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PERFORMANCE OF INDUSTRIAL-TYPE ENGINES IN MILITARY EQUIPMENT USING SYNTHETIC CRANKCASE OILS

by

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The investigation was to determine the possibility of eliminating crankcase oil changes in engines used in Military equipment. Based on the results, it appears that an extended oil change interval can be used which would result in significant savings.

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SUMMARY

Recent claims by industry regarding the use of synthetic oils for engine crankcase lubrication necessitated an investigation of the possibility of eliminating crankcase oil and filter changes in Military engines and equipment. Such claims state that synthetic engine oils outperform conventional oils by providing better high-temperature stability, reduced oil consumption, better oil-pressure retention, and reduced engine wear.

Investigation of the industry claims was accomplished under a two-phase test program using synthetic crankcase oils to effect a "no drain add makeup oil" crankcase servicing procedure for fielded Military equipment. Phase I consisted of testing the small bore 1.5-, 3-, and 6-hp Military Standard Gasoline Engines and Phase II consisted of testing the DOD Diesel Engine-Driven Generator family 5- to 100-kW sets.

Phase I was initiated in 1977 and a total of 11,653 hours was accumulated on the gasoline engines using two different synthetic oils. The engines were run for 1500 hours without an oil change. Chemical and spectrometric analyses were obtained from samples; however, these data were not plotted because of the high oil consumption. Oil consumption using synthetic oil was about twice that of conventional oils making it decidedly uneconomical and unworthy of serious consideration. No excessive wear or detrimental effects were observed from the use of synthetic oils during this testing.

Phase II was initiated in 1978 and included 12 production generator sets utilizing 6 different diesel engine models and 2 different synthetic oils. Although some sets ran for 5000 hours without an oil change, most required a change at about 3400 hours. The reason for the oil change was the loss of the alkaline reserve, not viscosity or wear metal levels. A total of 55,100 hours of engine operation was accumulated. Following completion of the tests, all engines were torn down for inspection. No excessive wear was detected that could be attributed to use of synthetic oil.

Based on these test results and the average usage rate per year, the oil change interval for the diesel sets using synthetic oils could be extended to a 1000-hour or 1-year change interval. This policy as shown in the economic analysis would yield almost a million dollars per year savings over current drain intervals. This does not include the savings in man-hours or the logistics of stocking less oil.

PREFACE

Gene H. Austin, Support Equipment Branch, Engineering Division, Electrical Power Laboratory, compiled the final report.

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

The test data were collected and compiled by Lewis Cheek, Product Assurance and Testing Directorate.

The analyses and interpretation of the oil sample data were performed by Basil Zanedis, Material Technology Laboratory.

The day-to-day monitoring of the test program was performed by Ernest Fitzgibbons, Support Equipment Branch, Engineering Division, Electrical Power Laboratory.

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I. INTRODUCTION

1. Statement of the Purpose. The purpose of this test program was to determine if a "no drain add makeup oil" concept for gasoline and diesel engines used by the Army is feasible without affecting the reliability and life cycle of the engine in the DOD Family of Gasoline and Diesel Engine-Driven Generator Sets.

2. Background. A Production Engineering Measures (PEM) project was submitted and approved in 1977 for a two-phase test program to evaluate synthetic crankcase oils in gasoline and diesel engines. The DOD family of generator sets was chosen because the generator offers a ready means of loading the engine and provides an economical means of conducting the tests. Additionally, baseline data had already been established on the DOD family of generator sets using conventional MIL-L-2104C oils.* This baseline serves as a basis of comparison in both performance and in making an economic analysis. The 200-kW set was not tested because a baseline had not been established using MIL-L-2104C oil and because of the high cost of fuel.

II. PROCEDURE

3. Approach.

a. Phase I. Phase I was conducted from December 1977 to May 1978. Twelve engines (four each 1.5-, 3-, and 6-hp) were used for the performance and endurance testing. The engines were tested for 1500 hours each. Tests were conducted by the Electrical and Mechanical Division, Product Assurance and Testing Directorate, MERADCOM.

b. Phase II. Phase II was conducted from December 1978 to September 1979. Twelve production DOD diesel engine-driven generator sets powered by six different diesel engines were subjected to long-term endurance tests. Total test time for Phase II was 55,100 hours. Tests were conducted by the Electrical and Mechanical Division, Product Assurance and Testing Directorate, MERADCOM.

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

* Chester R. Gurski, John W. Dreger, and Ernest Fitzgibbons, EXTENDED OIL-CHANGE AND OIL-FILTER-CHANGE INTERVALS FOR DOD 5- TO 200-KILOWATT DED GENERATOR SETS, MERADCOM Report 2234 (March 1978).

Table 1. Phase I Gasoline Engines

Power (kW)	Frequency (Hz)	Engine Serial Number	Engine Model	Oil Type	Hours
.5	60	M041390	1A08	C	1500
.5	60	M041324	1A08	C	1500
.5	60	M040306	1A08	D	1500
.5	60	M041348	1A08	D	1153
1.5	60	N85753	2A016	C	1500
1.5	60	N85426	2A016	C	1500
1.5	60	N85531	2A016	D	1500
1.5	60	N85719	2A016	D	1500
3	60	J97508	4A032	C	1500
3	60	J103367	4A032	C	1500
3	60	J103290	4A032	D	1500
3	60	J103361	4A032	D	1500

Table 2. Phase II Diesel Engine-Driven Generator Sets

Power (kW)	Frequency (Hz)	DOD Model	Set Serial Number	Engine Model	Oil Type	Hours
5	60	MEP002A	E200297	Onan DJE	A	5000
5	60	MEP002A	E200937	Onan DJE	B	4300
10	60	MEP003A	E200052	Onan DJF	A	4700
10	60	MEP003A	E200053	Onan DJF	B	4800
15	60	MEP004A	R220030	White	A	4800
15	60	MEP004A	R221277	White	B	4400
30	60	MEP005A	R251233	White	A	5000
30	60	MEP005A	R251245	White	B	4900
60	60	MEP006A	F201243	A.C. 3500	A	4600
60	60	MEP006A	F201254	A.C. 3500	B	4700
100	60	MEP007A	U200709	Cat D333T	A	4600
100	60	MEP007A	U200697	Cat D333T	B	4300

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 200-hour points for the model 1A108 engine and at 100-hour points for the models 2A016 and 4A032 engines for the 1500-hour duration.

b. Phase II. Phase II consisted of performing both a chemical and a spectrometric analysis of oil samples taken at 100-hour points for the duration of the 5000-hour test. 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. Each generator set was inspected and checked for proper operation. Engines were changed in the four 15- and 30-kW sets to evaluate the commercial version of the White D198ER and D298ER engines. These commercial engines are identical to the ones being used in the sets except that the bore size has been increased from 3.750 to 4 inches. Log books were maintained for each set and included an account of set operations, servicing, and maintenance performed; failures; and all other pertinent information relating to operation. Notations were included regarding fuel type and sulfur content, identification of type synthetic oil used, and fuel and oil consumption.

d. Preparation of Sets for Test. The generator sets were prepared for operation in accordance with the procedures contained in the applicable technical manuals. An external fuel supply line was connected to the set. An oil sampling valve with the necessary plumbing was installed on each engine in the lube oil gallery to provide a means for taking oil samples during the course of the endurance test.

e. Instrumentation. Various temperature, pressure, and electrical parameters were measured in order to determine performance of the engine and the generator. All instruments were of laboratory grade and were maintained under a periodic calibration program.

f. Fuel and Lubricants. The fuel used for Phase I was unleaded gasoline conforming to Federal Specification VV-G-1690B, and the fuel used for Phase II was grade DF2 diesel fuel conforming to Federal Specification VV-F-800B. The lubricating oils used were:

	OIL C	OIL D
PHASE I:	Ester Base	Ester Base
	OIL A	**OIL B**
PHASE II:	Alkylated Benzene with Petroleum Base	Polyalpha Olefin with Ester Base

Phase I oils were SE/CC-quality-level products qualified under Military Specification MIL-L-46152. The Phase II oils were SE/CD-quality-level oils.

g. Pre-Endurance Operation. All starting and operating procedures were in accordance with the applicable technical manuals except for oil changes and oil filter changes.

h. Endurance Tests. All tests were conducted as follows:

Phase I:

Check Test and Run-In
Maximum Power Test — Pre-Endurance and Post-Endurance
Endurance Test — 1500 Hours (See Table 3)
Teardown and Inspection

Table 3. Endurance Load-Cycle Schedule Phase I and Phase II

Step Number	Total Time (Hours)	Load Condition
1	24	50% Rated Load
2	4	0% Rated Load
3	24	100% Rated Load
4	24	25% Rated Load
5	24	75% Rated Load

Phase II:

All tests were conducted in accordance with MIL-STD-705 as follows:

METHOD

640.1c	Pre-Endurance Maximum Power Test
670.1a	Pre-Endurance Fuel Consumption Test
	Endurance Test (See Table 3)
640.1c	500-Hour Maximum Power Test
640.1c	1000-Hour Maximum Power Test
640.1c	1500-Hour Maximum Power Test and Fuel Consumption Test
640.1c	2000-Hour Maximum Power Test
670.1a	2000-Hour Fuel Consumption Test
640.1c	2500-Hour Maximum Power Test
670.1a	2500-Hour Fuel Consumption Test
640.1c	3000-Hour Maximum Power Test
640.1c	3500-Hour Maximum Power Test and Fuel Consumption Test
640.1c	4500-Hour Maximum Power Test and Fuel Consumption Test
640.1c	Final Maximum Power Test
670.1a	Final Fuel Consumption Test

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

Date, shift hours, and total elapsed test hours all adjustments were 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.

i. **Oil samples.** 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 since last oil sample was taken and amount of oil added if any since last sample.

j. **Scheduled Maintenance.** Maintenance was performed in accordance with Table 4 and the following maintenance schedules:

Table 4. Servicing and Adjustment Schedule -- Phase I

Before Test	Hours Between Service Periods During Test	Item
X	8	All maintenance, such as tightening and retorquing nuts, bolts, and screws. Parts, components, and accessories replacement or any major maintenance that requires removal of other components, accessories, or shrounding, such as oil pans, cylinder heads, and connecting rods shall be recorded with cause determination.
X	a	Cleaning, regapping, or replacing spark plugs.
X	b	Servicing fuel filter.
X	250	Checking compression pressures.
X	8	Adding lubricating oil.
X	8	Adjusting carburetor.
X	b	Cleaning carburetor.
X	8	Adjusting govenor (normal speed adjustment).
X	c	Changing lubricating oil.
X	c	Changing lubricating oil filter element.
X	100	Servicing air cleaner.
X	a	Adjusting and dressing breaker points.
X	a	Adjusting ignition timing.
X	b	Cleaning combustion chamber and manifolds.
X	a	Replacing breaker points.
X	a	Replacing condensor or coil.

Table 4. Servicing and Adjustment Schedule – Phase I (Cont'd)

Before Test	Hours Between Service Periods During Test	Item
	500	Retorque head nuts (250 in-lb).
	b	Gasket replacement.

[a] As required by apparent misfire or loss of power.

[b] If required.

[c] To be determined by oil analysis.

Phase II Maintenance Schedule 5- Through 100-kW

8-Hour Check:

- Perform visual inspection.
- Check oil level; add oil when the level is at or below the "add oil" mark. Secure 5- and 10-kW. Check oil level after 5 minutes.
- Check battery level.

100-Hour Check:

- Perform visual inspection.
- Remove one 1-ounce size oil sample.
- Remove one 4-ounce size oil sample for the 5- and 10-kW size sets on even 100-hour points; i.e., 200, 400, 600 etc.
- Remove one 8-ounce size oil sample from the 15- through 100-kW size sets on even 100-hour points; i.e., 200, 400, 600, etc.
- Check oil level; add oil to return level to "full" mark on dip stick.
- Check shutter assembly for proper operation.
- Check V-belts for proper condition if applicable.
- Replace air cleaners on 15- through 100-kW size sets.

- Check coolant level.
- Clean crankcase breather.
- Clean fuel transfer pump filters.

NOTE: On 5- and 10-kW:

- Adjust governor and throttle linkage if necessary.
- Clean dust cap on air cleaner.

500-Hour Service to be Performed at 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, and 5000 Hours:

- Change fuel filters.
- Check and adjust valve tappet clearance.
- Remove oil samples (see 100-hour service sheet).
- Check oil level and return to full mark on dip stick.
- Check shutter assembly for proper operation.
- Clean fuel pump transfer pump filters.
- Change air cleaners on 5- and 10-kW size sets.
- Clean crankcase breather.
- Conduct a short-term 608.1 and a maximum power test (640.1 or 640.3).

1000-Hour Service to be Performed at 1500, 2500, 3500, and 4500 Hours:

- Perform visual inspection.
- Remove one 1-ounce size oil sample.
- Check oil level and return to full mark on dip stick.
- Check shutter assembly for proper operation.

- Replace all belts.
- Change fuel filters.
- Clean crankcase breather.
- Clean fuel pump transfer pump filters.
- Check and adjust valve tappet clearance.
- Check compression pressures.
- Check injectors for proper operation.
- After above test, conduct a short-term 608.1 and a maximum power test (640.1 or 640.3).
- Perform 2-hour fuel consumption test.

2500-Hour Service to be Performed at 2500 and 5000 Hours:

- Check injector for proper operation.
- Obtain compression pressures.
- Perform 500-hour service.

5. Description of Oil Analyses and Sampling Procedures.

a. Oil Analysis. A description of the chemical and spectrometric oil analyses performed during this program is included in Tables 5 and 6. 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.

Table 5. Chemical Oil Analysis

Chemical Property	Test Methods	Significance	Precautionary Limits
Viscosity	ASTM-0445	(1) Establishes viscosity index. (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).
Total Acid and Total Base	ASTM-0664	The total acid number (TAN) to a degree defines the buildup of acid materials in oil resulting from combustion and oil oxidation, while the total base number (TBN) relates to the oil alkaline reserve providied 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). TBN limit has been reached when TBN decreases to one-half original value of new oil (batch sample).
Insolubles Percent Pentane	ASTM-2276	In principle, the arithmetic difference between the Pentane and Benzene insolubles is a measure of oxidation.	Pentane: When percentage of Pentane insolubles reaches 1.50 percent.

Table 6. Spectrometric Oil Analysis.

Metal	Allis Chalmers Model No. 3500 Parts	Warning Limit (p/m)	Caterpillar Model No. D333T Parts	Warning Limit (p/m)
Aluminum	Pistons Blowers Bearings	80	Pistons Main Bearings Rod Bearings Oil-Pump Bushing Timing Gear Bushing Crankshaft Thrust Bushing Fuel-Pump Lifter	18
Tin	Bearings	30	Bearings	40
Chromium	Piston Rings 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 Cylinders Shafts	125	Crankshafts Cylinder Liners Camshaft Connecting Rod and Gears	120
Copper	Bushings Bearings	60	Rocker-Arm Bushings Wrist-Pin Bushings Timing-Gear Thrust Washer Governor Bushing Fuel-Transfer-Pump Bushing Oil-Pump-Drive Thrust Washer	30

b. Sampling Procedures.

(1) One 4-oz size sample was taken for chemical analysis after the first 100 hours of engine operation and after each 200 hours of operation thereafter in the 5- and 10-kW generator sets. One 8-oz sample was taken after the first 100 hours of engine operation and after each 200 hours thereafter for the 15- through 100-kW generator sets. One 1-oz size sample was taken for spectrometric analysis after each 100 hours of engine operation.

(2) **Spectrographic Procedures.** The Jarrell-Ash Model 750 Atom Counter, Atomic Emission, Direct-Reading Spectrometer was used in the analysis. The electrodes used were National, Disc Type L 4075 AGKSP ½-inch diameter, 1/8-inch thick, Counter Electrode Type L3957 AGKSP ¼-inch rounded upper 1/16-inch radius. Maximum impurity of the electrodes: Aluminum 0.5 p/m, iron 0.4 p/m, copper 0.5 p/m, silicon 2.4 p/m. The instrument was standardized with Continental Oil Company CONOSTAN Type D-20 metallo-organic standards in the following concentrations: 0, 10, 30, 50, 100, and 300 p/m ranges.

III. TEST RESULTS

6. Oil Analyses Test Data. During this program, the results of the chemical and spectrometric oil analyses were tabulated and plotted by use of a Cal Comp Plotter. This computer printout technique greatly simplified making decisions as to oil condition. These tabulations are given in the Appendix to this report.

7. Oil Consumption Data. Oil consumption data are given in Table 7.

8. Discussion of Oil Analyses. Results are discussed in the following paragraphs for Phase I and Phase II and are presented graphically in the Appendix.

a. Phase I. The oils used in Phase I are formulated for gasoline engines and therefore are different from those used in Phase II. The oil consumption of the gasoline engines was much higher than when MIL-L-2104C oils were used. There was no degradation of the oils as determined by chemical and spectrometric analyses. The engines ran the entire endurance test without an oil change. However, the high oil consumption had the effect of replenishing the oil every 100 hours. No further discussion of Phase I is warranted because the high oil consumption is undesirable.

Table 7. Summary of Oil Consumption – Phase II

Unit Size	Total Oil (qt)	Consumption Rate – Quarts per 100 Hours					
		1st 1000 Hours	2nd 1000 Hours	3rd 1000 Hours	4th 1000 Hours	5th 1000 Hours*	Average
Consumption for Oil A							
5-kW	59.0	0.75	1.20	1.25	1.45	1.34	1.20
10-kW	64.8	0.88	1.20	1.42	1.65	2.27	1.41
15-kW	44.8	0.88	1.08	0.90	1.20	0.67	0.91
30-kW	60.0	0.65	1.00	0.85	1.35	2.20	1.21
60-kW	220.5	2.90	4.60	0.47	6.50**	6.60	4.79
100-kW	204.5	5.10	4.50	0.45	3.90	4.80	4.54
Consumption for Oil B							
5-kW	35.5	0.38	1.00	0.90	0.98	1.50	0.85
10-kW	66.5	0.92	1.08	1.00	2.20	2.07	1.41
15-kW	31.5	0.45	0.95	0.60	0.85	1.00	0.73
30-kW	97.8	0.16	0.23	1.82	2.00	2.62	2.04
60-kW	87.5	0.13	0.13	1.55	2.00	4.33	1.90
100-kW	296.0	0.64	1.06	5.88	5.70	5.00	7.05

* All but one unit operated less than 1000 hours.

** Unit experienced oil seal leakage problem.

b. Phase II.

(1) **100-kW Generator Sets.**

(a) **Chemical Data.** Pentane insolubles increased in the Type A oil. The mean values of 0.180 vs 0.146 are an indication of this general trend. The data with respect to the midrange cumulative hours (1500-3000) engine running time also favor Type B oil.

The viscosity of both oils indicated one significant departure from mean values in Engine 1 from 2200- to 3000-cumulative-hour time frame in Type A oil and in Engine 14 from 1500- to 1900-cumulative-hour time frame in Type B oil.

The total acid for Type A oil had three significant increases in the first 1200 hours of testing. The system settled out after this time frame to an overall mean value of 4.4. The total base value decreased to 1; however, an oil change at 3500 hours reversed the trend and brought the system back to average values throughout the remainder of the test period. The total acid and total base values for Type B oil followed a more uniform pattern as indicated by standard deviation data of 0.67 vs. 1.5 and 0.94 vs 1.7. In general, the lower mean values throughout the test period indicates less acid buildup in Type B oil usage.

(b) **Spectrographic Data.** The Type A oil demonstrated a significant increase in the lead content. This would signify a possible bearing problem with these engines. However, as the cumulative engine time increased beyond 3000 hours, the metal content normalized to initial levels. This pattern was not repeated with oil B and thus would signify a true wear/lubrication relationship at the indicated time frame. The Type B oil demonstrated a moderate increase in the tin analysis. This indicates a heavy wear factor or pitting beyond the lead overlay area in either the main or rod bearings.

The other elements — aluminum, iron, copper, chromium, and silicon — showed no significant increase in wear metal content. However, each engine displayed unusual variations in maximum/minimum data curve configurations, but the significance was masked by the unusual amounts of oil added to each generator.

(2) **60-kW Generator Sets.**

(a) **Chemical Data.** The pentane insolubles in Type A oil were increased significantly over Type B. This pattern is similar to the 100-kW reported earlier in this report; however, engine No. 13 had two oil changes in the 5000-hour test cycle period. This makes comparative analysis difficult; however, a few generalizations follow:

Type A oil demonstrated a more uniform viscosity profile and less total acid buildup in the system; a low TBN value (alkaline reserve) for Type B oil was reflected at 1400 and 3200 hours necessitating oil changes at these intervals.

(b) Spectrographic Data. Type B oil indicated a significant increase in the iron wear metal contents; which indicates a general wear problem in cylinders, shafts, rods, and gears but not specifically related to any one specific area. The most significant wear indicator was shown by the high copper content of the oil; copper is normally found in bushings and bearings. This element demonstrated a 4X increase in the mean values, Type B oil (93.1 p/m) compared to Type A oil (21.9 p/m); this signifies a major wear area for this engine/oil combination. Type A oil spectrographic patterns of the tin wear metal were improved (less wear indicated) over Type B oil; however, wide fluctuations of this index for both engines decreased the forecast value of these data. In general, Type A oil appeared to demonstrate less wear than Type B.

(3) 30-kW Generator Sets.

(a) Chemical Data. The chemical analyses of the Type A and B oils for these engines are comparatively similar with a slight edge in favor of Type B oil. The pentane insolubles and the total acid mean values were slightly higher in Type A oil. The viscosity increased to approximately 22 cSt from 3800 to 4200 engine hours in Type B oil, but returned to normal, 12 cSt, after the above period. The only explanation for this event is that the oil consumption trend decreased slightly during this period, which increased the viscosity of the remaining oil in the sump.

(b) Spectrographic Data. Type A oil demonstrated increases in aluminum, iron, and lead when compared to Type B oil. This indicates an overall wear problem throughout the engine and could be related to a difference in oil lubrication performance.

Specifically, the individual elemental graphs indicate abnormal patterns for engine No. 3 at 2900 hours for aluminum, 1400 hours for iron, and 1800 hours for lead. An identical lead wear metal pattern was repeated for oil Type B but at a decreased level. The other elements — chromium, copper, tin, and silicon — did not display significant differences in wear patterns.

(4) 15-kW Generator Sets.

(a) Chemical Data. The mean values for pentane insolubles and total acid were higher in the Type A oil. Also, the pentane insolubles (Appendix) demonstrated overall excessive levels during midrange engine running time (1800 and 2800 hours). Type B oil peaked at the 3900-hour area and displayed a more uniform viscosity curve (standard deviation) (0.762 cSt vs 1.34 cSt) for Type A oil; also Type A oil demonstrated a major viscosity increase deviation (16 cSt) (2400) followed by a sharp decrease (9 cSt) without any apparent change in oil consumption patterns.

(b) Spectrographic Data. The wear metal concentration for aluminum was slightly higher in Type A oil. The remaining metal indicators were similar, except for lead, which again increased slightly in the Type A oil. Also, Type A engine indicated an abnormal spike in the copper line but returned to average values at 1100 hours. The trend in Type B oil was reversed and no explanation can be found for this result. In general, with the above exceptions, the specific curves for each metal indicator displayed similar patterns. The silicon, lead, iron, tin, and chromium patterns were uniform throughout the test period.

(5) 10-kW Generator Sets.

(a) Chemical Data. The viscosity and total acid for both oils increased with engine running time. Type A oil viscosity values peaked at 33 cSt and Type B oil, at 30 cSt. Type A oil developed a significant amount of acid 6.37 vs 4.54 mean values for Type B oil. More significantly, during the last 1000 hours of running time, the values of A oil were doubled (10 vs 5 for Type B oil). Comparisons can be generalized only since Type B oil/engine system had one oil change at 2600 hours and used more oil (5.5 quarts) than did Type A during the same period.

(b) Spectrographic Data. The wear metal concentration for lead in Type A oil was significantly higher than in Type B oil. The specific wear pattern for each engine/oil was similar with the highest wear indicated near 2000-hour engine running time. The Type B oil demonstrated an abnormal spike at 400 hours but returned to normal values at 500 hours. Except for the above-mentioned peak, Type B oil was consistently lower throughout the test period. The mean value for aluminum was slightly higher in Type A oil; the remaining elements were similar in both systems. The chromium value for Type B oil demonstrated an unusual spike at the end of the test period; while the silicon wear metal indicator became apparent at 1200 hours in Type A oil and 2600 and 4200 hours in Type B oil.

(6) 5-kW Generator Sets.

(a) Chemical Data. The total acid for Type A oil significantly increased to peak values of 10 during the last 1000-hour test cycle. Type B oil demonstrated lower and more uniform values during the total test period. The pentane insolubles also increased significantly during the total test period for Type A oil. Both engine/oil sets displayed high initial results in the first 500 hours of engine running time. The viscosity displayed a generally normal response trend with ranges of 25 cSt for Type A oil and 15 cSt for Type B oil during the last 1000-hour test cycle.

(b) Spectrographic Data. The iron wear metal concentration for Type B oil was higher than for Type A. The wear metal pattern was similar with two abnormal patterns at 1500 and 3500 hours for Type B and 1500 and 4000 for Type A. The mean value for lead was also significantly higher for Type B oil, but the wear patterns were different. The copper wear metal indicator was slightly increased (10 p/m) over Type B oil; with both engines displaying highest wear values during the 2500- to 3000-hour test period. Silicon metal increased wear values through the 4000-hour test period for both engines; the mean values were similar — 14.9 for Type A oil and 16.6 for Type B oil.

c. Data Presentation. Chemical analyses data are summarized in Tables 8 and 9; data for spectrographic analyses are in Tables 8 and 9; data for oil consumption are in Table 7. Chemical analysis for each engine/oil type is located in the Appendix. Spectrographic analysis wear metals for each engine/oil type is located in the Appendix.

