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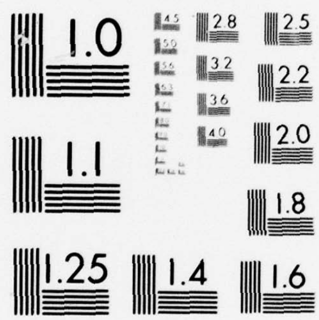


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# EXTENDED OIL-CHANGE AND OIL-FILTER-CHANGE INTERVALS FOR DOD 5- TO 200-KILOWATT DED GENERATOR SETS

By

Chester R. Gurski

Ernest Fitzgibbons

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The in-house investigation described was to determine whether the industry- and military-standard oil-change interval of 100 hours could be extended for the DOD Family of Diesel Engine Driven Generator Sets using MIL-L-2104C specification lubricating oil. The investigation was conducted in two phases. In Phase I, the oil and filter were changed each 100 hours in accordance with the servicing and maintenance guide specified for the preproduction model 5,000-hour reliability and acceptance tests. In Phase II, the oil-change and filter-change intervals were established by the condition of the oil. The condition of the oil was monitored by


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chemical and spectrometric analyses. Based on the test results and the urgency of the current energy crisis, the Project Manager, Mobile Electric Power, issued an oil-change policy for the 15- through 200-kW size generator sets directing that the oil and oil filters be changed each 300 hours of engine running (normal running conditions) or after 6 months whichever comes first. It is conservatively estimated that a savings in excess of $1.7 million a year can be realized by the military with the implementation of this directive for generator sets alone.

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## SUMMARY

Since July 1972, MERADCOM has been conducting an in-house, two-phase test program to determine whether the industry and military-standard, engine-oil-change interval of 100 hours could be extended for the DOD Family of Diesel Engine Driven (DED) Generator Sets using Specification MIL-L-2104C lubricating oil.

Under Phase I of the program, a total of 54,392 hours of engine running was accumulated on 13 *preproduction* model generator sets that included seven different models of diesel engines. Chemical and spectrometric data, obtained from analyses of oil samples that were taken at regular 100-hour intervals, were plotted for baseline reference.

Phase II of the program was initiated in February 1974 and included eight *production* model generator sets utilizing four different diesel engine models. The major difference between Phase I and II was in the oil-change and oil-filter-change intervals. Under Phase I, the oil and the oil filter were required to be changed each 100 hours in accordance with the servicing and maintenance guide applicable to the preproduction model, 5000-hour reliability and acceptance test. Under Phase II, the oil and the oil filter were changed only when required as indicated by the condition of the oil based on oil-sample analyses. A total of 22,138 hours of engine operations was accumulated. Repeatable oil-change and oil-filter-change intervals of 700 hours on each of the 15- and 30-kilowatt sets, 600 hours on each of the 60-kilowatt sets, and 1000 hours on each of the 100-kilowatt sets were obtained. Included also under Phase II were 1851 hours of "Extreme-Temperature" and "Stand-by, Low-Usage" operations on each of the 60- and 100-kilowatt sets. There was no variation in analyses data noted in oil samples taken during these operations as compared to the patterns previously established under normal, ambient conditions. Following completion of all engine running, several engines were disassembled, and critical parts were examined on a "one-to-one" basis, i.e., Phase I vs Phase II of like models. The examinations revealed no major differences in the wear patterns on parts.

Based on the test results and the urgency of the current energy crisis, the Project Manager, Mobile Electric Power, issued a new oil-change policy, effective date, 20 January 1976, directing that the oil and the oil filters be changed each 300 hours of engine running or after each 6 months, whichever occurs first, for all DOD Diesel Engine Driven Generator Sets in the 15- through 200-kilowatt range when operating under normal running conditions. It is conservatively estimated that a savings in excess of $1.7 million a year can be realized by the military with the implementation of this directive. This does not include the man-hours that will be saved in servicing, stocking, and handling.

# PREFACE

Chester R. Gurski and Ernest Fitzgibbons, Support Equipment Group, Engineering Division, Electrical Power Laboratory, MERADCOM, compiled this final report.

John W. Dreger, the Project Engineer, prepared the interim report, MERDC 2153, dated August 1975, and coordinated the findings with Colonel R. H. Sievers, Jr., DOD Project Manager, Mobile Electric Power, AMC (DARCOM).

The analysis and interpretation of the oil sample data were performed by Sidney Levine and Basil Zanedis. The chemical and wear-metal analyses were performed by SP4 R. T. Wood, J. Bennett, and N. H. Arshad, Material Technology Laboratory, MERADCOM.

The computer programing and printout graphs were compiled by Dorothine Murphy, Mathematical and Computer Sicence Division, MERADCOM.

The inspections and the evaluation of wear patterns on critical engine parts were made by Thomas C. Bowen, Energy and Water Resources Laboratory, Fuels and Lubricants Division, MERADCOM.

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## ILLUSTRATIONS



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# EXTENDED OIL-CHANGE AND OIL-FILTER-CHANGE INTERVALS FOR DOD 5- TO 200-KILOWATT DED GENERATOR SETS

## I. INTRODUCTION

1. **Statement of the Purpose.** The purpose of this controlled test program was to determine an optimum oil-change and oil-filter-change interval, using Military Specification MIL-C-2104C lubricating oil, that would not adversely affect the reliability or total life cycle of engines in the DOD Family of Diesel Engine Driven (DED) Generator Sets.

2. **Background.** At the request of the DOD Project Manager, Mobile Electric Power (PM-MEP), in May 1972, a two-phase test program was formulated and subsequently approved. The program included both preproduction- and production-model sets of the DOD, diesel engine driven generator family currently being procured. Phase I of the program was made a part of the scheduled 5000-hour reliability and acceptance tests required by contract for the preproduction-model generator sets and included 13 sets which used 7 different models of engines. A baseline of reference was developed from the oil analyses data based on the specified 100-hour oil-change and oil-filter-change intervals.

Initially, Phase II of the program was to include two production-model DOD sets of each size ranging from 5 through 200 kilowatts. Each set was to run 5000 hours at normal, ambient temperature with oil changes being dictated by the condition of the oil as determined by chemical and spectrometric analyses of oil samples taken at specified intervals during set operations. However, during the course of the program, changes were made in the schedule, i.e., the 5000 hours of operation was reduced to 3000 hours and "extreme temperature" and "stand-by, low-usage" operations were added for the 60- and 100-kilowatt sets. Also, no testing was accomplished on either the 5- or 10-kW sets because of the long leadtime for delivery, and the 200-kW sets were not tested because the engine manufacturer had proposed making major changes to this series of engines for all future production.

## II. PROCEDURE

3. **Approach.**

a. **Phase I.** Phase I was conducted from July 1972 through December 1973. Thirteen preproduction-model DOD generator sets of varied sizes powered by seven different models of diesel engines were subjected to long-term endurance running

(2200/5278 hours) at normal, ambient temperatures. Tests were conducted by the U.S. Army Mobility Equipment Research and Development Command (MERADCOM), Fort Belvoir, Virginia, and by the Test and Evaluation Command (TECOM), Aberdeen Proving Ground, Aberdeen, Maryland.

b. **Phase II**. Phase II was conducted from February 1974 through December 1976. Eight production-model DOD generator sets of four sizes powered by four different models of diesel engines were subjected to long-term endurance running (1465/3578 hours) at normal, ambient temperatures. In addition, two different size sets were subjected to 300 hours operation at +125° F ambient temperature, and two other sets were subjected to "stand-by, low-usage" type operations that consisted of running at variable loads for 1 hour in every 8 hours for 350 hours. All of the testing was conducted at MERADCOM or at a commercial facility – General Environments Corporation, Hartwood, Virginia.

c. **Test Units and Test Time**. The types and sizes of the generator sets, the makes and models of the diesel engines powering each set, the type of running, and the accumulated number of hours for each set are included in Table 1 for Phase I and Table 2 for Phase II.

Table 1. Phase I – Preproduction-Model DOD Generator Sets

| Power (kW) | Frequency (Hz) | Set Serial Number | Engine Model | Test Mode | Hours |
|---|---|---|---|---|---|
| 5 | 60 | 359821 | Onan DJE 99E | Norm Amb | 5,048 |
| 10 | 60 | 359823 | Onan DJF 99E | Norm Amb | 4,984 |
| 15 | 60 | RZ-00001 | Hercules D198ER | Norm Amb | 2,500 |
| 15 | 400 | RZ-10012 | Hercules D198ER | Norm Amb | 2,917 |
| 30 | 60 | RZ-30002 | Hercules D298ER | Norm Amb | 2,200 |
| 30 | 400 | RZ-40002 | Hercules D298ER | Norm Amb | 2,824 |
| 60 | 60 | 2001 | Allis Chalmers 3500 | Norm Amb | 5,118 |
| 60 | 60 | 2003 | Allis Chalmers 3500 | Norm Amb | 5,115 |
| 60 | 400 | 6002 | Allis Chalmers 3500 | Norm Amb | 5,101 |
| 100 | 60 | 4302-001 | Caterpillar D-333T | Norm Amb | 5,278 |
| 100 | 60 | 4302-002 | Caterpillar D-333T | Norm Amb | 5,200 |
| 200 | 60 | 4305-001 | Caterpillar D-343T/A | Norm Amb | 4,275 |
| 200 | 60 | 4305-004 | Caterpillar D-343T/A | Norm Amb | 3,832 |
| | | | | Total Hours | 54,392 |

Table 2. Phase II – Production-Model DOD Generator Sets

| Power (kW) | Frequency (Hz) | Set Serial Number | Engine Model | Test Mode | Hours |
|---|---|---|---|---|---|
| 15* | 60 | RZ-00001 | Hercules D198ER | Norm Amb | 2,341 |
| 15** | 400 | RZ-10012 | Hercules D198ER | Norm Amb | 2,089 |
| 30* | 60 | TZ-30002 | Hercules D298ER | Norm Amb | 1,465 |
| 30** | 400 | RZ-40002 | Hercules D298ER | Norm Amb | 1,708 |
| 60 | 60 | FZ-00455 | Allis Chalmers 3500 | Norm Amb | 3,315 |
| | | | | +125°F Temp | 302 |
| 60 | 400 | FZ-06024 | Allis Chalmers 3500 | Norm Amb | 3,348 |
| | | | | Stand-by, Low-Usage | 352 |
| 100 | 60 | UZ-00001 | Caterpillar D333T | Norm Amb | 3,578 |
| | | | | +125° Temp | 300 |
| 100 | 60 | UZ-02008 | Caterpillar D333T | Norm Amb | 3,001 |
| | | | | Stand-by, Low-Usage | 339 |
| | | | | Total Hours | 22,138 |

* Preproduction-model generator set with new engine installed.
** Original preproduction-model generator set.

**4. Description of Test Program.**

a. **Phase I**. Phase I consisted of performing both a chemical and a spectrometric analysis of oil samples taken at the regularly scheduled, 100-hour oil-change and oil-filter-change intervals during the entire reliability endurance test program for preproduction-model DOD generator sets. The endurance reliability test was a contractual requirement contingent on the release of each set for further production. All engine maintenance and servicing were performed as specified for the endurance reliability program.

b. **Phase II.** Phase II consisted of running new production model DOD generator sets, except as shown in Table 2, with the oil change and oil-filter change being performed only as the data from the chemical and spectrometric oil analyses required. The oil analyses were performed within 24 hours after the oil samples were taken from the engines; therefore, there were no delays that could possibly jeopardize the results of the program. There were over 520 chemical and 2080 spectrometric analyses made on oil samples taken during testing. All other engine and generator set maintenance and servicing were performed in accordance with the technical manuals applicable to each size set.

c. **Receiving Inspection.** A visual inspection of each production-model generator set was made, and the sets were found to be in satisfactory, "as new" condition with only a very few hours registered on the time meters. The oil, oil filters, and fuel filters were changed on each set. A logbook, initiated for each set, contained all the identification information, i.e., set type; size; serial number; manufacturer; engine make, model, and serial number; dates of manufacture; location of test site; and operating hours registered at time of delivery of the set. The logbooks include a continuing account of set operations, servicing, and maintenance performed; failures; and all other instances relative to successful operation. Notations were included regarding fuel type and sulfur content, lubricating oil specification including bulk batch-lot number, fuel and oil consumption, and when an oil sample was taken.

d. **Preparation of Sets for Test.** The generator sets were prepared for operation in accordance with the procedures contained in the applicable DOD generator technical manuals as listed in Table 3. An external fuel-supply line was connected to the set auxiliary fuel pump.

Table 3. Technical Manuals Used for Generator Preparation

| Set | Model Number | TM Number |
|---|---|---|
| 15 kW, 60 Hz | MEP-004A (T.U.)[1] | TM 5-6115-464-12 |
| 15 kW, 400 Hz | MEP-113A (T.P.)[2] | TM 5-6115-464-12 |
| 30 kW, 60 Hz | MEP-005A (T.U.) | TM 5-6115-465-12 |
| 30 kW, 400 Hz | MEP-114A (T.P.) | TM 5-6115-465-12 |
| 60 kW, 60 Hz | MEP-006A (T.U.) | TM 5-6115-545-12 |
| 60 kW, 400 Hz | MEP-115A (T.P.) | TM 5-6115-545-12 |
| 100 kW, 60 Hz | MEP-007A (T.U.) | TM 5-6115-457-12 |
| 100 kW, 60 Hz | MEP-106A (T.P.) | TM 5-6115-457-12 |

1. T.U. – Tactical Utility
2. T.P. – Tactical Precise

An oil-sampling valve with the necessary plumbing was installed on each engine in the lube gallery to provide a means for taking oil samples as required during the course of the endurance test. The installation of the oil-sampling valve can be seen in Figure 1.

e. **Instrumentation.** Various temperature, pressure, and electrical parameters were measured.

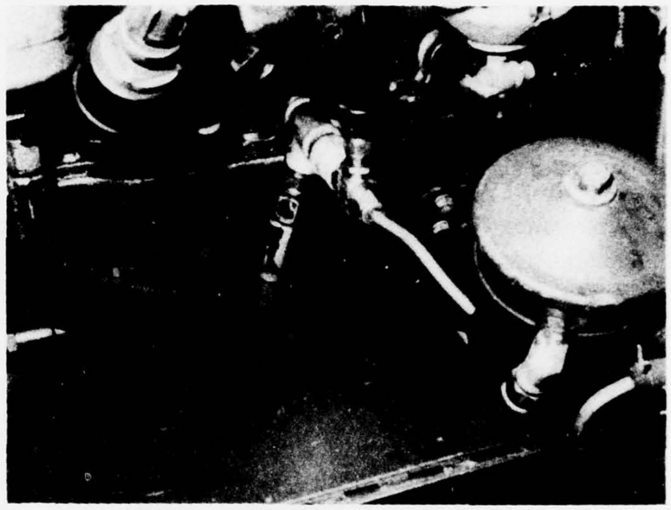

Figure 1. Oil sampling valve.

(1) **Temperature.** The following temperatures were measured:

Engine coolant "in" and "out"
Intake manifold
Air inlet
Engine exhaust
Engine oil in sump and gallery
Generator frame
Ambient air
Fuel oil

(2) **Pressure.** The following pressures were measured:

Lube gallery
Exhaust manifold
Inlet manifold

(3) **Electrical.** The following electrical measurements were made:

Terminal voltage
Line current
Power
Frequency

All instruments were of laboratory grade and were maintained under a periodic calibration program to meet the requirements of MIL-C-45662.

f. **Fuel and Lubricants.** The diesel fuel used during testing was grade DF2 certified to meet the requirements of VV-F-800a.

The lubricating oil used during testing was SAE grade 30 certified to meet the requirements of MIL-L-2104C.

g. **Pre-endurance Operation.** All starting and operating procedures were in accordance with the appropriate technical manuals except as pertain to the scheduled oil-change and oil-filter-change intervals which were dictated by the condition of the oil based on the analysis of oil samples.

Set installation for tests was in such a manner as to minimize the ingestion of exhaust gases between engines.

h. **Endurance Tests.** All tests were conducted in accordance with MIL-STD-705B, Test Method 690.1C, except as noted.

The generators were connected, using the three-phase, 120-volt connection, to suitable load banks having a ¼-load-step and 0.8 power-factor capability.

All temperature, pressure, and electrical data were observed and recorded hourly.

Smoke readings were taken during each rated-load step of the schedule.

Atmospheric conditions were noted on a daily basis and recorded on data sheets.

Normal, ambient operation was performed on a 24-hour, 7-day basis in accordance with the load-cycle schedule given in Table 4.

Plus 125°F operation was at the "full-load" condition with no oil change or oil-filter change.

Stand-by, low-usage operation included 1 hour of each 8 hours running in accordance with the load-cycle given in Table 5. This approximated a 5-month period with no oil change or oil-filter change.

Table 4. Endurance Load-Cycle Schedule

| Step No. | Total Time (hr) | Load Condition |
|---|---|---|
| 1 | 20 | ½ |
| 2 | 4 | 0 |
| 3 | 24 | Full |
| 4 | 24 | ¼ |
| 5 | 24 | ¾ |

Table 5. Stand-by, Low-Usage, Load-Cycle Schedule

| Step No. | Total Time (min) | Load Condition |
|---|---|---|
| 1 | 5 | Start – Full |
| 2 | 15 | ¼ |
| 3 | 10 | Full |
| 4 | 10 | ¼ |
| 5 | 10 | ½ |
| 6 | 10 | 0 |

The following logbook entries were made during each shift as applicable:

Date, shift hours, and total elapsed test hours.
All adjustments made.
Information regarding scheduled maintenance performed.
Title and test method number of all performance tests performed.
Explanation of all shutdowns.
Results of periodic, visual inspections.
All failures which occurred and repair parts used.
Oil added between oil changes.

i. **Oil Samples.** Samples of oil were taken as follows:

One quart of each certified lot of lubricating oil prior to start of test.
One ounce every 25 hours of engine operation.
Eight ounces every 100 hours of engine operation.

Each oil sample was identified with the following information on the label:

Generator set serial number.
Total number of hours that oil was used.
Total number of engine operating hours.
Pertinent servicing, maintenance, failure, and parts replacement and/or adjustments since last oil sample was taken and amount of oil added if any since last sample.

j. **Scheduled Maintenance.** Scheduled maintenance was performed as required in accordance with Tables 6, 7, and 8.

Table 6. Maintenance Schedule for 15- and 30-Kilowatt Generator Sets

| Every 8 Hours |
|---|
| (1) Check for unusual noise and vibration |
| (2) Check oil sump level (do not shut engine down for oil level checks.) |
| (3) Service air cleaner as necessary |
| (4) Check fault indicator panel lights and control panel for proper operation |
| **Every 40 Hours** |
| (1) Tighten loose and leaking connections |
| (2) Check condition of air filters |
| (3) Check condition of fan and alternator belts |
| (4) Check engine coolant level |
| (5) Check specific gravity of battery electrolyte |
| (6) Wipe the engine and generator of excessive oil and dirt |
| **Every 100 Hours** |
| (1) Inspect lifting frame, skid base, shutter assembly, thermostat housing, intake exhaust manifolds, and belts for looseness or damage and replace as necessary |
| (2) Clean fuel strainer and fuel pump screens |
| (3) Check hydraulic-oil sump level |
| **Every 500 Hours** |
| (1) Inspect radiator and grille for damage and obstructions to air flow |
| (2) Check valve tappet clearance and adjust if necessary |
| (3) Check compression pressure at cranking speed |
| (4) Clean or replace as necessary fuel injector nozzles |

Table 7. Maintenance Schedule for 60-Kilowatt Generator Sets

**Every 8 Hours**

(1) Check for unusual noise and vibration
(2) Check sump-oil level – do not shut down engine for oil-level checks

**Every 40 Hours**

(1) Tighten loose and leaking connections
(2) Check condition of air filters
(3) Check condition of fan and alternator belts
(4) Check engine coolant level
(5) Check specific gravity of battery electrolyte
(6) Wipe the engine and generator of excessive oil and dirt

**Every 100 Hours**

(1) Change fuel filters (2)
(2) Clean crankcase breather
(3) Clean fuel strainer
(4) Clean fuel-pump screens
(5) Check hydraulic-oil sump level on precise set

**Every 250 Hours**

(1) Pressure test radiator cap and cooling system
(2) Clean governor actuator strainer

**Every 500 Hours**

(1) Change hydraulic-oil filter on precise set
(2) Change hydraulic oil on precise set
(3) Check valve clearance – replace valve-cover gasket
(4) Clean fuel nozzles, check the popping pressure of the injectors, and leak test the injector nozzle valve
(5) Check compression
(6) Change engine coolant
(7) Adjust fan- and alternator-belt tension

**Every 1,000 Hours**

Replace fuel nozzles

Table 8. Maintenance Schedule for 100-Kilowatt Generator Set

| Every 8 Hours |
| --- |
| (1) Check for unusual noise and vibration<br>(2) Check sump-oil level – do not shut down engine for oil-level checks |
| **Every 40 Hours** |
| (1) Tighten loose and leaking connections<br>(2) Clean the air filters<br>(3) Wipe excessive dirt and oil off the engine and generator |
| **Every 100 Hours** |
| (1) Change fuel filters (2)<br>(2) Clean fuel strainer<br>(3) Clean crankcase breather<br>(4) Check fan- and alternator-belt tension<br>(5) Check hydraulic-oil sump level on precise set<br>(6) Check specific gravity of battery electrolyte |
| **Every 250 Hours** |
| (1) Change hydraulic filter on precise set<br>(2) Check engine coolant level<br>(3) Drain water and sediment from fuel filters<br>(4) Drain water and sediment from day tank<br>(5) Pressure test radiator cap and cooling system<br>(6) Clean governor-actuator strainer |
| **Every 500 Hours** |
| Change hydraulic oil on precise set |
| **Every 1,000 Hours** |
| Check valve clearance (first check will be performed at 500 hours) |

5. **Description of Oil Analyses and Sampling Procedures.**

a. **Oil Analyses.** A description of the chemical and spectrometric oil analyses performed during this program is included in Tables 9 and 10. The precautionary limits discussed in the chemical tests were established prior to initiation of Phase I through coordination with manufacturers and laboratory personnel. These limits reflect current research and field experience. The warning limits outlined for the spectrometric analysis were established through coordination with the respective engine manufacturers. The manufacturers cautioned that the wear-metal concentrations could vary between engines depending upon basic internal engine construction, type of service (i.e., duty cycle), and the regularity with which routine maintenance is performed. Consequently, these limits were used as a guide tempered with a certain degree of discretion. No information on wear-metal concentrations was available from the Hercules engine manufacturer.

b. **Sampling Procedures.**

(1) **Chemical Analysis.** Eight-ounce oil samples were taken from each generator set at established intervals and stored in plastic bottles for eventual analysis. The samples were analyzed in accordance with the designated ASTM method for determination of each property.

(2) **Spectrometric Analysis.** Samples taken from each generator set at established intervals were stored in unused 1-ounce polyethylene vials. The samples were analyzed utilizing a Jarrell-Ash Model 750 Atom-Counter, Atomic-Emission, Direct-Reading Spectrometer. The electrodes of the spectrometer were made by National: the solution disc electrode was a Type L4075 AGKSP, 1/2-inch-diameter, 1/8-inch thick; the counter electrode was a Type L3957 AGKSP, 1/4-inch rounded upper, 1/16-inch radius. The maximum impurity concentrations for these electrodes were as follows: Aluminum – 0.5 ppm, Copper – 0.5 ppm, Iron – 0.4 ppm, and Silicon – 2.4 ppm. The instrument was standardized with Continental Oil Company Conostan Type D-12 metallo-organic standards in the following concentrations: 0-, 10-, 30-, 50-, 100-, and 300-ppm ranges.

## III. TEST RESULTS

6. **Oil Analyses Test Data.** During this program, the results of each chemical and spectrometric oil analysis were tabulated and plotted using a CalComp Plotter. This computer printout technique greatly simplified making decisions to change oil and oil filters on each generator set during Phase II and also provided a reference for comparison with Phase I data (Appendices A and B).

Table 9. Chemical Oil Analysis

| Chemical Property | Test Methods | Significance | Precautionary Limits |
|---|---|---|---|
| Viscosity – 100°F and 210°F | ASTM-D445 | (1) Establishes viscosity index.<br><br>(2) An indication of oxidation can be summarized by observing successive differences between viscosity at 100°F and 210°F. | Limit has been reached when viscosity at 210°F either increases in value to the next higher SAE grade (maximum oxidation) or decreases in value to the next lower SAE grade (maximum fuel dilution). |
| Flashpoint | Cleveland Open Cup | This is a key physical property in determining fuel dilution into the oil. | Limit has been reached when the flashpoint reaches 300°F or lower (maximum fuel dilution). |
| Total Acid and Total Base | ASTM-D664 and D2896 | The total acid number (TAN) to a degree defines the buildup of acidic materials in oil resulting from combustion and oil oxidation, while the total base number (*TBN*) relates to the oil alkaline reserve provided to combat acidic products. Decreasing TAN is indicative of additive depletion. | TAN limit has been reached when TAN increases two whole numbers from that value recorded for new oil (batch sample).<br><br>*TBN limit has been reached when TBN decreases to* one-half original value of new oil (batch sample). |
| Insolubles – Percent Benzene and Pentane | ASTM-D-893, Procedure B | In principle, the arithmetic difference between the Pentane and Benzene insolubles is a measure of oxidation | Benzene:<br>When percentage of Benzene insolubles reaches 1.00 percent.<br><br>Pentane:<br>When percentage of Pentane insolubles reaches 1.50 percent. |

Table 10. Spectrometric Oil Analysis

| Metal | Allis Chalmers Model No. 3500 Parts | Warning Limit (ppm)* | Caterpillar Model No. D333T Parts | Warning Limit (ppm)* |
|---|---|---|---|---|
| Aluminum | Pistons<br>Blowers<br>Bearings | 80 | Pistons<br>Main Bearings<br>Rod Bearings<br>Oil-Pump Bushing<br>Timing Gear Bushing<br>Crankshaft Thrust Bushing<br>Fuel-Pump Lifter | 18 |
| Tin | Bearings | 30 | Bearings | 40 |
| Chromium | Piston Rings<br>Shafts | 50 | Piston Rings | 20 |
| Lead | Bearings | 60 | Overlay on Main and Rod Bearings | 75 |
| Silicon | Air-Cleaner Element | 30 | Air-Cleaner Element | 30 |
| Iron | Piston Rings<br>Cylinders<br>Shafts | 125 | Crankshafts<br>Cylinder Liners<br>Camshaft<br>Connecting Rod and Gears | 120 |
| Copper | Bushings<br>Bearings | 60 | Rocker-Arm Bushings<br>Wrist-Pin Bushings<br>Timing-Gear Thrust Washer<br>Governor Bushing<br>Fuel-Transfer-Pump Bushing<br>Oil-Pump-Drive Thrust Washer | 30 |

* *Wear-metal concentrations are based on manufacturer's recommendation. This information was not available for the Hercules, Model D-198 and D-298, engines.*

7. **Oil Consumption Data.** Oil consumption for Phase I (preproduction models) is given in Table 11 and for Phase II (production models), in Table 12.

Table 11. Oil Consumption – Phase I, Preproduction Models

| Set Description | | | | |
|---|---|---|---|---|
| Power (kW) | Frequency (Hz) | Serial No. | Total Accumulated Hours | Average Oil Consumption (qt/100 h) |
| 5 | 60 | 359821 | 5,048 | Not Available |
| 10 | 60 | 359823 | 4,984 | Not Available |
| 15 | 60 | RZ-00001 | 2,500 | 3.0 |
| 15 | 400 | RZ-10002 | 2,917 | 1.75 |
| 30 | 60 | RZ-30002 | 2,200 | 4.0 |
| 30 | 400 | RZ-40002 | 2,824 | 4.25 |
| 60 | 400 | 6002 | 5,101 | 0.5 |
| 60 | 60 | 2001 | 5,118 | 0.75 |
| 60 | 60 | 2003 | 5,115 | 1.37 |
| 100 | 60 | 4302-001 | 5,278 | 1.0 |
| 100 | 60 | 4302-002 | 5,200 | 2.0 |
| 200 | 60 | 4305-001 | 4,275 | 30.0 |
| 200 | 60 | 4305-004 | 3,832 | 25.0 |

Note: A 100-hour, oil-change interval was maintained while the above generator sets were run at normal, ambient temperatures.

8. **Discussion of Oil Analyses Results.** Results are discussed as follows for Phase I and Phase II and are presented graphically in Appendices A and B.

a. **Phase I.** The chemical and spectrometric analyses for Phase I are reviewed as follows:

(1) **Chemical Data.**

(a) **Viscosity.** The viscosity-at-210°F data did not exceed the established precuationary limits. The mean values obtained from the smaller sets were slightly higher than those for the 100-kilowatt set. These values can be attributed to possibly three factors: engine design, sump capacity, and oil consumption and replenishment. The individual oil test samples from each engine never approached the upper precautionary viscosity limit; therefore, any adverse factors associated with changes in viscosity (i.e., oxidation or dilution) were not evident at the 100-hour, oil-change interval.

Table 12. Oil Consumption – Phase II, Production Models

| Set Description | | | | | | | |
|---|---|---|---|---|---|---|---|
| Power (kW) | Frequency (Hz) | Serial Number | Mode of Operation | Accumulated Hours | Oil-Change Interval (hr) | Oil Consumption (qt) | Average Oil Consumption (qt/100 h) |
| 15* | 60 | RZ10001 | Norm. Amb. | 700 | 700 | 36.5 | |
| | | | Norm. Amb. | 1400 | 700 | 31.0 | |
| | | | Norm. Amb. | 2089 | 689 | 22.0 | |
| | | | | | Avg 696 | Avg 29.8 | 4.2 |
| 15** | 60 | RZ00002 | Norm. Amb. | 778 | 778 | 42.5 | |
| | | | Norm. Amb. | 1500 | 722 | 52.0 | |
| | | | Norm. Amb. | 2341 | 841 | 63.0 | |
| | | | | | Avg 780 | Avg 52.5 | 6.7 |
| 30* | 60 | RZ40002 | Norm. Amb. | 800 | 800 | 58.5 | |
| | | | Norm. Amb. | 1465 | 665 | 26.7 | |
| | | | | | Avg 732 | Avg 42.6 | 5.8 |
| 30** | 60 | RZ30002 | Norm. Amb. | 307 | 307 | 14.0 | |
| | | | Norm. Amb. | 1109 | 802 | 37.5 | |
| | | | Norm. Amb. | 1708 | 599 | 33.0 | |
| | | | | | Avg 569 | Avg 28.1 | 4.9 |
| 60 | 60 | FZ00455 | Norm. Amb. | 606 | 600 | 12.0 | |
| | | | Norm. Amb. | 1308 | 702 | 17.5 | |
| | | | Norm. Amb. | 1866 | 558 | 11.5 | |
| | | | Norm. Amb. | 2466 | 600 | 14.4 | |
| | | | Norm. Amb. | 3118 | 652 | 14.0 | |
| | | | | | Avg 622 | Avg 13.9 | 2.2 |
| | | | Stand-by, Low Usage | 3470 | 352 | 4.0 | 1.0 |

Table 12. Oil Consumption – Phase II, Production Models (Cont'd)

| Set Description | | | Mode of Operation | Accumulated Hours | Oil-Change Interval (hr) | Oil Consumption (qt) | Average Oil Consumption (qt/100 h) |
|---|---|---|---|---|---|---|---|
| Power (kW) | Frequency (Hz) | Serial Number | | | | | |
| 60 | 400 | FZ06024 | Norm. Amb. | 606 | 597 | 15.5 | |
| | | | Norm. Amb. | 1258 | 652 | 12.8 | |
| | | | Norm. Amb. | 1857 | 599 | 9.0 | |
| | | | Norm. Amb. | 2457 | 600 | 17.7 | |
| | | | Norm. Amb. | 3013 | 556 | 10.5 | |
| | | | | | Avg 600 | Avg 13.1 | 2.2 |
| | | | +125°F Temp. | 3315 | 302 | 19.5 | 6.5 |
| 100 | 60 | UZ00001 | Norm. Amb. | 1112 | 1000 | 45.5 | |
| | | | Norm. Amb. | 2112 | 1000 | 37.2 | |
| | | | Norm. Amb. | 3112 | 1000 | 31.5 | |
| | | | | | Avg 1000 | Avg 38.1 | 3.8 |
| | | | +125°F Temp. | 3444 | 332 | 6.5 | 2.0 |
| 100 | 60 | UZ02008 | Norm. Amb. | 1018 | 1000 | 61.3 | |
| | | | Norm. Amb. | 2018 | 1000 | 48.6 | |
| | | | Norm. Amb. | 3018 | 1000 | 27.5 | |
| | | | | | Avg 1000 | Avg 45.8 | 4.6 |
| | | | Stand-by, Low-Usage | 3340 | 339 | 8.0 | 2.3 |

* Preproduction–model generator set with new engine installed.
** Original, preproduction–model generator.

(b) **Flashpoints.** The mean flashpoint of the oil samples was within 20°F with a standard deviation of 10°F. It is evident from the data that diesel fuel was not present in any of the oil samples and that fuel dilution of the oil would not be a factor in affecting the hydrodynamic lubricating film during the Phase I program.

(c) **Pentane Insolubles.** The mean value for the pentane insolubles for oil samples from the smaller sets was higher than the value obtained for the 100-kilowatt sets. This indicated that more fuel soot was generated in the smaller sets. The typical patterns displayed on the CalComp plot were normal values for this test. In a few isolated cases, the higher values returned to a normal-trend pattern when successive, 100-hour samples were analyzed.

(d) **Benzene Insolubles.** The mean value for the benzene insolubles for oil samples from the smaller sets was again higher than the value obtained from the 100-kilowatt sets. The mean difference of pentane versus benzene, which is an indication of oil oxidation products, would signify that a lesser formation of oil-degradation products (i.e., varnish, lacquer, resins, and sludges) would be found in the 100-kilowatt sets. The overall results of these tests indicate that the oil-change interval was five times below established precuationary limits and that oil degradation would pose no serious problem to the internal engine components.

(e) **Total Acid Number.** The mean value of TAN for the smaller sets was lower than the value for the 100-kilowatt set. Some sporadic values were recorded above the precuationary limits; however, these data points returned to normal prior to the conclusion of the test interval. The acid component buildup, i.e., sulfuric acid or weak organic acids, did not materialize to a significant degree at the 100-hour samples.

(f) **Total Base Number.** The mean value of TBN for the smaller sets as compared to that for the 100-kilowatt set demonstrates a greater alkaline reserve for the smaller engines. These data in conjunction with the TAN data indicate sufficient alkaline reserve in the smaller sets. The 100-kilowatt set reveals a decreasing TBN trend during the latter 1,000 hours of testing; no similar pattern is demonstrated by the smaller sets. The observed TBN values for the 100-kilowatt set are still within tolerable limits and are considered satisfactory at the 100-hour level of testing.

(2) **Spectrometric Data.** The spectrometric effort was directed toward seven key elements as follows: aluminum, chromium, copper, iron, lead, silicon, and tin. Since the 60- and 100-kilowatt units were of different manufactured design, the data were evaluated for those units only. The monitoring of these elements represented wear trends of major component parts in each engine. See Table 10 for a description of each component part and the element associated with its composition.

(a) **Sixty-Kilowatt Generator Set (Allis Chalmers (AC) Model 3500 Engine).** The internal engine condition was monitored through elemental analysis as follows:

**Aluminum** – The mean value of 14.7 ppm was five times below the established warning limit. There was an even pattern of wear from the 2,000- to 5,000-hour level. This would indicate a general wear pattern of attrition and indicate a satisfactory pattern for this engine.

**Chromium** – The mean value of 2.8 ppm was 25 times below the established warning limit. The two significant high values at 3,000 hours were attributed to ring seating. In general, the metallic contaminant levels were exceedingly low, and engine wear associated with this element was considered nil.

**Copper** – The mean value of 5.8 ppm was 10 times below the established warning limit. The high copper content at 400 hours is associated with the bushing and bearing break-in process. A stabilization pattern was established at about 500 hours into the test period.

**Iron** – The mean value of 15.5 ppm was eight times below the established warning limit. Iron content, however, is considered attrition rather than contamination.* The engines did not display any rapid rise after the initial break-in period at 400 hours; consequently, this mean wear pattern is indicative that oil meeting MIL-L-2104C is capable of providing satisfactory generator lubricating service.

**Lead** – The mean value of 15.5 ppm was eight times below the established warning limit. The element appeared to increase at the 3,000-hour level in conjunction with the two significant wear patterns of chromium. The pattern persisted to the 4,000-hour level. Since lead is associated with the overlay on the bearings, these surfaces were demonstrating component wear. However, the levels peaked at 20 ppm which is three times below the warning limit; consequently, these lead levels were considered normal.

**Tin** – The mean value, 7.8 ppm, was four times below the established warning limit. This metallic pattern followed a longer initial break-in period (700 hours) as compared to copper, lead, and iron and patterned itself more closely to aluminum. At 3,500 hours, the levels increased to points approaching the warning limit. This pattern could signify some excessive wear on the bearings. The pattern did not persist, and along with lead levels the spectrometric evaluation was

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* Iron and copper displayed the same wear patterns.

considered normal. This element demonstrated the highest wear patterns associated with the Allis Chalmers Model 3500 engine.

**Silicon** – The mean value for silicon, 4 ppm, was about seven times less than the established warning limit. This element is primarily associated with dirt contamination and air cleaner efficiency. Aluminum also can signify this development; however, because its presence may be attributable to normal engine wear, aluminum is not considered a reliable indicator in this regard. These two elements in combination did not signify any apparent failure in the air-intake system, and associated indicators of wear through dirt contamination were regarded as being at a satisfactory performance level.

**(b) One-Hundred-Kilowatt Generator Set (Caterpillar (CAT)) Model D-333T Engine).** This engine was also subjected to elemental analysis as follows:

**Aluminum** – The mean value of 17 ppm was just 1 ppm below the warning limit for this engine design. From a period beyond 3,500 hours, all results were slightly above the warning limit. However, this engine has a 279-horsepower rating and a 638 inch$^3$ displacement as compared to the AC Model 3500 engine which has a 184-horsepower rating and a 426 inch$^3$ displacement and which has a warning limit four times above that of the Cat. engine. During the period of initial break-in, the warning limit was exceeded for the first 1,200 hours. The values when compared to those for the AC engine were about 2.3 ppm above the warning limit which is reasonable when taking into account the increased aluminum surface areas exposed in these engines. Therefore, the 17-ppm aluminum was considered a normal trend and a satisfactory level. Only by performing an engine teardown and surface evaluation of this engine design could a complete and effective lubrication performance be established to the contrary.

**Chromium** – The mean value of 9.3 ppm was two times below the established value. A significant wear pattern developed at 2,400 hours and peaked at 3,000 hours. This pattern also was shown in the AC engine and, although prolonged in the Cat. engine, is attributable to a piston ring break-in period. The value again decreased to 2 ppm levels throughout the remainder of the test period. This indicated a satisfactory performance and a normal wear pattern for this engine design.

**Copper** – The mean value of 1 ppm, a value 30 times below the warning limit, indicated satisfactory performance levels. An indication of slight bearing wear manifested itself at 4,500 hours. The level at this point is three times higher than the established trend; however, testing did not continue beyond 5,000 hours, and results are speculative. However, the level at 4,500 hours is exceedingly low when compared to an established 30-ppm warning limit.

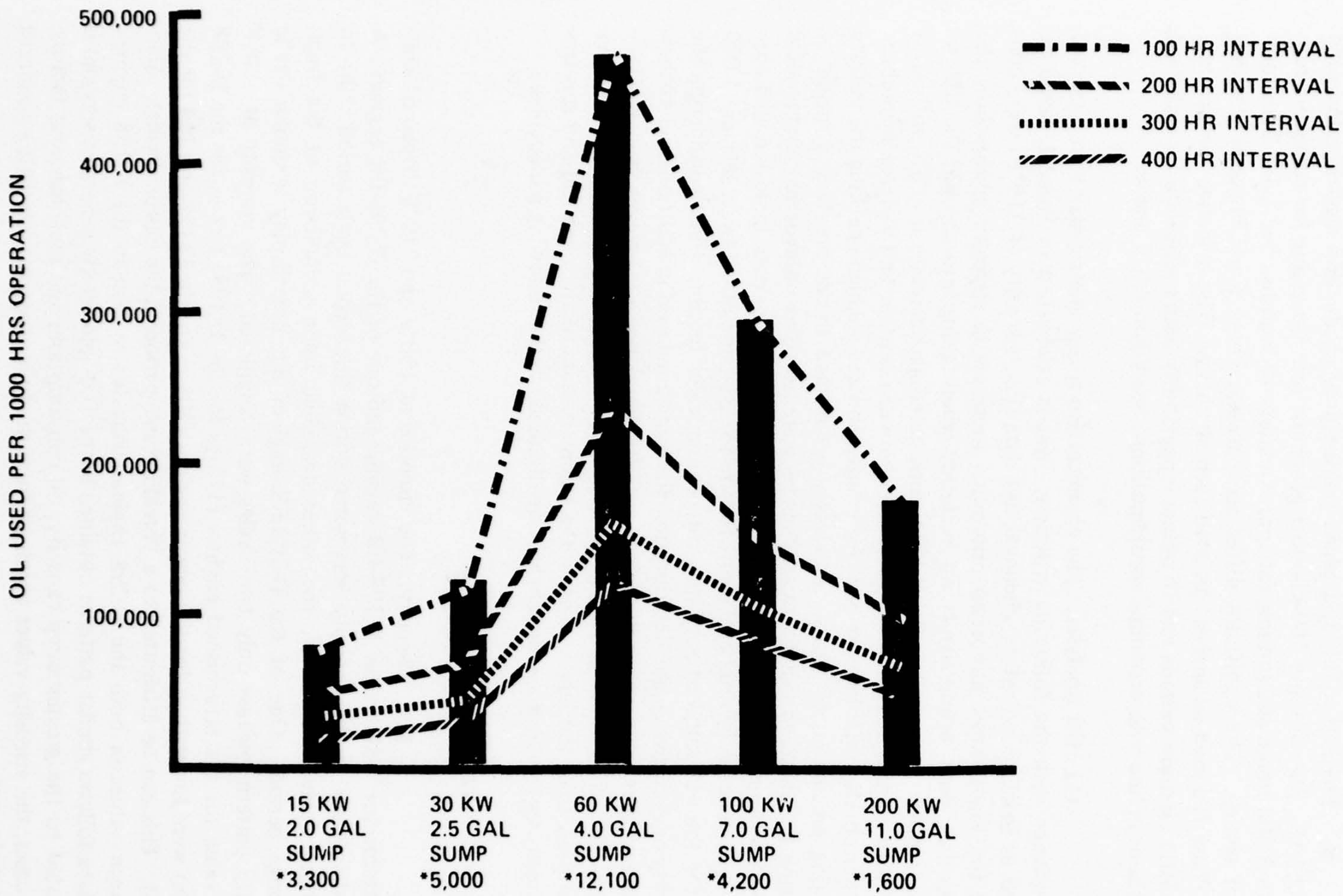
**Iron** – The mean value of 7 ppm was 17 times below the established warning limit. This pattern demonstrates a long-range level which is considered an attrition wear pattern. As previously discussed, iron values indicate general features; and these values are considered satisfactory.

**Lead** – The mean value of 6 ppm was 12 times below the established warning limit. This element increased from the 2,000-hour level and peaked at the 3,200-hour level following a similar wear pattern of chromium. This was also demonstrated in the AC engine, and a general repeatability of wear indicators can be loosely interpreted.

**Tin** – The mean value of 7.3 ppm was five times below the established warning limit. This metallic wear pattern had two significant peak areas: one at 2,000 hours and a second at 3,500 hours. The first wear pattern resembles the chromium and lead spectrometric analyses; however, tin indicators persisted to the 5,000-hour test interval at which time the peak levels of lead and chromium were observed and tin reverted to its baseline level. This low-level pattern was also repeated in the AC engine; however, there is no apparent explanation for these extremely low readings. In general, the values of tin were considered to be at a satisfactory wear level.

**Silicon** – The mean value for silicon, 3.7 ppm, was about eight times below the established warning limit. As discussed previously, it appears that no apparent problem has manifested itself because of dirt contamination. A general trend can be established which suggests that lower allowable levels of silicon are practical when the unit is operated under similar field conditions. This is important because of the direct relationship between increases in silicon and increases in iron and aluminum as overall indicators of internal component wear.

**(3) Summary of Test Data.** The Phase I wear patterns for both engines were appreciably below the established warning limits. The various used-oil analyses data accumulated on these engines demonstrated that the 100-hour, fixed-schedule drain was a conservative time interval. Monitoring these engines, test personnel found that abrupt increases in metallic elements suspended in the lubricating oil, indicative of internal component wear and possible indicators of pending engine failure, did not manifest themselves during the program. Therefore, successive 100-hour test sequences and mean wear patterns were used as indicators to the increased probability of a pending failure; the certainty of equipment degradation can be correlated only through a teardown inspection and dimensional checks in suspect wear areas.




* NOTE: Population data, Stratification Report Generator Sets Worldwide, July 1973

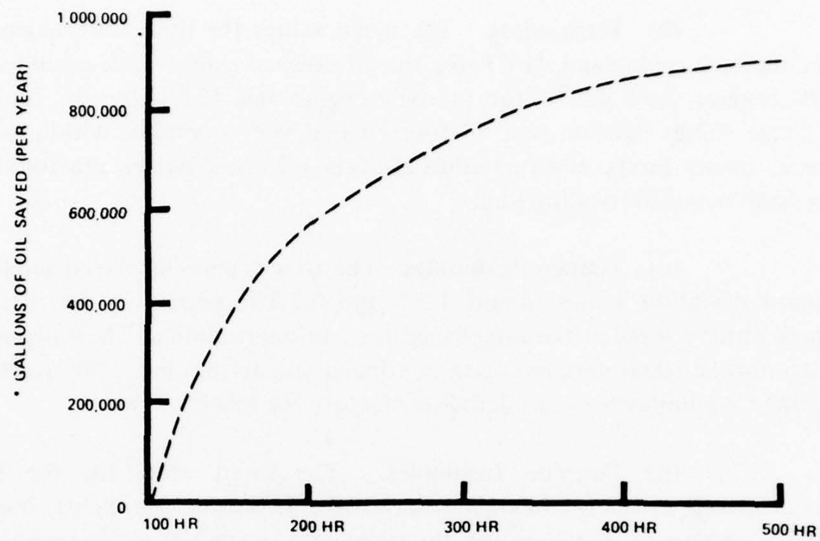
**Figure 2. Oil consumption vs. oil-change interval.**

b. **Phase II.** This test phase consisted of production models comprising two each, 15-, 30-, 60- and 100-kilowatt generator sets, operating for totals of from 1,600 to 3,800 hours and running for approximately 12 months. See Table 2 for total hours of testing. The significant difference between Phase I and Phase II was that during Phase II a used-oil analysis dictated each oil change. The objective was to establish realistic oil-drain periods and to obtain repeatability with cyclic data for statistical comparisons in line with economic considerations. See Figures 2, 3, and 4.

(1) **Oil Analyses.** The chemical and spectrometric data were analyzed in accordance with the following criterion: trends established in Phase I would be regarded as baseline indicators; chemical test data (i.e., viscosity at 210°F) were considered the single, most important criterion. Increases in viscosity approaching the precuationary limit would signify oil oxidation when taking into account the following test results: increases in TAN with corresponding decreases in TBN without a change in flashpoint and increased differences between pentane and benzene insolubles. This criterion also established a basis for comparison and enabled checking the validity of existing precuationary limits. Previously established trends provided a means of comparing test data; any sharp, rapid changes were noted as unfavorable, and gradual and upward slopes were considered normal. A review of the data indicated that continued set operation beyond 600 hours for the 15-, 30-, and 60-kilowatt sets and 1,000 hours for the 100-kilowatt sets was not economically feasible when considering the possibility of excessive engine deterioration and a marginal gain in additional oil savings. Since the smaller size engines in the 15- and 30-kilowatt sets (Hercules models D198-ER and D298-ER) could normally be expected to show more rapid and excessive deterioration than the larger engines, the summary data of the chemical and spectrometric analyses for these smaller engines are discussed in the following paragraphs.

(2) **Chemical Data.**

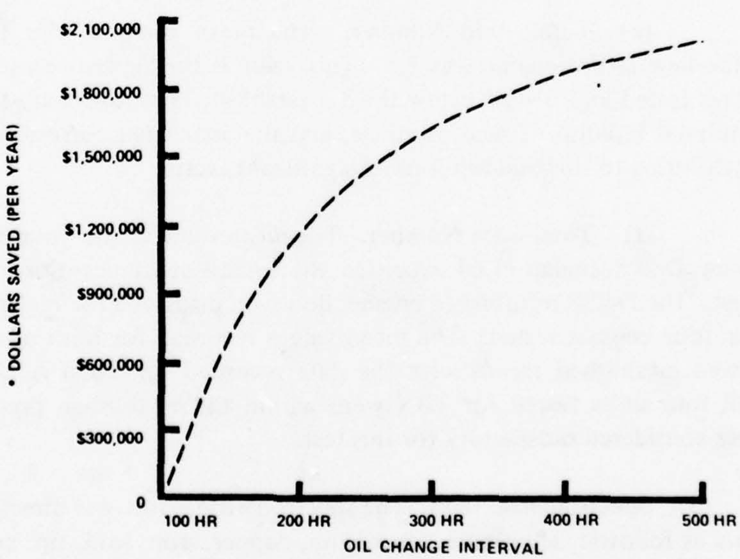
(a) **Viscosity.** The viscosity at 100°F and 210°F displayed similar patterns for both of the D-198-ER engines and one of the D-298-ER engines. A marked increase in the viscosity was noted during the second cycle period (700- to 1400-hour cycle). However, the values decreased upon completion of the final, oil-change period. One of the D-298-ER engines did not display a similar cyclic viscosity pattern because only two cycles were completed. The viscosity at 100°F mean value for the refurbished engines (175 cs for the D-198, 167 cs for the D-298 engines) were lower than for the newer engines (203 cs for the D-198 and 184 for the D-298). This can be attributed to a "breaking in" period in the newer engines. Also, the mean values in both the D-298 engines were lower than in the D-198 engines. This data follows similar patterns obtained in the 100- and 60-kW generator sets and is attributed to the greater sump capacity, oil consumption, and replenishment factors. In all cases, the viscosity values obtained from the four generator sets were considered to be satisfactory.




NOTE: Composite quantity of DOD generator sets 26,200 units based on Stratification Report, Generator Sets Worldwide July 1973

* Quantity of oil saved, based on sets being operated 1000 hr per year.

**Figure 3. Composite of oil saved vs oil-change interval.**




NOTE: Composite quantity of DOD generator sets 26,200 units based on Stratification Report, Generator Sets Worldwide July 1973

Price of oil based on $80.00/55 gal. drum, and $2.00/oil filter element.

* Dollar savings, based on sets being operated 1000 hr per year.

**Figure 4. Composite of dollars saved vs oil-change interval.**

(b) **Flashpoints.** The mean values for the D-198 engines were 434°F for the new engine and 414°F for the refurbished engine. The mean values for the D-298 engines were 426°F for the new engine and 421°F for the refurbished engine. These values indicate that all four engines were operating within the established precuationary limits, and fuel dilution of the oil would not be a factor in affecting the hydrodynamic lubricating film.

(c) **Pentane Insolubles.** The four engines displayed similar mean and standard deviation values (about 1.3% and 0.7% respectively), and there were some values which exceeded the established precautionary limits. These higher values returned to normal trend patterns upon continued engine running. The overall result of the pentane insolubles was considered satisfactory for this test.

(d) **Benzene Insolubles.** The mean value for the benzene insolubles produced by the D-198 engines was 0.9%. This value was slightly lower than for the D-298 engines (1.0%); however, the trend pattern established was similar to the above pentane insoluble test. In both cases, these values approached the established precautionary limit of 1%. This would indicate that the oil degradation products (i.e., varnish, lacquers, resins, and sludges) produced could be a contributing factor to engine wear if the oil-change interval exceeded 700 hours. The benzene insolubles approached the upper precautionary limit established for this test.

(e) **Total Acid Number.** The mean value of the Total Acid Number for the new D-198 engine was 2.3. This value is the highest recorded among the four engines tested and is well below the 3.5 established precautionary limit. This indicates a minimal buildup of acid products, and the associated corrosion and wear degradation attributed to this buildup is not a significant factor.

(f) **Total Base Number.** The mean value of the Total Base Number for the new D-298 engine (1.6) exceeded the established precautionary limit of 1.5 for this test. The D-298 refurbished engine, however, displayed the highest alkaline reserve of the four engines tested. The mean values recorded for both of the D-198 engines followed established trends with the data recorded for Total Acid Number. In general, all four units tested for TBN were within the established precautionary limits and were considered satisfactory for this test.

(3) **Spectrometric Data.** The spectrometric effort was directed toward seven elements as follows: aluminum, chromium, copper, iron, lead, tin, and silicon. The monitoring of these elements represented wear trends of major component parts in each engine. The D-198 and D-298 engines were designed by the same manufacturer (Hercules). The main difference between each engine was the horsepower rating (61 vs 90 hp, 4-cylinder vs 6-cylinder) and the sump size (8 vs 10 qt). These units were

evaluated on a comparison basis for each respective element as follows: obvious abnormal peaks, statistical values using mean and standard deviation, and general wear-pattern trends established for metallic element.

**Aluminum.** The mean values for the D-198 and the D-298 engines were 30 ppm ± 2 ppm from each other. The wear metal content was found to be lowest at each oil-change interval; however, this pattern would normalize after a period of about 300 hours. There were no abnormal peaks or spikes, and the overall trend was similar in each of the four engines. This indicates a general wear pattern of attrition and a satisfactory performance for these engines.

**Chromium.** The mean value was less than 1 ppm for the D-198 and the D-298 engines. This element displays a "double spike" pattern which is attributed to ring seating. This pattern was similar to that found in the 60-kW and 100-kW engine designs. The general wear pattern for this element is within normal limits and is considered satisfactory for this engine design.

**Copper.** The mean value for the D-198 and the D-298 engines was about 2 ppm. The low values are displayed throughout the test period and conform to the wear patterns associated with this element. This element, like chromium, also displays a typical break-in pattern for bushings, bearings, and thrust washers. This pattern is formed at the beginning of the test period near the 700-hour mark and to a lesser degree than that displayed for chromium. After a period of 1000 hours running time, the values approach the 1- to 2-ppm range and remain there throughout the completion of the test. The overall wear pattern for this element was considered to be satisfactory.

**Iron.** The mean value for the new D-298 engine (60 ppm) was the highest value in this series. The two D-298 engines displayed increased concentrations of iron when compared to the two D-198 engines tested. Also, the refurbished engines were significantly lower (15 ppm) than their new counterparts. Iron is considered an overall, general wear index indicator in these designs, and these patterns display a gradual elemental increase prior to each oil-change period. Such trends are of a typical engine performance cycle and do not indicate any abnormalities resulting from wear or breakdown. It is further indicative that the oil (MIL-L-2104C) is capable of providing satisfactory engine lubrication.

