NRC Form 366
(9-83)

U.S. NUCLEAR REGULATORY COMMISSION
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EXPIRES: 8/31/88

LICENSEE EVENT REPORT (LER)

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

TITLE (4) Fatigue Crack Failures of "A" and "C" Diesel Generator Building Ventilation Supply Fans

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)
0 3	0 2	8 8	8 8	0 0 8	0 0	0 3	3 1	8 8	Brunswick Unit 2	0 5 0 0 0 3 2 4
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OPERATING MODE (9)	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)			
1	20.402(b)	20.405(c)	50.73(a)(2)(iv)	73.71(b)
POWER LEVEL (10) 1 0 0	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
M. J. Pastva Jr., Regulatory Compliance Specialist	AREA CODE 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	[illegible]	F A N	*	Y							

SUPPLEMENTAL REPORT EXPECTED (14)		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
X YES (If yes, complete EXPECTED SUBMISSION DATE)	NO		0 7	1 4	8 8

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

During Unit 1 power operation at 100% concurrent with the Unit 2 1988 refuel/maintenance outage, at 1500 hours on 3/2/88, a determination was made that a generic failure mechanism existed for the supply fans of the units' common Diesel Generator (DG) Building ventilation system. The A fan failed on 12/13/87, the C fan failed on 3/1/88, and a liquid penetrant (LP) test of the B fan blades, which had not failed, showed similar cracking of the blade material as in the failures of A and C fans. Service lives were similar in the A, B, and C fans. The building D supply fan had previously been replaced after approximately ten years service. An analysis is in progress to determine the effect of this event upon operability of the DGs.

The cracking is attributed to mechanically stressing the fan blade material (cast 365 aluminum) due to excessive start/stop cycling of the fans. This resulted from inadequate procedural controls for maintaining Diesel Generator Building temperature.

The A and B fan rotors were replaced and were returned to service on 2/12/88 (A) and 3/13/88 (B). After receipt of a replacement rotor, C fan will be returned to service. The fans' temperature control loop will be modified and appropriate procedure changes will be made to reduce the start/stop cycling.

*Manufacturer code identification unavailable.

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Initial Conditions

Unit 1 was at 100% power and Unit 2 was at 73% power. While performing routine surveillance on the 50-foot elevation of the units' common Diesel Generator (DG) Building (EIIS/NB), an Auxiliary Operator (AO) discovered, on December 13, 1987, at 0727 hours, that pieces of the fan blades from the building A ventilation supply fan, Joy Technologies, Model No. 66-26-1170 Series 2000, (EIIS/VJ/FAN) were scattered about the vicinity of the fan. A preliminary inspection determined seven of the fan blades were broken at the blade root and an eighth fan blade was broken below the root in the boss of the blade. In addition, two of the fan straightening vanes (EIIS/VJ/*) were found to have been damaged, apparently as a result of the fan failure. Following this discovery, an equipment clearance was placed on the fan and a Work Request/Job Order (WR/JO) was initiated for repair of the fan. At the time, the remaining three building ventilation supply fans, B, C, and D, were operable.

The corporate testing and analysis facility, located at the Carolina Power & Light Co. Harris Energy and Environmental Center (HE&EC), was requested to perform a failure analysis on the A fan. Following completion of required repairs, the A fan was returned to service on February 12, 1988. As the A fan failure was the first such occurrence at the Brunswick plant involving these fans, this event was considered to be isolated. However, a program was initiated to perform a liquid dye penetrant test of the B and C fans by May 10, 1988. The D fan was not included since its rotor had been replaced and restored (failed motor) to service in late November 1987.

Event Description

At approximately 0815 hours on March 1, 1988, a plant security guard on routine rounds in the DG Building discovered that the building C supply fan had failed mechanically. This discovery was reported to the Control Room by a Maintenance technician in the area. At the time, Unit 1 was operating at 100%, while the Unit 2 1988 refueling/maintenance outage was ongoing. The Control Room turned off the control switch to the fan and dispatched an Auxiliary Operator to the Diesel Building to place a clearance on the breaker.

The failure appeared to be of the same mode as the failure of the A fan on December 13, 1987. At approximately 1030 hours, the B supply fan was shutdown as its service life was similar to that of the A and C fans at the time of their failures. A Shift Foreman's clearance was then placed on the B fan to prevent operation of the fan and a limiting condition for operation (LCO) was established due to less than required number (3) of operable Diesel Generator Building supply

*EIIS component description unavailable.

fans as specified in the plant Final Safety Analysis Report. Arrangements were initiated to have the blades on the B supply fan inspected by the Nondestructive Evaluation (NDE) group via a fluorescent liquid penetrant test.