9. Engine Teardown Inspections. Inspections were conducted on the engines and lubricants contained in Table 12.

a. Wear Ratings. The inspection wear ratings were made in accordance with CRC Manual N05 except in the case of piston deposits where the CRC "F" system was used. Detailed ratings are attached in Table 11.

b. Analysis of Data. Differences in performance were observed between the two test lubricants. As can be seen from Table 10, oil B offered better control of piston deposits than did oil A. Although piston deposits were considered acceptable for the majority of the engines, they did present a problem in the 5- and 10-kW units. Here, the high level of deposits caused excessive loss of ring side clearance which resulted in numerous instances of stuck or sluggish compression rings. Also, it is believed these deposits contributed to the severe distress observed in the No. 4 cylinder of EZ00052 (10-kW unit. STA No. 5). Other differences were observed in the area of intake valve and combustion chamber deposits: engines operated on oil A had lower levels of intake valve deposits while those operated on oil B consistently had less combustion chamber buildup. With the exception of the aforementioned piston deposits exhibited by the 5- and 10-kW units, the observed deposition levels were considered satisfactory.

Table 11 summarizes inspection findings other than the previously discussed deposit ratings. With a few exceptions, conditions of the engines were considered acceptable; however, it was noted that lubricant B allowed a slightly higher level of distress/wear than did oil A. Exceptions to satisfactory performance are as follows:

(1) 5-kW Units. Both units experienced excessive wear to govenor assemblies. Based on previous testing with MIL-L-2104C lubricants, the wear problem was attributed to governor design and not considered related to the performance of the oils under test.

Table 8. Summary of New and Used Oil Analyses – Phase II (Oil A)

Property	New Oil	Average Value for Generator – Used Oil					
		5-kW	10-kW	15-kW	30-kW	60-kW	100-kW
Viscosity (cSt) @ 210° F	10.32	16.21	17.74	11.45	11.11	10.64	10.33
@ 210° F	72.1	152.6	184.5	92.6	87.9	88.1	80.9
TAN	2.1	6.0	6.4	5.1	5.0	5.1	4.4
TBN	3.7	4.0	3.3	3.1	2.4	2.8	3.7
Pentane Insolubles (%)	0.0	0.22	0.17	0.21	0.19	0.20	0.18
Elemental (Wear/Contaminant) (p/m)							
Al	13	31	28	23	33	20	17
Fe	0	373	383	190	344	111	115
Cr	0	18	15	13	15	7	4
Cu	0	24	32	15	12	22	62
Sn	8	24	25	23	23	16	17
Pb	0	1[illegible]6	216	125	144	52	111
Si	4	15	14	11	14	9	8

Table 9. Summary of New and Used Oil Analyses – Phase II (Oil B)

Property	New Oil	Average Value for Generator – Used Oil					
		5-kW	10-kW	15-kW	30-kW	60-kW	100-kW
Viscosity (cSt) @ 210° F	10.58	12.96	16.27	10.46	10.30	10.26	98.4
@ 210° F	61.3	93.7	130.3	67.3	67.7	67.9	64.8
TAN	2.1	3.8	4.5	4.7	4.3	5.2	3.3
TBN	3.5	3.3	2.5	2.2	2.6	2.3	2.9
Pentane Insolubles (%)	0.0	0.12	0.16	0.14	0.15	0.14	0.15
Elemental (Wear/Contaminant) (p/m)							
Al	10	22	20	15	20	15	17
Fe	0	450	363	200	247	218	91
Cr	0	19	14	13	14	9	5
Cu	0	14	13	11	13	93	75
Sn	9	23	25	21	21	22	24
Pb	0	221	157	96	77	46	59
Si	4	17	12	11	9	12	7

Table 10. Summary of Engine Deposit Ratings

Units	STA No.	Oil	Piston Deposits[a] TGF	Piston Deposits[a] WTD	Sludge[b]	Valve Deposits[c] Intake	Valve Deposits[c] Exhaust	Combustion Chamber[c]
5-kW	6	A	98	3526	9.4	3.5	1.0	1.5
5-kW	9	B	90	1059	9.5	4.0	1.0	2.0
10-kW	5	A	100	3914	9.4	4.0	1.0	3.4
10-kW	10	B	92	2833	9.2	4.5	1.0	2.8
15-kW	4	A	64	1116	NR	1.5	1.0	3.9
15-kW	11	B	48	426	NR	3.7	1.0	2.0
30-kW	3	A	66	1093	NR	1.7	1.0	3.0
30-kW	12	B	61	598	NR	3.5	1.0	2.0
60-kW	2	A	85	1989	9.1	3.0	1.0	1.2
60-kW	13	B	93	1312	9.3	4.0	1.0	1.0
100-kW	1	A	51	419	9.7	3.3	1.0	1.1
100-kW	14	B	29	199	9.7	3.8	1.0	1.0

[a] TGF = Top Groove Filling, %; WTD = Weighted Total Demerit

[b] 10 = Clean, NR = Not rated

[c] Deposits were assigned the following demerits: Heavy = 10, Medium = 5, Light = 2, and Very Light = 1. The demerits were weighted using the percent coverage by a deposit level and then averaged for the engine.

Table 11. Summary of Engine Condition

	Unit	Oil A Lubricated Engines	Oil B Lubricated Engines
Piston and Cylinders	5-kW	No unusual conditions.	No unusual conditions.
	10-kW	Severe distress No. 4 cylinder and piston (scored; scuffed).	No unusual condition.
	15-kW	No unusual condition.	No unusual condition.
	30-kW	Deep scratch No. 2 cylinder due to broken ring.	No unusual condition.
	60-kW	Light wiping on pin bushing (con. rod).	Pin bushing wear (con. rod). Wear in Nos. 3, 4, and 6 cylinders.
	100-kW	No unusual condition.	No unusual condition.
Rings	5-kW	Two stuck.	Oil ring spring worn.
	10-kW	Two stuck; two sluggish; face distress all rings No. 4 piston.	Three stuck.
	15-kW	No unusual condition.	All No. 1 compression rings showed signs of blowby.
	30-kW	All oil rings stuck. All No. 1 rings showed signs of blowby. No. 1 ring of piston 2 was broken.	Five oil rings stuck. All compression rings showed signs of blowby. No. 1 rings of pistons 3 and 5 were broken.
	60-kW	Some wear on oil ring spring.	No unusual condition.
	100-kW	No unusual condition.	No unusual condition.
Rockers (R), Valves (V), and Tappets (T)	5-kW	R – no unusual condition. V – slight wear on tip caps.	R – no unusual condition. V – light wear on tip caps, some guide wear, face distress (intake).
	10-kW	R – no unusual condition. V – slight on tips and tip caps, face distress (intake).	R – no unusual condition. V – wear on tips and tip caps; one intake showed face distress.

Table 11. Summary of Engine Condition (Cont'd)

	Unit	Oil A Lubricated Engines	Oil B Lubricated Engines
	15-kW	R – no unusual condition. V – no unusual condition. T – light scuffing.	R – some indication of wear. V – medium-to-heavy face wear. T – light scuffing to scuffing.
	30-kW	R – no unusual condition. V – faces lightly pitted. T – no unusual condition.	R – light-to-medium wear. V – medium-to-heavy face wear. T – no unusual condition.
	60-kW	R – wear and scuffing of pads and bushings; shaft showed some scuffing. V – exhaust tips scuffed, faces pitted, and stem wear.	R – wear and scuffing of pads, bushings, and shaft. V – exhaust tips scuffed, faces pitted, and stem wear.
	100-kW	R – slight pad wear; some bushing wear. V – one face showed channeling; some pitting on two faces. T – no unusual condition.	R – some slight wear of two pads. V – two exhaust faces showed channeling. T – no unusual condition.
Bearings	5-kW	Slight wiping of rod brgs.	Heavy wiping/wear of rod brgs.
	10-kW	Slight wiping of rod brgs.	Heavy wiping/wear of rod brgs.
	15-kW	No unusual condition.	Light wear pattern of main brgs.
	30-kW	No unusual condition.	Wear of rod brgs.
	60-kW	Light pitting of rod brgs.	One rod brg pitted.
	100-kW	Heavy wiping of rod brgs.	Medium-to-heavy wiping and light pitting of rod brgs.

Table 12. Engines and Lubricants

Unit	Unit SN	Station No.	Oil	Test Hours
5-kW	EZ00297	6	A	4906
5-kW	EZ00937	9	B	4212
10-kW	EZ00052	5	A	4603
10-kW	EZ00053	10	B	4707
15-kW	RZ20030	4	A	4801
15-kW	RZ21277	11	B	4300
30-kW	RZ51233	3	A	5003
30-kW	RZ01245	12	B	4806
60-kW	FZ01243	2	A	4504
60-kW	FZ01254	13	B	4606
100-kW	UZ00709	1	A	4500
100-kW	UZ00697	14	B	4211

(2) **10-kW Units.** Both units experienced wear to govenor assemblies Since these units are identical to those used in the 5-kW sets, the previous comments are applicable. Also, unit EZ00052 had severe piston and bore distress of the No. 4 cylinder assembly. This condition was considered related to lubrication as covered (see paragraph b) under the discussion of engine deposits.

(3) **15-kW Units.** None.

(4) **30-kW Units.** None.

(5) **60-kW Units.** Both units experienced excessive wear and distress of the rocker arm shaft, rocker arms, valves, and valve guides. Since similar distress was observed in previous tests, the problem was not considered a function of test lubricant performance.

(6) 100-kW Units. After 2500 hours of operation, both engines required replacement of the rocker arm shafts because of excessive wear. The wear problem was considered to be design related (i.e., size of the lubricant passage) and not associated with performance of the test oils. The shaft has been redesigned by the manufacturer. It should be noted that the problem, wear and pitting of connecting rod bearings, was observed. This problem may have been related to oil performance or the duration of lubricant usage.

10. Economic Analysis. A detailed economic analysis is available in the engineering division.

A list of worldwide assets of each generator set size as obtained from the Worldwide Inventory Stratification Report as of December 1979 follows:

Generator Size	No. of Sets
5-kW	1,082
10-kW	3,204
15-kW	4,566
30-kW	8,723
60-kW	8,835
100-kW	4,150
Total	30,560

Figure 1 indicates the percentage cost reduction of synthetic vs conventional oils by generator set size. Figure 2 illustrates the annual percentage synthetic oil cost vs conventional oil by oil change interval. Figure 3 compares the cost of synthetic oil and conventional oil by oil change interval. Figure 4 compares the annual cost by generator set size. Figure 5 compares the oil consumption for 100 hours per set. The results in Figures 1 through 5 indicate that the longer the change interval, the greater is the potential cost savings. Since the average usage per year is 1000 hours, this interval is the most logical since oil should be changed at least once a year. The 1000-hour interval yields a cost savings over current intervals approaching $1 million annually. The cost of conventional oil has been increasing at a greater rate than synthetic oils. In the near future the annual savings could be several million dollars per year. The economic study did not take into account the possible savings related to logistics.

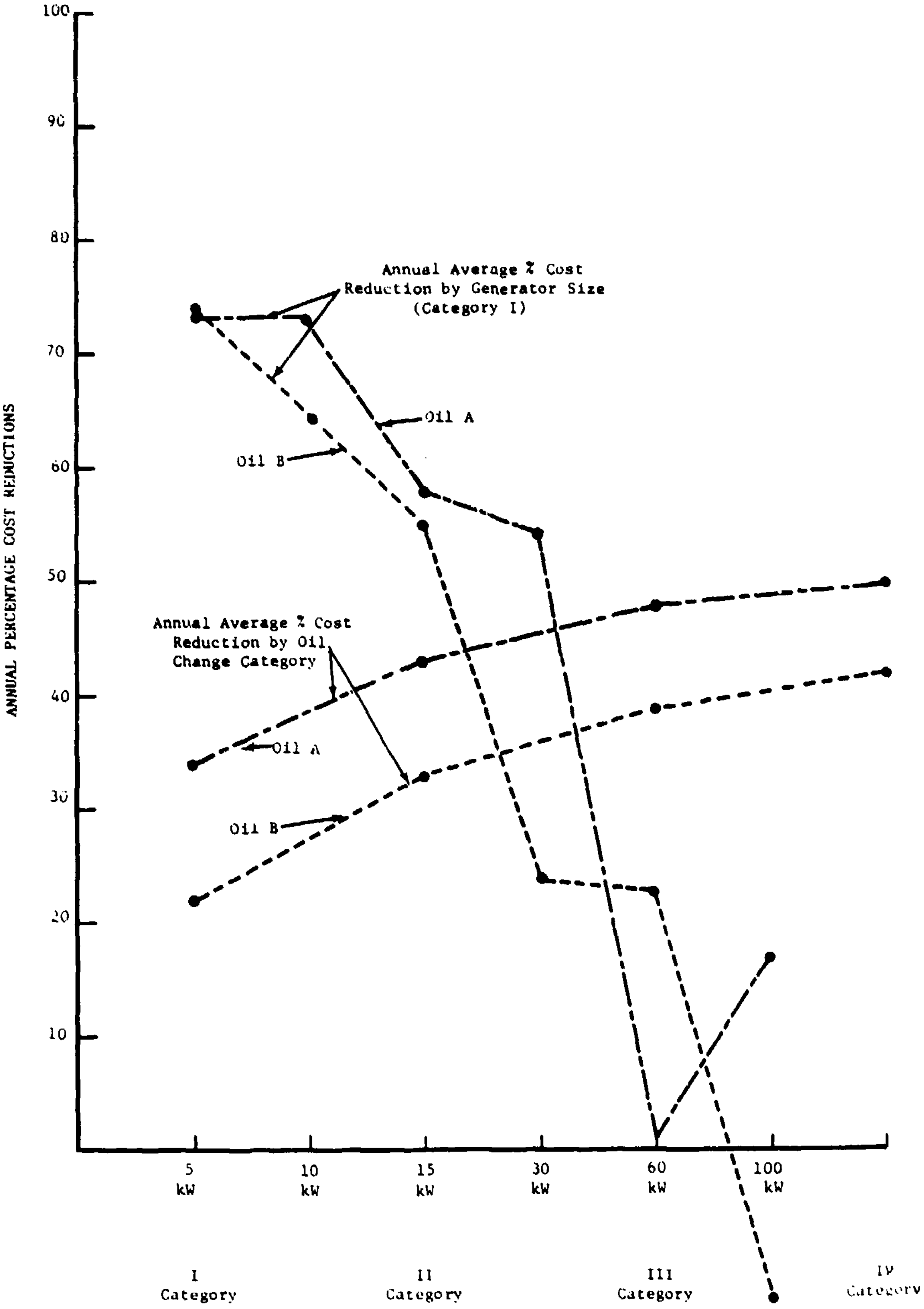


Figure 1. Percent cost reduction — synthetic vs petroleum oil.

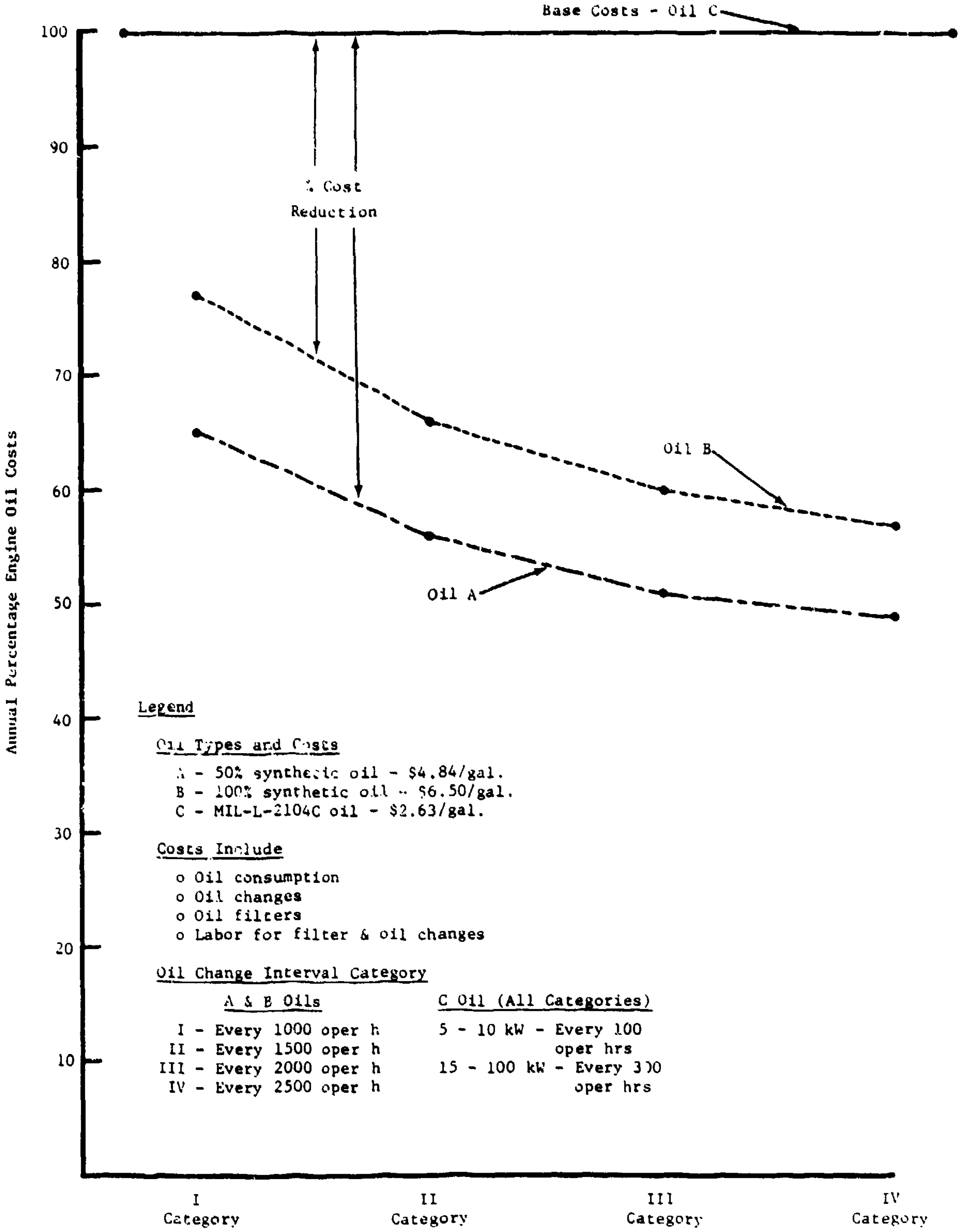


Figure 2. Synthetic oil cost vs base cost MIL-L-2104C

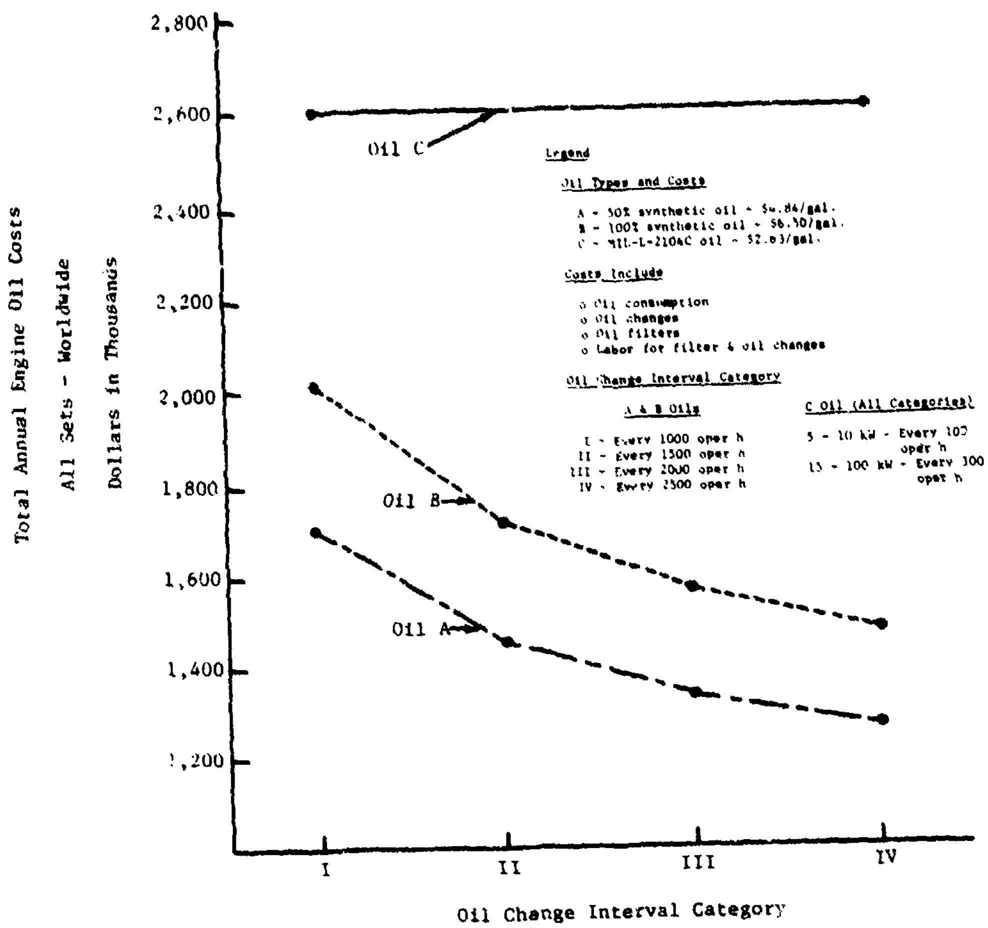


Figure 3. Dollars vs oil change interval.

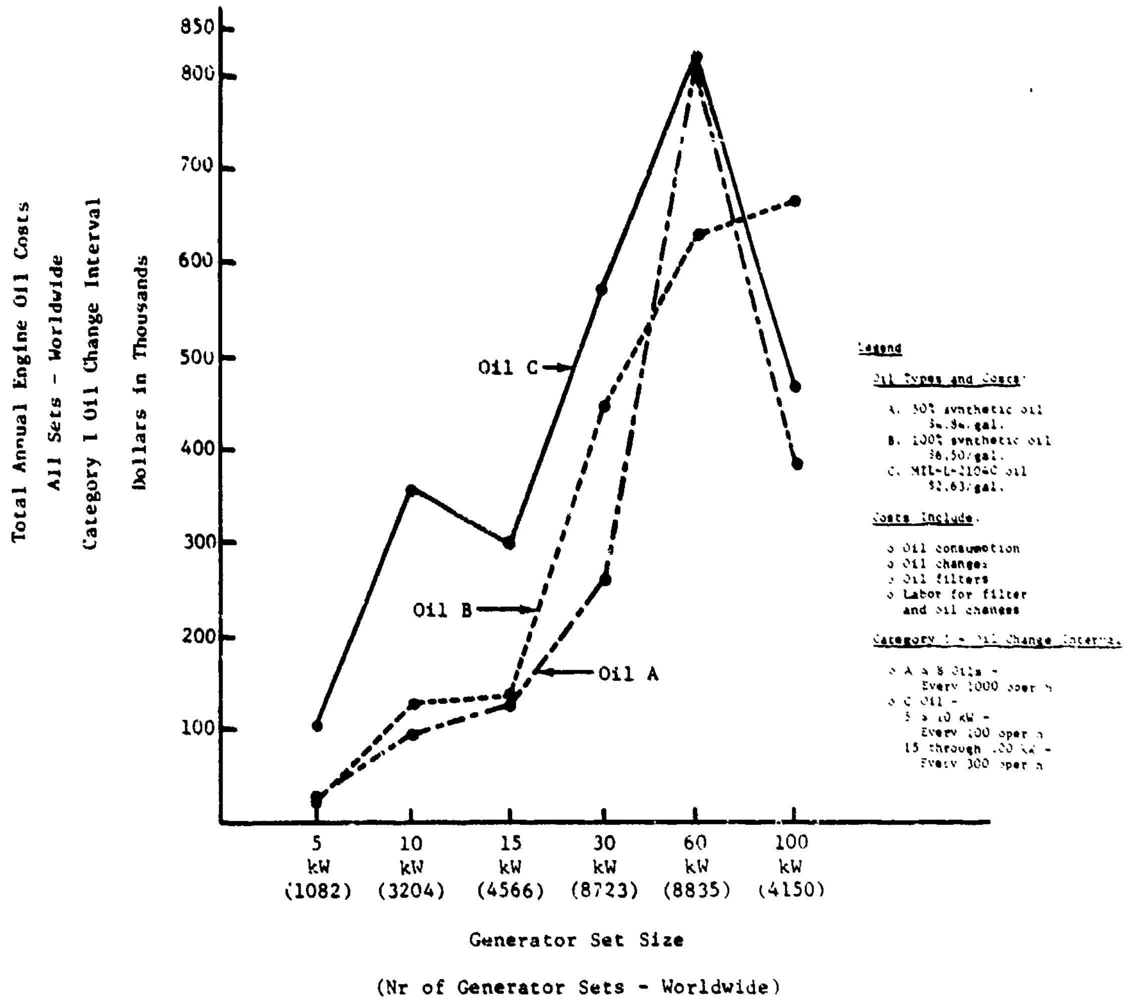


Figure 4. Cost comparison vs generator size.

