NRC Form 366 (9-83)

U.S. NUCLEAR REGULATORY COMMISSION
APPROVED OMB NO. 3150-0104
EXPIRES: 8/31/88

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1): Brunswick Steam Electric Plant Unit 1
DOCKET NUMBER (2): 0 5 0 0 0 3 2 5
PAGE (3): 1 OF 1 1

TITLE (4): Inoperability of High Pressure Coolant Injection (HPCI) System (E41) Due to Failure of HPCI Turbine Steam Inlet Isolation Valve, E41-F001, During Operability Testing

EVENT DATE (5) MONTH	DAY	YEAR	LER NUMBER (6) YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	REPORT DATE (7) MONTH	DAY	YEAR	OTHER FACILITIES INVOLVED (8) FACILITY NAMES	DOCKET NUMBER(S)
0 7	0 1	8 8	8 8	0 1 7	0 1	0 9	0 7	8 8		0 5 0 0 0
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THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

OPERATING MODE (9): 1
POWER LEVEL (10): 0 6 8

	20.402(b)		20.405(c)		50.73(a)(2)(iv)		73.71(b)
	20.405(a)(1)(i)		50.36(c)(1)		50.73(a)(2)(v)		73.71(c)
	20.405(a)(1)(ii)		50.36(c)(2)	X	50.73(a)(2)(vii)		OTHER (Specify in Abstract below and in Text, NRC Form 366A)
	20.405(a)(1)(iii)		50.73(a)(2)(i)		50.73(a)(2)(viii)(A)		
	20.405(a)(1)(iv)		50.73(a)(2)(ii)		50.73(a)(2)(viii)(B)		
	20.405(a)(1)(v)		50.73(a)(2)(iii)		50.73(a)(2)(x)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER AREA CODE	
M. J. Pastva Jr., Regulatory Compliance Specialist	9 1 9	4 5 7 - 2 3 1 5

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS
X	B J	M O	P 2 9 6	Y					

SUPPLEMENTAL REPORT EXPECTED (14)

[ ] YES (If yes, complete EXPECTED SUBMISSION DATE) [X] NO

EXPECTED SUBMISSION DATE (15): MONTH | DAY | YEAR

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

At 1102 hours on 6/30/88, the Unit 1 High Pressure Coolant Injection (HPCI) System (E41) was declared inoperable (LER 1-88-014) due to inoperability of HPCI high steam line flow instrument, 1-E41-PDT-N004-2. At approximately 0305 hours on 7/1/88, while performing the operability test of the Unit 1 HPCI System, Periodic Test (PT)-09.2, the HPCI turbine steam supply isolation, 1-E41-F001, would not open. Unit 1 was at 68% power. Due to this event, Unit 1 was shut down at 0831 hours on 7/14/88.

F001 would not open due to failure of the valve motor windings resulting from thermal binding of the valve disc within the body. The binding can occur for approximately two hours after returning the system to service following cool-down of the subject piping.

The F001 motor was replaced with different gears installed in the valve actuator and a larger power supply cable to the motor. A standing instruction was implemented to provide for a four-hour warm-up of the subject piping. Procedural revisions will be evaluated to address this issue. Plant modifications will be implemented on each unit to install a double (split) disc in place of the present single flex wedge disc for the F001 valve. Subsequent Unit 1 criticality was at 1740 hours on 7/21/88 with synchronization to the main power grid at 0625 hours on 7/22/88. The HPCI System was returned to operability at 1636 hours on 7/22/88.

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FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6) YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	PAGE (3)
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TEXT (If more space is required, use additional NRC Form 366A's) (17)

Initial Conditions

At 1102 hours on June 30, 1988, the Unit 1 High Pressure Coolant Injection (HPCI) System (E41) (EIIS/BJ) was removed from standby readiness, and a limiting condition for operation (LCO) was established in accordance with technical specifications (T/Ss). This was done following a determination that the setpoint for HPCI high steam line flow instrument 1-E41-PDT-N004-2 (EIIS/BJ/PT) was nonconservative. (See LER 1-88-014 for more specifics regarding the N004-2 instrument.) On July 1, 1988, at approximately 0300 hours, Unit 1 was operating at 68% power. The unit Reactor Core Isolation Cooling (RCIC) System (EIIS/BN), along with the Automatic Depressurization System (ADS) (EIIS/*), Residual Heat Removal/Low Pressure Coolant Injection (RHR/LPCI) System (EIIS/BO), and the A and B core spray (CS) subsystems (EIIS/BM) were operable and in standby readiness. Testing was being initiated to restore the HPCI System to operable status following resolution of the N004-2 problem.

