REVISION TO DESCRIPTION OF DIESEL GENERATOR BEARING RELIABILITY DEMONSTRATION TEST PROGRAM

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I. INTRODUCTION

A meeting with the NRC staff was held at the Fermi-2 site on January 24, 1986 to review the history of the Fermi-2 Emergency Diesel Generators (EDGs), their performance, and actions taken and planned by Detroit Edison to restore the EDGs to reliable operation. An important element of Detroit Edison's efforts to confirm the reliability of the EDGs, the Demonstration Test Program, was described in the January 24 meeting. Handouts presented at the January 24 meeting and additional key points were documented in Reference 8.

Subsequently, Detroit Edison met with the NRC Staff in the Region III offices on February 14, 1986. From this meeting and subsequent discussions with the Staff, it became clear that additional information and clarification of this issue was required. Detroit Edison is providing this report to delineate more clearly the maintenance history of the Fermi 2 EDGs, the scope and results of the Demonstration Test Program, and additional information requested by the NRC Staff. This report expands the discussion of the recent EDG bearing issues beyond that provided in Reference 8 and is intended to supersede Reference 8 in its entirety.

II. INDUSTRY EDG DATA

In its investigation of the Fermi-2 EDG bearing problems, Detroit Edison made a significant effort to determine how the Fermi 2 EDG operation/maintenance program compares with other programs in the nuclear industry. Detroit Edison has initiated numerous conversations with others in the industry during the evaluations of the EDG bearing failure reviews. These conversations have involved the engine manufacturer, NRC, consultants and users of Fairbanks-Morse EDGs including nuclear utilities and the Navy. A phone survey of nuclear utilities provided information from many sites and entailed conversations with plant and engineering personnel responsible for the EDGs during the past 3-6 years. The phone surveys were initially made to determine both the methods and frequency of bearing inspections. Information was also gathered relative to EDG starting/loading, prelubrication, lubricating oils and overall engine performance. The industry information on manufacturer and type of lube oil used is discussed in section IV.3 of this report.

It was also determined that bearing gap checks are currently being utilized by the utility and Navy personnel contacted. Visual bearing inspections are performed only if the bearing fails the gap check, or engine maintenance has resulted in opening of the bearing caps. The Navy once performed visual inspections on a frequency based upon hours of operation, but they have abandoned this approach. One utility contacted by Detroit Edison used to perform some visual inspections of certain bearings, but they, too, have abandoned this approach.

Edison's contacts confirmed that the frequency of bearing gap checks is based upon the manufacturer's inspection per Technical Specifications and is either 12 or 18 months. The method for performing gap checks is based upon Fairbanks-Morse recommendations, and is usually performed by a representative of the engine manufacturer.

General information from other nuclear utilities indicates a similarity in performance and requirements for the EDGs. The EDGs are generally fast started (10-12 seconds) and loaded to 60-100% of continuous rated load for 1-4 hours on a periodic schedule of 14 or 31 days. Prelubrication prior to planned starts was conducted by the utilities contacted, and ranged from 1 to 4 minutes. The utilities reported EDG maintenance activities involving the air start system, bearings, blowers, liners, wrist pin extrusion, etc. Based upon the 3-6 years of information available from the phone interviews, isolated bearing replacement has occurred, and has been detected in conjunction with the manufacturer's 12 or 18 month inspections.

III. HISTORY

The history of operation and repair of the Fermi-2 EDGs was presented at the January 24 meeting. The handouts distributed in this meeting are provided in Enclosure 2. The handouts and the discussion at the January 24 meeting, and the discussion of Chronology in Reference 8, focused on EDG bearings replaced because they had "failed" or had significant surface scoring. To date, formal discussions in meetings with the Staff and in Reference 8 emphasized the replacement of these bearings only because Detroit Edison understood these to be of greatest interest to the NRC Staff. As the NRC Staff knows, Detroit

Edison also replaced bearings for reasons other than "failure". Some bearings were replaced because of heightened concern about bearing surface conditions, such as yellow discoloration, black spots, stains, tracks left by foreign material, or very minor surface deformity, e.g., scratches or pitting. Other bearings were replaced because the crankshaft was replaced.

To ensure that the Staff has a clear understanding of both the total number and reasons for bearing replacements, Edison formally transmitted a summary of the EDG operating logs to the NRC in Reference 9. To complement the information provided in Reference 9, a detailed review of EDG bearing inspections and replacements is provided in Enclosure 3.

IV. DEMONSTRATION TEST PROGRAM

IV.1 Purpose

The bearing problems at Fermi-2 occurred at a time of heightened NRC concerns about Emergency Diesel Generator (EDG) reliability, primarily because of problems encountered with Transamerica Delaval, Inc. diesel generators. The type of EDG employed at Fermi-2, Fairbanks Morse (Division of Colt Industries), has a record of high reliability demonstrated in 49 nuclear applications.

The Demonstration Test Program was planned to restore confidence in the Fermi-2 EDGs as a reliable backup source of AC power. The Demonstration Test Program simulated the number of slow starts and fast starts expected of an EDG over an 18-month fuel cycle, and the run-time that might be needed to assure safe shutdown of the plant if EDG operation were required following a Loss of Coolant Accident coincident with a loss of offsite power.

IV.2 Scope

Emergency Diesel Generators 11 and 13 were selected for the Demonstration Test. The selection of these two EDGs was based on the following considerations:

- These EDGs are in separate Divisions.
- Both have had bearing failures.

- Both have had new upper crankshafts installed.
- EDG 11 experienced problems with the alignment of the bearing caps and, in general, had the most problems of the Fermi-2 EDGs.

IV.3 **Preparation**

Before starting the Demonstration Test, Detroit Edison completed the following on EDGs 11 and 13:

- A flush of the engine lube oil system was performed to help remove foreign material from the system (and reduce potential concerns about foreign material that may have been introduced by the bearing failures and crankshaft replacements in EDGs 11 and 13).
- A new brand of lube oil (Mobil) was installed in all four EDGs.

  (Detroit Edison contacted other owners of Fairbanks Morse engines to determine the type of oil used by each. Six of the other owners contacted use Mobil lube oil. To determine whether the brand of lube oil contributes to the bearing differences observed at Fermi-2, Detroit Edison initially decided to change from Shell lube oil to Mobil lube oil in EDG 13 and 14. Subsequent to the January 24, 1986 meeting, Edison decided to use Mobil in all Fermi 2 EDGs.)

- Before the Demonstration Test was started, EDGs 11 and 13 were run under load for a minimum of 100 hours to "season" the bearings, per the manufacturer's recommendations. (After any future bearing replacements, a 100 hour "seasoning" run will similarly be performed.)

The decision to flush EDGs 11 and 13 was based primarily on experience with EDG 13. As a result of the initial failure of EDG 13, debris from the failed #3 connecting rod and piston was introduced into the oil system. Much effort was taken to remove the debris manually and to wipe down the internals of the engine. After the cleanup and bearing repair, new oil and filters were installed. After post-maintenance testing, EDG 13 was run for over 100 hours and the upper crankline bearings were visually inspected. Two bearings were found that had significant foreign material tracks which appeared to have caused some secondary surface scoring adjacent to the tracks. From these findings, Detroit Edison concluded that an engine flush was required to assure removal of all residual debris from the bearing and piston failure. Because EDG 11 had experienced bearing failures, too, Edison decided to flush EDG 11.

It was not necessary to flush EDGs 12 and 14 because they have not had the mechanical problems that EDGs 11 and 13 have had that might have introduced an excessive amount of foreign material into the lube oil system.

IV.4 **Test Procedure**

The Demonstration Test included the following, in the order listed below:

1. Gap check on the upper crankshaft main bearings using a 0.002" feeler gauge between the bearing and the bearing saddle, per the manufacturer's recommendation.

2. Twenty (20) prelubed "slow" starts; after each slow start the EDG was run under load for a minimum of two (2) hours, including one (1) hour at a load of 2500 to 2600 kW.

3. Gap check on the upper crankshaft main bearings using a 0.002" feeler gauge.

4. Ten (10) prelubed "fast" starts; after each fast start the EDG was run under load for a minimum of two (2) hours, including one (1) hour at a load of 2500 to 2600 kW.

5. Gap check on the upper crankshaft main bearings using a 0.002" feeler gauge.

6. A seven (7)-day continuous run with the EDG under a load of 2500 to 2600 kW.

7. Gap check on the upper crankshaft main bearings using a 0.002" feeler gauge

After completing Step 7 above, Detroit Edison performed visual inspections of selected bearings to validate successful completion of the EDG Demonstration Test Program. The visual inspections involved six bearings (#3,5,6,8,9 and 13) on EDG 11 and five bearings (#3,4,7,10, and 13) on EDG 13. These bearings were selected by mutual agreement between Detroit Edison and the NRC. The selection was based upon consideration of the following factors:

(1) The engine manufacturer's recommendation

(2) The loading on the bearing

(3) Past performance of each bearing

(4) Detroit Edison's desire to comply with the engine manufacturer's recommendation to minimize bearing disassembly.

As discussed at the February 14 meeting in NRC's Region III office, the visual inspection was limited to the upper crankline, loaded-half bearings, since most of the EDG bearing concerns have been associated with the upper crankline bearings. The loaded-half bearing was selected because this part is subjected to engine loading during the starting transient and at load operation.

After reassembling each engine, Detroit Edison ran-in the bearings, following the run-in schedule of Colt Industries Service Information Letter, Volume A, Issue 5, sheet 1 through 3.

Upon completion of the bearing run-in procedure, the bearings were "gap checked" using a 0.002 in. feeler gauge. Following the gap check the EDGs were run continuously for a minimum of 100 hours at a load of 2500-2600 kW. At the conclusion of this run, the upper main bearings were gap checked again with a 0.002 in feeler gauge, and the bearings were found to be in satisfactory condition.

V. RESULTS OF THE DEMONSTRATION TEST PROGRAM

All parts of the Demonstration Test Program were completed successfully on both EDGs. The results of the Demonstration Test Program are summarized below:

	EDG 11	EDG 13
Post-Maintenance Run (hours)	152	162.5
Post-Maintenance Slow Starts	8	9
Post-Maintenance Gap Check Results	Satisfactory	Satisfactory
Demonstration Slow Starts Completed	22	21
Demonstration Gap Check Results	Satisfactory	Satisfactory
Demonstration Fast Starts Completed	10	10
Demonstration Gap Check Results	Satisfactory	Satisfactory
Demonstration Load Run (hours)	192.5	269
Demonstration Total Run Hours	263.5	341
Post-Demonstration Test Gap Check Results	Satisfactory	Satisfactory
Grand Totals for Combined Post-Maintenance Testing and Demonstration Test Program:		
Total Slow Starts	30	30
Total Fast Starts	10	10
Total Run Hours	415.5	503.5

All bearings on both EDGs passed the gap check. All bearings visually inspected, except the #13 bearings on both EDGs, were in excellent condition, with no signs of surface scoring. The #13 bearing on EDG 11 had a trace of surface scoring on the bearing surface. However, there was no observable aluminum transfer on the journal. With the concurrence of Fairbanks Morse, this bearing was reinstalled with no further work required. On EDG 13 the #13 bearing had a trace of surface scoring on the bearing surface, with a trace of aluminum about one-half-inch wide transferred to the area adjacent to the aft side of the oil groove area on the journal surface. The aluminum area was very thin and smooth, with no appendages that could penetrate the oil film while the machine was operating. Fairbanks Morse determined that the bearing was in satisfactory condition. The aluminum was removed from the journal and the bearing was reinstalled.

The following deviations occurred during the Demonstration Test. None negate the results of the Demonstration Test.

Event	Impact
Oil Foaming, EDG 11 (February 2, 1986)	Changed oil, then continued Test Program. Additional information was provided in Reference 9. No impact on test results.
Low Lube Oil Trip, EDG 11 (February 13, 1986)	Trip occurred on low lube oil pressure due to slow start with warm oil. Corrective action was to raise governor setting slightly during slow start for increased oil pressure. No impact on test results.
Fire on Exhaust Lagging, EDG 13 (January 26, 1986)	Replaced damaged wiring and a jacket cooling system gasket. No impact on test results.
Loss of Inspection Cover Cap Screw, EDG 13 (February 7, 1986)	During bearing inspection, dropped inspection cover cap screw. Unable to find cap screw inside or outside the engine. No impact on test results.

