NRC FORM 366 (5-92) U.S. NUCLEAR REGULATORY COMMISSION

APPROVED BY OMB NO. 3150-0104
EXPIRES 5/31/95

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: 50.0 HRS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Browns Ferry Nuclear Plant (BFN) Unit 2	05000260	1 OF 8

TITLE (4) Diesel Generator Turbocharger Failure That Resulted In Noncompliance With Technical Specification Limiting Condition For Operation

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
01	23	95	95	001	02	3	26	97	NA	
									FACILITY NAME NA	DOCKET NUMBER

OPERATING MODE (9)	N
POWER LEVEL (10)	100

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more) (11)

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)		50.73(a)(2)(vii)	OTHER
20.405(a)(1)(iii)	X	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 (Include Area Code)
Steven W. Austin, Licensing Project Manager	(205)729-2070

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	TUR	M494	N						

SUPPLEMENTAL REPORT EXPECTED (14)			EXPECTED SUBMISSION DATE (15)	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 January 23, 1995 at 2005 hours, TVA exceeded the Limiting Condition for Operation for an inoperable Emergency Diesel Generator (EDG). At 2005 hours, on January 16, 1995, following approximately two hours of operation, EDG C was declared inoperable when it failed to go through the proper shutdown sequence after a stop signal was initiated. The EDG was returned to operable status on January 25, 1995, at 1330 hours. Failure of the turbocharger planetary gear train initiated the event. The planetary gears supply the motive force for the turbocharger for engine loads less than 70 percent. At loads greater than 70 percent the exhaust gases provide the motive force for the turbocharger. During the event, as the engine was unloaded, the amount of available exhaust gas decreased to where the turbocharger would have been driven from the planetary gears. However, because the gears had failed, the turbocharger did not supply combustion air, and the engine shutdown. The EDG was repaired and returned to service. TVA's analysis identified bending fatigue of a gear tooth on the turbocharger sun gear as the most probable cause of the turbocharger failure. Subsequent analysis has determined that the gear failed due to fatigue that was the result of quench cracking that occurred during manufacturing. Therefore, the root cause of the failure was a manufacturing defect. TVA has recently instituted vibration monitoring program for the EDG turbochargers. The program is being used to identify abnormal operating characteristics of the turbochargers. TVA has provided vendor with the evaluation detailing the component failure mechanism.

I. PLANT CONDITIONS

Unit 2 was in the run mode at 100 percent power or 3293 megawatts thermal. Units 1 and 3 were shutdown and defueled.

On January 16, 1995 at approximately 1535 hours, operations commenced the Diesel Generator C Monthly Operability Test. This test is performed to determine the operability of the Emergency Diesel Generator (EDG) [EK].

II. DESCRIPTION OF EVENT

A. Event:

On January 23, 1995, at 2005 hours, TVA exceeded Limiting Condition for Operation (LCO) 3.9.B.3 for reactor operation with an inoperable EDG. This resulted in Unit 2 being in a condition prohibited by the plants Technical Specification (TS). The details which led to this event are provided below.

On January 16, 1995, at 2005 hours following approximately two hours of operation, the EDG C was unloaded and given a stop signal. When a stop signal is initiated, the EDG is designed to decelerate from full speed (900 revolutions per minute (RPM)) to idle speed (450 RPM) and sustain the idle speed for approximately 11.5 minutes then stop. This is necessary to allow the engine, especially turbocharger bearings, to cool. However, when the stop signal was given, the engine decelerated to approximately 150 RPM and shutdown.

Thus, TVA declared EDG C inoperable and entered a seven day LCO for an inoperable EDG. BFN Unit 2 TS state that, when one of the Units 1 and 2 Diesel Generator is inoperable, continued reactor power operation is permissible during the next seven days provided two offsite power sources are available and all Core Spray (CS) [BM], Residual Heat Removal (RHR) [BO] (Low Pressure Coolant Injection and Containment Cooling) systems and the remaining Units 1 and 2 Diesel Generators are operable. If this requirement cannot be met, the reactor shall be in cold shutdown condition in 24 hours.

Due to the time involved in obtaining the necessary parts and making the repairs, TVA was unable to return the EDG to operable status within the required LCO time limit. Thus, on January 23, 1995, at 2005 hours, TVA exceeded the seven day LCO for the inoperable EDG. Prior to the LCO time limit expiring,

TVA requested and received Discretionary Enforcement from the requirements of the TS. TVA received permission to continue reactor power operation for an additional 72 hours while the repairs were being made to the EDG.

On January 25, 1995 at 1330 hours, after completing the necessary repairs and passing the required post maintenance testing, EDG C was declared operable and the established LCO was exited.

This event is reportable in accordance with 10 CFR 50.73 (a)(2)(i)(B), as any operation or condition prohibited by the plant's TSs.

Inoperable Structures, Components, or Systems that Contributed to the Event:

None.