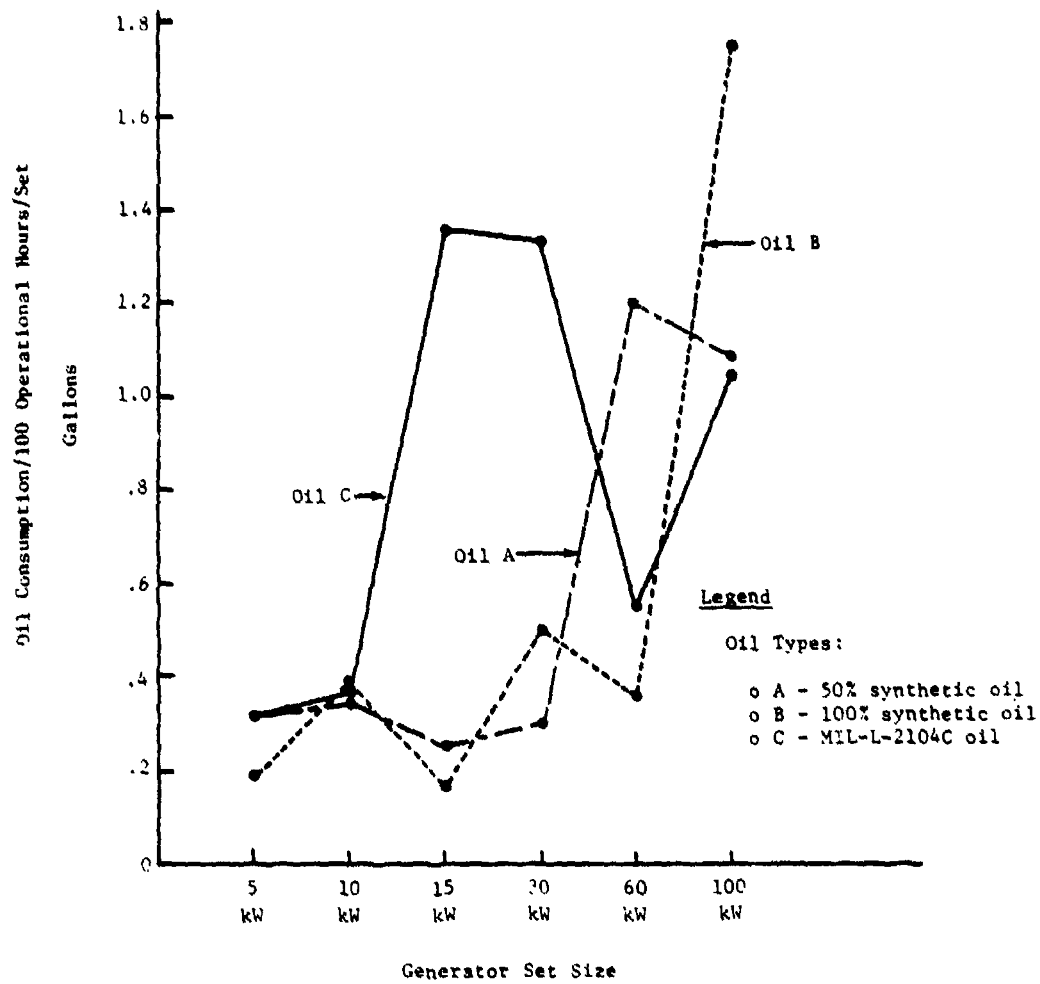


Figure 5. Oil consumption vs generator size.

IV. CONCLUSIONS

11. Conclusions. The following conclusions were made:

a. There were no failures attributed to use of synthetic crankcase oil.

b. The present 32° F ambient temperature wherein oil change is required for cold starting can be lowered to 0 to 10° F using synthetic oils of the type tested.

c. The oil consumption on the small bore gasoline engines is much higher when synthetic oil is used.

d. It is not economical currently to use synthetic oil in the small bore gasoline engines.

e. The chemical and spectrometric analysis indicated that the oil performed satisfactory and the the present oil change interval (100 hours, 5- and 10-kW; 300 hours, 15- to 100-kW) for diesels can be extended safely for normal service conditions through use of synthetic oil.

f. Diesel generator sets ranging in size from 5-kW through 100-kW can operate satisfactorily using synthetic oil with a 1000-hour/1-year change interval without engine performance, reliability, or total life cycle being affected adversely.

g. When test oil A is used, a 1000-hour/1-year oil-change interval offers the maximum economic benefit and cost-saving compromise to the Military while maintaining a minimum risk of engine malfunctions or failures attributable to extended lubricating-oil change intervals.

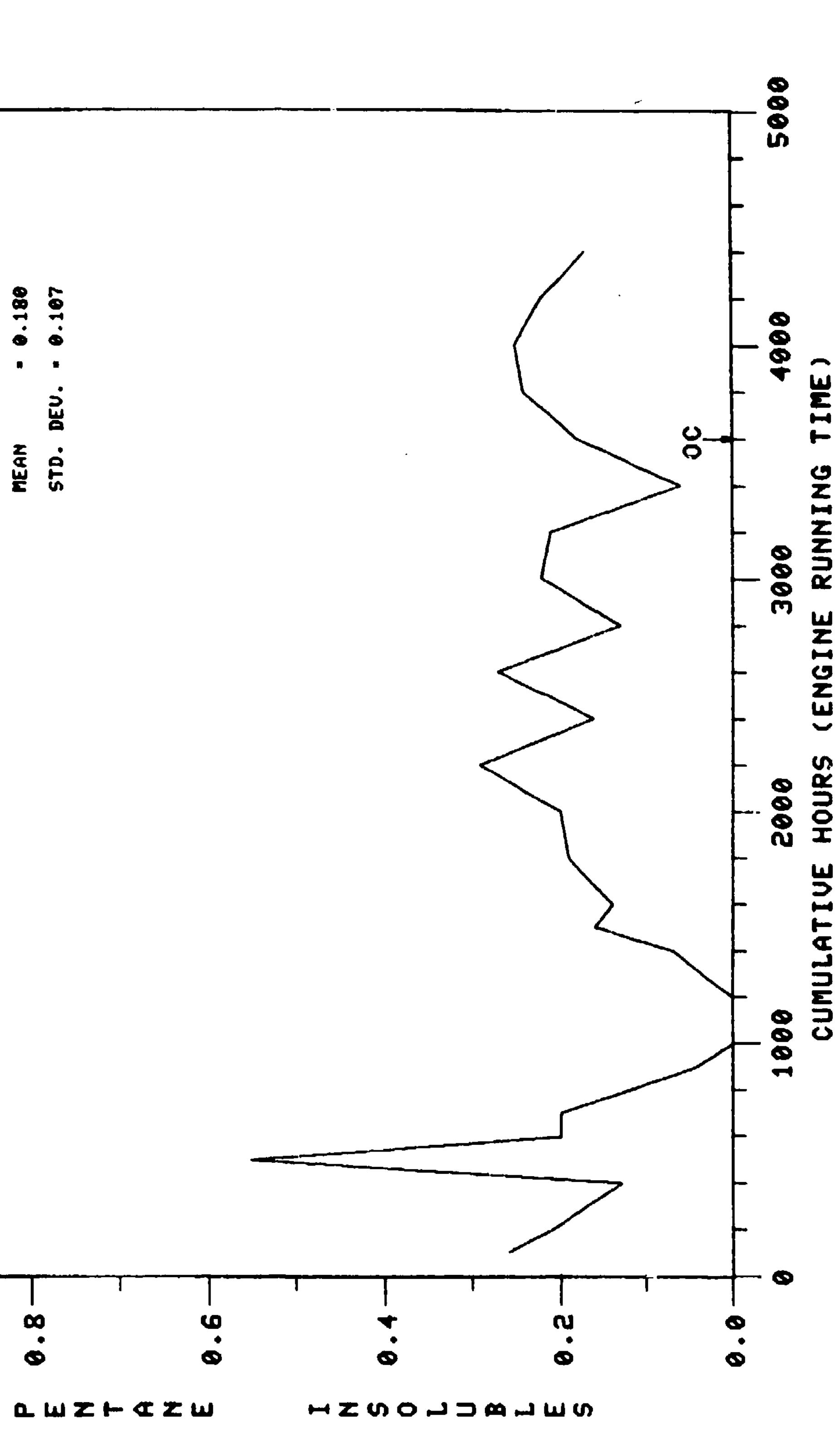
APPENDIX

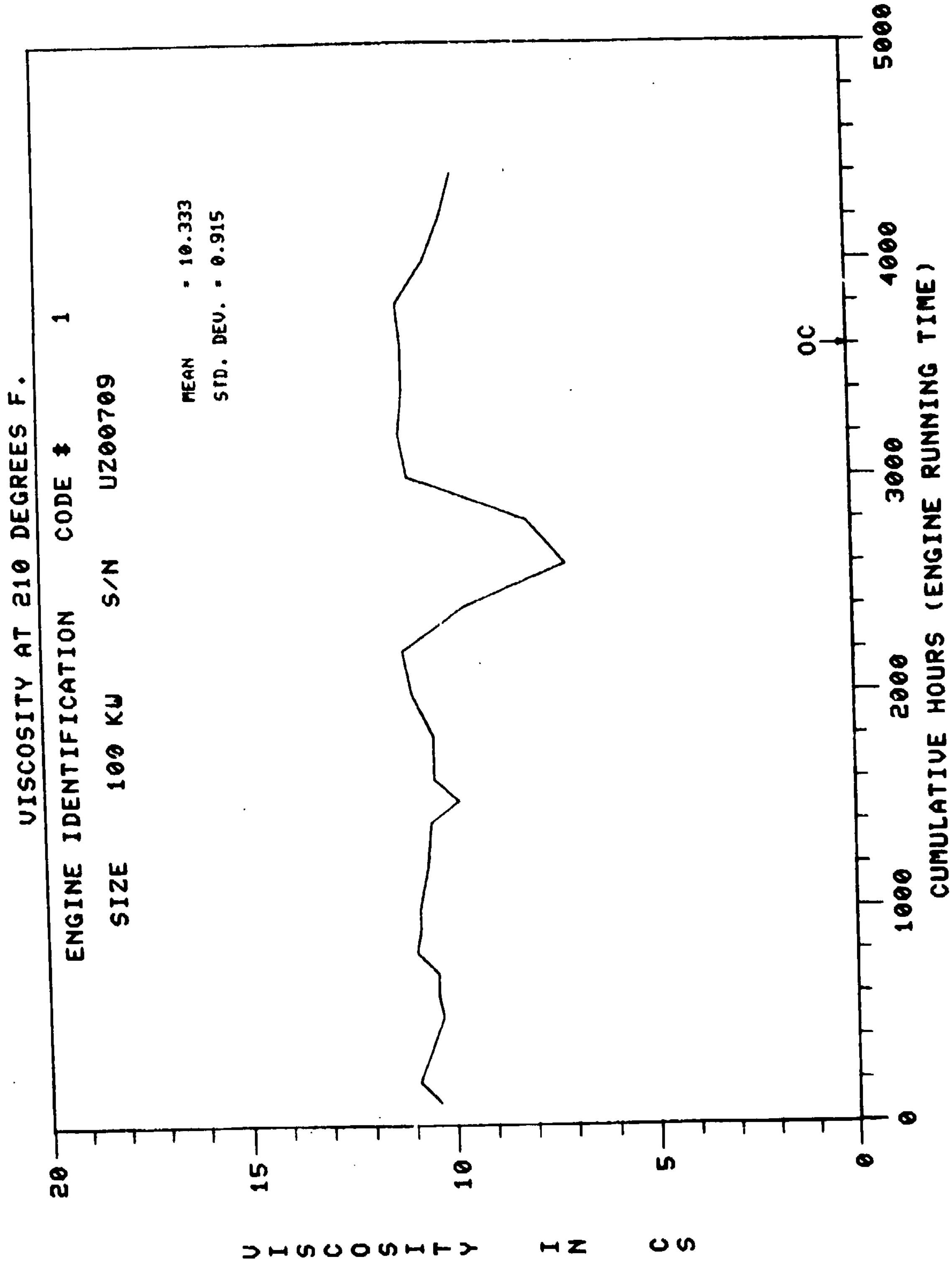
OIL ANALYSES TEST DATA

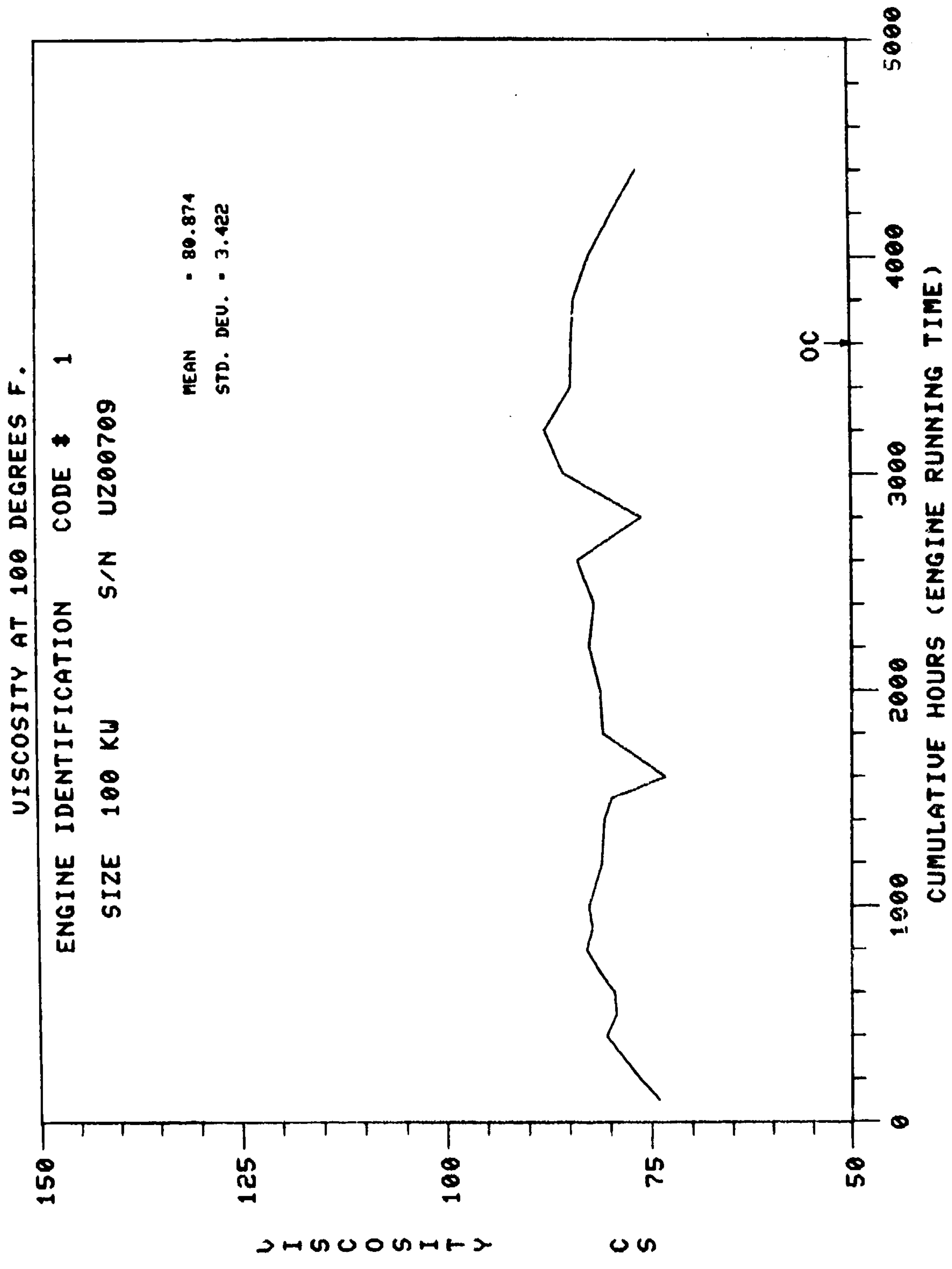
LEGEND

ENGINE IDENTIFICATION CODES

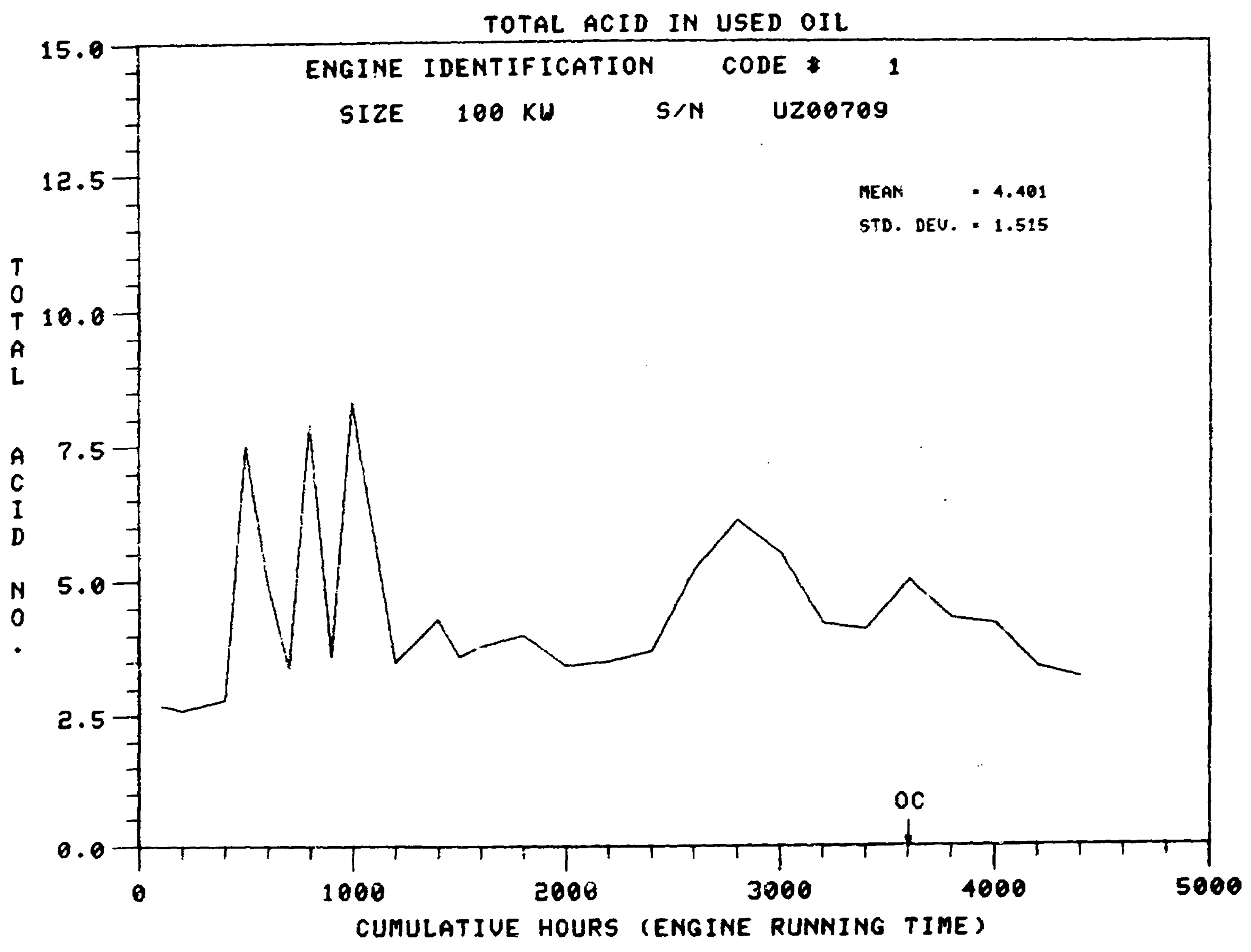
Code	Engine	Generator Set Size (kW)	Oil	Page
1	Caterpillar	100	A	133-144
2	Allis Chalmers	60	A	133-144
3	White	30	A	133-144
4	White	15	A	133-144
5	Onan	10	A	133-144
6	Onan	5	A	133-144
9	Onan	5	B	133-144
10	Onan	10	B	133-144
11	White	15	B	133-144
12	White	30	B	133-144
13	Allis Chalmers	60	B	133-144
14	Caterpillar	100	B	133-144


PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
MEAN = 0.180
STD. DEV. = 0.107
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
1.0
0.8
0.6
0.4
0.2
0.0
PENTANE INSOLUBLES

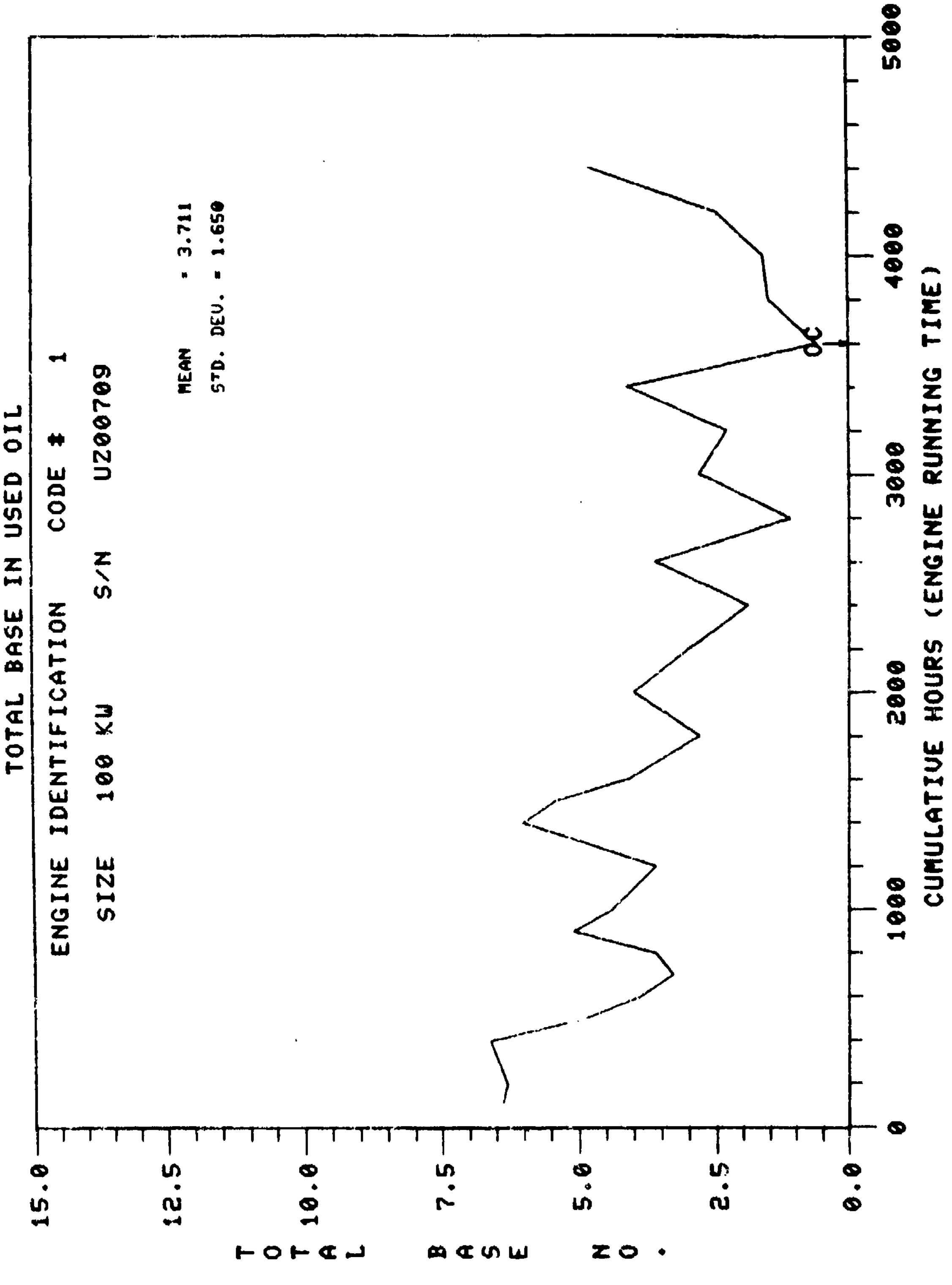

VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
MEAN = 10.333
STD. DEV. = 0.915
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
20
15
10
5
0
VISCOSITY IN CS

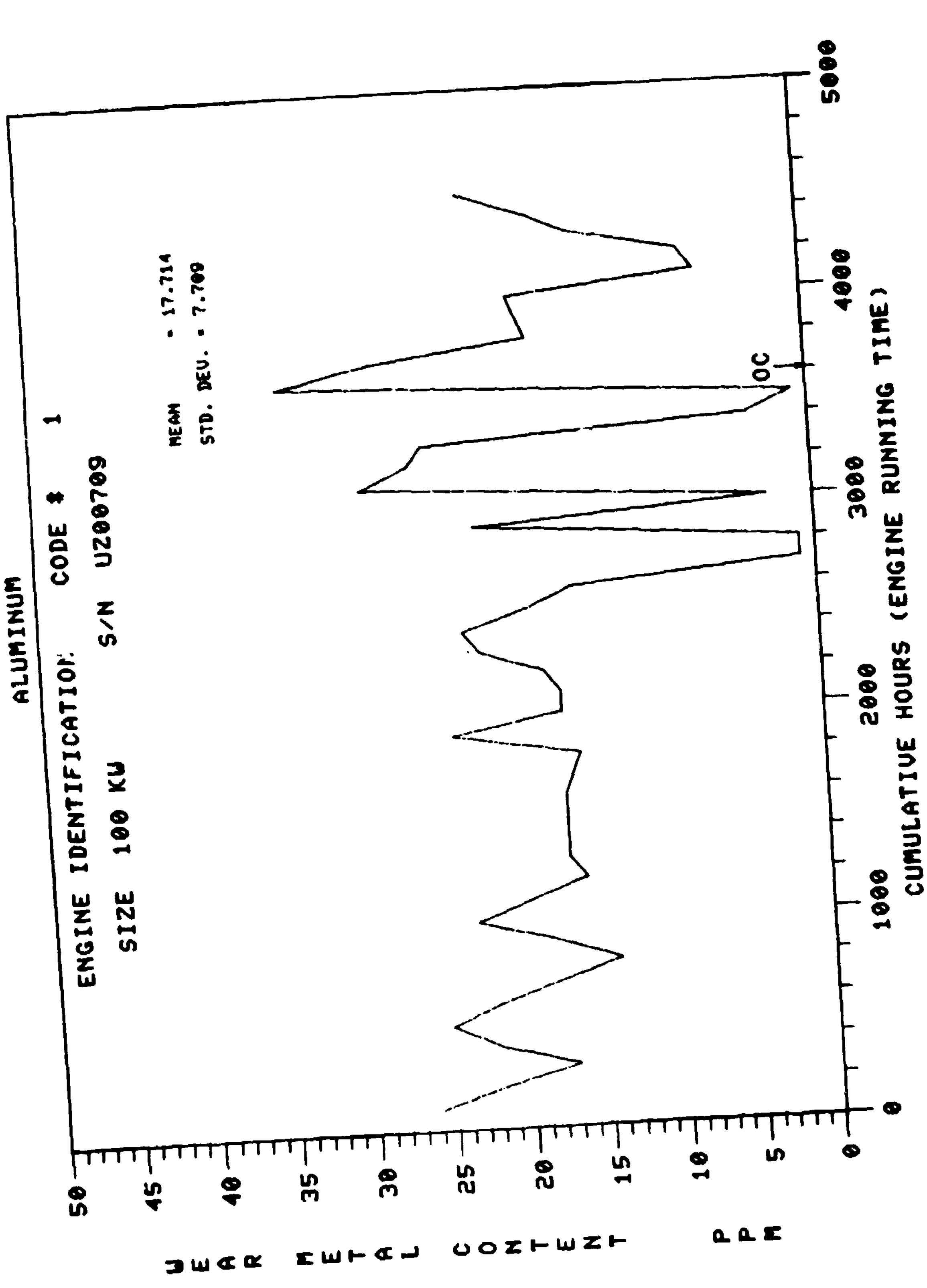


VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
MEAN = 80.874
STD. DEV. = 3.422
OC
VISCOSITY CS
150
125
100
75
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