Following completion of a fluorescent liquid penetrant (LP) test of the fan blades, a determination was made at 1500 hours on March 2, 1988, that a generic failure mechanism existed involving the failure of the A supply fan in December 1987, the failure of the C supply fan, and crack indications on the B fan.

The Diesel Generator Building ventilation system consists of four supply fans that exhaust to a common supply plenum (EIIS/VJ/DUCT) from which the four diesel generator cells, the four 480 volt (V) switchgear rooms, and the building basement are ventilated. Each supply fan is controlled by a four-position switch (EIIS/VJ/ZIS) located on the Reactor Turbine Gage Board (RGTB). The positions are MANUAL, AUTO 1, AUTO 2, and OFF. In the MANUAL position, the fan runs continuously. In either AUTO position, the supply fan control is from the thermostats in the diesel cells. The control logic is such that if any one of the four temperature switches (EIIS/VJ/TS) in the cells reaches its setpoint, all of the supply fans in the AUTO position will start until the temperature switch is satisfied, at which time they will shut down. The exhaust fans (EIIS/VJ/FAN) in the individual diesels will start five seconds after the fans in the AUTO position start. The exhaust fans in other areas of the Diesel Building operate on their individual thermostats when placed in the AUTO mode with the exception of the basement exhaust fan which is operated manually.

Cause of Event

By original design, the ventilation system was to be operated such that one fan is always in the MANUAL position, two are in the AUTO position, and one is in the OFF position. However, due to a problem maintaining diesel generator lube oil temperature during the colder times of the year, the operating procedure was changed directing the operators to place three fans in AUTO with the fourth fan in the OFF position, if the outdoor temperature was less than 70 degrees F. It is believed this change was made in late 1986. In this configuration, the supply fans started automatically on the thermostat setting and cycled to maintain a temperature of 78 degrees F in the diesel cells. Due to the small deadband built into the control system (approximately one degree), the fans in AUTO cycle approximately every seven minutes when the outdoor air temperature is between approximately 45 and 55 degrees.

The primary cause of the failures appears to be from the frequent starts and stops that the fans have been subjected to as a result of the procedure change

*EIIS component description unavailable.

and due to the setpoint and small deadband. A secondary cause is possible turbulent airflow conditions that may be present in the fans. The root cause is still under investigation.

The blades from the A fan were analyzed by the HE&EC metallurgy lab and by the Mechanical Stress Analysis group. The mode of the failures appears to be fatigue resulting from repeated exposure of the blades to stresses that exceeded the endurance limit of the blade material, cast 365 aluminum (al). Forces were estimated to be on the order of 30 ksi (the endurance limit of 365 al is estimated to be 22 ksi). The forces were applied such that the suction side of the blades were exposed to tensile stresses; however, the blades were designed such that the suction side of the blade should be under compression while the fan is running. After repeated exposure to these stresses (40,000 to 120,000 cycles), the cracks propagated to the point where the remaining portion of the blade did not have the required cross-sectional area to support the normal tensile load to which it is exposed during run conditions.

The investigation determined that after one blade broke off, the subsequent out-of-balance condition caused such high forces on the remaining blades that they quickly failed, which resulted in the self-destruction of the fan.

Corrosion products were found on the fatigued portion of the blades, but not on the overstressed portion of the blades. This indicates that the cracks propagated over a period of time; however, the length of time was not determinable. Preliminary analysis of the failed C supply fan blades indicates that the failure mode is the same as experienced by the A fan. It appears that the fatigue striations are closer on these blades, therefore, there were more cycles to failure and lower stresses. Quantitative analysis of the stresses has not yet been completed. Corrosion products were also found to be present on the fatigued areas.

The blades from the B fan were also sent to the lab for analysis where they will first be radiographed to determine the extent of the cracks. The blades will also be analyzed to verify that the failure mode is the same as the A and C fans.

Event Assessment

The purpose of the ventilation system in the Diesel Building is to provide a suitable atmosphere for the diesel generators and switchgear to operate. Loss of supply ventilation could subsequently result in loss of the diesels and associated 480 volt switchgear if no operator action were taken (see LER 1-86-033).

If both fans had failed at the same time and the diesels had started, there would have been only two operable supply fans. The design of the system requires three fans. However, an analysis has been performed by the Corporate Nuclear Safety group using the computer code CONTEMPT4/MOD5 to model the Diesel Generator Building heat load while the diesels are running. The results of the model show that, with an outdoor temperature of 90 degrees, the temperature in the diesel cells would stabilize at approximately 98 degrees after ten minutes. Since the diesels and associated components are qualified to 104 degrees, there would have been no adverse affect on the diesel components.