**Lead.** The mean value for both the D-198 and the D-298 engines was established at 31 ppm ± 2 ppm. The D-298 engine displayed two significant peaks which were attributed to wear patterns. Upon continued running, however, these values experienced marked decreases and approached the typical patterns associated with this element. Since lead is associated with bearings surfaces, some abnormal wear may have occurred at various points in the cycle; but these periods are not definite and cannot be explained as was the chromium pattern. In general, the lead values are low (20 ppm) at the initial periods and cycle (60 ppm) prior to oil-change periods. The values for this element are considered normal. Actual wear abnormalities can only be ascertained by teardown and surface examination of pertinent parts.

**Tin.** The mean value for the D-198 and the D-298 engines was 33 ± 1 ppm. This value is the most consistent of the seven elements tested and is also present in the second highest concentration (iron being first) for this design. In general, this element follows a pattern which is similar to the established lead pattern; but unlike lead it does not display abnormal peaks. The presence of this element is lowest at the oil-change period, increases within the next 200-hour interval, and subsequently stabilizes at the 40 ppm vicinity until the next cycle period. The tin patterns displayed by this engine design are considered to be at a satisfactory performance level.

**Silicon.** The mean value of 12 ppm for the new D-298 engine was the highest recorded value for this series. Also, the high silicon established by this engine coincided with the highest values in iron and, to a lesser degree, copper, chromium, and tin. This element characterizes engine air filtration efficiency, and these high values denote external particulate contamination of the system and may account for some increased wear. The initial silicon values are in excess of 40 ppm but decrease to near normal values by 1000 hours running time. After the 1000-hour period, the silicon stabilized to about 10 ppm which is considered a satisfactory level for this engine design. The two D-198 engines and the one D-298 refurbished engine displayed similar patterns to the new D-298 engine but at consistently lower levels throughout the test period. The mean value for these three test engines was 4 ppm, and the engines were also considered to be performing at a satisfactory level.

**(4) Extreme-Temperature Testing.** High-temperature tests (125°F) were conducted on two generator sets, i.e., the 60 kW, #06024 (AC Model 3500 engine), and the 100-kW #UZ00001 (Cat. Model D333T engine) for one cycle period of 300 hours to determine any deleterious effects of elevated, ambient temperatures on lubrication performance, wear-pattern levels, and engine operation in general.

**(a) Chemical Oil Analysis.** The AC Model 3500 engine demonstrated a marked increase in the viscosity level at 100°F (250 cs) and 210°F (20 cs) as compared to the ambient operating test temperatures. The Cat. Model D333T engine operated at a level of performance equal to the ambient range. This level reached a viscosity plateau of 190 cs at 100°F; however, data for 210°F were inconsistent. The range varied from 13 to 17 cs but in general did not exceed the established upper precautionary limit for this test. The flash points for both engines were at the same level recorded for new oil (440°F) with no apparent oil dilution in the system. The pentane and benzene insolubles for the AC Model 3500 engine were below the established precautionary limits. The general trend showed a slightly increasing slope prior to an oil-change period which is a normal pattern for this engine. The Cat. Model D333T engine demonstrated the same general trend and relationship with the exception of one abnormal peak at the 150-hour interval. This value immediately returned to the trend pattern in the next analysis period. It is considered an unexplained abnormality which could have developed through faulty analytical or sampling procedures. The total acid and total base levels for the AC Model 3500 engine were within the established precautionary limits. The general trend in pattern development demonstrated satisfactory performance levels for these tests. The Cat. Model D333T engine demonstrated moderate increases during the high-temperature test period when compared to the ambient range; however, it did not exceed the precautionary levels. The total base showed a normal decreasing slope which did exceed the precautionary limit after 125 hours of testing. At the conclusion of the test period, the alkaline reserve level reached 0.5 TBN which is a similar pattern developed under the ambient test program.

**(b) Spectrometric Analysis.** The AC Model 3500 engine displayed similar patterns for aluminum, chromium, copper, and silicon. The iron pattern in general was lower in value but displayed the same slope characteristics. The value for lead (50 ppm) peaked at the 100-hour period but remained below the established warning limit. The values for tin (40 ppm) exceeded the established limits; this element was the only pattern which increased in the high-temperature test. Continued testing after the high-temperature test period displayed a similar wear pattern in excess of the 30 ppm warning limit. The overall wear pattern (from initial to end of cycle) in the high-temperature test was doubled in comparison to the following 300-hour cycle. The tin wear was considered the most severe in the AC Model 3500 engine. The Cat. Model D333T engine displayed similar patterns for chromium and copper. The iron pattern followed the same general-trend relationship shown in the ambient cycles with about ½ the wear metal content. The aluminum pattern indicated an upward slope, and the values exceeded the warning limits by 50 ppm. The wear-metal levels, after the high-temperature cycle, returned to the warning limit; however, the cycle prior to the high-temperature cycle exceeded all values in wear-metal content. The lead and tin analyses had similar wear patterns with the peak being reached at 150 hours into the high-temperature test cycle. Both values (lead and tin) demonstrated the same concentration levels, 40 ppm at the peak, and then decreased to 25 ppm at the end of the test cycle. These patterns did not follow any general trend established by the previous ambient test cycles.

**(5) Stand-by Low-Usage Duty Cycle.** These tests were conducted on two other generator sets; i.e., the 60 kW, #F200455 (AC Model 3500 engine); and the 100 kW, #UZ02008 (Cat. Model D333T engine) for one cycle period of 300 hours at ambient temperature.

**(a) Chemical Oil Analysis.** Both of the engines displayed normal viscosity patterns with the exception of an isolated peak value exceeding the established precautionary limit. The flash points for both engines were at 425°F. These values were slightly lower than the standard, duty-cycle pattern, 440°F, but with no apparent oil dilution in this cycle. The pentane and benzene insolubles for the AC Model 3500 engine were the lowest recorded value for the entire 3600-hour test period. The Cat. Model D333T engine displayed similar patterns with the exception of the initial value. This is considered insignificant when the total cycle is evaluated. The total acid and the total base values for the AC Model 3500 engine displayed a slight improvement in the overall pattern. The Cat. Model D333T engine also demonstrated an improvement in the total acid performance and a significant increase in total base number performance. In the previous cycle, the data had indicated that the oil exceeded the established precautionary limit of 1.5; however, in the low duty cycle, the values for total base were below the precautionary limit.

**(b) Spectrometric Analysis.** The AC Model 3500 engine displayed similar wear patterns for aluminum, chromium, and copper. The iron pattern was lower in wear-metal content but had the same general slope characteristics. The lead content displayed one abnormal peak at the mid-cycle point but returned to near-normal levels at the conclusion of the cycle period. The tin analysis indicated a generally higher wear pattern than the standard duty cycle. This increase exceeded the established warning limit by 10 ppm throughout most of the test cycle but decreased during the last 50 hours of the cycle period to 20 ppm – a value below the warning limit. The silicon content (3 ppm) was lower in this cycle period but did not display any similar slope patterns to the previous standard cycle. The Cat. D333T engine displayed a similar pattern for chromium. The iron pattern was lower in wear-metal content but had the same general slope characteristics. The aluminum varied from previous patterns. It was lower in wear-metal content than the previous cycles, but it also exceeded the warning limits. The copper analysis was lowest in this cycle period with values three times lower than the established warning limit. The lead content displayed two major peaks at mid-cycle point, but these values returned to normal at the conclusion of the cycle period. The tin analysis indicated moderate increases in the wear-metal content. In one case, the value exceeded the warning limit but returned to the mean value at the end of the cycle period. The silicon content increased to 8 ppm at mid cycle; then, it decreased to a level of 2 ppm until the conclusion of the test period. This level was the lowest recorded for this element.

9. **Oil-Change Intervals.** Based on the results of the chemical and spectrometric analyses of oil samples and engine inspections under Phase II as described herein, the following repeatable, oil-change intervals were established:

a. 15 kW (Hercules Model D198 engine) – 700 hours.
b. 30 kW (Hercules Model D298 engine) – 700 hours.
c. 60 kW (Allis Chalmers Model 3500 engine) – 600 hours.
d. 100 kW (Caterpillar Model D333T engine) – 1000 hours.

10. **Engine Teardown Inspections.**

a. **Units Inspected.** Inspections were conducted on the following units at the General Environments Corporation facility, Hartwood, Virginia:

| Unit | S/N | Engine | Time (Hr) | Oil Change (Hr) |
|---|---|---|---|---|
| 60 kW | FZ2001 | AC-3500 | 5118 | 100 |
| 60 kW | FZ6024 | AC-3500 | 3700 | 600 |
| 100 kW | VZ00001 | Cat. D333T | 3878 | 1000 |
| 100 kW | VZ02008 | Cat. D333T | 3340 | 1000 |

b. **Wear Ratings.** The inspection wear ratings were made in accordance with CRC Rating Manual No. 5 and included the following:

Pistons
Liners
Rings
Rockers, Shaft, and Tappets
Valves
Main and Connecting-Rod Bearings
Camshaft and Crankshaft
Head, Oil Pans, Oil Pump, Timing Gears

c. **Inspection Data.** The inspection data, including photographs, are too voluminous to be included in this report; therefore, they will be part of the project record file.

d. **Summary.** In regard to oil performance, all engines had been adequately lubricated under the service conditions by which they were operated. It is possible only to draw general comparisons relative to lubricant performance under standard or extended-oil-drain intervals because of the effects of lubricant quality and differences in engine operations.

**(1) Allis Chalmers Model 3500 Engines.** Only one major problem was observed during the inspection. Both engines showed distress (abrasive wear/galling) between the rocker arms and the rocker shaft and fretting corrosion between the rocker shaft and shaft support mounts. Continued wear in this area could cause engine malfunction. In addition, the connecting-rod bearings appeared to have somewhat higher wear with one bearing from generator FZ06024 showing severe fatigue and metal removal. Although this wear was noted, ratings were visual; and it did not appear that the wear had reached a point of critical concern. Since the two units operated on different oil-drain intervals, the following comments are made relative to lubricant performance. From a deposit standpoint, the engine using the extended-drain intervals exhibited lower piston deposits and less port restriction than the engine operated under the standard, 100-hour-change period. The reverse was true in the area of valve operation and stem deposits. Here, the engine using the extended-drain interval exhibited sluggish valves which was likely the result of the carbon and lacquer noted on the valve stem in the guide travel area. This condition was not observed in the engine operated on standard drains where the valves were free and the stems clean in the guide area. With the exception of the above, lubricant performance was essentially equal under both the extended and standard oil-drain conditions.

**(2) Caterpillar, Model D333T Engines.** Both engines showed severe pitting of the cylinder liners on the coolant side. In addition, wear in the rocker-camshaft area was noted for the engine from unit UZ00001. Continued deterioration of these conditions would result in engine malfunctions/failures.

Although the major portions of the engines were in satisfactory condition, the excessive wear in the rocker-camshaft areas and the severe liner pitting (coolant side) are of critical concern. It should be noted that wear ratings are visual, and no numerical values are available to determine the true extent of the damage. For example, rocker shaft wear could be felt by touch on the front portions of the shaft but becomes only visible moving toward the rear portion. It is not possible to determine if the wear were lubricant related, a lubricant-mechanical problem, or strictly from a mechanical source. No matter what the source, the wear will eventually result in an engine malfunction. Likewise, the liner pitting could result in an engine failure. The most severe pitting (estimated 1/8 to 1/4 depth) occurred in the lower section of all liners. Again, the cause of pitting could not be determined directly.

With the exception of the severe liner pitting (coolant side), the engine was in satisfactory condition and had been adequately lubricated. Also, it should be noted that coolant had leaked into the crankcase. The source and time of this leakage could not be determined; therefore, it was not possible to evaluate the overall effect of the leak on the observations made during the inspection.

## IV. CONCLUSIONS

11. **Conclusions.** Based on the work reported herein, it is concluded that:

a. The initial precautionary limits established in the Phase I testing were conservative except for a few isolated instances during which some engines operated beyond these limits.

b. There were no engine failures or signs of pending trouble areas attributable to the lubricating oil under Phase I testing.

c. The chemical and spectrometric analyses under Phase I indicated that the oil was performing in a satisfactory manner and that the standard, 100-hour, oil-change interval was conservative and could be safely extended.

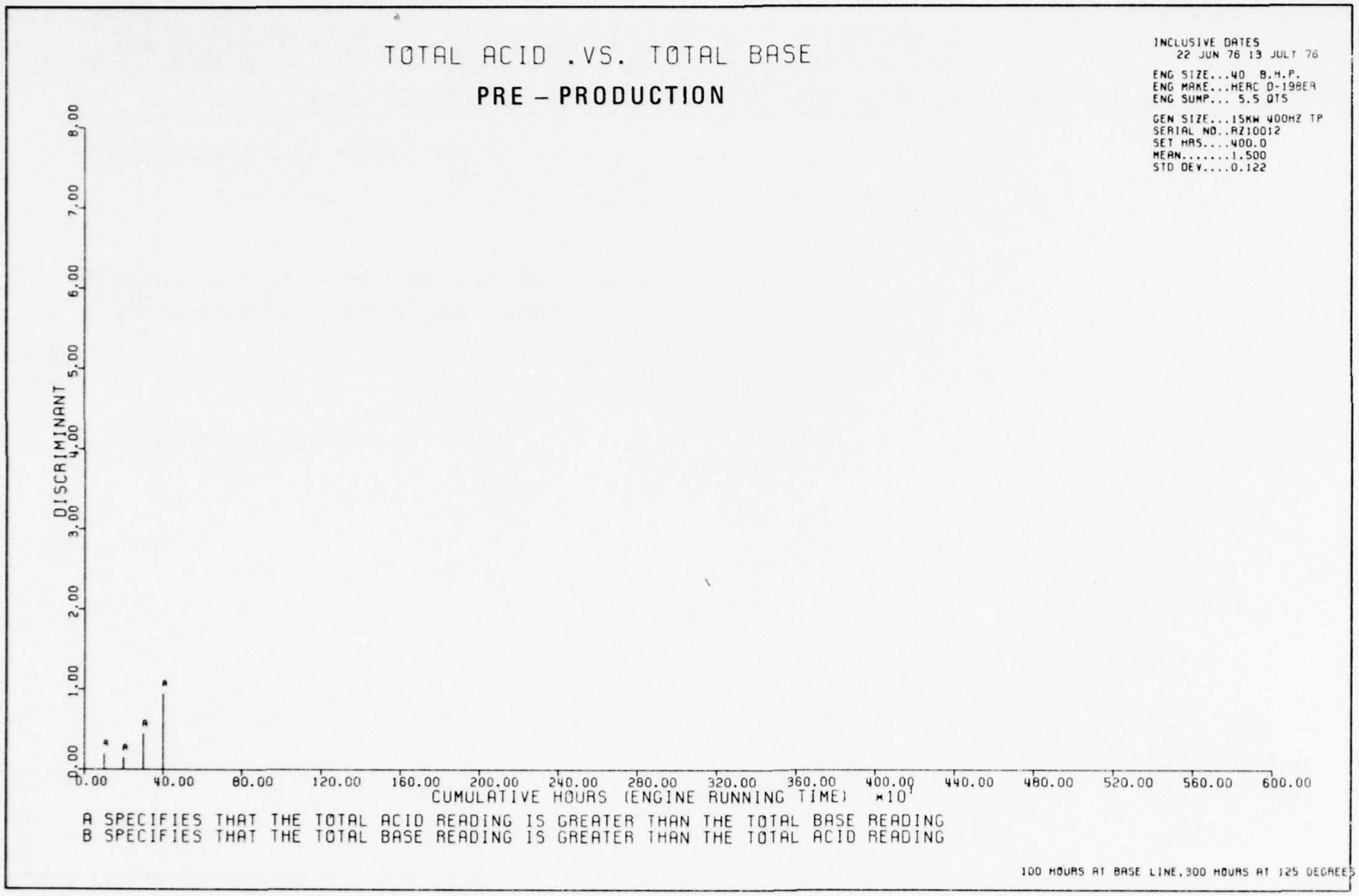
d. Under Phase II testing, there were no engine failures or any deleterious effects directly attributable to the extended-oil-change intervals established, i.e., 600, 700, and 1000 hours for the engines being tested.

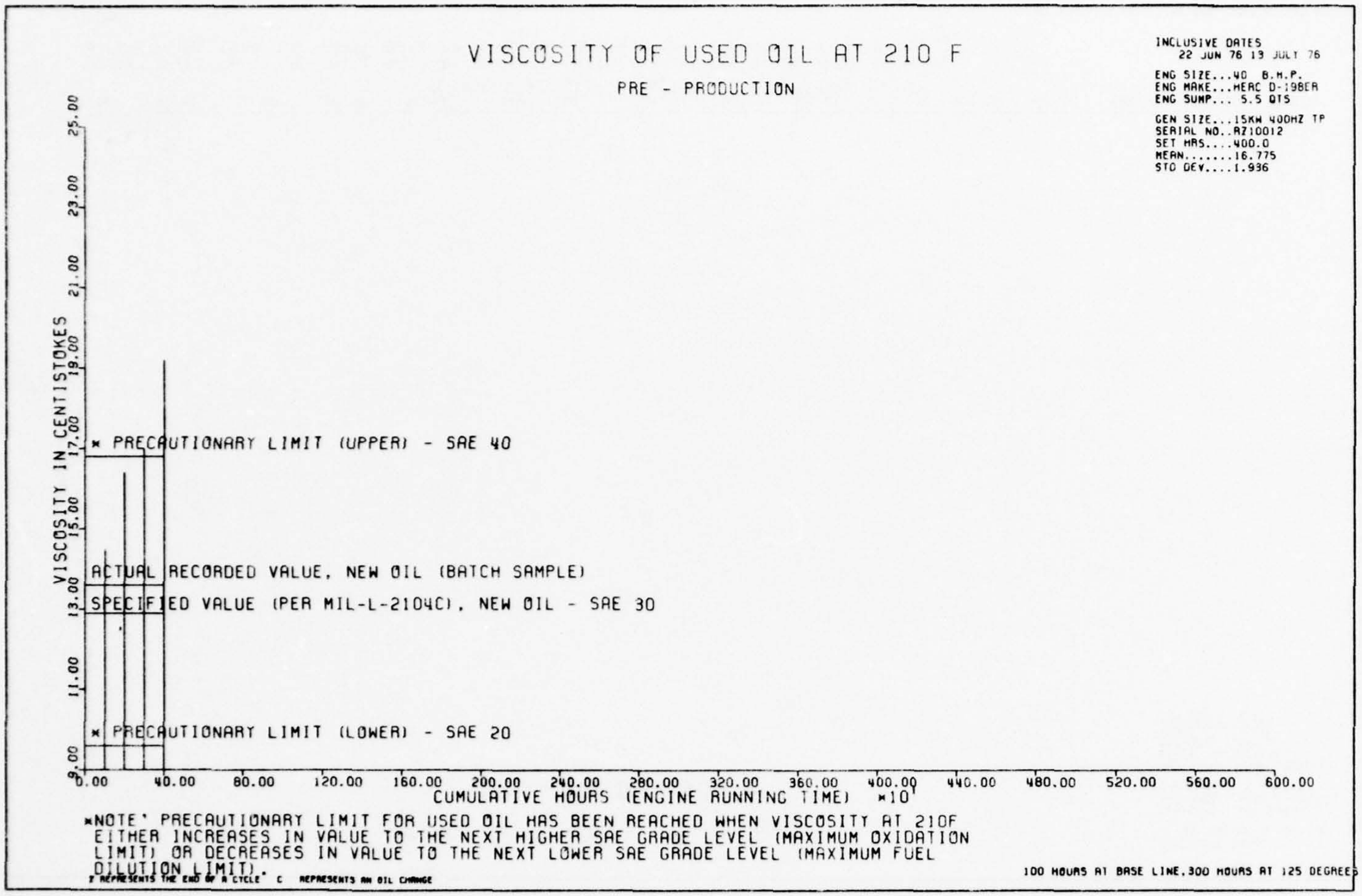
e. The test results indicate that generator sets ranging in size from 15 kW through 100 kW using MIL-L-2104C lubricating oil and operating under normal, ambient conditions or extreme temperatures up to 125°F or under stand-by, low-duty service could operate satisfactorily with a 300-hour/6-month oil-change interval without engine performance, reliability, or total life cycle being adversely affected.

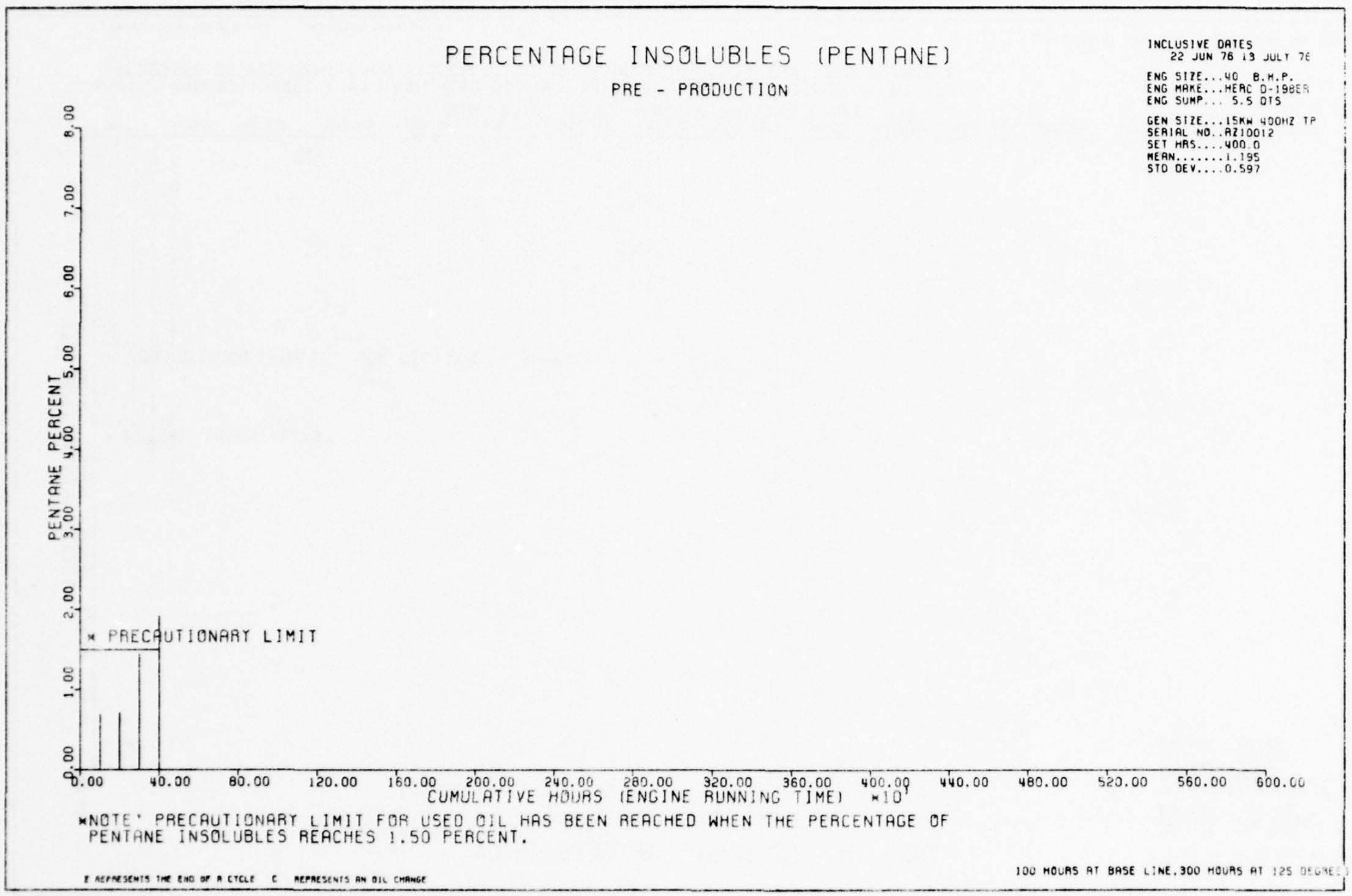
f. A 300-hour/6-month oil-change interval offers the maximum benefit and cost-saving compromise to the military while maintaining a minimum 100 percent safety factor with respect to risks of engine malfunctions or failures attributable to extended, lubricating-oil-change intervals.

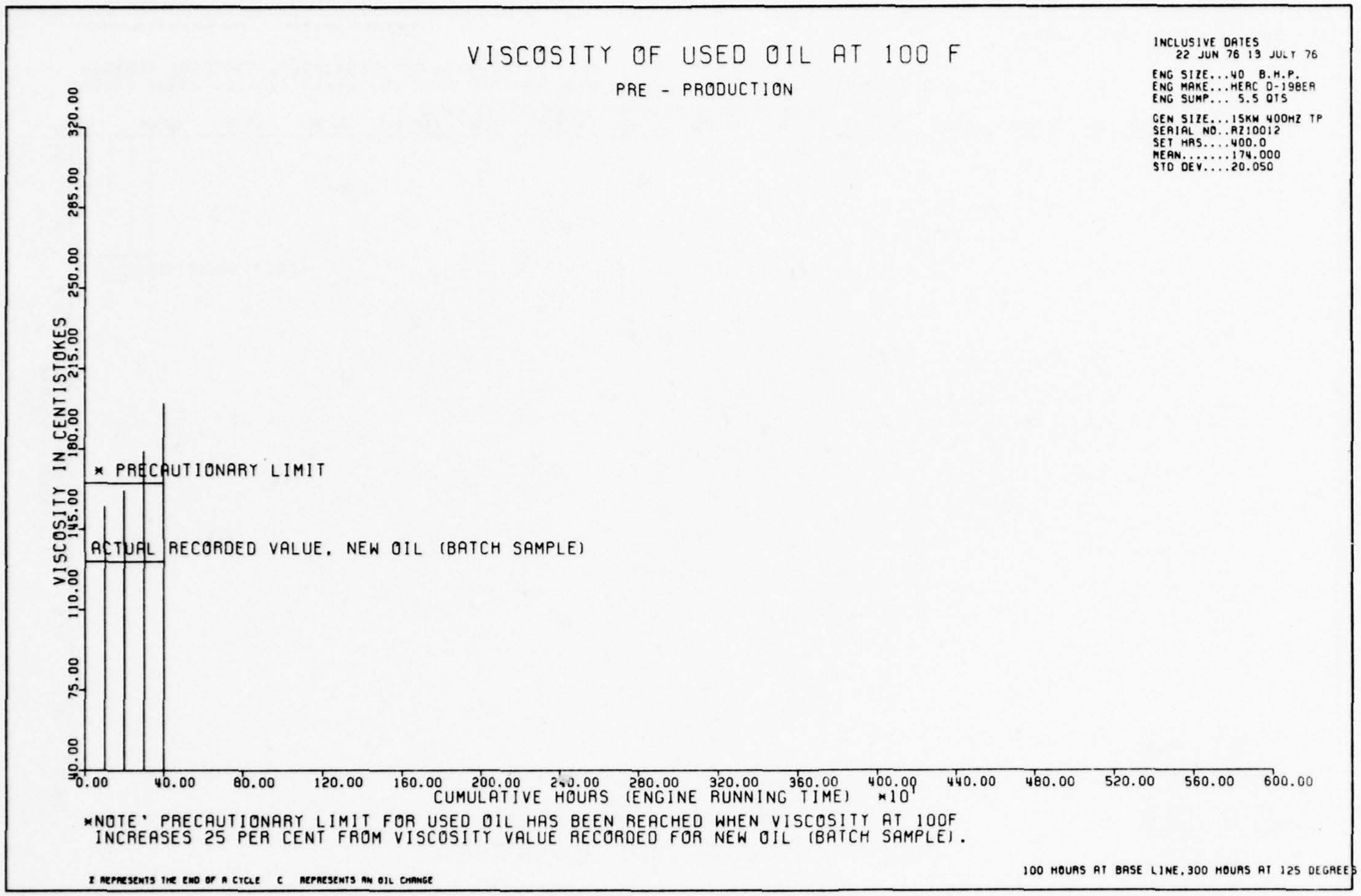
## APPENDIX A

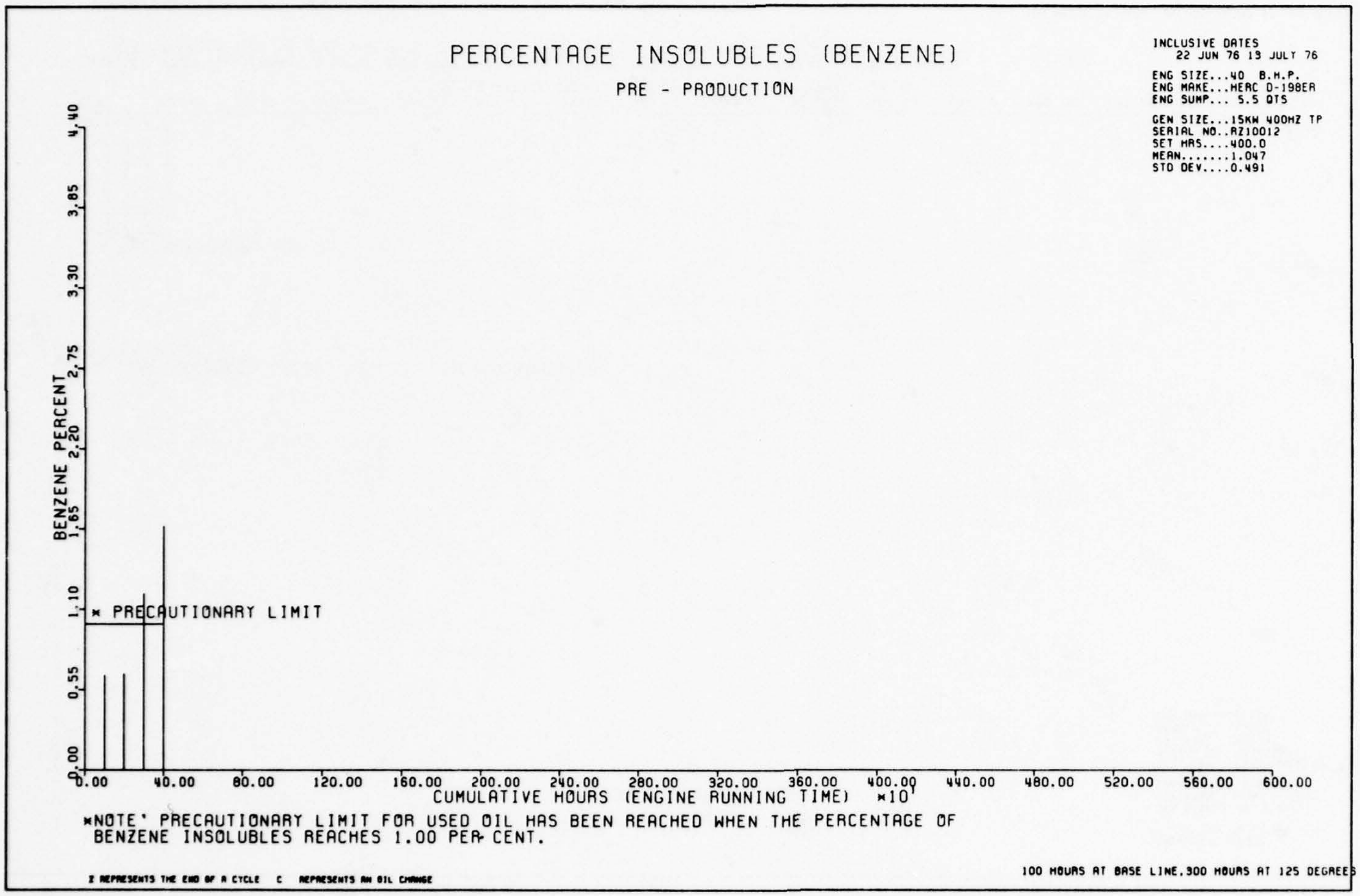
## PHASE I PRE-PRODUCTION MODELS

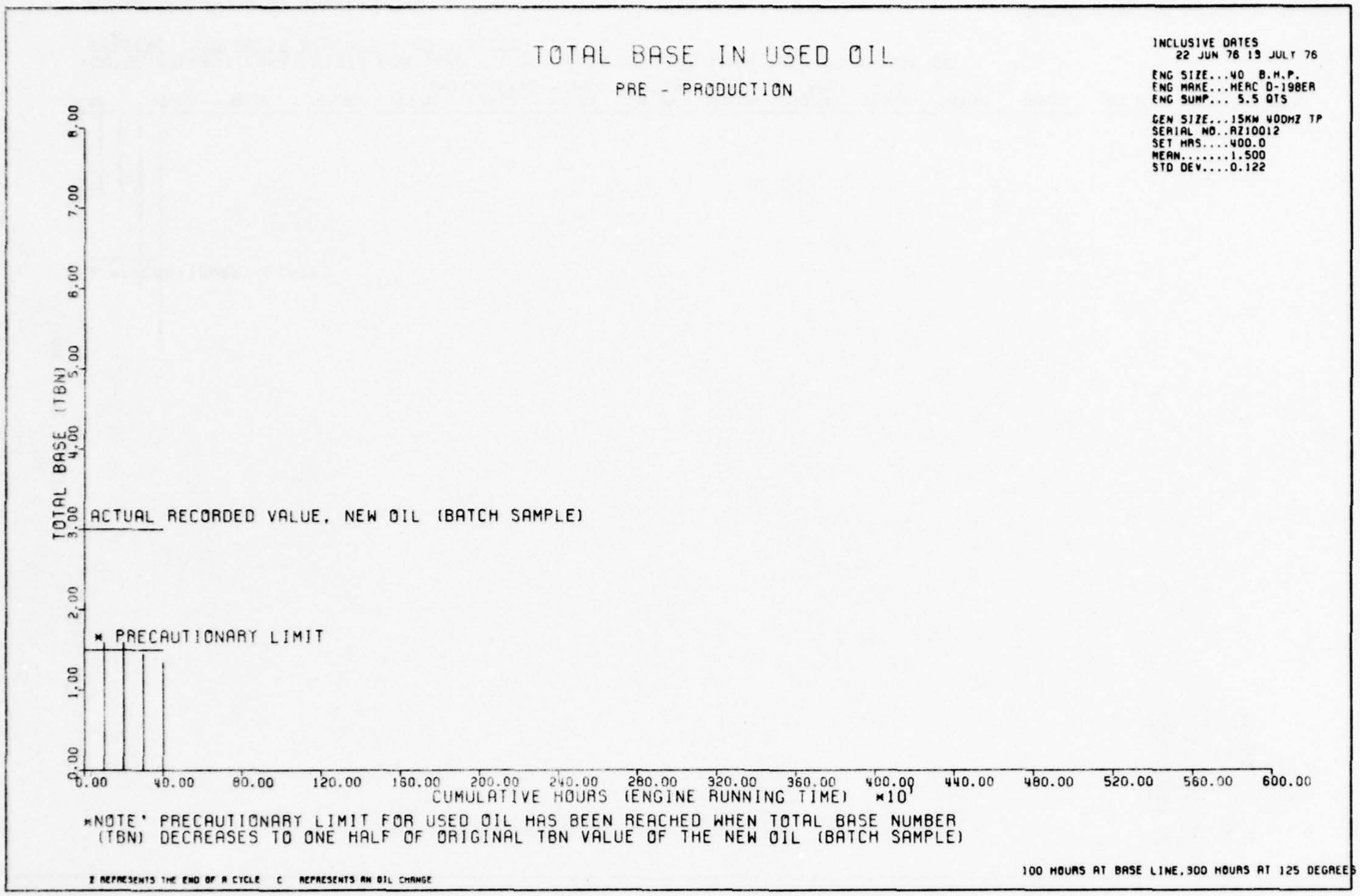

TOTAL ACID .VS. TOTAL BASE
PRE – PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..AZ10012
SET HRS....400.0
MEAN.......1.500
STD DEV....0.122
DISCRIMINANT
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
A
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) ×10
A SPECIFIES THAT THE TOTAL ACID READING IS GREATER THAN THE TOTAL BASE READING
B SPECIFIES THAT THE TOTAL BASE READING IS GREATER THAN THE TOTAL ACID READING
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES


VISCOSITY OF USED OIL AT 210 F
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..RZ10012
SET HRS....400.0
MEAN.......16.775
STD DEV....1.936
VISCOSITY IN CENTISTOKES
9.00
11.00
13.00
15.00
17.00
19.00
21.00
23.00
25.00
* PRECAUTIONARY LIMIT (UPPER) - SAE 40
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL - SAE 30
* PRECAUTIONARY LIMIT (LOWER) - SAE 20
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).
Z REPRESENTS THE END OF A CYCLE' C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES


PERCENTAGE INSOLUBLES (PENTANE)
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..RZ10012
SET HRS....400.0
MEAN.......1.195
STD DEV....0.597
PENTANE PERCENT
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
* PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF PENTANE INSOLUBLES REACHES 1.50 PERCENT.
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES


VISCOSITY OF USED OIL AT 100 F
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..RZ10012
SET HRS....400.0
MEAN.......174.000
STD DEV....20.050
VISCOSITY IN CENTISTOKES
40.00
75.00
110.00
145.00
180.00
215.00
250.00
285.00
320.00
* PRECAUTIONARY LIMIT
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 100F
INCREASES 25 PER CENT FROM VISCOSITY VALUE RECORDED FOR NEW OIL (BATCH SAMPLE).
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES


PERCENTAGE INSOLUBLES (BENZENE)
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..RZ10012
SET HRS....400.0
MEAN.......1.047
STD DEV....0.491
BENZENE PERCENT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
* PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF BENZENE INSOLUBLES REACHES 1.00 PER CENT.
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES



TOTAL BASE IN USED OIL
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..RZ10012
SET HRS....400.0
MEAN.......1.500
STD DEV....0.122
TOTAL BASE (TBN)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
* PRECAUTIONARY LIMIT
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL BASE NUMBER (TBN) DECREASES TO ONE HALF OF ORIGINAL TBN VALUE OF THE NEW OIL (BATCH SAMPLE)
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

## TOTAL BASE IN USED OIL

PRE - PRODUCTION

INCLUSIVE DATES
22 JUN 76 13 JULY 76

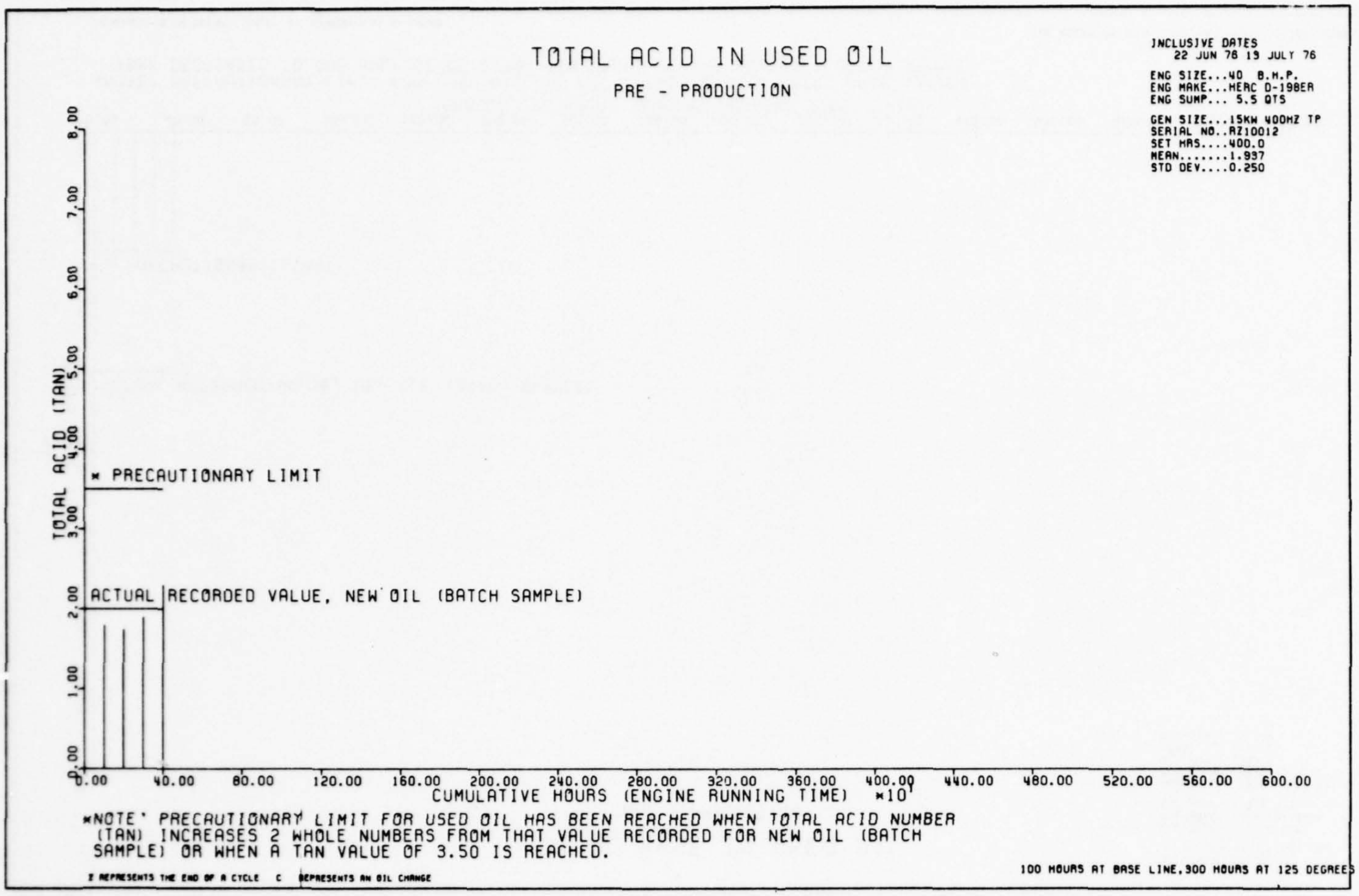
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS

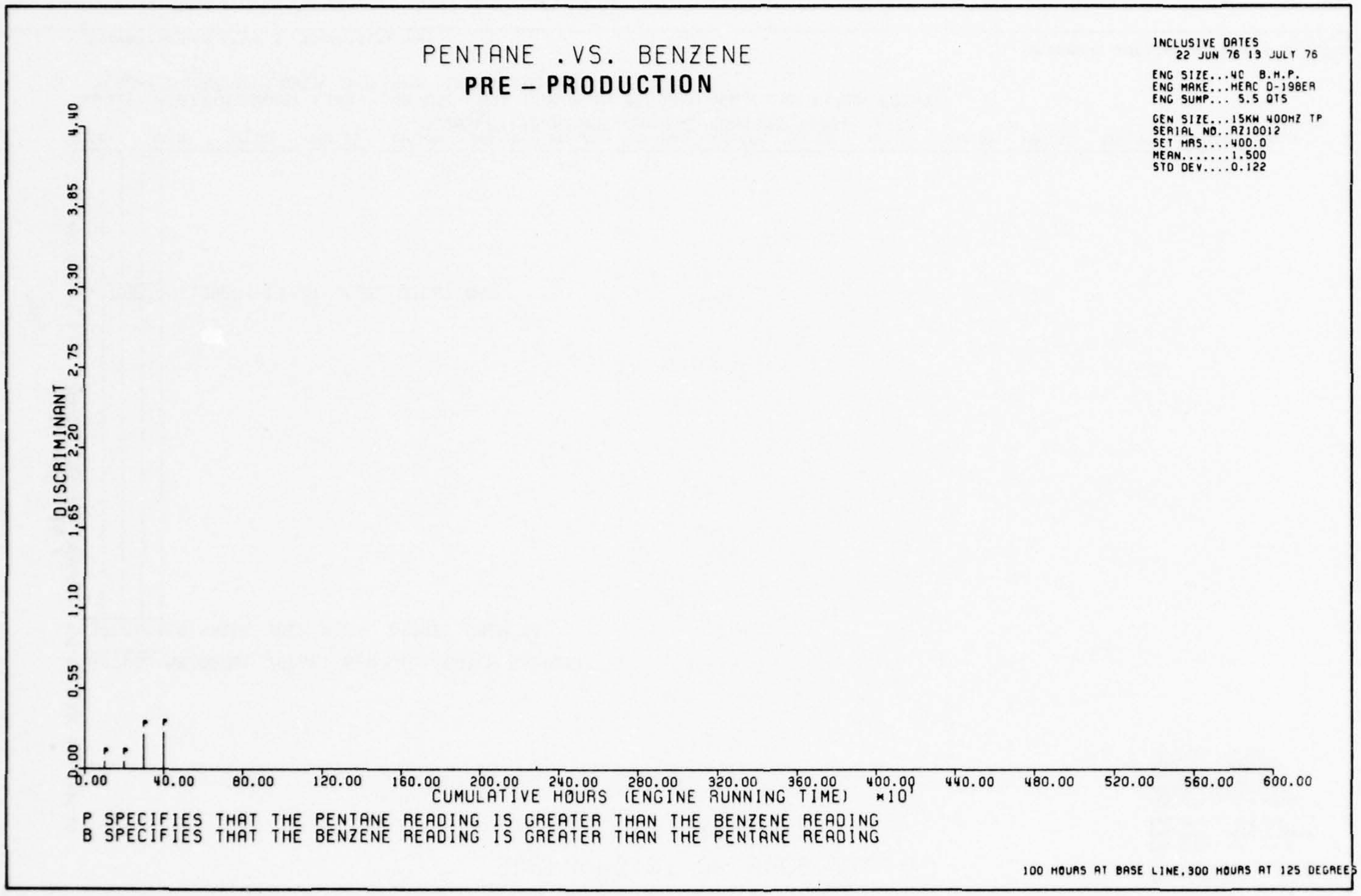
GEN SIZE...15KW 400HZ TP
SERIAL NO..AZ10012
SET HRS....400.0
MEAN.......1.500
STD DEV....0.122

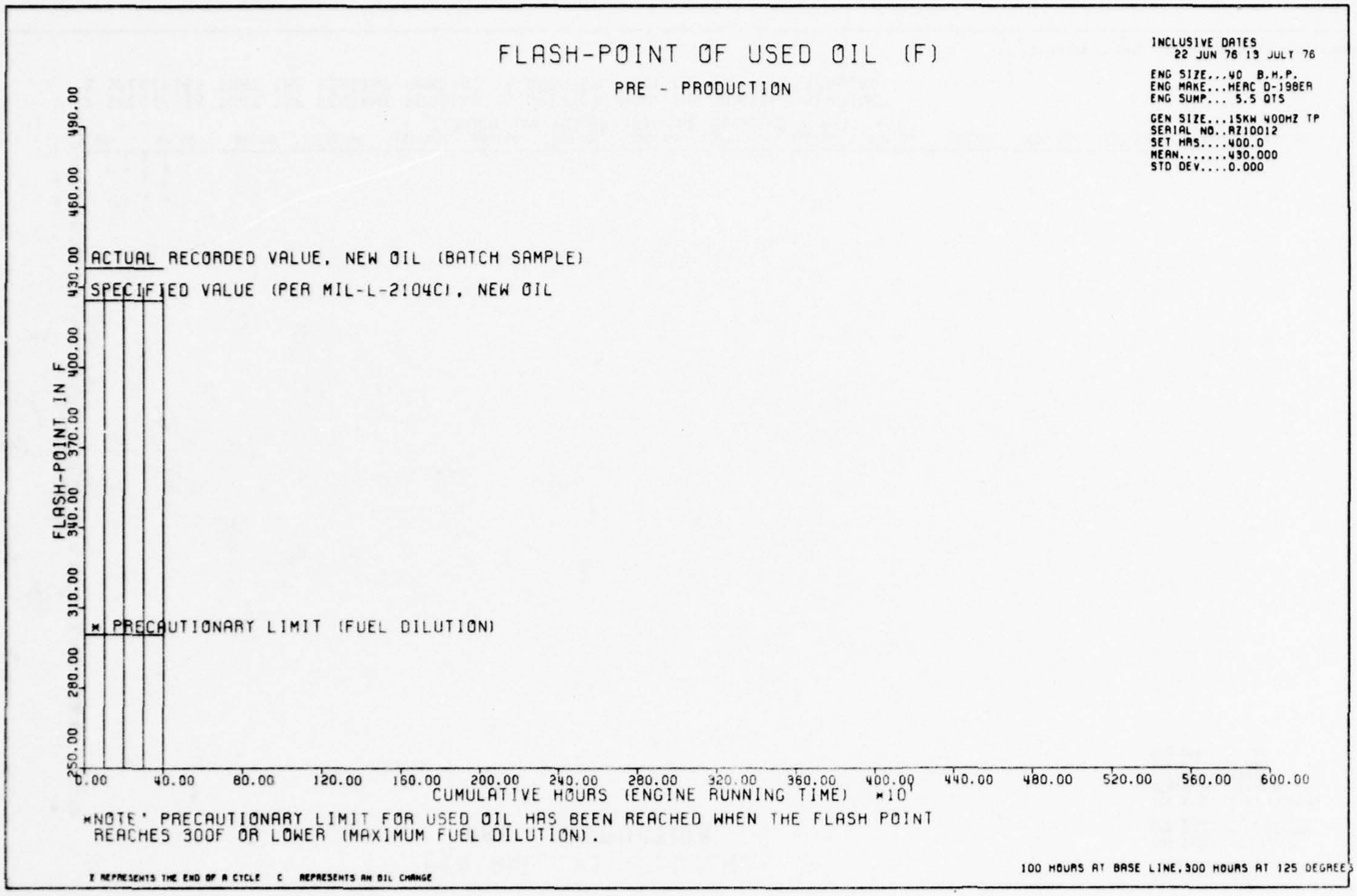

*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL BASE NUMBER (TBN) DECREASES TO ONE HALF OF ORIGINAL TBN VALUE OF THE NEW OIL (BATCH SAMPLE)

Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

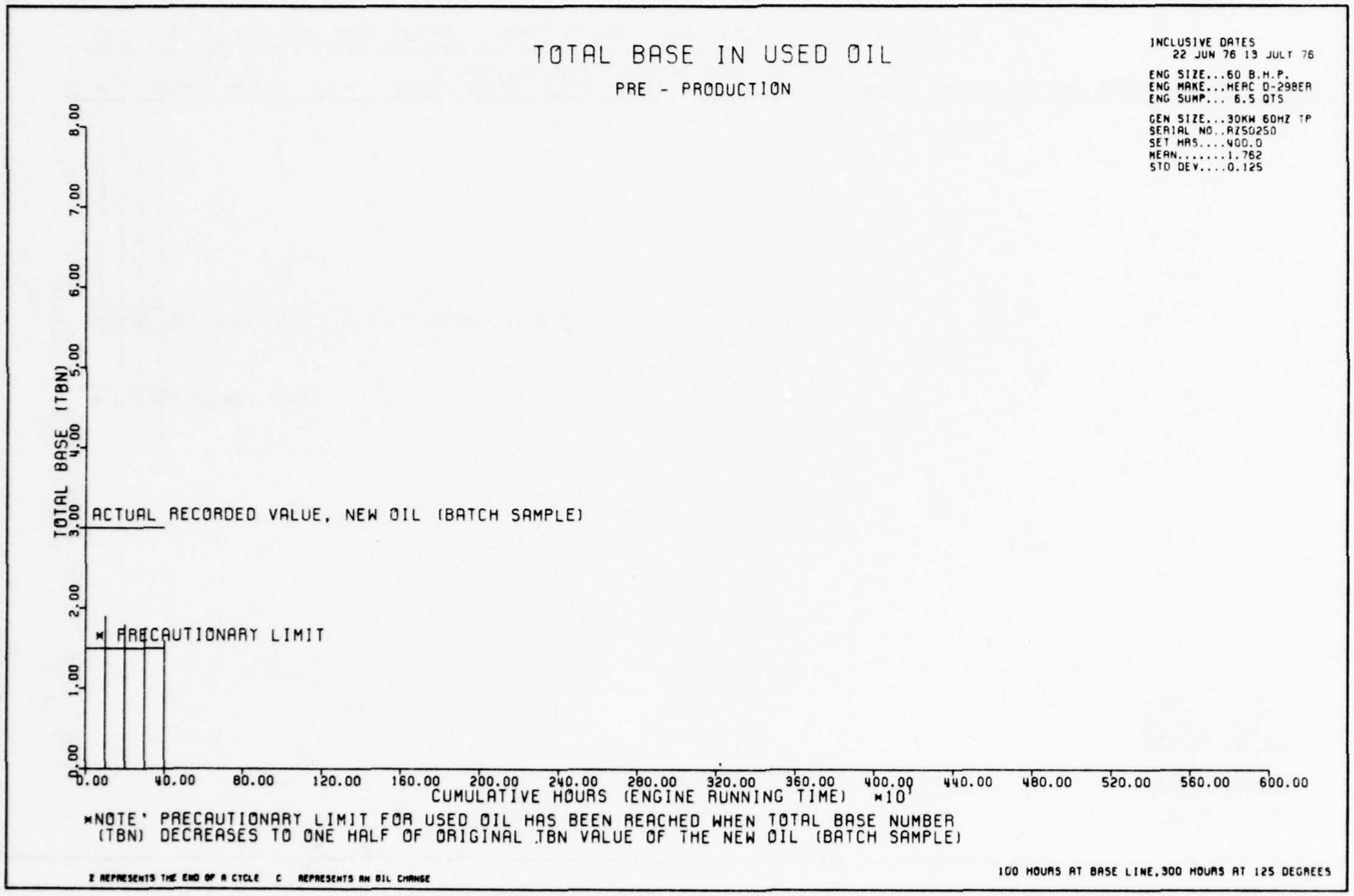
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES


TOTAL ACID IN USED OIL
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 19 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..AZ10012
SET HRS....400.0
MEAN.......1.937
STD DEV....0.250
TOTAL ACID (TAN)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
* PRECAUTIONARY LIMIT
ACTUAL
RECORDED VALUE, NEW OIL (BATCH SAMPLE)
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL ACID NUMBER (TAN) INCREASES 2 WHOLE NUMBERS FROM THAT VALUE RECORDED FOR NEW OIL (BATCH SAMPLE) OR WHEN A TAN VALUE OF 3.50 IS REACHED.
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES

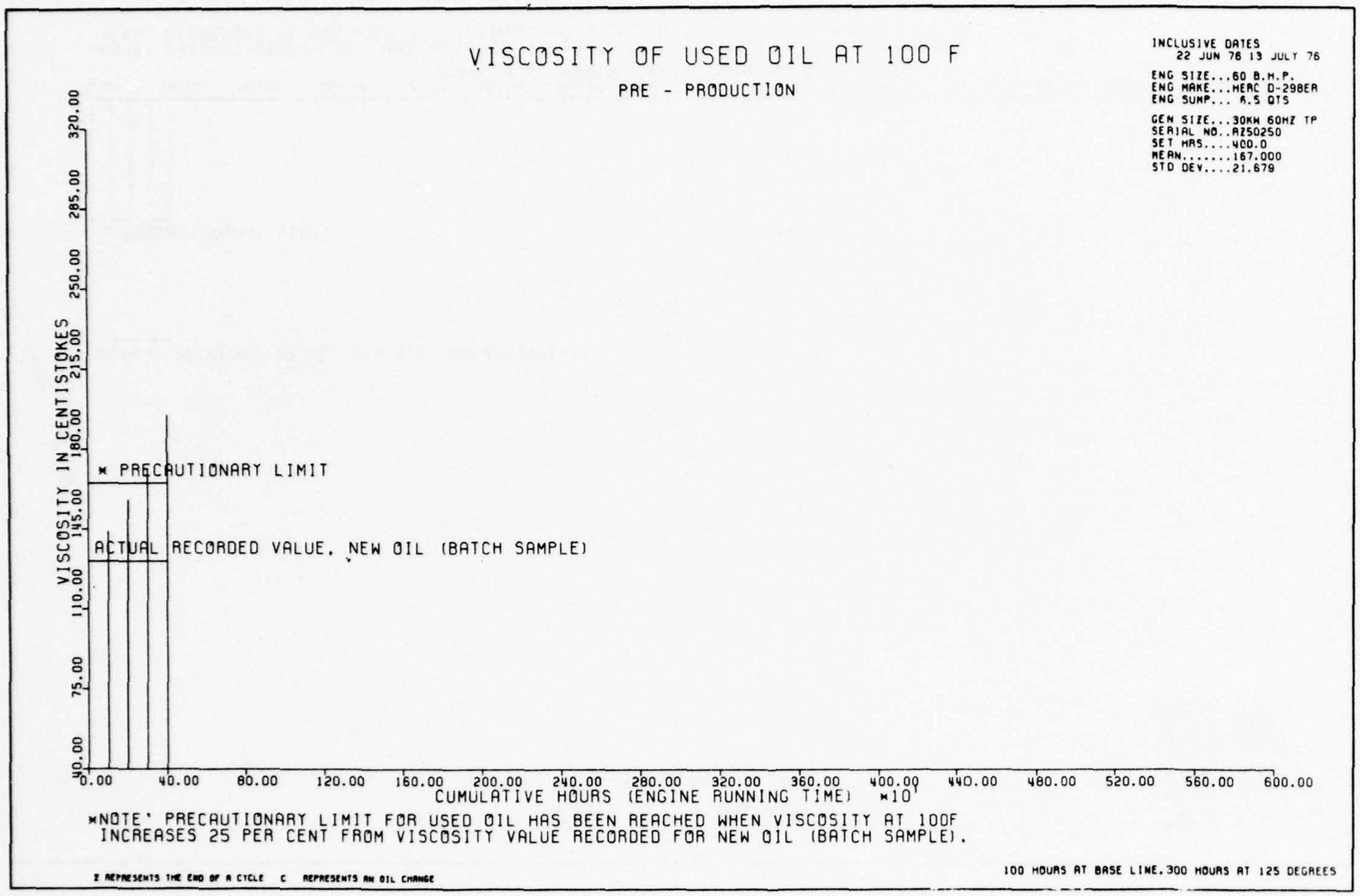

PENTANE .VS. BENZENE
PRE – PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198EA
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..RZ10012
SET HRS....400.0
MEAN.......1.500
STD DEV....0.122
DISCRIMINANT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
P SPECIFIES THAT THE PENTANE READING IS GREATER THAN THE BENZENE READING
B SPECIFIES THAT THE BENZENE READING IS GREATER THAN THE PENTANE READING
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES

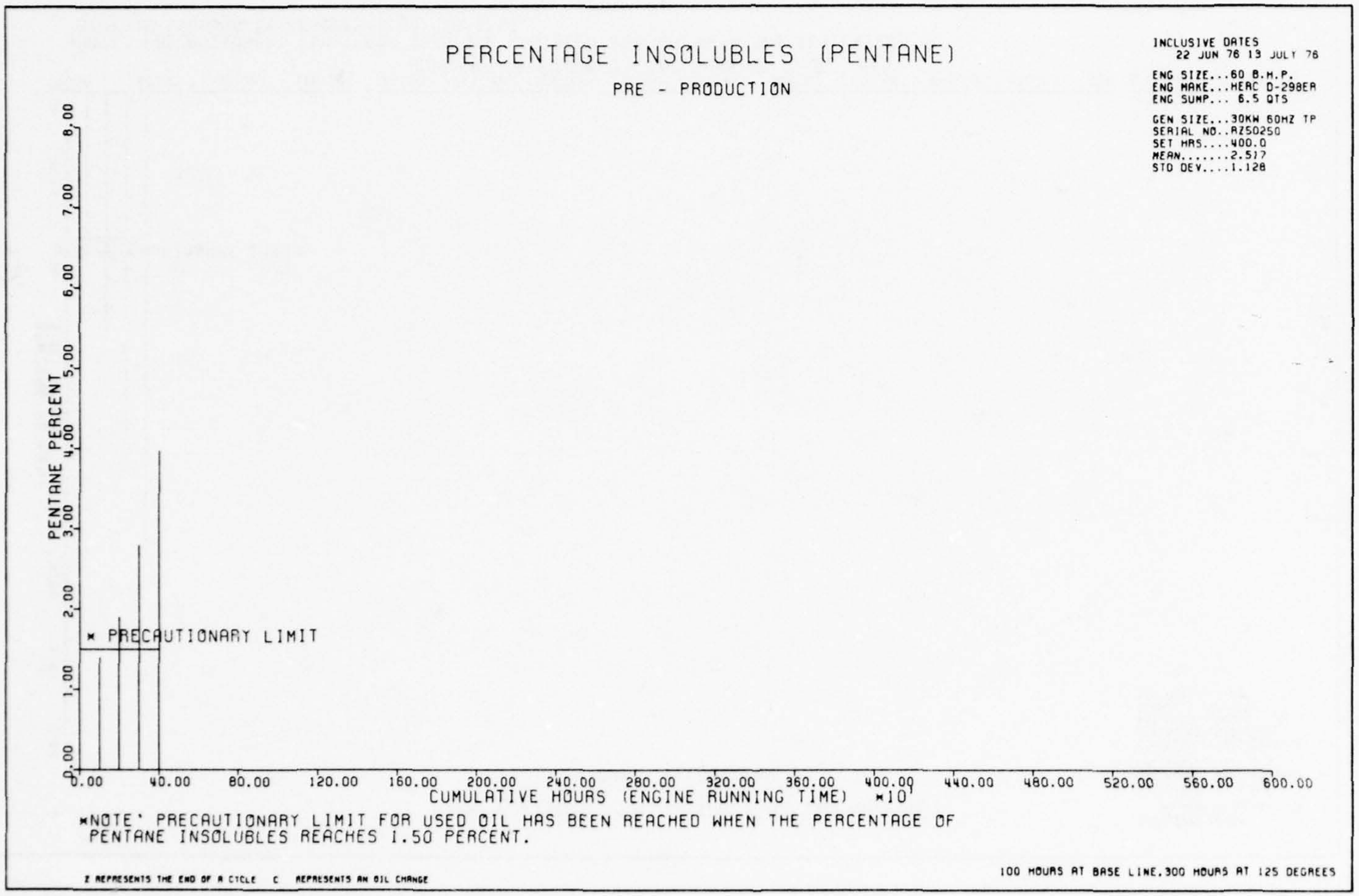


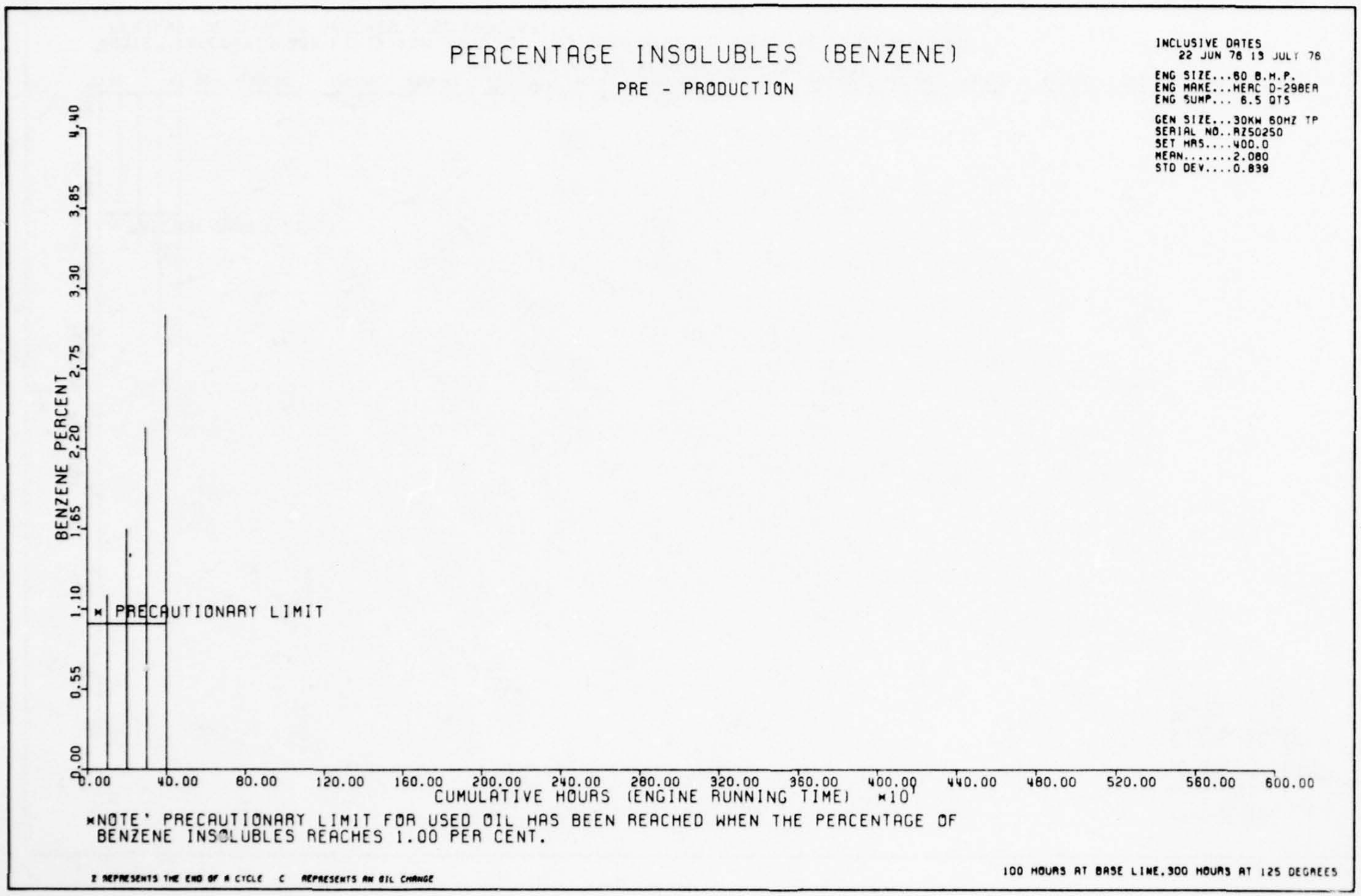
FLASH-POINT OF USED OIL (F)
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...40 B.H.P.
ENG MAKE...HERC D-198ER
ENG SUMP... 5.5 QTS
GEN SIZE...15KW 400HZ TP
SERIAL NO..RZ10012
SET HRS....400.0
MEAN.......430.000
STD DEV....0.000
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL
PRECAUTIONARY LIMIT (FUEL DILUTION)
FLASH-POINT IN F
250.00 280.00 310.00 340.00 370.00 400.00 430.00 460.00 490.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

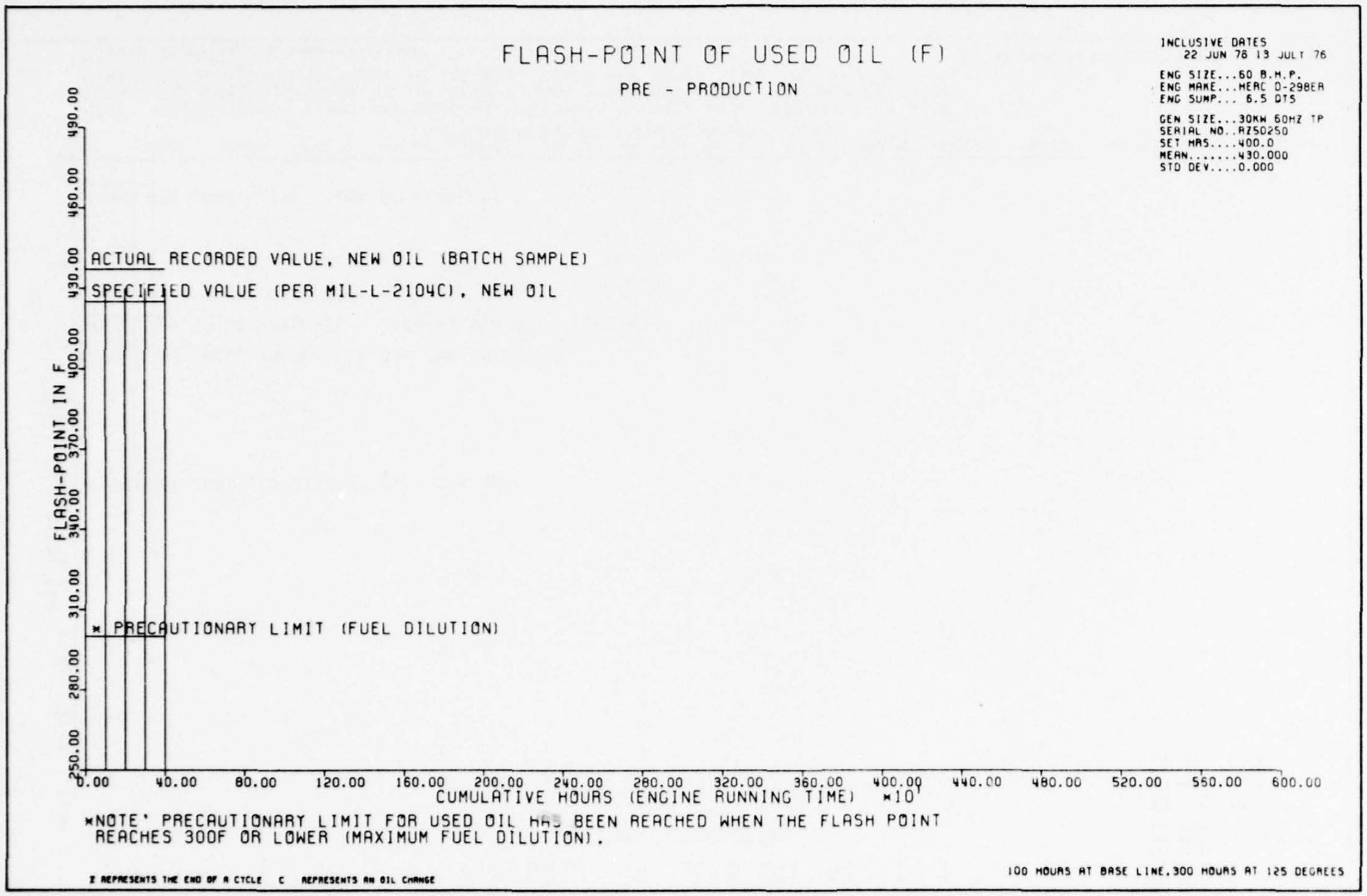


TOTAL BASE IN USED OIL
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...HERC D-298ER
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......1.762
STD DEV....0.125
TOTAL BASE (TBN)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
PRECAUTIONARY LIMIT
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL BASE NUMBER
(TBN) DECREASES TO ONE HALF OF ORIGINAL TBN VALUE OF THE NEW OIL (BATCH SAMPLE)
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES

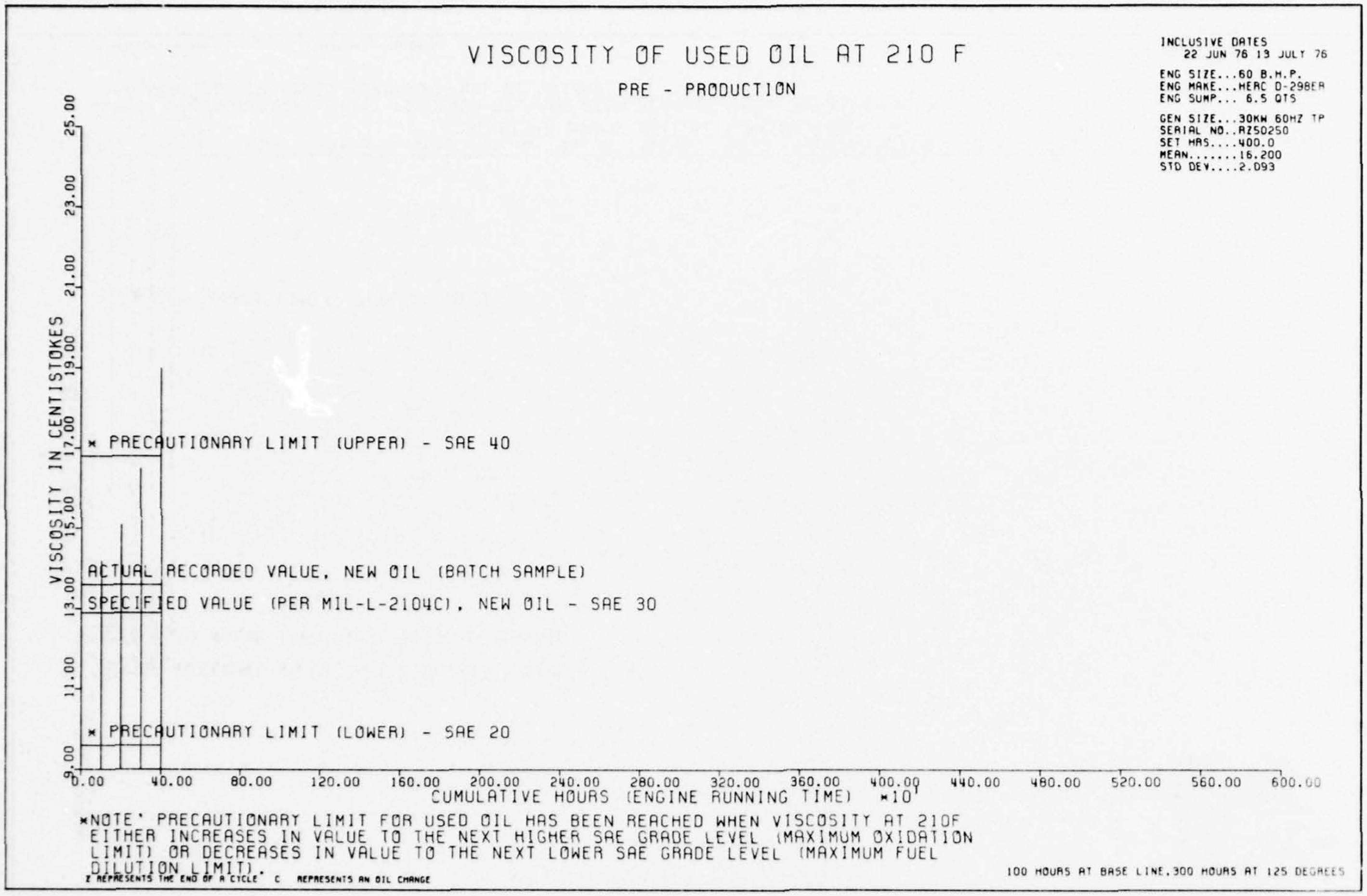

VISCOSITY OF USED OIL AT 100 F
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...HERC D-298ER
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......167.000
STD DEV....21.679
VISCOSITY IN CENTISTOKES
40.00
75.00
110.00
145.00
180.00
215.00
250.00
285.00
320.00
* PRECAUTIONARY LIMIT
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 100F INCREASES 25 PER CENT FROM VISCOSITY VALUE RECORDED FOR NEW OIL (BATCH SAMPLE).
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES

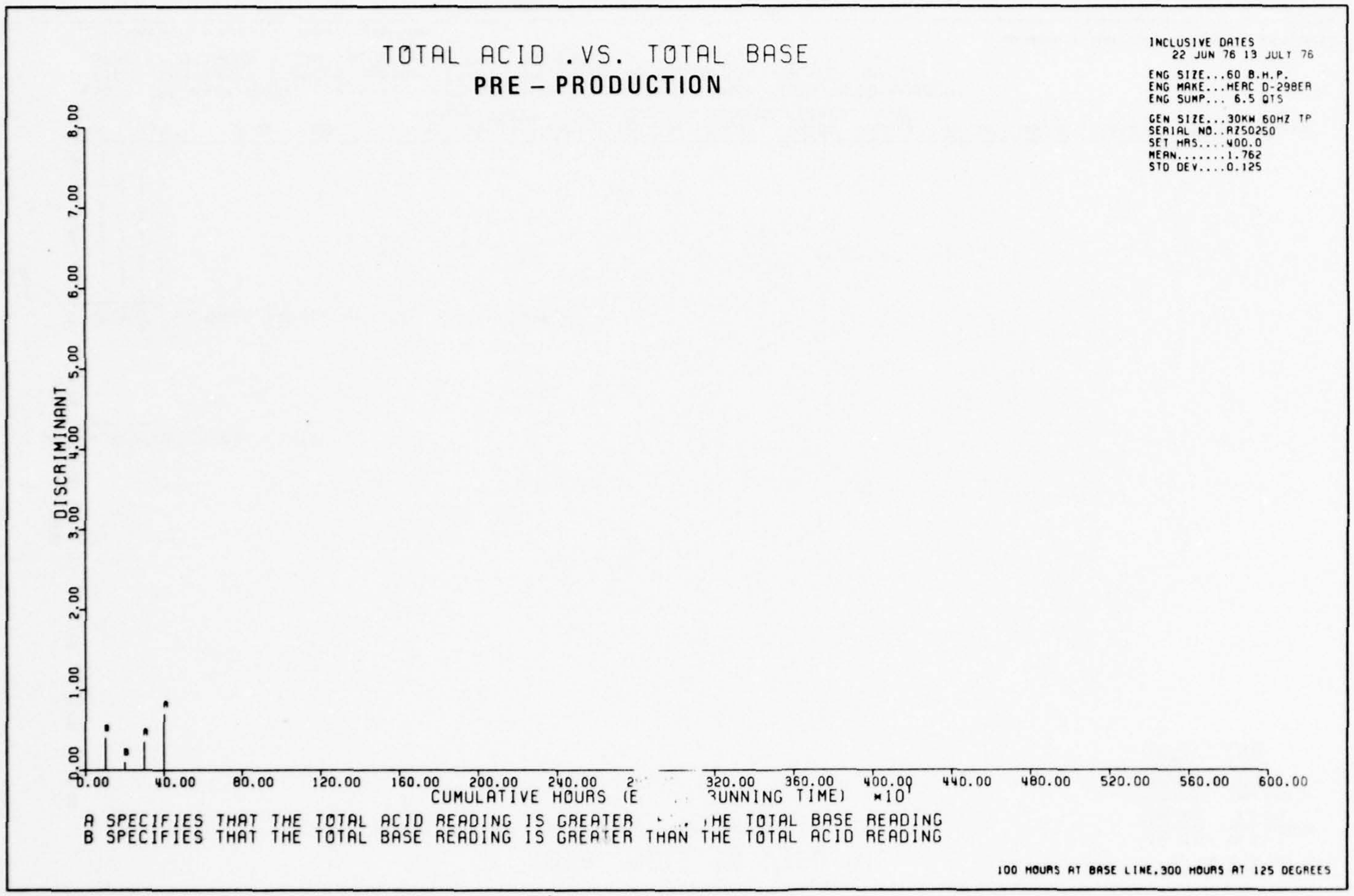

PERCENTAGE INSOLUBLES (PENTANE)
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...HERC D-298ER
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......2.517
STD DEV....1.128
PENTANE PERCENT
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
* PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF PENTANE INSOLUBLES REACHES 1.50 PERCENT.
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES

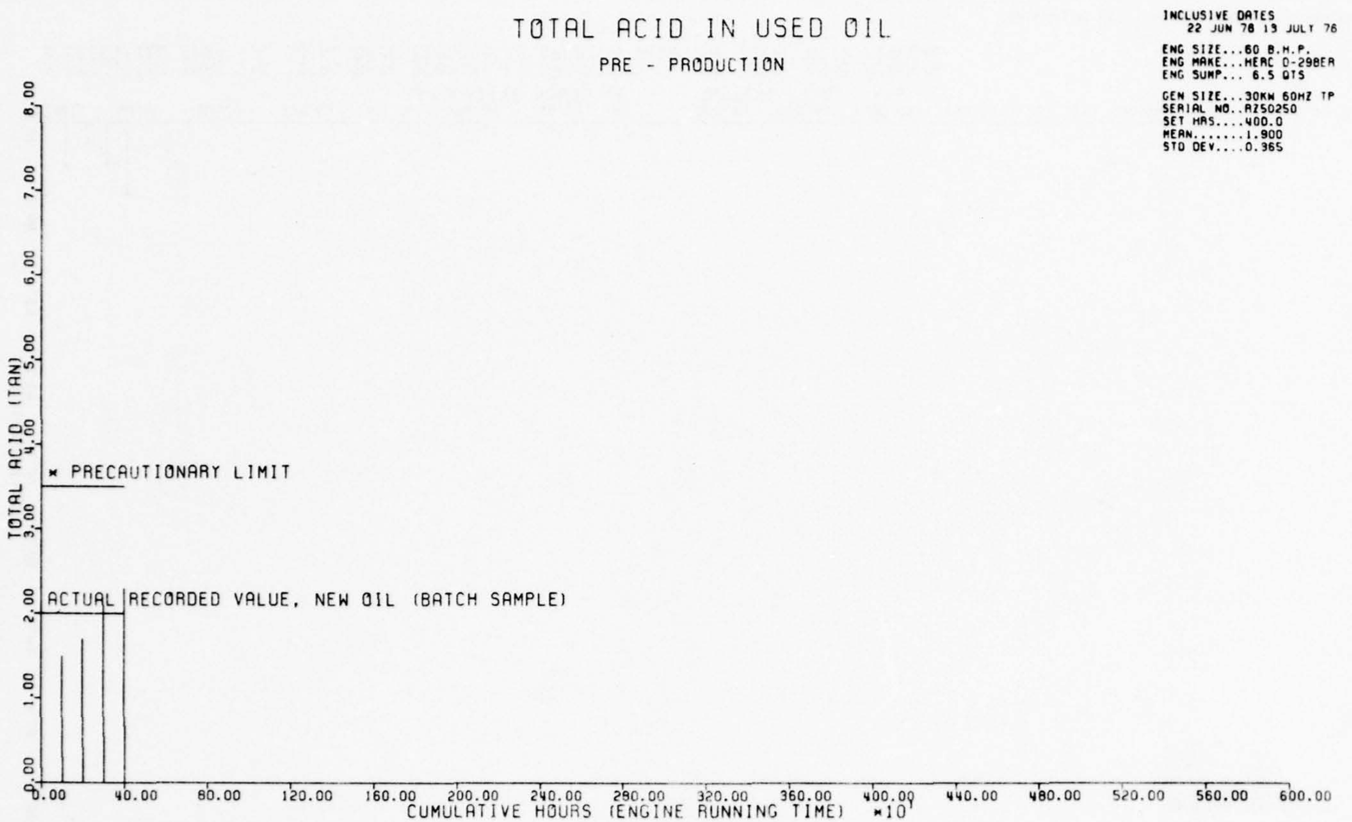

PERCENTAGE INSOLUBLES (BENZENE)
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...HERC D-298ER
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......2.080
STD DEV....0.839
BENZENE PERCENT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
* PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF BENZENE INSOLUBLES REACHES 1.00 PER CENT.
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES



FLASH-POINT OF USED OIL (F)
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...HERC D-298ER
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......430.000
STD DEV....0.000
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL
* PRECAUTIONARY LIMIT (FUEL DILUTION)
FLASH-POINT IN F
250.00
280.00
310.00
340.00
370.00
400.00
430.00
460.00
490.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT
REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES


VISCOSITY OF USED OIL AT 210 F
PRE - PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...HERC D-298ER
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......16.200
STD DEV....2.093
VISCOSITY IN CENTISTOKES
9.00
11.00
13.00
15.00
17.00
19.00
21.00
23.00
25.00
* PRECAUTIONARY LIMIT (UPPER) - SAE 40
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL - SAE 30
* PRECAUTIONARY LIMIT (LOWER) - SAE 20
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).
Z REPRESENTS THE END OF A CYCLE' C REPRESENTS AN OIL CHANGE
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES

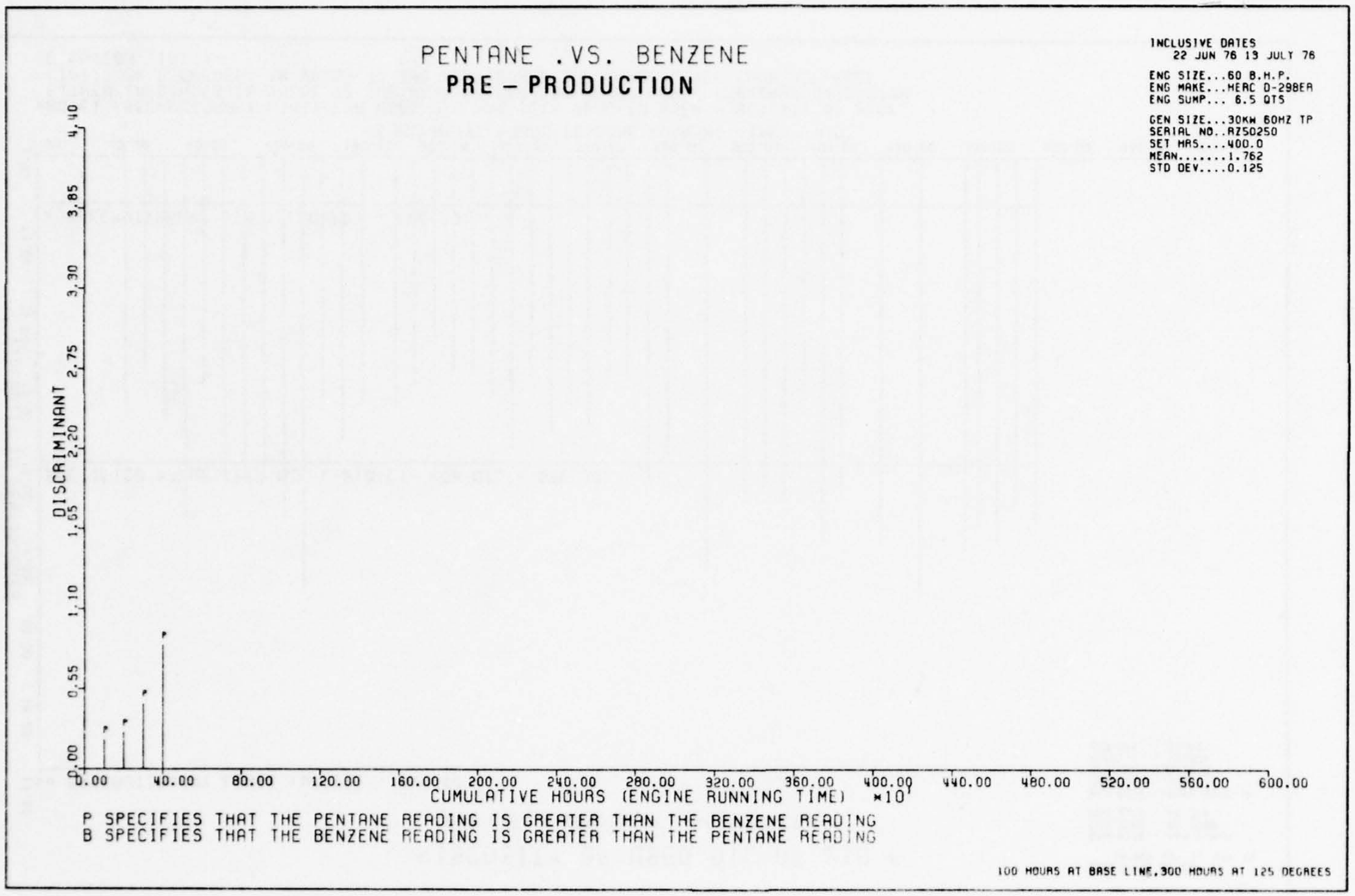

TOTAL ACID .VS. TOTAL BASE
PRE – PRODUCTION
INCLUSIVE DATES
22 JUN 76 13 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...HERC D-298ER
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......1.762
STD DEV....0.125
DISCRIMINANT
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS
RUNNING TIME)
*10
A SPECIFIES THAT THE TOTAL ACID READING IS GREATER
HE TOTAL BASE READING
B SPECIFIES THAT THE TOTAL BASE READING IS GREATER THAN THE TOTAL ACID READING
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES

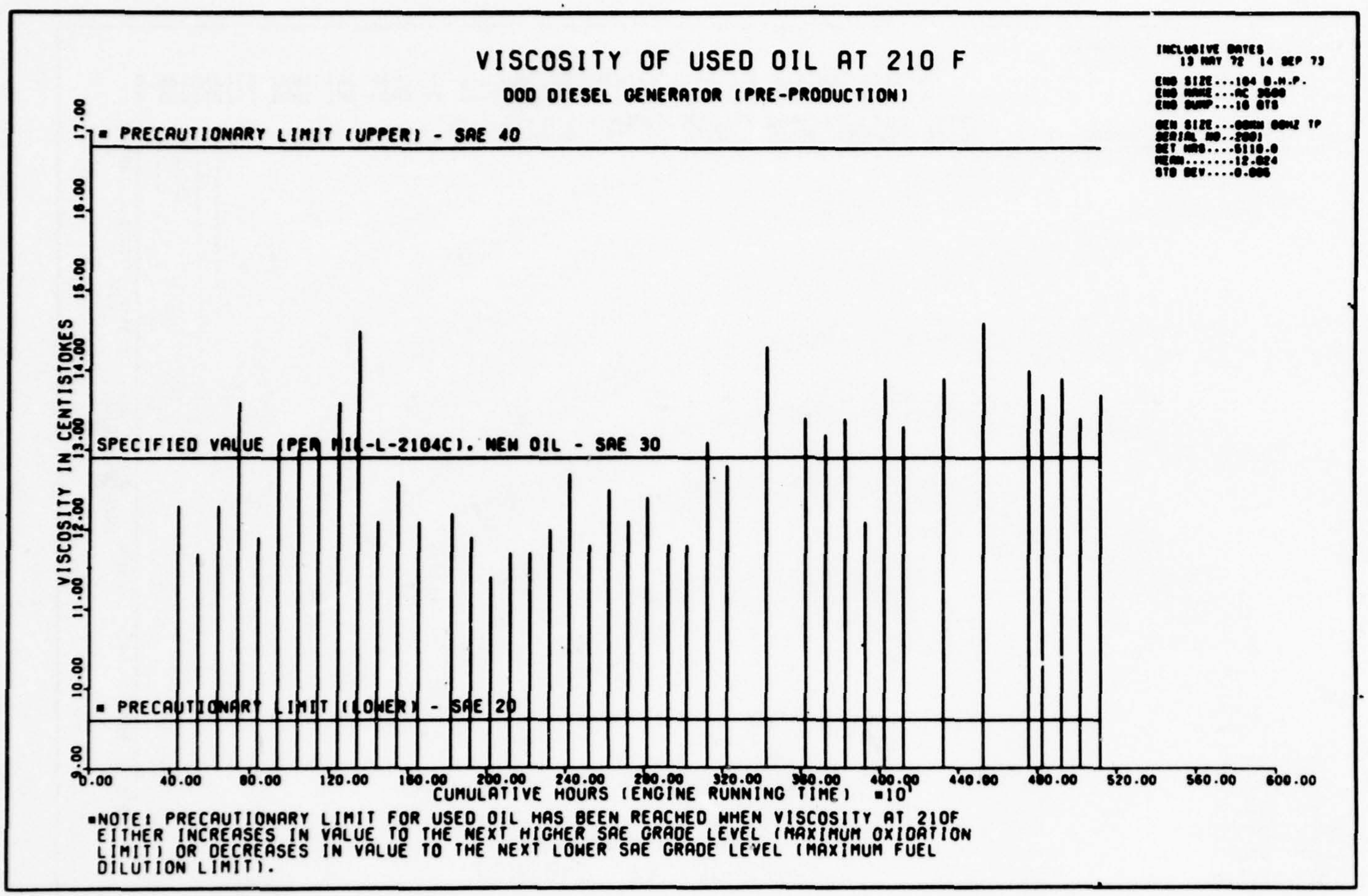


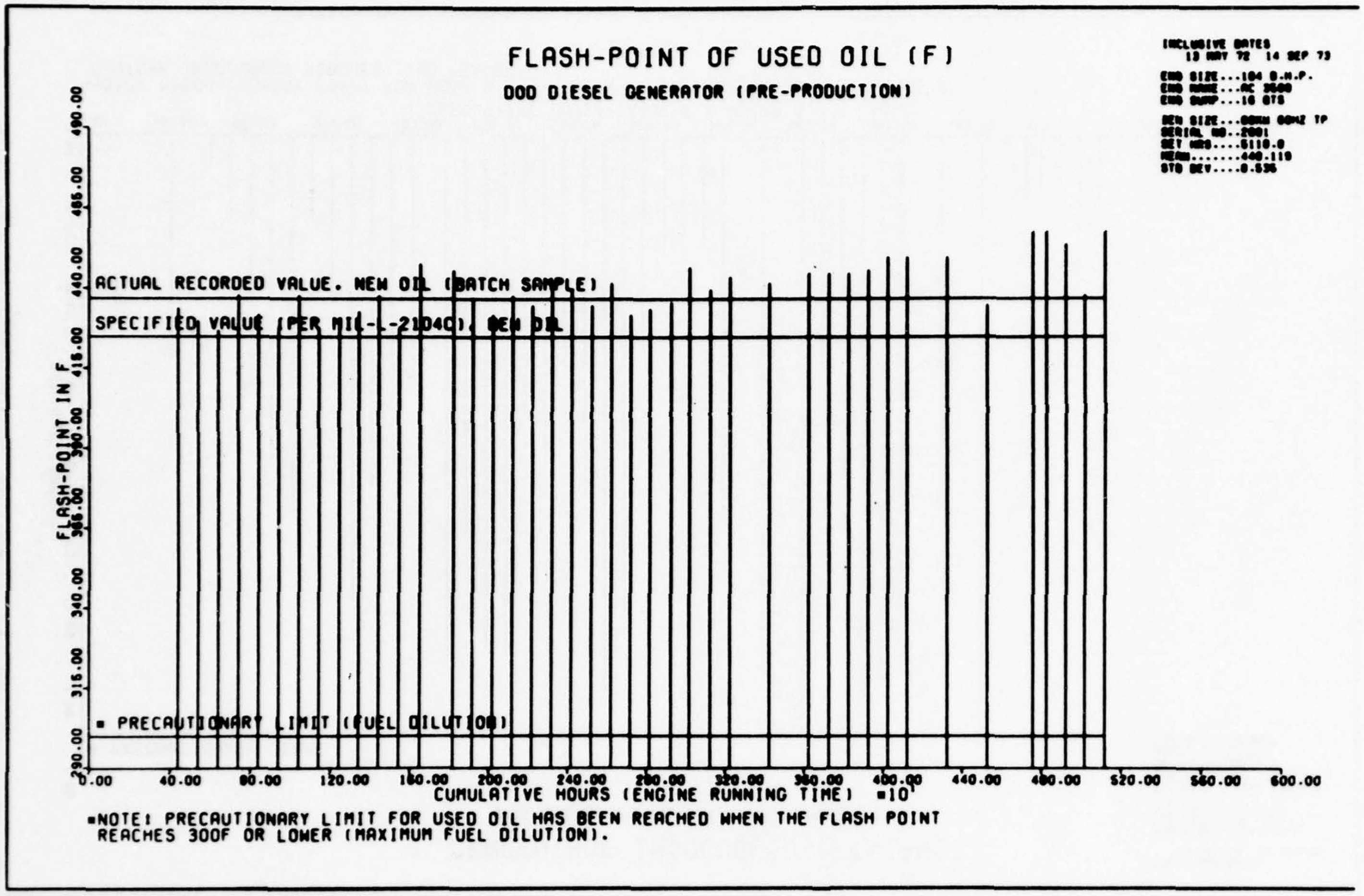

*NOTE' PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL ACID NUMBER (TAN) INCREASES 2 WHOLE NUMBERS FROM THAT VALUE RECORDED FOR NEW OIL (BATCH SAMPLE) OR WHEN A TAN VALUE OF 3.50 IS REACHED.

I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

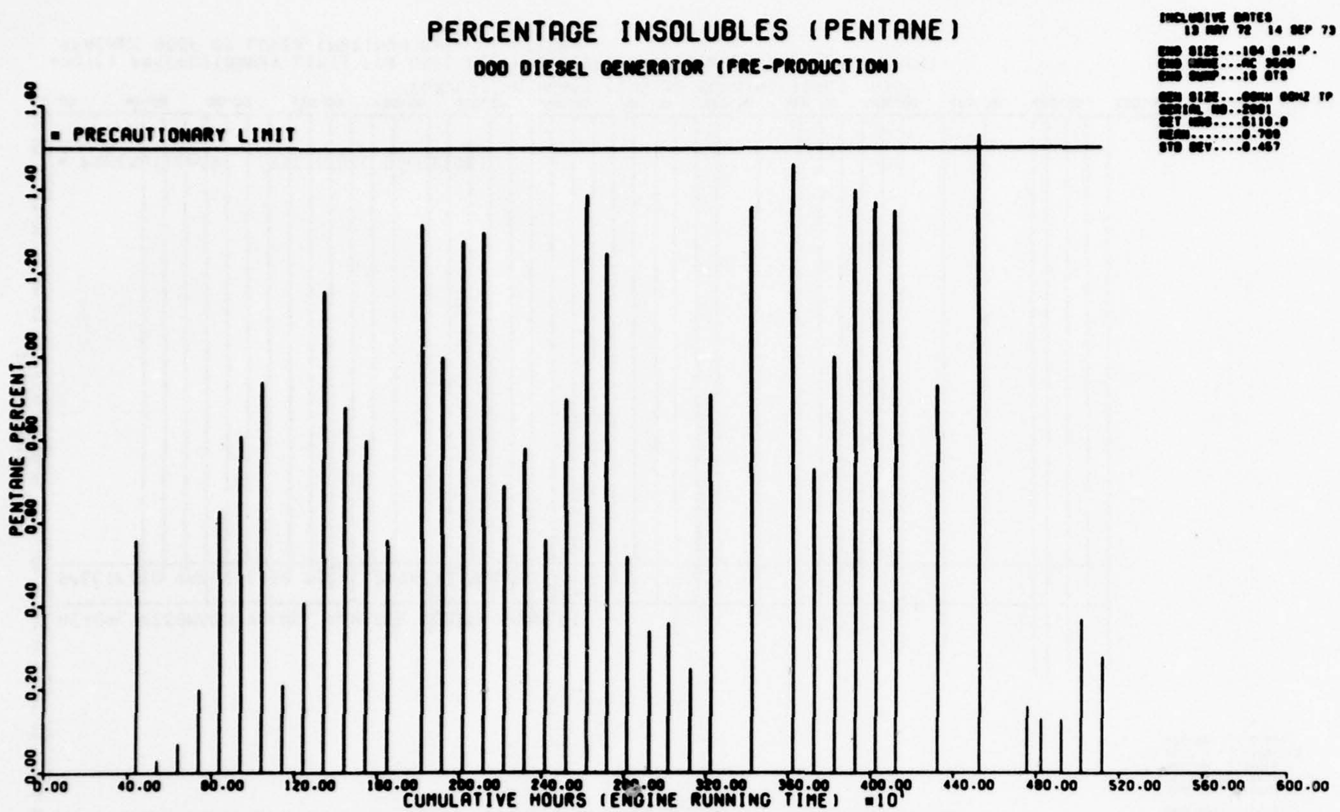
100 HOURS AT BASE LINE, 300 HOURS AT 125 DEGREES


PENTANE .VS. BENZENE
PRE – PRODUCTION
INCLUSIVE DATES
22 JUN 76 19 JULY 76
ENG SIZE...60 B.H.P.
ENG MAKE...MERC D-298EA
ENG SUMP... 6.5 QTS
GEN SIZE...30KW 60HZ TP
SERIAL NO..RZ50250
SET HRS....400.0
MEAN.......1.762
STD DEV....0.125
DISCRIMINANT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
P SPECIFIES THAT THE PENTANE READING IS GREATER THAN THE BENZENE READING
B SPECIFIES THAT THE BENZENE READING IS GREATER THAN THE PENTANE READING
100 HOURS AT BASE LINE,300 HOURS AT 125 DEGREES


VISCOSITY OF USED OIL AT 210 F
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
13 MAY 72 14 SEP 73
* PRECAUTIONARY LIMIT (UPPER) - SAE 40
SPECIFIED VALUE (PER MIL-L-2104C). NEW OIL - SAE 30
* PRECAUTIONARY LIMIT (LOWER) - SAE 20
VISCOSITY IN CENTISTOKES
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).



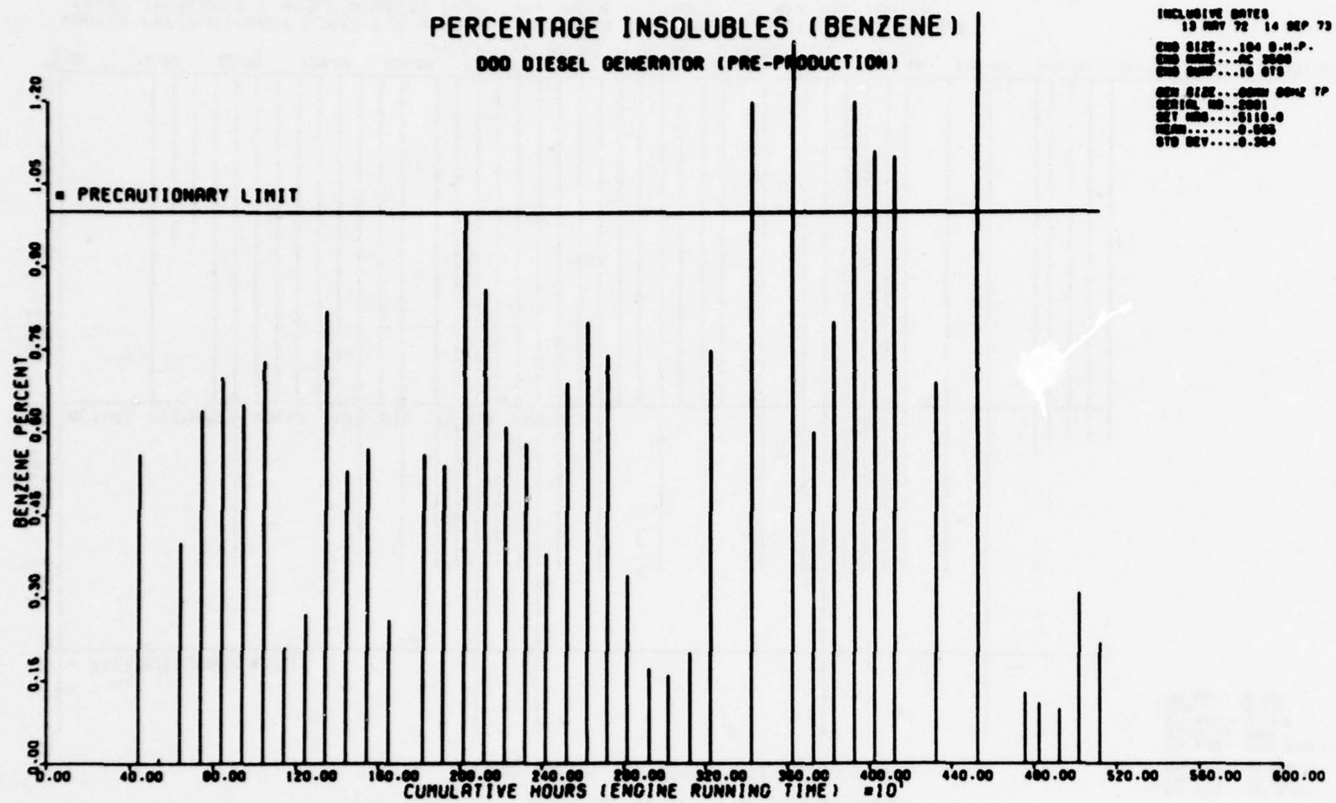
FLASH-POINT OF USED OIL (F)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
ACTUAL RECORDED VALUE. NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C). NEW OIL
* PRECAUTIONARY LIMIT (FUEL DILUTION)
FLASH-POINT IN F
290.00
315.00
340.00
365.00
390.00
415.00
440.00
465.00
490.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).



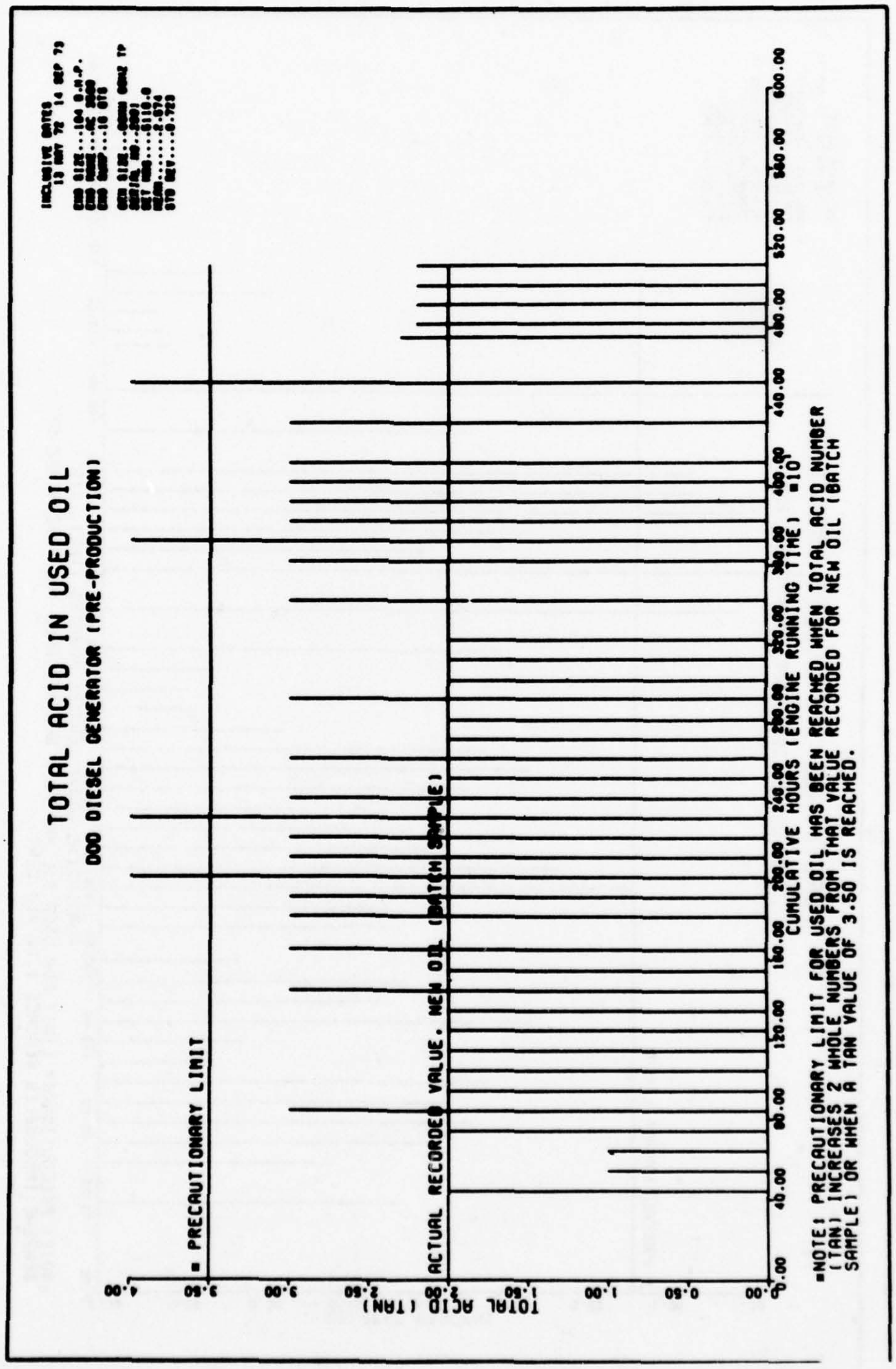

*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF PENTANE INSOLUBLES REACHES 1.50 PERCENT.