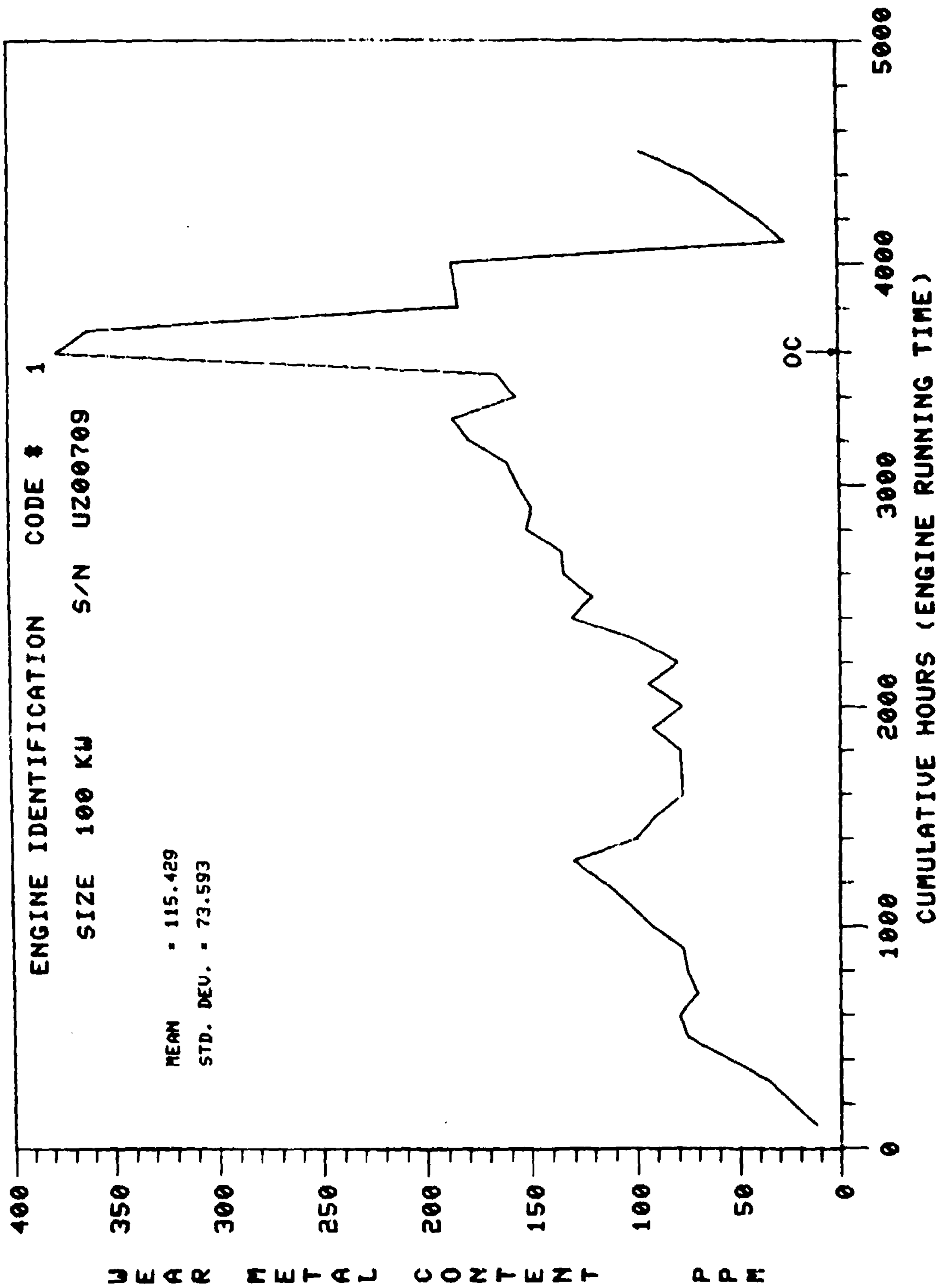


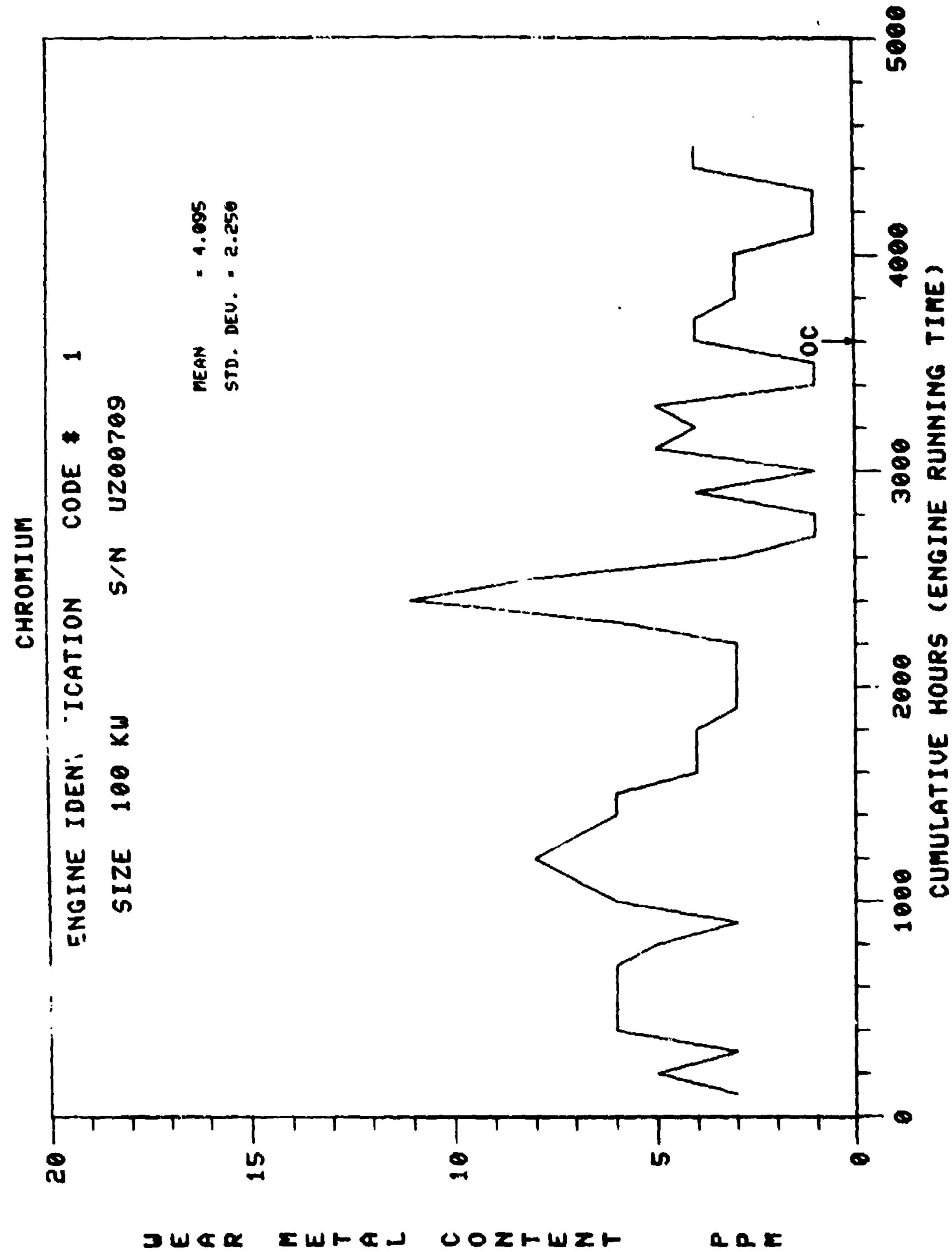
TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
MEAN = 4.401
STD. DEV. = 1.515
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)

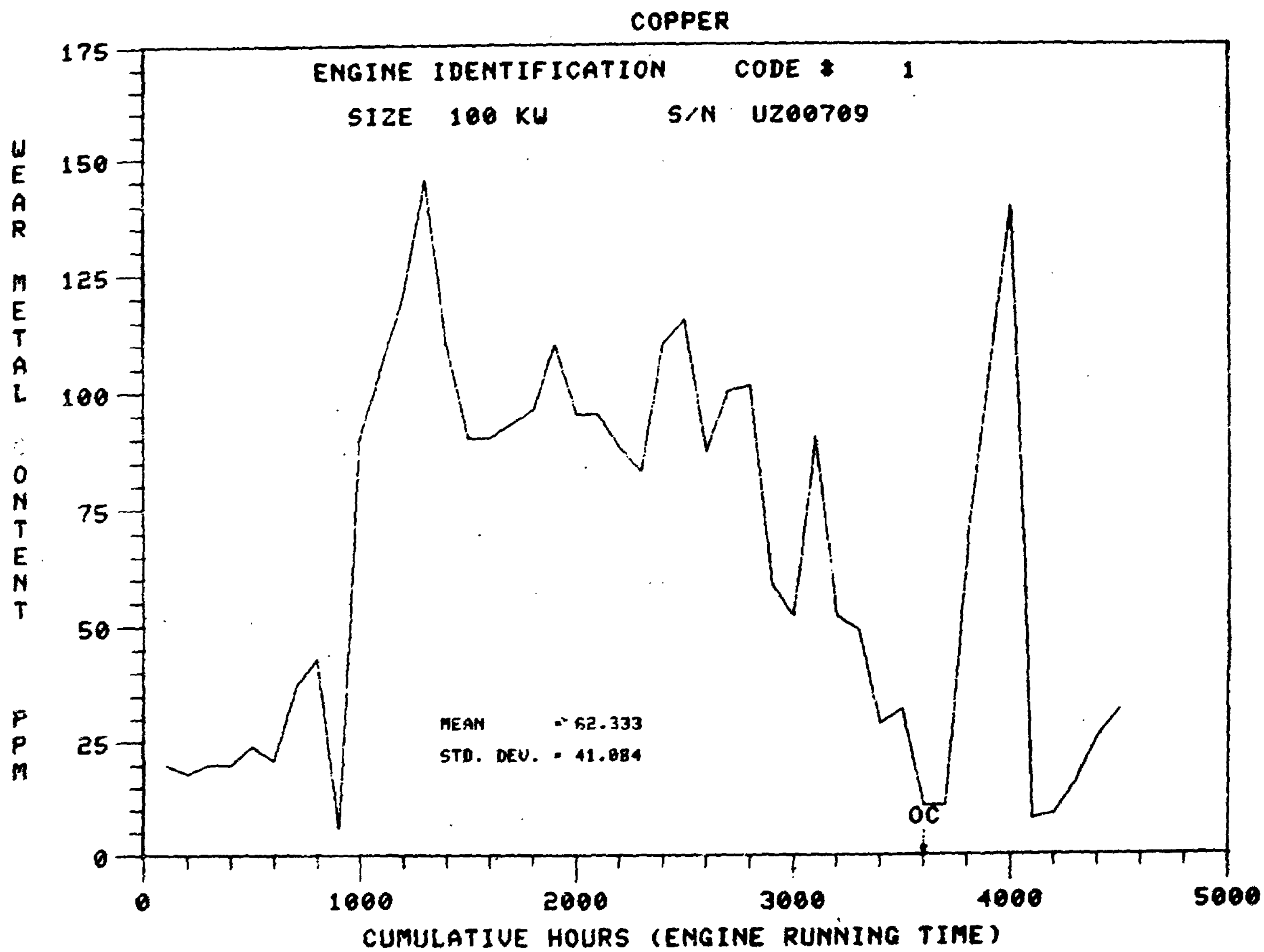

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N U200709
MEAN = 3.711
STD. DEV. = 1.650
OC
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

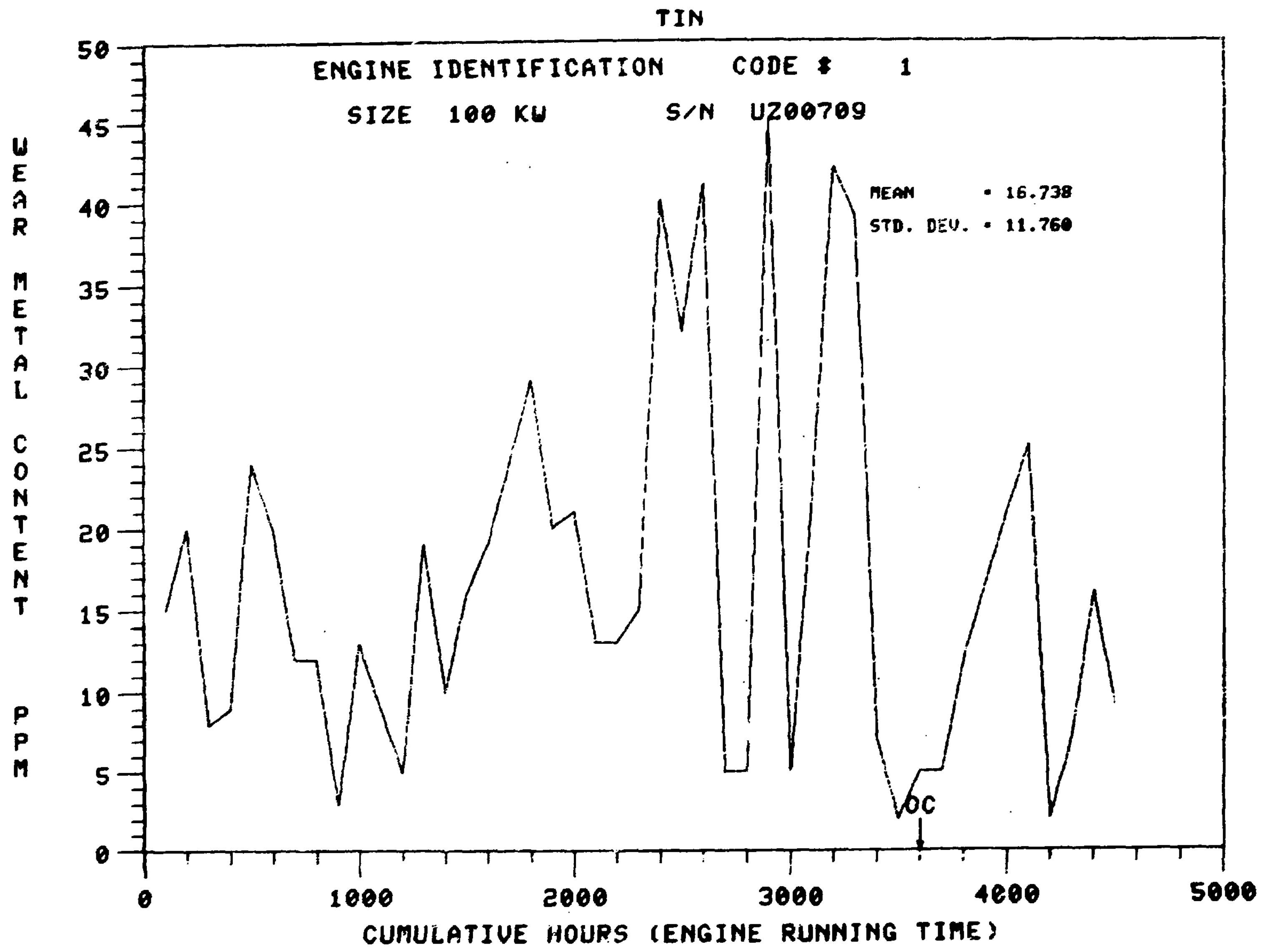


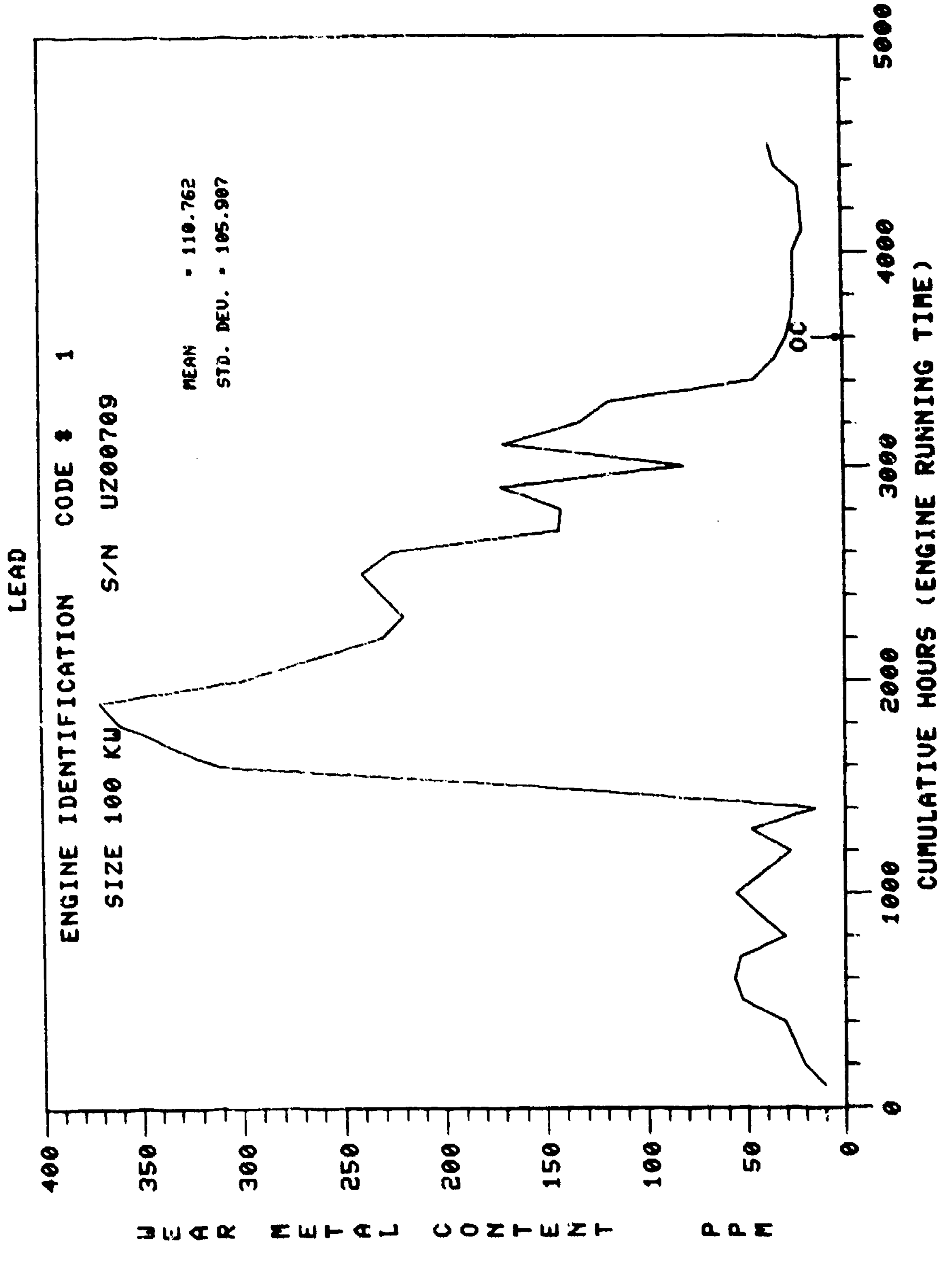
ALUMINUM
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N U200709
MEAN = 17.714
STD. DEV. = 7.709
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
WEAR METAL CONTENT PPM
0
1000
2000
3000
4000
5000
0
5
10
15
20
25
30
35
40
45
50


IRON
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
MEAN = 115.429
STD. DEV. = 73.593
OC
WEAR METAL CONTENT PPM
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
50
100
150
200
250
300
350
400
1000
2000
3000
4000
5000


CHROMIUM
ENGINE IDEN ICATION CODE # 1
SIZE 100 KW S/N U200709
MEAN = 4.095
STD. DEV. = 2.250
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
WEAR METAL CONTENT PPM


COPPER
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
WEAR METAL CONTENT PPM
0
25
50
75
100
125
150
175
MEAN = 62.333
STD. DEV. = 41.084
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