In addition to the above, a small piece of a piston oil ring segment was found in EDG 12 during a gap check. Edison found no damage due to the presence of this piece and could not conclusively determine when the piece was introduced into the engine. Fairbanks Morse was asked to review their records to determine if the piece might have been introduced during manufacture of the engine. Edison's findings are discussed further in Reference 9.

VI. TEST RESULTS EVALUATION

The Demonstration Test Program was considered successful when the EDGs completed the twenty "slow" and ten "fast" starts, and the seven day run. A successful Demonstration Test validates that the EDGs can reliably perform their intended function.

For the Demonstration Test Program and subsequent operation of the EDGs, Detroit Edison and Fairbanks Morse consider the gap check as the primary measure of bearing integrity. As noted above, all bearings passed the gap check, confirming the "success" of the Demonstration Test Program. The visual inspections performed to validate the "success" of the Demonstration Test Program supported the findings of the gap check. Although some trace surface scoring was seen on the #13 bearings of EDGs 11 and 13, it was not significant enough to fail the bearings. Final acceptance of these bearings was made by Fairbanks Morse.

The results of the Demonstration Test Program are supported by the following facts:

- All bearing disassembly and reassembly, as well as bearing inspection and acceptance for the visual bearing inspection, were done by Fairbanks Morse personnel.

- The Fairbanks Morse personnel performing the visual examinations have, respectively, 9 and 19 years experience with Fairbanks Morse engines. Both have received extensive training on Fairbanks Morse engines and have spent the referenced years supervising repairs and maintenance of engines.

- The Detroit Edison personnel (maintenance foremen) supervising work on the EDGs were specially trained for their assignment (or qualified by equivalent training on Fairbanks Morse diesels in the Navy). Their experience meets Edison's commitment to ANSI-N18.1-1971 for the Maintenance Foremen and General Maintenance Journeyman positions (high school diploma plus four years experience in the craft or discipline they supervise).

VII. BASIS FOR NOT CONTINUING ROUTINE VISUAL INSPECTIONS

Since November, 1985 Detroit Edison has removed all EDG bearings for visual examination, in part to satisfy the NRC's requests for information. The NRC has suggested that Detroit Edison continue visual bearing inspections on a frequent basis. Fairbanks Morse maintains that the risk of damage to the bearings during removal and reinstallation and the potential for system contamination or misassembly, outweigh the information obtained from direct visual inspection of the bearing surfaces. Detroit Edison's experience confirms the validity of Fairbanks' recommendation. Fermi-2 EDG 14 had no bearing problems until the bearings were disassembled for visual examination.

The gap check is the accepted method for detecting bearing failure and is used by both nuclear and commercial customers of Fairbanks Morse. Detroit Edison is aware of no other owner of Fairbanks Morse engines who currently disassembles bearings for visual determination of bearing condition on a routine basis. Fairbanks Morse maintains, as stated in the January 24 meeting with the NRC, that the gap check provides an adequate indication of bearing integrity. Detroit Edison agrees with the manufacturer's position and will rely on the gap check as the primary measure of bearing integrity.

In reaching this position, Detroit Edison (and the NRC) must evaluate the benefits of periodic visual inspection against:

- Recognition that, industry-wide, the contribution of bearing and lube oil problems to overall failure rates of Fairbanks Morse diesels is small

- The potential for creating problems is increased by disassembling the EDG to perform visual inspections

- The time needed to disassemble the EDG for the visual inspection, reassemble, and test the EDG to restore it to operable condition would significantly impact EDG availability, and could impact plant availability

Completing the visual inspection requires disassembly, reassembly, and post-maintenance testing of the EDG. The post-maintenance testing includes a bearing break-in run recommended by Fairbanks Morse (see Enclosure 5) and a 100-hour reliability run. Even without considering time required for maintenance activities, the time required for testing following visual inspection exceeds the Technical

Specification Limiting Condition for Operation of 72 hours. This would require starting the other EDGs and, ultimately, would lead to taking the plant to Cold Shutdown.

In summary, Detroit Edison believes that routine visual bearing inspections are unwarranted because:

- Bearing disassembly and reassembly has a potential for reducing bearing reliability
- The vendor-recommended feeler gauge gap check is an adequate and sufficient method for detecting failed bearings
- Concerns about the EDG 11 bearings have been resolved and results verified by inspection of the #3, 5, 6, 8, 9, and 13 bearings
- Concerns about EDG 13 bearings have been resolved and results verified by inspection of the #3, 4, 7, 10, and 13 bearings. A special visual inspection of the #13 bearing will be performed at the next scheduled 18-month Technical Specification surveillance inspection.
- Future gap checks will be performed every 6 months or after three non-manually-prelubed starts. This frequency provides ample opportunity to detect bearing problems in a timely manner.
- The surveillances required by Technical Specifications and Regulatory Guide 1.108 provide adequate EDG testing to ensure reliability and operability on a routine basis.

VIII. COMMITMENTS FOR EDG SURVEILLANCE

VIII.1 Lube Oil Filter Inspection

In March, 1985, Detroit Edison proposed more frequent inspection of the EDG lube oil filter as one element of the program intended to detect incipient bearing failures. Subsequent experience has indicated that inspection of the lube oil filter is ineffective in predicting bearing failures. In addition, more frequent inspection of the oil filter increases the likelihood of contaminating the lube oil system. Therefore, Detroit Edison plans to eliminate the oil filter sampling program described in Reference 4. This letter is referenced in paragraph 2.C.(10) of the Fermi-2 Operating License. Accordingly, Detroit Edison will seek a license amendment to revise the reference to the March 14, 1985 letter. That request for license amendment will be filed separately.

VIII.2 Future Bearing Gap Checks

Successful completion of the Demonstration Test Program defines an "envelope of acceptability" within which the reliability of the EDG crankshaft bearings have been demonstrated. Detroit Edison recognizes that all of the EDG starts during the Demonstration Test Program were manually-prelubricated starts. Detroit Edison made a previous commitment to pre-lube all planned starts. During plant operation, a limited number of non-manually-prelubed starts are expected to occur, in response to loss-of-offsite power and spurious or actual accident signals.

Recognizing NRC concerns about the potential effects of non-prelubricated starts, Detroit Edison will revise the maintenance procedure pertaining to EDG bearing gap checks to address occurrence of non-manually-prelubed starts. The procedure will require a gap check of the upper and lower crankshaft main bearings after three (3) non-manually-prelubed starts or six (6) months, whichever occurs first. This frequency of gap checks will continue until experience confirms that it can be relaxed.

The limit of three non-manually-prelubed starts was defined, in part, by Edison's examination of the start history of the Fermi-2 EDGs. The start history is summarized below.

Fermi-2 EDG Start History
May, 1982 through January, 1985
(Starts Made Before Bearing Failures Occurred on EDGs 11 & 12)

	Number of Occurrences for Type of Start			
Type of Start	EDG 11	EDG 12	EDG 13	EDG 14
Prelubed	127	52	25	30
No Prelube, Wet, Booster	112	89	78	72
No Prelube, Booster	63	63	56	68
No Prelube, No Booster	0	0	0	2
Total Starts	302	204	159	172

In this table, a "Prelubed Start" is defined as manually prelubricating the EDG immediately before starting. A "Wet" start is defined as starting the EDG within one hour of the previous EDG shutdown, without manually prelubricating the EDG. "No Prelube, Booster" means the start occurred more than one hour after the previous shutdown, and was assisted by the air/oil booster system, without manual prelubrication. "No Prelube, No Booster" indicates that the start occurred without assistance of the air/oil boost system and without manual prelubrication.

Examination of this data indicates that EDG 11 experienced 63 "No Prelube, Booster" starts before a bearing failure occurred. These starts would be identical to the conditions encountered in an unplanned start today. Including the 112 "Wet" starts in the total of non-prelubed starts would indicate 175 non-prelubed starts occurred before bearing failure on EDG 11. EDG 12 experienced 63 "No Prelube, Booster" starts before bearing failure (identified by gap check). Through January 1985, each of the Fermi-2 EDGs experienced an average of 62.5 fast starts engine with air/oil boost and without manual prelubrication. This supports Edison's view that the EDGs can tolerate at least 63 non-prelubricated starts before bearing failure would be expected.

This demonstrated experience of approximately 60 non-manually-prelubed fast starts, and the EDG reliability specified in Generic Letter 84-15 (95% minimum), form the basis for Edison's recommendation to gap check the bearings after three non-manually-prelubed starts. Gap checking the bearings after three (of 60) starts is commensurate with the Fermi-2 Technical Specification requirement to increase the frequency of testing when more than one failure has occurred in the last twenty valid tests of the EDGs.

It is important to note that the design life of the EDG bearings is based on bearing wear (i.e., minimum thickness of bearing shell). The manufacturer typically experiences over 10,000 hours of operation on its engines before bearing replacement is required due to wear. Detroit Edison estimates that normal surveillance and operation will require each EDG to run typically less than 100 hours per year. At this rate, each EDG would be expected to operate between 2000 and 4000 hours over the 40-year life of the plant. Therefore, the expected bearing life exceeds the anticipated hours of operation by a factor of 2.5 to 5. Detroit Edison believes that the limit of three (3) non-manually-prelubed starts or six months, provides a conservative criterion for triggering a gap check, without unduly restricting operability of the EDGs. Detroit Edison expects that this limit may be relaxed as EDG operating experience confirms the level of reliability.

VIII.3 Special Inspection of EDG 13 Thrust Bearing

The feeler gauge (gap check) inspections of all main bearings will include the #13 main thrust bearing. During the gap check, each main bearing is inspected for external indications of bearing degradation, such as formation of tin pimples, changes in shape, and any other abnormal condition. To provide further assurance that the #13 upper top half thrust bearing of EDG 13 is not degrading, Detroit Edison will perform a special visual inspection of this bearing at the next 18-month Technical Specification surveillance inspection.

IX SUPPLEMENTAL INFORMATION

IX.1 Issues Discussed in January 24 Meeting

(1) Oil Viscosity

In December, 1985, Detroit Edison's surveillance of the EDGs revealed reduced viscosity of the lube oil in EDGs 12 and 14. In EDG 14 the engine lube oil was changed and subsequent testing revealed that the viscosity of the replacement oil remained within limits. This leads Detroit Edison to conclude that the reduced viscosity resulted from dilution of the lube oil with a small quantity of fuel oil. Fuel oil is used to clean the crankshaft journals and may have been introduced in excessive quantity during the bearing repairs and replacements.

A trend of decreasing viscosity was identified previously in surveillance of the lube oil of EDG 12. Several steps were taken to resolve this condition. The twenty-four fuel injector nozzles were tested for leakage in accordance with vendor procedures. No leakage was observed. The twenty-four fuel injector pumps were checked for plugging. No distinctive differences were observed from the fuel injector leakoff points and no clean fuel leakoff lines were found plugged. The seal on the main shaft-driven fuel oil pump was replaced, but it was not possible to verify that the new seal was leak-free, because of the configuration of the equipment and the lack of an inspection port. The crankcase vacuum was decreased by replacing an orifice in the crankcase inductor. The crankcase vacuum previously was slightly high, and might have induced oil flow into the crankcase. Finally, the Shell Caprinus lubricating oil was changed to Mobilguard 450 lubricating oil in this and the other three EDGs.

After this work was completed, EDG 12 was restarted and run for several days. Initially, the oil viscosity decreased slightly, then stabilized at a value between 137 and 138 Centistokes. The minimum acceptable value of viscosity is 120 Centistokes (40 degrees C). The viscosity data from this run are shown below.