Event Description

Following resolution of the setpoint concern the 1-E41-PDT-N004-2, preparations were begun to run the HPCI System in accordance with the system operability test, Periodic Test (PT)-09.2. At approximately 0303 hours on July 1, 1988, following a warm-up of the HPCI System turbine steam supply line (EIIS/BJ/PSX) in accordance with the PT, the unit Control Operator (CO) attempted to open the system turbine steam supply valve, 1-E41-F001 (single flex wedge disc). Initial Control Room (EIIS/NA) indication of the valve position showed the valve starting to open, as evidenced by a dual open-close position indication on the unit Reactor/Turbine Gauge Board (RTGB) (EIIS/NA/MCBD). An Auxiliary Operator (AO), stationed in the HPCI turbine/pump room reported to the Control Room that the valve remained in the closed position. Also, the AO detected a strong burned odor in the immediate vicinity of the valve. While the AO proceeded to the valve 250 volt (V) direct current (dc) breaker compartment, B21 (EIIS/BJ/PL), located on motor control center (MCC) 1XDA (EIIS/BJ/MCC), to investigate the failure of the valve to open, Control Room position indication of the valve was lost. This was approximately three minutes after the CO had initiated the open signal to the valve. Upon arrival at the MCC, the AO discovered that the valve motor breaker had tripped on magnetic overloads. At the time of the breaker trip, an alarm annunciation of a HPCI System motor overload and a 250 Vdc bus ground annunciation were received and acknowledged in the Control Room.

As a result of the involved LCO on the HPCI System, wh[illegible] expired at 1102 hours on July 14, 1988, a reactor shutdown was performed in accordance with technical specifications. At 0831 hours on July 14, 1988, a reactor scram signal was manually initiated in accordance with plant procedure for shutdown of the unit.

*EIIS system description unavailable.

Event Investigation

On the afternoon of July 1, 1988, a meeting with plant management was convened which designated a task force to investigate the cause of the valve failure. The task force included representatives from various plant groups, as well as from the On-Site Nuclear Safety and Corporate Nuclear groups.

Initial troubleshooting revealed the valve motor (EIIS/BJ/MO), Porter-Peerless Part No. 698-941-60, had failed. In addition, arrangements were made for an on-site inspection of the valve and valve actuator (EIIS/BJ/84) by vendor technical representatives.

Root cause failure analysis of the valve actuator motor determined the cause of the motor failure was high current due to a locked rotor, which resulted in heat buildup and burnout of the motor. Detailed inspections of the valve components and the valve motor feeder breaker compartment revealed normally expected component wear with no conditions or damage indicative of binding of the valve or its actuator. Other indications associated with a high heat condition in the motor were blistered paint and presence of an oily substance determined to be residue from degradation of the motor winding insulation. The incurred high current condition in the valve motor is attributed to thermal binding of the valve actuator stem/valve stem/ disc assembly. Tests to determine the required operating torque under various valve temperature conditions, including use of the motor actuator characterizer (MAC) test equipment, revealed that the amount of torque required to unseat and move the valve disc at different stages of warm-up of the valve varied substantially depending on the valve temperature when closed and the amount of warm-up time prior to reopening. Testing showed that the time period during which thermal binding of the valve occurs is within the initial two hours after returning the system to standby following isolation of the system. The investigation determined that while in a stalled condition, as a result of the binding problem, heat within the motor had risen until the insulation in the motor windings began to melt. At this point, the motor windings electrically shorted, resulting in a trip of the motor breaker and the subject alarm annunciations.

During performance of the root cause failure analysis to determine the cause of the valve failure, 16 potential causes for the failure were identified (see Table 1 for a summary discussion of the involved investigative actions and probability assessments relative to each potential cause).