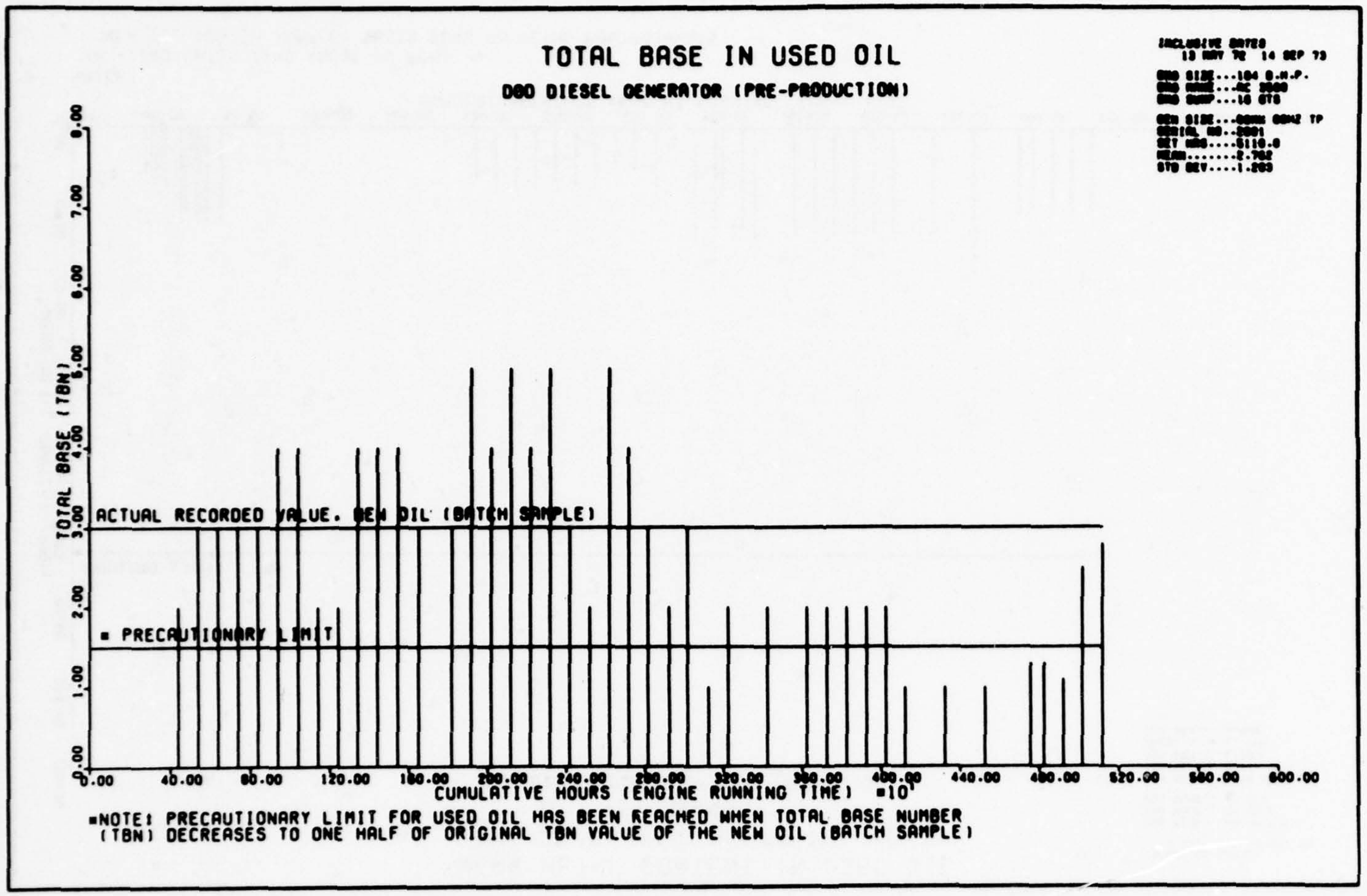
PERCENTAGE INSOLUBLES (BENZENE)

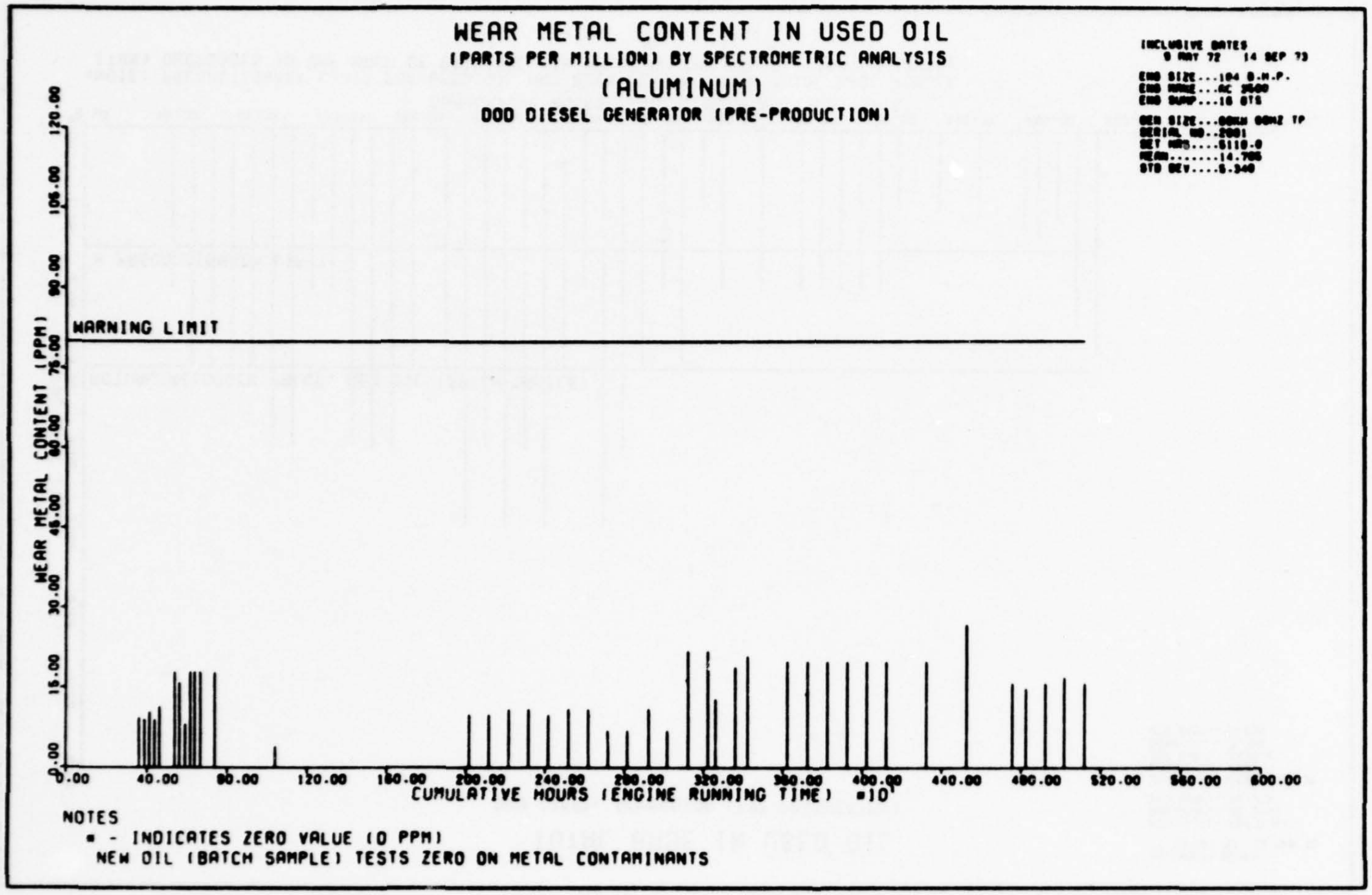
DOD DIESEL GENERATOR (PRE-PRODUCTION)

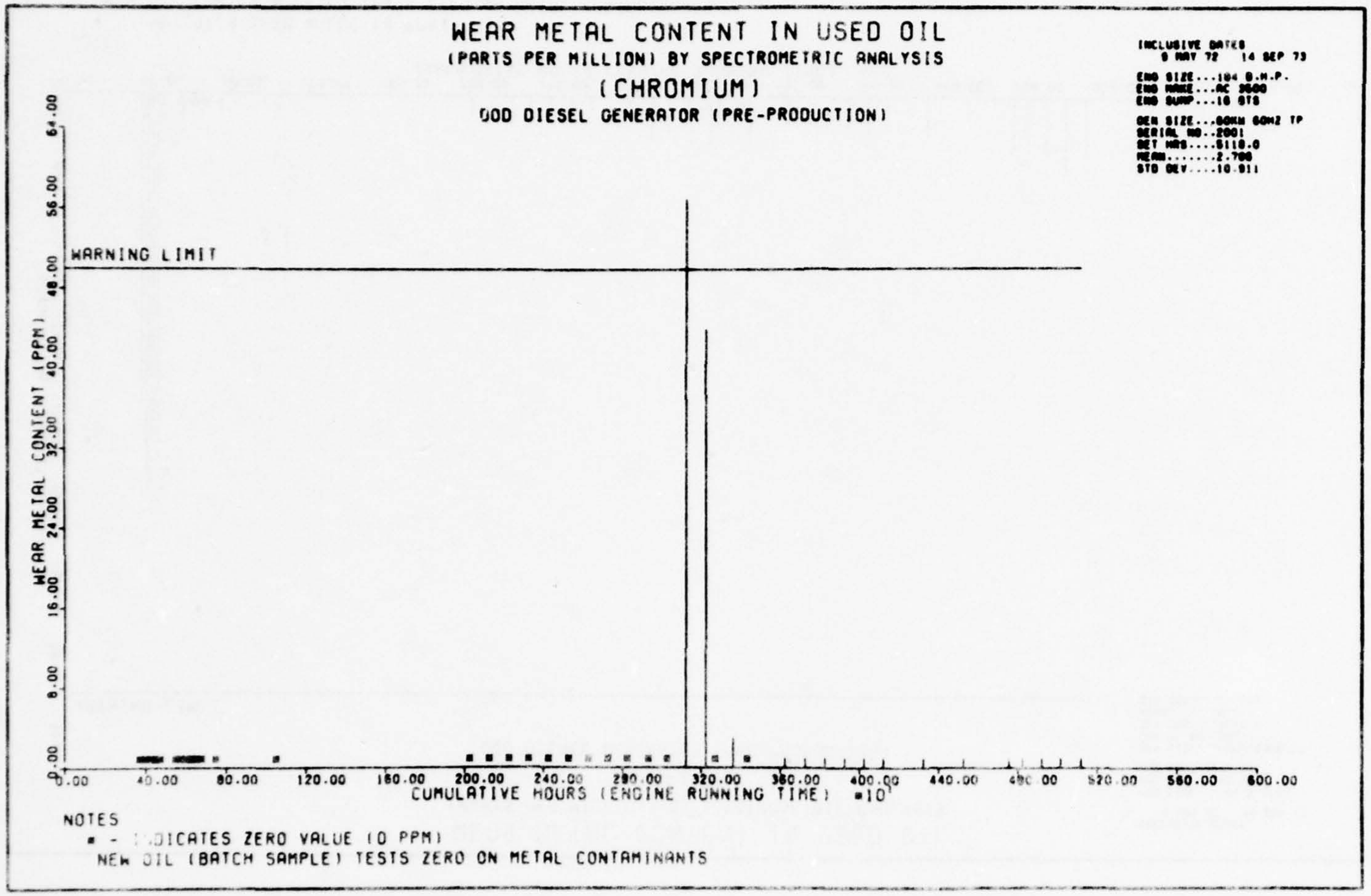


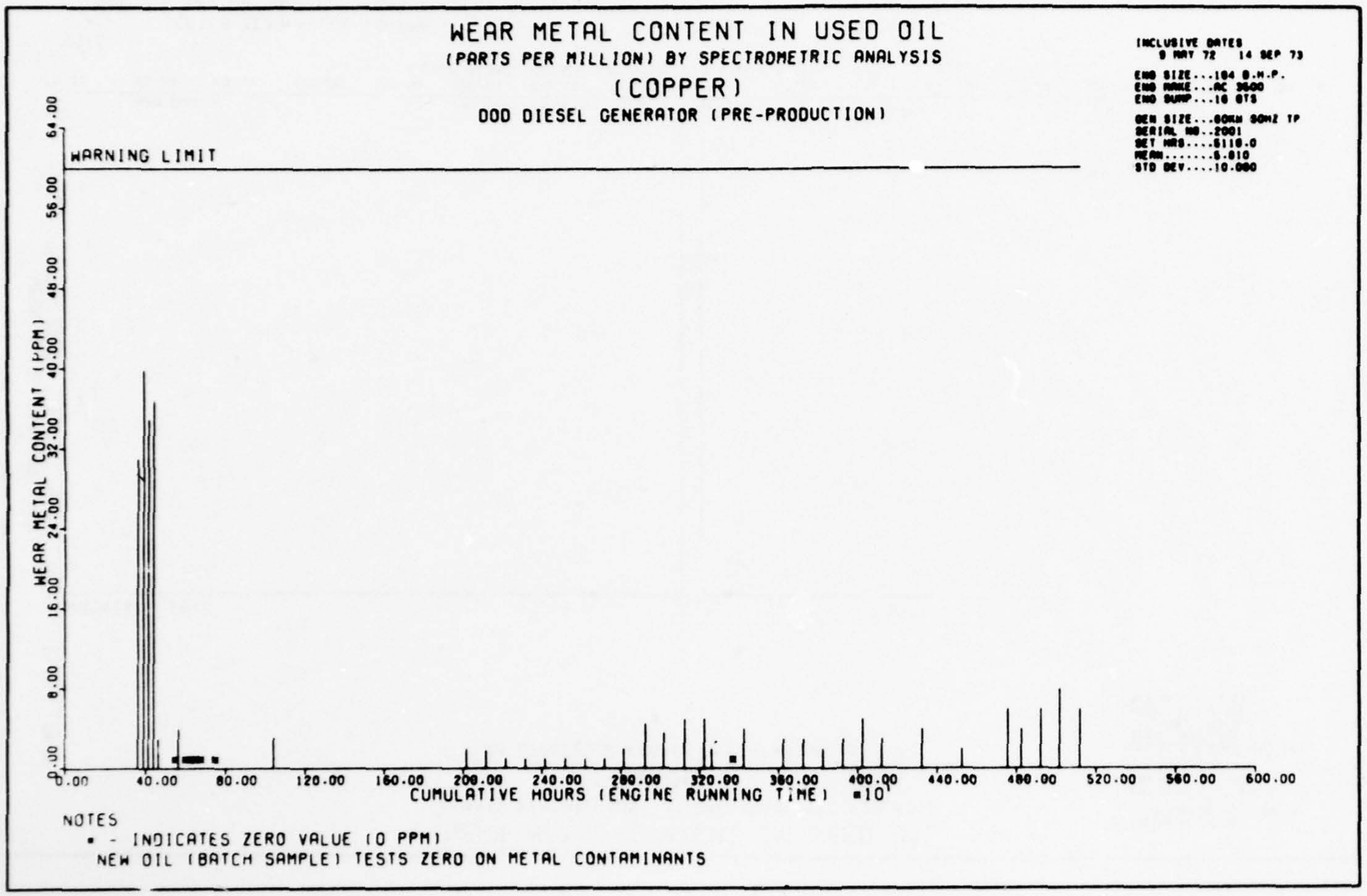

*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF BENZENE INSOLUBLES REACHES 1.00 PER CENT.

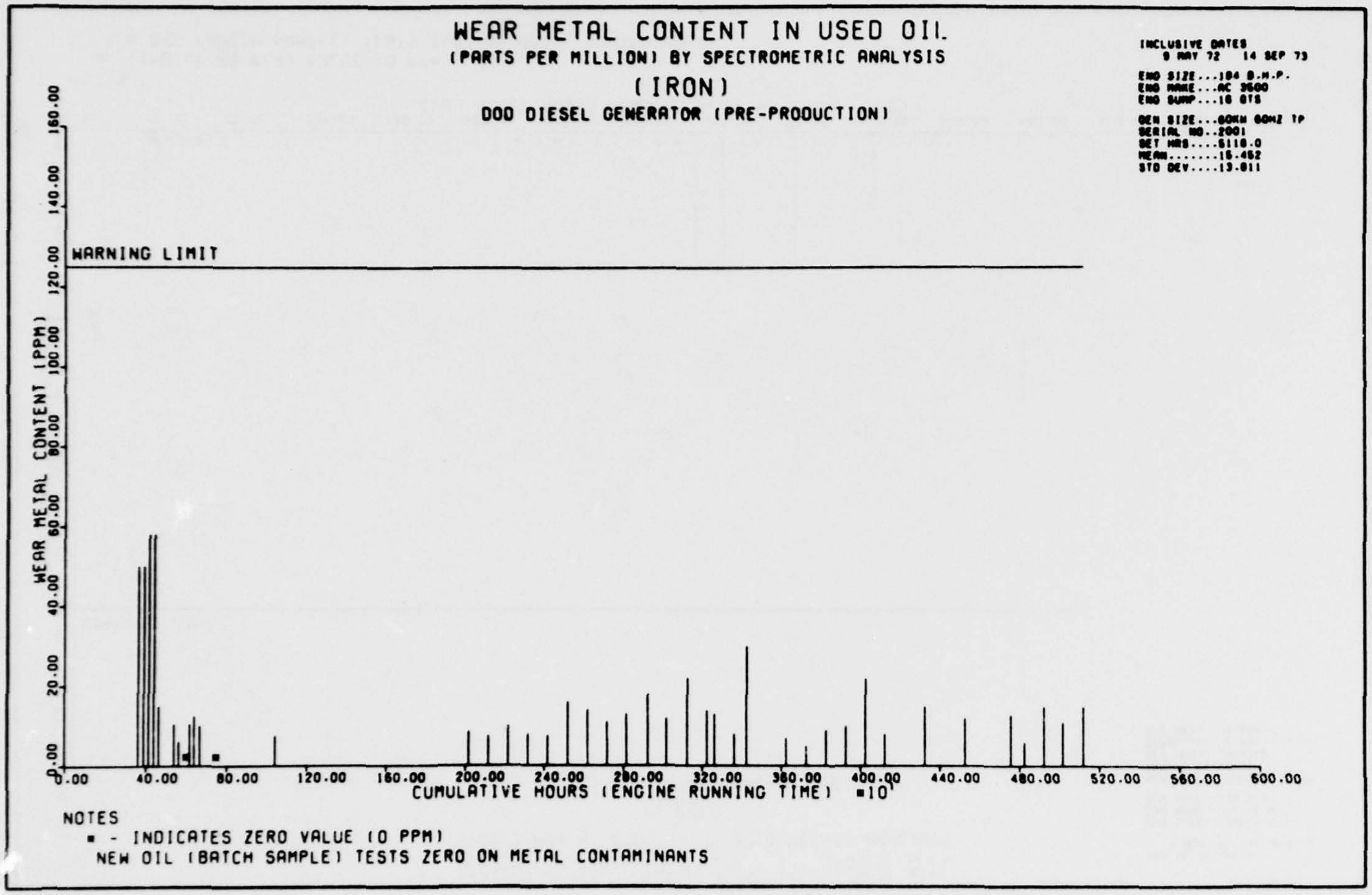

TOTAL ACID IN USED OIL
DOD DIESEL GENERATOR (PRE-PRODUCTION)
* PRECAUTIONARY LIMIT
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
TOTAL ACID (TAN)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL ACID NUMBER (TAN) INCREASES 2 WHOLE NUMBERS FROM THAT VALUE RECORDED FOR NEW OIL (BATCH SAMPLE) OR WHEN A TAN VALUE OF 3.50 IS REACHED.

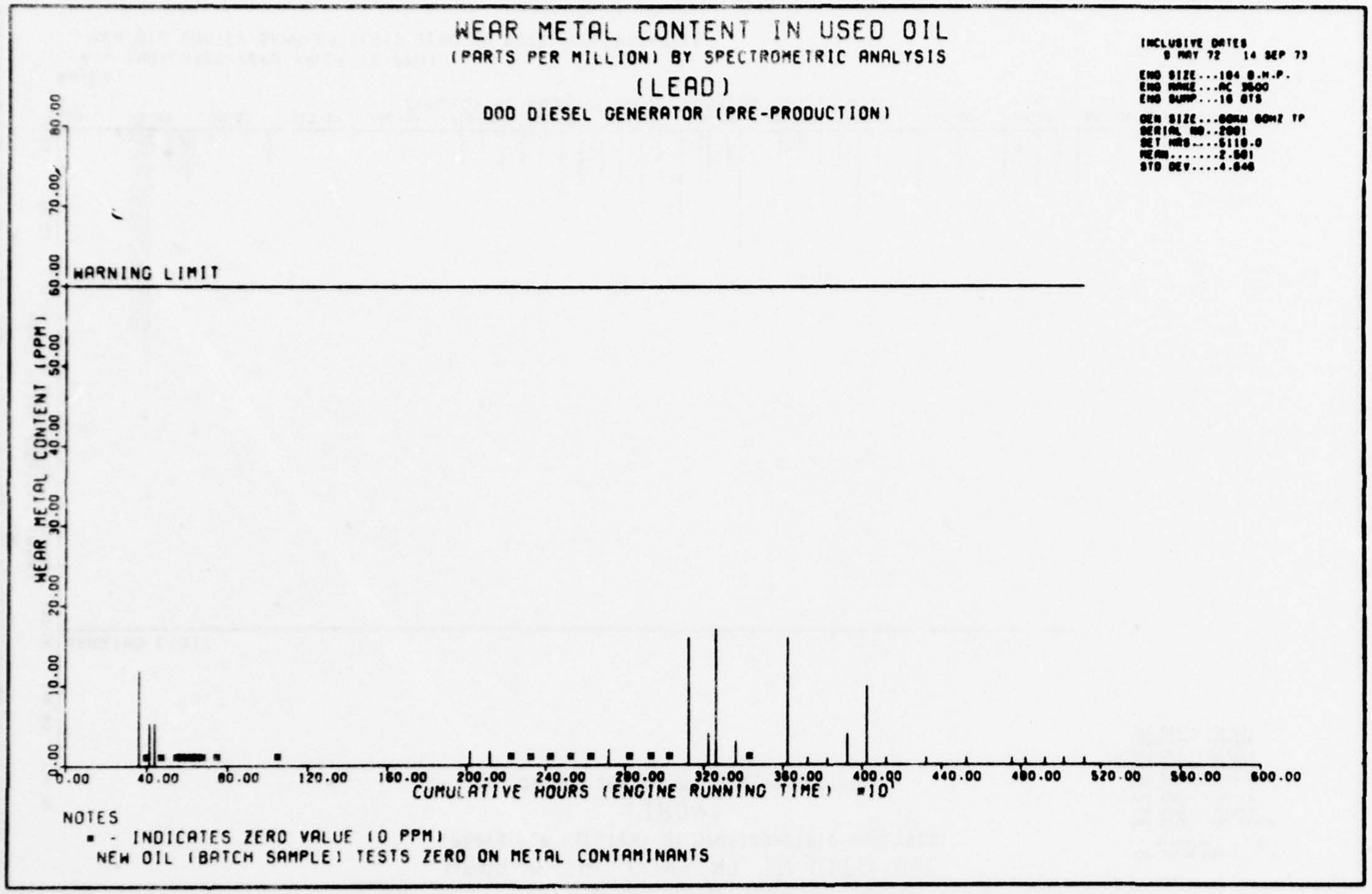

TOTAL BASE IN USED OIL
D8D DIESEL GENERATOR (PRE-PRODUCTION)
TOTAL BASE (TBN)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
ACTUAL RECORDED VALUE. NEW OIL (BATCH SAMPLE)
= PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL BASE NUMBER (TBN) DECREASES TO ONE HALF OF ORIGINAL TBN VALUE OF THE NEW OIL (BATCH SAMPLE)

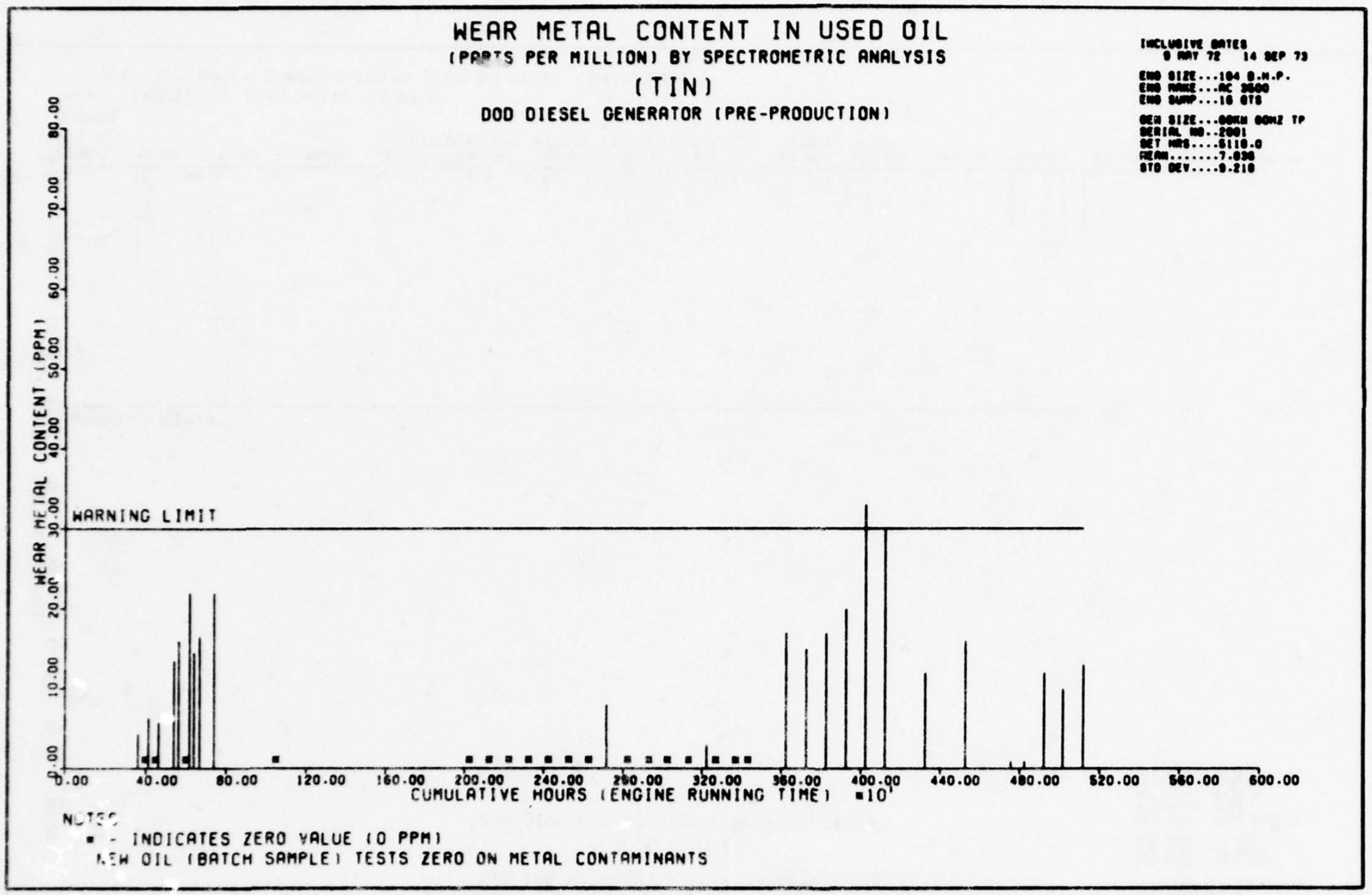

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(ALUMINUM)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
9 MAY 72 14 SEP 73
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

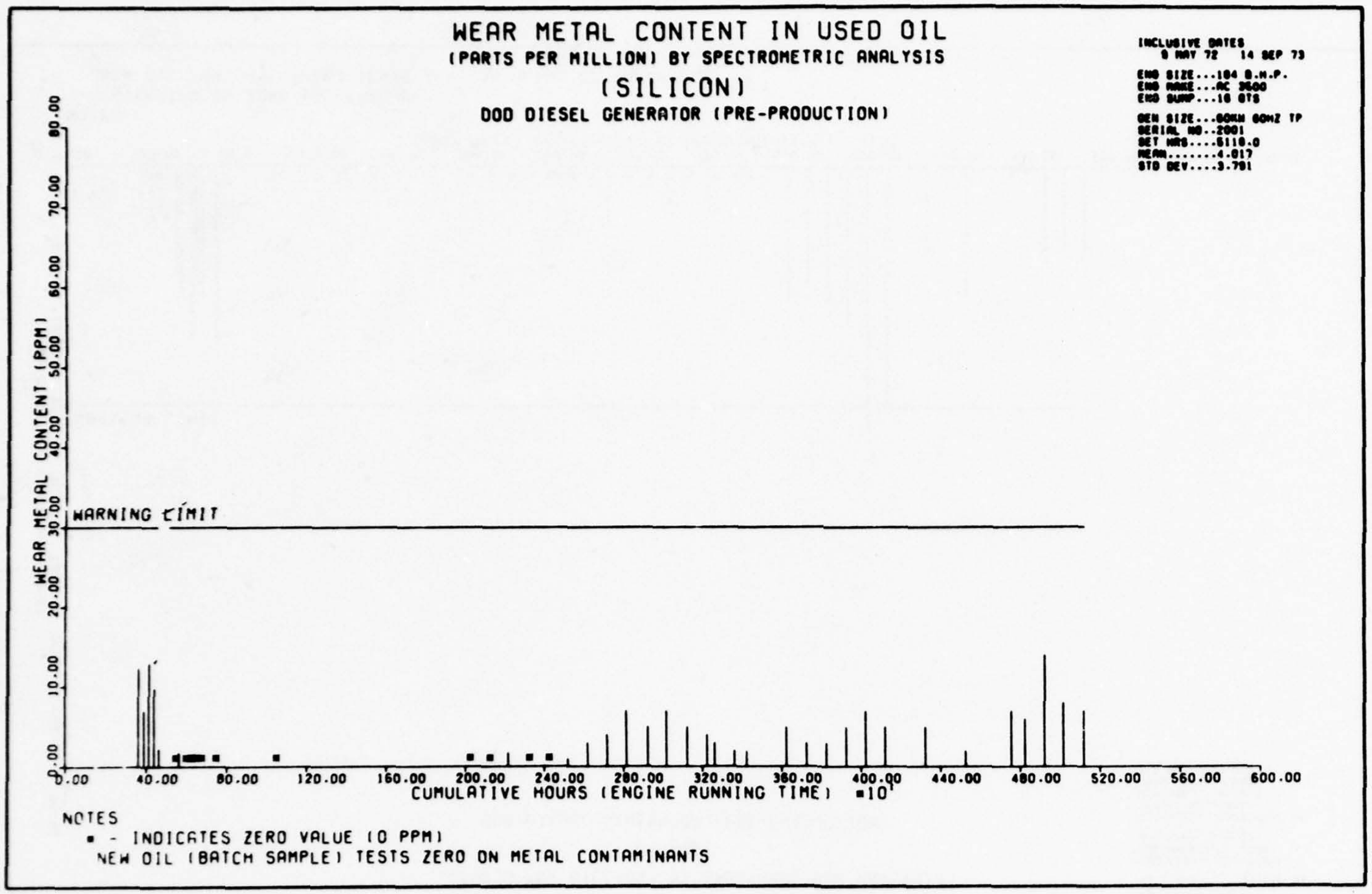

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(CHROMIUM)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
9 MAY 72 14 SEP 73
ENG SIZE...104 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW 60HZ TP
SERIAL NO..2001
SET HRS....5118.0
MEAN.......2.700
STD DEV....10.911
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

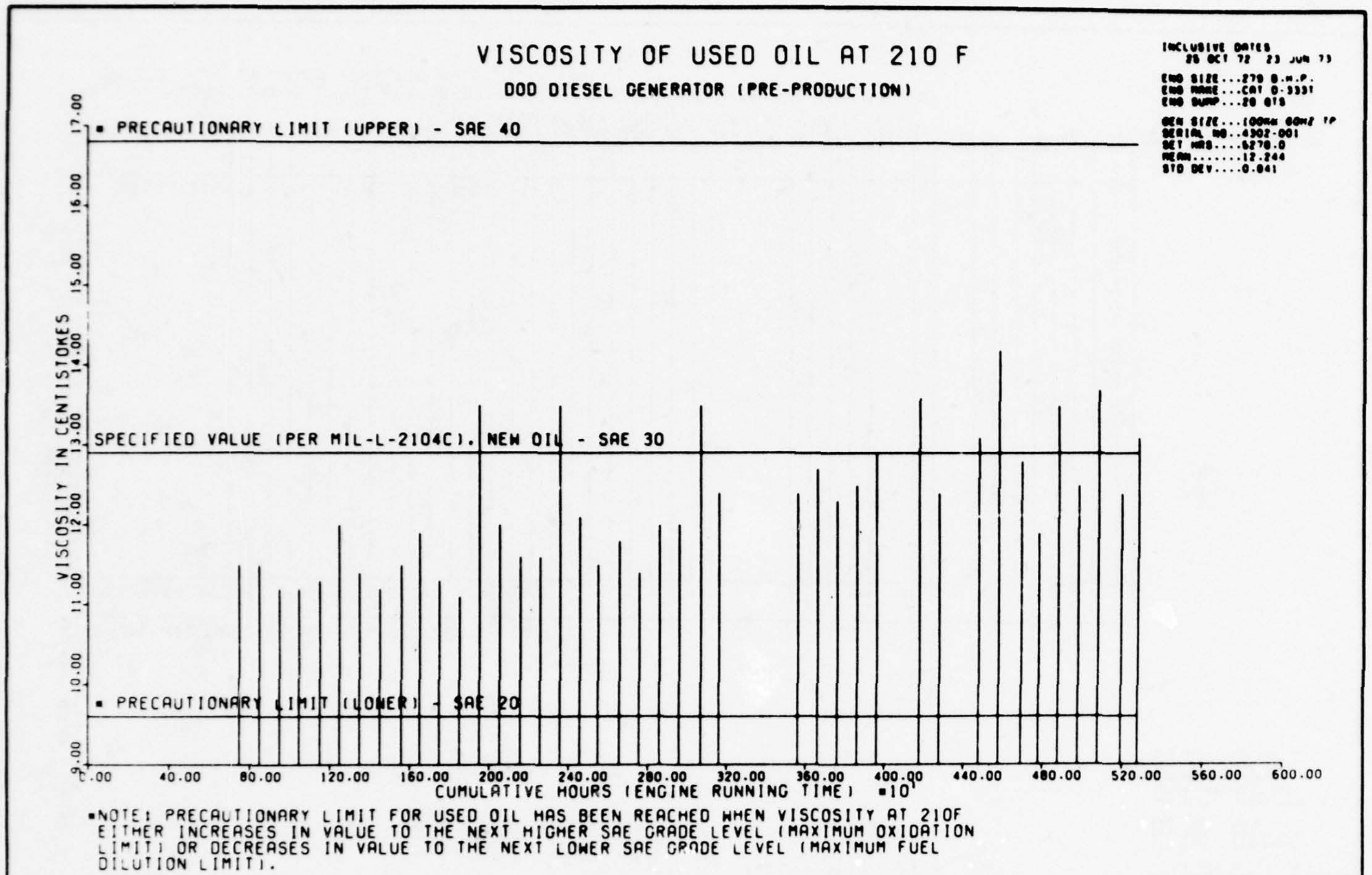

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(COPPER)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
9 MAY 72 14 SEP 73
ENG SIZE...104 B.H.P.
ENG MAKE...AC 3600
ENG SUMP...16 QTS
GEN SIZE...60KW 60HZ 3P
SERIAL NO..2001
SET HRS....5116.0
MEAN........5.610
STD DEV....10.080
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
▪ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

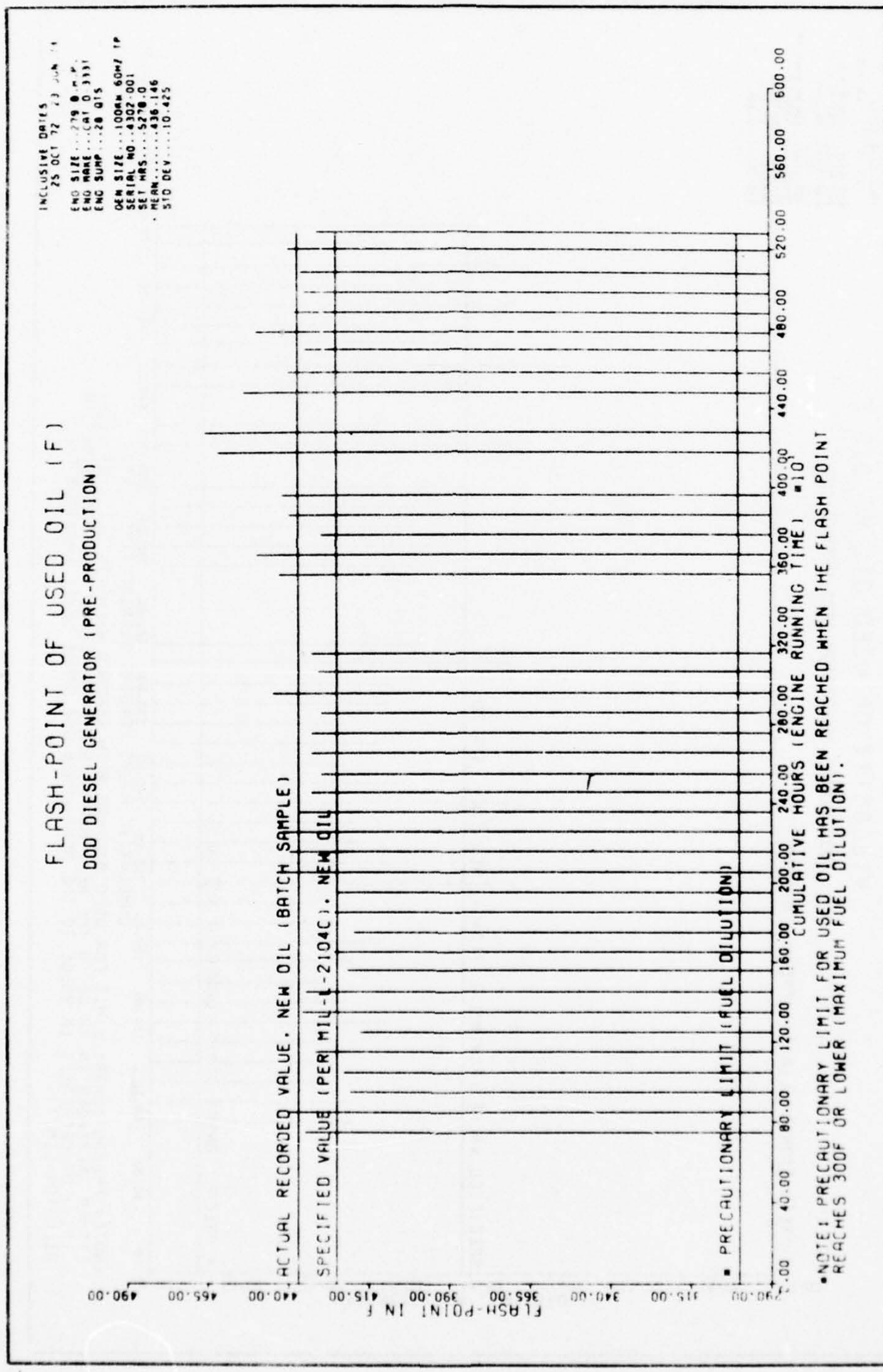

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(IRON)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
9 MAY 72   14 SEP 73
ENG SIZE...104 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW 60HZ 1P
SERIAL NO..2001
SET HRS.....5118.0
MEAN........15.452
STD DEV.....13.011
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(LEAD)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
14 SEP 73
ENG SIZE...104 B.H.P.
SET HRS....5110.0
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
▪ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

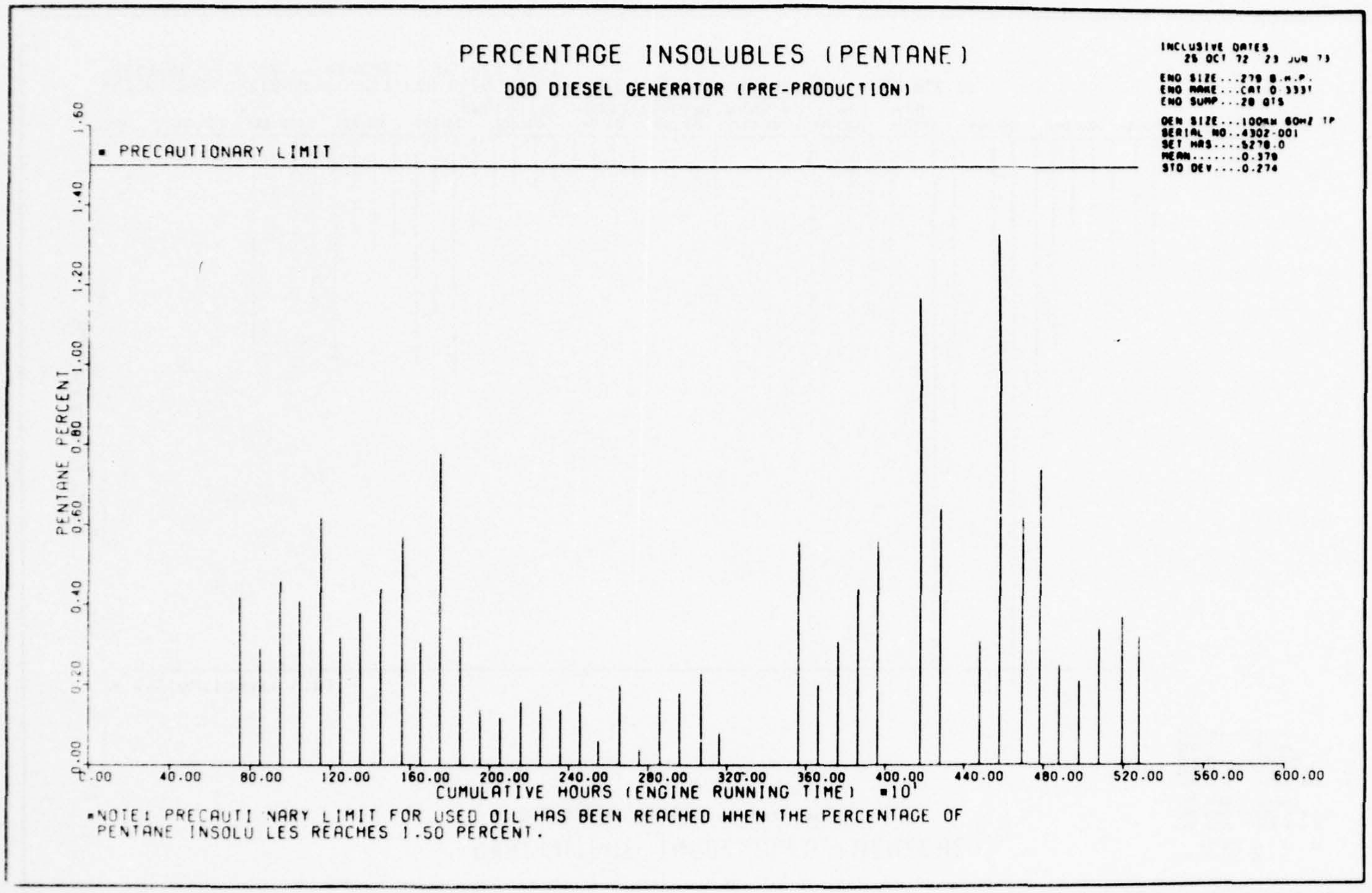

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(TIN)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
9 MAY 72 14 SEP 73
ENG SIZE...104 B.H.P.
SERIAL NO..2001
SET HRS....5110.0
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

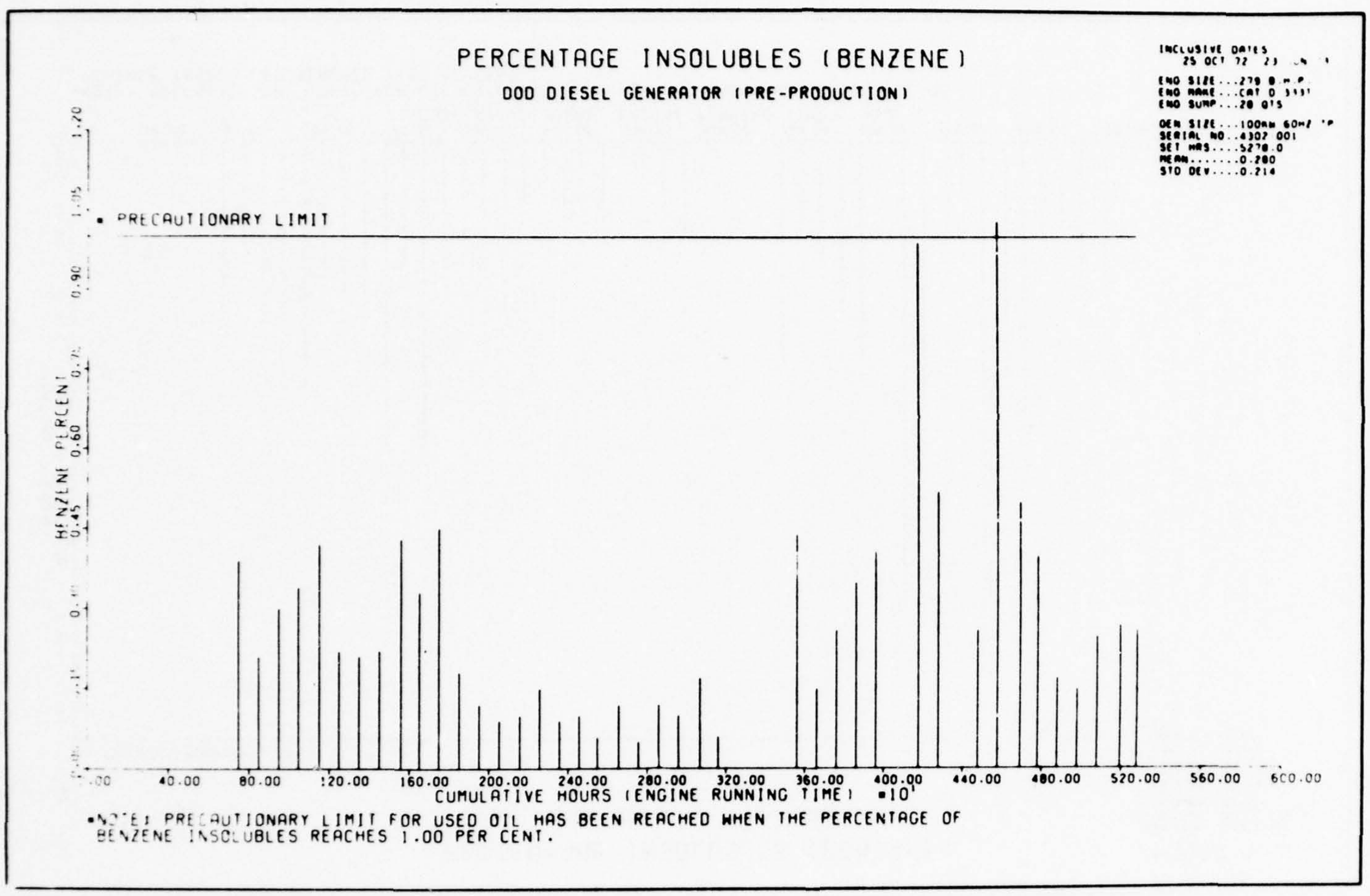

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(SILICON)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
9 MAY 72 14 SEP 73
ENG SIZE...104 B.H.P.
ENG MAKE...AC 3600
ENG SUMP...16 QTS
GEN SIZE...60KW 60HZ TP
SERIAL NO..2001
SET HRS....5110.0
MEAN........4.017
STD DEV....3.791
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
WARNING LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

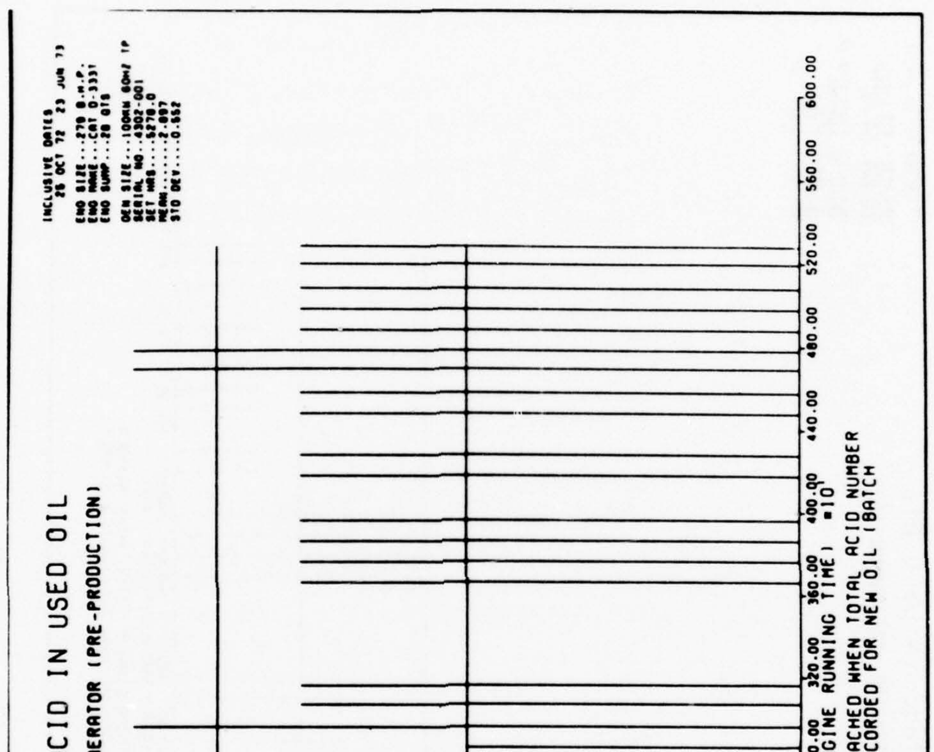

VISCOSITY OF USED OIL AT 210 F
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
25 OCT 72 23 JUN 73
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-3331
ENG SUMP...20 QTS
GEN SIZE...100KW 60HZ 3P
SERIAL NO..4302-001
SET HRS....5278.0
MEAN.........12.244
STD DEV....0.041
* PRECAUTIONARY LIMIT (UPPER) - SAE 40
SPECIFIED VALUE (PER MIL-L-2104C). NEW OIL - SAE 30
* PRECAUTIONARY LIMIT (LOWER) - SAE 20
VISCOSITY IN CENTISTOKES
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).

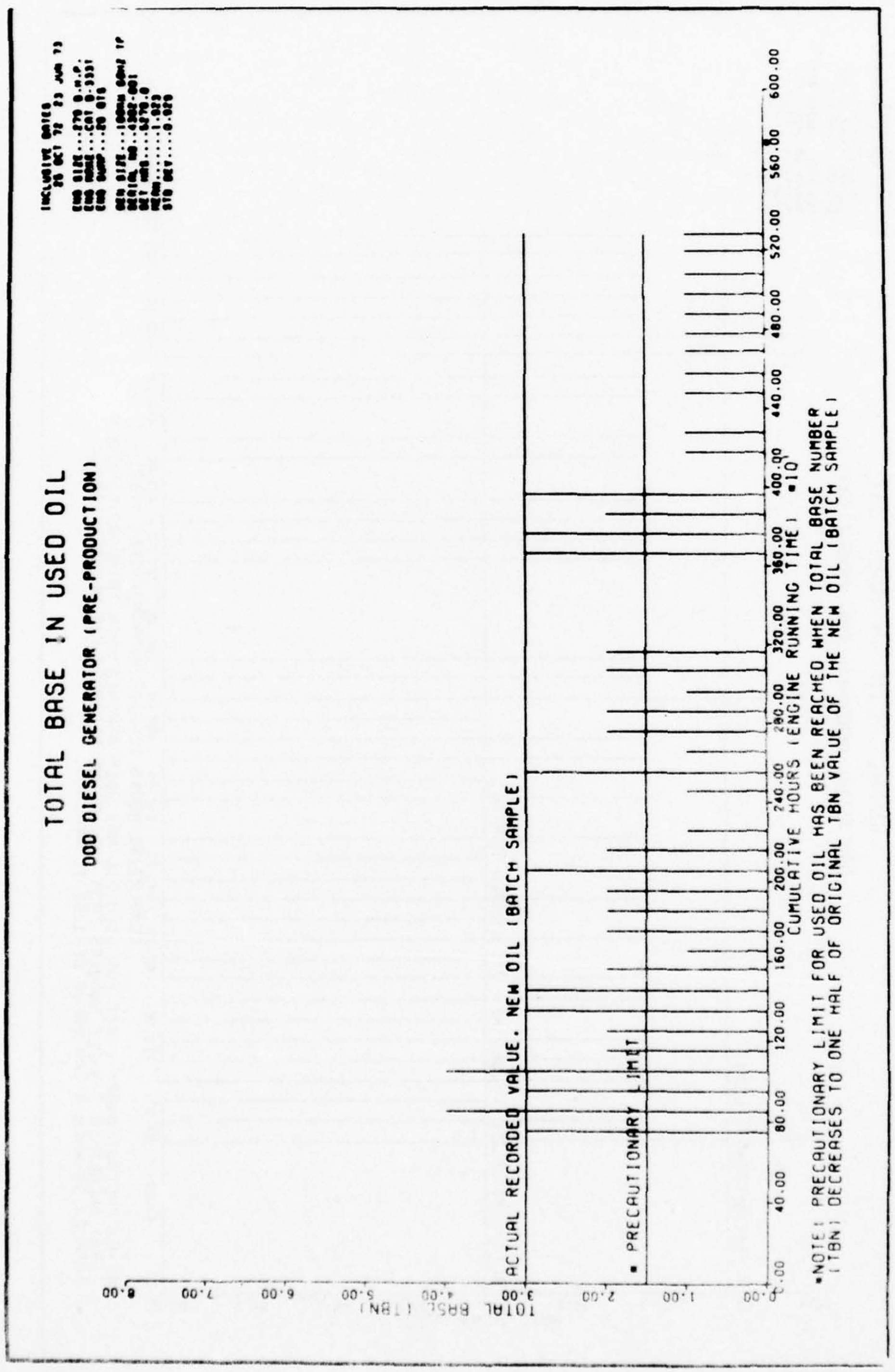


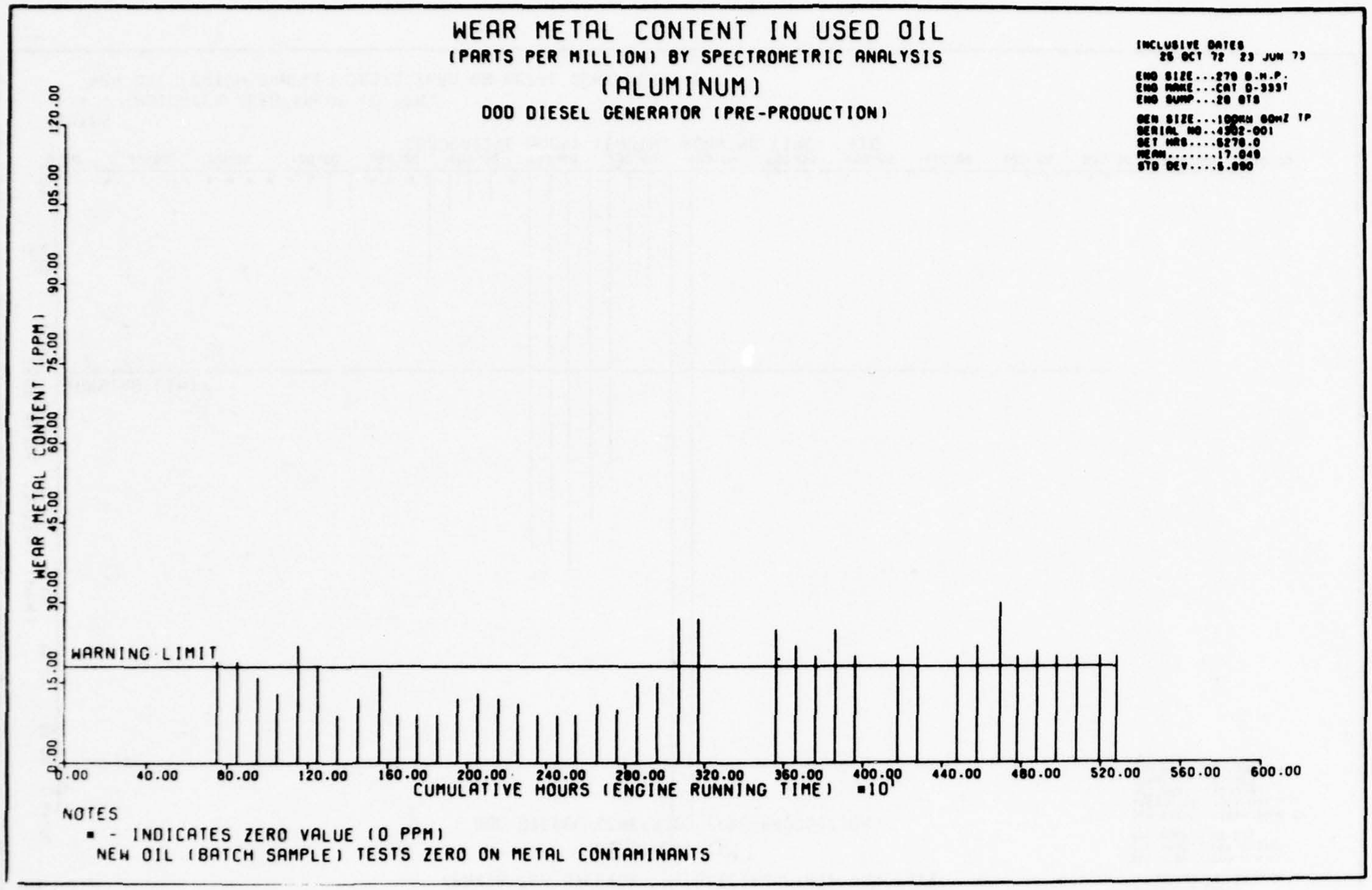
FLASH-POINT OF USED OIL (F)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
25 OCT 72 23 JUN 7?
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D 333
ENG SUMP...28 QTS
GEN SIZE...100KW 60HZ 1P
SERIAL NO..4302-001
SET HRS....5270.0
MEAN.......436.146
STD DEV....10.425
ACTUAL RECORDED VALUE. NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C). NEW OIL
* PRECAUTIONARY LIMIT (FUEL DILUTION)
FLASH-POINT IN F
290.00
315.00
340.00
365.00
390.00
415.00
440.00
465.00
490.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).


