NRC Form 366 (9-83)	LICE	ENSEE EVEN	T REPORT	(LER)	U.S. NUC	LEAR REGULATO	RY COMMISSION 0. 3150-0106
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Brunswick S	team Electric	Plant Unit	1	0	1510101	0 3 1 2 1 5	1 OF 1 1 1
TITLE IN Inoperability of	High Pressure	Coolant In	jection (H	(PCI) Syste	em (E41)	Due to Fa	ilure of
HPCI Turbine Steam Inl	et Isolation V	alve, E41-	FOO1, Duri	ng Operabi	lity Tes	ting	
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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 0305 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 (EJIS/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/Turline 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, where 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.

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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 unseal 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).

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Motor Design Evaluation

An evaluation of the 1-E41-FCO1 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-FOO1 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 UER 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 day or resulting from thermal binding, a standing instruction was implemented whic. 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.

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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 ACIC 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) Sach 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 date 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).

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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 degra ed 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

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

In addition, plant modifications to relocate these valves to a lens 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 resistor: 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).

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	с.	1-E41-F042, containment	HPCI pump isolation	suctio valve	n from	n supp) (EII	ress S/BJ	ion) /ISV	0001).	inbo	ard	prim	hary		
	d.	1-E41-F059, to the HPCI	HPCI pump turbine of	discha il cool	rge co er and	ooling d baro	; wat	er su ic co	upp1; onde	y iso nser	lat: (EI)	ion v IS/BJ	valve J/ISV).	
	е.	1-E51-F019, (EIIS/BJ/IS)	RCIC pump V).	discha	rge m	inimum	210	w lin	ne i	solat	ion	valv	7e		
	f.	1-E51-F029, PCIV (EIIS/I	RCIC pump BN/ISV).	suctio	n supj	ply fr	om s	uppre	essi	on po	01 0	outbo	ard		
	g.	1-E51-F031, PCIV (EIIS/)	RCIC pump BN/ISV).	suctio	n supj	ply fr	om s	uppre	essi	on po	01 :	inbos	ard		
12	h.	1-E51-F045													
	i.	1-E51-F046, to the RCIC	RCIC pump turbine o	discha il cool	rge co er and	ooling i baro	g wat	er su ic co	upp1; onde:	y iso nser	lat: (EI)	ion v IS/BN	valve V/ISV).	
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7.	An ana	implementation lysis will be	n plan to issu/d by	correct Februa	the p ry 28	proble , 1989	ems i	dent	ifie	d dur	ing	the			

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.

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TABLE 1

Root Cause Failure Analysis

- 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 Uperations of breaker manipulations since the installation of the motor confirmed that a variator 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.

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6.	Starting resistors. Analys that, while motor life migh been reduced sufficiently t parameters were normal. Th considered a probable cause	is of the starting and the reduced, availant to prevent motor oper the installation of st the of the motor failur	resist able t ratior tartir re.	tor tore in if	instal que wou f all o resisto	lation ld not ther v rs is	show have alve not	5					
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 provable cause of motor failure.												
8.	Torque switch adjustment. failure, the torque switch setting for this switch is adjustment is not considered	During troubleshoot: setting was found to 75 to 77 ft-lbs. In ed a probable cause of	ing of o be 7 ncorre of the	f tl 72 d act a ma	he valv ft-lbs. torque otor fa	e moto The switc ilure.	r ideal h						
9.	Inadequate voltage. Field valve was supplied by No. 1 larger cables might have al installed cable sizes are a Inadequate voltage is not o failure.	eld verification of cables revealed that the Unit 1 o. 10 cables. Calculations show that, while e allowed additional torque to be obtained, the re adequate for the design of the system. ot considered a probable cause of the motor											
10.	Contactor malfunction. Dur failure, the breaker was in These inspections revealed breaker. Therefore, contac cause of the motor failure	ring troubleshcoting nspected in accordance no deficiencies in t ctor malfunction is r	of the contract of the contrac	he th pond	valve m plant p ition o idered	otor rocedu f the a prob	res. able						
11.	Motor manufacturing defect not reveal any defect in th found is attributed to over considered a probable cause	. The preliminary mo he manufacture of the rheating. A manufact e of the motor failu	otor i e valv turing re.	fai ve. g d	lure an The o efect i	alysis nly da s not	did mage						

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13.	. Plant modifications. Research of plant modifications that have affected operation of the FOOL 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.														
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LICENSEE EVENT REPORT	(LEP) TEXT	CONTINUATION
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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 postdisassembly inspection of components reveals no credible reason for the valve motor failure aside from thermal binding.



Carolina Power & Light Company

Brunswick Steam Electric Plant P. O. Box 10429 Southport, NC 28461-0429

September 7, 1988

FILD: E09-13510C SER(AL: BSEP/88-0837 10CFR50.73

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,

Alemens 1.

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

MJP/bvc

Enclosure

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