Motor Design Evaluation

An evaluation of the 1-E41-F001 installation showed that, under worst case conditions (i.e., loss of off-site power) without the incidence of thermal binding, the valve motor was inadequately sized to reliably perform its design function. The 1-E41-F001 valve motor was originally installed with a starting resistor in the valve motor control circuit to limit voltage to the valve motor during the initial starting sequence. Consequently, the amount of starting current to the motor during the initial starting sequence is reduced, which in turn decreases the available torque from the motor. Due to the starting resistor in the valve motor control circuitry, the installed power supply cable (No. 6 cable) on Unit 1 was inadequately sized. Consequently, it is believed the motor may not have developed sufficient torque to reliably open the valve under the worse case conditions of a loss of off-site power.

Corrective Actions

A replacement motor was installed in place of the failed motor. As part of the motor replacement, different gears were installed in the motor actuator in order to increase the mechanical advantage and resultant torque output capability of the motor. In order to further enhance the margin for the opening capability of the valve, plant modifications were implemented which bypassed the starting resistor in the valve and installed a No. 6 power supply cable to the valve motor.

Subsequent Unit 1 criticality was achieved at 1740 hours on July 21, 1988, with synchronization of the unit to the main power grid at 0625 hours on July 22, 1988. The HPCI System operability test was satisfactorily completed and the system was subsequently declared operable at 1636 hours on July 22, 1988.

As the result of additional review and evaluation of this event and a prior similar failure of 1-E41-F001 on May 28, 1988 (see LER 1-88-012), plant modifications will be implemented on each unit to install a double (split) disc in place of the presently installed single flex wedge disc for E41-F001. Planned completion of this action is during the next refueling/maintenance outage for Unit 2 and during the subsequent refueling/maintenance outage for Unit 1.

In order to preclude a recurrence of valve motor damage resulting from thermal binding, a standing instruction was implemented which requires a four-hour warm-up of the HPCI turbine steam line after placing the system in a standby lineup. In addition, this issue will be further assessed for appropriate procedural revisions.

Generic Concerns

A. Evaluation of Similar Installation Designs

As a result of the failure of the 1-E41-F001 valve motor, an evaluation was performed on other similar safety-related valve installations. The valves evaluated were the Unit 2 E41-F001 and the HPCI pump discharge injection valve, E41-F006 (EIIS/BJ/ISV), Reactor Core Isolation Cooling (RCIC) (E51) System pump discharge injection valve, E51-F013 (EIIS/BN/ISV), and the RCIC turbine steam supply isolation valve, E51-F045 (EIIS/BN/ISV), valves for both units.

The common factors that led to the evaluation of these valves were that: 1) Each is used in a safety-related function. 2) Each is operated by a dc motor and includes starting resistors in the control circuits. 3) Each valve must be able to operate against a high differential pressure (1000 psid). 4) Each must open to perform its function. 5) Each may be subject to relatively high thermal transients. Valves that must close to perform their design function were not considered because thermal binding only affects the ability of the valve to open.

Evaluation of the Unit 2 E41-F001 revealed that this valve may be subject to the same failure as the 1-E41-F001. However, the Unit 2 valve experiences a small degree of leakage during normal operation which serves to heat the valve quicker and assists in avoiding thermal binding. The maintenance history of this valve, along with the historical data taken of motor currents and special diagnostic testing, indicates that the potential for failure of the valve to open is less than that of the Unit 1 valve.

Evaluation of the E41-F006 valves was inconclusive. While these valves are not subject to thermal binding, other factors were noted that could affect the performance of the valves. Other concerns identified were the length and size of the valve motor supply cable, the presence of starting resistors, and the effects of high temperature. Due to a very long cable run from the motor control center to the valve, the motor torque is limited by available current. The starting resistor installed in the control circuit of each valve limits the available torque during the initial valve starting sequence when opening. In addition, this valve could be subjected to very high temperatures in a steam line break accident, which would further limit available torque due to increased resistance in the motor and supply cables (see LER 1-88-19).

The evaluation performed on the E51-F013 valves concluded that the valve installation is acceptable with no modification. Calculations show that, with starting resistors and in a degraded voltage condition, the valve motor can develop sufficient torque to operate the valve. This valve operates in an environment where it is not subject to thermal binding. On this basis, it was determined that the Reactor Core Isolation Cooling System is acceptable.

The E51-F045 valves are globe valves and, as such, are not subject to thermal binding nor are they subject to the same opening force requirements as a gate valve.

Additional Corrective Actions

1. As a result of the evaluations performed on dc motor-operated safety system valves, the Unit 2 HPCI System was removed from service on July 5, 1988.

