North Atlantic

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The Northeast Utilities System

December 29, 2000

Docket No. 50-443

NYN-00109

United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Seabrook Station
Voluntary Licensee Event Report (LER) 00-008-00 for
Emergency Diesel Generator Failure During Surveillance Testing

Enclosed is Licensee Event Report (LER) 00-008-00 for an event that occurred at Seabrook Station on November 1, 2000. This event is being reported as a voluntary LER.

Should you require further information regarding this matter, please contact Mr. James M. Peschel, Manager-Regulatory Programs at (603) 773-7194.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

Ted C. Feigenbaum
Executive Vice President and
Chief Nuclear Officer

cc: H. J. Miller, NRC Region I Administrator
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ENCLOSURE 1 TO NYN-00109

NRC FORM 366 (4-95) U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

(See reverse for required number of digits/characters for each block)

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TITLE (4)

Voluntary LER for Emergency Diesel Generator Failure During Surveillance Testing

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 NAME	DOCKET NUMBER
11	01	00	00	008	00	12	29	00	FACILITY NAME	DOCKET NUMBER

OPERATING MODE (9)	6	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more) (11)			
POWER LEVEL (10)	0	20.2201(b)	20.2203(a)(2)(v)	50.73(a)(2)(i)	50.73(a)(2)(viii)
		20.2203(a)(1)	20.2203(a)(3)(i)	50.73(a)(2)(ii)	50.73(a)(2)(x)
		20.2203(a)(2)(i)	20.2203(a)(3)(ii)	50.73(a)(2)(iii)	73.71
		20.2203(a)(2)(ii)	20.2203(a)(4)	50.73(a)(2)(iv)	X OTHER
		20.2203(a)(2)(iii)	50.36(c)(1)	50.73(a)(2)(v)	Specify in Abstract below or in NRC Form 366A
		20.2203(a)(2)(iv)	50.36(c)(2)	50.73(a)(2)(vii)	

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
James M. Peschel, Manager – Regulatory Programs	(603) 773-7194

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	EK	ENG	C470	Y					

SUPPLEMENTAL REPORT EXPECTED (14)		EXPECTED SUBMISSION	MONTH	DAY	YEAR
YES (If yes, complete EXPECTED SUBMISSION DATE).	X NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

On November 1, 2000 at 1726, Control Room operators initiated an emergency shutdown of Diesel Generator (DG) 1B upon the receipt of high crankcase pressure and high vibration alarms. The DG was approximately four hours into a 24-hour surveillance run. While coasting down, the engine experienced a crankcase explosion that lifted the crankcase relief cover assemblies and displaced the crankcase exhauster hose. Subsequent investigation revealed damage to the DG's number seven piston and cylinder. The cylinder liner was scuffed/scored and it revealed heavy bonding of aluminum from the piston skirt.

The most significant causes of this event have been determined to be due to a combination of the following factors: fast engine starts, rapid loading, high loading, and inadequate cylinder liner surface finish caused by carbon polishing of the cylinder liners. There were no adverse safety consequences as a result of this event since DG-1B was already out of service and the opposite train DG remained operable. Significant corrective actions include inspecting and rebuilding both DGs, changing loading profiles, increasing keep-warm system temperatures, and revising maintenance procedures to address cylinder liner surface condition requirements. A Technical Specification change request will be submitted to propose modifications to DG testing requirements.

TEXT *(If more space is required, use additional copies of NRC Form 366A)* (17)

I. Description of Event

On November 1, 2000 at 1726, Control Room operators initiated an emergency shutdown of the Diesel Generator (DG) [EK] 1B upon the receipt of high crankcase pressure and high vibration alarms. The DG was approximately four hours into a 24-hour surveillance run. While coasting down, the engine experienced a crankcase explosion that lifted the crankcase relief cover assemblies and displaced the crankcase exhauster hose. The operator and mechanic who were in the DG room at that time observed a "fire ball" emanating from the vicinity of the crankcase exhauster hose and the room immediately filled with white smoke. Control Room operators entered the fire response abnormal procedure, and the fire brigade was activated. The fire brigade inspected the DG room and reported that there was no active fire and no evidence that there had been an active fire. The Control Room operators subsequently exited the fire response abnormal procedure.