C. **Dates and Approximate Times of Major Occurrences:**

January 16, 1995, at 2005 CST	EDG C is declared inoperable. TVA subsequently enters a seven day LCO.
January 23, 1995, at 2005 CST	TVA exceeds the seven day LCO for an inoperable EDG. Previously that day, TVA requested and received Discretionary Enforcement from the requirements of the LCO.
January 25, 1995, at 1330 CST	Repairs were completed and the EDG C is declared operable. The LCO for an inoperable EDG is exited.

D. **Other Systems or Secondary Functions Affected:**

None.

E. **Method of Discovery:**

Personnel in the EDG room witnessed the failure of the EDG to properly shutdown.

F. **Operator Actions:**

None.

G. Safety System Responses:

None.

III. CAUSE OF THE EVENT

A. Immediate Cause:

The immediate cause of the event was the failure of the turbocharger which resulted in a failure of EDG C to go through the shutdown sequence.

B. Root Cause:

This event resulted from a failure of the turbocharger planetary gears and sun gear (see attached figure). The root cause of the failure has been determined to be a manufacturing defect.

TVA performed a metallurgical evaluation of the failed turbocharger components. TVA's evaluation identified evidence of fatigue on the sun gear and the planetary gears. TVA also identified signs of overheating, including discoloration and oxide-filled cracks, in these gears. The bearings appeared to have sustained no damage. This analysis found the most probable cause of the gear failures was fatigue; however, due to the extensive thermal and mechanical damage to the sun gear and planetary gears, TVA could not conclusively determine the root cause of the failure.

Following the analysis of the failed components performed by TVA, a separate metallurgical evaluation of the failed turbocharger components was performed by an independent laboratory.

It was determined during the evaluation that the failure of the components from EDG C was due to quench cracking that occurred during the manufacturer's heat treatment process. The quench cracking was followed by an area of fatigue cracks that propagated across the tooth section of the gears until final catastrophic failure. Therefore, TVA has concluded that the root cause of the failure of EDG C was a manufacturing defect.

The failed components from EDG 3A (See Section II.B, Previous LERs on Similar Events) were also evaluated. The results of the evaluation on EDG 3A components indicated the same failure mechanism as EDG C. That is, the gears failed due to quench cracking that occurred during the manufacturer's heat treatment process. Accordingly, TVA has concluded that the root cause of the failure of EDG 3A was a manufacturing defect.

The turbocharger is driven by a connecting gear train which drives the turbocharger during starting, and light load (less than 70 percent load) conditions. Under these conditions, there is not enough energy in the exhaust gases to drive the turbocharger. When the engine reaches approximately 70 percent load, exhaust gas energy will drive the turbocharger faster than the gear train. Then the turbocharger will disengage itself from the gear train and be driven by the exhaust gases.

During the event, as the engine was unloaded and the amount of available exhaust gases decreased, the turbocharger decelerated to a point where it should have been driven from the planetary gear train. The decrease in the exhaust gas resulted in a removal of the driving force to the turbocharger. Because the gear train had failed, combustion air was lost. At this point, the engine shutdown.

During the operability test, the EDG performed as designed. Up to the time the shutdown sequence was initiated, the personnel involved had no indication that the turbocharger failure was about to occur.

In 1986 the EDGs were updated, replacing the turbochargers with high capacity units. The EDG turbochargers have been in service since then. TVA has been trending EDG reliability data since mid-1987. The turbocharger for EDG C failed after over 157 starts. Additionally, TVA's maintenance program follows guidance provided by the vendor. Therefore, it is highly unlikely that the failure could be attributed to age or improper maintenance.

In addition to the turbocharger replacement, TVA replaced the engine stub shaft assembly with one of a revised design. However, after the installation, it was determined that the revised stub shaft assembly's oil chamber did not completely match the diesel engine block and the stub shaft assembly would have to be replaced. The stub shaft assembly that was on the engine at the time of the turbocharger failure was refurbished and returned to service.

C. Contributing Factors:

None.

IV. ANALYSIS OF THE EVENT

The EDGs are part of the standby AC power system that provides a highly reliable source of power as required for Emergency Core Cooling Systems. The EDGs ensure no single credible event can disable the core standby cooling functions.

EDG C supplies emergency power to RHR pump 2B, CS Pump 2B, RHR Service Water Pump B2 [BI], and Emergency Equipment Cooling Water Pump B3 [BI].

BFN is analyzed for a seven day allowed outage time (AOT), during which no single failure is assumed to occur in conjunction with a Design Basis Accident. TVA requested Discretionary Enforcement that extended the AOT an additional 72 hours. During that time, standby auxiliary power for the above equipment was not available from its normal EDG. The three remaining RHR and CS pumps were powered from both the normal offsite power source and, if required, their normal EDGs. For long term loss of offsite power, EDG 3C could have been manually aligned through existing board tie breakers to supply power to the equipment normally powered by EDG C.