TIN
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
MEAN = 16.738
STD. DEV. = 11.760
OC
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)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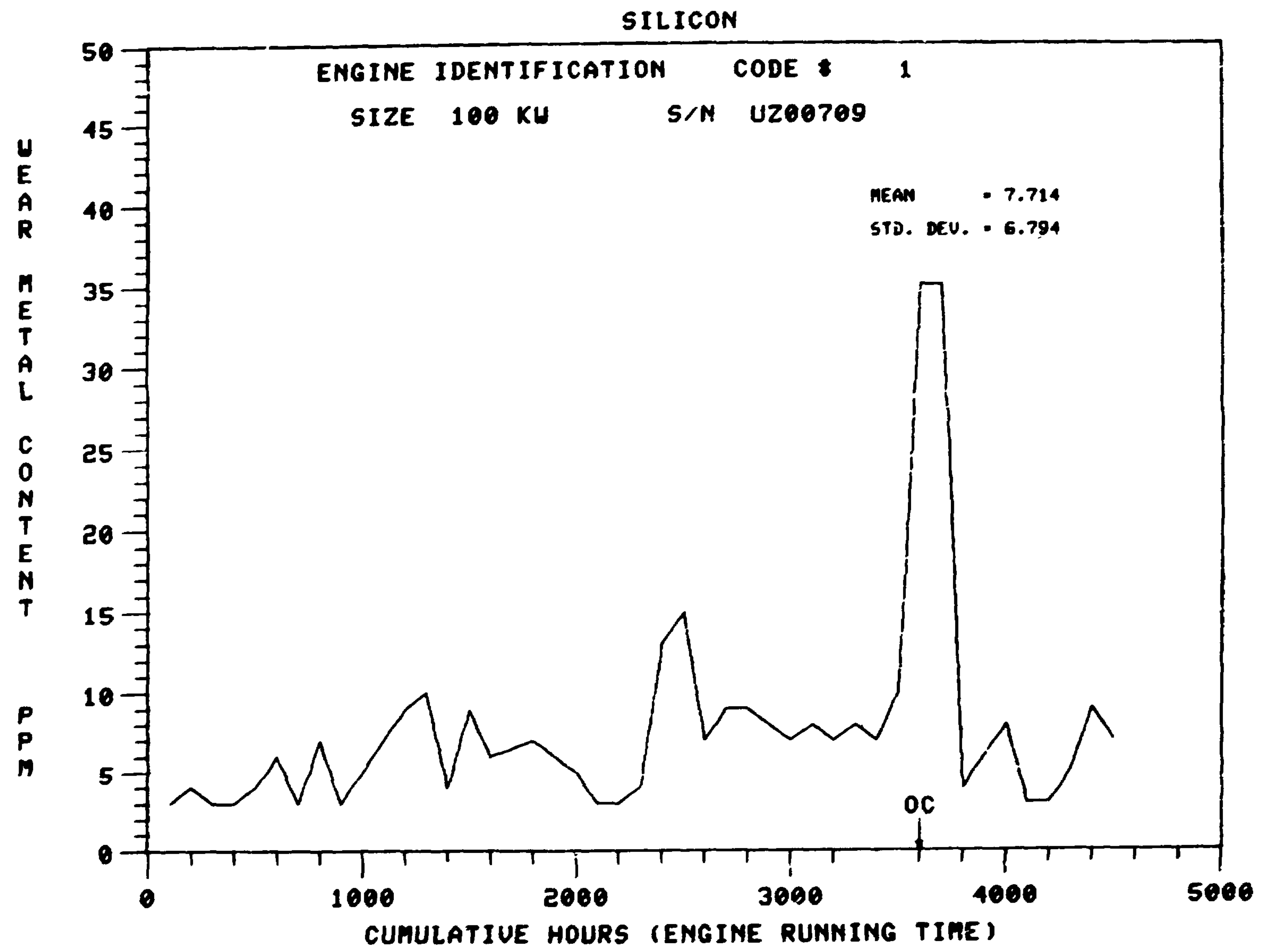
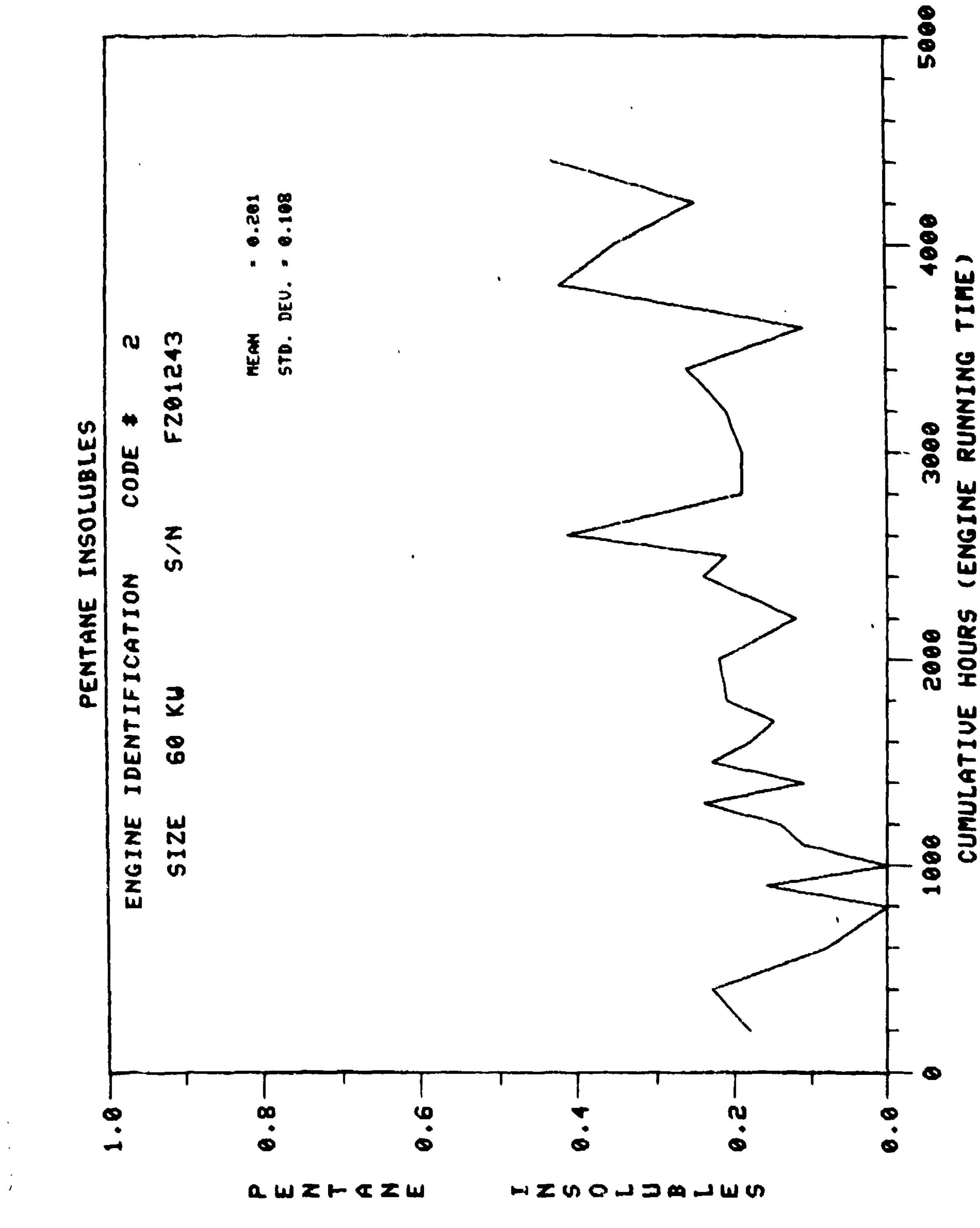
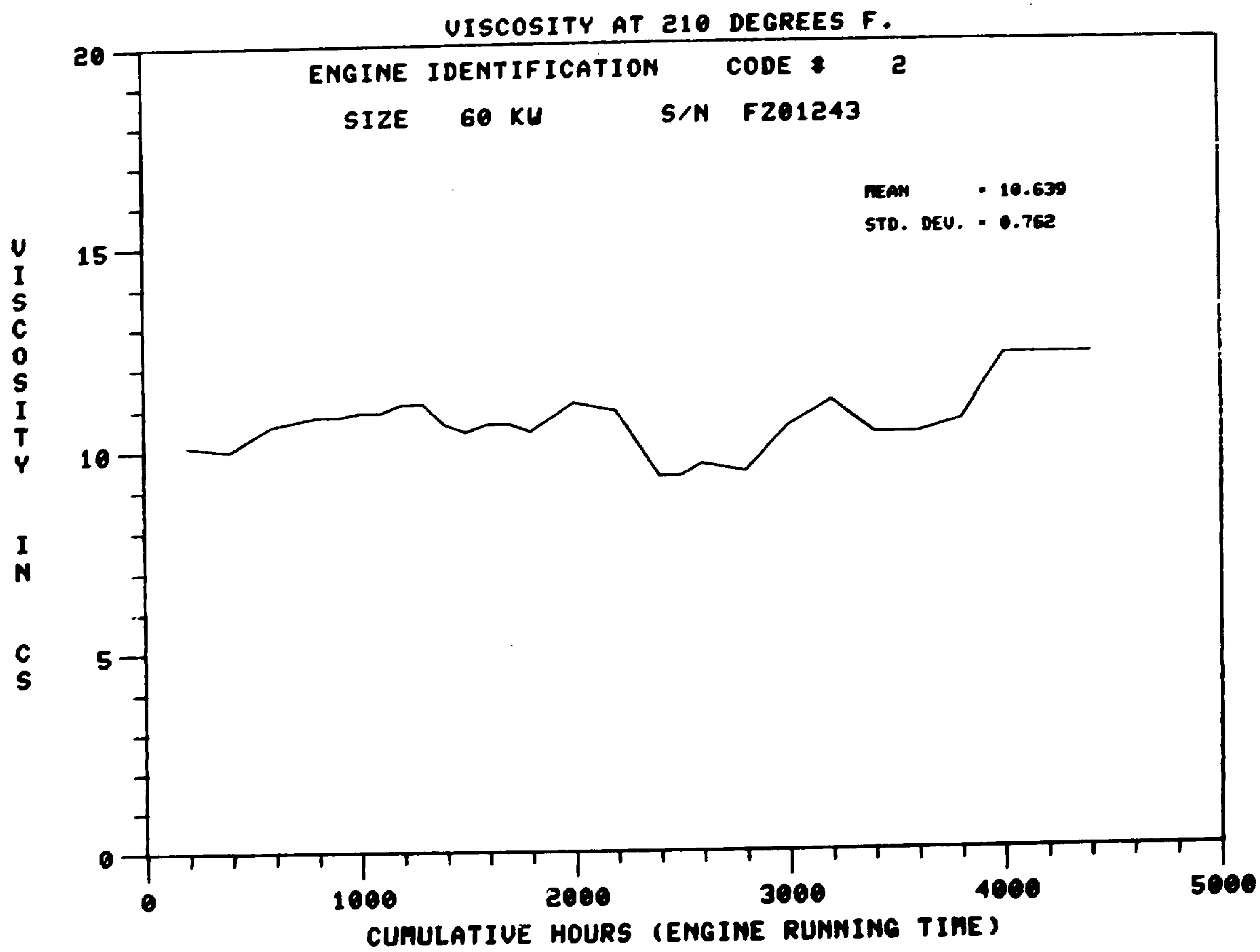
SIZE 100 KW S/N UZ00709
MEAN = 110.762
STD. DEV. = 105.907
OC
WEAR METAL CONTENT PPM
0
50
100
150
200
250
300
350
400
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


SILICON
ENGINE IDENTIFICATION CODE # 1
SIZE 100 KW S/N UZ00709
MEAN = 7.714
STD. DEV. = 6.794
OC
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 0.201
STD. DEV. = 0.108
PENTANE INSOLUBLES
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)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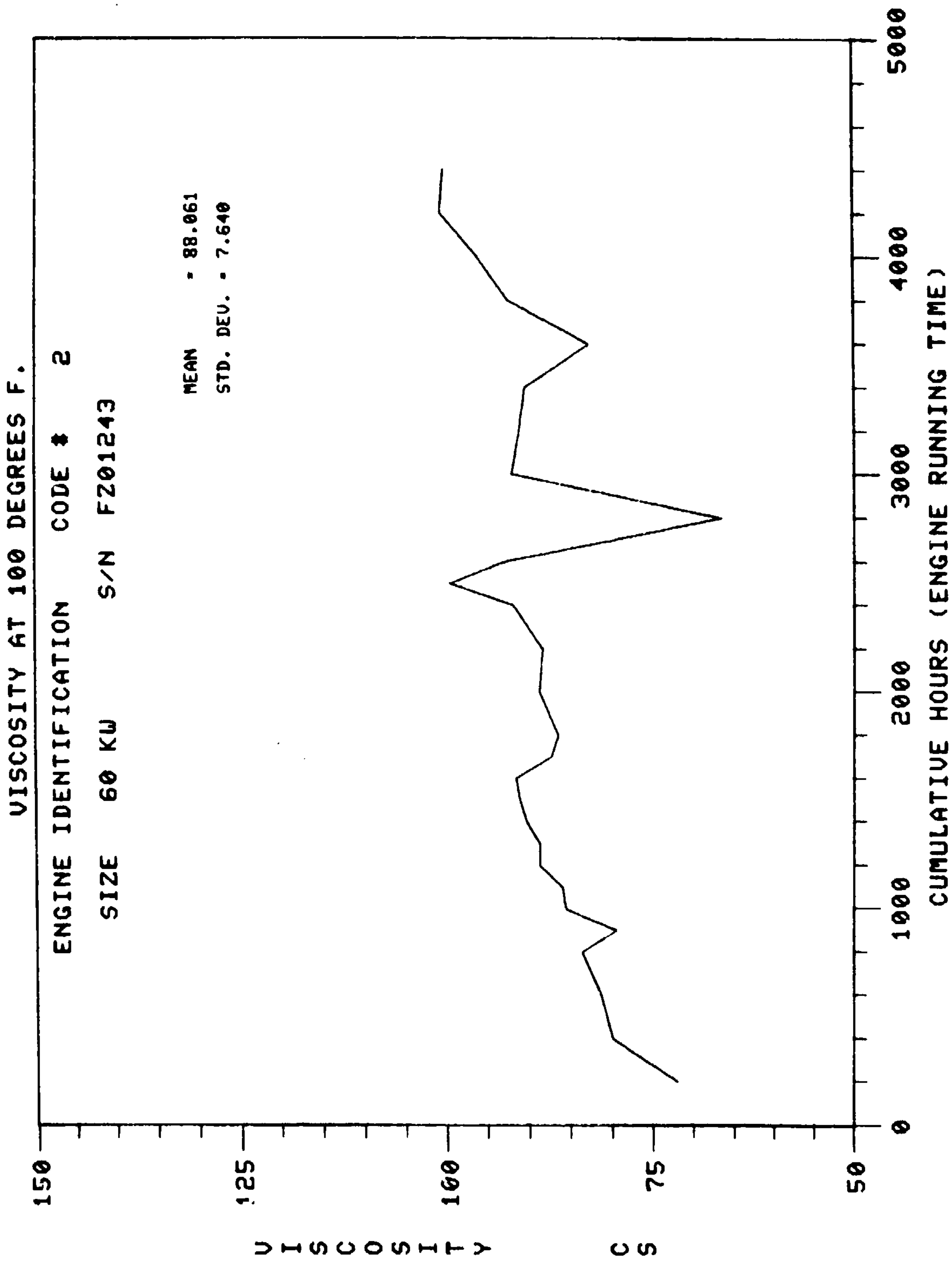
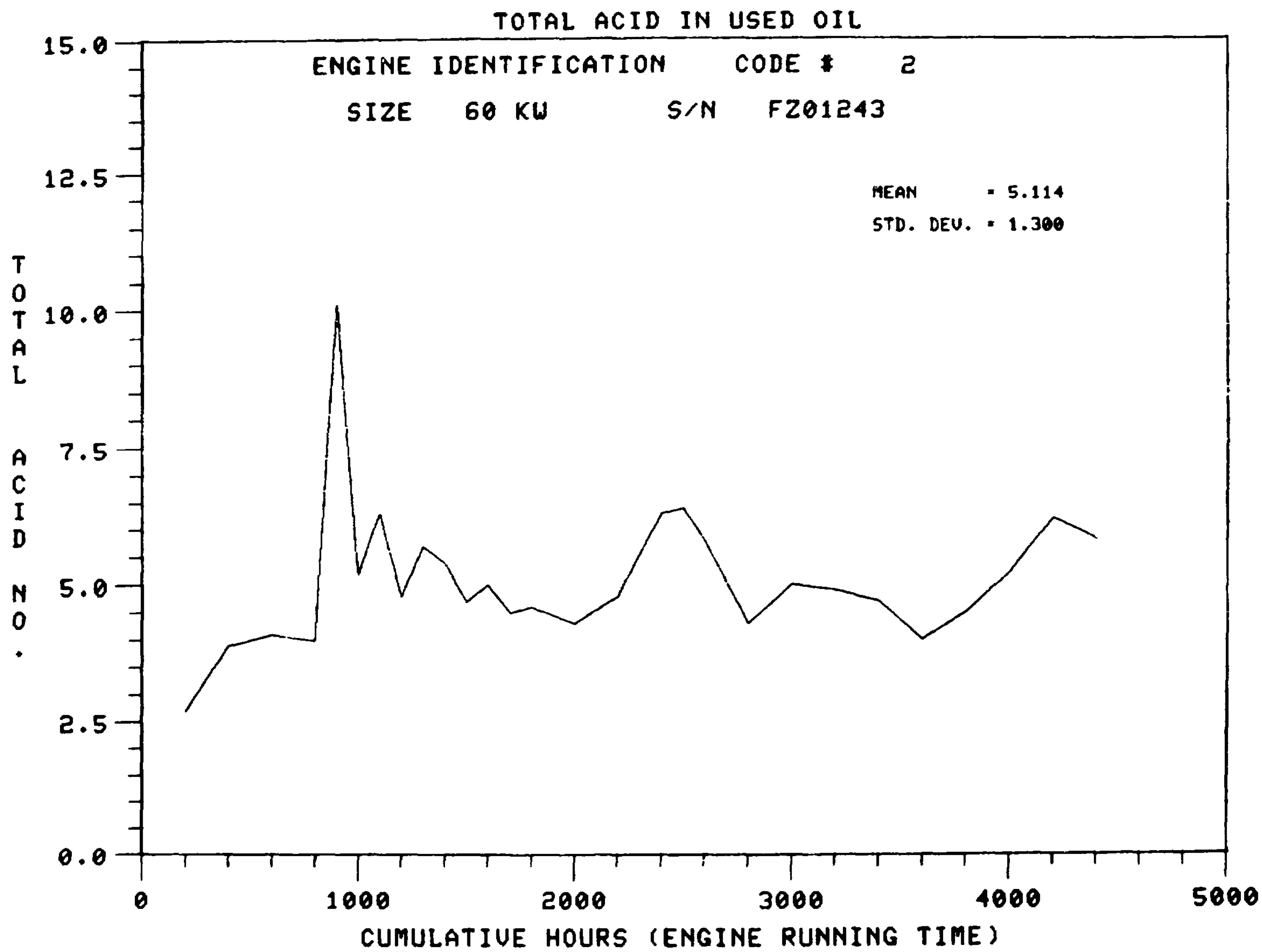
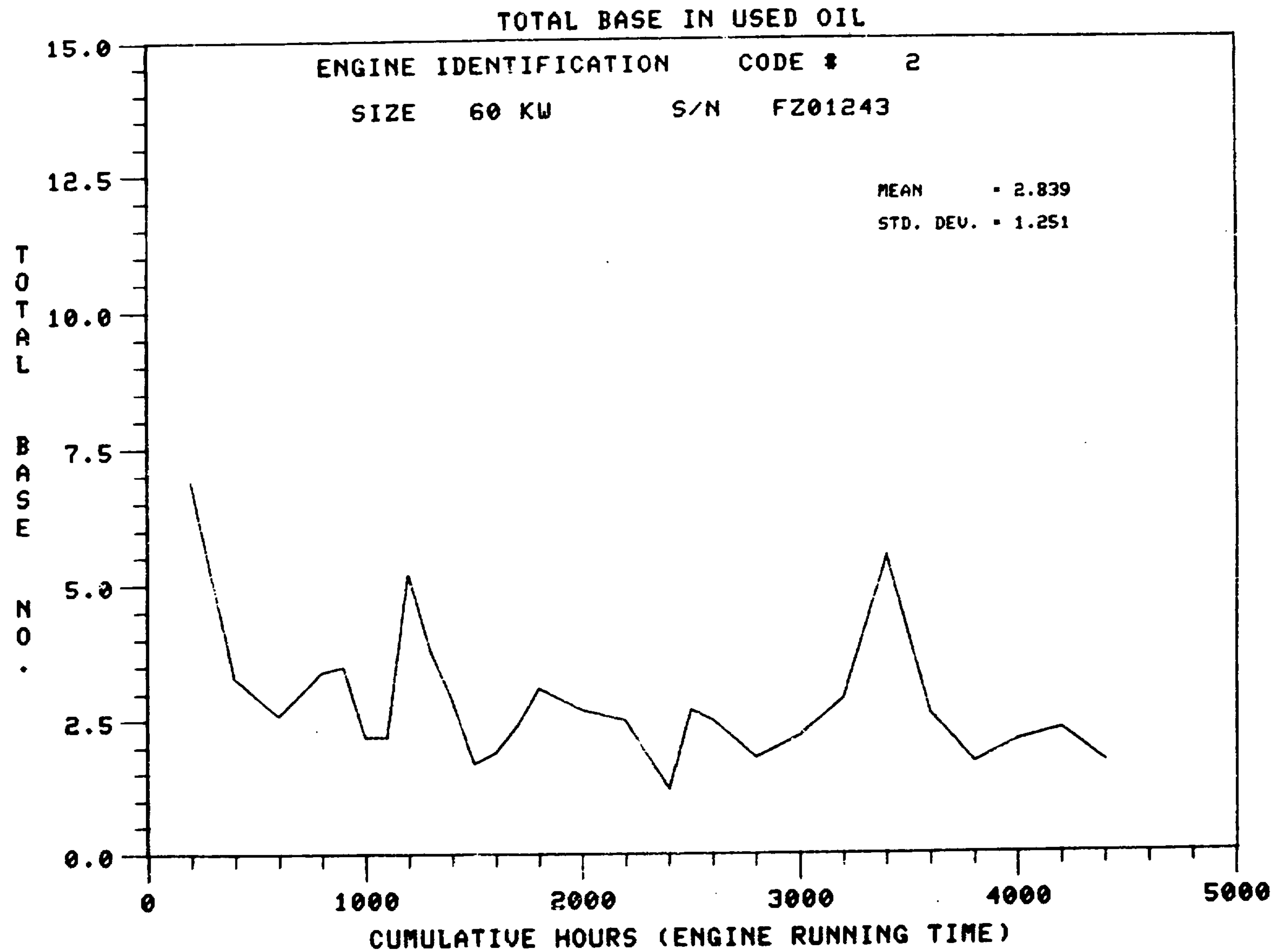
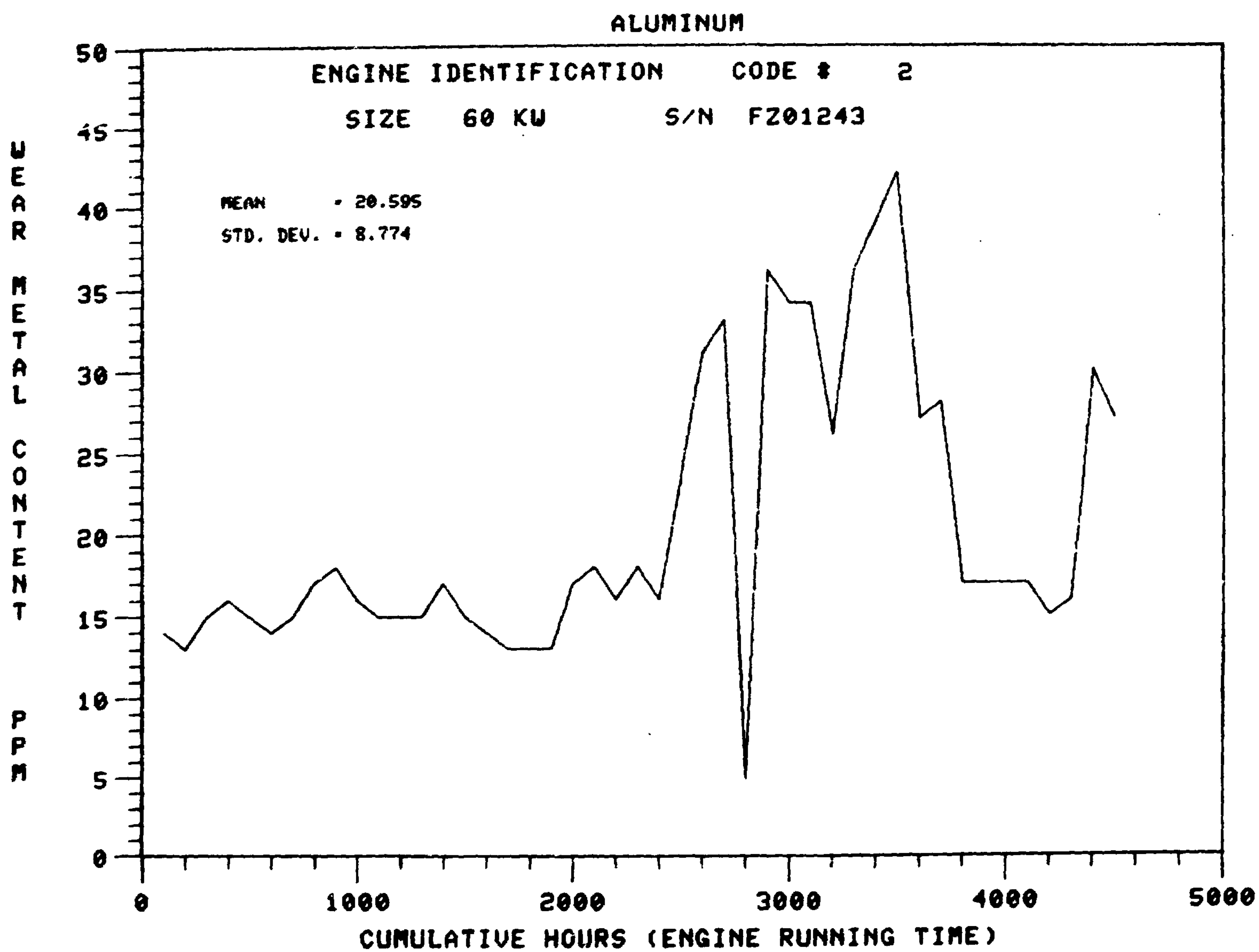
SIZE 60 KW S/N FZ01243
MEAN = 10.639
STD. DEV. = 0.762
VISCOSITY IN CS
20
15
10
5
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

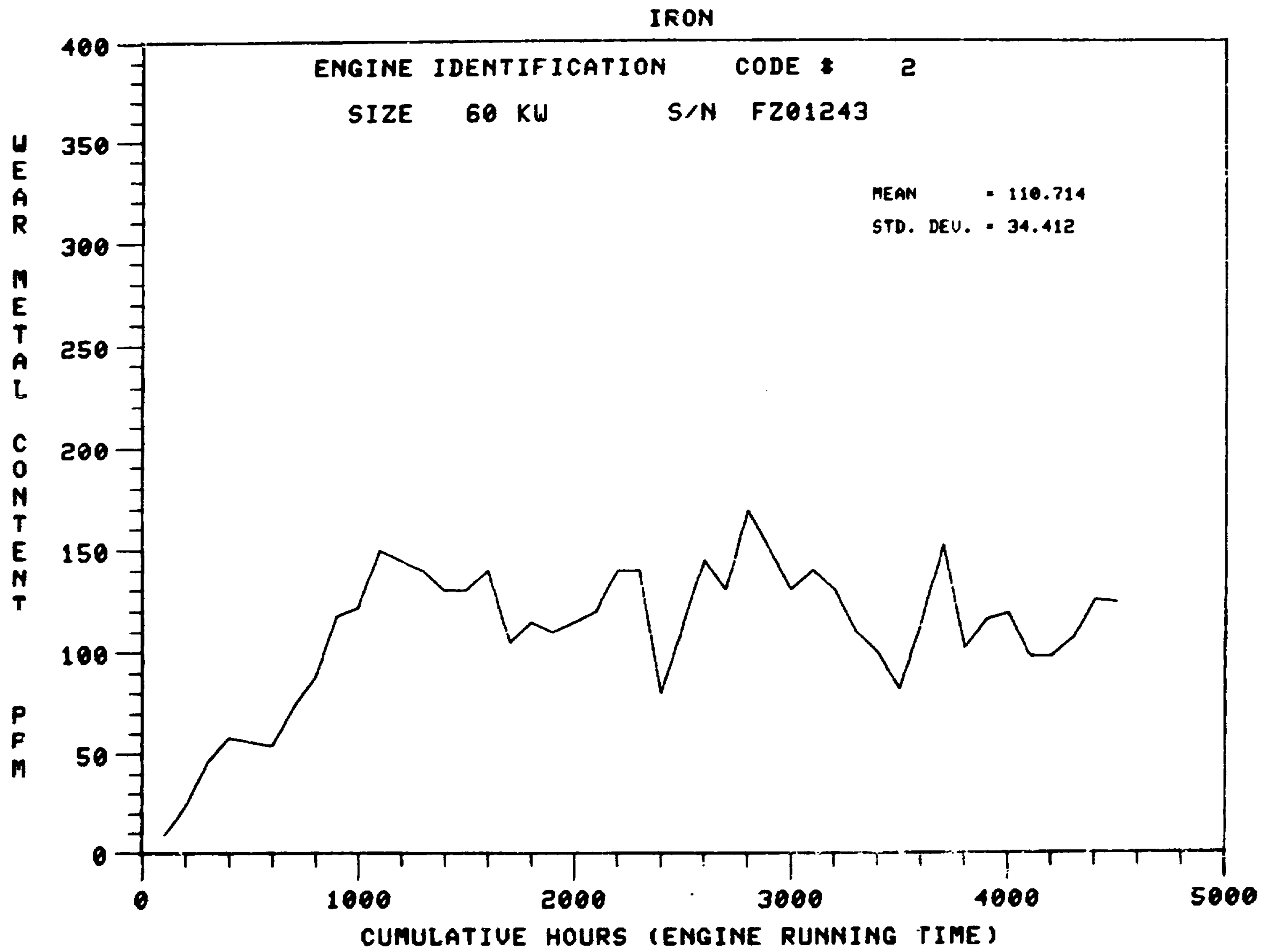

VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 88.061
STD. DEV. = 7.640
150
125
100
75
50
VISCOSITY
CS
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