DG-1B, which utilizes a 16 cylinder Colt Pielstick PC2.3 diesel engine, was being returned to service after undergoing inspection and maintenance as part of the seventh refueling outage. As part of this restoration, the diesel generator is operated for 24 hours to satisfy Technical Specification Surveillance Requirement 4.8.1.1.2f.7. This surveillance includes a fast start of the DG (attaining rated voltage and frequency in 10 seconds) and operation at 110 percent load during the first two hours and 100 percent load during the remainder of the 24-hour period. This 24-hour surveillance had twice been terminated prior to the event due to high differential pressure in the lubricating oil strainer and once due to an outage schedule conflict unrelated to the diesel test. In total, the DG had been started for testing fourteen times over a period of eight days during the refueling outage.

Subsequent investigation revealed damage to the DG's number seven piston and cylinder. The cylinder liner was scuffed/scored and it revealed heavy bonding of aluminum from the piston skirt. The piston skirt exhibited galling and the cylinder liner exhibited significant bore polishing (i.e., lack of adequate surface finish).

II. Cause of Event

Immediately following this event, a team was formed to determine the most probable cause of the failure and the most probable failure scenario for the DG-1B. The team also focused on the potential for transportability of the DG-1B event to DG-1A and the transportability of the DG-1B event to other nuclear units with Colt Pielstick PC2.3 engines. Subsequently, a root cause team was formed to identify the organizational, programmatic and performance issues related to this event. The root cause investigation is currently ongoing. Presented below are findings from the event team regarding the most probable cause of the failure and the most probable failure scenario.

The investigation determined that the damage in the number seven cylinder was attributed to non-uniform thermal growth of the piston skirt which resulted in scoring and transfer of aluminum piston skirt material onto the cylinder liner. Scoring and aluminum deposition on the cylinder liner affected the ability of the cylinder liner to retain lubricating oil and impacted the operation of the piston rings particularly in the lower ring travel area. The heat generated by the scuffing and scoring caused the piston skirt to grow further, resulting in increased interference with the liner and eventual failure.

This event was determined to be a random, independent failure of the DG that is the result of a combination of the factors described below over a long period of time. The failure is random since it is not possible to predict the occurrence in any piston and cylinder. The failure is independent in that the failure of the number seven piston and cylinder was not dependent on interaction from other pistons and cylinders. The failure was confined to the number seven piston and cylinder, however, indications of cylinder liner polishing was evident in other cylinders. The randomness of the failure in one cylinder out of sixteen cylinders can be attributed to the variation in as-built piston and cylinder liner clearances and tolerances and the combustion conditions that existed in that cylinder. The following are the most important factors that lead to the failure.

A. Fast Starts

A fast diesel generator start is defined as when the engine starts and accelerates from zero speed to generator rated voltage and frequency in less than 10 seconds without pre-lubrication. The cylinder liners and piston skirts in Colt Pielstick diesel engines are not fully pre-lubricated before fast starts in that the oil delivered by pre-lubricating pumps does not reach all of that wear interface. In effect, during a fast start, the piston rings and lower skirt on the thrust and non-thrust sides of the piston are rubbing on a liner with very little lubricating oil film. This condition degrades the long-term service life of the piston and liner by promoting premature, aggressive wear in the engine. This reduced lubrication condition may result in microscopic welding or metal transfer of the parts as the initial motion between parts takes place.

Fast starts also promote cylinder wear due to carbon polishing. To achieve the fast start capability required of standby nuclear service diesel generators, the engine's fuel injection pump racks move to the full fuel delivery position upon receipt of a start signal. In this starting mode, each cylinder is supplied with more diesel fuel than can be burned as the engine starts rolling and the turbochargers are not yet up to speed. Most of the excess fuel is largely unburned and leaves the engine in the form of black exhaust smoke. However, some partially burned fuel remains to form carbon deposits on the piston crown and the cylinder liner surfaces. These carbon deposits may accumulate and contribute to cylinder liner polishing (refer to discussion on Cylinder Liner Surface, below). In addition, some of the raw diesel fuel impinges on the cylinder liner walls, which tends to breakdown the residual lubricating oil film on the cylinder liner.

Most DG-1B starts since plant startup have been fast starts as defined above. There have been in excess of 400 fast starts on this engine to date and there were fourteen fast starts made on the engine during the seventh refueling outage.

Fast starts are required by the current Seabrook Station TS. Specifically, TS Surveillance Requirements 4.8.1.1.2a, 4.8.1.1.2f, and 4.8.1.1.2g, which perform DG testing every 31 days, 18 months, and 10 years, respectively, all require fast starts. The fast start provision was incorporated in August 1992 via License Amendment 13. Prior to that time, the TS allowed gradual acceleration starts for all starts (except once every 184 days) in accordance with the recommendations of Generic Letter 84-15. License Amendment 13 was issued in response to North Atlantic's request for relaxation of DG testing requirements. The fast start requirement was reestablished during the development of Amendment 13 upon recognition by the NRC that the governors on the DGs do not allow for a slow starts without manual action.