PERCENTAGE INSOLUBLES (PENTANE)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
25 OCT 72  23 JUN 73
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D 333T
ENG SUMP...28 QTS
GEN SIZE...100KW 60HZ 1P
SERIAL NO..4302-001
SET HRS....5278.0
MEAN.......0.379
STD DEV....0.274
* PRECAUTIONARY LIMIT
PENTANE PERCENT
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE: PRECAUTI NARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF PENTANE INSOLU LES REACHES 1.50 PERCENT.

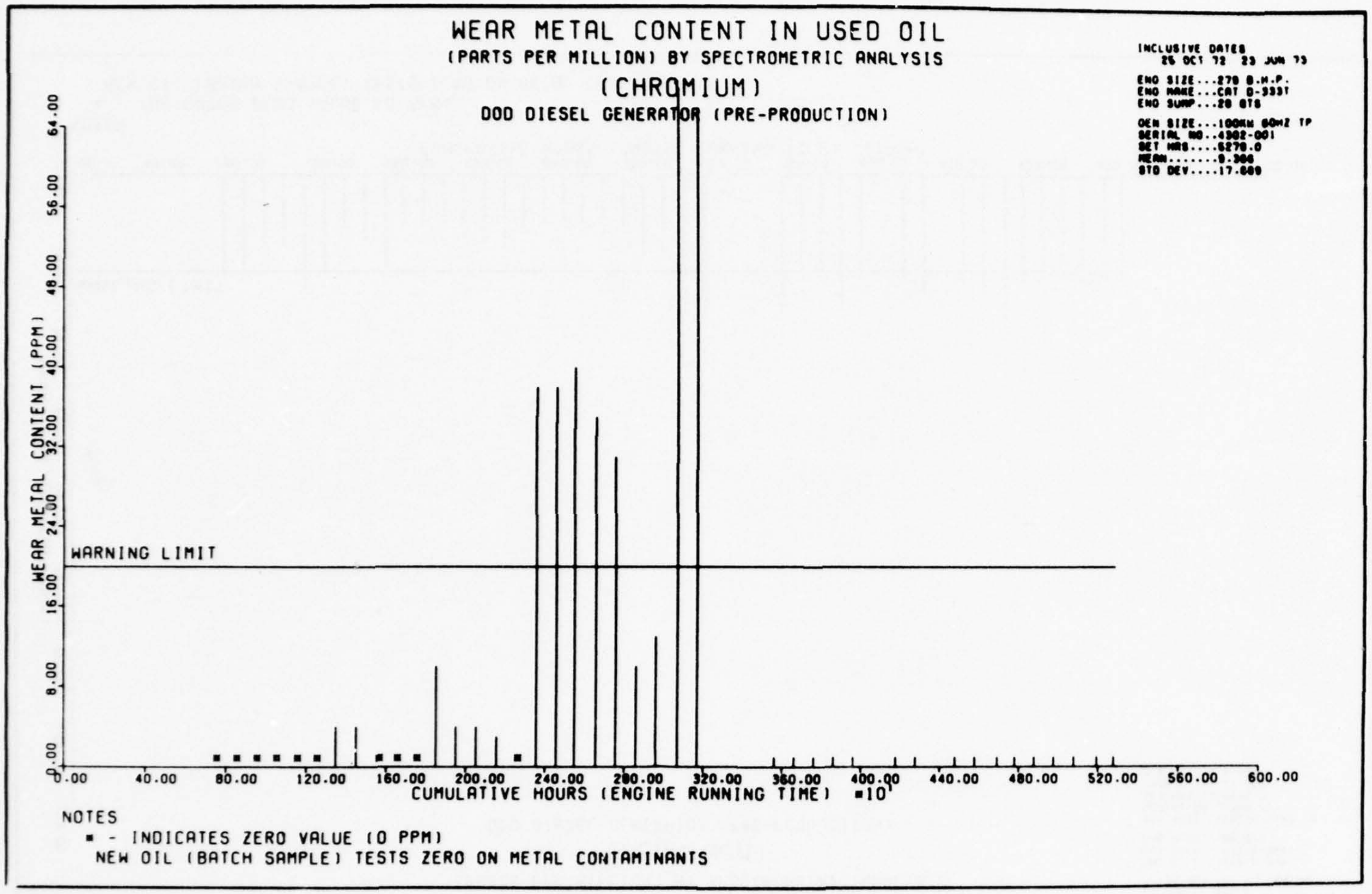

PERCENTAGE INSOLUBLES (BENZENE)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
25 OCT 72
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D
ENG SUMP...20 QTS
GEN SIZE...100KW 60HZ
SERIAL NO..4302 001
SET HRS....5278.0
MEAN........0.280
STD DEV....0.214
* PRECAUTIONARY LIMIT
BENZENE PERCENT
1.20
1.05
0.90
0.60
0.45
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF BENZENE INSOLUBLES REACHES 1.00 PER CENT.

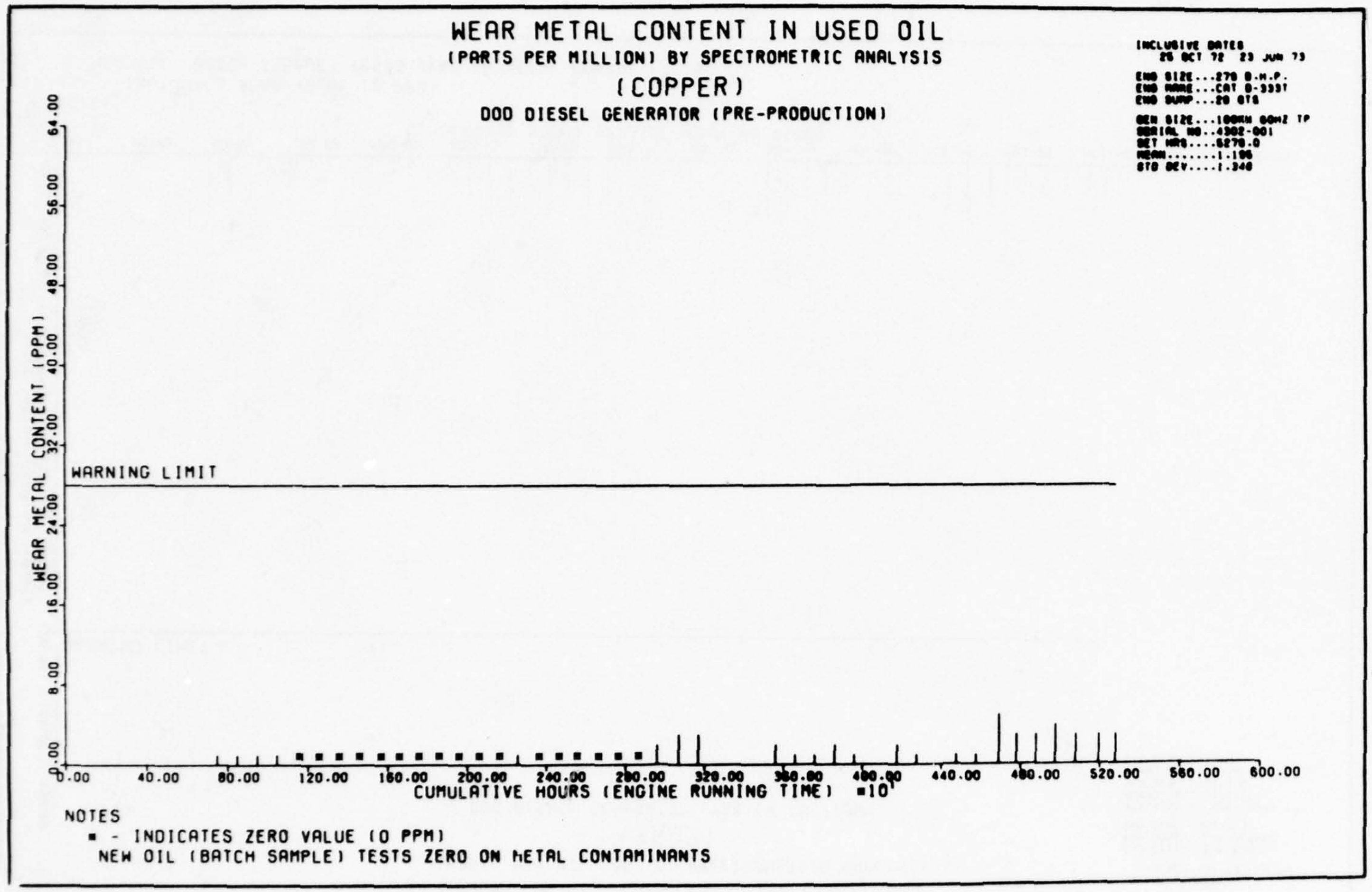

TOTAL ACID IN USED OIL
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
25 OCT 72  23 JUN 73
▪ PRECAUTIONARY LIMIT
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
TOTAL ACID (TAN)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) ✱10[1]
✱NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL ACID NUMBER (TAN) INCREASES 2 WHOLE NUMBERS FROM THAT VALUE RECORDED FOR NEW OIL (BATCH SAMPLE) OR WHEN A TAN VALUE OF 3.50 IS REACHED.

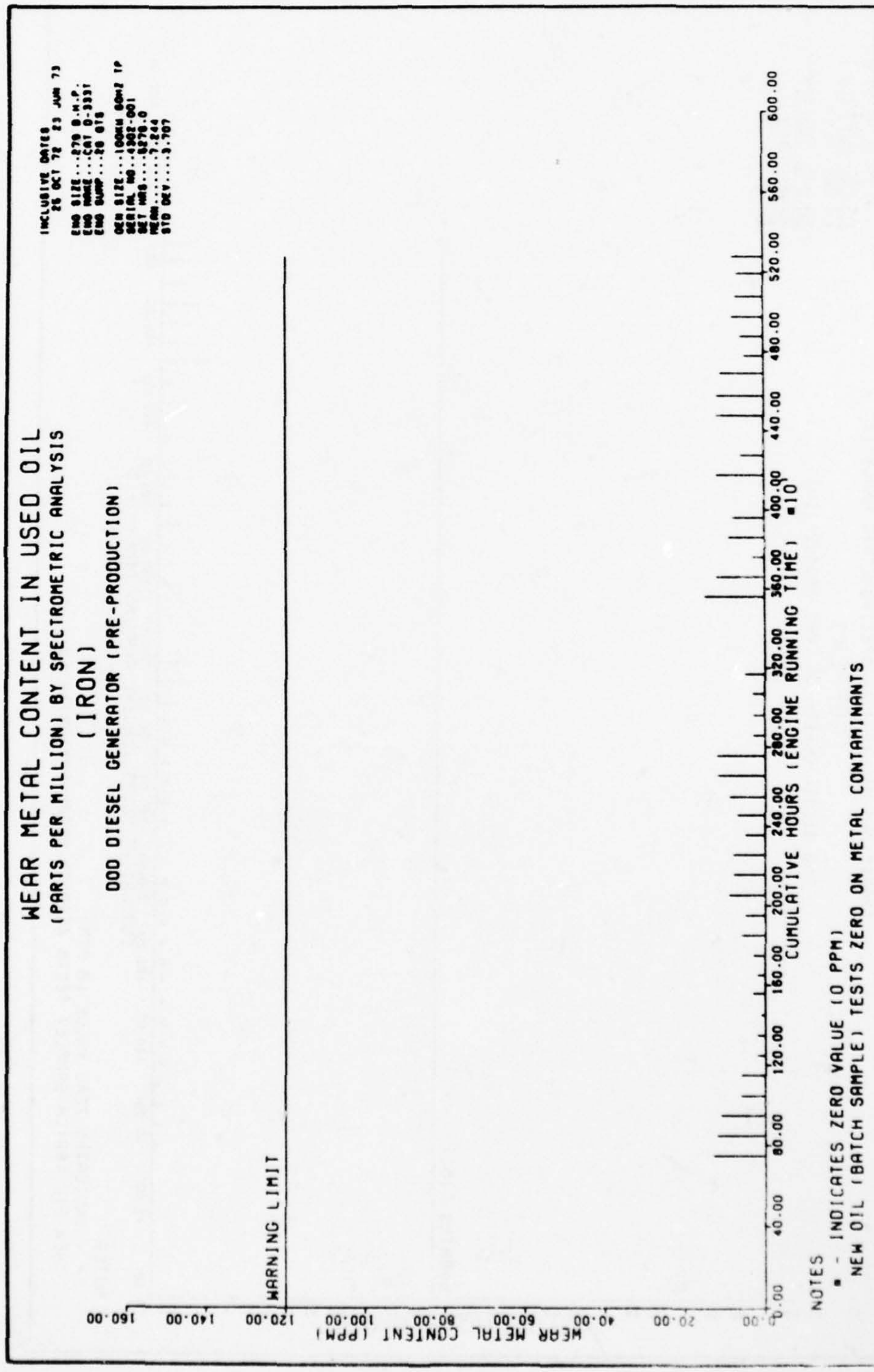

TOTAL BASE IN USED OIL
DOD DIESEL GENERATOR (PRE-PRODUCTION)
ACTUAL RECORDED VALUE. NEW OIL (BATCH SAMPLE)
* PRECAUTIONARY LIMIT
TOTAL BASE (TBN)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL BASE NUMBER
(TBN) DECREASES TO ONE HALF OF ORIGINAL TBN VALUE OF THE NEW OIL (BATCH SAMPLE)

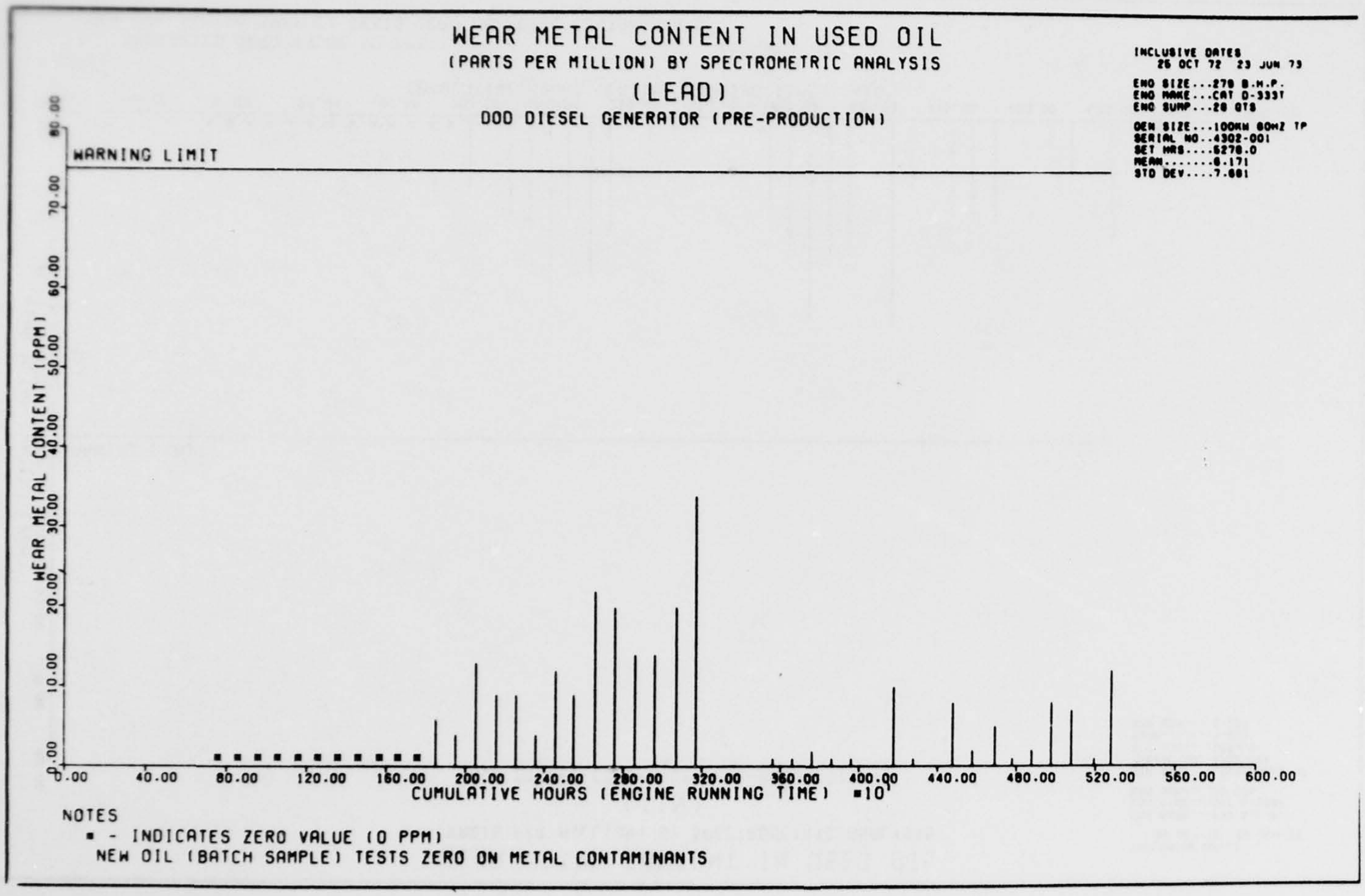


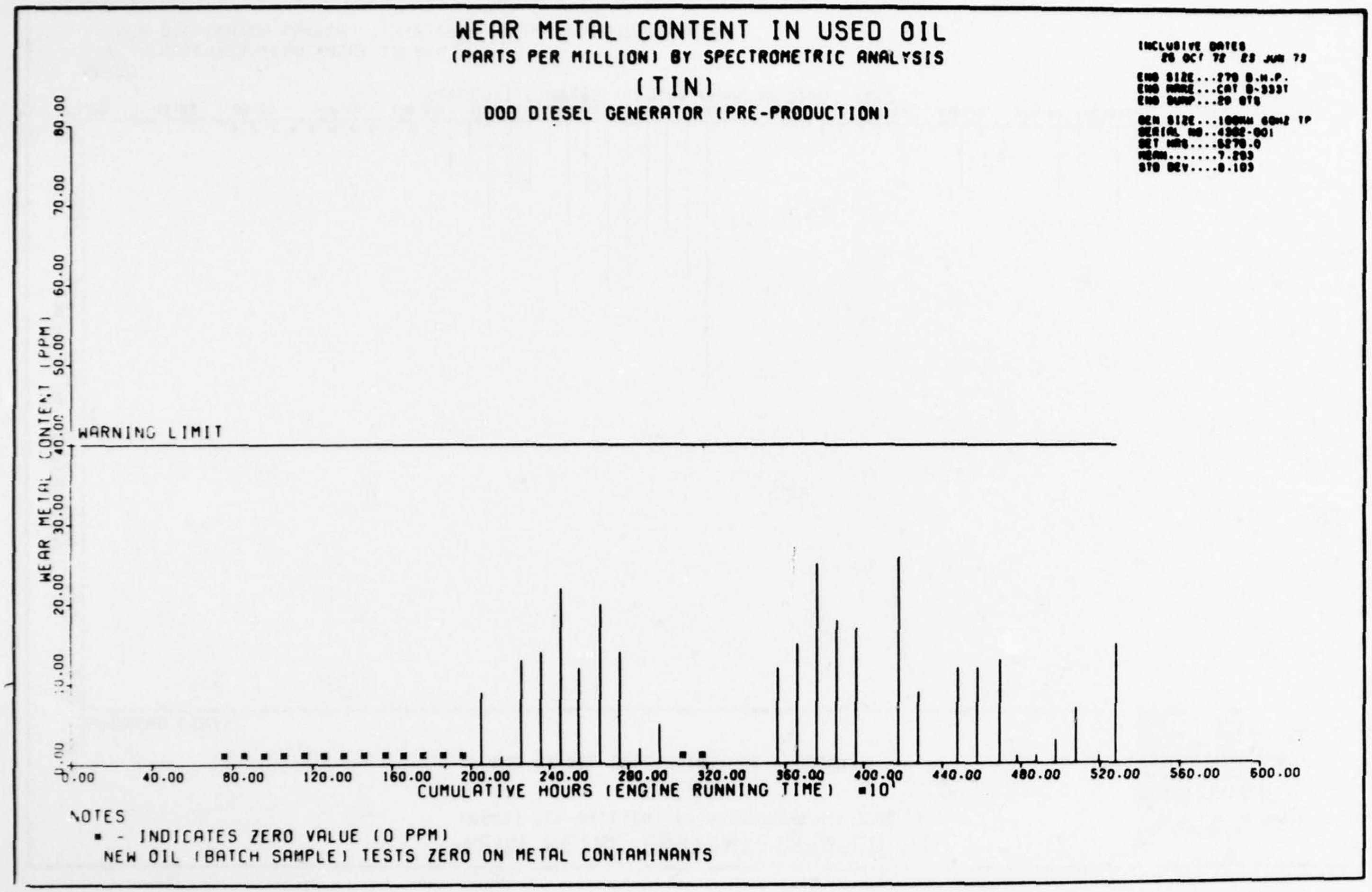
WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(ALUMINUM)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
26 OCT 72 23 JUN 73
ENG SIZE...270 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...20 QTS
GEN SIZE...100KW 60HZ 1P
SERIAL NO..4302-001
SET HRS....5270.0
MEAN........17.049
STD DEV....6.090
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
WARNING LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
▪ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

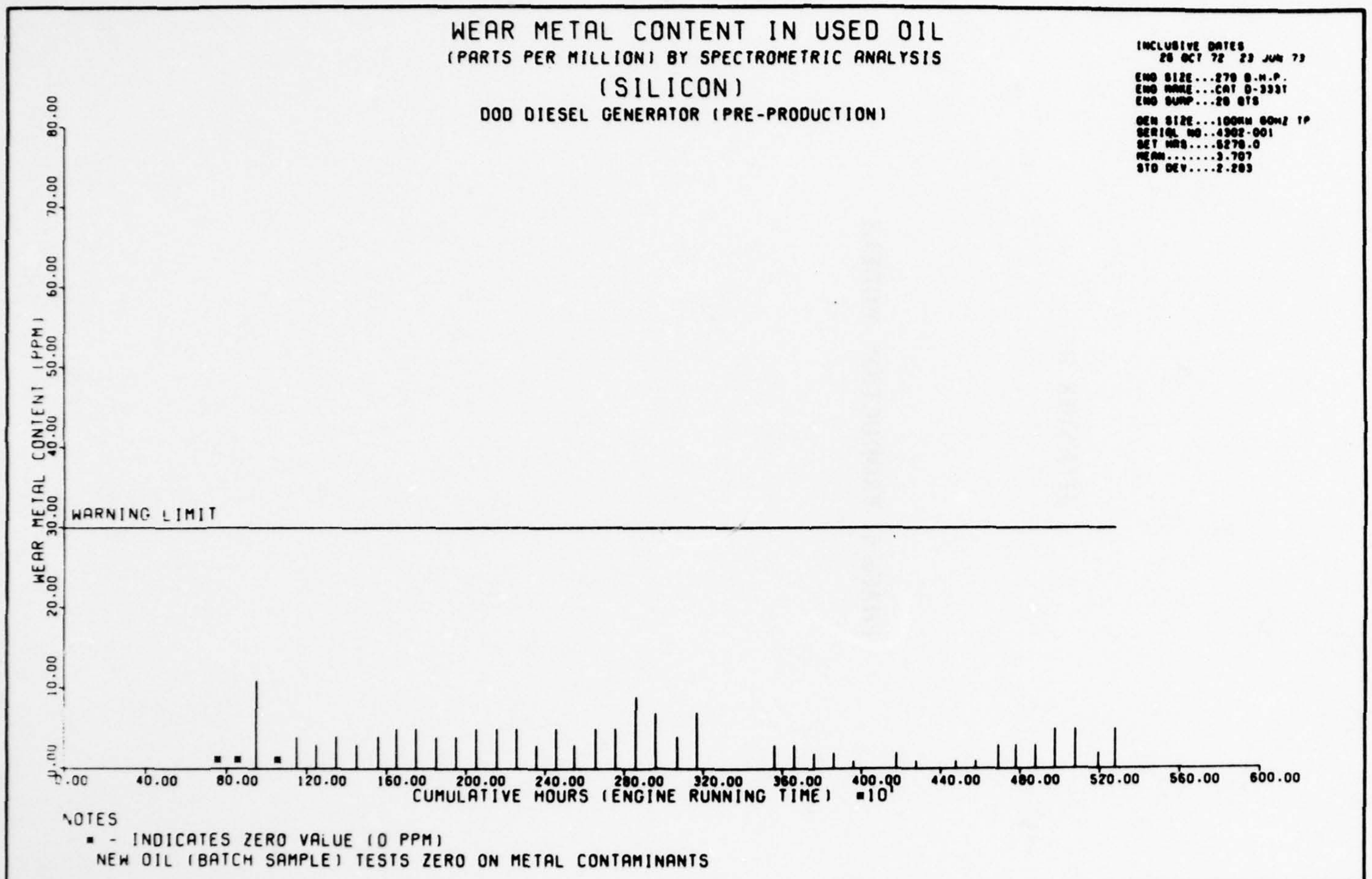

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(CHROMIUM)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
25 OCT 72 23 JUN 73
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...20 QTS
GEN SIZE...100KW 60HZ TP
SERIAL NO..4302-001
SET HRS.....6279.0
MEAN........9.306
STD DEV....17.089
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(COPPER)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
26 OCT 72 23 JUN 73
ENG SIZE...270 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...20 QTS
GEN SIZE...100KW 60HZ TP
SERIAL NO..4302-001
SET HRS....5270.0
MEAN........1.196
STD DEV....1.348
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(IRON)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

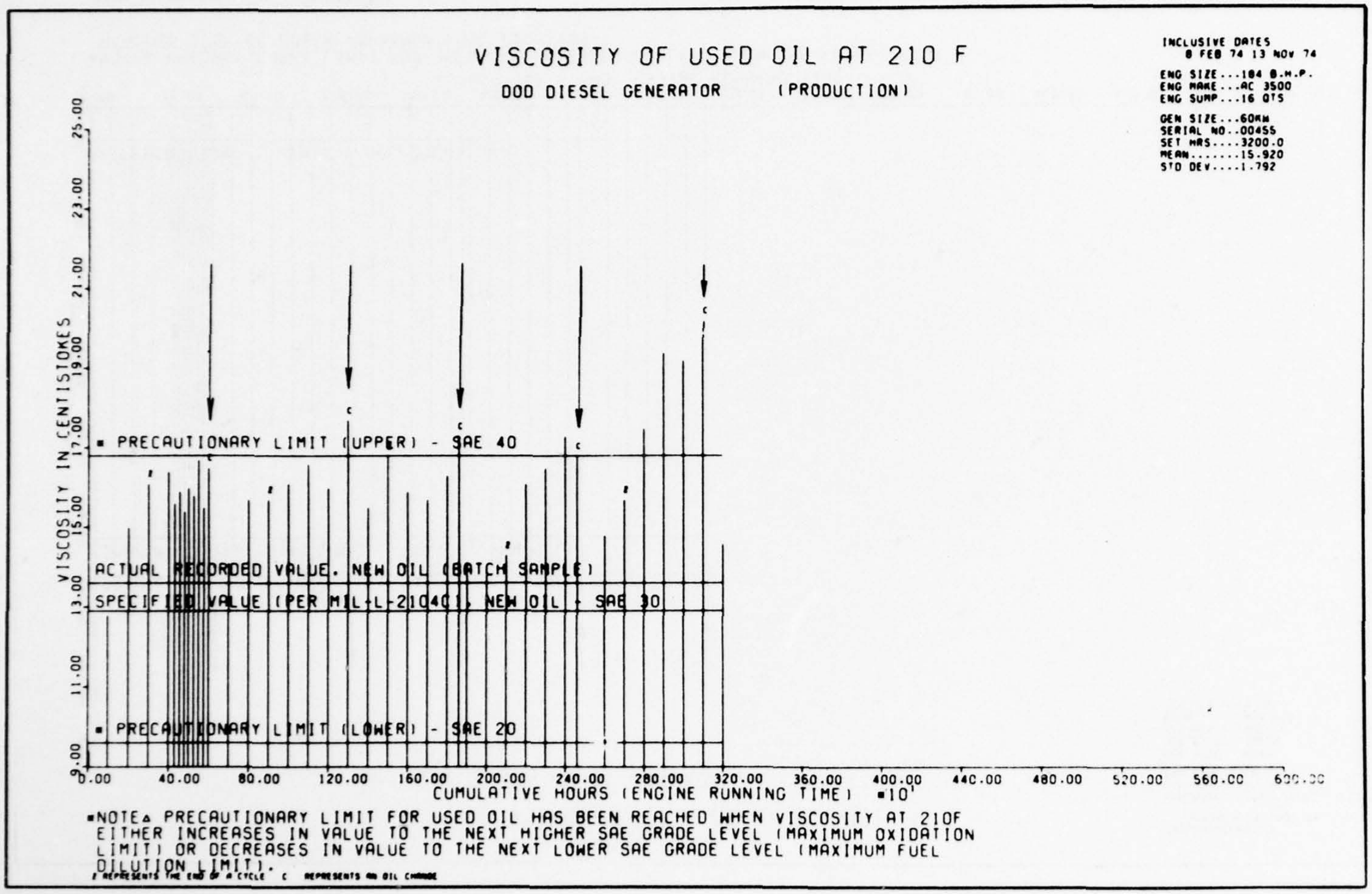

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(LEAD)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
26 OCT 72 23 JUN 73
ENG SIZE...270 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...28 QTS
GEN SIZE...100KW 60HZ
SERIAL NO..4302-001
SET HRS....5278.0
MEAN.......6.171
STD DEV....7.681
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

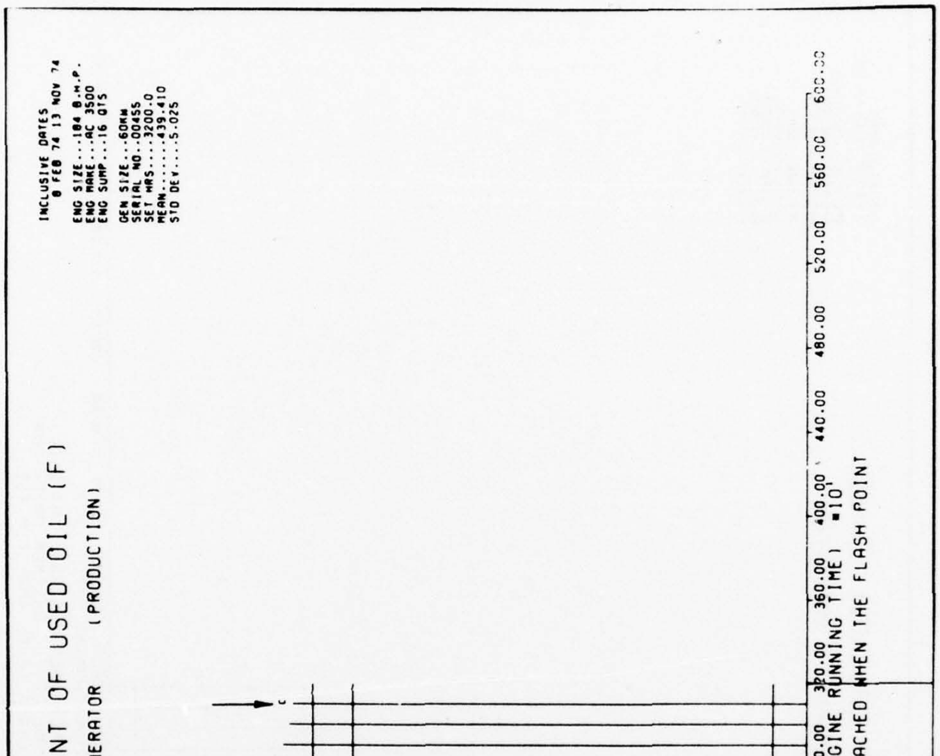

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(TIN)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
26 OCT 72 23 JUN 73
ENG SIZE...270 B.H.P.
MEAN........7.293
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
▪ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

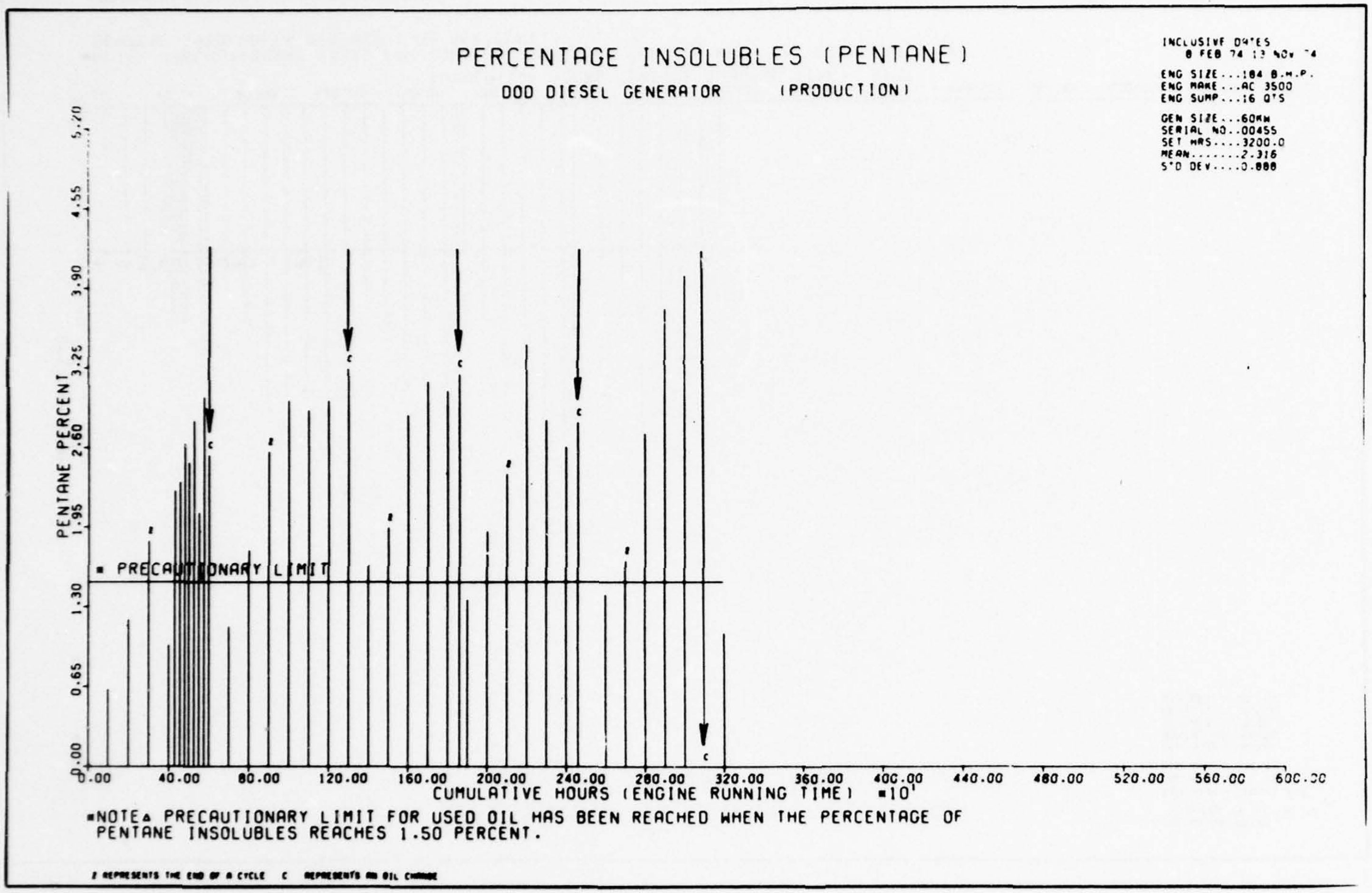

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(SILICON)
DOD DIESEL GENERATOR (PRE-PRODUCTION)
INCLUSIVE DATES
26 OCT 72 23 JUN 73
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...28 QTS
GEN SIZE...100KW 60HZ 1P
SERIAL NO..4302-001
SET HRS....5278.0
MEAN........3.707
STD DEV....2.283
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
WARNING LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
▪ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

## APPENDIX B

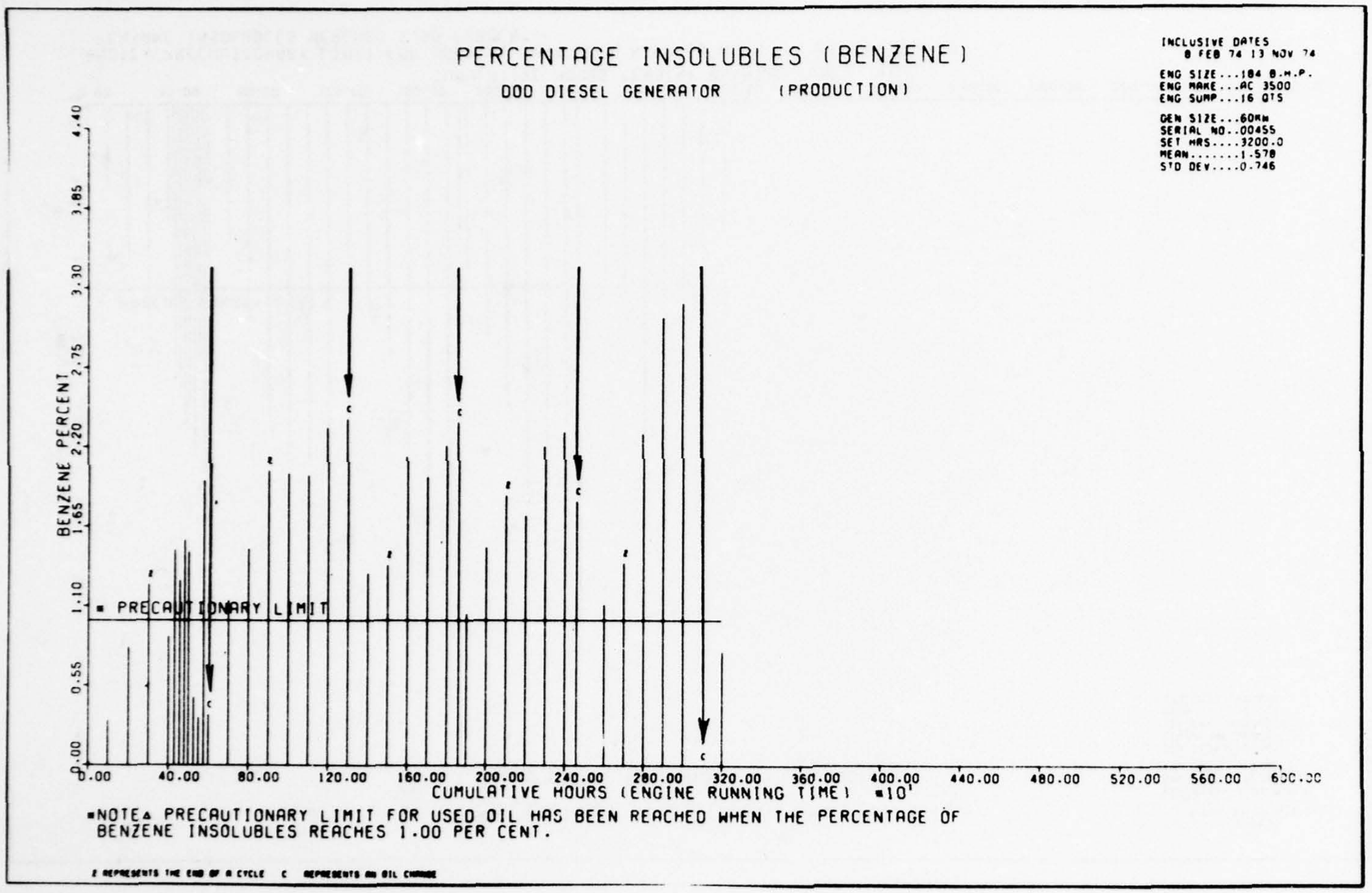
## PHASE II PRODUCTION MODELS

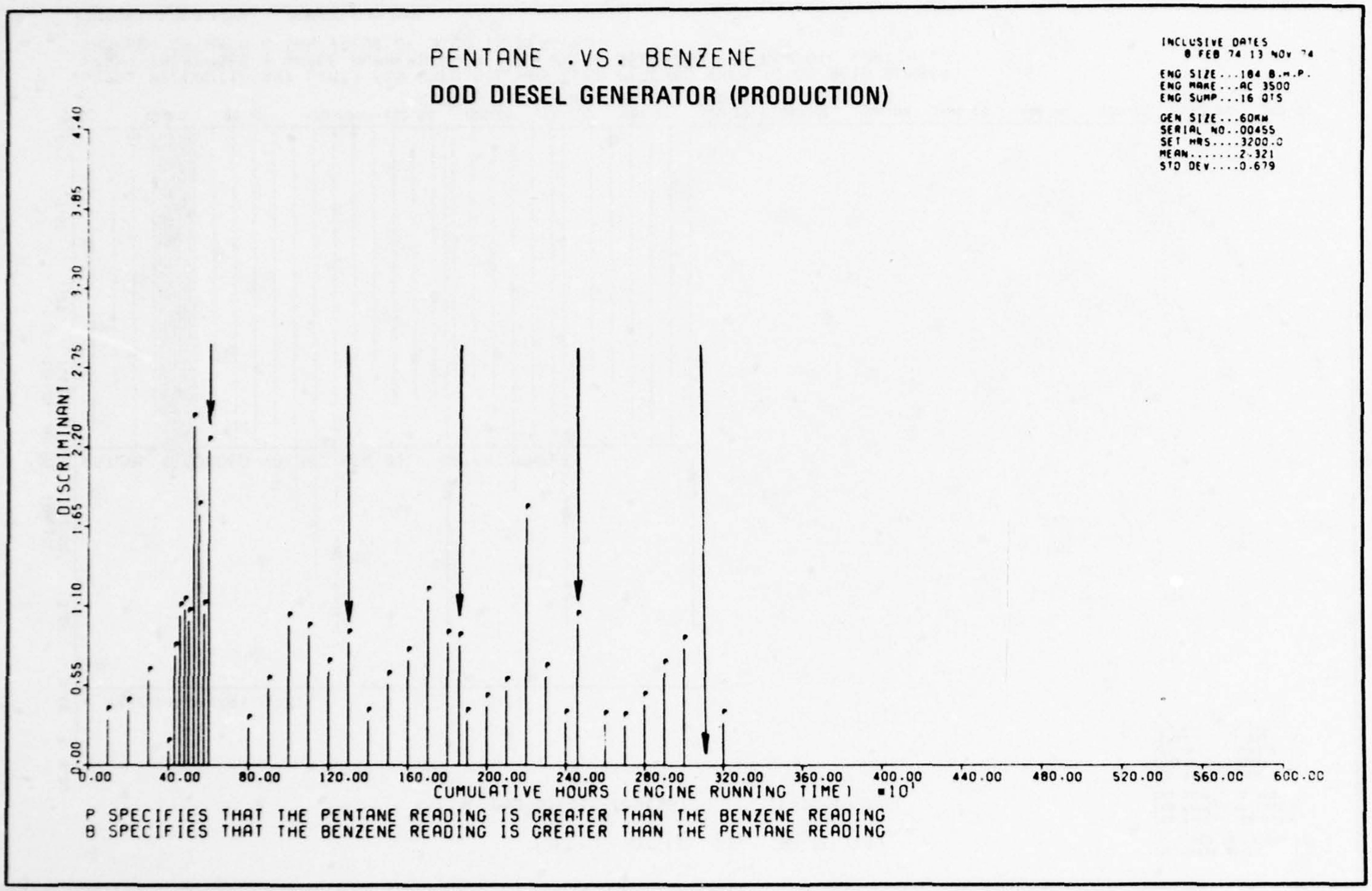

VISCOSITY OF USED OIL AT 210 F
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 13 NOV 74
ENG SIZE...104 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......15.920
STD DEV....1.792
VISCOSITY IN CENTISTOKES
9.00
11.00
13.00
15.00
17.00
19.00
21.00
23.00
25.00
* PRECAUTIONARY LIMIT (UPPER) - SAE 40
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL - SAE 30
* PRECAUTIONARY LIMIT (LOWER) - SAE 20
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

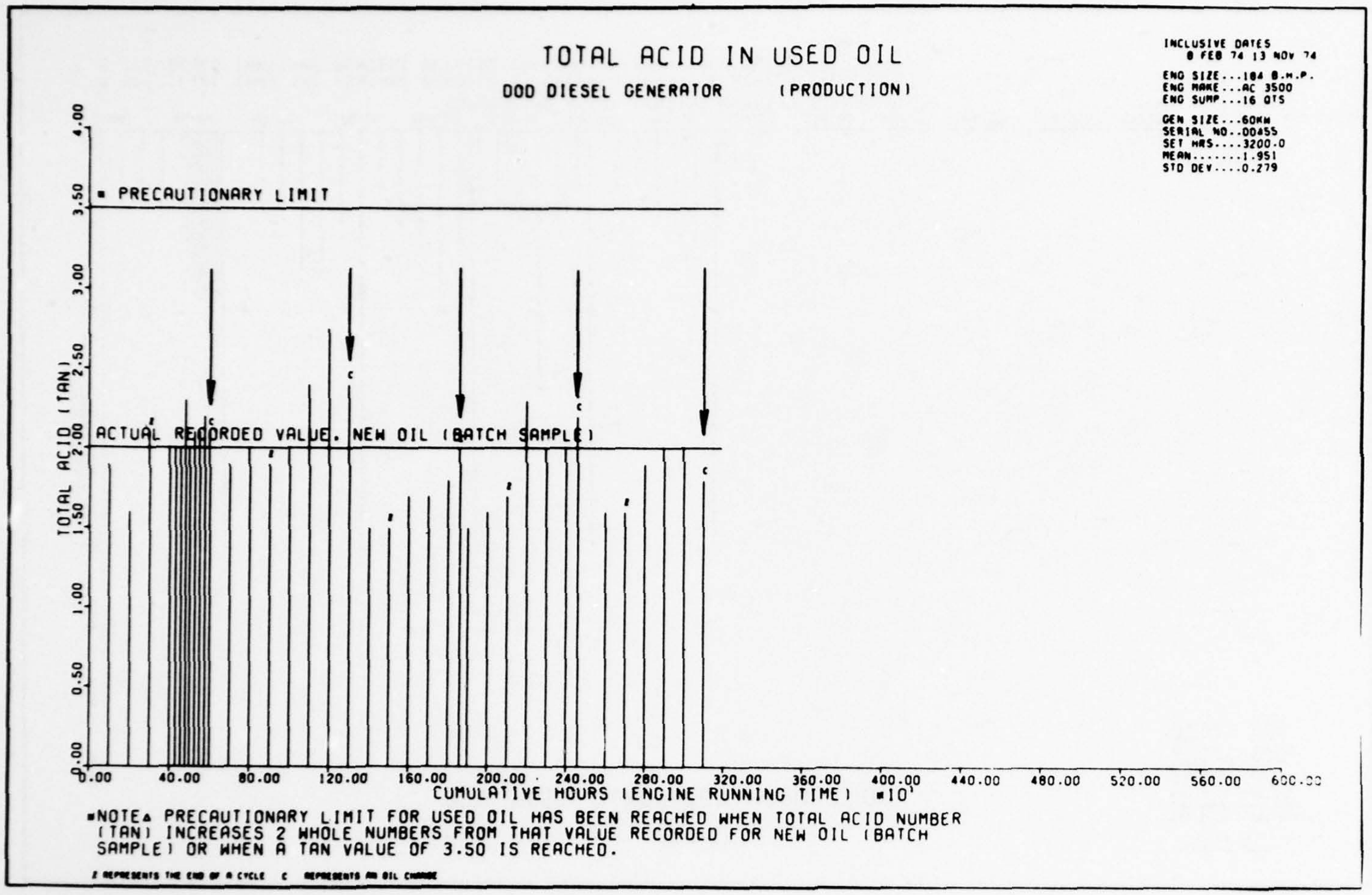

FLASH-POINT OF USED OIL (F)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 13 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......439.410
STD DEV....5.025
FLASH-POINT IN F
290.00
315.00
340.00
365.00
390.00
415.00
440.00
465.00
490.00
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL
* PRECAUTIONARY LIMIT (FUEL DILUTION)
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).

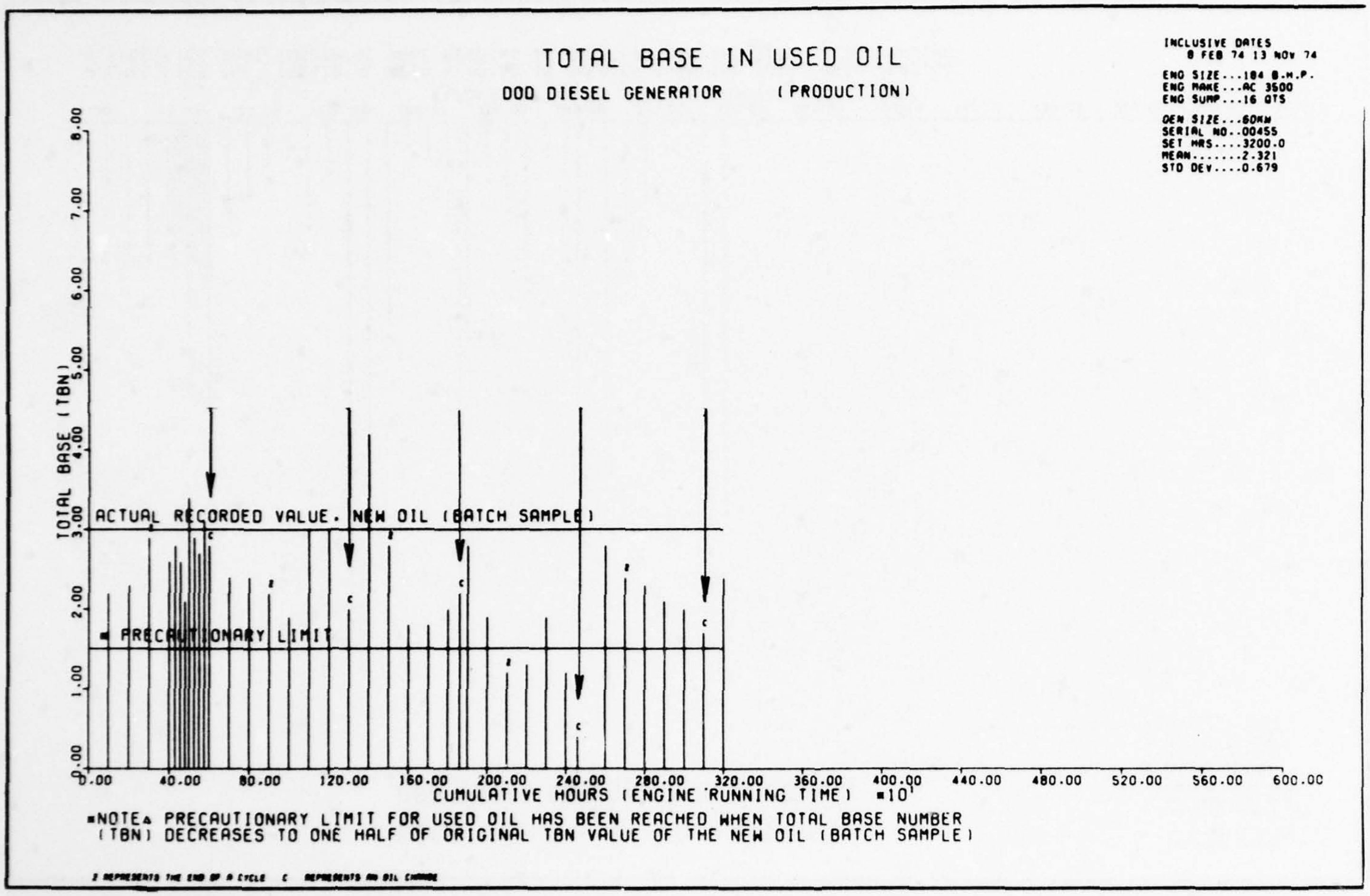


PERCENTAGE INSOLUBLES (PENTANE)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES 8 FEB 74 13 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......2.316
STD DEV....0.888
PENTANE PERCENT
0.00
0.65
1.30
1.95
2.60
3.25
3.90
4.55
5.20
* PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
*NOTE PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF PENTANE INSOLUBLES REACHES 1.50 PERCENT.

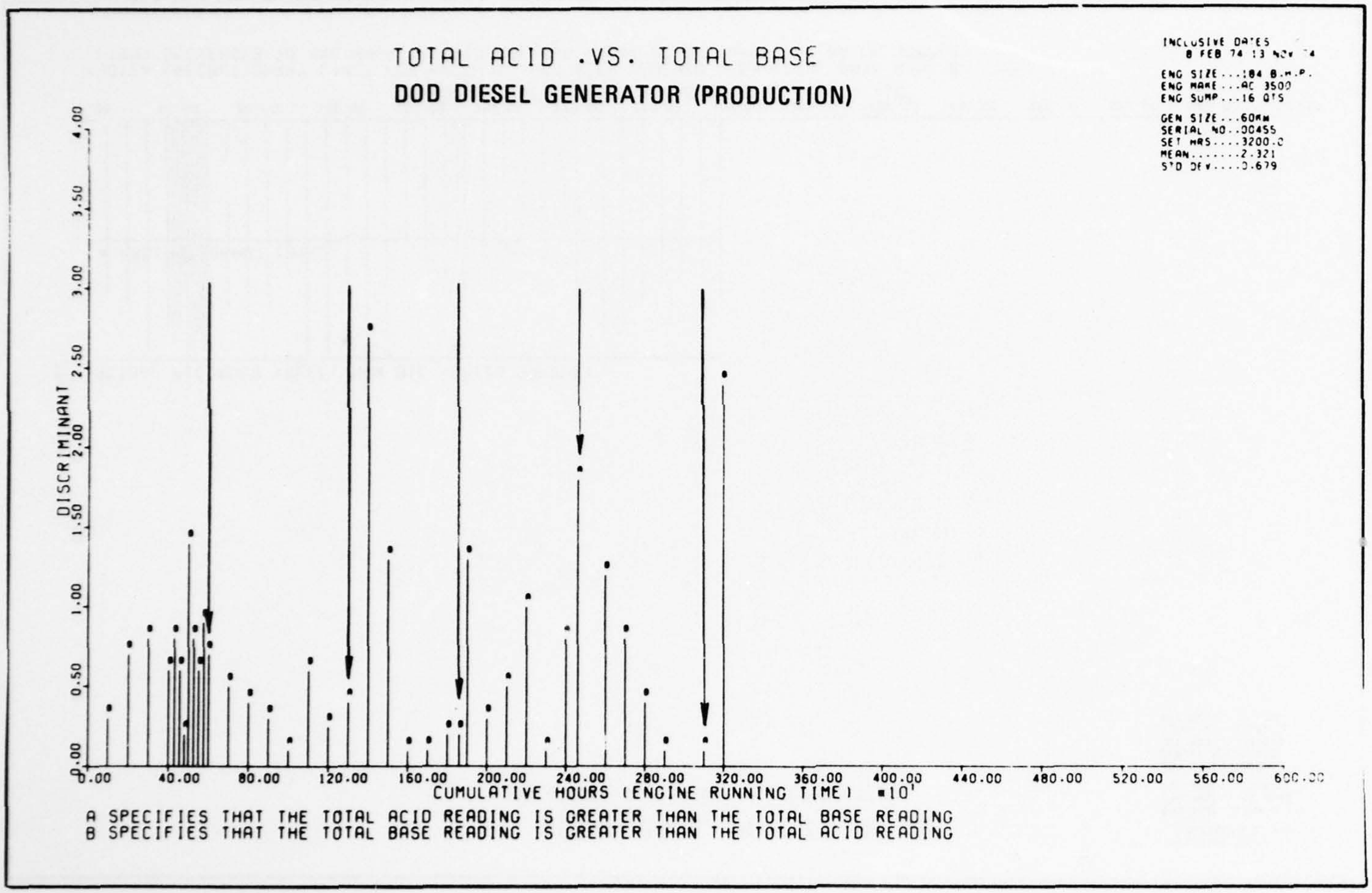

PERCENTAGE INSOLUBLES (BENZENE)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 13 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......1.578
STD DEV....0.746
BENZENE PERCENT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
* PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF BENZENE INSOLUBLES REACHES 1.00 PER CENT.