Sample Identification (Date, Time)	Measured Viscosity (Centistokes, 40C)
2/22/86, 0630	144
2/23/86, 0535	144
2/24/86, 0035	142
2/25/86, 0351	140
2/26/86, 0049	138
2/27/86, 0210	138
2/28/86, 0110	138
3/1/86, 0245	136.5
3/2/86, 0145	137.8
3/3/86, 0045	137.6
3/4/86, 0115	137.8
3/5/86, 0125	137.4

The EDG was shutdown on March 5, 1986. Because the viscosity has stabilized, no further corrective action is considered necessary. Routine surveillance will assure that viscosity values remain within limits. This surveillance includes an oil sample obtained during each monthly surveillance test run of all EDGs.

(2) EDG Alignment During Installation

At the January 24 meeting with the NRC, a question was raised concerning the skid-to-foundation alignment of the Division 2 EDGs. Detroit Edison has reviewed the installation records for the EDG skids and verified that the alignment was held to within +/- 1/16th inch. Fairbanks Morse specifies tolerances of +/- 1/8th inch at the skid corners and +/- 1/16th inch at the midpoint of the skid.

Fairbanks Morse has stated that the design of the EDG skid makes it unlikely that misalignment of the skid on its foundation would distort the engine block. If the engine block had been distorted, a distinctive bearing wear pattern would have been seen. During the inspection of EDG 11, no such wear pattern was observed.

IX.3 Endorsement by Fairbanks Morse and Failure Analysis Associates

In the January 24 meeting, the NRC asked representatives of Fairbanks Morse and Failure Analysis Associates (FAA), whether they agreed with the course of action proposed by Detroit Edison to restore confidence in the reliability of the Fermi-2 EDGs. The representatives indicated their approval of the Edison Demonstration Test Program presented to the NRC. Detroit Edison later requested that FM and FAA put their endorsement in writing for inclusion in both Reference 8 and this report. Copies of their letters of endorsement are provided in Enclosure 5.

After the February 14 meeting with the NRC, Detroit Edison requested Fairbanks Morse to more definitively document their position on the need and advisability of visually inspecting bearings after the Demonstration Test Programs operability runs. The subject response is also provided in Enclosure 5.

IX.4 Independent Lab Bearing Evaluation

Detroit Edison has committed to have an independent laboratory analyze several bearings with different conditions noted on each. The subject bearings were selected from bearings removed in the November-December, 1985 inspections. This will provide an independent determination of the cause of the various conditions noted on several bearings. Detroit Edison will evaluate the results of the laboratory's analysis when they become available. Detroit Edison will factor these results into future corrective action, if appropriate.

IX.5 Study of Oil Booster System

In Supplement 5 to the Fermi 2 Safety Evaluation Report, the NRC stated:

> ".....we recommend that the applicant study whether it should increase the (oil booster/accumulator system) reservoir tank volume to some appropriate volume larger than 1.25 gallons so that it will provide a proper amount of lube oil, adequately distributed, and in the shortest possible time. The results of such a study should be submitted to us."

In response to this, a study of the oil booster/accumulator system has been prepared by Fairbanks Morse and a draft report is currently in the review process. The draft report concludes that the oil booster empties during the first one second, providing approximately one cup of oil to the bearings at essentially zero pressure. After approximately three seconds, the engine driven pump has filled all passageways with oil, and has established pressure at the upper main bearings. The subject draft report indicates that increasing the volume of oil in the reservoir will only result in the same oil flow rate being provided for a longer period of time.

The lube oil modification kit installed by Detroit Edison included more than the air/oil booster. This modification reduced voids in the lube oil system from approximately 60 gallons to less than 5 gallons, thus improving the response time for the engine-driven lube oil pump. The lower crankshaft is continuously lubricated by circulating lube oil. With the keep-warm system, the lube oil is maintained at an elevated temperature, approximately 135F, by a large lube oil heater.

As noted, the draft report is in the review cycle, and completion of this review has been delayed due to the recent EDG bearing concerns discussed in this submittal. The contents of this draft report, as well as the design of the entire oil booster/accumulator system, have been considered by the Detroit Edison EDG Task Force in discussions of bearing failures; but Task Force conclusions have not implicated the oil booster/accumulator as one of the causes of the recent EDG problems. Detroit Edison is aware that other nuclear facilities' EDGs have operated successfully with and without the booster. The results of the oil booster study will be submitted separately.

X. CONCLUSION

Detroit Edison is confident that the Demonstration Test Program and the post-test visual bearing inspection documented above confirm the reliability of the Fermi-2 EDGs. The bases for this conclusion include:

- Fairbanks Morse engines have a proven record of reliability in the nuclear industry. This reliability is based upon an integrated program involving training, technical specification and surveillance requirements, and periodic maintenance including bearing gap checks.

- The Demonstration Test Program included 30 starts per engine. This is more than the 23 starts required by Regulatory Guide 1.108 for the initial demonstration of EDG reliability.

- The Demonstration Test Program simulates the total number of starts that would be expected over an 18-month fuel cycle and the run time that would be needed to assure safe shutdown following a design basis Loss of Coolant Accident coincident with a loss of offsite power.

- All bearings passed the gap checks which were performed throughout the Demonstration Test Program.

- Visual inspections were performed on several bearings on EDGs 11 and 13 to validate the results of the Demonstration Test Program, and to confirm that the gap check provides adequate assurance of bearing integrity. All visually inspected bearings passed.

- Engine disassembly should be minimized.

- Both the engine manufacturer (Fairbanks Morse) and Detroit Edison's consultant (Failure Analysis Associates) stand behind the Fermi-2 Demonstration Test Program.

- The slow start modification, installed in 1985, further reduces the wear on the EDGs caused by planned surveillance runs.

Detroit Edison maintains that the Demonstration Test Program provides the basis for the NRC to conclude that the Fermi-2 EDGs are a reliable backup power source.

XI. REFERENCES

1. Detroit Edison letter to NRC, NE-85-0329, "Request to Revise Draft Fermi-2 Technical Specifications", dated February 14, 1985.

2. Detroit Edison letter to NRC, NE-85-460, "Additional Information on Diesel Generators", dated March 6, 1985.

3. Detroit Edison letter to NRC, NE-85-0455, "Additional Change to Draft Fermi-2 Technical Specification for Diesel Generators", dated March 9, 1985.

4. Detroit Edison letter to NRC, NE-85-0459, "Clarification of Diesel Generator Commitments", dated March 14, 1985.

5. Detroit Edison letter to NRC, NE-85-0461, "Letter Correction", dated March 15, 1985.

6. Detroit Edison letter to NRC, NE-85-0462, "Transmittal of Additional Information Relative to Diesel Generator Commitments", dated March 15, 1985.

7. Detroit Edison letter to NRC, VP-85-0216, "Emergency Diesel Generator Status", dated December 13, 1985.

8. Detroit Edison letter to NRC, VP-86-0010, "Emergency Diesel Generator Crankshaft Bearing Reliability Demonstration Test Program", dated February 5, 1986.

9. Detroit Edison letter to NRC, VP-86-0011, "Emergency Diesel Generators (EDGs) Testing and Operating Chronology", dated March 1, 1986.

Enclosure 2
March 18, 1986
VP-86-0025

Copy of Handouts Presented in January 24, 1986
Meeting with NRC Staff on EDG Bearings
Reliability Demonstration Test Program

[NOTE As reflected in Enclosure 1, "History", the intent of the presentation for which the enclosed slides were used was to focus discussion on EDG bearings replaced due to "failure" and significant surface scoring. The enclosed slides may not, by design, fully delineate bearing replacements prompted by other concerns.]

AGENDA

EQUIPMENT

HISTORY

PROBLEMS

OTHER CAUSES

CORRECTIVE ACTION

SCHEDULE

EQUIPMENT

FOUR EMERGENCY DIESEL GENERATORS (EDG'S)