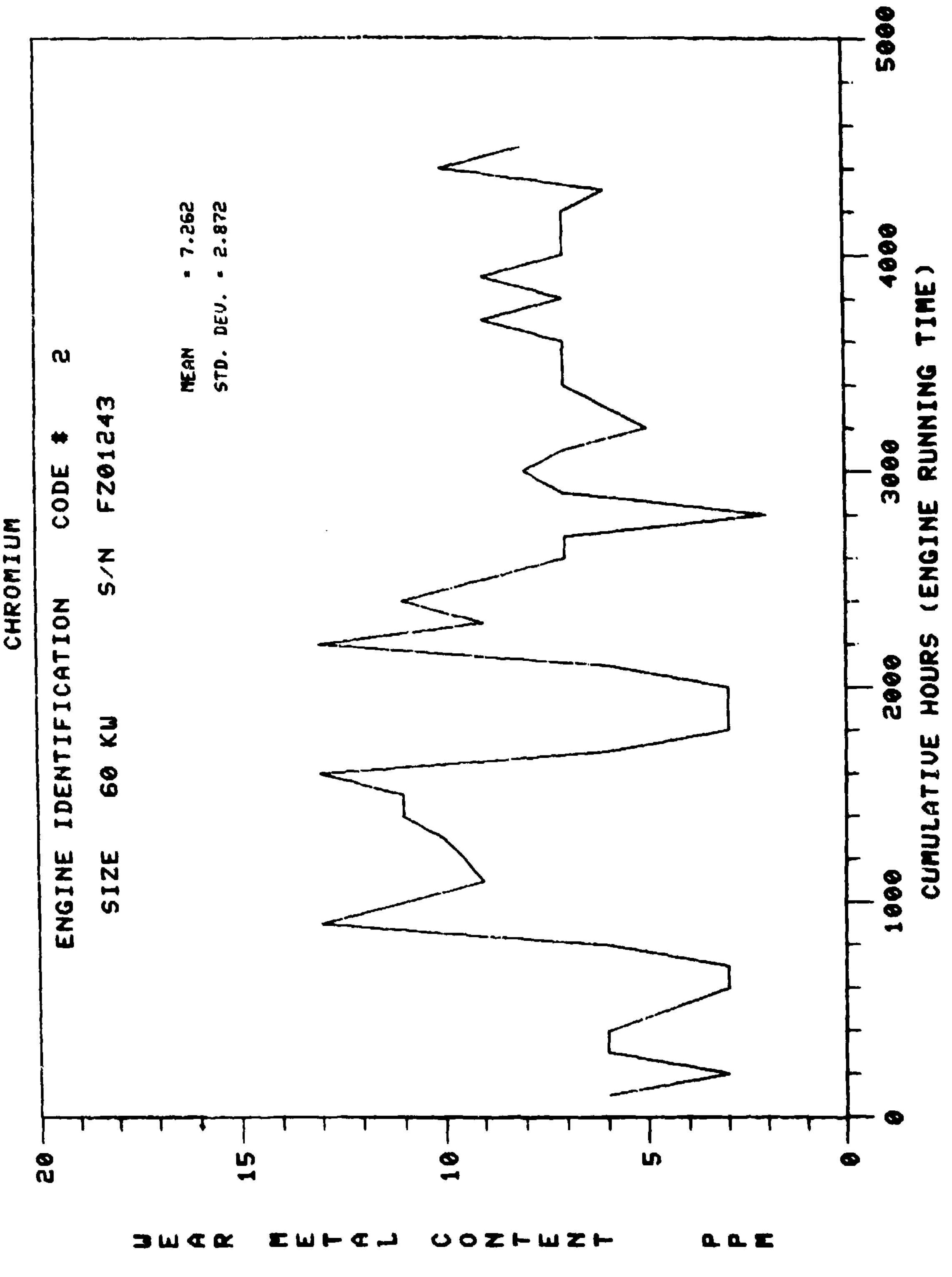

TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 5.114
STD. DEV. = 1.300
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

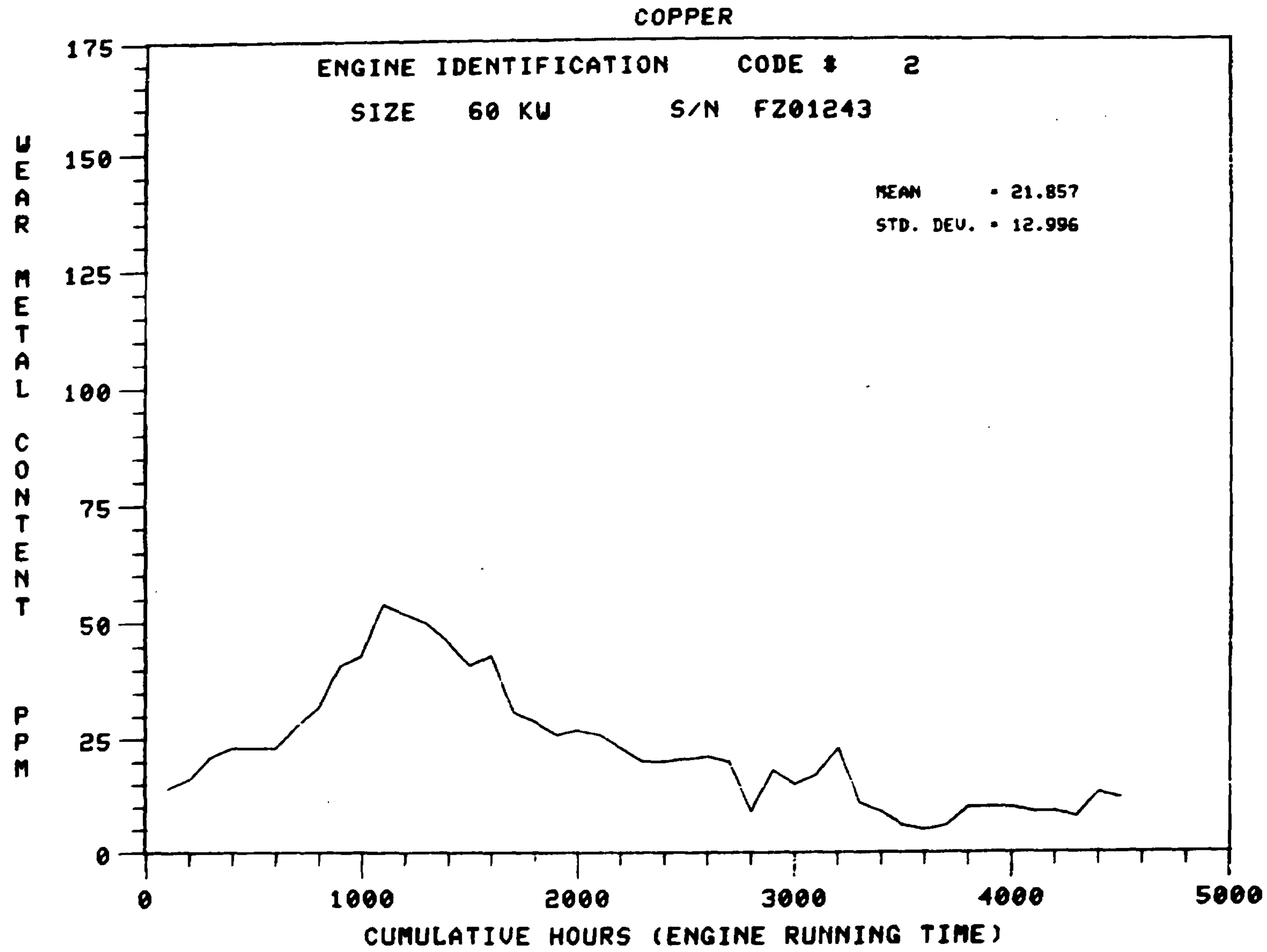

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 2.839
STD. DEV. = 1.251
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

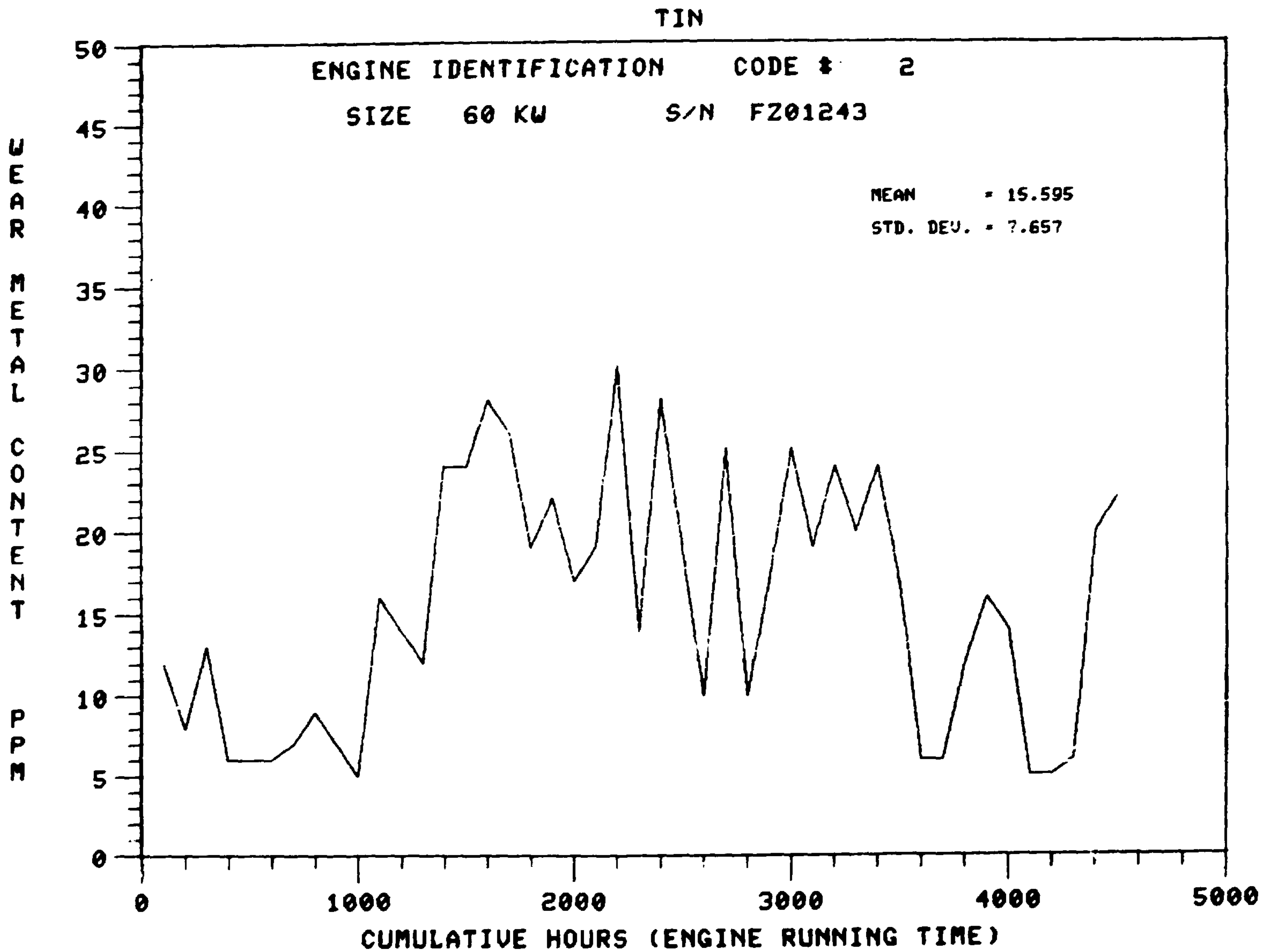


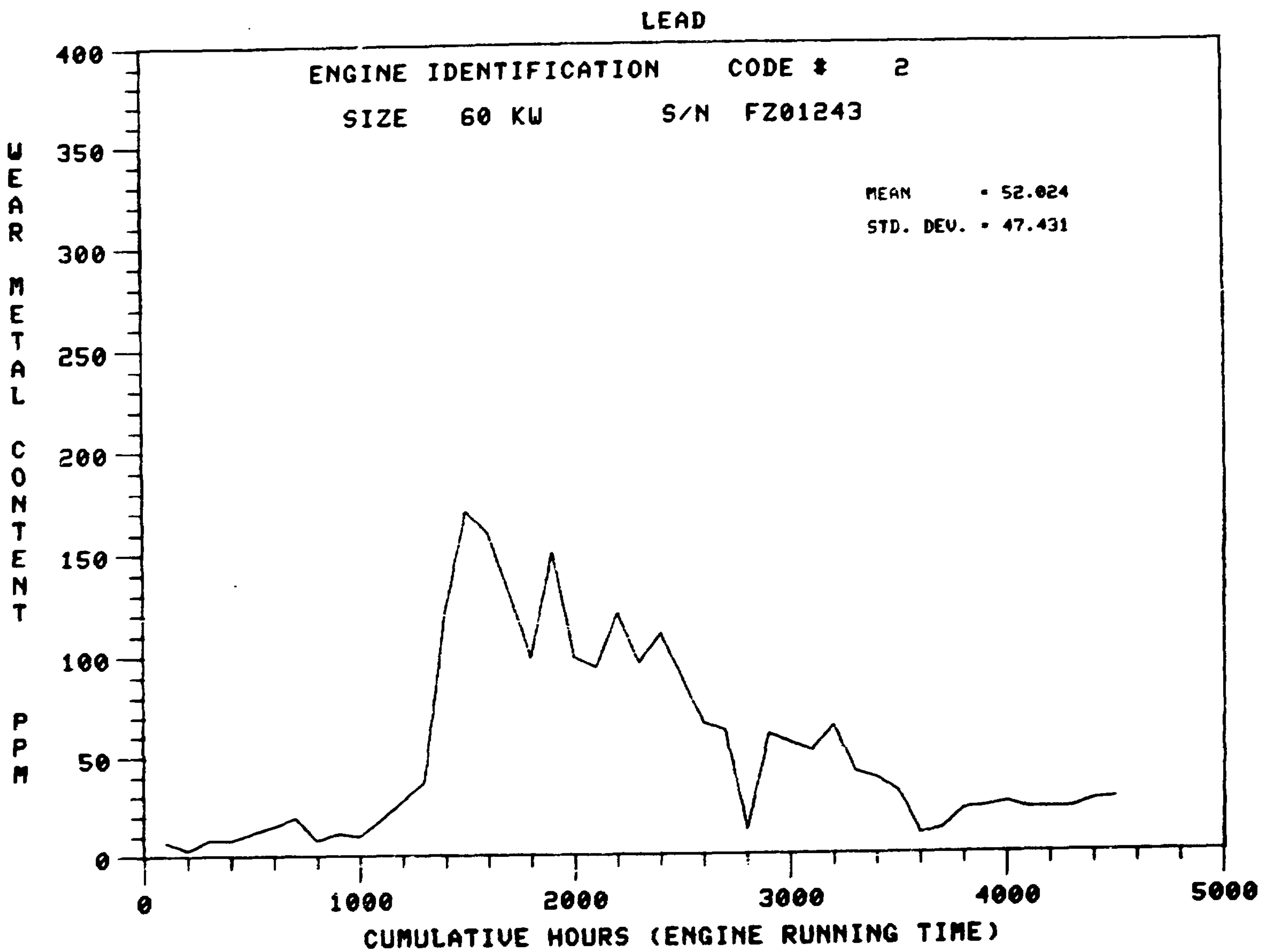
ALUMINUM
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 20.595
STD. DEV. = 8.774
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

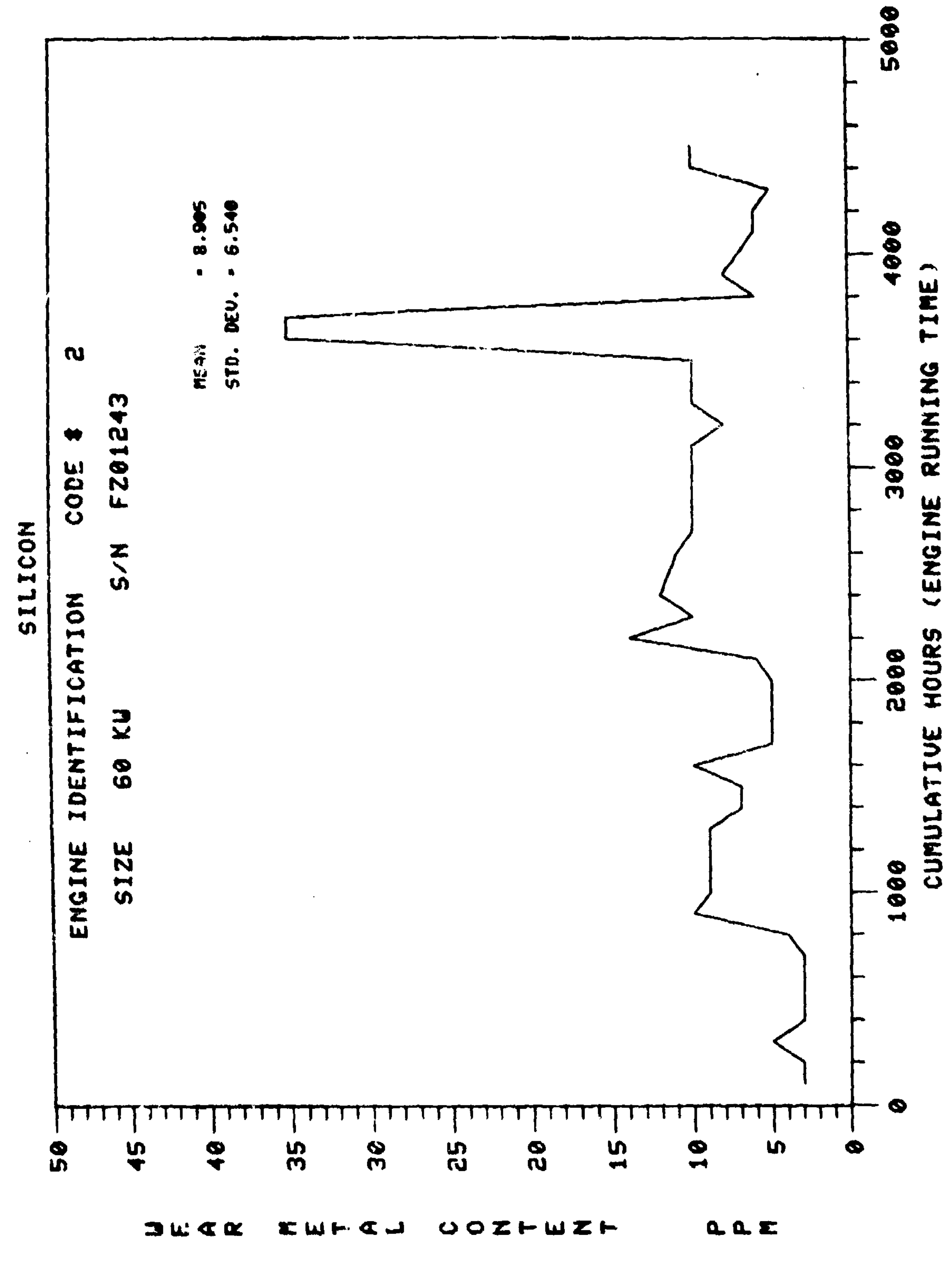

IRON
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 110.714
STD. DEV. = 34.412
WEAR METAL CONTENT PPM
0
50
100
150
200
250
300
350
400
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

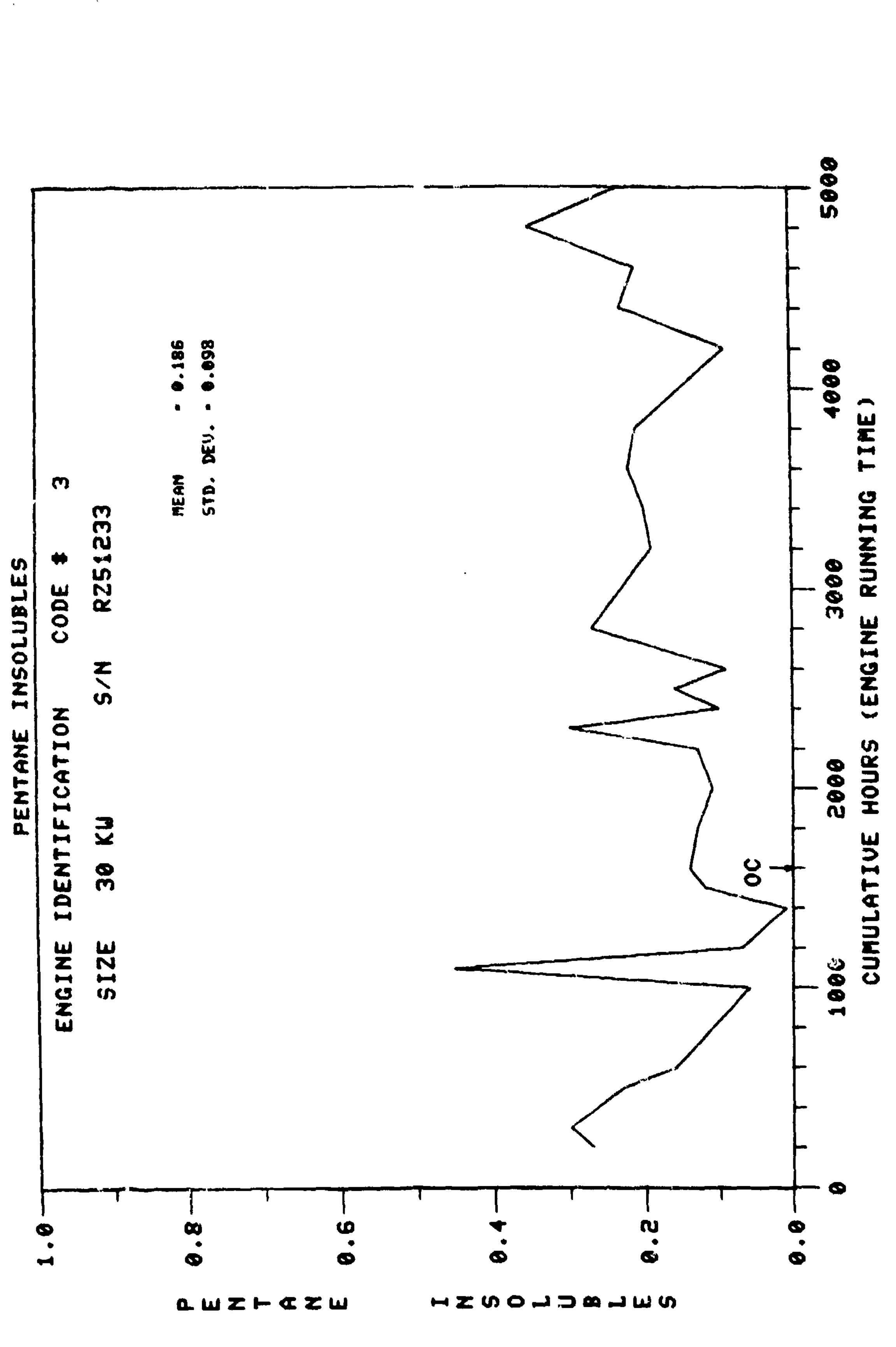

CHROMIUM
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 7.262
STD. DEV. = 2.872
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
WEAR METAL CONTENT PPM

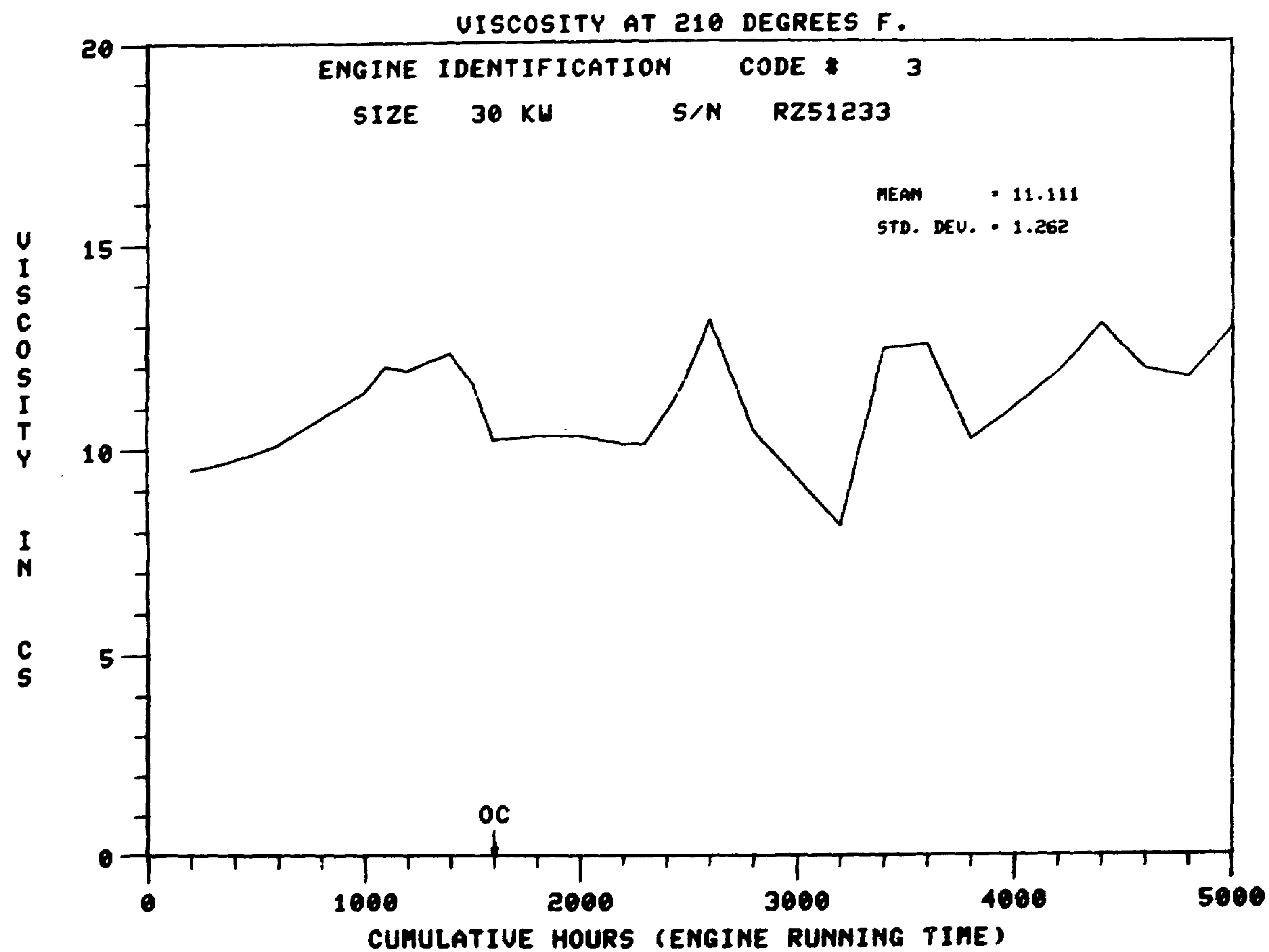

COPPER
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 21.857
STD. DEV. = 12.996
WEAR METAL CONTENT PPM
0
25
50
75
100
125
150
175
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