Corrective Actions Planned

The C fan will be repaired and returned to service. By May 15, 1988, the set-points for the Diesel Building Ventilation Control System will be changed to reduce cycling of the supply fans. A plant modification will be written by December 9, 1988, to permanently change the control system to reduce starts on the fans.

The possible turbulence problem is still under review. The modifications required and the extent of the benefit of those modifications has not yet been determined. Further information on the action to be taken on the turbulence will be supplied in a supplement to this LER to be submitted on or before July 14, 1988.

TABLE 1: SEQUENCE OF EVENTS

The following is a chronology of the events and actions taken in response to the failures of the A and C fans and the results of the LP of the B fan blades:

December 13, 1987

"A" supply fan failed mechanically.

December 14, 1987

The Harris Energy and Environmental Center was requested to perform a failure analysis on the A fan. Personnel from the Metallurgy Unit and from the Mechanical Unit reported to the site at approximately 1800 hours. The preliminary conclusion from the visual inspection was that seven of eight fan blades failed from fatigue and the other failed from overstress. The cracks in the blades initiated from the suction of the blades (the side normally in compression). The blade pieces were gathered and returned to the metallurgy lab for analysis.

December 15, 1988

Vibration data on the supply fans was collected to determine if any abnormal readings were detected. Prior vibration data taken on December 1, 1987, was within vendor specifications. Readings on the A supply fan were as follows:

Horizontal	-	2.4 mils @ 0.7 in/sec
Vertical	-	1.7 mils @ 0.6 in/sec
Axial	-	4.0 mils @ 0.4 in/sec

Disassembly of the A fan was performed. The repair plan was to disassemble the fan, repair the cracked straightening vanes, reassemble the fan, and then take vibration readings prior to returning the fan to operable condition. The shaft runout was checked to ensure that the failure was not caused by a bent shaft (high-axial vibration is a symptom of a bent shaft).

Drawings of the fan arrangements were sent to the fan manufacturers, Joy Technologies, for evaluation of the inlet and outlet conditions. The Joy representative indicated that turbulent inlet conditions could probably exist on some of the fans. A recommendation was made by the representative to test the inlet conditions qualitatively using a string test. The string test will indicate turbulent conditions and uneven airflow loading.

WR/JOs were initiated requesting Maintenance to perform vibration spectrum analysis on the other Diesel Generator Building supply fans as well as the RHR and core spray room cooler fans (EIIS/BO/FAN) and (EIIS/BM/FAN).

December 16, 1988

Additional cracks were identified in the straightening vanes of the A fan. These cracks did not appear to come from the failure of the blades, but from an earlier or other long-term occurrence. The vendor indicated these cracks are also evidence of turbulent airflow.

December 17, 1988

Weld repairs on the straightening vanes were completed.

The spectrum analyses on the Diesel Generator Building supply fans was completed by Maintenance. The B and C fans showed no readings above the manufacturers recommended limits. The D supply fan showed high-axial vibration; however, this was attributed to the turbulence. Since the rotor is relatively new, operability of the D fan was not considered a concern.

December 18, 1988

The rotor for the A fan was replaced with a new rotor. The blades of the new rotor did not clear the housing all the way around. The housing appeared to be out-of-round possibly due to the impact of the blades during failure. Engineering directed Maintenance to correct the clearance problem by removing metal from the housing as long as it did not go below minimum wall thickness.

December 21, 1987

The A fan repair was completed and vibration analysis taken. The fan exhibited high-axial vibration (6.2 mils). The vendor (Joy Technologies) indicated that this is suggestive of turbulent airflow conditions on the inlet or outlet of the fan. The string tests were performed on all the running fans (A, B, and D). The string tests produced evidence that the inlet conditions were turbulent particularly on the A fan but also on the D fan. The turbulent conditions on the A fan were severe enough to cause the string to hang in a direction opposite the expected flow at one point in front of the fan (i.e., the string pointed away from the fan). The vendor also recommended that the fan could be tested by reducing the airflow loading on the blades.

December 22, 1987

The fan blades were depitched to their lowest setting and vibration readings taken again. With the reduced airflow, the axial vibration was reduced to 3.5 mils at 0.22 in/sec. Maintenance was instructed to restore the fan to its specified blade pitch.

December 30, 1987

It was discovered that an old rotor with approximately ten years of service life was on site. The rotor had been removed from the D supply fan during a motor repair and was determined to be too pitted to be put back on the fan. This rotor was visually inspected for signs of cracks such as those that occurred in the A fan. Due to the possible appearance of cracks in the blades, Maintenance was requested to disassemble the rotor so it could be further inspected via liquid penetrant tests.