B. Rapid Loading

Rapid loading is defined as application of 100 percent of rated load within approximately 10 minutes of breaker closing. Rapid loading contributes to additional stress on the engine's power parts by not allowing enough time for the parts to come to an equilibrium temperature, therefore reducing clearances between the piston and cylinder liner.

There are a number of factors when rapid loading degrades cylinder liner and piston service life:

- As noted above, the piston-to-liner lubricating oil film is still not very well established.
- The piston crown is rapidly heated due to the very high gas temperatures in the combustion chamber associated with the high power production.
- Much of the heat in the piston crown is transferred to the upper skirt region that tends to expand in a radial direction.
- During the first few minutes of rapid loading operation, the cylinder liner temperature remains relatively stable at only slightly above the original jacket water keep warm temperature.

The above sequence tends to produce uneven heating within the piston skirt, the crown and the cylinder liner that may result in metal-to-metal contact and resultant wear. If the engine load is increased from no-load to rated load over a much longer time period, the thermal growth of all the engine components will be more gradual and the potential for unacceptable wear is significantly reduced.

Nearly every DG loading profile since plant startup has been a rapid load in that load is applied approximately evenly up to 100 percent in a 10 minute period after the breaker is closed. The TS allow for gradual loading in accordance with the manufacturer's recommendations for the majority of surveillance tests. However, North Atlantic had established what was believed to be a more conservative (i.e., aggressive) loading profile from a testing perspective, as stated above.

C. High Loading

High loading is defined as operation at greater than 100 percent of design rated load. High loading contributes to additional engine stress and wear by increasing internal cylinder brake mean effective pressure (BMEP) and temperatures. BMEP is the average pressure in the cylinder over the cycle of the engine. The wear of the engine power parts (piston rings and cylinder liner surfaces) is approximately proportional to the square of the BMEP. With 110 percent normal BMEP, the wear of the engine at that loading would be 121% of the wear at rated load.

Seabrook Station TS require the demonstration of the DG's ability to operate up to 110 percent of design rating during the first two hours of operation of each 18 month 24 hour surveillance run. Following maintenance during the seventh refueling outage, DG-1B was loaded to 110% of design rating on four different occasions within a relatively short period of time. At Seabrook Station, the start of loading to 110% of design rating is typically accomplished approximately one hour after the engine start.

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D. Long Duration between Runs

Long duration between runs, particularly when there is no pre-lubrication of the cylinder when the engine is started, allows lubricating oil to drain from the cylinder wall. Engine designers and manufacturers acknowledge that most engine wear occurs within the first few seconds of an engine start when there is only minimal lubricating oil film established between wear surfaces. Since the emergency diesel generator is typically started after 30 days of being maintained in standby condition, there is likely to be significant wear occurring between the pistons and liners.

Under normal nuclear power plant operating conditions and plant TS requirements, emergency diesel generators are started and operated at or near rated load at least once every 30 days. Between the monthly surveillance runs, the engines are shutdown and maintained in a keep warm condition of approximately 105 to 110°F for the jacket water system and 120 to 125°F for the lubricating oil system. At this temperature, the engine lubricating oil flows comparatively freely. The DG's were designed and built with a keep warm system so that when the engine is started the oil would be able to rapidly reach all the wear points within the engine. A disadvantage of maintaining the engine in the warm condition is that the residual lubricating oil film on the cylinder liner tends to drain off. That leaves the cylinder liner surface with reduced lubricating oil film except that which is trapped between the rings on the piston. Notwithstanding, it is believed that there is an overall net benefit in reducing engine wear when keep warm temperatures are maintained closer to normal engine operating temperature.

E. Cylinder Liner Surface

Diesel engines require a cylinder liner surface finish that will retain a quantity of lubricating oil to ensure that when the piston rings move up or down the liner, an adequate hydrodynamic lubricating film is developed and maintained. An overly smooth or polished liner surface will allow the oil to readily drain off the surface. For the Colt Pielstick PC2.3 diesel engine, the specified cylinder liner surface finish for a new liner should range between 80 to 120 micro-inches, rms. Portions of selected cylinder liners from DG-1B were found to have surface finishes as smooth as 10 micro-inches, rms.