2. A plant modification was written, and the starting resistor in the 2-E41-F001 valve control circuit was bypassed.

3. Unit 1 was removed from service and shut down on July 14, 1988. An appropriately qualified motor of greater torque capacity (150 foot-pounds of torque versus 100 foot-pounds) was installed on the 1-E41-F006 valve, and the starting resistor in the 1-E51-F013 valve control circuit was bypassed. The same modifications have been accomplished on Unit 2.

4. A plant modification was written, and the starting resistor was bypassed in the valve control circuits for the E41-F006 valves for both units.

   In addition, plant modifications to relocate these valves to a less severe environment are scheduled to be performed during the next scheduled refueling outage for the respective units.

5. Analysis has been completed, and plant modification preparation has commenced to bypass the starting resistors in the control circuits for the following valves:

   a. 1-E41-F012, HPCI pump discharge minimum flow line isolation valve (EIIS/BJ/ISV).

   b. 1-E41-F041, HPCI pump suction from suppression pool outboard primary containment isolation valve (PCIV) (EIIS/BJ/ISV).

c. 1-E41-F042, HPCI pump suction from suppression pool inboard primary containment isolation valve (PCIV) (EIIS/BJ/ISV).

d. 1-E41-F059, HPCI pump discharge cooling water supply isolation valve to the HPCI turbine oil cooler and barometric condenser (EIIS/BJ/ISV).

e. 1-E51-F019, RCIC pump discharge minimum flow line isolation valve (EIIS/BJ/ISV).

f. 1-E51-F029, RCIC pump suction supply from suppression pool outboard PCIV (EIIS/BN/ISV).

g. 1-E51-F031, RCIC pump suction supply from suppression pool inboard PCIV (EIIS/BN/ISV).

h. 1-E51-F045

i. 1-E51-F046, RCIC pump discharge cooling water supply isolation valve to the RCIC turbine oil cooler and barometric condenser (EIIS/BN/ISV).

6. On August 15, 1988, a task group project plan was promulgated which will, by December 31, 1988, utilize systematic analysis to determine the design operating margin of each safety-related motor-operated valve and evaluate each valve with respect to environmental and degraded voltage scenarios.

7. An implementation plan to correct the problems identified during the analysis will be issued by February 28, 1989.

Event Assessment

This event rendered the HPCI System incapable of an automatic response to a reactor low level condition; however, should the HPCI System have been required to operate, the HPCI E41-F001 could have been manually opened to operate the system. The consequences of a reactor low level condition during the time frame of this event were mitigated due to the availability of the ADS, RHR, RCIC, and CS Systems which would have automatically operated in order to restore and maintain reactor level.

TABLE 1

Root Cause Failure Analysis

1. Valve failure. After failure of the valve operator motor, the valve was completely disassembled and subjected to a detailed inspection. This inspection revealed normal wear on valve components with no damage found that would result in an excessive valve operating force requirement. Due to the lack of damage to valve components, valve failure is not considered a probable cause of the motor failure.

2. Actuator failure. After failure of the valve operator motor, the valve actuator was disassembled and subjected to detailed inspection. The inspection revealed no damage to the actuator components. Due to the lack of damage to actuator components, actuator failure is not considered a probable cause of the motor failure.

3. End-of-life motor failure. The motor which failed had been installed following a prior failure on May 28, 1988, and had experienced limited operating time during that period. (See LER 1-88-012 for more information regarding this installation of the motor.) End-of-life is not considered a probable cause of the motor failure.

4. Thermal binding. After failure of the valve motor, tests were performed to determine required operating torque under various valve temperature conditions. MAC test equipment was installed during these tests to monitor required torque and valve movement. The torque required to unseat and move the valve varied substantially depending on the valve temperature when closed and warm-up time prior to reopening. The variation of torque required indicates that thermal binding is the most likely cause of the motor failure.

5. High voltage surge motor failure. The preliminary motor failure analysis determined that the motor appeared to fail due to high current in a stalled condition. The insulation resistance of the shunt and series windings was found to be acceptable. Insulation resistance between the shunt and series windings was also acceptable. No indication was found of failure due to a high voltage surge. In addition, a review by Operations of breaker manipulations since the installation of the motor confirmed that a varistor had been used during all breaker operations. This should preclude the possibility that the motor was subjected to a voltage surge. A high voltage surge is not considered a probable cause of the motor failure.