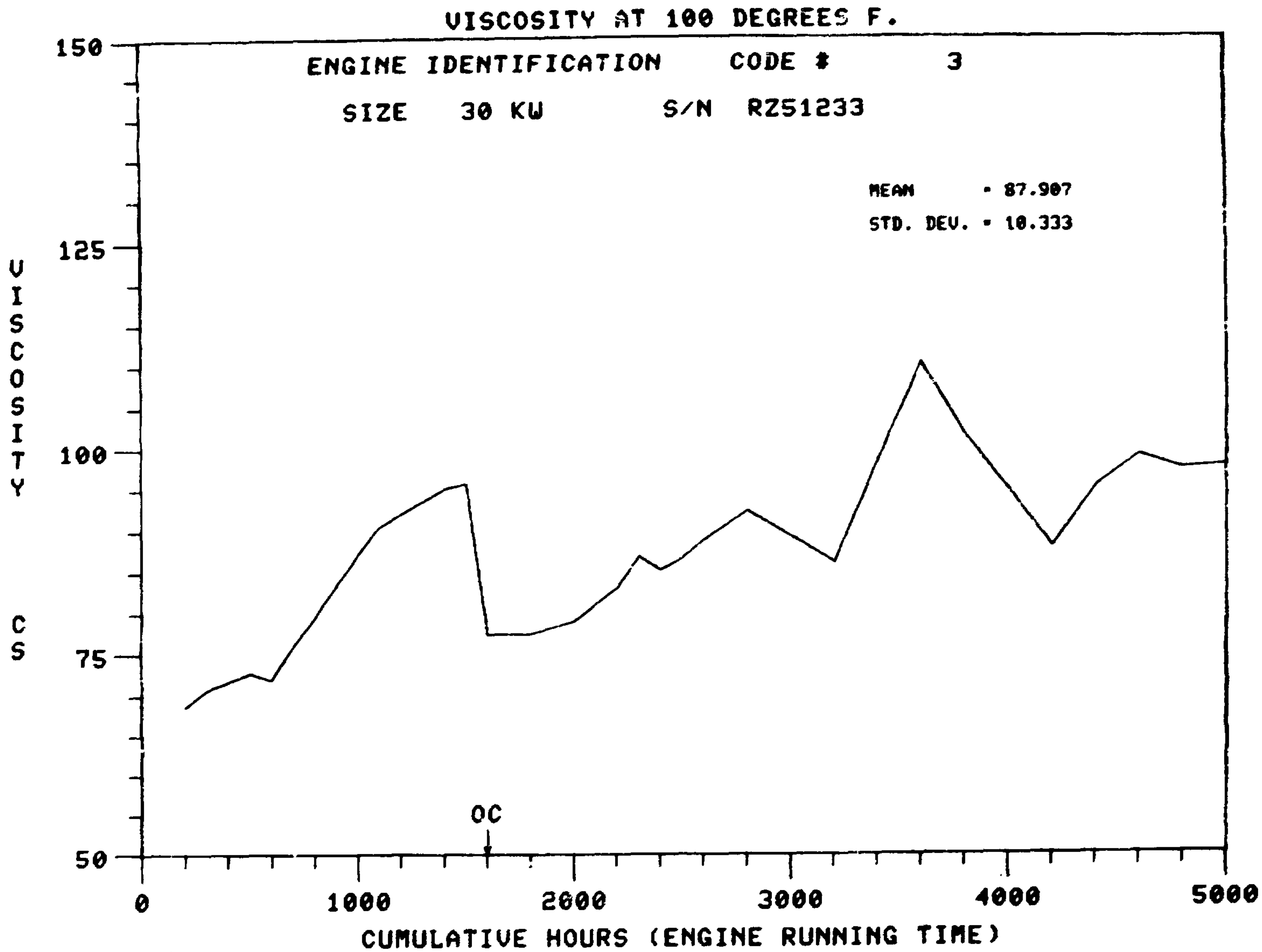

TIN
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 15.595
STD. DEV. = 7.657
WEAR METAL CONTENT PPM
50
45
40
35
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

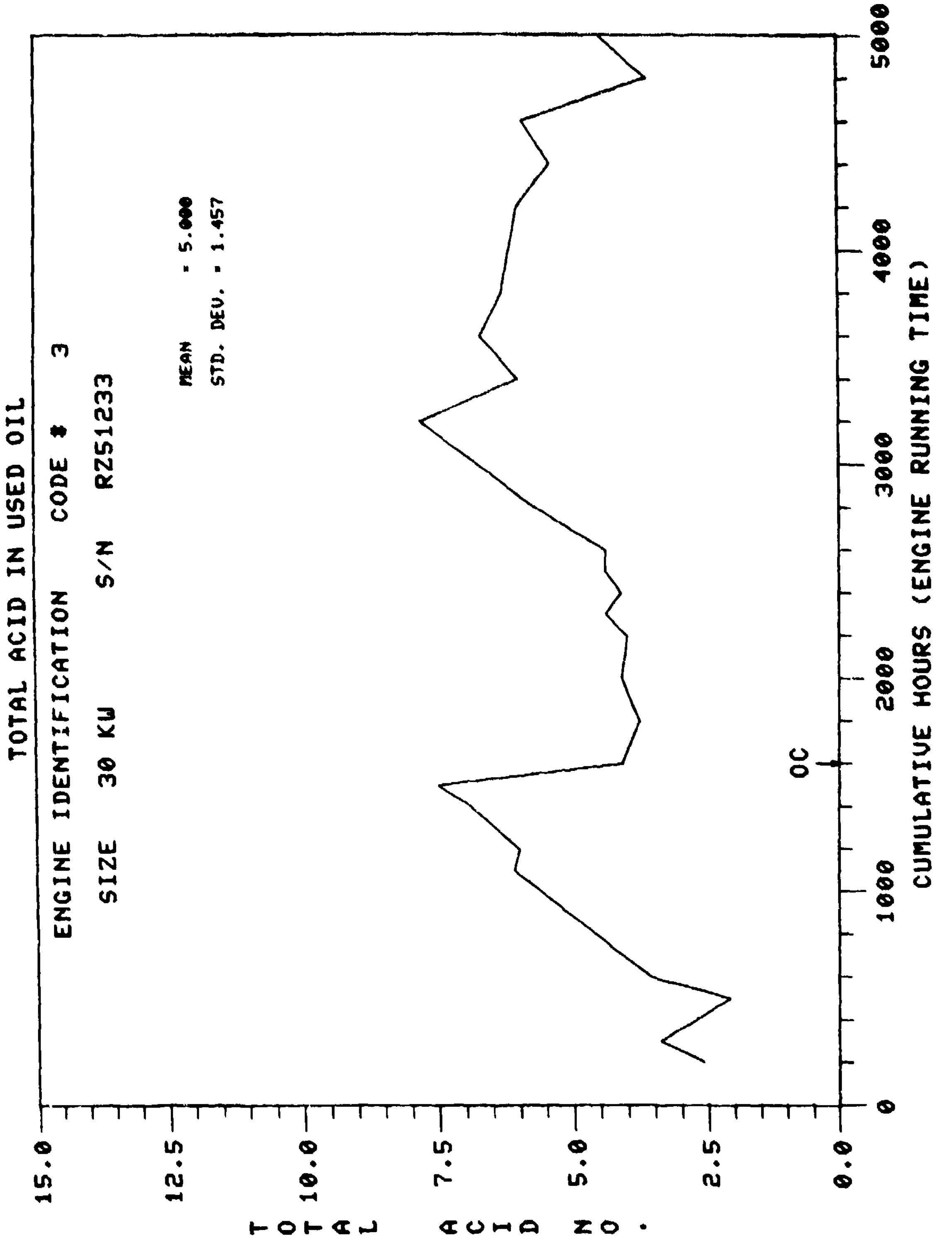

LEAD
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 52.024
STD. DEV. = 47.431
WEAR METAL CONTENT PPM
400
350
300
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


SILICON
ENGINE IDENTIFICATION CODE # 2
SIZE 60 KW S/N FZ01243
MEAN = 8.905
STD. DEV. = 6.540
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
25
30
35
40
45
50
WEAR METAL CONTENT PPM

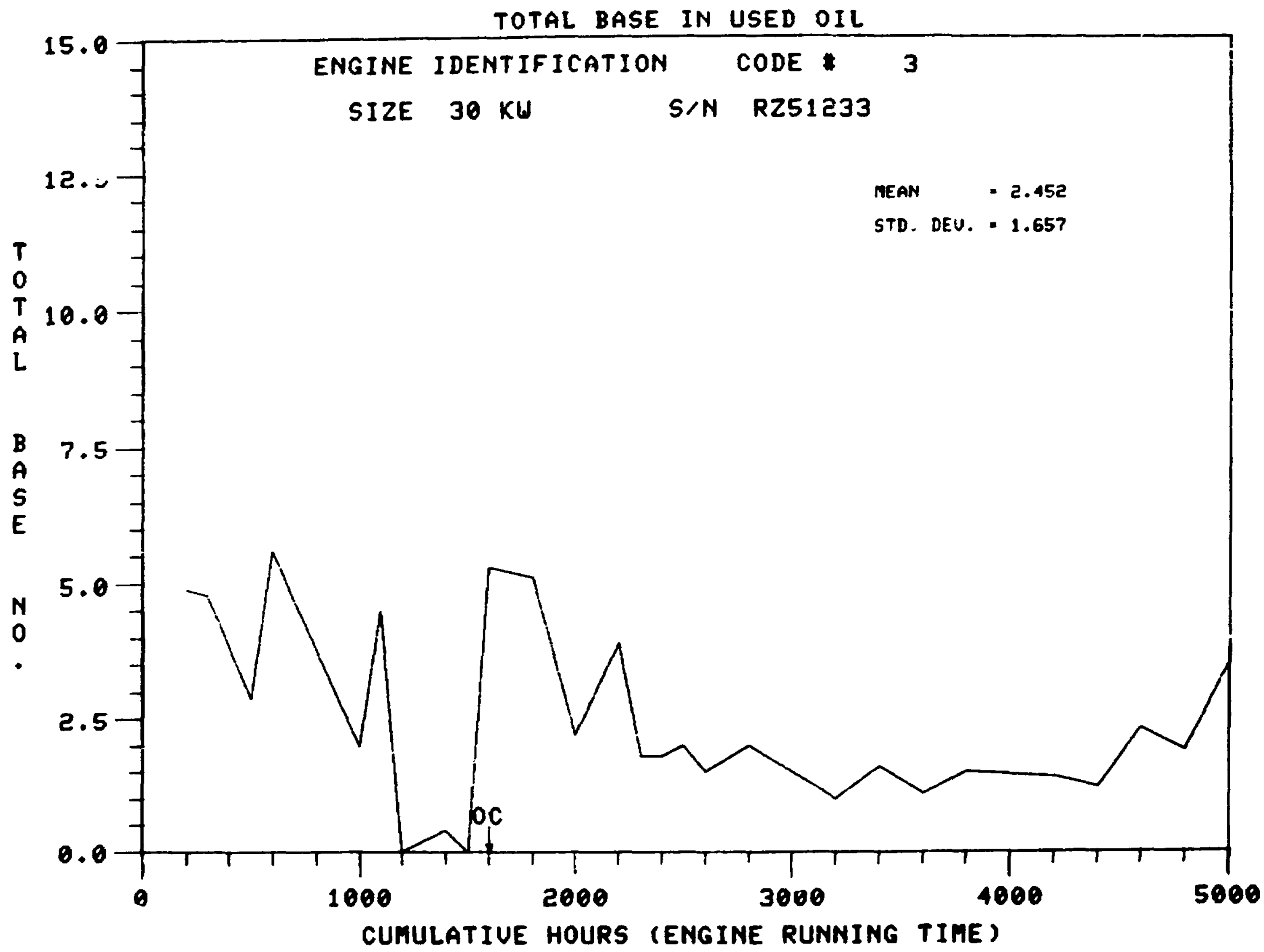

PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 0.186
STD. DEV. = 0.098
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
PENTANE INSOLUBLES
0.0
0.2
0.4
0.6
0.8
1.0


VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 11.111
STD. DEV. = 1.262
VISCOSITY IN CS
20
15
10
5
0
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

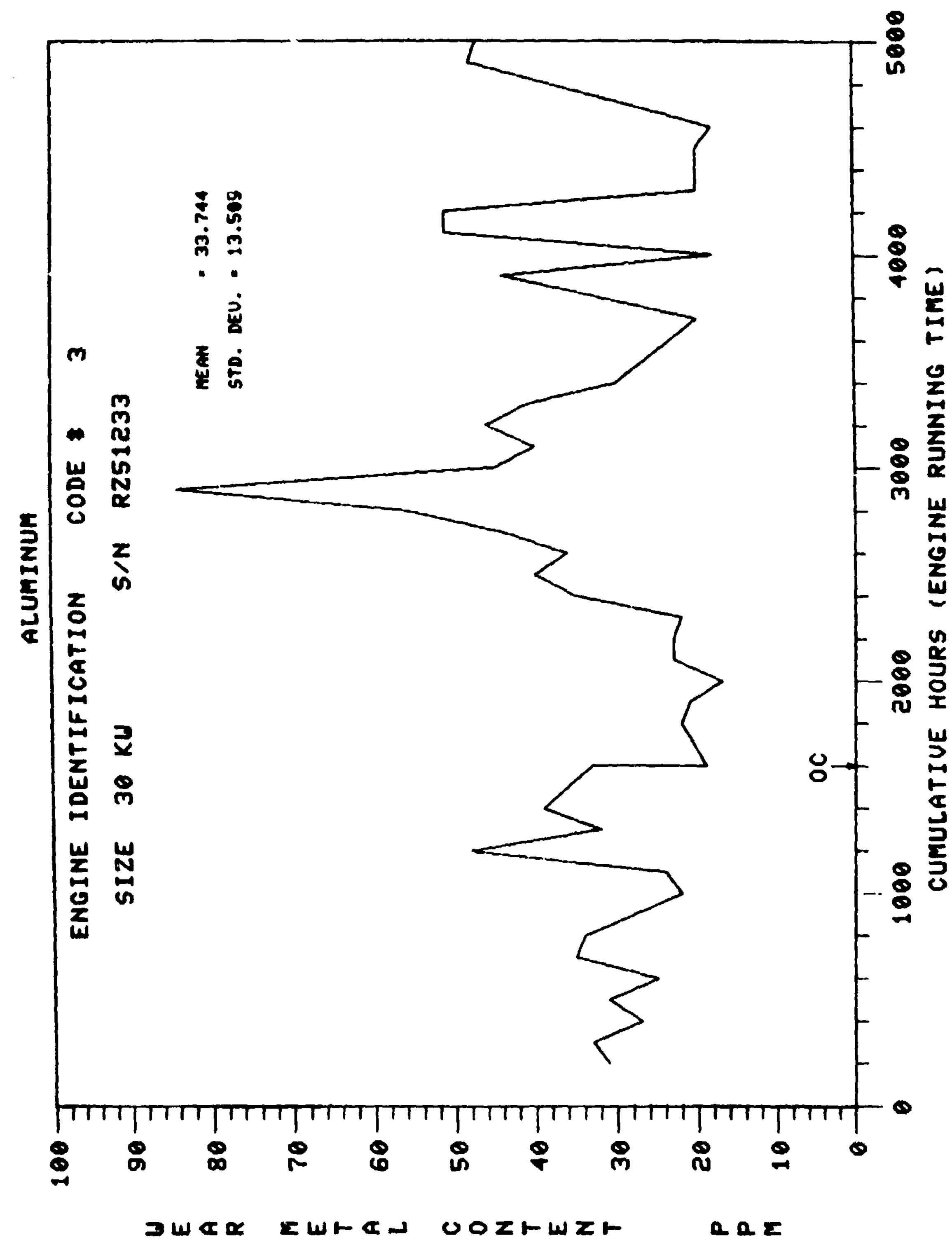

VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 87.907
STD. DEV. = 10.333
VISCOSITY CS
150
125
100
75
50
0
1000
2000
3000
4000
5000
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)

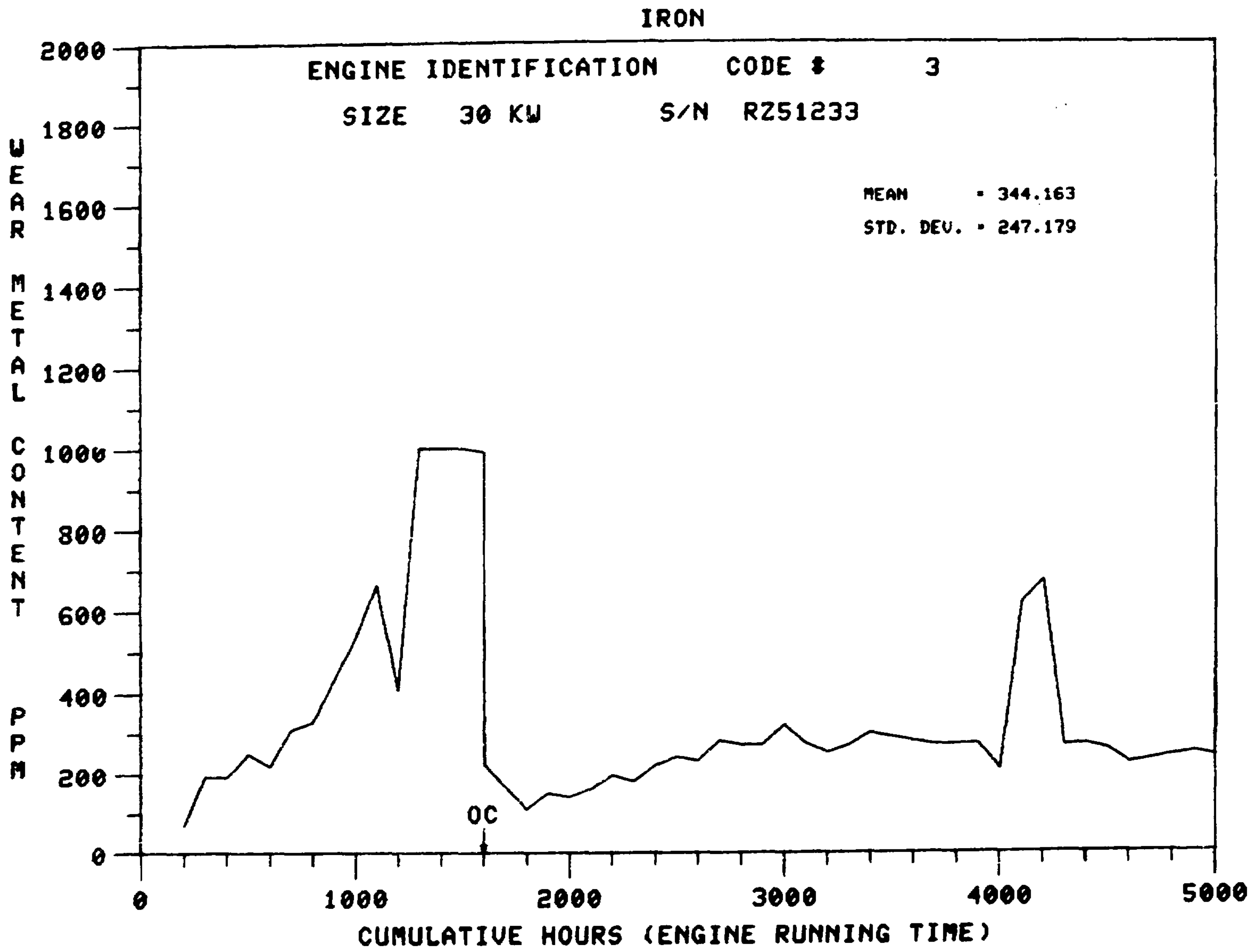


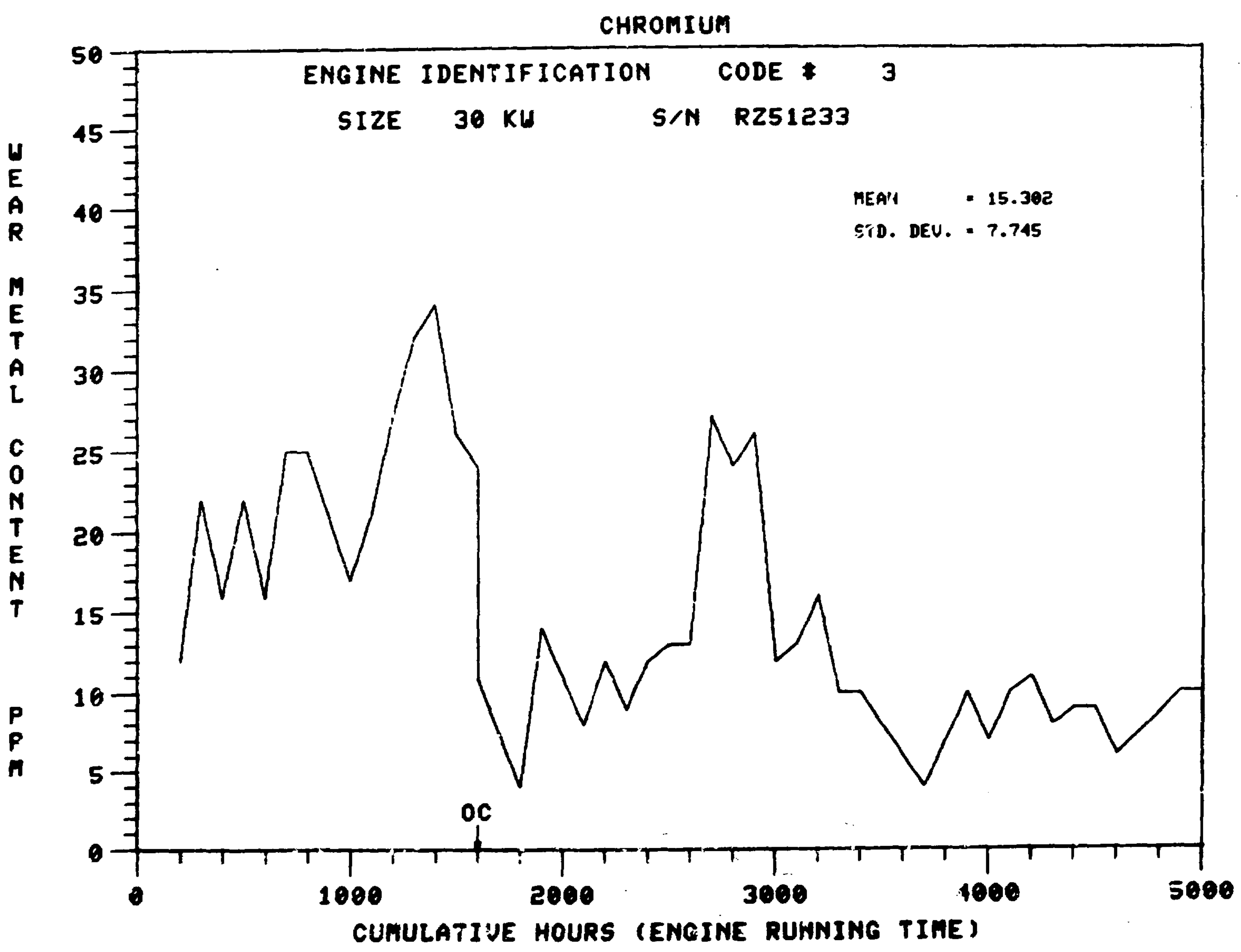
TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 5.000
STD. DEV. = 1.457
OC
TOTAL ACID NO.
0.0
2.5
5.0
7.5
10.0
12.5
15.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

