting on demand or in providing isolation protection. It would appear to be desirable to retain the position indication of the check valve in the control room even if the valve actuator is disabled for example, since isolation valve position indication plays an important role in preventing the occurrence of an interfacing LOCA involving the high-pressure RCS and the interfacing low-pressure systems. It allows early detection of check valve failures. Possible approaches are described in Appendix B.

REFERENCES

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2. Inspection Report 50-366/83-38, U.S. Nuclear Regulatory Commission, Region II, January 9, 1984.

3. "Instruction Book for Testable Check Valves," Rockwell International, S.O. 36-61247, March 8, 1974.

4. Letter from J. T. Beckham, Jr., Georgia Power Company, to H. Denton, Director, NRR, U.S. Nuclear Regulatory Commission, "Inservice Testing of RHR LPCI Check Valves," April 30, 1982.

5. "Rules for Inservice Inspection of Nuclear Power Plant Components," ASME Boiler and Pressure Vessel Code, Section XI, July 1, 1977.

6. "Regulatory Guide 1.139, Guidance for Residual Heat Removal," U.S. Nuclear Regulatory Commission, May, 1978.

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12. "Interim Reliability Evaluation Program: Analysis of the Browns Ferry, Unit 1, Nuclear Power Plant," NUREG/CR-2802, August, 1982.

13. "Interim Reliability Evaluation Program: Analysis of the Millstone Point Unit 1, Nuclear Power Plant," Vol. 1, NUREG/CR-3085, January, 1983.

APPENDIX A

A PRELIMINARY ASSESSMENT OF THE PROBABILITY OF AN INTERFACING LOCA

The probability of an interfacing LOCA associated with the situation when the LPCI inboard check valve is held open by its actuator while the plant is operating at power (and pressure) is related to the single failure of the outboard motor-operated injection valve and the likelihood of the held open check valve failing to reclose. The single failure of the motor-operated LPCI injection valve refers to its inadvertent opening as a result of a spurious actuation or a disk rupture. The probability of such a single failure is estimated to be of the order of 2×10^{-4} over the four-month pierod. This estimate is derived as follows. First, the rate of inadvertent opening of a normally closed, motor-operated valve due to spurious signals is of the order of 10^{-8} per hour as assessed in IEEE Standard-500 (Ref. 9). The rate of disk rupture of a motor operated valve in a BWR is of the order of 10^{-7} per hour as determined in a recent study by EG&G, Idaho, Inc. (Ref. 10), and in the Reactor Safety Study (Ref. 11). These generic failure rates give a failure probability of the injection valve for a four-month interval of 2×10^{-4} from $(1.1 \times 10^{-7}/hr)(120\ days)(24\ hrs/day)(0.8)$, assuming a 80% capacity factor.

If little or no credit were taken for the held-open check valve to reclose because of uncertainties regarding actuator interference, flow conditions associated with a sudden discharge of reactor coolant and the capability of the check valve to withstand dynamic loadings, this probability of the motor-operated LPCI injection valve failing open would then be that of the interfacing LOCA. In this situation, the only barrier between the RCS and RHR system is the motor-operated LPCI injection valve. A probability of approximately 2×10^{-4} per a four-month interval (or 6×10^{-4} per reactor year) as estimated above for an interfacing LOCA involving the RCS and RHR system would be higher by several orders of magnitude than those assessed in comprehensive risk studies (Refs. 11, 12 and 13) which were approximately 10^{-7} per reactor year.

If a great deal of credit were to be given to the successful reclosure of the held-open check valve even though its likelihood of occurrence was judged uncertain, a value of the order of 10^{-1} to 10^{-2} may be assigned to the failure probability to reclose. This in turn leads to a probability of the order of 2×10^{-5} to 2×10^{-6} per a four-month interval (or 6×10^{-5} to 6×10^{-6} per reactor year) for the occurrence of an interfacing LOCA. This value is still significantly higher than those assessed in the aforementioned risk studies (about 10^{-7} per reactor year). Thus, the event would appear to be significant because it involves a substantial reduction in the safety margins (i.e., a significant increase in risk) in the prevention of a serious accident.

It should be noted that the probability estimates presented here are not intended to give a precise quantification of the likelihood of occurrence of the postulated accident or its associated risks. Instead, they are intended to focus attention on the safety significance of the event and to provide a risk perspective in the discussion in the main body of this report.

APPENDIX B

DEACTIVATION OF AIR ACTUATOR

It may be beneficial to plant safety to deactivate the air-operated actuator and at the same time retain the position indication capability if flow testing of the check valve according to ASME Section XI is adopted. This could be accomplished in any one of several ways. It could be accomplished by permanently capping the pressure line to the four-way solenoid valve. This would effectively disable the air-operated actuator regardless of the solenoid valve position since it would not receive any motive power to rotate the valve disk open. The power supply to the proximity switch for position indications would be maintained. Another approach would be to disconnect the two air supply lines to the air-operated actuator. A third way would be to interrupt the power supply to the solenoid valve in a way which does not at the same time cut off the power supply to the proximity switch. This is similar to the modification made to an isolation check valve on the Pilgrim HPCI system to resolve an earlier concern regarding the potential of spurious opening of the check valve bypass line which predated the event referenced in this report. However, at Pilgrim the position indication for the check valve was not retained.