TWO EMERGENCY DIESEL GENERATORS PER DIVISION

DIVISION 1 - EDG 11 & 12
DIVISION 2 - EDG 13 & 14

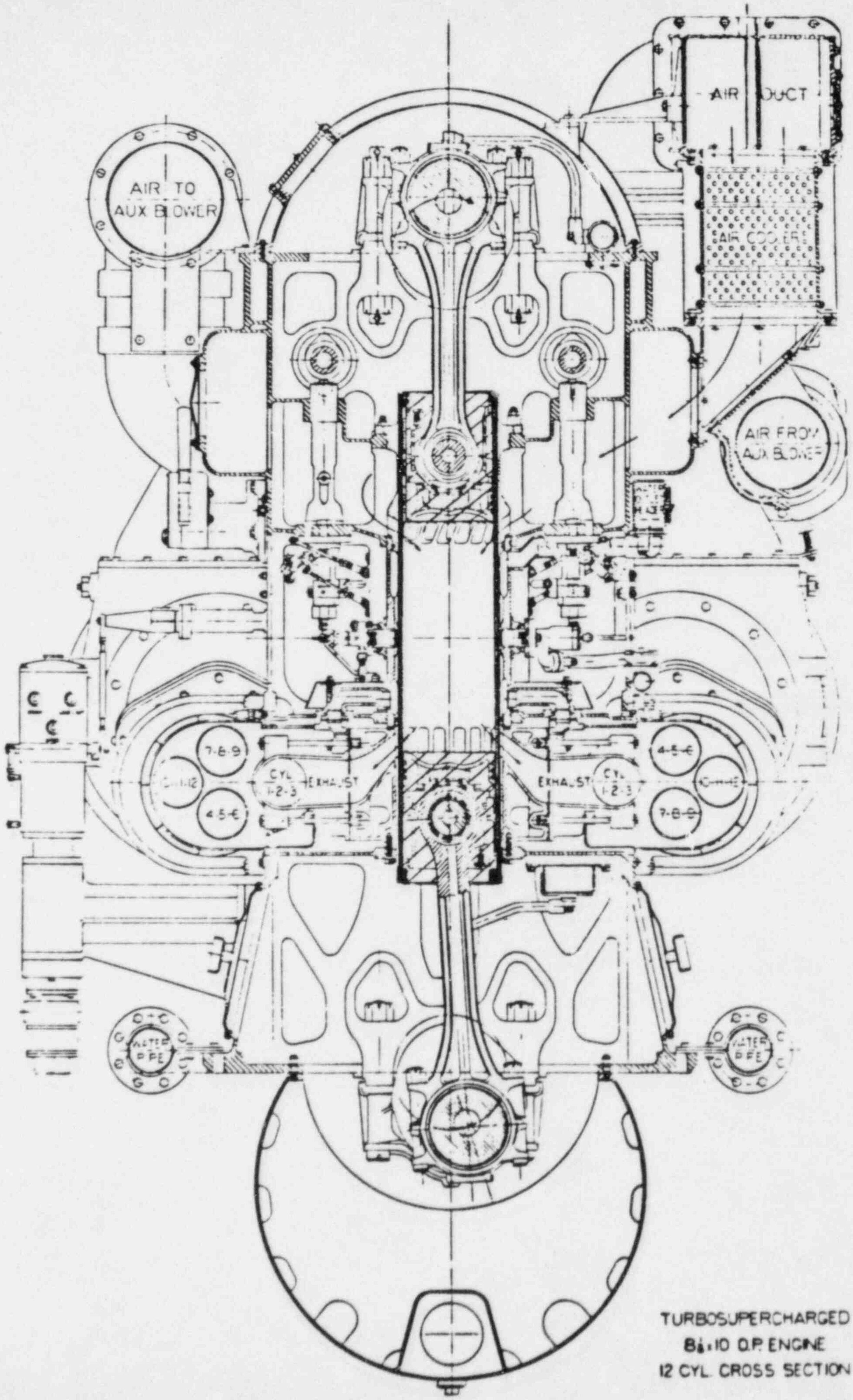
BACKUP ON-SITE A.C. POWER SOURCE

REDUNDANT POWER SOURCES

FAIRBANKS MORSE DIESEL ENGINES

- NAVY 400
- NUCLEAR PLANTS 49
- OTHER

SURVEILLANCE TEST PROGRAM



TURBOSUPERCHARGED
$8\frac{1}{8}$ x 10 O.P. ENGINE
12 CYL. CROSS SECTION

HISTORY

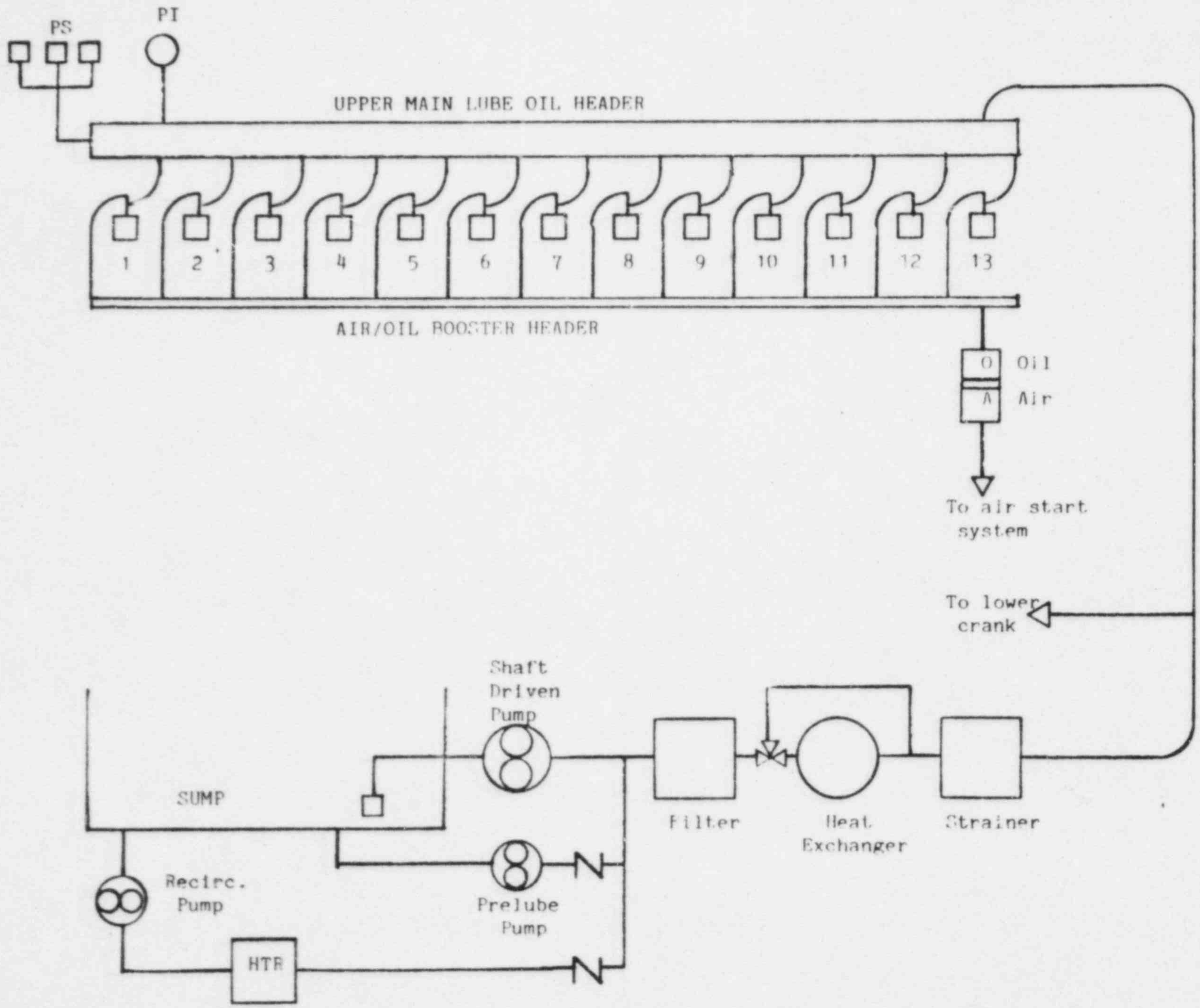
BUILT 1974 - 1977

INSIDE STORAGE

PERMANENT LOCATION

ONE ENGINE SOLD AND REPLACED (EDG 14)

OIL SYSTEM MODIFICATION



EDG LUBE OIL SYSTEM

TERMS

FAILED BEARING (.002 IN. GAP CHECK)

SURFACE SCORING

HEALED SURFACE SCORING

EDG 11

Date	********	Jan 85	********	Dec 3,85	********	Dec 27,85	****
Bearings							
1		X					
2		X					
3		X		o		o	
4		X					
5		X		o		X	
6		X		o		X	
7							
8				o			
9				o			
10							
11							
12							
13		o		o (Lower & Upper)		o	
14							
	********		********		********		****
Run Hours	346		125		20		
Starts							
Fast(PLM)	127		25		0		
Fast(NPL)	175		1		0		
Slow	0		8		10		
Total	302		34		10		
Hours/Start	1.1		3.6		2.0		
Notes		-Replaced the Upper Crank -Replaced all Upper Bearings		-Replaced all Upper Bearings		-Realigned Caps -Replaced Failed & Distressed Bearings -Flush Engine	

NOTE: THE ASSOCIATED CONNECTING RODS FAILED IN JAN 85.

PLM=Manual Prelube, NPL=Not Manually Prelubed

EDG 12

Date	|********|	Jan 85	|********|	Dec 85	|********|
Bearings					
1		X			
2		X			
3		X			
4					
5					
6					
7		X			
8		X			
9					
10					
11					
12					
13				o (Lower)	
14					
	|********|		|********|		|********|
Run Hours	292		137		240
Starts					
Fast(PLM)	52		23		0
Fast(NPL)	152		1		0
Slow	0		7		8
Total	204		31		8
Hours/Start	1.4		3.6		30
Notes		-Replaced upper crank bearings -Inspected 14M, 12M, 10M and 8M on lower crank -Gap checked all other bearings		-Replaced 13M lower	

PLM=Manual Prelube, NPL=Not Manually Prelubed

EDG 13

Date	|********|	Jan 85	|********|	Nov 85	|********|	Dec 85	|****
Bearing							
1							
2							
3				X		o (Groove)	
4				o (Lower)			
5							
6							
7						o (Groove)	
8							
9							
10							
11							
12							
13				o		o	
14							
Hours	214		94		234		
Starts							
Fast(PLM)	25		24		3		
Fast(NPL)	134		0		0		
Slow	0		6		46		
Total	159		30		49		
Hours/Start	1.3		3.1		4.8		
Notes		-Inspected Upper Crank Bearings 1 - 6 -All Other Bearings were gap checked		-Replaced the Upper Crank -Replaced all Upper Bearings -Replaced 4M Lower Bearing		-Replaced 3M, 7M & 13M -Flushed Engine -Demonstration	

PLM=Manual Prelube, NPL=Not Manually Prelubed

EDG 14

Date	|********|	Jan 85	|********|	Dec 85	|********|	Jan 86	|****
Bearings							
1						o	
2							
3							
4							
5							
6							
7							
8							
9						o	
10							
11							
12							
13						o	
14							
	|********|		|********|		|********|		|****
Run Hours	270		117		250		
Starts							
Fast(PLM)	30		20		0		
Fast(NPL)	142		2		0		
Slow	0		7		8		
Total	172		29		8		
Hours/Start	1.6		4.0		31.3		
Notes		-Inspected Bearings 1-6 -Observed some bearings had a dull matte partial finish		-Inspected all upper and lower bearings -Replaced all upper crank-line bearings		-Three bearings reused	

PLM=Manual Prelube, NPL=Not Manually Prelubed

TYPICAL CAUSES OF BEARING FAILURE

DIRT OR FOREIGN MATERIAL IN OIL

INSUFFICIENT LUBRICATION

MISASSEMBLY

MISALIGNMENT

OVERLOAD

CORROSION

DESIGN

OTHER

NOVEMBER 1985

EDG 13

EVENT: OPERATOR SHUTDOWN EDG 13 DUE TO NOISE CHANGE

PROBLEM: BEARINGS 3CR, 3M AND 4M FAILED

13 M HAD BEARING WEAR

CAUSE: PRIMARY - BEARING 3CR FAILED DUE TO MISASSEMBLY

IN JANUARY 1985, THE BEARING WAS INSPECTED

NO DISCOLORATION = NO HIGH TEMPERATURE

ALUMINUM DID NOT EXPERIENCE A HIGH TEMPERATURE

FRETTING ON CONNECTING ROD FACES

BENT CONNECTING ROD BOLTS

BEARING FRAGMENTED

SECONDARY - BEARING 3M FAILED DUE TO DECREASED OIL FLOW TO BEARING FACES

BEARING 13M BEARING TO JOURNAL CONTACT

ACTION:

- CHECKED ALL OTHER PREVIOUSLY REWORKED BEARINGS. NO OTHERS WERE FOUND TO BE A CONCERN.
- REPLACED UPPER CRANKSHAFT
- REPLACED ALL UPPER BEARINGS

JANUARY 1985

EDG 11

EVENT: EDG 11 SHUTDOWN AUTOMATICALLY ON A LOW LUBE OIL PRESSURE SIGNAL

PROBLEM: SEVEN FAILED BEARINGS

CAUSE: BEARINGS FAILED DUE TO INADEQUATE LUBRICATION DURING FAST STARTS

ACTION:

PRELUBE ALL PLANNED STARTS

TEST EDG'S AT PLANT SPECIFIC LOAD LEVELS

IMPROVED OIL SAMPLING PROGRAM

INAUGURATED OIL FILTER SAMPLING PROGRAM

REVISED PROCEDURES

REVISED TECHNICAL SPECIFICATIONS

INCORPORATE SLOW START FEATURE (DELAYED)

(ACTION STEPS APPLIED TO ALL EDG'S)

EDG 12

EVENT: GAP CHECK INSPECTION

PROBLEM: FIVE FAILED BEARINGS

CAUSE: SAME AS EDG 11

ACTION: SAME AS EDG 11

DECEMBER

EDG 13

EVENT: VISUAL INSPECTION OF UPPER BEARINGS FOLLOWING SUCCESSFUL COMPLETION OF DEMONSTRATION

PROBLEM: BEARINGS 3M, 7M AND 13M FOUND WITH SURFACE SCORING

CAUSE: BEARINGS 3M AND 7M - FOREIGN MATERIAL IN OIL

BEARING 13M - BEARING TO JOURNAL CONTACT

ACTION: REPLACED THREE BEARINGS

:

NOVEMBER 1985

EDG 14

EVENT: VISUAL INSPECTION OF ALL BEARINGS

PROBLEM: NONE

CAUSE: N/A

ACTION: REPLACED ALL UPPER CRANK BEARINGS TO ELIMINATE A "DULL ROUGH" SURFACE APPEARANCE

JANUARY 1986

EDG 14

EVENT: SECOND VISUAL INSPECTION

PROBLEM: 3 BEARINGS WITH A TRACE OF SURFACE SCORING

CAUSE: BEARING TO JOURNAL CONTACT

ACTION: REINSTALLED BEARINGS

:

NOVEMBER 1985

EDG 12

EVENT: VISUAL INSPECTION OF ALL BEARINGS

PROBLEM: BEARING 13M LOWER FOUND WITH SURFACE SCORING

CAUSE: BEARING TO JOURNAL CONTACT

ACTION: REPLACED BEARING

DECEMBER 3, 1985

EDG 11

EVENT: VISUAL INSPECTION OF ALL BEARINGS

PROBLEM: BEARINGS 3M, 5M, 6M, 8M, 9M, 13M(UPPER AND LOWER) FOUND WITH SURFACE SCORING

CAUSE: BEARING TO JOURNAL CONTACT AGGRAVATED BY ALIGNMENT

ACTION: REPLACED ALL UPPER MAIN BEARINGS AND ONE LOWER BEARING

DECEMBER 27, 1985

EDG 11

EVENT: INSPECTION DURING BEARING RUN-IN

PROBLEM: TWO FAILED BEARINGS AND TWO BEARINGS WITH SURFACE SCORING

CAUSE: BEARING TO JOURNAL CONTACT AGGRAVATED BY ALIGNMENT

ACTION: DETAILED REALIGNMENT OF UPPER BEARING CAPS

ENGINE BEARINGS

FUNCTIONAL REQUIREMENTS

- PROVIDE LOW-FRICTION, LOW-WEAR JUNCTION BETWEEN MAJOR ENGINE COMPONENTS:

    PISTON - WRIST PIN

    WRIST PIN - CONNECTING ROD

    CONNECTING ROD - CRANKSHAFT

    CRANKSHAFT - ENGINE BLOCK

- PROMOTE FORMATION OF LUBRICATING OIL FILM BETWEEN BEARING AND ADJACENT SHAFT OR JOURNAL.