F. Carbon Polishing

Hard packed carbon deposits were identified on the number seven cylinder upper piston top ring land surfaces. As carbon deposits accumulate, there is a tendency for some of the carbon to wear off and become lodged between the rings and the cylinder liner surfaces in the ring travel area. The lodged carbon particles can become polishing agents such that they wear down the honed surface finish of the liner. In addition, carbon particles can become lodged between the piston rings and the piston ring lands. If enough carbon builds up in this location it can prevent the free rotation of the piston rings causing more wear between the piston ring and the liner. Eventually the polishing action smooths the liner surface such that it may progress to a polished metal surface in the formerly honed liner surface.

G. Temperature Difference Between Standby and Operating Conditions

Non-uniform heating caused the piston skirt to expand at a higher rate than the cylinder liner during rapid engine loading. The piston skirt is aluminum, which has a coefficient of thermal expansion approximately twice that of the cast iron cylinder liner. Since the cylinder liner is maintained at approximately 105 to 110°F in standby

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condition by the DG keep warm system, (50°F cooler than the normal operating temperature) the cylinder liner diameter is smaller than it is at normal operating temperature. This condition results in a reduced clearance between the piston skirt and liner during startup and loading.

The keep warm systems are provided to circulate lubricating oil and jacket water through the engine. The lubricating oil keep warm system 'pre-lubricates' the bearings and wrist pins to allow the engine to be fast started with less stress than would be created if the system was not pre-warmed. It also keeps the engine warm so that there is less temperature difference as the unit is started and loaded. The closer the keep warm temperature is to the operating temperature, the less stress and parts clearance changes there would be upon starting and loading the engine.

III. Analysis of Event

The actual failure of the number seven cylinder assembly was most likely initiated during the second 24-hour Technical Specification Test run that was conducted on October 29, 2000, which was eight days into the seventh refueling outage. There was an indication of an increased lubricating oil strainer differential pressure during that surveillance run. Since a similar increase in strainer differential pressure also occurred during the third 24-hour surveillance run on October 29/30, 2000, the degradation in the number seven cylinder appeared to have continued during that period. During the fourth 24-hour surveillance run, on November 1, 2000, the degradation in the cylinder became severe enough to cause the failure of that cylinder. There is no evidence to suggest that the DG-1B was inoperable prior to October 29, 2000.

Subsequent oil analysis results confirmed that the first indication of piston skirt scoring was during the second surveillance run on October 29, 2000. The scuffing and accumulation of aluminum material probably continued during the other runs, finally getting to the point on November 1, 2000 of encumbering the motion of the piston.

There were no adverse safety consequences associated with this event since it occurred when the diesel DG-1B was already taken out of service for maintenance and the opposite train diesel (DG-1A) was operable. At the time of this event, reactor fuel had been off loaded from the reactor vessel and was in the spent fuel pool.

There is no evidence that indicates that the DG-1B was inoperable during the operating cycle for a period of time that was longer than the Technical Specification allowed outage time. Additionally, since inspection of the DG-1A has only identified indications of wear that do not affect operability of the engine, this condition did not result in a safety system failure since one train of emergency power was always available when required by the TS.

IV. Corrective Action

The following is a summary of most significant corrective actions associated with this event:

- Both DG-1A and DG-1B were partially disassembled, inspected, and rebuilt to the manufacturer's specifications and tolerances regarding cylinder liner finish and piston cleanliness.
- The water jacket and lubricating oil keep-warm system temperatures have been increased for both DGs based on input from the DG vendor.

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- The DG loading rate for the monthly TS surveillance runs has been reduced.
- A License Amendment Request will be submitted to propose revising the TS surveillance requirements for the DG's to allow for slow engine starts, eliminate the requirement for starts from a standby condition on repeat 18 month surveillances, and eliminate the requirement to test at 110 percent of load every 18 months.
- The DG preventative maintenance program will be revised to include cylinder liner visual examinations that would be adequate to identify the precursors of an engine failure.
- A design change will be evaluated that will allow installation of a slow start DG governor.

V. Additional Information

The above described failure is potentially transportable to other Colt-Pielstick PC2.3 engines that are operated under similar conditions and potentially to all other diesel generators operated under similar conditions.

Subsequent to the rebuilding of DG-1B, the engine experienced a main bearing failure during a run to facilitate engine break-in. Additional reviews of this bearing failure are currently underway. The main bearings were replaced on DG-1B during rebuilding activities. At this time, there is no evidence to indicate that the bearing failure is related to the original engine failure.

Similar Events

This is the first event of its type at Seabrook Station involving a DG crankcase explosion.

Manufacturer Data

Colt Pielstick PC 2.3 Diesel Engine