TABLE 1 (Cont'd)

Root Cause Failure Analysis

6. Starting resistors. Analysis of the starting resistor installation shows that, while motor life might be reduced, available torque would not have been reduced sufficiently to prevent motor operation if all other valve parameters were normal. The installation of starting resistors is not considered a probable cause of the motor failure.

7. Inadequate design. The determination of design adequacy must be considered in two parts, with starting resistors (as installed) and without starting resistors (as assumed by Limitorque when valve specifications were originally determined). Analysis demonstrates that with or without starting resistors, sufficient torque should be available to open the valve under normal conditions. These analyses assume that the valve is in a good state of repair and does not suffer from thermal binding. Thus for normal operating conditions, inadequate design is not considered a pr⸱able cause of motor failure.

8. Torque switch adjustment. During troubleshooting of the valve motor failure, the torque switch setting was found to be 72 ft-lbs. The ideal setting for this switch is 75 to 77 ft-lbs. Incorrect torque switch adjustment is not considered a probable cause of the motor failure.

9. Inadequate voltage. Field verification of cables revealed that the Unit 1 valve was supplied by No. 10 cables. Calculations show that, while larger cables might have allowed additional torque to be obtained, the installed cable sizes are adequate for the design of the system. Inadequate voltage is not considered a probable cause of the motor failure.

10. Contactor malfunction. During troubleshooting of the valve motor failure, the breaker was inspected in accordance with plant procedures. These inspections revealed no deficiencies in the condition of the breaker. Therefore, contactor malfunction is not considered a probable cause of the motor failure.

11. Motor manufacturing defect. The preliminary motor failure analysis did not reveal any defect in the manufacture of the valve. The only damage found is attributed to overheating. A manufacturing defect is not considered a probable cause of the motor failure.

TABLE 1 (Cont'd)

Root Cause Failure Analysis

12. Manual torquing of valve. After failure of the valve motor, troubleshooting activities included verification of torque required to unseat the valve. In addition, Operations review of activities associated with the failed valve do not reveal any manual torquing of the valve since the last repair evolution (reference LER 1-88-012). Manual torquing of the valve is not considered a probable cause of the motor failure.

13. Plant modifications. Research of plant modifications that have affected operation of the F001 valve does not reveal any changes that would degrade the ability of the valve motor to perform its function. Plant modifications are not considered to be a probable cause of the valve motor failure.

14. Original purchase order discrepancies. A comparison of the original valve/actuator purchase order to nameplate data does not identify any discrepancies. Purchase order discrepancies are not considered a probable cause of the valve motor failure.

15. Stuffing box. After the valve motor failure, the calculations for live-loading of the valve packing were reviewed. Calculations were found to be correct. The valve stem had been replaced during the prior repair evolution. The valve inspection after disassembly found no damage to the valve stem, and torque checks prior to disassembly did not reveal excessive opening force requirements. Improper assembly of stuffing box components is not considered a probable cause of the valve motor failure.

TABLE 1 (Cont'd)

Root Cause Failure Analysis

16. Abnormal operating conditions. At the time of valve motor failure, the valve was being returned to service following an extended cooldown period. The valve had been shut with the system hot. Since the valve had a relatively short period in which to warm up, the valve internals may have been subject to transient conditions that would not be experienced during normal operation. The result of this transient would most likely be thermal binding of valve components. Thermal binding due to system temperature transients is considered to be the probable cause of the motor failure.

In summary, examination of postfailure testing, design criteria, and post-disassembly inspection of components reveals no credible reason for the valve motor failure aside from thermal binding.

CP&L

Carolina Power & Light Company

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September 7, 1988

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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

BRUNSWICK STEAM ELECTRIC PLANT UNIT 1
DOCKET NO. 50-325
LICENSE NO. DPR-71
SUPPLEMENT TO LICENSEE EVENT REPORT 1-88-017

Gentlemen:

In accordance with Title 10 to the Code of Federal Regulations, the enclosed Supplemental Licensee Event Report is submitted. The original report fulfilled the requirement for a written report within thirty (30) days of a reportable occurrence and is in accordance with the format set forth in NUREG-1022, September 1983.

Very truly yours,

J. L. Harness, General Manager
Brunswick Steam Electric Plant

MJP/bvc

Enclosure

cc: Mr. B. C. Buckley
Dr. J. N. Grace
BSEP NRC Resident Office

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