ENGINE BEARINGS
SPECIFIC REQUIREMENTS

- o DESIGNED TO CONTROL STRESSES WITHIN PROVEN CAPABILITIES
- o MANUFACTURED TO CLOSE DIMENSIONAL TOLERANCES
- o MATERIALS SELECTED TO PROVIDE:
  - LOW FRICTION WITH JOURNAL
  - ABILITY TO ABSORB AND NEUTRALIZE ABRASIVE PARTICULATES
  - STRENGTH FOR LONG, RELIABLE LIFE
  - COMPATIBILITY WITH ENGINE OIL
- o VIABLE MATERIALS:
  - FOR BEARING PHASE

    TIN, LEAD, CADMIUM, INDIUM
  - FOR MATRIX PHASE

    COPPER, ALUMINUM

ENGINE BEARINGS

DESIGN PROCEDURES

1) COMPUTE LOADS

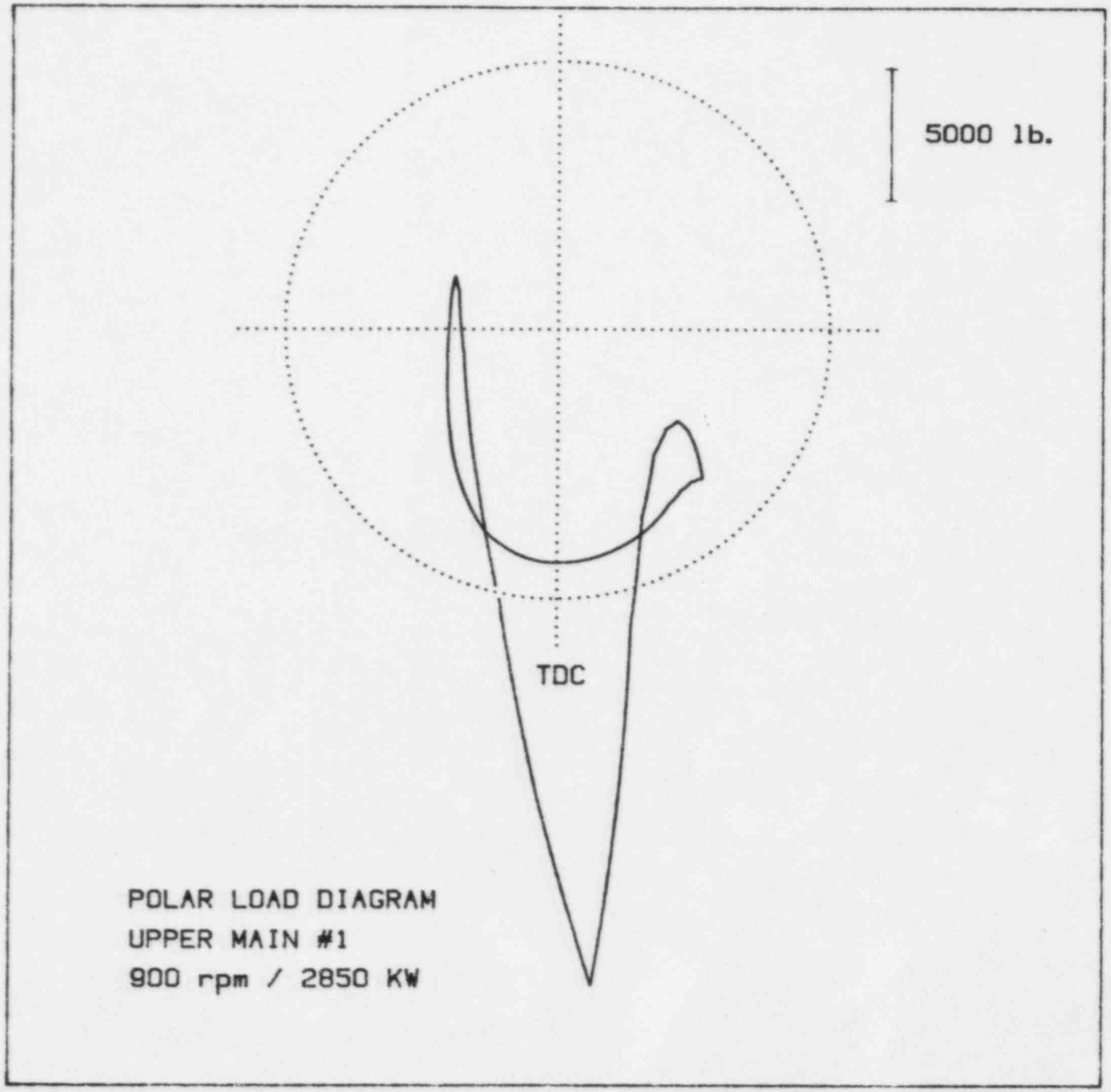
INPUTS: HORSEPOWER
COMBUSTION PRESSURE
FIRING ORDER
COMPONENT WEIGHTS
COUNTERWEIGHTS
GEARS AND ACCESSORIES

2) SELECT SIZES

LENGTH AND DIAMETER
GROOVES, OIL HOLES
CLEARANCES

3) SELECT LUBRICANT

VISCOSITY AND VISCOSITY INDEX
SUPPLY PRESSURE
SUPPLY TEMPERATURE


5000 lb.
TDC
POLAR LOAD DIAGRAM
UPPER MAIN #1
900 rpm / 2850 KW

ENGINE BEARINGS

ANALYTICAL TECHNIQUES

UNIT LOAD

#1 MAIN BEARING

$$\text{UNIT LOAD} = \frac{24343 \text{ LB.}}{8" \times (2.75"-.4375")} = 1316 \text{ P.S.I.}$$

JOURNAL ORBIT ANALYSIS

SOLVES DIFFERENTIAL EQUATIONS OF FLUID FLOW IN BEARING FOR EVERY 1° OF CRANKSHAFT ROTATION.

OUTPUT: PEAK OIL FILM PRESSURES
MINIMUM OIL FILM THICKNESSES

INTERPRETATION: COMPARISON TO GUIDELINES ESTABLISHED BY THE ANALYSIS OF MANY DIFFERENT ENGINES

ENGINE PARTS DIVISION
CLEVITE
ENGINE BEARING JOURNAL ANALYSIS AT 900 RPM
REFERENCE NO.- 25586021

NO. 1 MAIN

CUSTOMER	FAAA/DETROIT ED/TE	BORE	8.1250	REC WEIGHT	93.200
MODEL	COLT 2 CYCLE OP 12	STROKE	10.0000	ROT WEIGHT	38.900
BHP	0.00	COMP RATIO	0.0000	ENGINEER	M M VOGLER
CYLINDERS	5	C/L C/L LGT	23.0000	DATE	JAN 21, 86
RAD.CLEAR	0.0049	VISCOS(MREYNS)	3.2934	SHAFT DIA	7.9950
EFFEC. LTH	1.1563	OIL GRADE(4)		BRG GRV	(8)360-DEG
		OIL PRESSURE	35.00		
		OIL TEMP	170.00		

A MAXIMUM OIL FILM PRESSURE OF 10178 PSI

OCCURS AT A CRANK ANGLE OF 20 DEGREES
WITH AN ANGLE RELATIVE TO THE BEARING OF 183 DEGREES
AND AN ANGLE RELATIVE TO THE JOURNAL OF 163 DEGREES
THE LOAD AT THIS POINT IS 24343 POUNDS
ACTING AT AN ANGLE OF 176.9 DEGREES

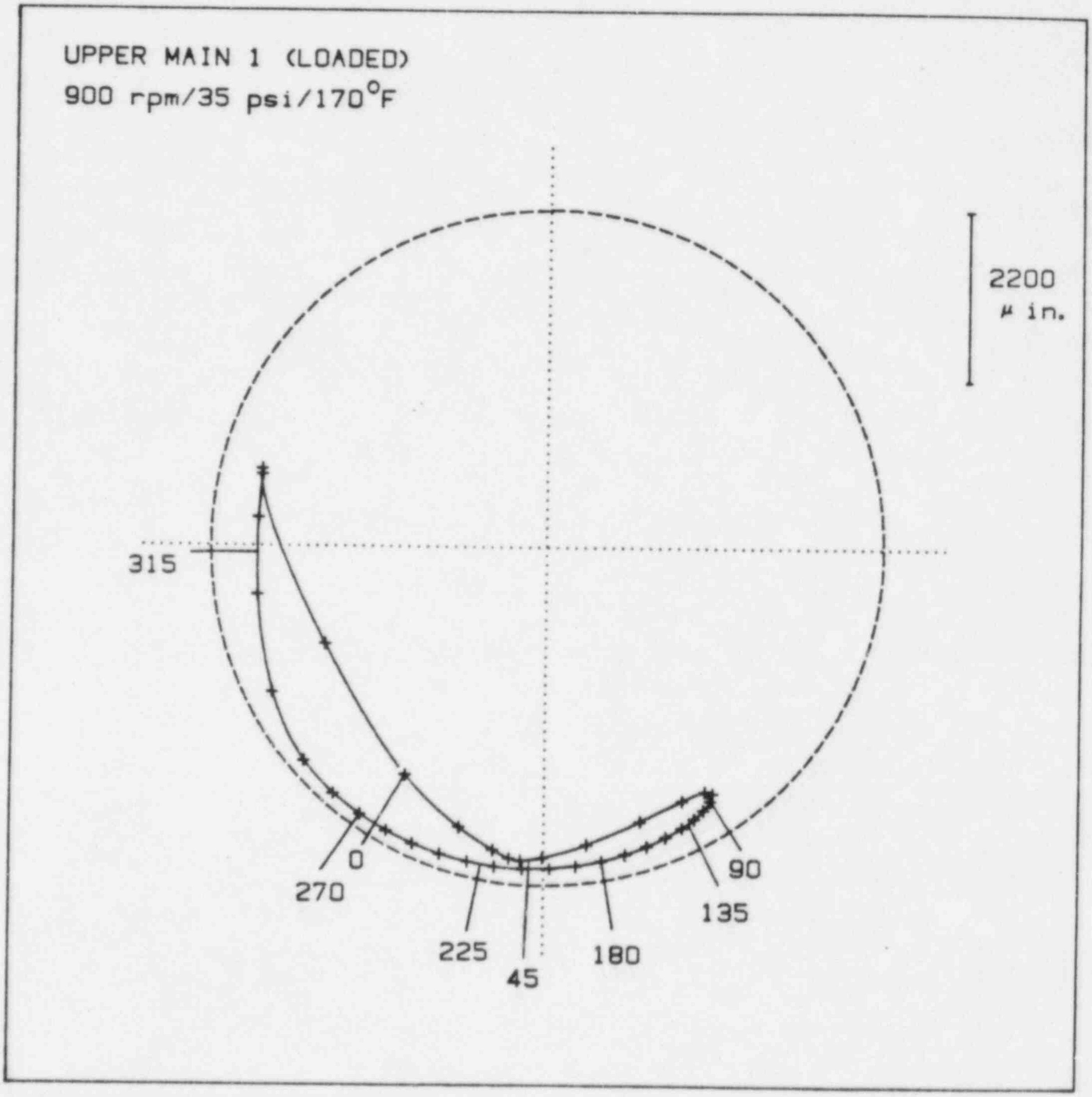
THE MEAN OIL FILM PRESSURE IS 3331 PSI

A MINIMUM OIL FILM THICKNESS OF .000169 INCHES

OCCURS AT A CRANK ANGLE OF 276 DEGREES
WITH AN ANGLE RELATIVE TO THE BEARING OF 218 DEGREES
AND AN ANGLE RELATIVE TO THE JOURNAL OF 302 DEGREES
THE LOAD AT THIS POINT IS 5255 POUNDS
ACTING AT AN ANGLE OF 230.2 DEGREES