Discussions with the vendor have indicated that the two failures at BFN are the only incidents of failure of the turbocharger due to planetary gear deterioration in the engines used in a nuclear or nonnuclear applications. There is no indication that the BFN application has exacerbated the gear failures. TVA believes that it is highly improbable that multiple failures would occur during a 100-day period for accident mitigation. TVA bases this on the large number of turbochargers in service with the gears supplied by the same manufacturer. Moreover, BFN has over 1578 starts on the installed turbochargers with no failures to accept and carry loads due to planetary gear train deterioration.

The failure of the EDG turbocharger was discovered during the unloading and shutdown sequence of the EDG. The failure became self-evident upon unloading of the EDG. However, had a failure of this nature occurred during the startup the EDG would not have fulfilled its design function. Because the EDG operated as designed up to the time when the turbocharger failure occurred, this event did not affect the safety of the plant, its personnel, or the public.

V. CORRECTIVE ACTIONS

A. Immediate Corrective Actions:

EDG C was placed under an administrative hold and secured so it could not be started.

The turbocharger on the EDG was replaced. After completing post maintenance testing, the EDG was returned to standby readiness.

B. Corrective Actions to Prevent Recurrence:

TVA has recently instituted vibration monitoring program for the EDG turbochargers. The program provides valuable information which is being used to identify any abnormal operating characteristics of the turbochargers.

As previously stated, the vendor has indicated that the two failures at BFN are the only incidents of failure of the turbocharger due to planetary gear deterioration in the engines used in a nuclear application. The gears involved in the failures discussed were manufactured in 1985. TVA has provided the metallurgy evaluations detailing the component failure mechanism to the vendor for use in identifying any additional corrective actions.

VI. ADDITIONAL INFORMATION

A. Failed Components:

The failed sun gear and planetary gear train are part of a model 9526867 turbocharger from Power Systems Division of MKW (formally Morrison-Knudsen), supplied as part of a Model 999-20 General Motors (GM) stationary power generating plant.

B. Previous LERs on Similar Events:

There have been no previous LERs issued where an EDG could not be returned to service during the seven day LCO time limit. However, on two recent occasions, TVA experienced a turbocharger failure on one of the EDGs.

On October 17, 1984, EDG 3A experienced a failure with one of the original capacity turbochargers. In this instance, the turbocharger itself experienced a failure. TVA believed the cause of this failure to be failure of the compressor bearing assembly. The turbocharger was replaced and the EDG was returned to service on October 21, 1984, within the allowed LCO time limit.

On August 25, 1992, EDG 3A experienced a failure of one of the high capacity turbochargers. The EDG 3A was returned to service on September 1, 1992, within the LCO time limit.

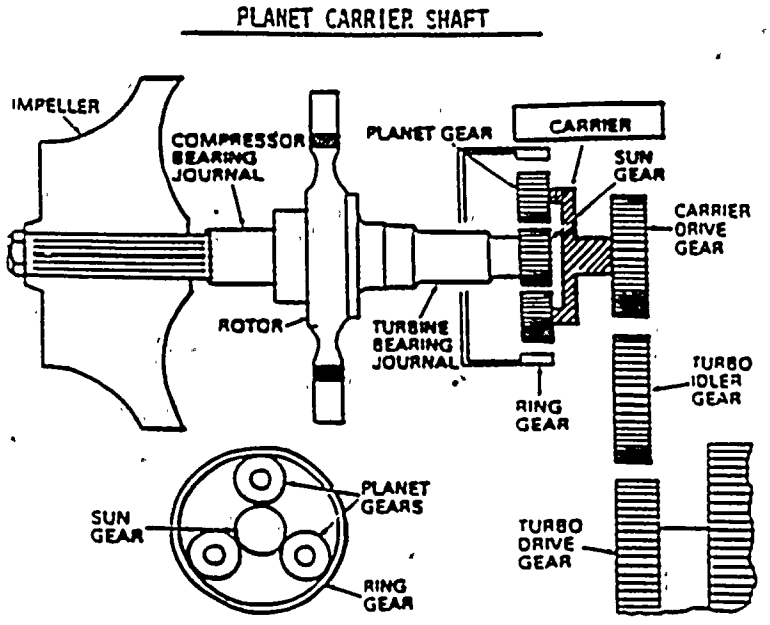
TVA's investigation found that the planetary gear set and the sun gear failed, initiating the event. The turbocharger was shipped to the vendor for failure analysis. It was determined that the cause of the failure was planetary bearing failure, which caused a loss of concentricity within the gear train. The loss of

concentricity within the gear train resulted in an improper meshing of the associated gear teeth. The vendor could not determine the root cause of the bearing failure, but similar failures have occurred at other utilities due to improper lubrication. However, during disassembly of EDG C, lubricating oil was evident on all bearing surfaces and all drilled oil passages appeared to be clear.

VII. Commitments:

none

TURBOCHARGER PLANET GEAR TRAIN



Figure

Energy Industry Identification System (EIIS) system and component codes are identified in the text with brackets (e.g., [XX]).