PENTANE .VS. BENZENE
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 13 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......2.321
STD DEV....0.679
DISCRIMINANT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
P SPECIFIES THAT THE PENTANE READING IS GREATER THAN THE BENZENE READING
B SPECIFIES THAT THE BENZENE READING IS GREATER THAN THE PENTANE READING

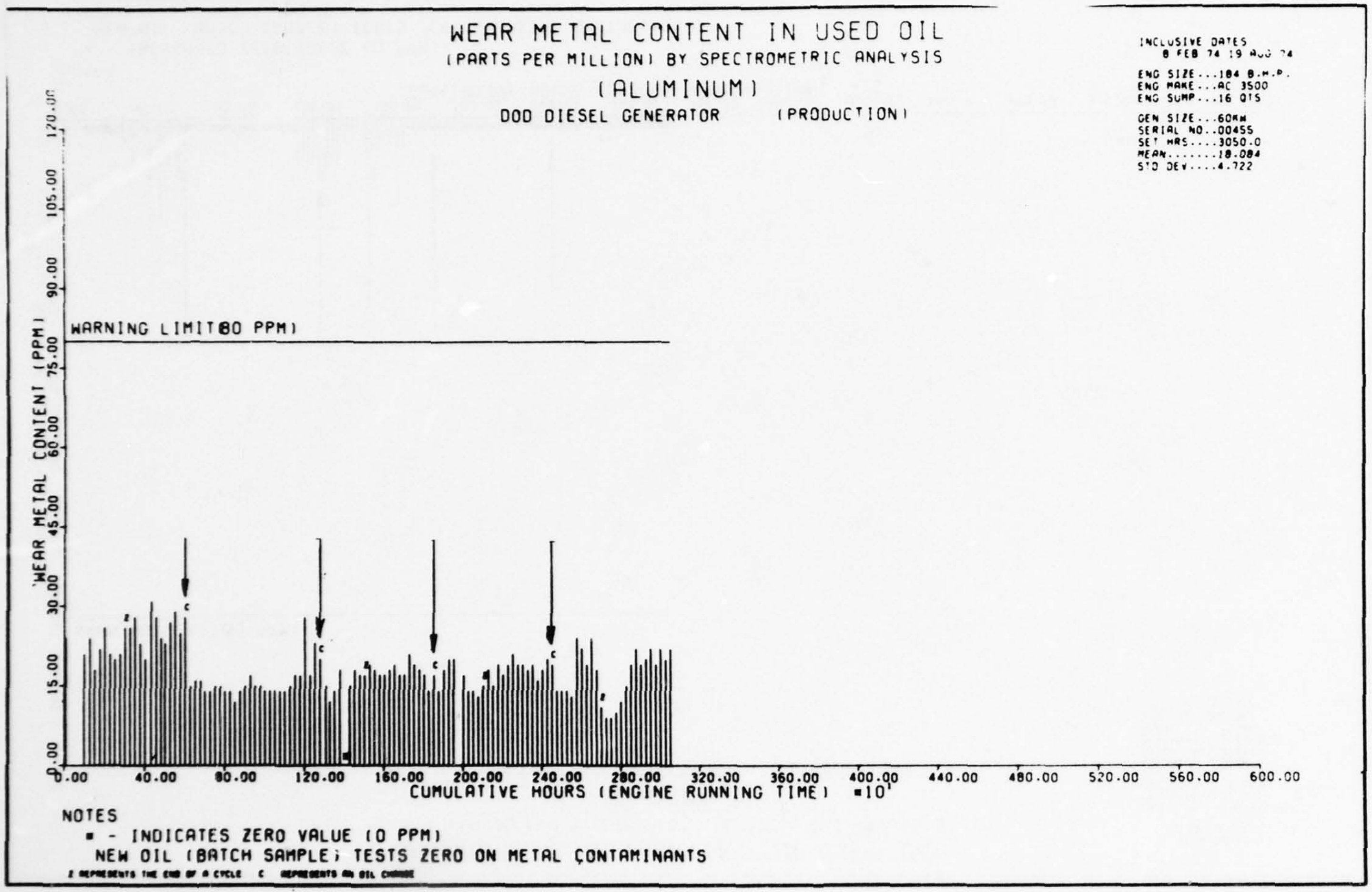

TOTAL ACID IN USED OIL
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 13 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......1.951
STD DEV....0.279
* PRECAUTIONARY LIMIT
ACTUAL RECORDED VALUE. NEW OIL (BATCH SAMPLE)
TOTAL ACID (TAN)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
*NOTE▲ PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL ACID NUMBER
(TAN) INCREASES 2 WHOLE NUMBERS FROM THAT VALUE RECORDED FOR NEW OIL (BATCH
SAMPLE) OR WHEN A TAN VALUE OF 3.50 IS REACHED.
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

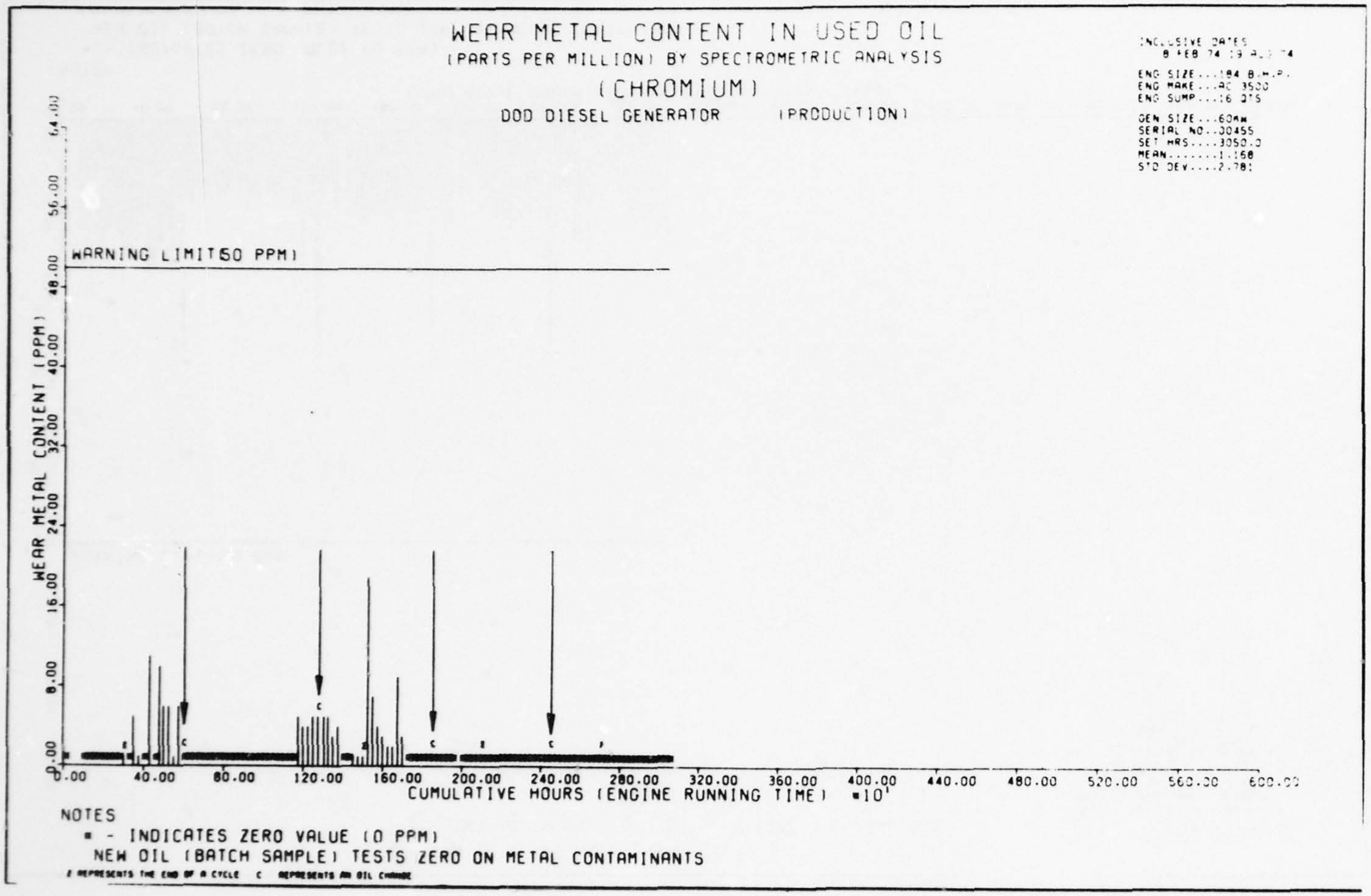


TOTAL BASE IN USED OIL
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 13 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......2.321
STD DEV....0.679
TOTAL BASE (TBN)
ACTUAL RECORDED VALUE. NEW OIL (BATCH SAMPLE)
* PRECAUTIONARY LIMIT
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL BASE NUMBER (TBN) DECREASES TO ONE HALF OF ORIGINAL TBN VALUE OF THE NEW OIL (BATCH SAMPLE)



TOTAL ACID .VS. TOTAL BASE
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 13 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3200.0
MEAN.......2.321
STD DEV....0.679
DISCRIMINANT
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
A SPECIFIES THAT THE TOTAL ACID READING IS GREATER THAN THE TOTAL BASE READING
B SPECIFIES THAT THE TOTAL BASE READING IS GREATER THAN THE TOTAL ACID READING


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(ALUMINUM)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 19 AUG 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3050.0
MEAN.......18.084
STD DEV....4.722
WARNING LIMIT(80 PPM)
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(CHROMIUM)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3050.0
MEAN........1.168
WARNING LIMIT 50 PPM)
WEAR METAL CONTENT (PPM)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
E REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

AD-A056 216 ARMY MOBILITY EQUIPMENT FESEARCH AND DEVELOPMENT COMM--ETC F/G 11/8
EXTENDED OIL-CHANGE AND OIL-FILTER-CHANGE INTERVALS FOR DOD 5- --ETC(U)
MAR 78 C R GURSKI, E FITZGIBBONS, J W DREGER
UNCLASSIFIED MERADCOM-2234 NL

2 OF 2
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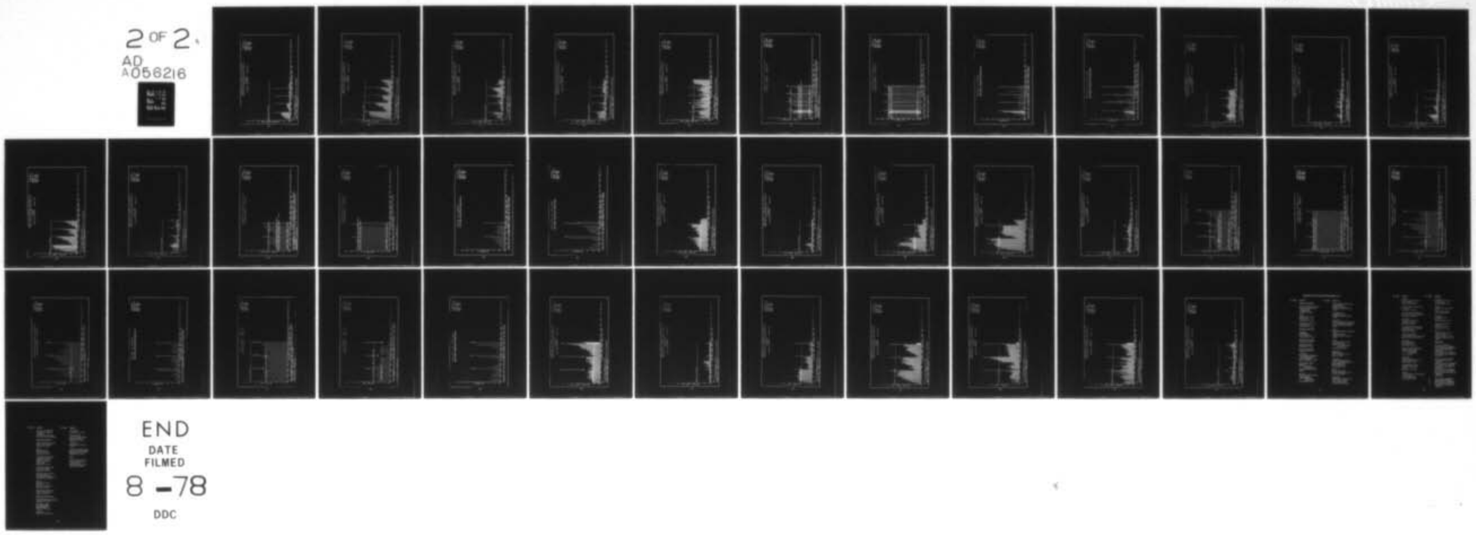

END
DATE
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8 -78
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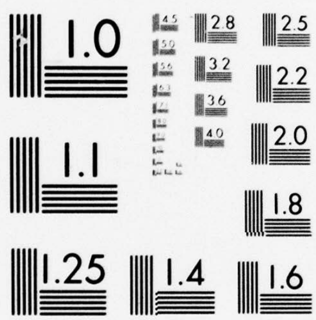



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

# WEAR METAL CONTENT IN USED OIL

(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS

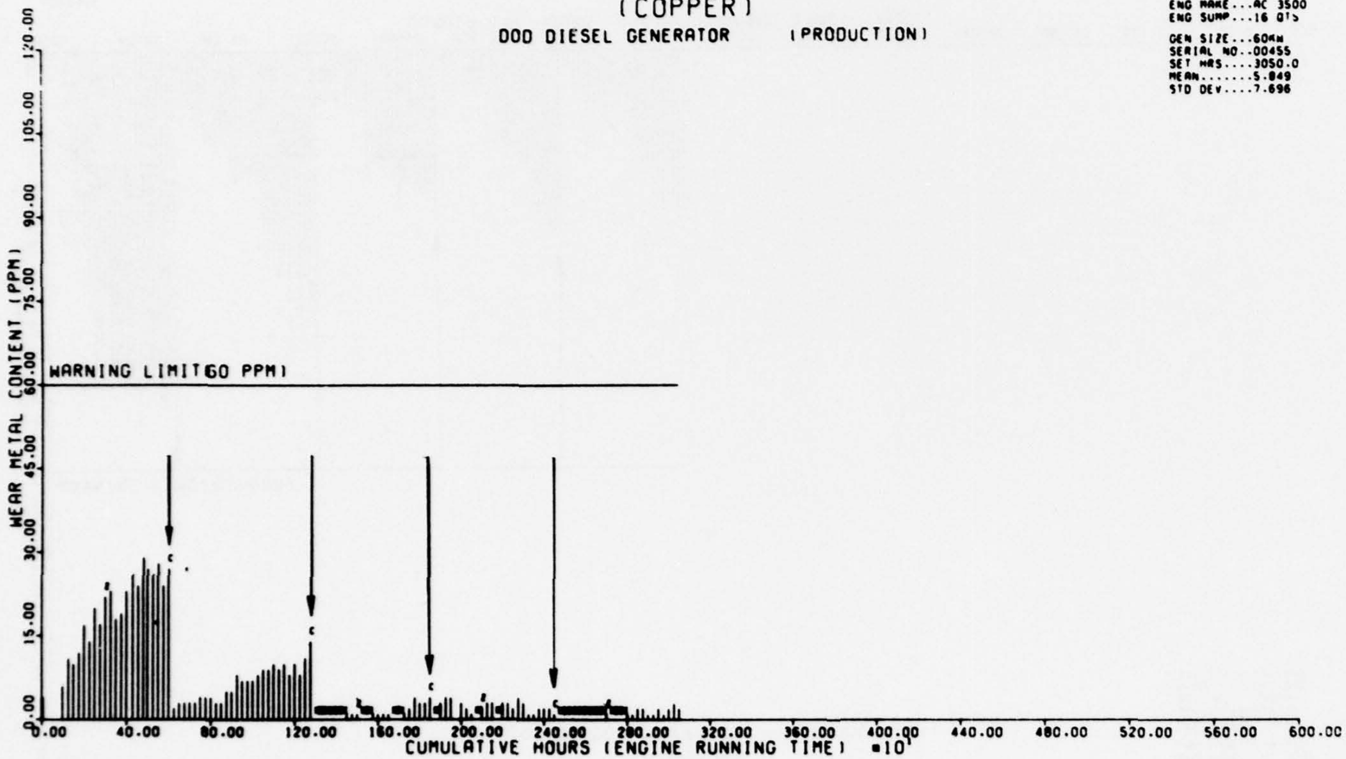
(COPPER)

DOD DIESEL GENERATOR (PRODUCTION)

INCLUSIVE DATES
8 FEB 74 19 AUG 74

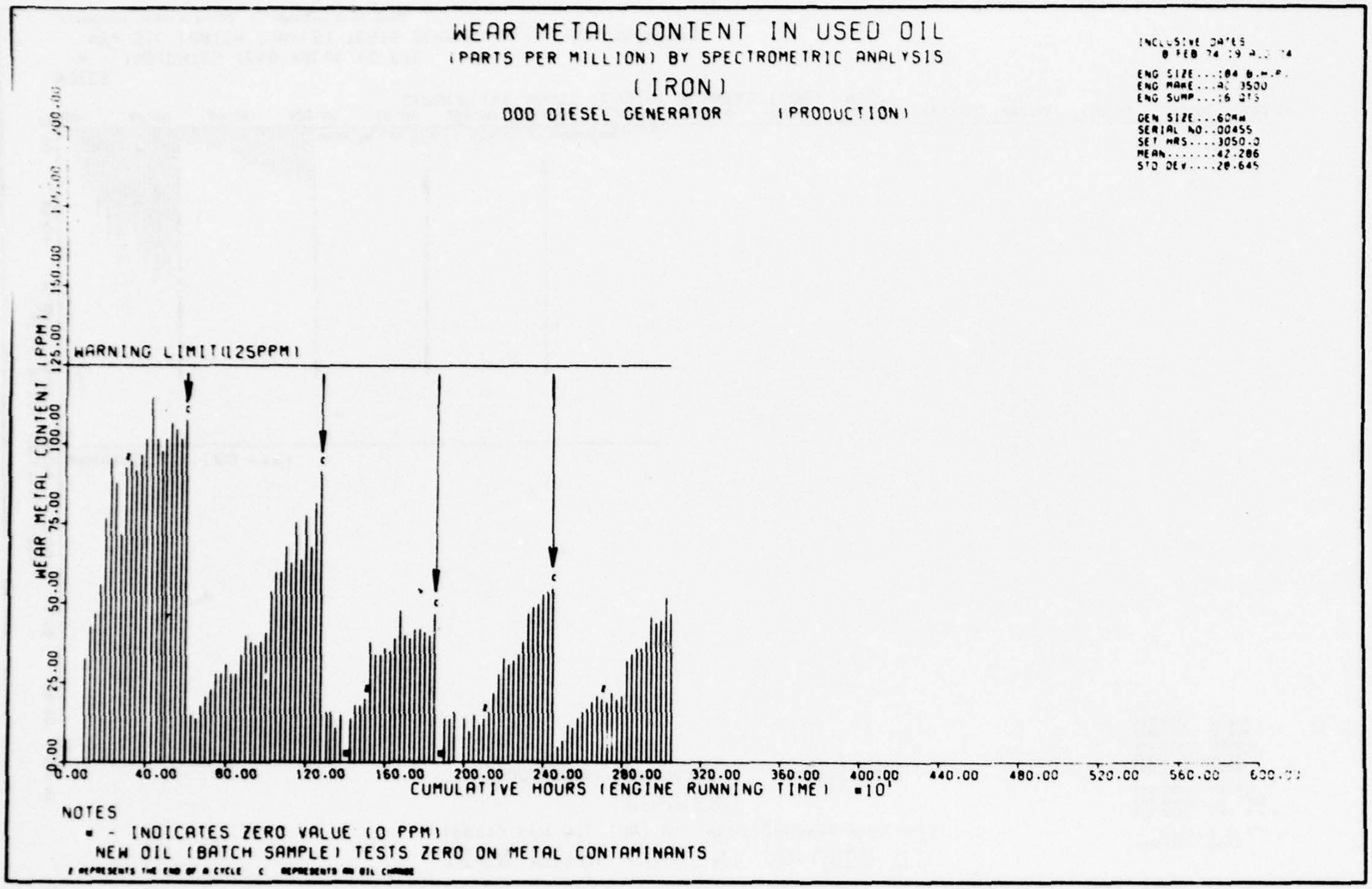
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS

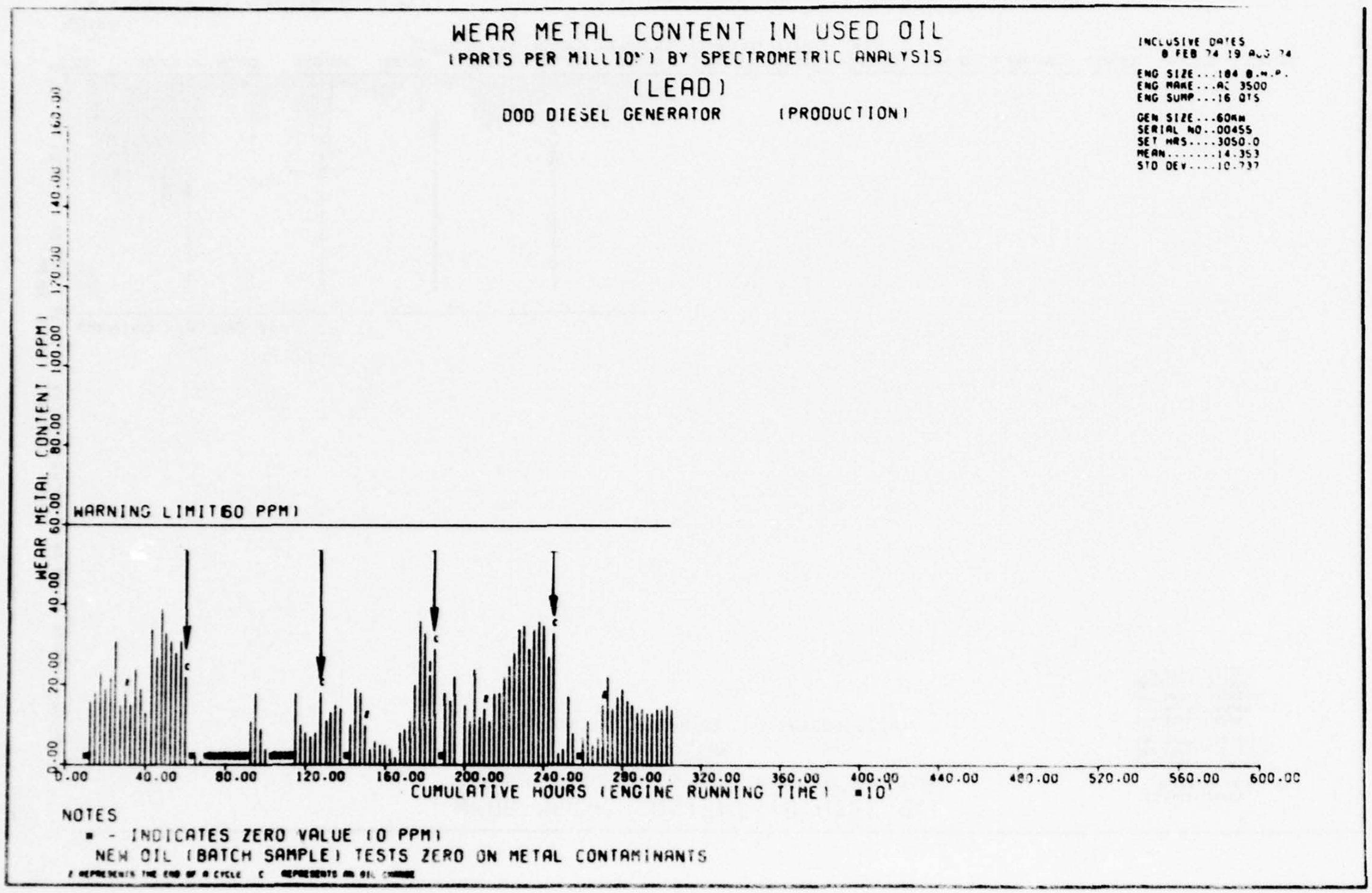
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3050.0
MEAN.......5.849
STD DEV....7.696

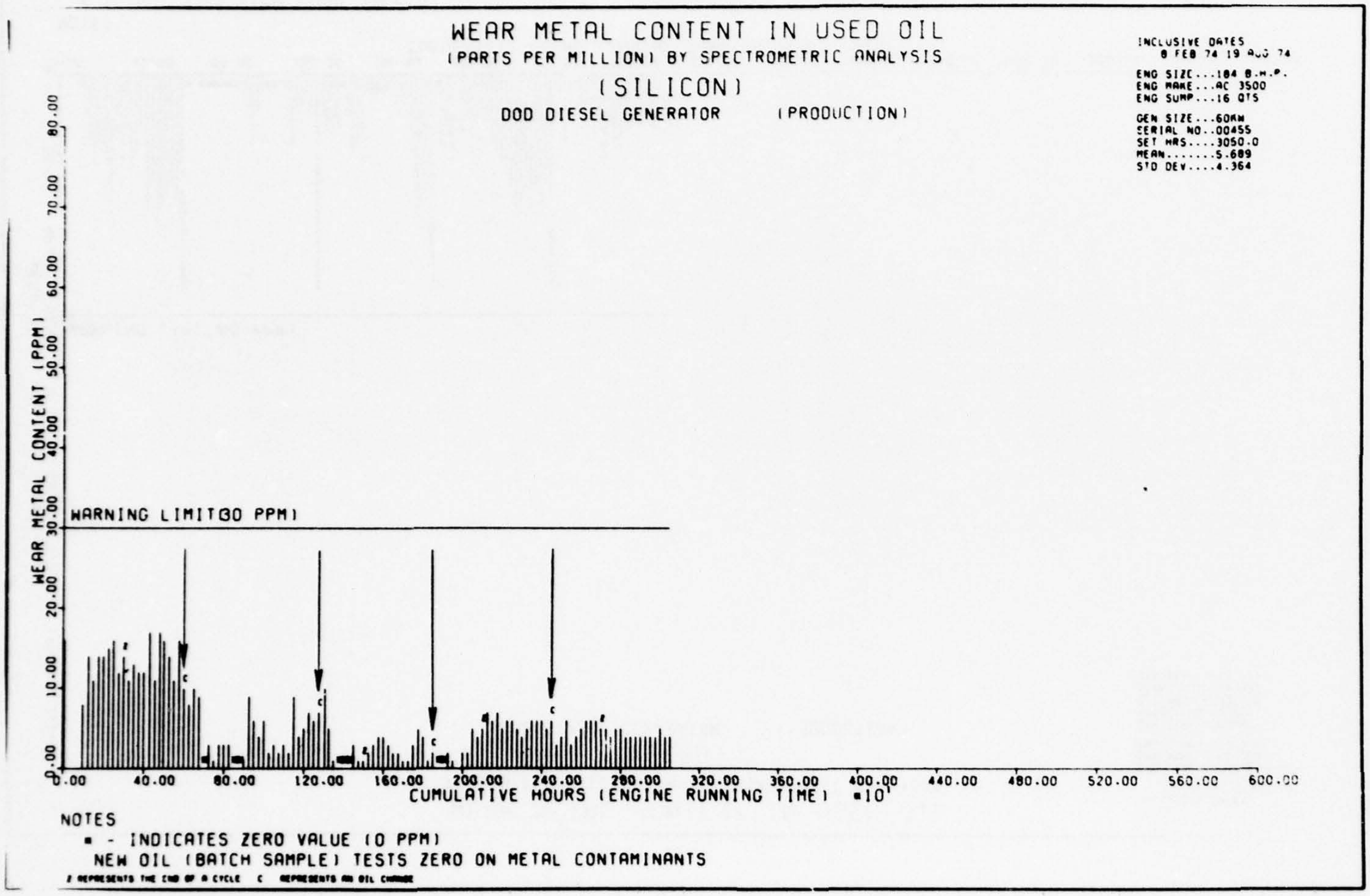


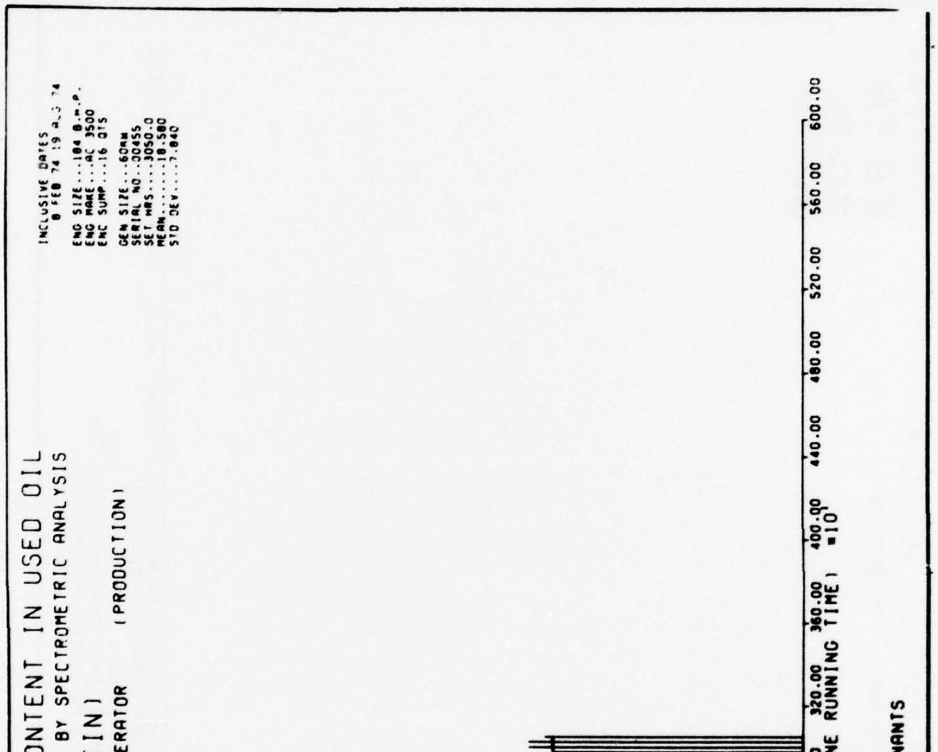

NOTES
- ■ - INDICATES ZERO VALUE (0 PPM)
- NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

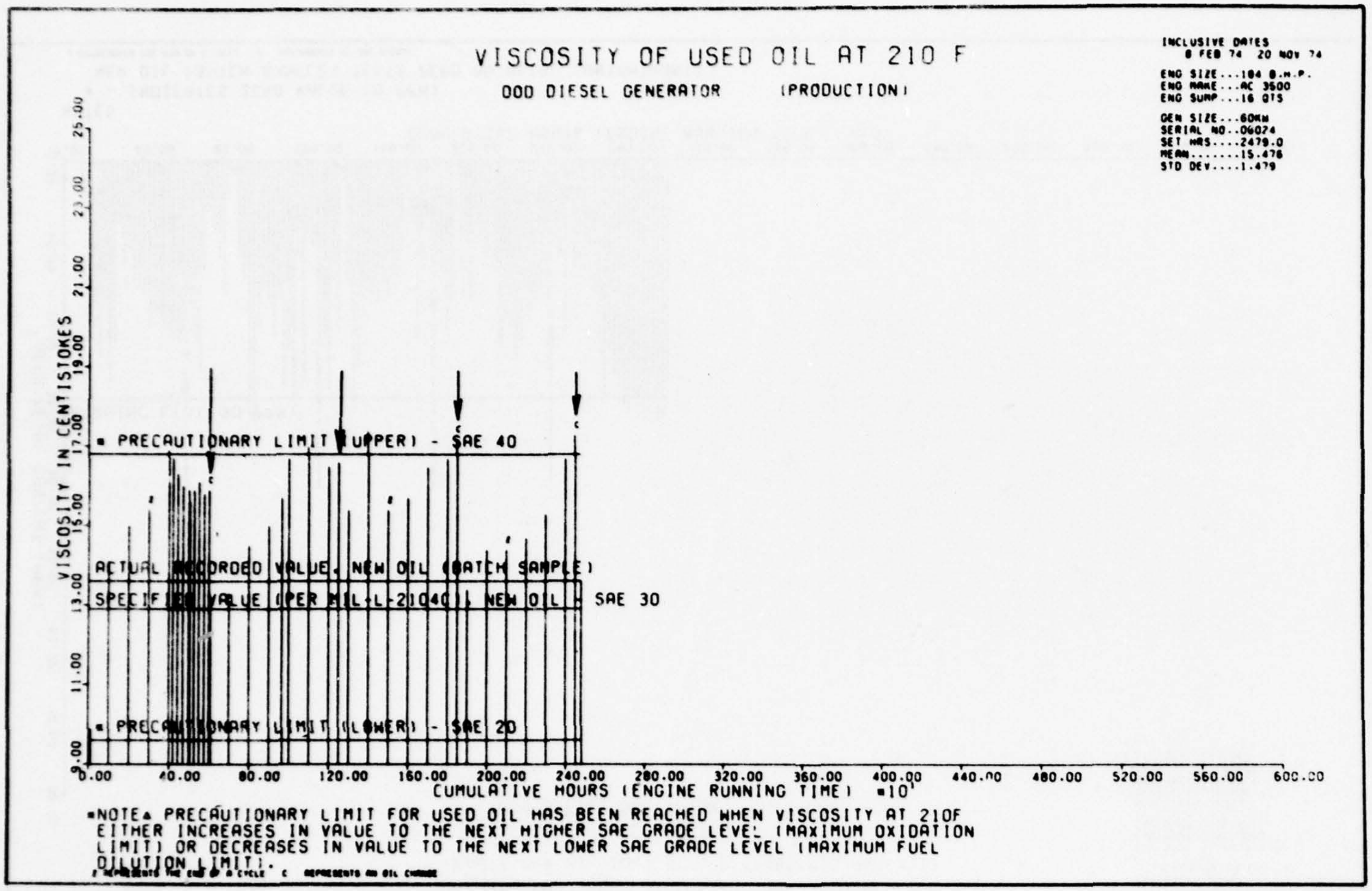
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(IRON)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
ENG SIZE
ENG MAKE
ENG SUMP
GEN SIZE
SERIAL NO..00455
SET HRS....3050.0
MEAN........42.286
STD DEV....20.645
WARNING LIMIT(125PPM)
WEAR METAL CONTENT (PPM)
0.00
25.00
50.00
75.00
100.00
125.00
150.00
200.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(LEAD)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 19 AUG 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3050.0
MEAN.......14.353
STD DEV....10.737
WARNING LIMIT(60 PPM)
WEAR METAL CONTENT (PPM)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(SILICON)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 19 AUG 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..00455
SET HRS....3050.0
MEAN.......5.689
STD DEV....4.364
WARNING LIMIT(30 PPM)
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
▪ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(TIN)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 19 AUG 74
ENG SIZE....104 B.H.P.
ENG MAKE....AC 3500
ENG SUMP....16 QTS
GEN SIZE....60KW
SERIAL NO...00455
SET HRS.....3050.0
MEAN........18.580
STD DEV.....7.040
WARNING LIMIT(30 PPM)
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


VISCOSITY OF USED OIL AT 210 F
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 20 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..06074
SET HRS.....2479.0
MEAN.........15.476
STD DEV.....1.479
VISCOSITY IN CENTISTOKES
9.00
11.00
13.00
15.00
17.00
19.00
21.00
23.00
25.00
* PRECAUTIONARY LIMIT (UPPER) - SAE 40
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL - SAE 30
* PRECAUTIONARY LIMIT (LOWER) - SAE 20
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).
C REPRESENTS AN OIL CHANGE

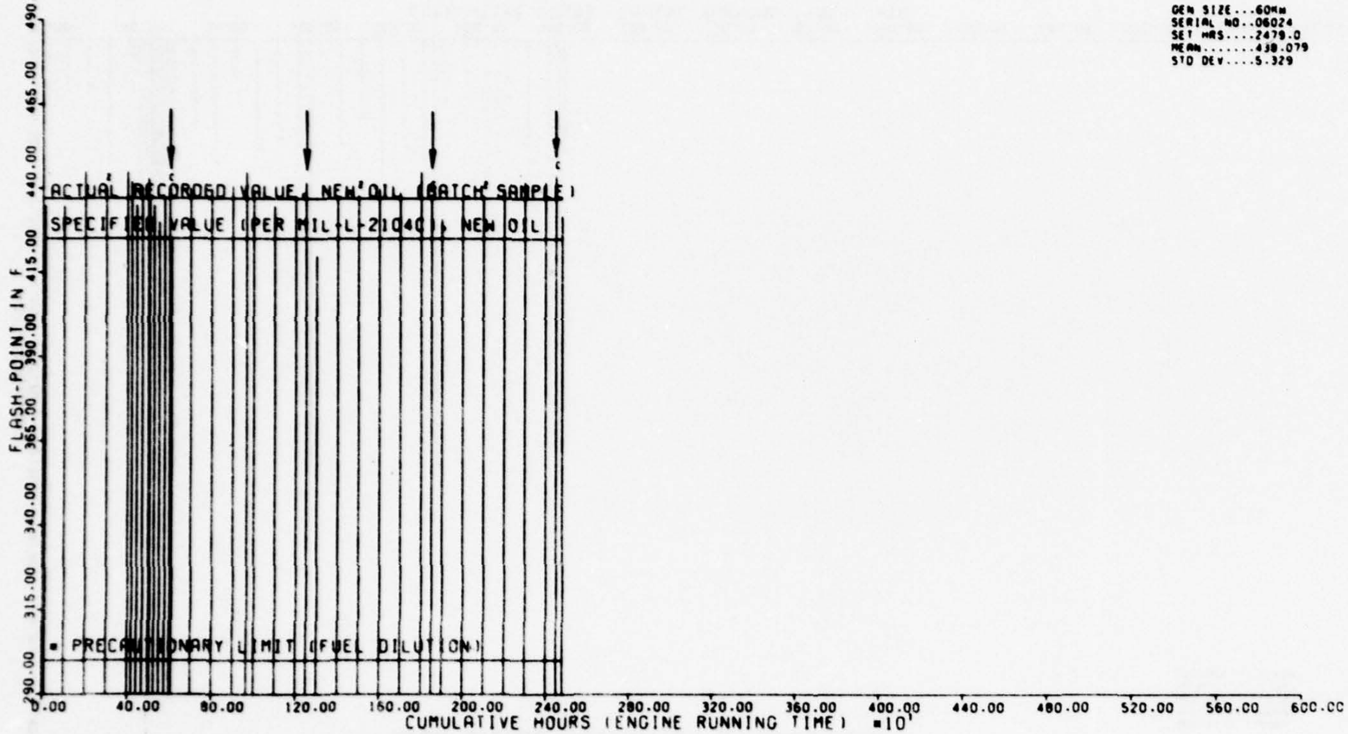
# FLASH-POINT OF USED OIL (F)

DOD DIESEL GENERATOR (PRODUCTION)

INCLUSIVE DATES
8 FEB 74 20 NOV 74

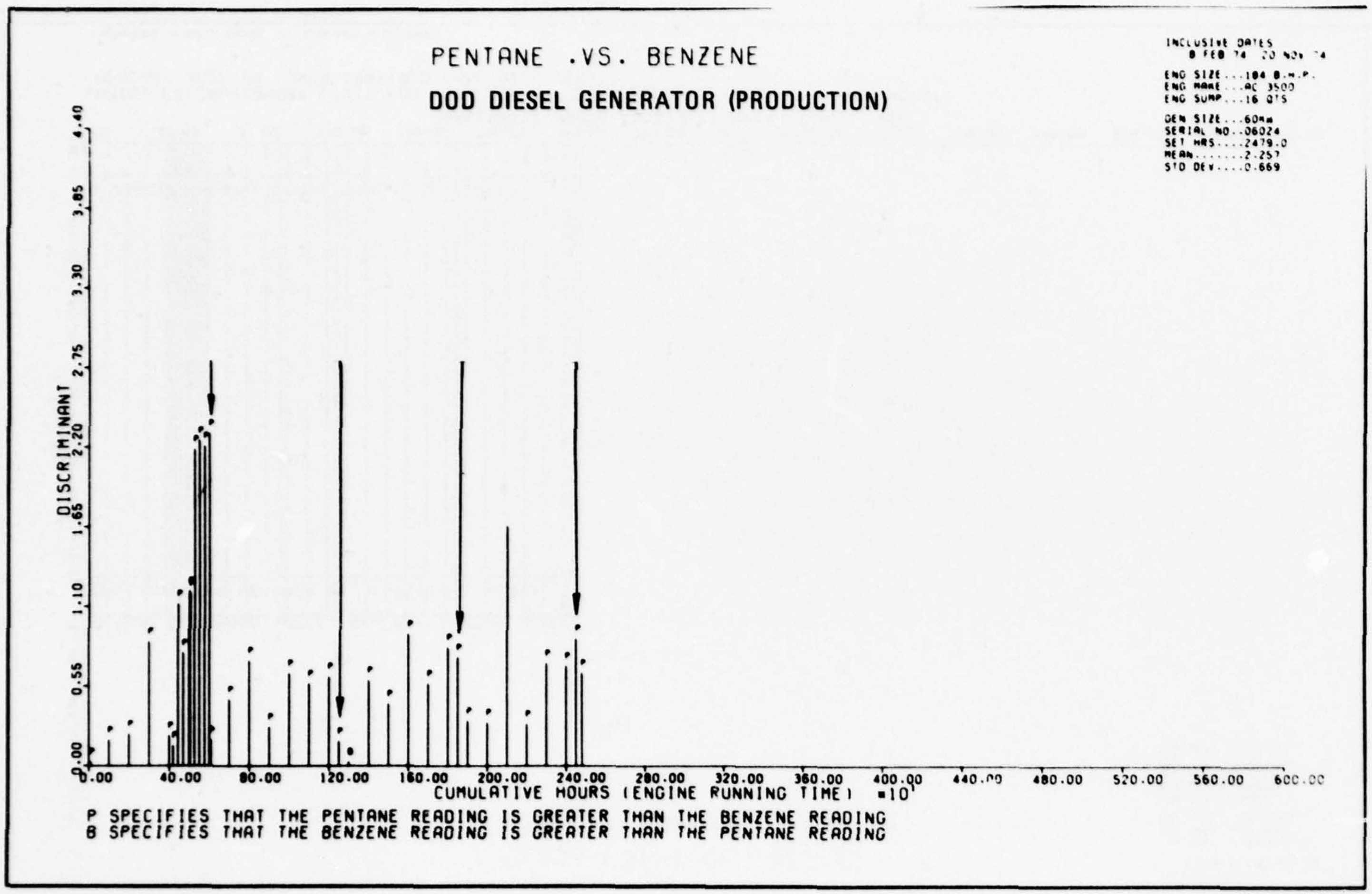
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS

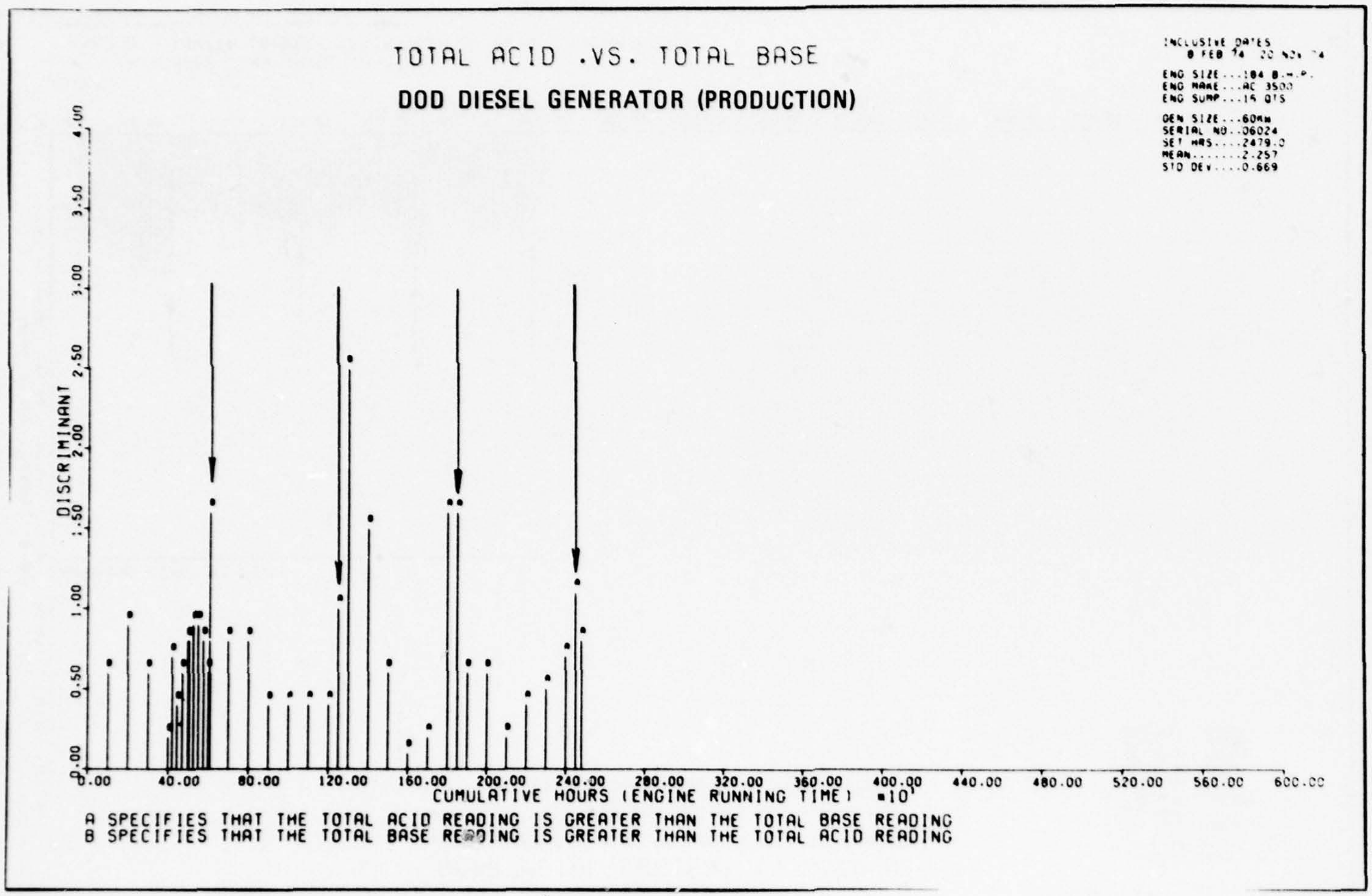
GEN SIZE...60KW
SERIAL NO..06024
SET HRS....2479.0
MEAN.......438.079
STD DEV....5.329




*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).

E REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


PENTANE .VS. BENZENE
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 20 NOV 74
ENG SIZE...104 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...16 QTS
GEN SIZE...60KW
SERIAL NO..06024
SET HRS....2479.0
MEAN.......2.257
STD DEV....0.669
DISCRIMINANT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
P SPECIFIES THAT THE PENTANE READING IS GREATER THAN THE BENZENE READING
B SPECIFIES THAT THE BENZENE READING IS GREATER THAN THE PENTANE READING


TOTAL ACID .VS. TOTAL BASE
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 20 NOV 74
ENG SIZE...184 B.H.P.
ENG MAKE...AC 3500
ENG SUMP...15 QTS
GEN SIZE...60KW
SERIAL NO..06024
SET HRS....2479.0
MEAN........2.257
STD DEV.....0.669
DISCRIMINANT
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
A SPECIFIES THAT THE TOTAL ACID READING IS GREATER THAN THE TOTAL BASE READING
B SPECIFIES THAT THE TOTAL BASE READING IS GREATER THAN THE TOTAL ACID READING

# WEAR METAL CONTENT IN USED OIL

(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS

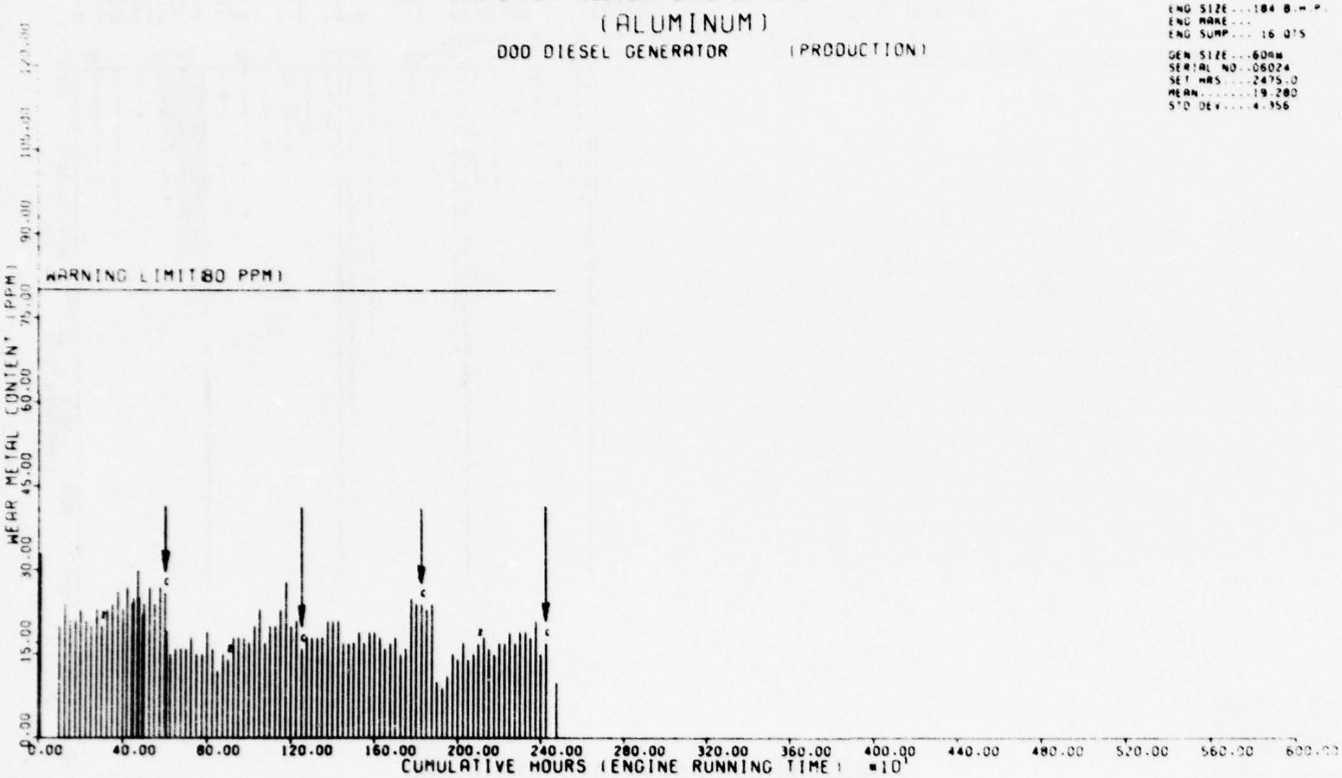
(ALUMINUM)

DOD DIESEL GENERATOR (PRODUCTION)

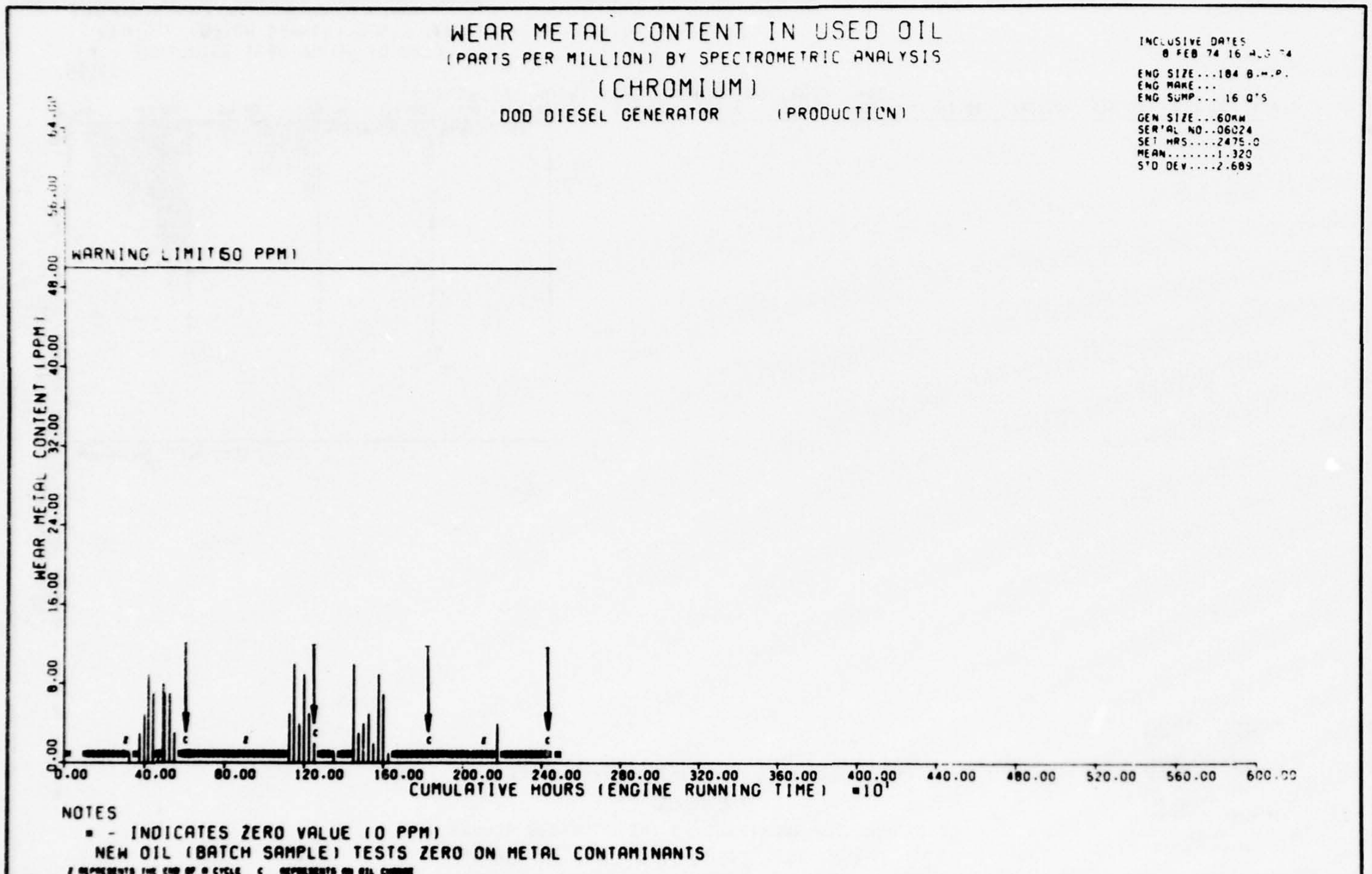
INCLUSIVE DATES
8 FEB 74 16 AUG 74

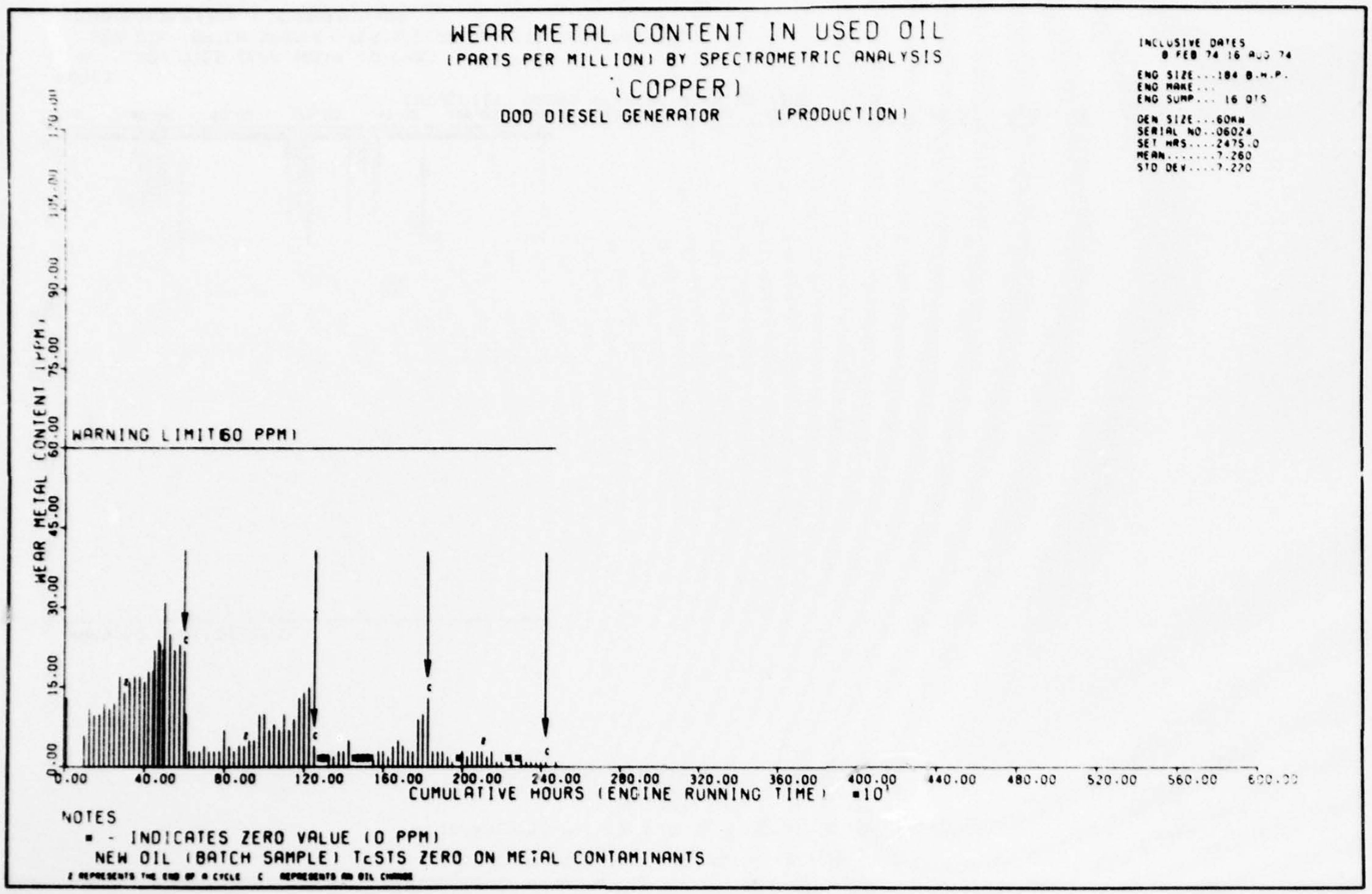
ENG SIZE....184 B.H.P.
ENG MAKE...
ENG SUMP.... 16 QTS

GEN SIZE....60KW
SERIAL NO..06024
SET HRS.....2475.0
MEAN........19.280
STD DEV.....4.356




NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(CHROMIUM)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 16 AUG 74
ENG SIZE...184 B.H.P.
ENG MAKE...
ENG SUMP... 16 QTS
GEN SIZE...60KW
SERIAL NO..06024
SET HRS....2475.0
MEAN.......1.320
STD DEV....2.689
WARNING LIMIT(50 PPM)
WEAR METAL CONTENT (PPM)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
56.00
64.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(COPPER)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 16 AUG 74
ENG SIZE...184 B.H.P.
ENG MAKE...
ENG SUMP... 16 QTS
GEN SIZE...60KW
SERIAL NO..06024
SET HRS....2475.0
MEAN.......7.260
STD DEV....7.220
WARNING LIMIT(60 PPM)
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

## WEAR METAL CONTENT IN USED OIL

(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS

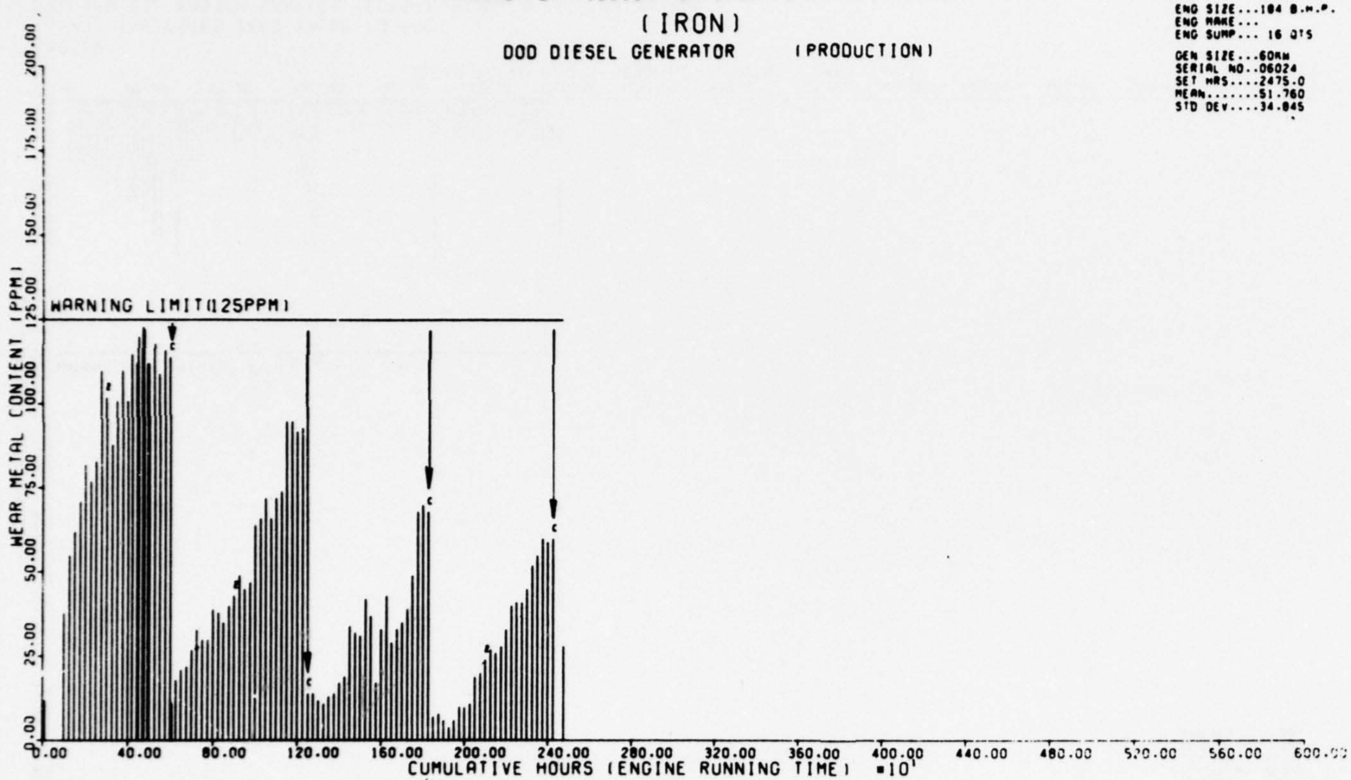
(IRON)

DOD DIESEL GENERATOR (PRODUCTION)

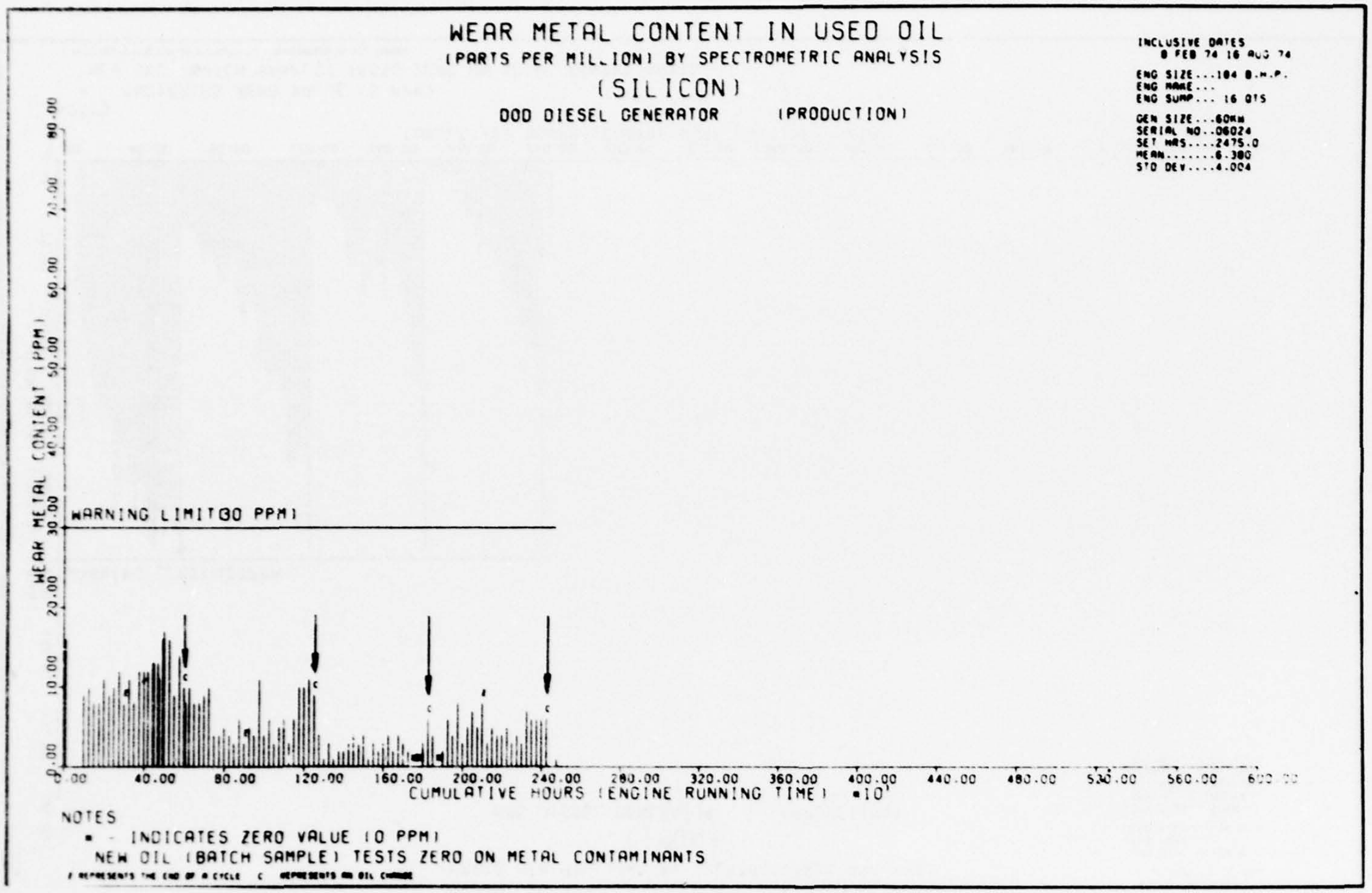
INCLUSIVE DATES
8 FEB 74 16 AUG 74

ENG SIZE...184 B.H.P.
ENG MAKE...
ENG SUMP... 16 QTS

GEN SIZE...60KW
SERIAL NO..06024
SET HRS....2475.0
MEAN.......51.760
STD DEV....34.845

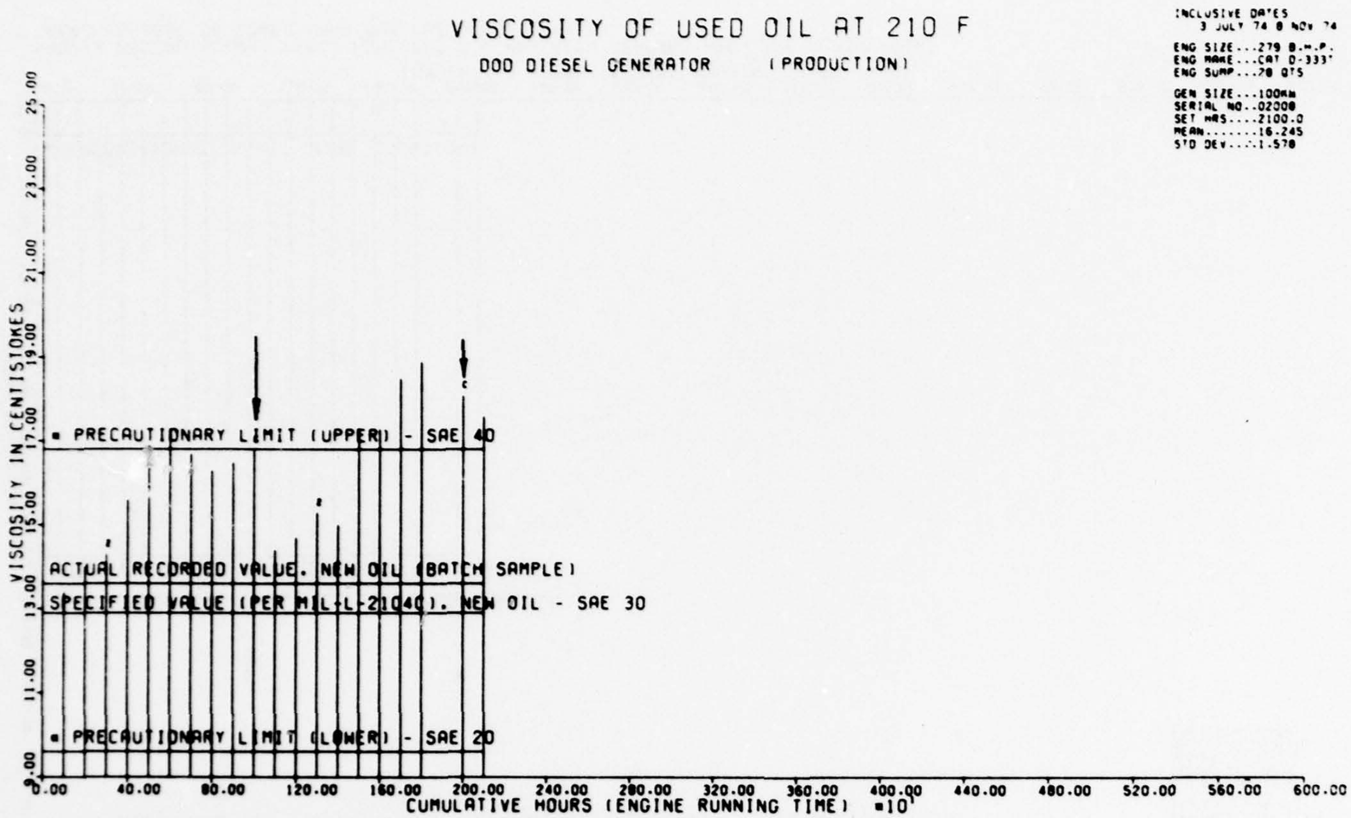



NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

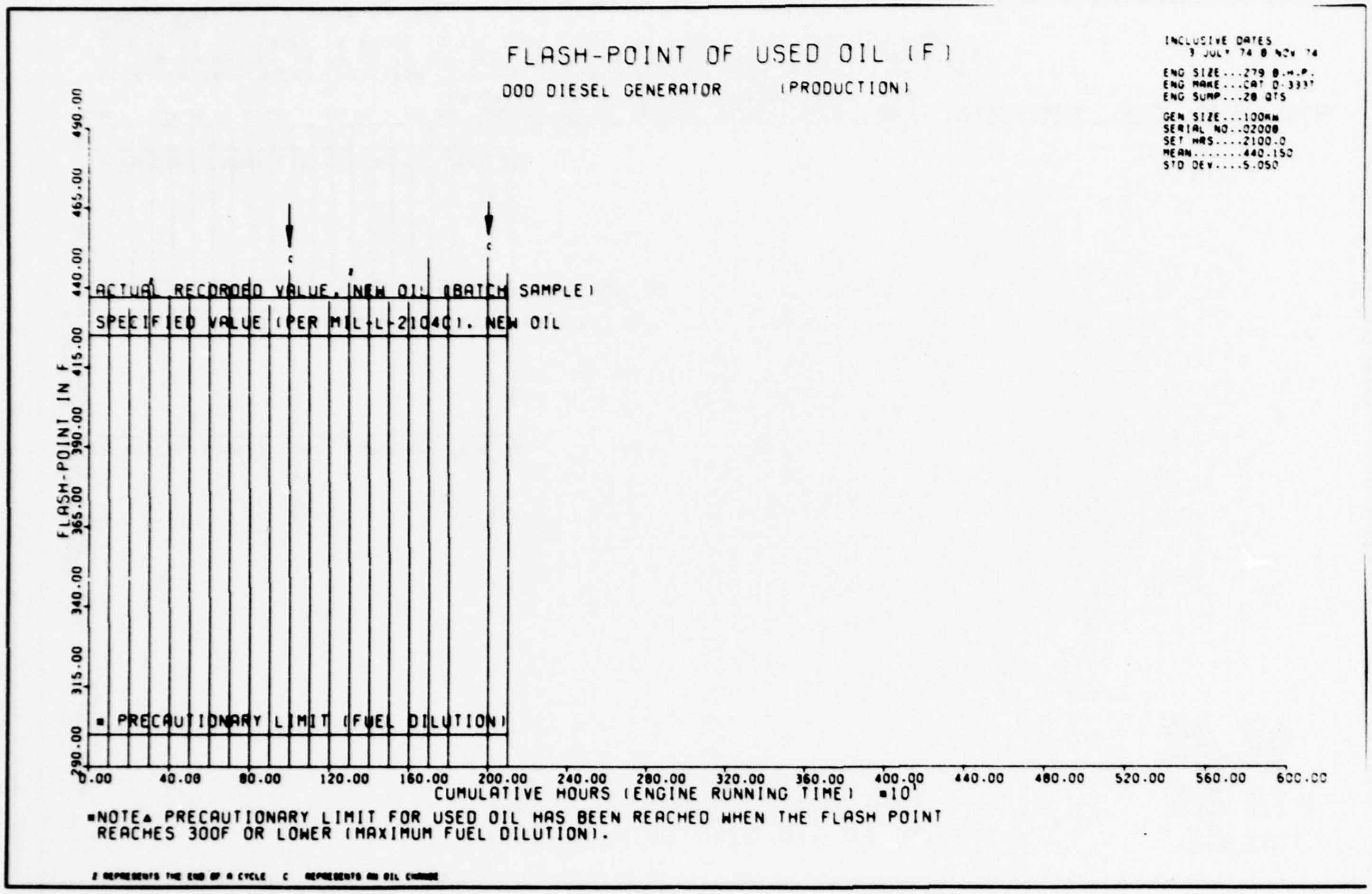

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(SILICON)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
8 FEB 74 16 AUG 74
ENG SIZE...104 B.H.P.
ENG MAKE...
ENG SUMP... 16 QTS
GEN SIZE...60KW
SERIAL NO..06024
SET HRS.....2475.0
MEAN........6.380
STD DEV.....4.004
WARNING LIMIT(30 PPM)
WEAR METAL CONTENT (PPM)
0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
# REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

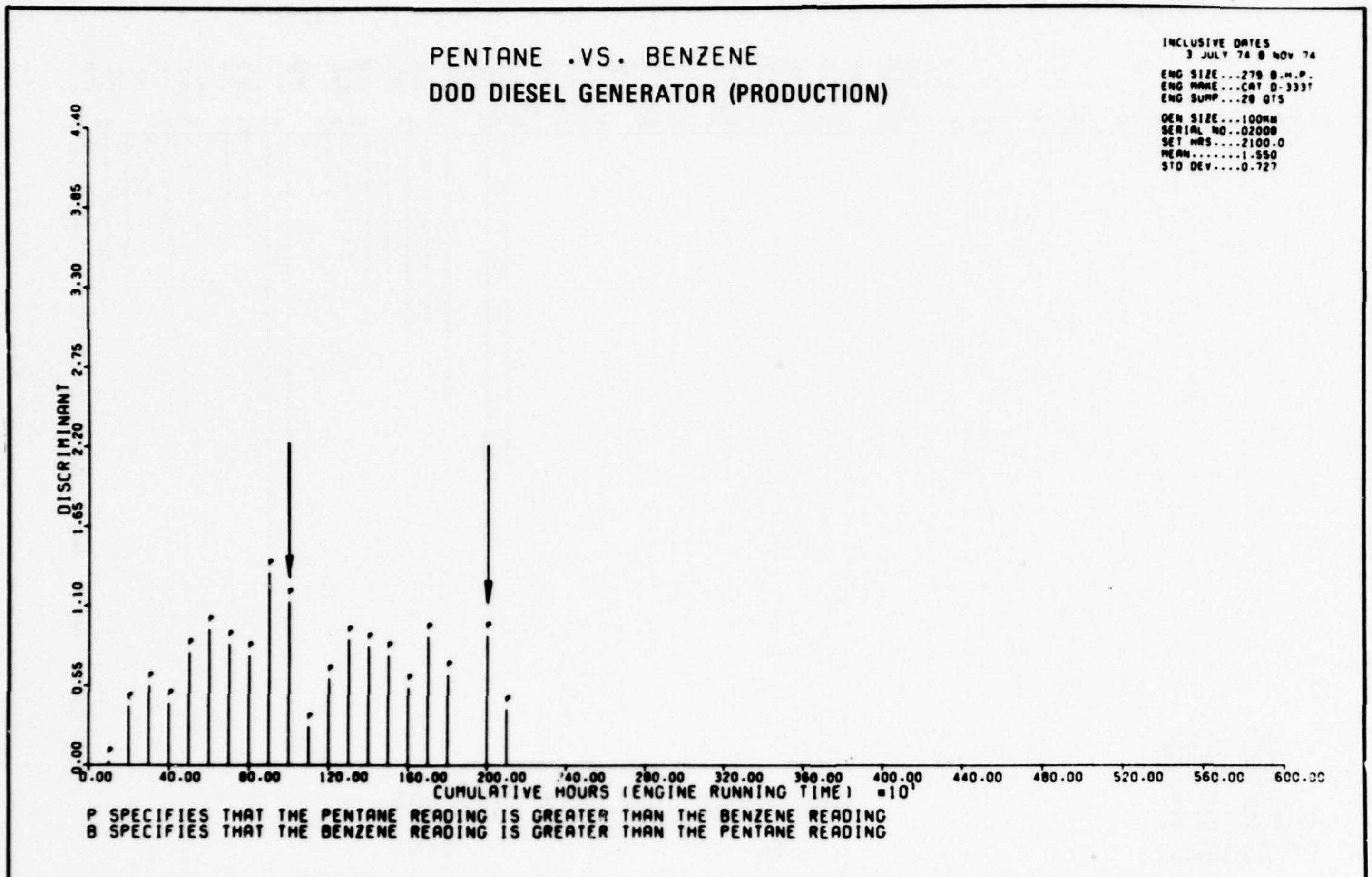
## VISCOSITY OF USED OIL AT 210 F

DOD DIESEL GENERATOR (PRODUCTION)



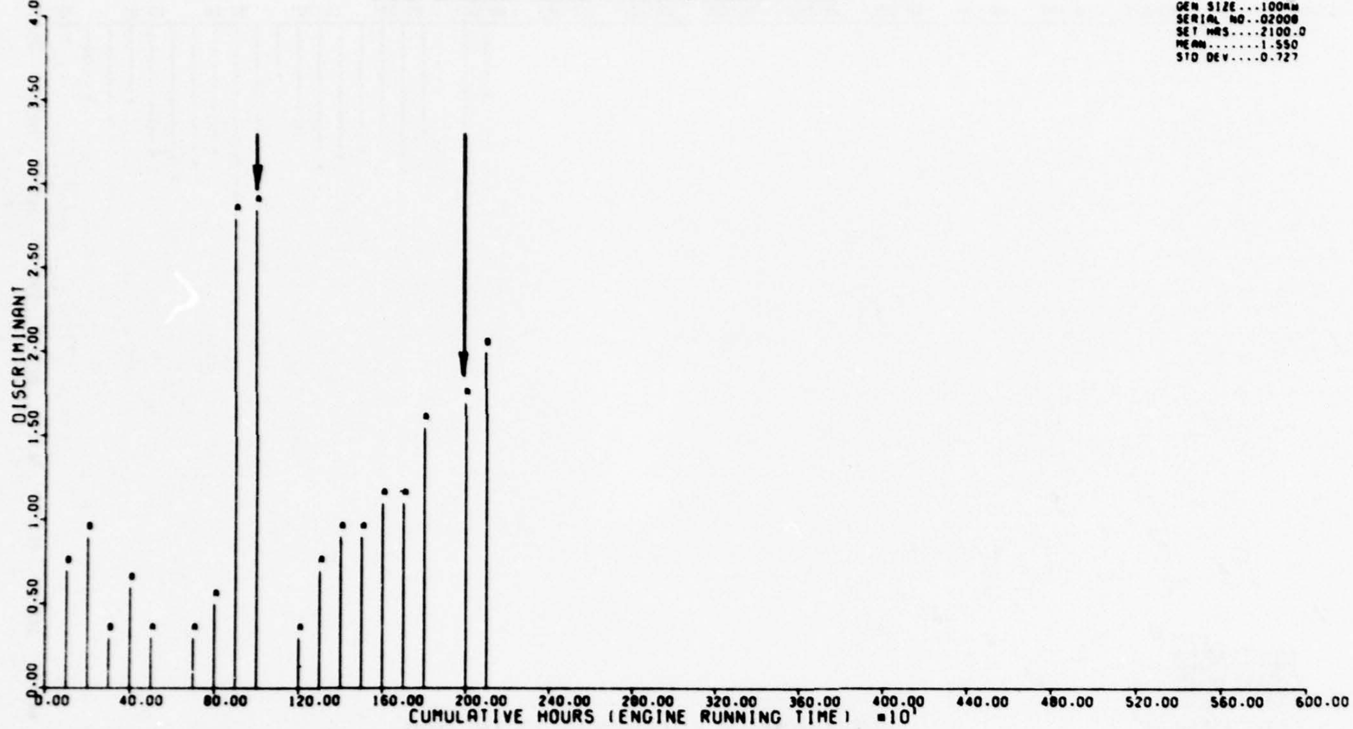

*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).


FLASH-POINT OF USED OIL (F)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
3 JULY 74 @ NOV 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...20 QTS
GEN SIZE...100KW
SERIAL NO..02000
SET HRS....2100.0
MEAN........440.150
STD DEV....5.050
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL
* PRECAUTIONARY LIMIT (FUEL DILUTION)
FLASH-POINT IN F
290.00
315.00
340.00
365.00
390.00
415.00
440.00
465.00
490.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE▲ PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).

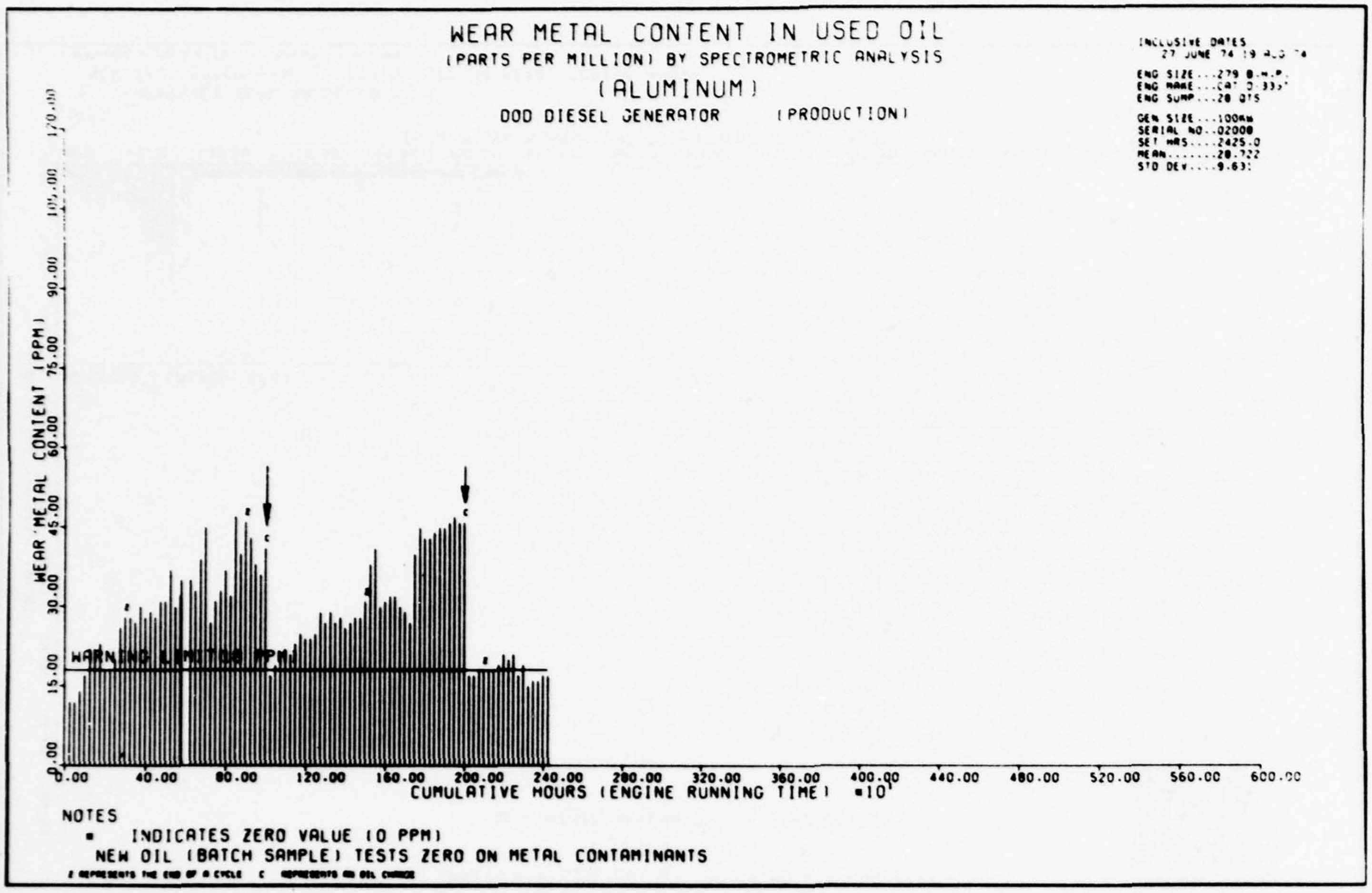

PENTANE .VS. BENZENE
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
3 JULY 74 8 NOV 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...20 QTS
GEN SIZE...100KW
SERIAL NO..02000
SET HRS....2100.0
MEAN........1.550
STD DEV....0.727
DISCRIMINANT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
P SPECIFIES THAT THE PENTANE READING IS GREATER THAN THE BENZENE READING
B SPECIFIES THAT THE BENZENE READING IS GREATER THAN THE PENTANE READING

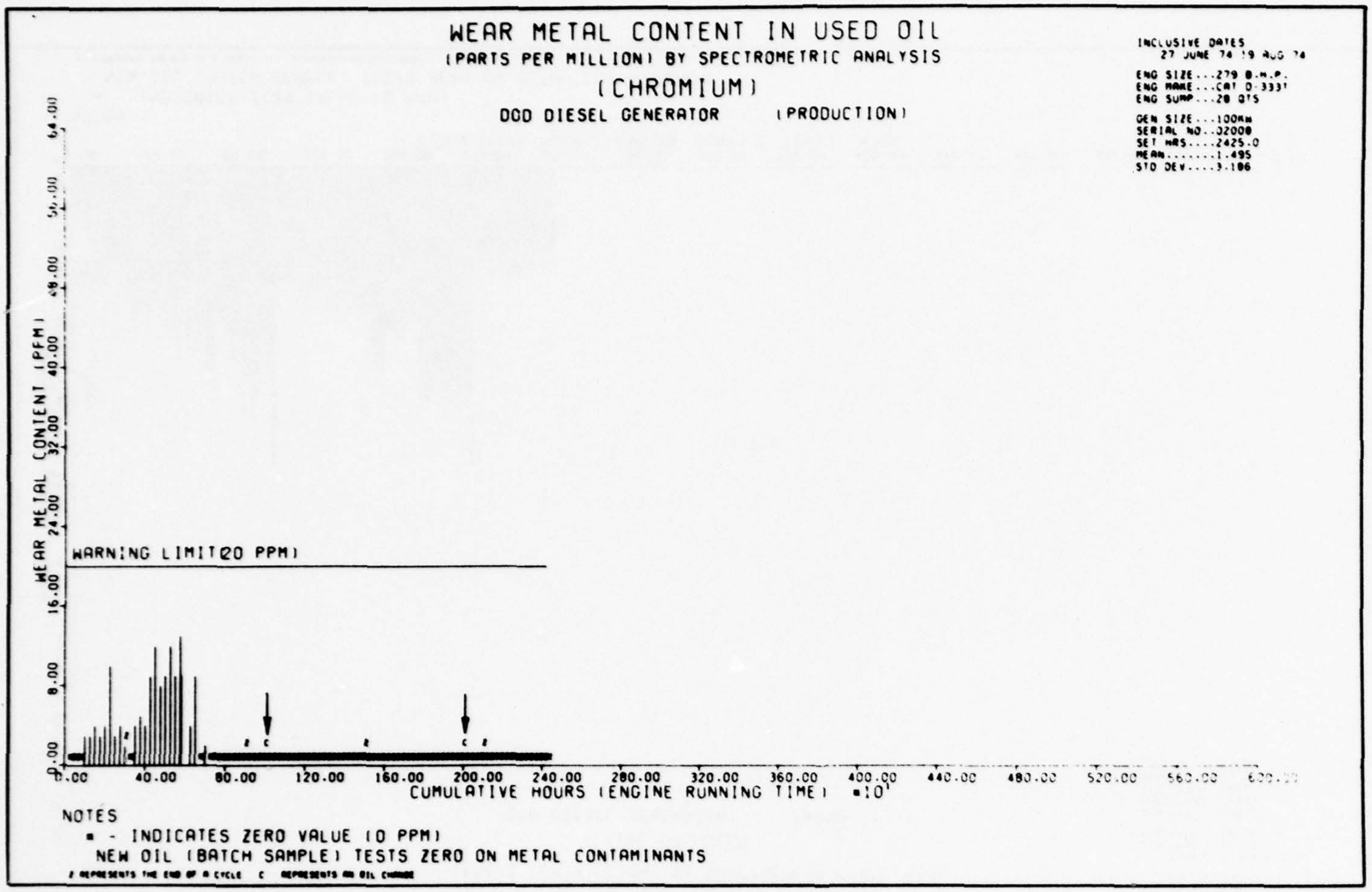
TOTAL ACID .VS. TOTAL BASE

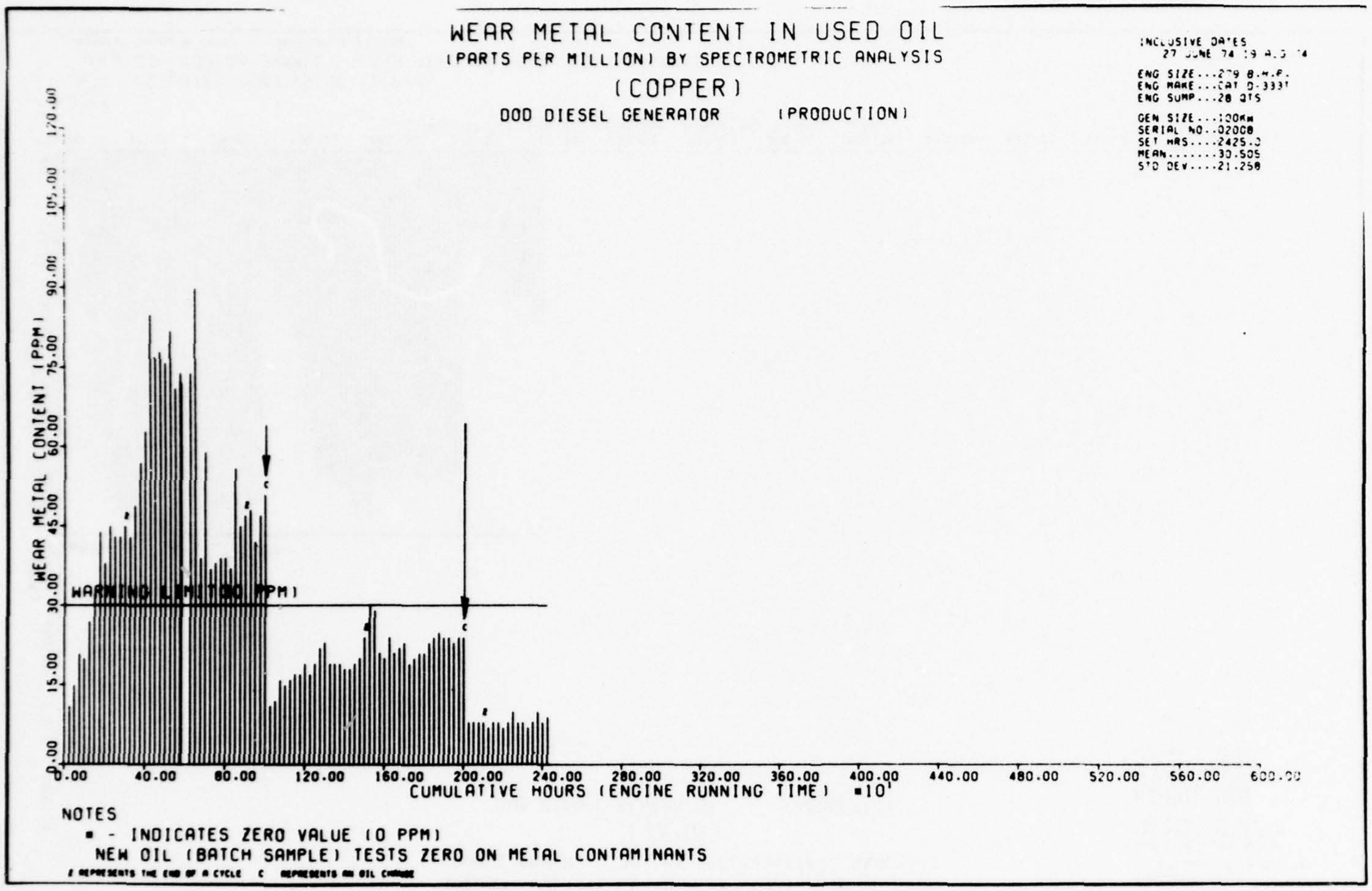
**DOD DIESEL GENERATOR (PRODUCTION)**

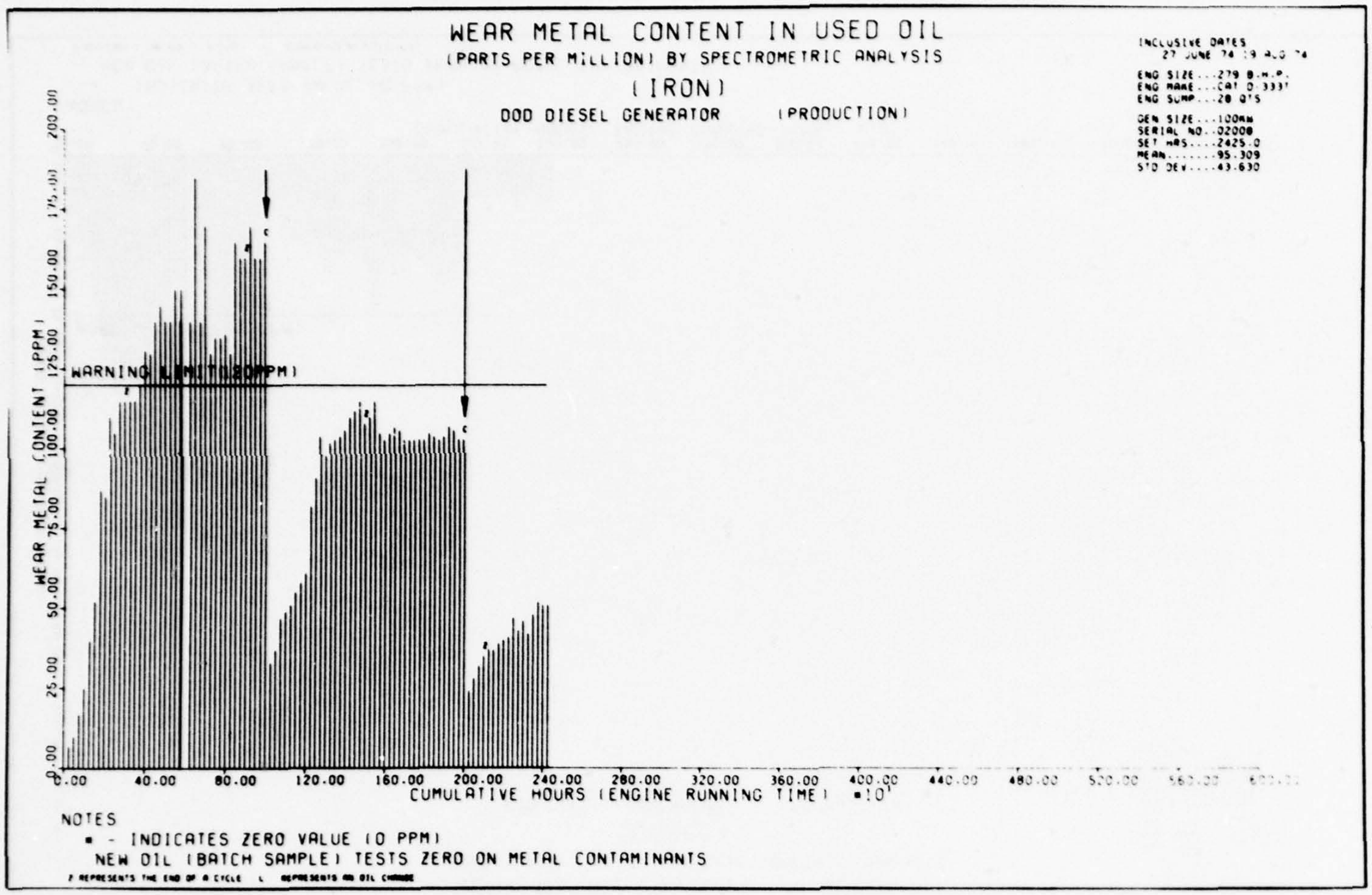


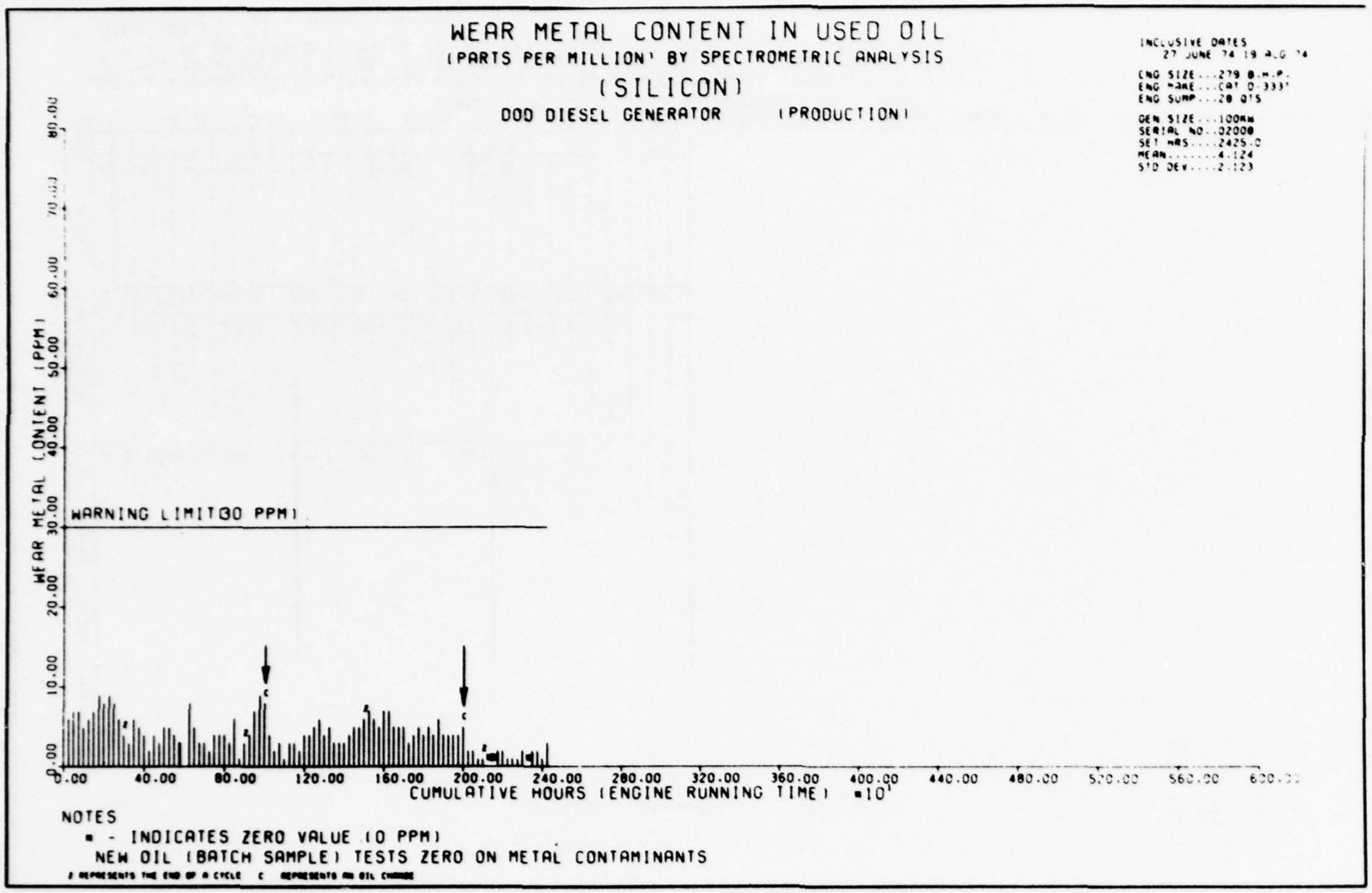

A SPECIFIES THAT THE TOTAL ACID READING IS GREATER THAN THE TOTAL BASE READING
B SPECIFIES THAT THE TOTAL BASE READING IS GREATER THAN THE TOTAL ACID READING

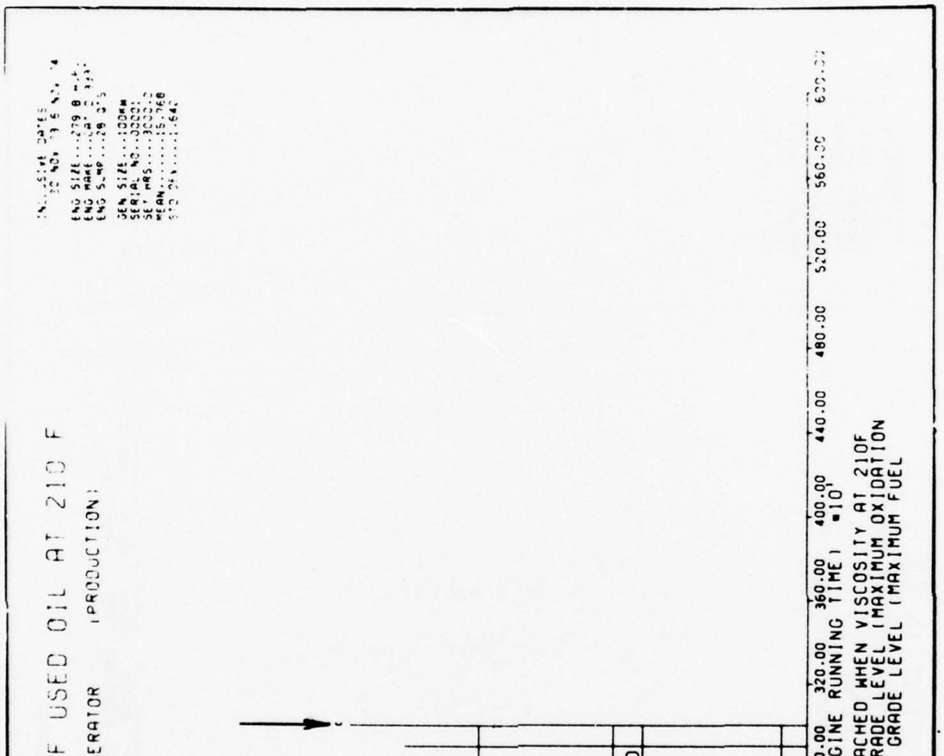

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(ALUMINUM)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
27 JUNE 74
ENG SIZE...279 B.H.P.
ENG SUMP...20 QTS
GEN SIZE...100KW
SERIAL NO..02000
SET HRS....2425.0
MEAN.......20.722
WARNING LIMIT
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
* INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(CHROMIUM)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
27 JUNE 74 19 AUG 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...20 QTS
GEN SIZE...100KW
SERIAL NO..02000
SET HRS....2425.0
MEAN.......1.495
STD DEV....3.186
WEAR METAL CONTENT (PPM)
WARNING LIMIT(20 PPM)
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(COPPER)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
ENG SIZE
ENG MAKE
ENG SUMP...28 QTS
GEN SIZE
SERIAL NO..02008
SET HRS....2425.
MEAN........30.505
STD DEV....21.258
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
WARNING LIMIT (30 PPM)
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(IRON)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
ENG SIZE...279 B.H.P.
ENG SUMP...20 QTS
GEN SIZE...100KW
SERIAL NO..02008
SET HRS....2425.0
MEAN.......95.309
STD DEV....43.630
WARNING LIMIT(120PPM)
WEAR METAL CONTENT (PPM)
0.00
25.00
50.00
75.00
100.00
125.00
150.00
200.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00
CUMULATIVE HOURS (ENGINE RUNNING TIME)
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(SILICON)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
27 JUNE 74 19 AUG 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333
ENG SUMP...20 QTS
GEN SIZE...100KW
SERIAL NO..02000
SET HRS....2425.0
MEAN.........4.124
STD DEV....2.123
WARNING LIMIT(30 PPM)
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


VISCOSITY OF USED OIL AT 210 F
DOD DIESEL GENERATOR (PRODUCTION)
PRECAUTIONARY LIMIT (UPPER) - SAE 40
ACTUAL RECORDED VALUE, NEW OIL (BATCH SAMPLE)
SPECIFIED VALUE (PER MIL-L-2104C), NEW OIL - SAE 30
PRECAUTIONARY LIMIT (LOWER) - SAE 20
VISCOSITY IN CENTISTOKES
9.00 11.00 13.00 15.00 17.00 19.00 21.00 23.00 25.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00 600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10^1
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN VISCOSITY AT 210F EITHER INCREASES IN VALUE TO THE NEXT HIGHER SAE GRADE LEVEL (MAXIMUM OXIDATION LIMIT) OR DECREASES IN VALUE TO THE NEXT LOWER SAE GRADE LEVEL (MAXIMUM FUEL DILUTION LIMIT).