THE ECCENTRICITY RATIO AT THIS POINT IS 0.96558

THE MEAN OIL FILM THICKNESS IS .000407 INCHES


UPPER MAIN 1 (LOADED)
900 rpm/35 psi/170°F
2200
μ in.
315
0
270
225
45
180
135
90

ENGINE PARTS DIVISION

CLEVITE

ENGINE BEARING JOURNAL ANALYSIS AT 900 RPM

REFERENCE NO.- 156105365

CON ROD BRG

CUSTOMER	FAAA/DETROIT ED/FE	BORE	8.1250	REC WEIGHT	93.200
MODEL	COLT 2 CYCLE OP 12	STROKE	10.0000	ROT WEIGHT	30.900
BHP	0.00	COMP RATIO	0.0000	ENGINEER	M M VOGLER
CYLINDERS	1	C/L C/L LGT	23.0000	DATE	DEC 31, 85
RAD.CLEAR	0.0049	VISCOS(MREYNS)	3.3571	SHAFT DIA	6.7560
EFFEC. LTH	1.5625	OIL GRADE(4)		BRG GRV	(8)360-DEG
		OIL PRESSURE	35.00		
		OIL TEMP	170.00		

A MAXIMUM OIL FILM PRESSURE OF 19506 PSI

OCCURS AT A CRANK ANGLE OF 20 DEGREES
WITH AN ANGLE RELATIVE TO THE BEARING OF 3 DEGREES
AND AN ANGLE RELATIVE TO THE JOURNAL OF 339 DEGREES
THE LOAD AT THIS POINT IS 52707 POUNDS
ACTING AT AN ANGLE OF 358.0 DEGREES

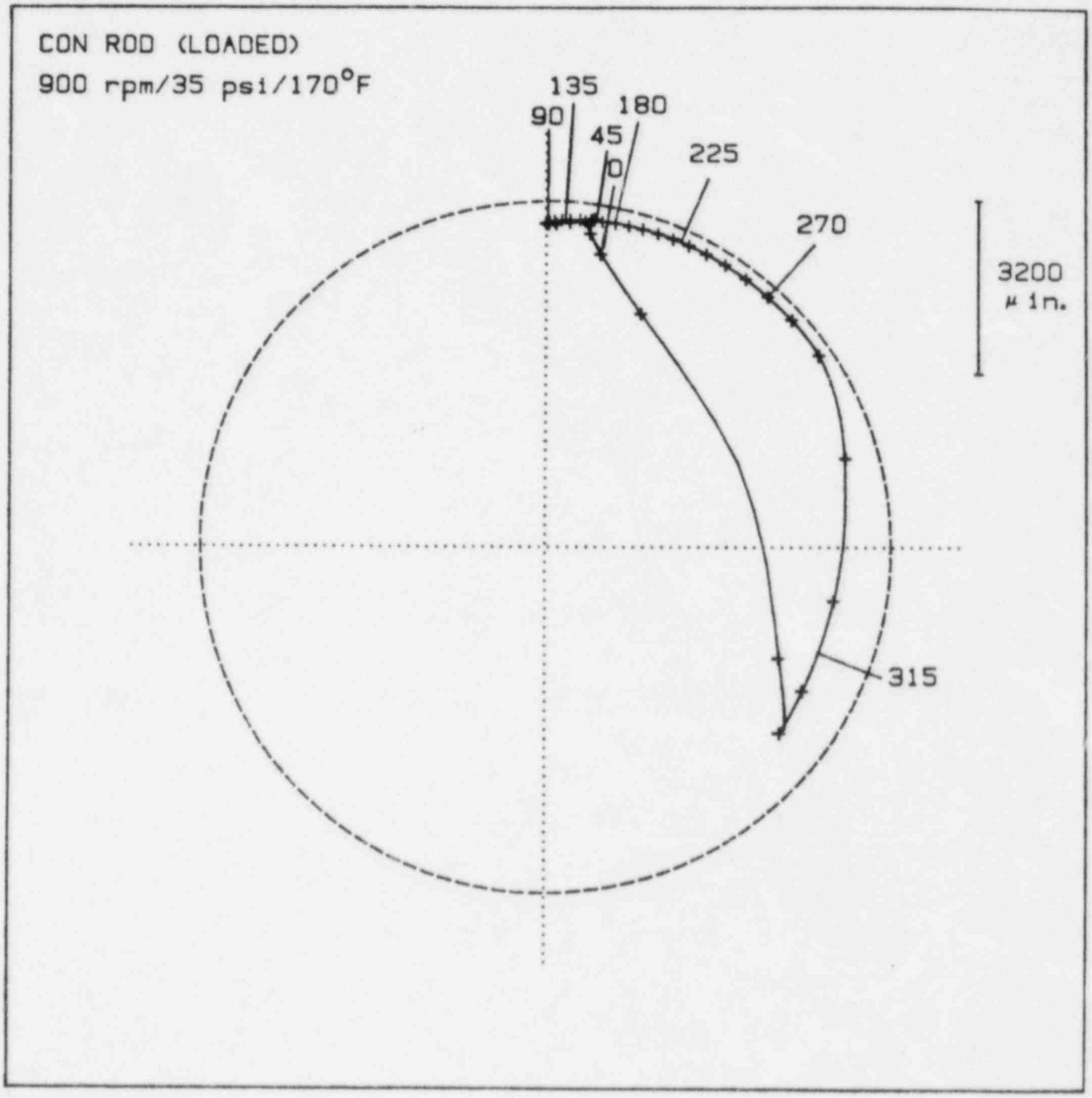
THE MEAN OIL FILM PRESSURE IS 6537 PSI

A MINIMUM OIL FILM THICKNESS OF .000214 INCHES

OCCURS AT A CRANK ANGLE OF 202 DEGREES
WITH AN ANGLE RELATIVE TO THE BEARING OF - 98 DEGREES
AND AN ANGLE RELATIVE TO THE JOURNAL OF 139 DEGREES
THE LOAD AT THIS POINT IS 5032 POUNDS
ACTING AT AN ANGLE OF 62.8 DEGREES

THE ECCENTRICITY RATIO AT THIS POINT IS 0.95588

THE MEAN OIL FILM THICKNESS IS .000469 INCHES


CON ROD (LOADED)
900 rpm/35 psi/170°F
135
180
90
45
0
225
270
3200
μ in.
315

ENGINE PARTS DIVISION
CLEVITE
ENGINE BEARING JOURNAL ANALYSIS AT 900 RPM
REFERENCE NO.- 166685342

NO. 4 MAIN

CUSTOMER	"FABA/FERMI 2/DETR	BORE	8.1250	REC WEIGHT	93.200
MODEL	"COLT 2 CYCLE OP 1	STROKE	10.0000	ROT WEIGHT	38.900
BHP	0.00	COMP RATIO	0.0000	ENGINEER	"M M VOGLER
CYLINDERS	5	C/L C/L LGT	23.0000	DATE	DEC 08, 85
RAD.CLEAR	0.0049	VISCOS(MREYNS)	3.2934	SHAFT DIA	7.9950
EFFEC. LTH	1.1563	OIL GRADE(4)		BRG GRV	(8)360-DEG
		OIL PRESSURE	35.00		
		OIL TEMP	170.00		

A MAXIMUM OIL FILM PRESSURE OF 17850 PSI

OCCURS AT A CRANK ANGLE OF 260 DEGREES
WITH AN ANGLE RELATIVE TO THE BEARING OF 174 DEGREES
AND AN ANGLE RELATIVE TO THE JOURNAL OF 274 DEGREES
THE LOAD AT THIS POINT IS 32545 POUNDS
ACTING AT AN ANGLE OF 168.6 DEGREES

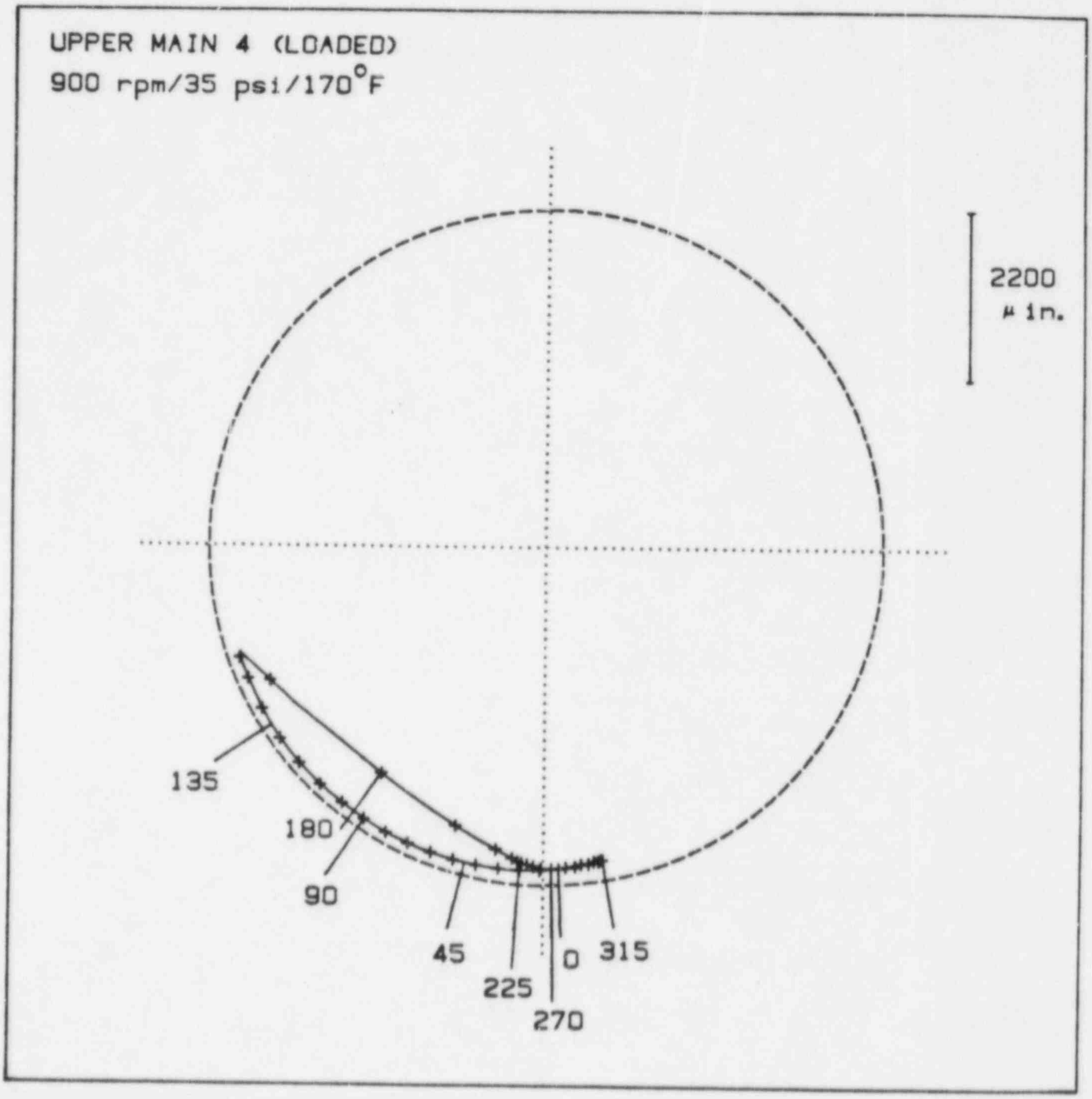
THE MEAN OIL FILM PRESSURE IS 7240 PSI

A MINIMUM OIL FILM THICKNESS OF .000133 INCHES

OCCURS AT A CRANK ANGLE OF 128 DEGREES
WITH AN ANGLE RELATIVE TO THE BEARING OF 233 DEGREES
AND AN ANGLE RELATIVE TO THE JOURNAL OF 105 DEGREES
THE LOAD AT THIS POINT IS 4945 POUNDS
ACTING AT AN ANGLE OF 243.9 DEGREES

THE ECCENTRICITY RATIO AT THIS POINT IS 0.97283

THE MEAN OIL FILM THICKNESS IS .000246 INCHES


UPPER MAIN 4 (LOADED)
900 rpm/35 psi/170°F
2200
μ in.
135
180
90
45
225
0
315
270

ENGINE BEARINGS

CONCLUSION FOR FAIRBANKS-MORSE DIESELS
AT FERMI II

o BEARING STRESSES DUE TO PEAK OIL FILM PRESSURE ARE SAFELY WITHIN CAPABILITY OF ALUMINUM - 6% TIN BEARINGS.