January 23, 1988

The liquid penetrant tests on the old rotor from the D supply fan were completed by the NDE group and plant personnel. The tests showed no linear indications were present in the root of the blade extending up the face of the blade approximately three inches.

January 28, 1988

The A fan blades appeared to be of different pitches when observed visually. The vendor had been contacted and the representative recommended an inspection that will check the blade pitches independent of the markings on the blade and hub. The vendor sent the necessary information to Systems Engineering for performance of the test. The results of the test showed the blades are at the same pitch, however, there is a linear displacement of the blades of approximately 1/2 inch. As the pitch is correct, the loading will be the same on the blades. The vendor was contacted and he indicated that the 1/2-inch displacement is within the manufacturing tolerances.

February 12, 1988

Using an IRD Mechanalysis Incorporated vibration analyzer, vibration spectrums were taken on the A Diesel Generator Building supply fan. There appeared to be a resonant vibration during shutdown of the fan. Approximately five seconds after shutdown, a peak exceeding 20 mils was observed.

March 1, 1988

C supply fan was found to have failed mechanically.

Due to the apparent similarities of the C fan failure to the previous A fan failure, Joy Technologies and the HE&E Center were contacted and requested to provide assistance to investigate the failures. The NDE organization was contacted to perform liquid penetrant tests on the blades for the B supply fan. The Corporate Nuclear Safety group was contacted and requested to run a computer analysis to determine the effect on diesel operability of only two operable supply fans. The limiting condition for operation (LCO) was canceled based upon a compensatory action requiring the doors to be opened should a diesel start. This compensatory action initiated from UE&C calculation 9527-6-VAD-57F performed due to the event identified in LER 1-86-0033. This LER identified a common mode failure of supply ventilation to the diesel cells during a loss of off-site power (due to a loss of interruptible air, which supplies the supply dampers).

March 2, 1988

The Corporate Nuclear Safety group reported the results of the computer analysis which showed the diesels would remain operable up to an outdoor air temperature of 90 degrees F.

March 3, 1988

Preliminary conclusions indicated that turbulence was a contributor to the failure as well as the frequent starts and stops of the fans. The vendor was given the original failure analysis, vibration data, as well as other supporting data to analyze in the vendor home office.

March 4, 1988

The vendor representative was briefed on site concerning operation of the system and the data collected on the first failure as well as the known history on the C fan. The representative was taken to the Diesel Building to investigate actual plant conditions. A recommendation was given to plant management that the setpoint of the fans be changed to allow more deadband in the control system. The current deadband is only one degree, at which time all of the fans in AUTO will cycle on at the same time. The Joy Technologies representative was contacted and reported that the conclusions are that the failures were primarily the result of frequent starts. The Joy representative also indicated that Reliance Electric, manufacturer of the fan motors, did not expect their motors to hold up under these operating conditions. The turbulence problem was described as a possible secondary contributor to the failure.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

March 5, 1988

The airflow calculation was reviewed as well as the assumptions that were used in developing the computer model used to determine operability of the diesels with only two supply fans in operation. A memorandum was issued to Operations indicating that the compensatory action of opening the doors when a diesel started was not necessary as long as two fans were operable and the outdoor air temperature was below 85 degrees F.

A review of the control system logic was begun to determine the feasibility of modifying the controls to cycle the fans less frequently.

March 6, 1988

The review of the control system was completed and the conclusion reached that the setpoint change alone would not sufficiently reduce the number of starts. It was concluded that a plant modification will be required to stage the fans as well as change the setpoints and the deadband.

A statement was issued to Operations requesting that one fan be left in the ON position unless diesel generator lube oil temperature approached the low temperature limit.

March 7, 1988

The decision was made to change the setpoint and the deadband of the supply fan starting circuit via an Engineering Evaluation per Engineering Procedure (ENP)-19 on a temporary basis to provide some relief from the cycling. A plant modification will be written to permanently change the setpoint and to stage the starting sequence of the fans.

March 13, 1988

The B supply fan repairs were completed and the fan returned to service.

CP&L
Carolina Power & Light Company

Brunswick Steam Electric Plant
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Southport, NC 28461-0429

March 31, 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
LICENSEE EVENT REPORT 1-88-008

Gentlemen:

In accordance with Title 10 to the Code of Federal Regulations, the enclosed Licensee Event Report is submitted. This report fulfills 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,

C. R. Dietz, General Manager
Brunswick Steam Electric Plant

MJP/tlw

Enclosure

cc: Dr. J. N. Grace
Mr. E. D. Sylvester
BSEP NRC Resident Office

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