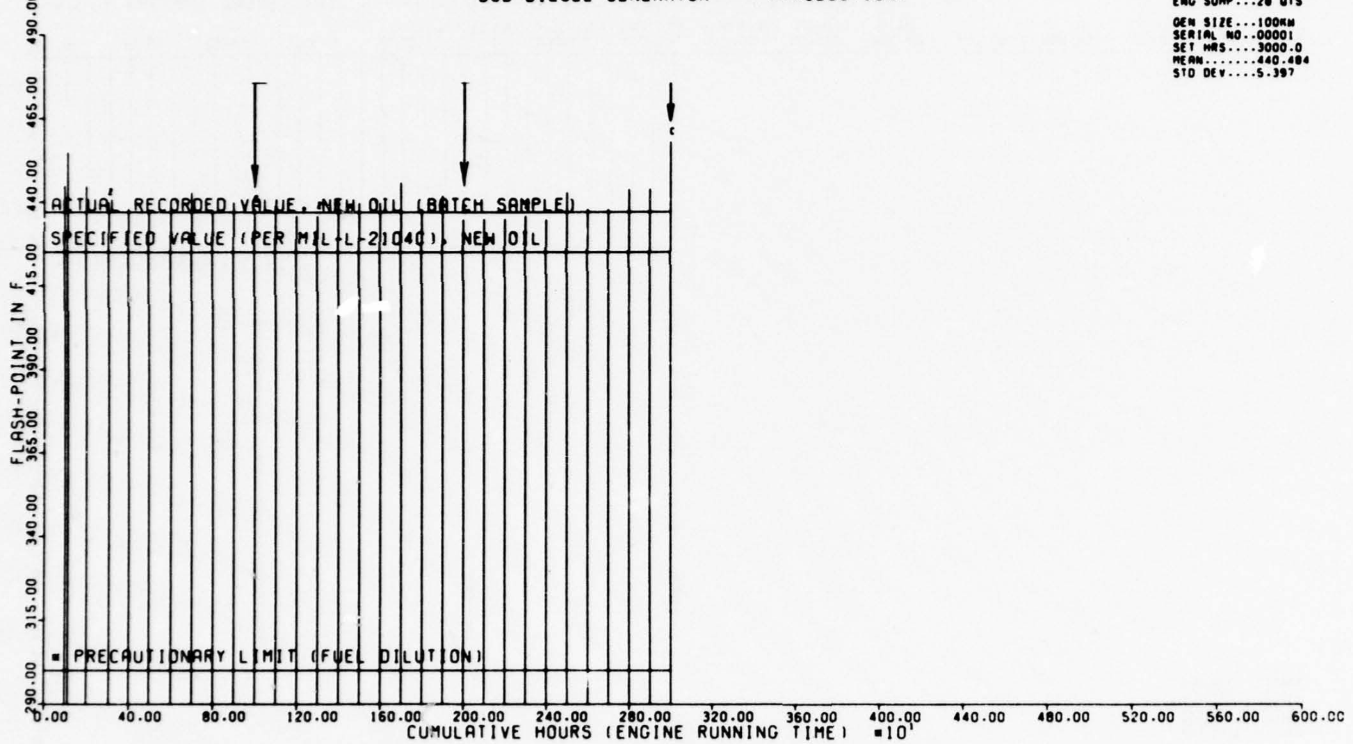
FLASH-POINT OF USED OIL (F)

DOD DIESEL GENERATOR (PRODUCTION)

INCLUSIVE DATES
30 NOV 73 & NOV 74

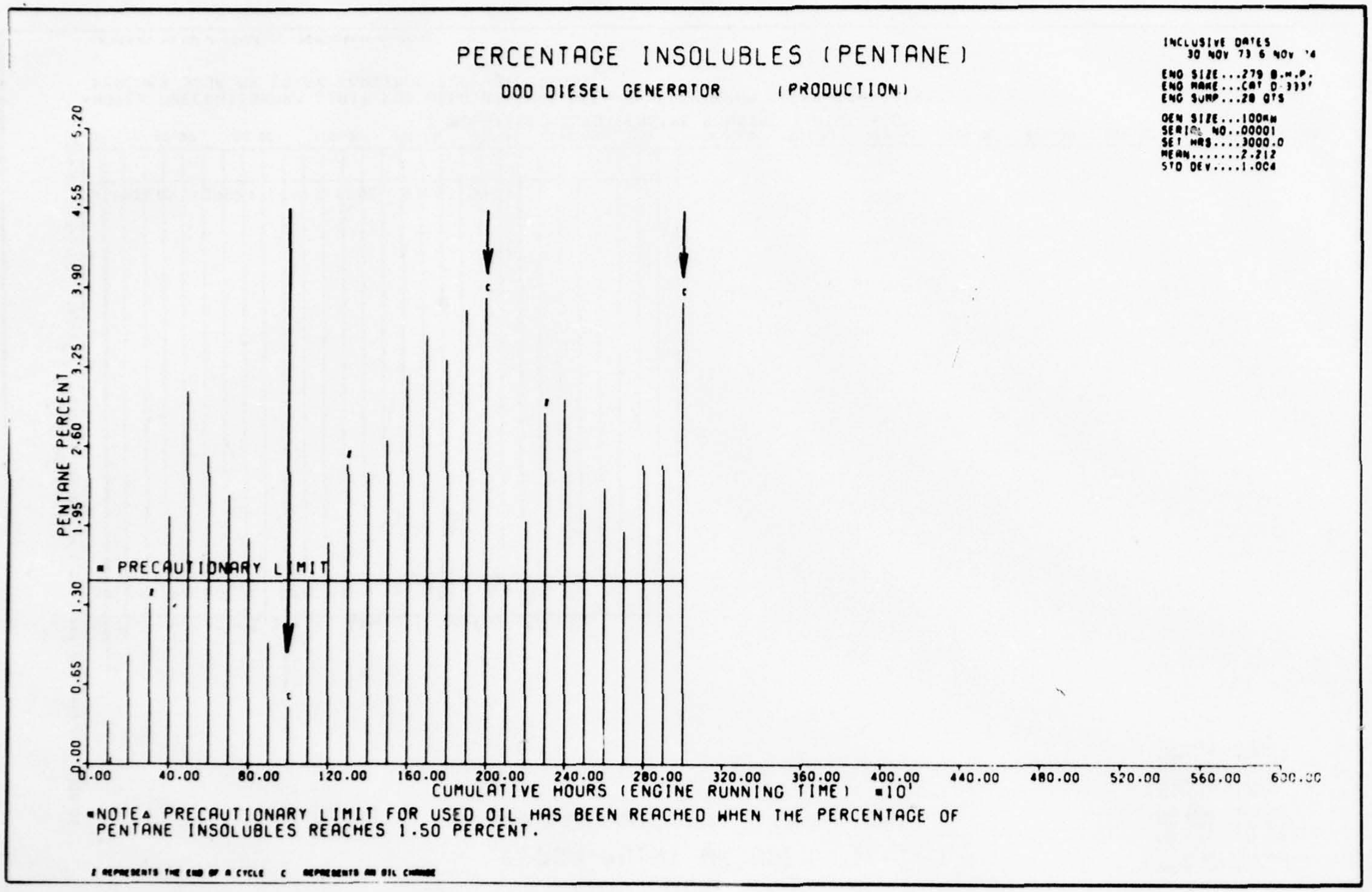
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...20 QTS

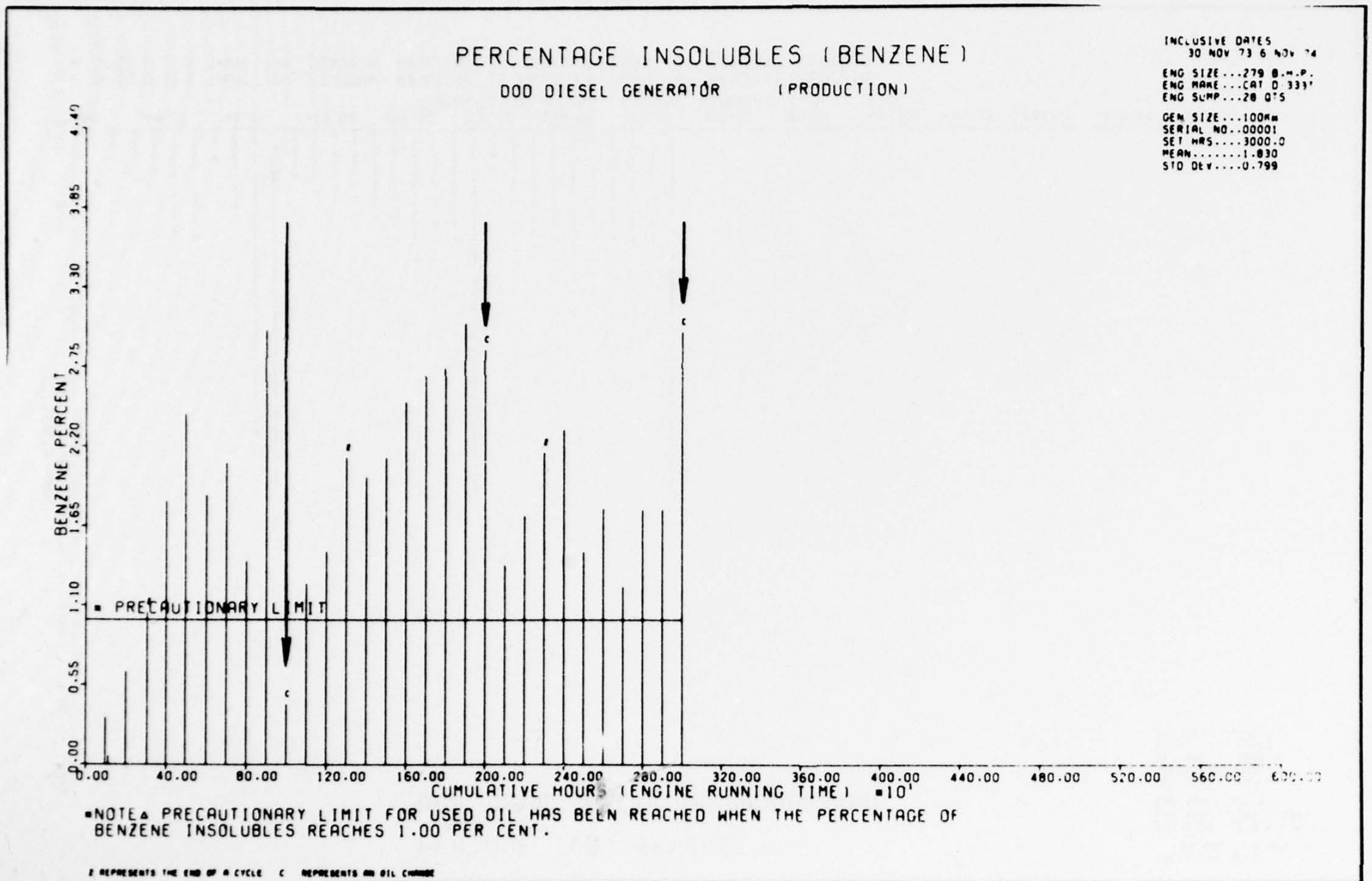
GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3000.0
MEAN.......440.404
STD DEV....5.397

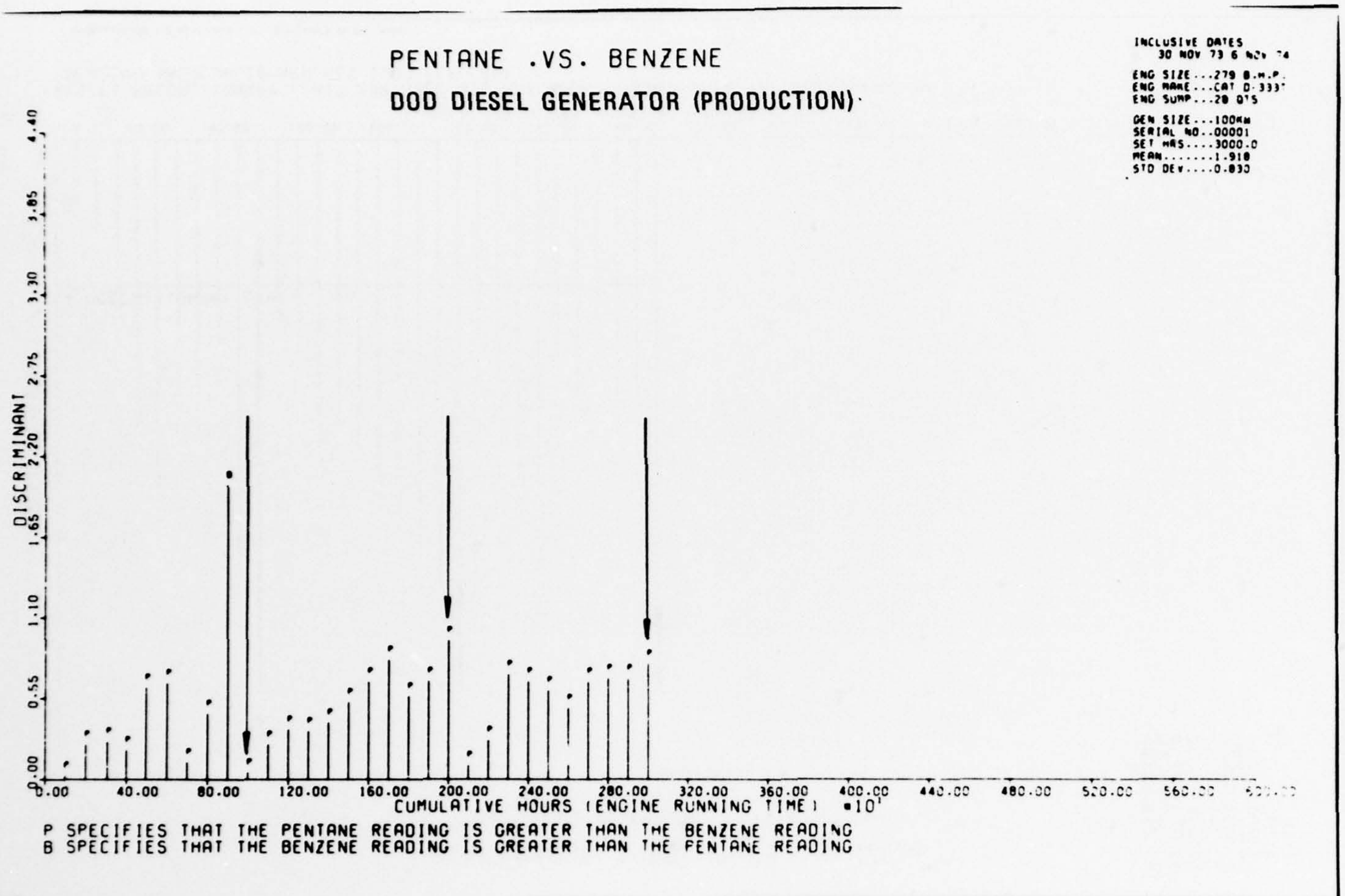



*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE FLASH POINT REACHES 300F OR LOWER (MAXIMUM FUEL DILUTION).

Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


PERCENTAGE INSOLUBLES (PENTANE)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
30 NOV 73 6 NOV 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D 333
ENG SUMP...28 QTS
GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3000.0
MEAN.......2.212
STD DEV....1.004
PENTANE PERCENT
0.00
0.65
1.30
1.95
2.60
3.25
3.90
4.55
5.20
= PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF PENTANE INSOLUBLES REACHES 1.50 PERCENT.
I REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


PERCENTAGE INSOLUBLES (BENZENE)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES 30 NOV 73 6 NOV 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D 333
ENG SUMP...28 QTS
GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3000.0
MEAN.......1.830
STD DEV....0.799
BENZENE PERCENT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
PRECAUTIONARY LIMIT
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
*NOTE: PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN THE PERCENTAGE OF BENZENE INSOLUBLES REACHES 1.00 PER CENT.
C REPRESENTS AN OIL CHANGE


PENTANE .VS. BENZENE
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
30 NOV 73 6 NOV 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333
ENG SUMP...20 QTS
GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3000.0
MEAN.......1.910
STD DEV....0.830
DISCRIMINANT
0.00
0.55
1.10
1.65
2.20
2.75
3.30
3.85
4.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
P SPECIFIES THAT THE PENTANE READING IS GREATER THAN THE BENZENE READING
B SPECIFIES THAT THE BENZENE READING IS GREATER THAN THE PENTANE READING

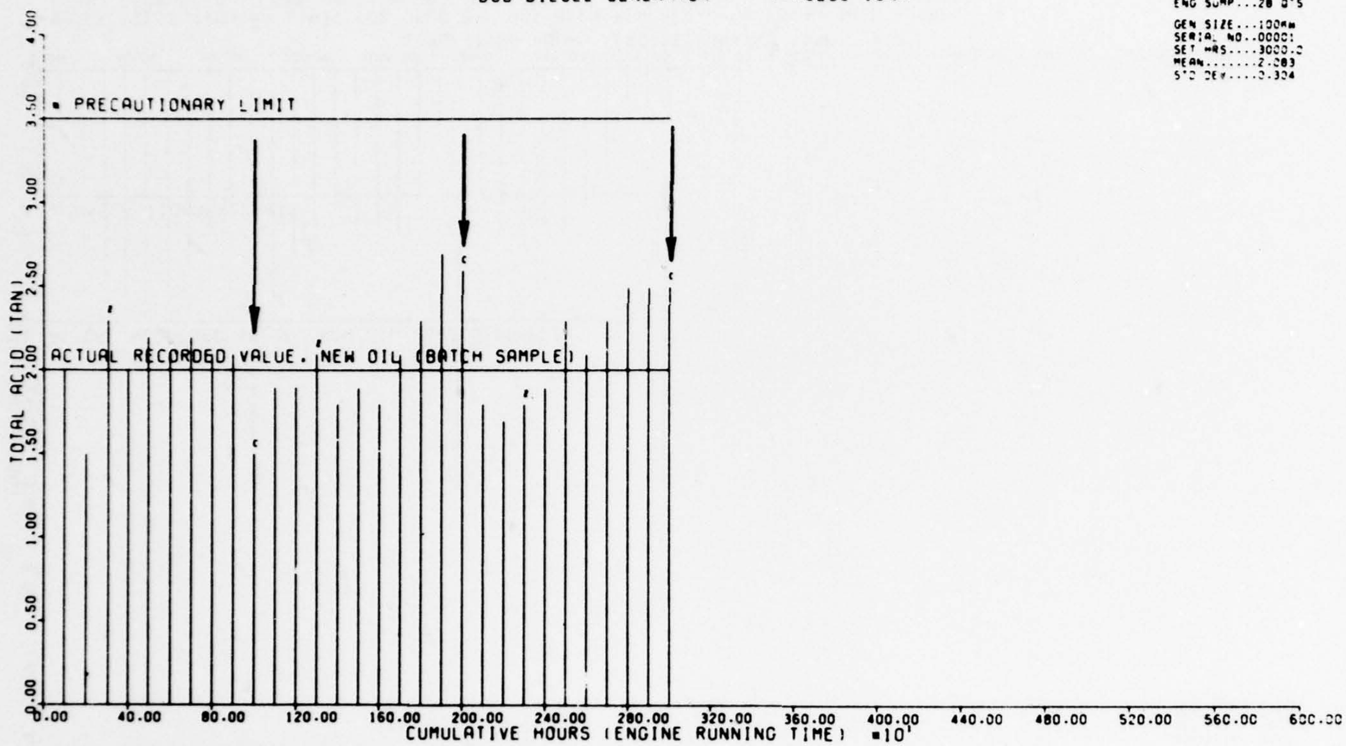
## TOTAL ACID IN USED OIL

DOD DIESEL GENERATOR (PRODUCTION)

INCLUSIVE DATES
30 NOV 73 6 NOV 74

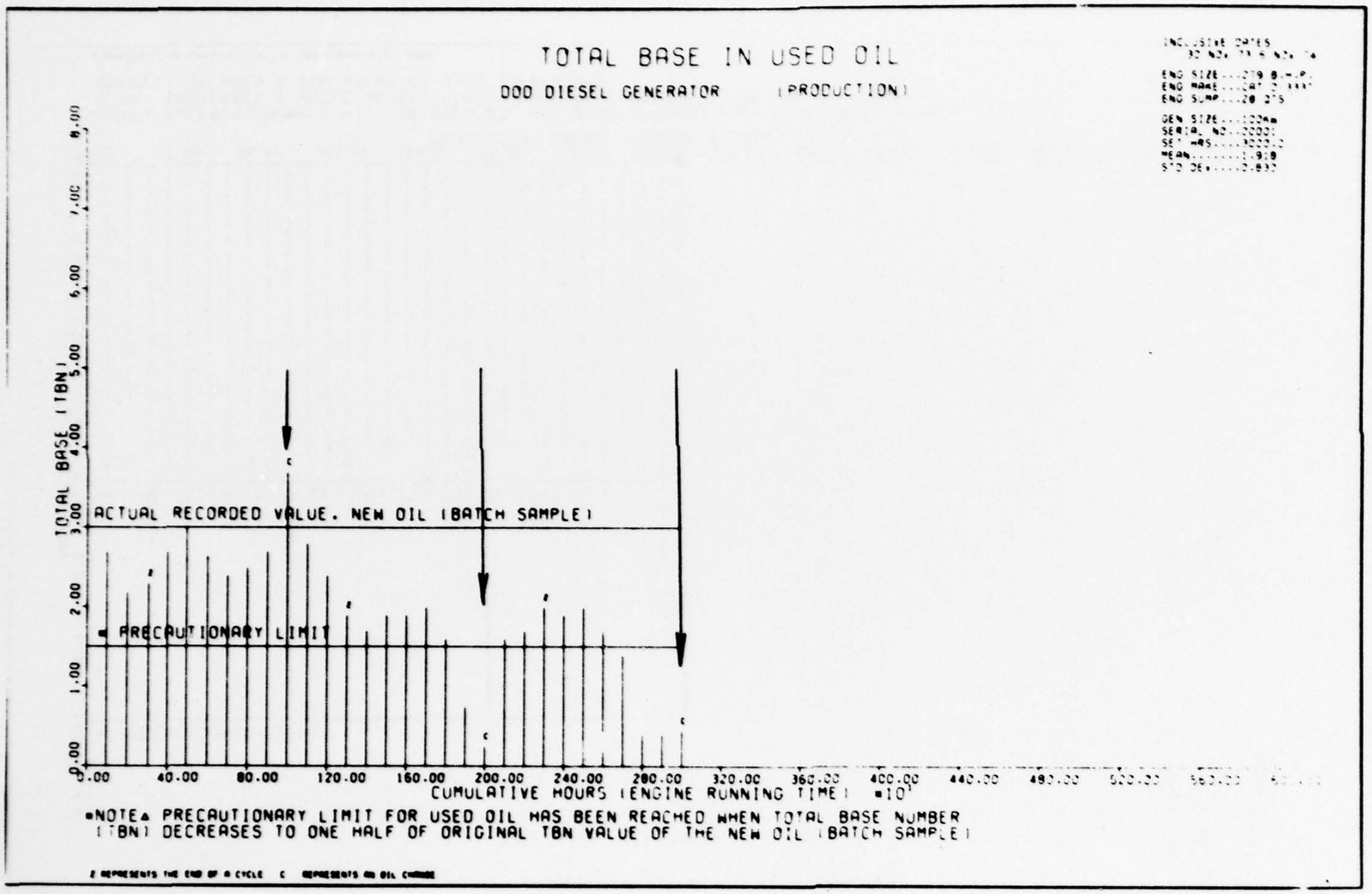
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...28 QTS

GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3000.0
MEAN.......2.083
STD DEV....0.304




*NOTE▲ PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL ACID NUMBER (TAN) INCREASES 2 WHOLE NUMBERS FROM THAT VALUE RECORDED FOR NEW OIL (BATCH SAMPLE) OR WHEN A TAN VALUE OF 3.50 IS REACHED.

Z REPRESENTS THE END OF A CYCLE   C REPRESENTS AN OIL CHANGE


TOTAL BASE IN USED OIL
DOD DIESEL GENERATOR (PRODUCTION)
TOTAL BASE (TBN)
ACTUAL RECORDED VALUE. NEW OIL (BATCH SAMPLE)
* PRECAUTIONARY LIMIT
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00
*NOTE▲ PRECAUTIONARY LIMIT FOR USED OIL HAS BEEN REACHED WHEN TOTAL BASE NUMBER (TBN) DECREASES TO ONE HALF OF ORIGINAL TBN VALUE OF THE NEW OIL (BATCH SAMPLE)
C REPRESENTS AN OIL CHANGE

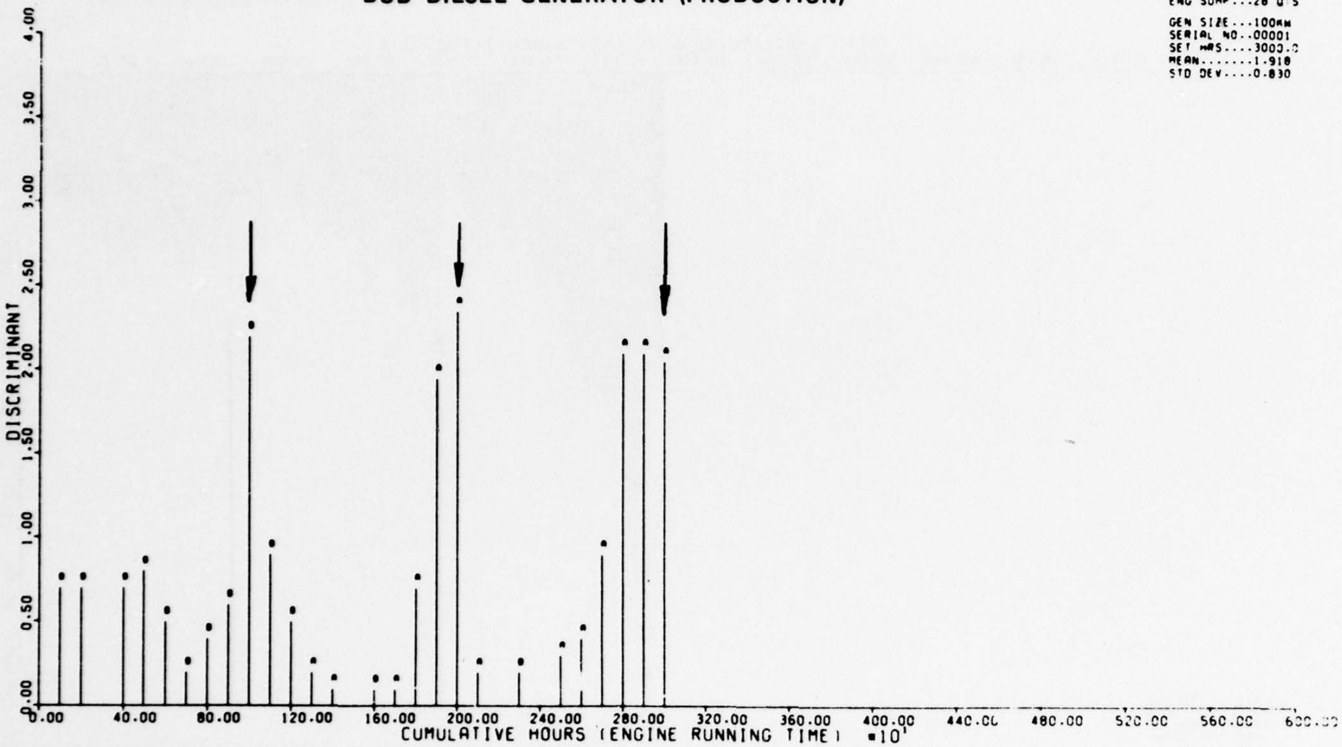
TOTAL ACID .VS. TOTAL BASE

**DOD DIESEL GENERATOR (PRODUCTION)**

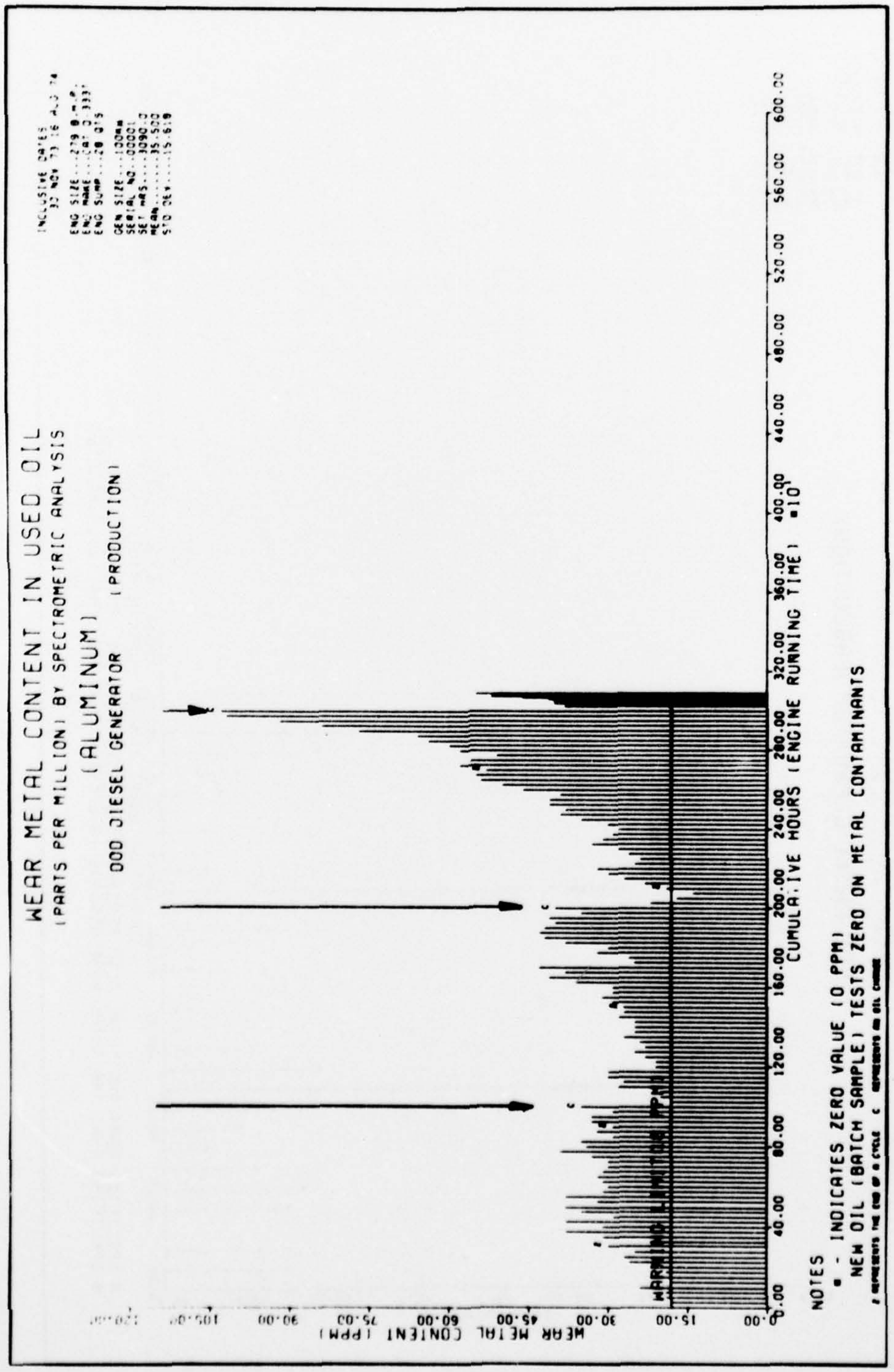
INCLUSIVE DATES
30 NOV 73 6 NOV 74

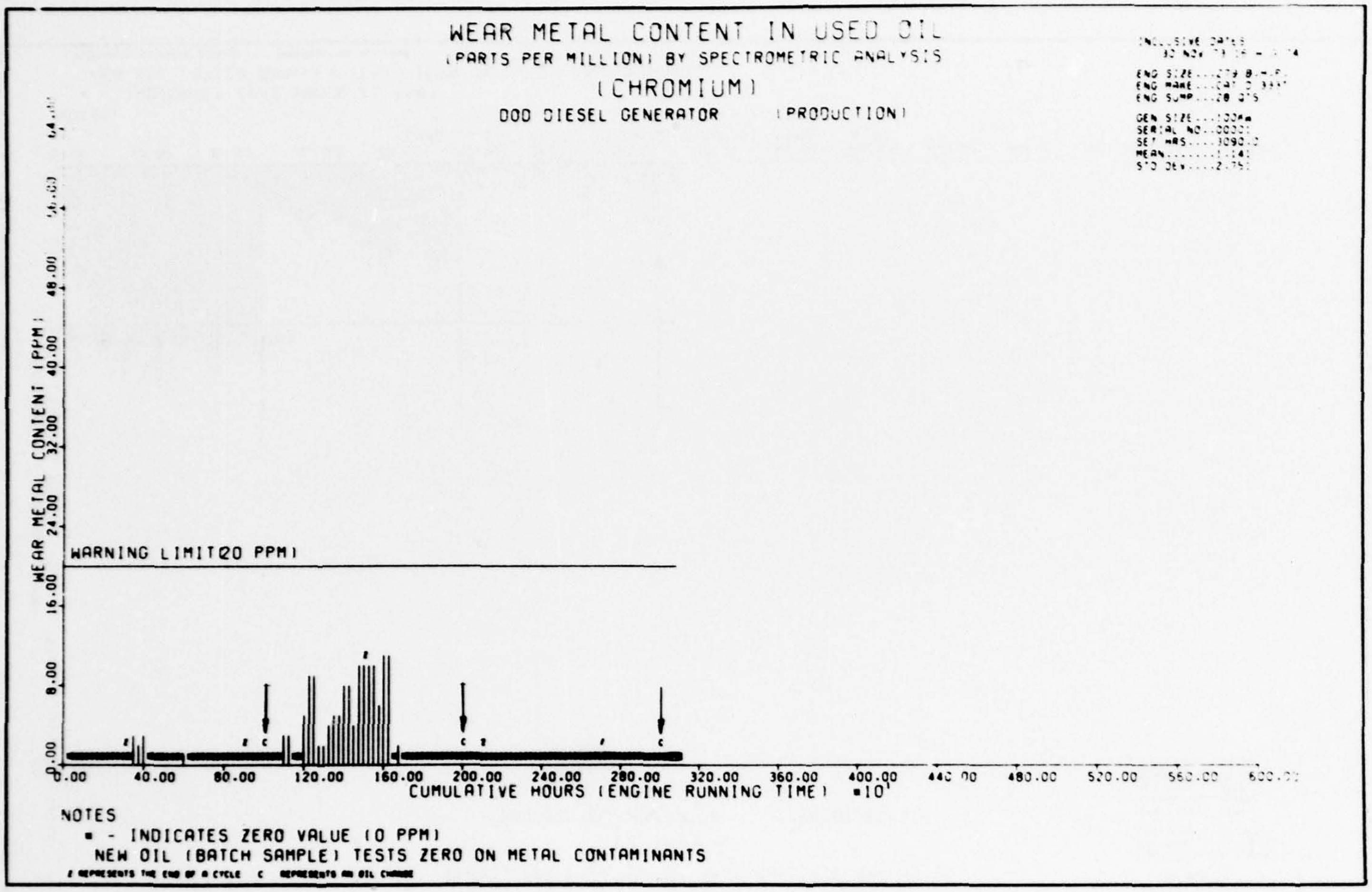
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...28 QTS

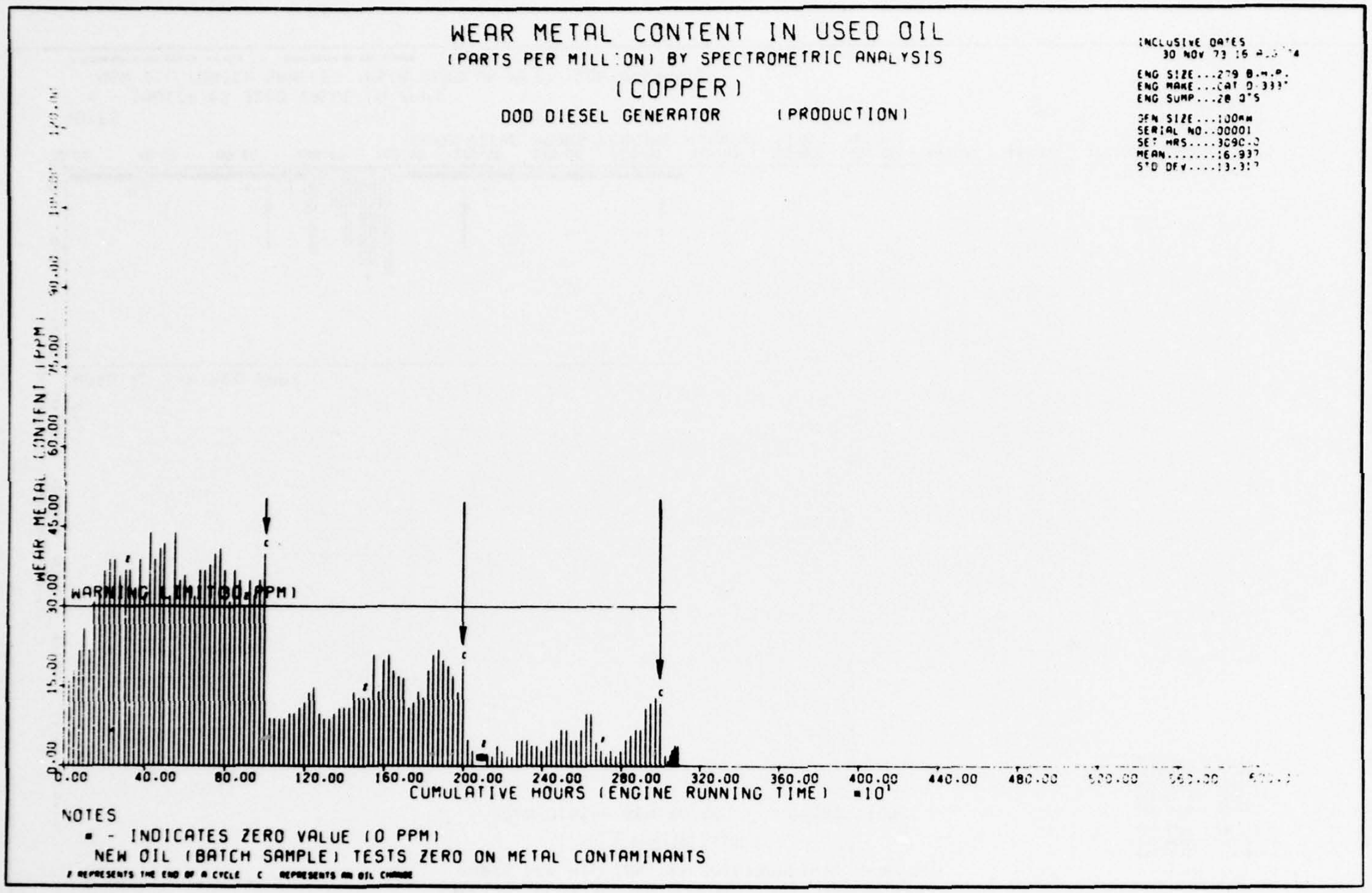
GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3000.0
MEAN.......1.918
STD DEV....0.830

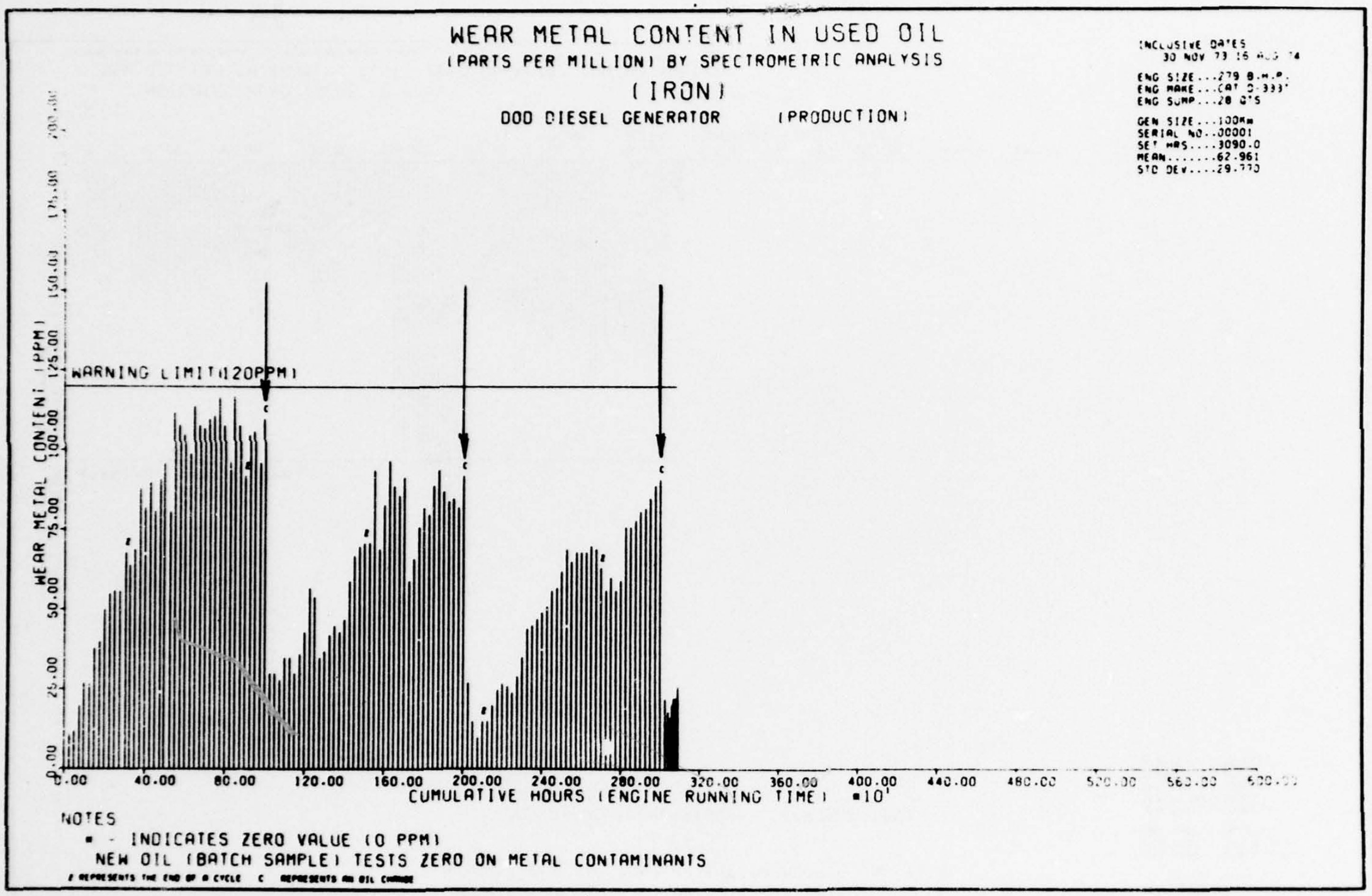


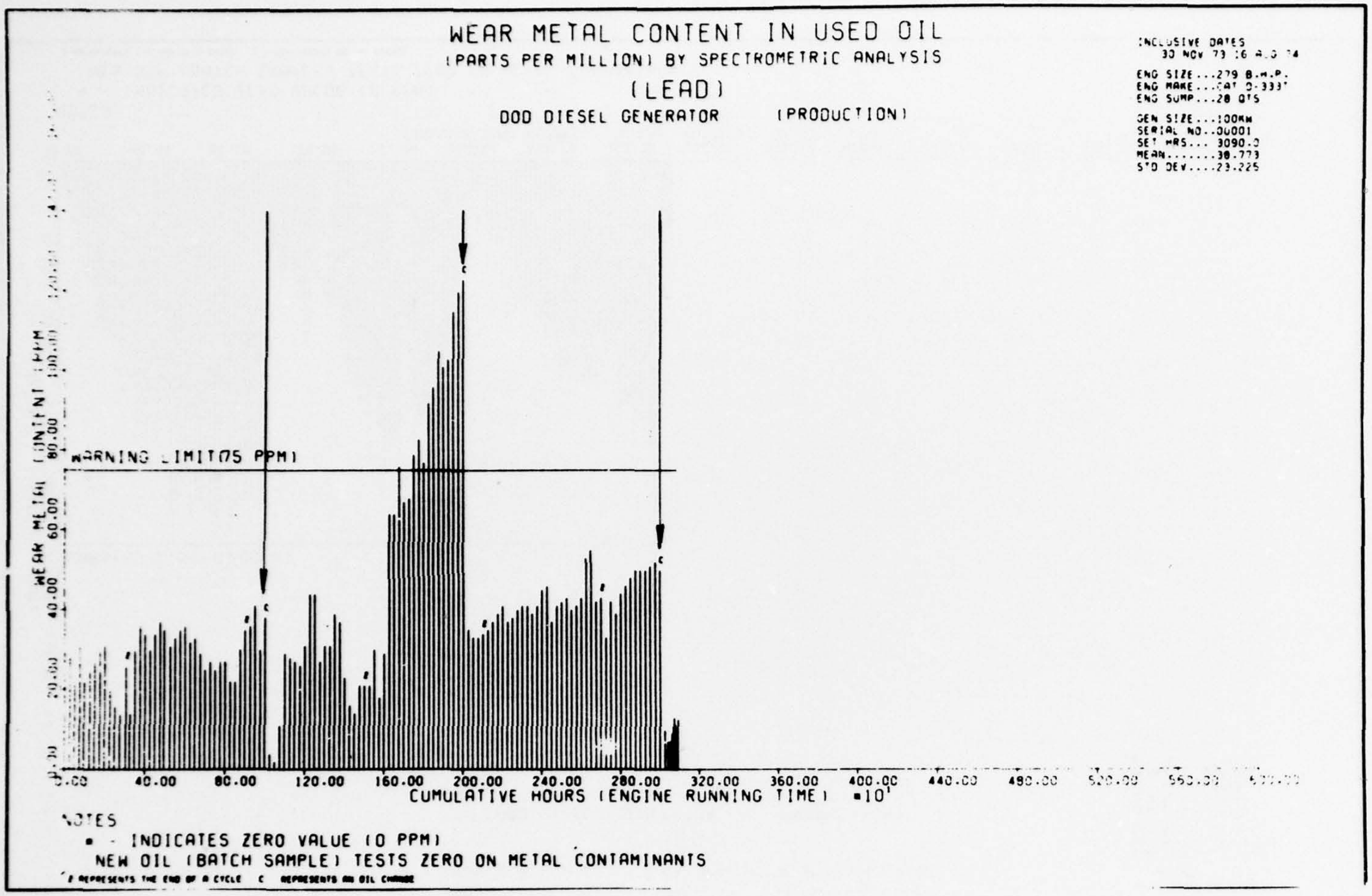

A SPECIFIES THAT THE TOTAL ACID READING IS GREATER THAN THE TOTAL BASE READING
B SPECIFIES THAT THE TOTAL BASE READING IS GREATER THAN THE TOTAL ACID READING

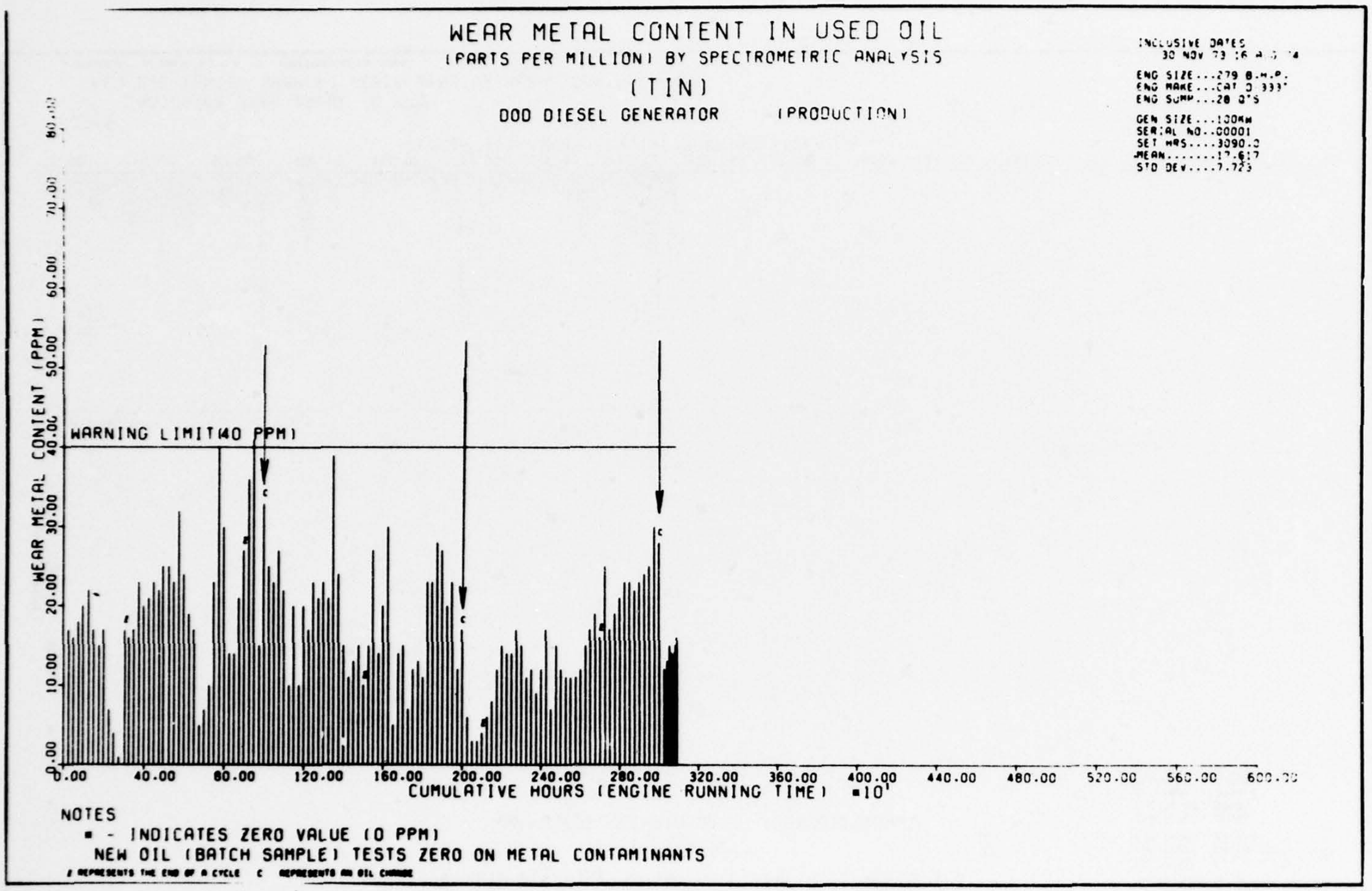

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(ALUMINUM)
DOD DIESEL GENERATOR
(PRODUCTION)
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
75.00
90.00
105.00
120.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS

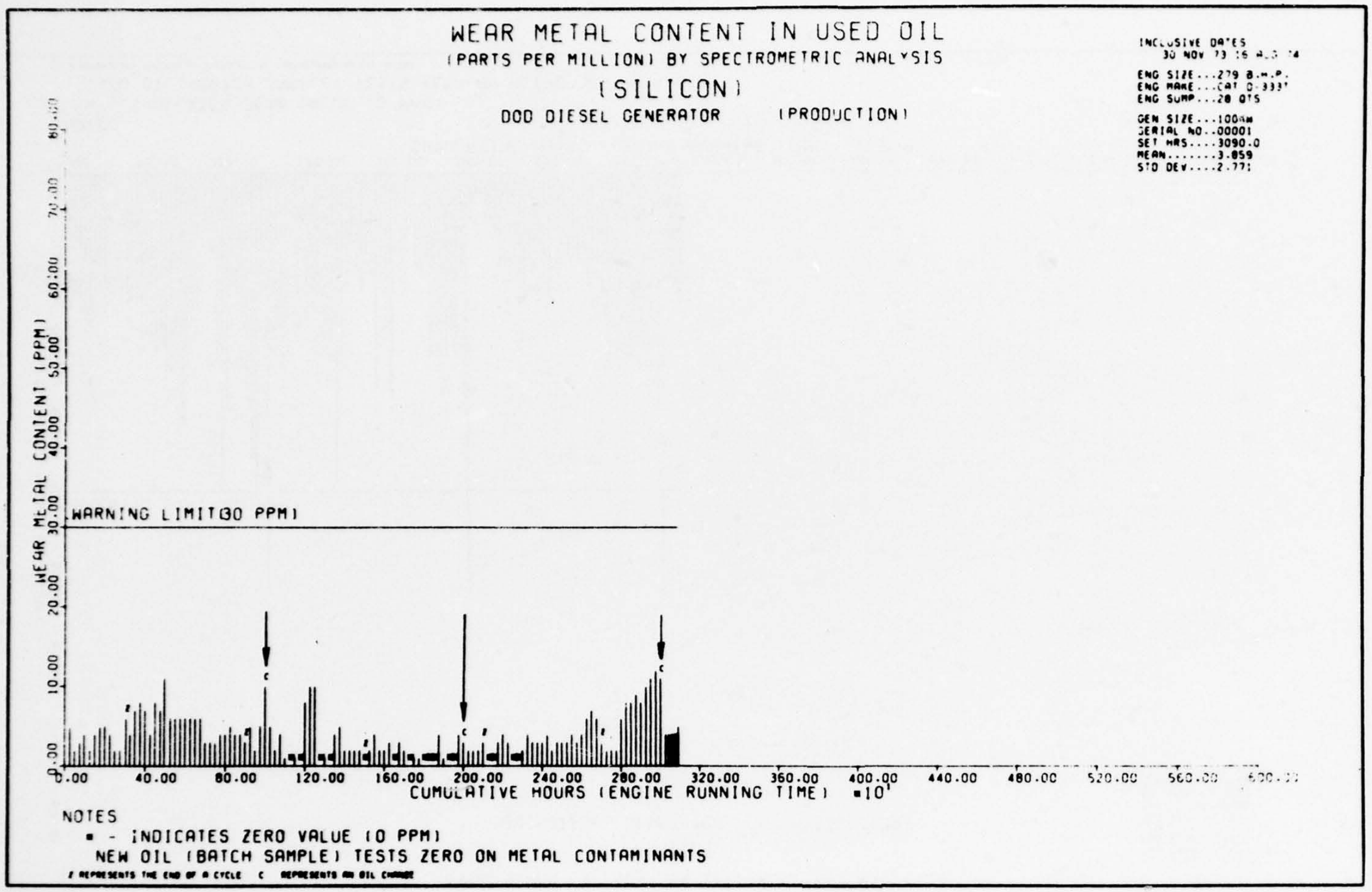

WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(CHROMIUM)
DOD DIESEL GENERATOR (PRODUCTION)
WARNING LIMIT(20 PPM)
WEAR METAL CONTENT (PPM)
0.00
8.00
16.00
24.00
32.00
40.00
48.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
480.00
520.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10[1]
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(COPPER)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
30 NOV 73
ENG SIZE...279 B.H.P.
ENG SUMP...28 Q'S
SERIAL NO..00001
MEAN.......16.937
WARNING LIMIT (30 PPM)
WEAR METAL CONTENT (PPM)
0.00
15.00
30.00
45.00
60.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(IRON)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
30 NOV 73 15 AUG 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333
ENG SUMP...28 Q'S
GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3090.0
MEAN........62.961
STD DEV....29.770
WARNING LIMIT(120PPM)
WEAR METAL CONTENT (PPM)
0.00
25.00
50.00
75.00
100.00
125.00
150.00
175.00
200.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
600.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(LEAD)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
30 NOV 73 16 AUG 74
ENG SIZE...279 B.H.P.
ENG MAKE...CAT D-333T
ENG SUMP...28 QTS
GEN SIZE...100KW
SERIAL NO..00001
SET HRS... 3090.0
MEAN.......38.773
STD DEV....23.225
WARNING LIMIT(75 PPM)
WEAR METAL CONTENT (PPM)
20.00
40.00
60.00
80.00
100.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10'
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
' REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(TIN)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
ENG SIZE...279 B.H.P.
ENG SUMP...28 Q'S
GEN SIZE...100KW
SERIAL NO..00001
SET HRS....3090.0
STD DEV....7.723
WARNING LIMIT(40 PPM)
WEAR METAL CONTENT (PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
400.00
440.00
480.00
520.00
560.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
NOTES
■ - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS


WEAR METAL CONTENT IN USED OIL
(PARTS PER MILLION) BY SPECTROMETRIC ANALYSIS
(SILICON)
DOD DIESEL GENERATOR (PRODUCTION)
INCLUSIVE DATES
30 NOV 73
ENG SIZE...279 B.H.P.
ENG SUMP...28 QTS
GEN SIZE...100
SERIAL NO..00001
SET HRS....3090.0
MEAN........3.059
STD DEV....2.771
WEAR METAL CONTENT (PPM)
WARNING LIMIT(30 PPM)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
0.00 40.00 80.00 120.00 160.00 200.00 240.00 280.00 320.00 360.00 400.00 440.00 480.00 520.00 560.00
CUMULATIVE HOURS (ENGINE RUNNING TIME) *10¹
NOTES
* - INDICATES ZERO VALUE (0 PPM)
NEW OIL (BATCH SAMPLE) TESTS ZERO ON METAL CONTAMINANTS
Z REPRESENTS THE END OF A CYCLE C REPRESENTS AN OIL CHANGE

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