P.O.F.P. CAPABILITY = 25000 PSI

o OIL FILM THICKNESSES ARE

- GENEROUS IN CONNECTING ROD
- ACCEPTABLE IN MAIN BEARINGS

FOR TYPICAL MEDIUM SPEED DIESEL ENGINES

<u>OTHER CAUSE</u>

BEARING SCORING MOST LIKELY OCCURS

- WITH A NEWLY LAPPED JOURNAL AND NEW BEARINGS PRIOR TO SHAFT SEASONING

- LOW OCCURRENCE PROBABILITY

SUMMARY

FAILED BEARINGS

EDG 11	INADEQUATE LUBE ALIGNMENT
EDG 12	INADEQUATE LUBE BEARING CONTACT
EDG 13	MISASSEMBLY

WORN BEARINGS (VISUAL INSPECTION)

EDG 11	ALIGNMENT
EDG 12	BEARING CONTACT
EDG 13	FOREIGN MATERIAL BEARING CONTACT
EDG 14	TRACE BEARING CONTACT

CORRECTIVE ACTION

- o REPLACED FAILED AND SCORED BEARINGS EXCEPT 3 ON EDG 14 (TRACE)
- o CONTINUE OIL SAMPLING PROGRAM
- o ELIMINATE OIL FILTER SAMPLING PROGRAM
- o FLUSH EDG'S 11 AND 13 WHICH EXPERIENCED BEARING FAILURES
- o CHANGE OIL TO MOBIL (ONE DIVISION)
- o SEASON BEARINGS FOLLOWING REPLACEMENT
- o MINIMIZE DISASSEMBLY
- o CONTINUE REQUIRED SURVEILLANCES
- o GAP CHECK BEARINGS EVERY 6 MONTHS
- o PROCEED WITH BATTELLE LABS ANALYSIS OF BEARINGS
- o RESOLVE EDG 12 OIL VISCOSITY PROBLEM
- o CONDUCT A RELIABILITY DEMONSTRATION
    - o SIMULATE A FUEL CYCLE
    - o 100 HOURS SEASONING RUN
    - o 20 SLOW STARTS
    - o 10 FAST STARTS
    - o RUN FOR 7 DAYS (168 HOURS)

SCHEDULE

ALL EDG WORK AND TESTING TO BE COMPLETED BY FEBRUARY 19, 1986

COLT'S POSITION

1. Long storage time (1975 - 1982) 7 years.

2. Galvanic action as shown by Technimet report.

3. Bearings were subjected to large number of fast starts (with quantity not pre-lubed) prior to bearings being conditioned to crankshaft.

4. As a result of the failures in Unit #11 in January 1985, all units were subjected to disassembly and replacement of bearings in Unit #12.

5. Units #13 & 14 - The upper bearings in position 1 thru 6 were removed, visually accepted and re-assembled. All bearings inspected were good.

6. Unit #13 failed #3 upper conn rod bearing due to improper re-assembly. As noted in brinnelling of cap & rod fits.

7. DECO & NRC decided to disassemble all engines to visually inspect bearings.

   a) Problem - Any disassembly of engine bearings places jeopardy on proper re-assembly.

   b) DECO/NRC replaced bearings against Colt's recommendation. Example - #14 unit upper main bearings. No problems until bearings were replaced.

   c) Opening crankshaft/bearing assembly introduces debris into bearings - As noted in #4 & 7 main bearings on #13 unit.

8. Colt recommends immediate stop to disassembling components for visual inspection of bearing surfaces. Inspect bearings with feeler gauge check only.

9. Correct problem with lube oil dilution on Unit #12 & 14.

10. Run engine per:

    a) Extended wear in - 40 hours
    b) Continuous load - 2500/2600 kw - 100 hours
    c) Check bearings w/feeler gauge
    d) Run NRC qualification tests
    e) Re-check bearings with feeler gauge.

SUMMARY

- o USE PROVEN SIESELS
- o EXTENSIVE DIESEL SURVEILLANCE PROGRAM
- o HAD SOME BEARING PROBLEMS AND SURFACE INDICATIONS
- o IDENTIFIED CAUSES (MISALIGNMENT, STORAGE, MISASSEMBLY, LACK OF PRELUBE, PARTICULATES
- o TAKING APPROPRIATE CORRECTIVE ACTIONS (ALIGNED, CONDITIONING, REASSEMBLED, PRELUBE, FLUSHED)
- o IMPLEMENTED SLOW START CAPABILITY
- o BELIEVE DIESELS WILL RELIABLY START AND OPERATE WHEN CALLED UPON
- o PLAN TO RESTART ABOUT 2/19 AND NEED TO IDENTIFY REGULATORY PROCESS SO THAT OUR ACTION SUPPORT TIME FRAME

Enclosure 3

Chronology of Bearing Replacements

In January, 1985, EDG 11 tripped on low oil pressure and high crankcase pressure. Detroit Edison identified problems with the upper crankshaft bearings. Detroit Edison replaced the upper crankshaft and a total of 14 main bearings and 12 connecting rod bearings in EDG 11:

EDG 11-January, 1985

Bearings Replaced Due To Failure	
Upper Main Bearings:	Nos. 1,2,3,4,5,6
Upper Connecting Rod Bearings:	Nos. 1,2,3,4,5,6
Bearings Replaced Due to Surface Scoring	
None	
Bearings Replaced for Other Reasons	
Upper Main Bearings:	Nos. 7,8, 9,10,11,12,13,14
Upper Connecting Rod Bearings:	Nos. 7,8,9,10,11,12

To determine root cause of the problem and the extent of the damage, Detroit Edison also examined the bearings of EDGs 12, 13, and 14. Detroit Edison replaced a total of 14 main bearings and 12 connecting rod bearings in EDG 12:

EDG 12-January, 1985

Bearings Replaced Due To Failure	
Upper Main Bearings:	Nos. 1,2,3,7,8
Bearings Replaced Due to Surface Scoring	
Upper Connecting Rod Bearings:	Nos. 1,2,3
Bearings Replaced for Other Reasons	
Upper Main Bearings:	Nos. 4,5,6,9,10,11,12,13 14
Upper Connecting Rod Bearings:	Nos. 4,5,6,7,8,9,10, 11,12

Detroit Edison also replaced one connecting rod bearing in EDG 13:

EDG 13-January, 1985

Bearings Replaced Due To Failure
None
Bearings Replaced Due to Surface Scoring
None

Bearings Replaced for Other Reasons
  Lower Connecting Rod Bearing: No. 5

One upper main bearing was replaced in EDG 14:

<u>EDG 14-January, 1985</u>
Bearings Replaced Due To Failure
  None
Bearings Replaced Due to Surface Scoring
  None
Bearings Replaced for Other Reasons
  Upper Main Bearing: No. 6

The apparent cause of the bearing failures in EDGs 11 and 12 was determined to be inadequate lubrication during repeated fast starts.

Following this repair, Detroit Edison performed the vendor-recommended bearing break-in procedure, in addition to a 40-hour seasoning run. Corrective actions were documented in detail in earlier reports to the NRC (References 1-5). The Fermi-2 EDGs completed this demonstration successfully in March, 1985.

In November, 1985, EDG 13 was manually tripped when operators heard unusual noises from the EDG. Detroit Edison examined EDG 13 and determined that one of the upper main bearings and upper connecting rod bearings had failed. Detroit Edison elected to replace the upper crankshaft and all upper main bearings. Detroit Edison replaced a total of 22 main bearings and 13 connecting rod bearings in EDG 13:

<u>EDG 13-November, 1985</u>
Bearings Replaced Due To Failure
  Upper Main Bearings: No. 3
  Lower Main Bearings: No. 4
  Upper Connecting Rod Bearings: No. 3
Bearings Replaced Due to Surface Scoring
  Upper Main Bearing: No. 13
Bearings Replaced for Other Reasons
  Upper Main Bearings: Nos. 1,2,4,5,6,7,8,9,10,11,12,14
  Lower Main Bearings: Nos. 2,5,6,7,8,10,13
  Upper Connecting Rod Bearings: Nos. 1,2,4,5,6,7,8,9,10,11,12

Lower Connecting Rod Bearings:	No. 3

Detroit Edison's investigation of the #3 connecting rod and main bearing failure is provided in Enclosure 4. The other bearings replaced were replaced to eliminate any questions about their integrity. The #4 lower main bearing had failed the gap check; however, it was performing its intended function. The bearing did reflect surface distress that was well healed.

Following a demonstration test run of EDG 13 in December 1985, visual inspection of the upper crankline revealed three bearings with questionable surface conditions. Detroit Edison replaced a total of 4 main bearings in EDG 13:

<u>EDG 13-Late December, 1985</u>

Bearings Replaced Due To Failure	
None	
Bearings Replaced Due to Surface Scoring	
Upper Main Bearings:	Nos. 3,7,13
Bearings Replaced for Other Reasons	
Upper Main Bearing:	No. 4

Surface scoring of upper main bearings 3 and 7 is attributed to foreign material in the lube oil. Detroit Edison considers both the damaged bearings and the extensive repairs performed earlier to be the most likely source of the foreign material introduced into the lube oil system.

When the scored bearings in EDG 13 were initially found, Detroit Edison inspected all upper and lower bearings of EDG 14. No scoring was found. Nonetheless, Detroit Edison elected to replace all of the upper crankline bearings in EDG 14 to eliminate concerns related to the gray, matted surface appearance of several bearings. Detroit Edison replaced a total of 14 main bearings and 14 connecting rod bearings in EDG 14:

<u>EDG 14-December, 1985</u>

Bearings Replaced Due To Failure	
None	
Bearings Replaced Due to Surface Scoring	
None	
Bearings Replaced for Other Reasons	
Upper Main Bearings:	Nos. 1 through 14
Upper Connecting Rod Bearings:	Nos. 1 through 12

Lower Connecting Rod Bearings:	Nos. 2,6

Because of the findings in EDG 13, Detroit Edison elected to inspect the bearings of EDGs 11 and 12 (which are the Division I EDGs). Detroit Edison replaced a total of nine main bearings and one connecting rod bearing in EDG 12:

<u>EDG 12-December, 1985</u>

Bearings Replaced Due To Failure	
None	
Bearings Replaced Due to Surface Scoring	
Upper Main Bearings:	Nos. 5,6,13
Lower Main Bearing:	No. 6,13
Bearings Replaced for Other Reasons	
Upper Main Bearings:	No. 14
Lower Main Bearings:	Nos. 1,3,5
Upper Connecting Rod Bearing:	No. 3

When EDG 11 was opened in early December, Detroit Edison found questionable surface conditions on six bearings, and elected to replace all upper main bearings. Detroit Edison replaced a total of 16 main bearings and 1 connecting rod bearing in EDG 11:

<u>EDG 11-December, 1985</u>

Bearings Replaced Due To Failure	
None	
Bearings Replaced Due to Surface Scoring	
Upper Main Bearings:	Nos. 3,5,6,8,9,13
Lower Main Bearing:	No. 13
Bearings Replaced for Other Reasons	
Upper Main Bearings:	No. 1,2,4,7,10,11,12, 14
Lower Main Bearings:	No. 1
Lower Connecting Rod Bearing:	No. 4

During the process of returning EDG 11 to service, two bearings failed. Subsequent investigation revealed an undesirable upper crankshaft bearing cap alignment pattern. Detroit Edison replaced a total of 5 main bearings and four connecting rod bearings, and performed a detailed realignment of bearing caps.

<u>EDG 11, Late December, 1985</u>

Bearings Replaced Due To Failure	
Upper Main Bearings:	Nos. 5,6
Bearings Replaced Due to Surface Scoring	
Upper Main Bearings:	Nos. 3,13
Upper Connecting Rod Bearing:	No. 6
Bearings Replaced for Other Reasons	
Upper Main Bearings:	No. 7
Upper Connecting Rod Bearings:	Nos. 3,4,5

Since December, 1985, there have been no further bearing replacements on any of the EDGs.

Additional Information on the Failure of EDG 13 No. 3 Main and Connecting Rod Bearings

In a conference call on February 21, the NRC staff requested additional information about the failure of the No. 3 main and connecting rod bearings in EDG 13 which occurred in November, 1985. The additional information, describing Edison's evaluation and determination of root cause, is provided below.

In January 1985 the EDG-13 #3 main and connecting rods were disassembled for visual inspection. The #3 main and connecting rod bearings were found to be in satisfactory condition. No abnormal conditions such as fretting was observed on the connecting rod cap surfaces. The most severe duty on the bearing occurred before this inspection, yet the the bearing was found to be in good condition. Before the visual inspection, the bearing had been subjected to 25 prelubed starts, 78 wet starts, 56 booster no-prelube starts, 159 total starts, 214 total run hours and an average of 1.3 hours per start.

There were no indications of overheating on the connecting rod or connecting rod bearing cap. In contrast the connecting rod failures found on EDG 11 in January 1985 showed signs of high temperature. Edison concluded that there was substantial oil flow present and that the failure was not accompanied by high temperatures and was not related to inadequate lubrication.

Examination of the bearing fragments found in the engine did not indicate that they had experienced melting, which would have resulted if high temperatures had been present. The fragments appeared to have undergone some degree of cold forming from the hammering effect of the failure. Testing has also indicated that the hardness of the bearing material had not changed, another indication that high temperatures were not present. This is further evidence that the connecting rod bearing did not fail as a results of inadequate lubrication.

Fretting was observed on the mating surfaces of the connecting rod and cap as well as on the cap nut faces. Fretting of this nature was not observed on any other failure, especially with the three connecting rod bearings that failed on EDG 11 in January 1985. Edison concluded that fretting normally should not be expected when a connecting rod bearing fails. The fretting indicates relative movement between the connecting rod and cap and indicates that either the cap was not clamped as tight as it should have been or that the failure of the bearing caused the relative movement.

None of the bearing fragments found were larger than the size of a half dollar. No fragments were found in the journal area. In contrast, significant pieces of smeared bearing material were found in the January 1985 EDG 11 connecting rod journals, though the bearing failures allowed the pistons to withdraw from the cylinder liners beyond the first piston ring. The relatively small size bearing fragments associated with this failure indicate a fatigue failure, rather than failure from a lack of lubrication.

In conclusion, Edison considers the following points to be particularly significant:

- The bearing was functioning properly prior to the January 1985 visual inspection,
- The bearing was worked on in January 1985,
- There were no signs of excessive temperatures,
- There was movement of the bearing cap relative to connecting rod
- The bearing failure was a fatigue failure rather than a failure due to the lack of lubrication.

It is concluded that the connecting rod bearing failed due to fatigue. The above information suggests that the fatigue resulted from an inadequate clamp on the bearing cap. The root cause, however, could not be determined conclusively from inspection of the failed components.

The #3 main bearing failed as a result of the #3 connecting rod bearing failure. When the #3 connecting rod bearing failed it allowed the lube oil to bypass directly to the crankcase. The bypass flow reduced the pressure in the main bearing cavity to such an extent that oil was no longer being fed to the bearing surfaces in adequate quantity. With inadequate lubrication to the bearing faces, the #3 main bearing failed.

After this failure, all upper and lower crankline bearings were visually inspected and no other indication of fatigue failure was found. The Demonstration Test Program reconfirmed the reliability of all EDG bearings.

Endorsements of Fermi-2
Emergency Diesel Generator Crankshaft Bearing
Reliability Demonstration Test Program
by Colt Industries and Failure Analysis Associates

1. Memorandum from C. Ankrum to Ed Greene, Colt Industries, Fairbanks Morse Engine Division, "Detroit Edison 205981 Contract, Special Engine Run-In Procedure", dated January 30, 1986.

2. Letter from Dr. L. Swanger, Failure Analysis Associates, to Mr. J. Nyquist, Detroit Edison, "Fairbanks Morse Diesel Engine, FaAA Case No. WDC17064", dated January 31, 1986.

3. Letter from E. D. Greene, Colt Industries, Fairbanks Morse Engine Division, to Mr. J. Nyquist, Detroit Edison, "Bearing Inspection - Detroit Edison EDG #11 and #13", dated February 26, 1986.

Engine Division
701 Lawton Avenue
Beloit, Wisconsin 53511
608/364-4411

Interoffice

To: Ed Greene

From: C. Ankrum

Subject: Detroit Edison 205981 Contract
Special Engine Run-in Procedure

Date: January 30, 1986

This memo is to confirm our verbal agreement with Detroit Edison to formalize the special run-in procedure recommended for the engines at the Enrico Fermi II plant.

All engines are to be run-in per the standard Fairbanks Morse Service Information letter Volume A, issue 5, sheet 1 through 3, dated August 13, 1985. Use the column for 900 rpm engine speed referenced in sheet 3. The 110% overload run will not be required.

Upon completion of bearing inspection by feeler gauge after engine run-in, the engine will be subjected to the following continuous runs:

a) 40 hours @ 2000-2200 kw.
b) 100 hours @ 2500-2600 kw.

Upon completion of the 100 hour run, a bearing inspection is to be made with feeler gauge. If units #12 and 14 pass this inspection, these units may be returned to service.

It was agreed in the meeting with DECO/NRC/Colt on January 24, 1985, that units #11 and 13 were to receive additional testing per the following:

a) 20 slow starts
b) 10 fast starts
c) 168 hour continuous run at 2500-2600 kw.

At the completion of these tests, the bearings are to be inspected by feeler gauge and if acceptable, the units can be returned to service. If at any point, a conn rod or main bearing fail the feeler gauge check, only that bearing and the bearing connected by the oil passage in the crankshaft are to be removed for rework. No other bearings are to be disassembled. After rework, the engine should be subjected to the full re-run as originally specified.

All scheduled starts, including the fast starts, the engines are to be pre-lubed prior to starting per previous agreement and Detroit Edison procedures.

After engines are returned to service, it is understood that for all future surveillance testing, the engines will be slow started and pre-lubed.

Utilizing the above procedures should provide the best assurance the engines will meet future demands of their intended service.

CAA:n
cc: P. Brown
T. Skinner G. Slaymaker T. Miller

Failure Analysis Associates

ENGINEERING AND METALLURGICAL CONSULTANTS
1100 SOUTH WASHINGTON STREET
ALEXANDRIA, VIRGINIA 22314 (703) 683-5550

January 31, 1986

Mr. John Nyquist
Detroit Edison Co.
Fermi II Nuclear Power Plant
6400 North Dixie Highway
Newport, MI 48166

Re: Fairbanks Morse Diesel Engine
FaAA Case No. WDC17064

Dear Mr. Nyquist:

Following up on questions asked by the NRC staff on January 24, 1986, I have the following observations and comments.

The demonstrations planned for EDG 13 and either EDG 11 or EDG 12 will be fair tests of the availability of the Fairbanks Morse diesels during an 18-month refueling cycle at Fermi II. Use of the .002 in. gap check to detect loss of free spread on the upper crank line main bearings is an appropriate acceptance criteria for this test. The loss of free spread that is revealed by a gap check failure is due to the non-uniform heating of the bearing's inner surface by friction after interruption of the hydrodynamic oil film. The thermal stresses cause the inner surface to yield in compression, creating a residual stress state that pulls the bearing parting lines in toward the crankshaft after cool-down.

Interruption of the oil film is caused by substantial transfer of aluminum from the bearings to the crankshaft, creating geometric deviations so large that hydrodynamic lubrication can no longer be developed.

Transfer of aluminum from the bearing to the shaft can occur in an amount low enough to avoid disruption of the oil film, but still cause some pitting or surface scoring of the bearing where aluminum is removed from its surface.

Considering the case where surface scoring has occurred, but not of sufficient intensity to disrupt the oil film and reduce free spread (i.e., cause gap check failure), the future reliability of such a bearing/journal pair is of concern to the NRC staff. Even in the presence of surface scoring, the retention of free spread (i.e., passing the gap check) shows that a hydrodynamic oil film continues to separate the bearing and journal, preventing a high friction, high temperature failure. The resulting oil film will be thinner than the oil film in a bearing without surface scoring, making the bearing more sensitive to oil-borne particulates, subsequent fast starts, or excursions in operating conditions. However, the surface scoring is not an inevitable precursor to failure as conservatively defined by the gap check.

At Fermi II, there has been evidence of recovery from the condition of surface scoring. Through the processes of normal wear and plastic flow of the bearing material, healing of scored bearings can occur and has been observed, e.g., EDG 13, lower crankshaft #4 main bearing. If every bearing survives the planned demonstration without failing the gap check, then the future availability of the diesels is reasonably assured with respect to bearing problems. The incorporation of the seven-day run at the end of the start cycles would allow even bearings that hypothetically had suffered surface scoring to begin the recovery process.

The upcoming demonstrations will show the benefit of "seasoning" crankshaft journals. The reported surface finish of a "seasoned" journal versus a freshly lapped journal decreases the probability of harmful bearing-to-journal contact and excessive transfer of aluminum to the journal.

Very truly yours,

Lee A. Swanger, Ph.D., P.E.
Mechanical & Metallurgical Engineer
Director, Washington Office

LAS2/MSW/L-FermiWDC17064

Colt Industries

Fairbanks Morse
Engine Division
701 Lawton Avenue
Beloit, Wisconsin 53511-5492
Telephone: 608/364-4411
Telecopier: 608/364-0382

Via Telecopier #313/586-5295

February 26, 1986
948-1679/86

Mr. John Nyquist
Detroit Edison
6400 N. Dixie Highway
Newport, MI 48166

Subject: Bearing Inspection
Detroit Edison EDG #11 & 13

Dear John,

We are submitting our letter from C.A. Ankrum, Engineering Department, reaffirming Colt's position on bearing inspection after the extended run-in on unit #11 and 13 has been completed.

For the reasons we discussed during several meetings with Detroit Edison and the NRC; most recently during a joint meeting on 2/14/86 in Glen Ellyn, Illinois, we feel that disassembly of the engine after proving its capabilities during the endurance running will not be of benefit and, in fact, creates the possibility of reduced reliability due to the opportunity for introduction of foreign material and/or disturbing the geometry of running bearing surfaces when hold down torque is removed and subsequently re-applied.

Our submittal dated 2/18/86 was considered a compromise position in lieu of complete upper crankline disassembly as requested by the NRC. If the NRC wishes to extend the inspection procedure we request that they submit their proposal in writing.

Very truly yours,

COLT INDUSTRIES OPERATING CORP.
FAIRBANKS MORSE ENGINE DIVISION

E. D. Greene

Ed D. Greene, Supervisor
Product Service Department

EDG/lm

Enclosure

cc: C. Ankrum
T. Skinner

Colt Industries

Fairbanks Morse
Engine Division
701 Lawton Avenue
Beloit, Wisconsin 53511
608/364-4411

Interoffice

To: Ed Greene

From: C. A. Ankrum

Subject: Bearing Inspection
Detroit Edison

Date: February 25, 1986

Ref: a) C. Ankrum memo to Ed Greene dated 2/17/86
b) Telecon - John Nyquist to C. Ankrum dated 2/25/86

Per reference (b), Detroit Edison requests that Colt clarify our position again on bearing inspection for the Unit #11 & 13 after extended tests.

The reference (a) memo was written as an alternative to break the deadlock between Colt's position to inspect bearings by .002" feeler gauge vs the NRC position that they want the bearings removed for visual inspection. It was only to give them some correlation between the feeler gauge check and visual inspection.

This memo is to restate (again) Colt's position that the engine should not be disassembled for visual bearing inspection. The satisfactory completion of the extended tests adequately insure the bearing are in serviceable condition. Disassembly and reassembly can only diminish the present condition.

John asked if you would relay this to him right away.

CAA:n

cc: P. Brown
T. Skinner
G. Slaymaker
T. Miller