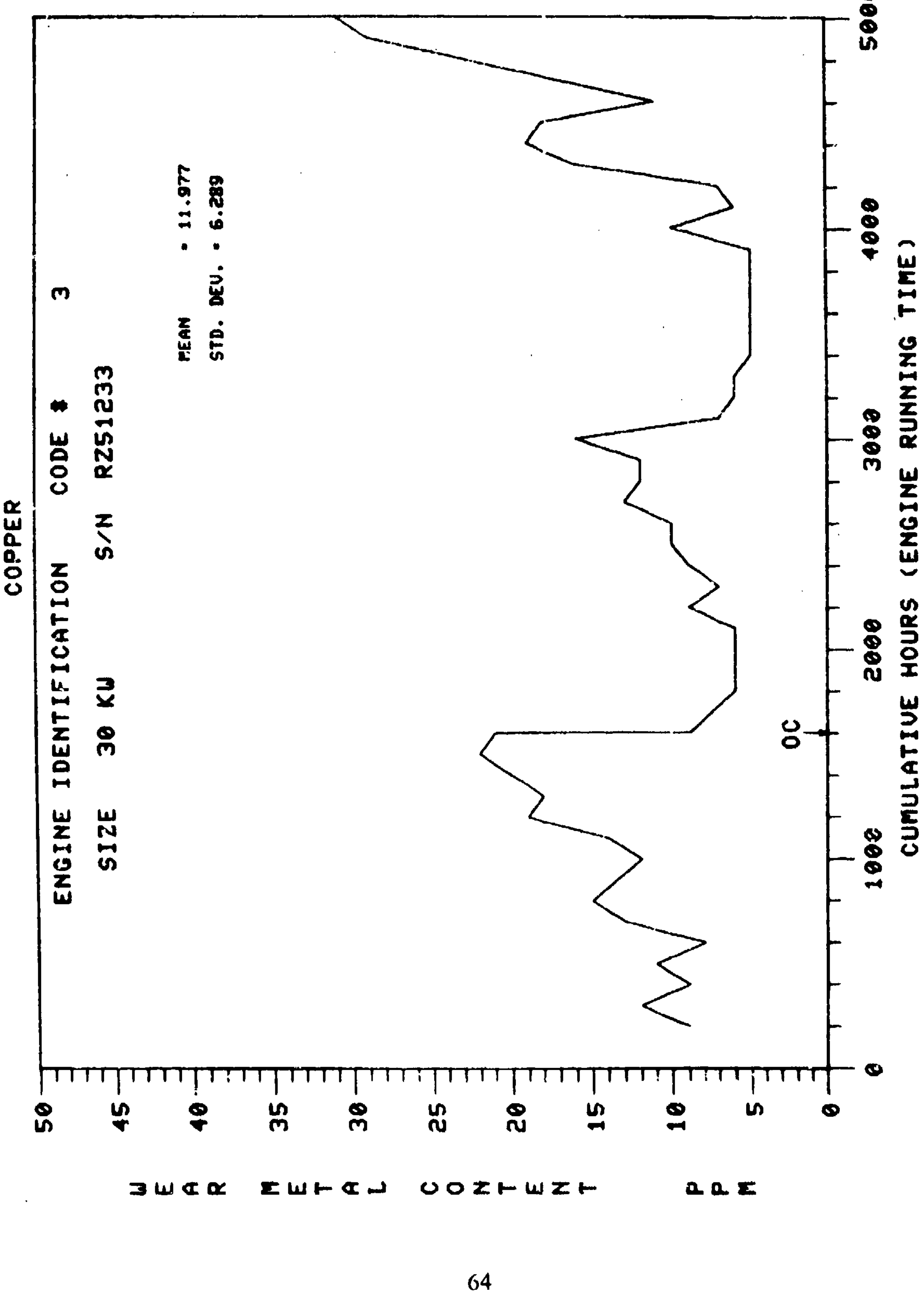


TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 2.452
STD. DEV. = 1.657
OC
TOTAL BASE NO.
15.0
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

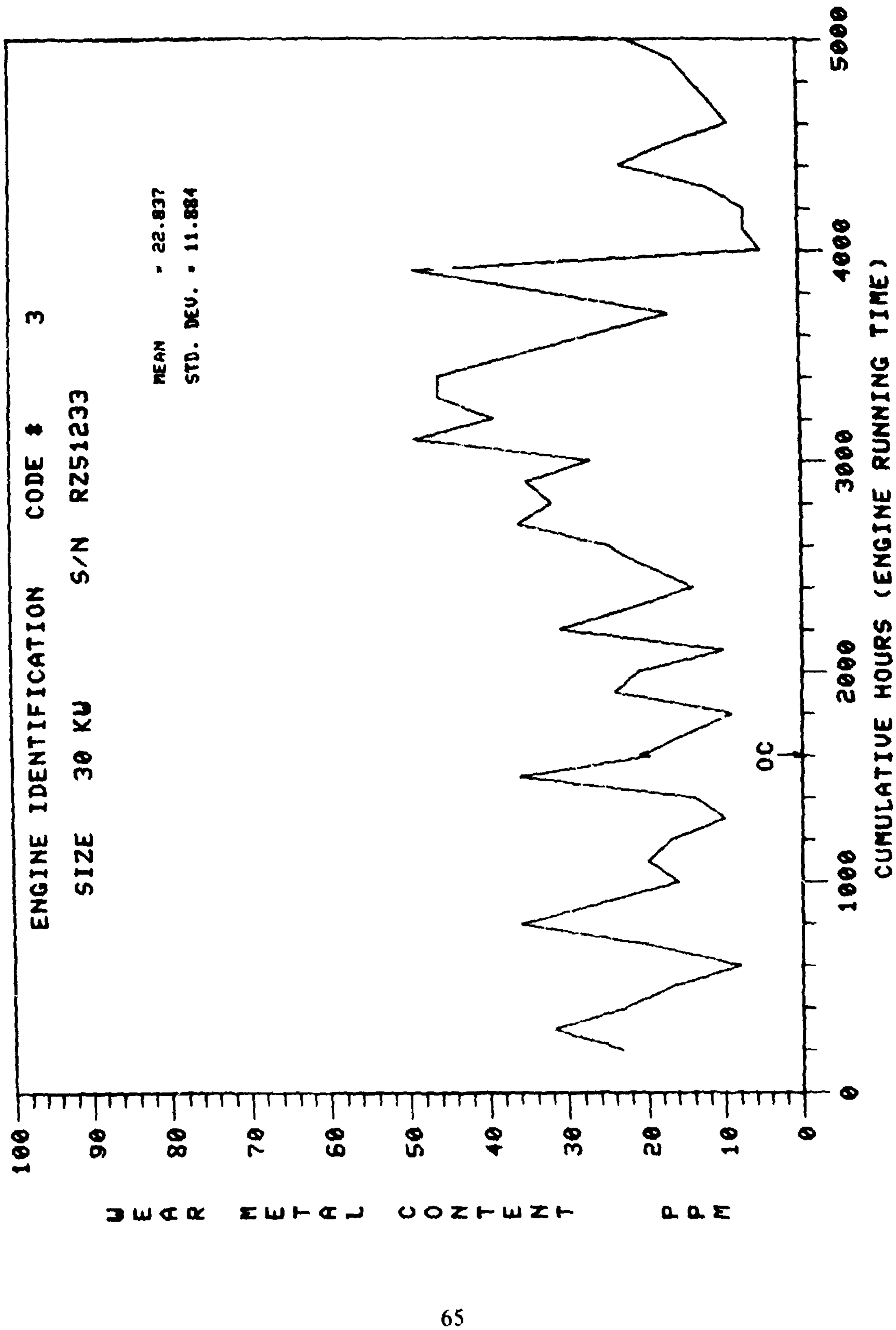

ALUMINUM
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 33.744
STD. DEV. = 13.509
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
10
20
30
40
50
60
70
80
90
100


IRON
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 344.163
STD. DEV. = 247.179
WEAR METAL CONTENT PPM
2000
1800
1600
1400
1200
1000
800
600
400
200
0
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

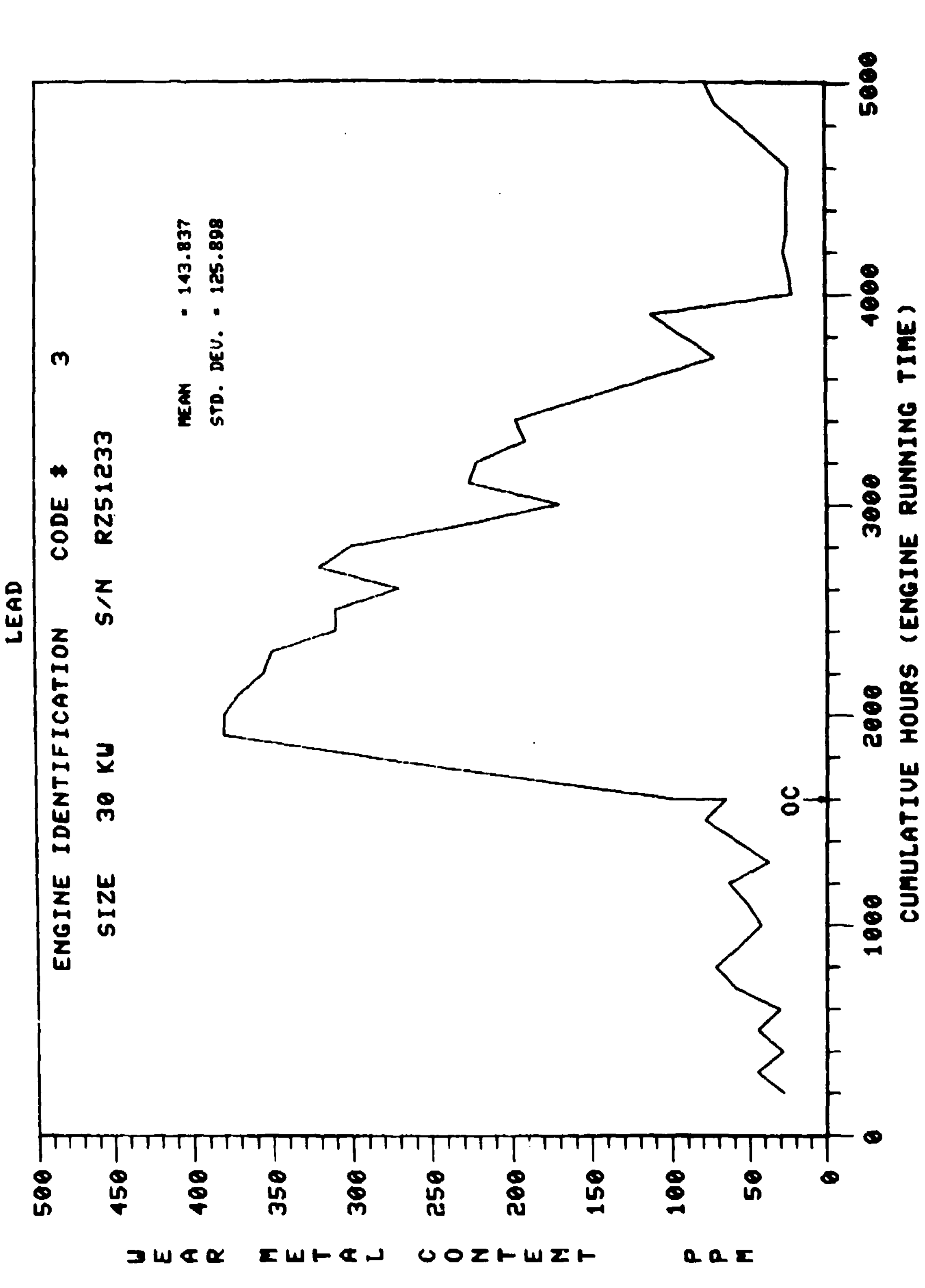

CHROMIUM
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 15.302
STD. DEV. = 7.745
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)



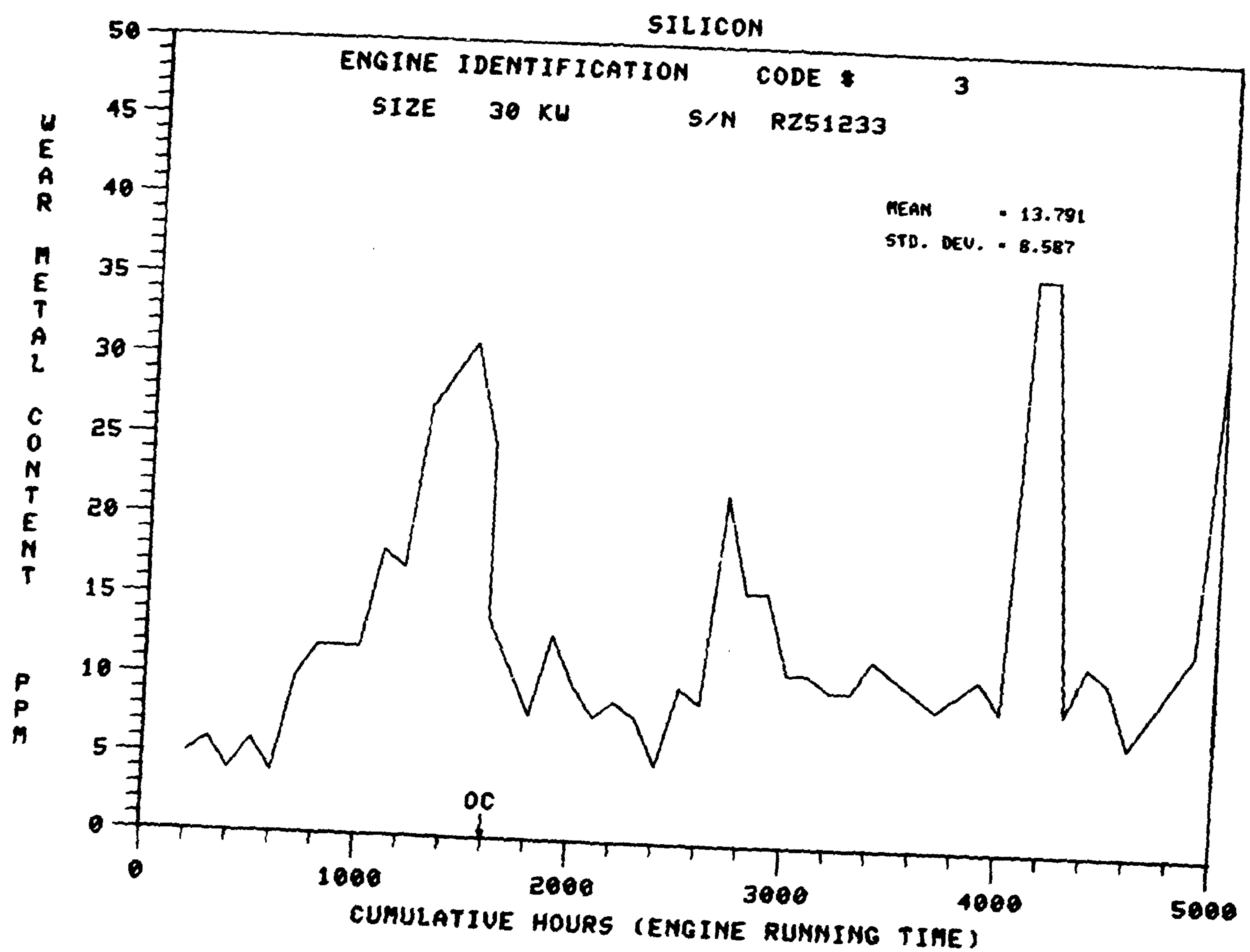
COPPER
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 11.977
STD. DEV. = 6.289
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50

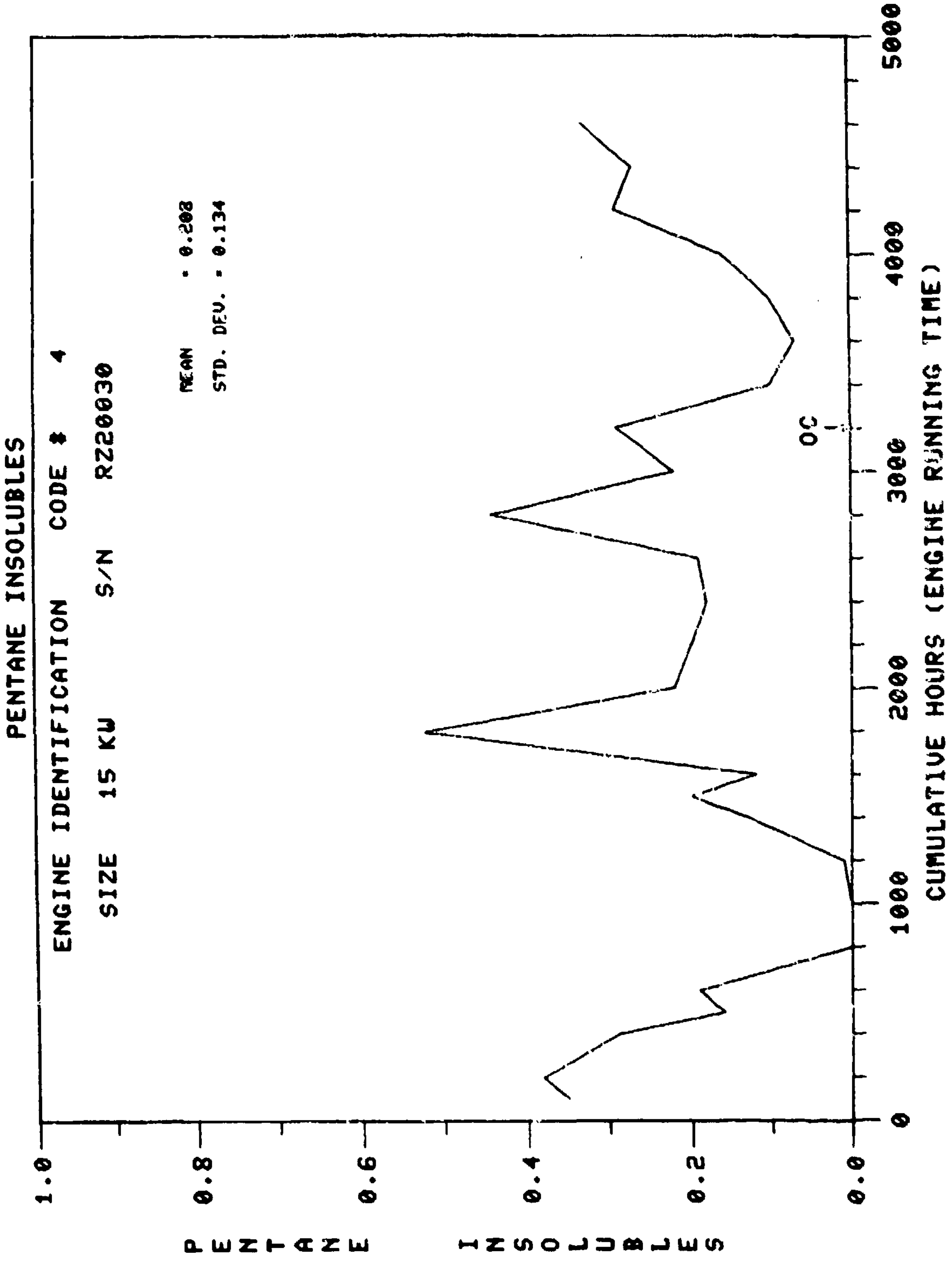


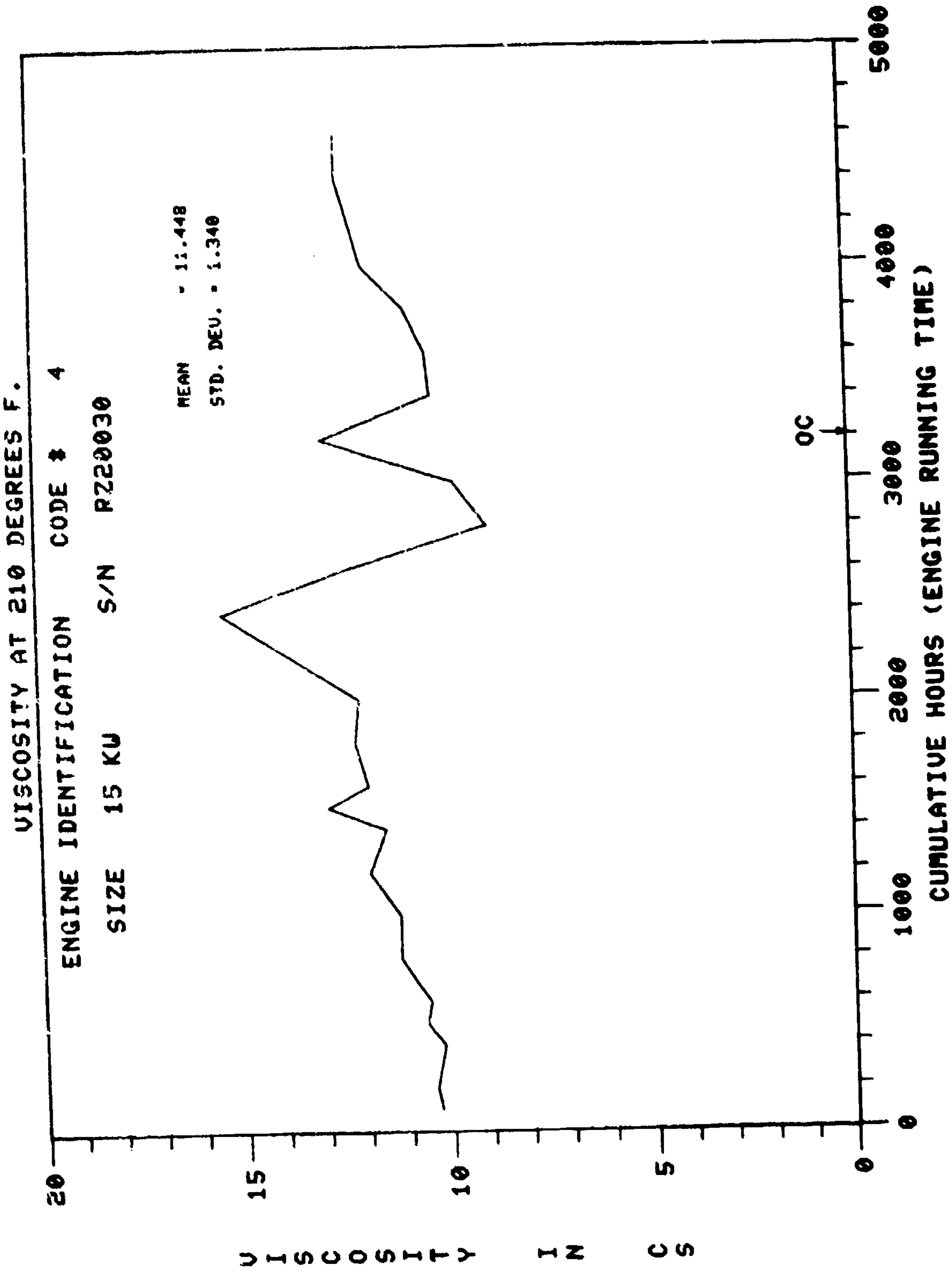
TIN
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 22.837
STD. DEV. = 11.884
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
WEAR METAL CONTENT PPM
0
1000
2000
3000
4000
5000
0
10
20
30
40
50
60
70
80
90
100

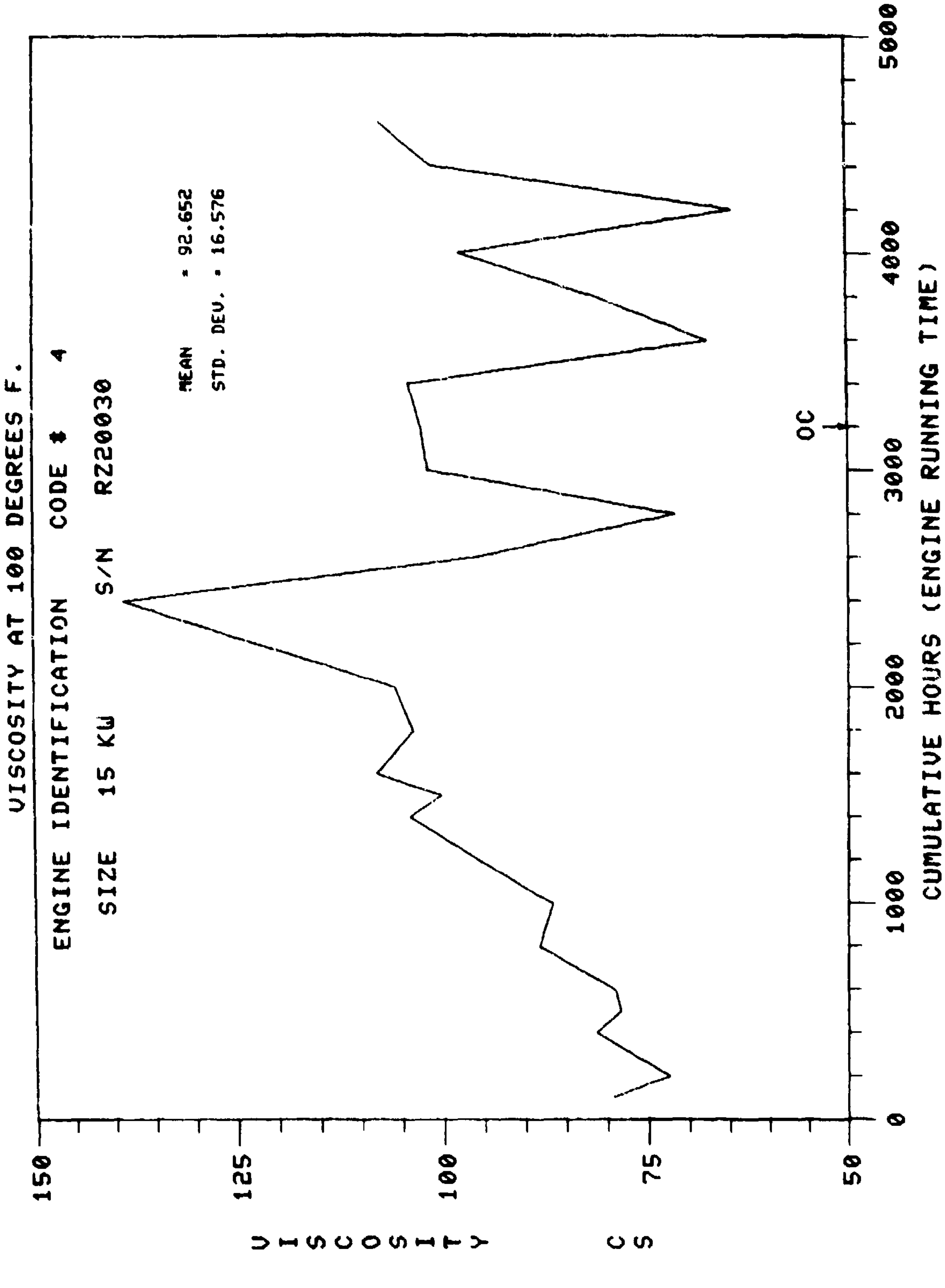


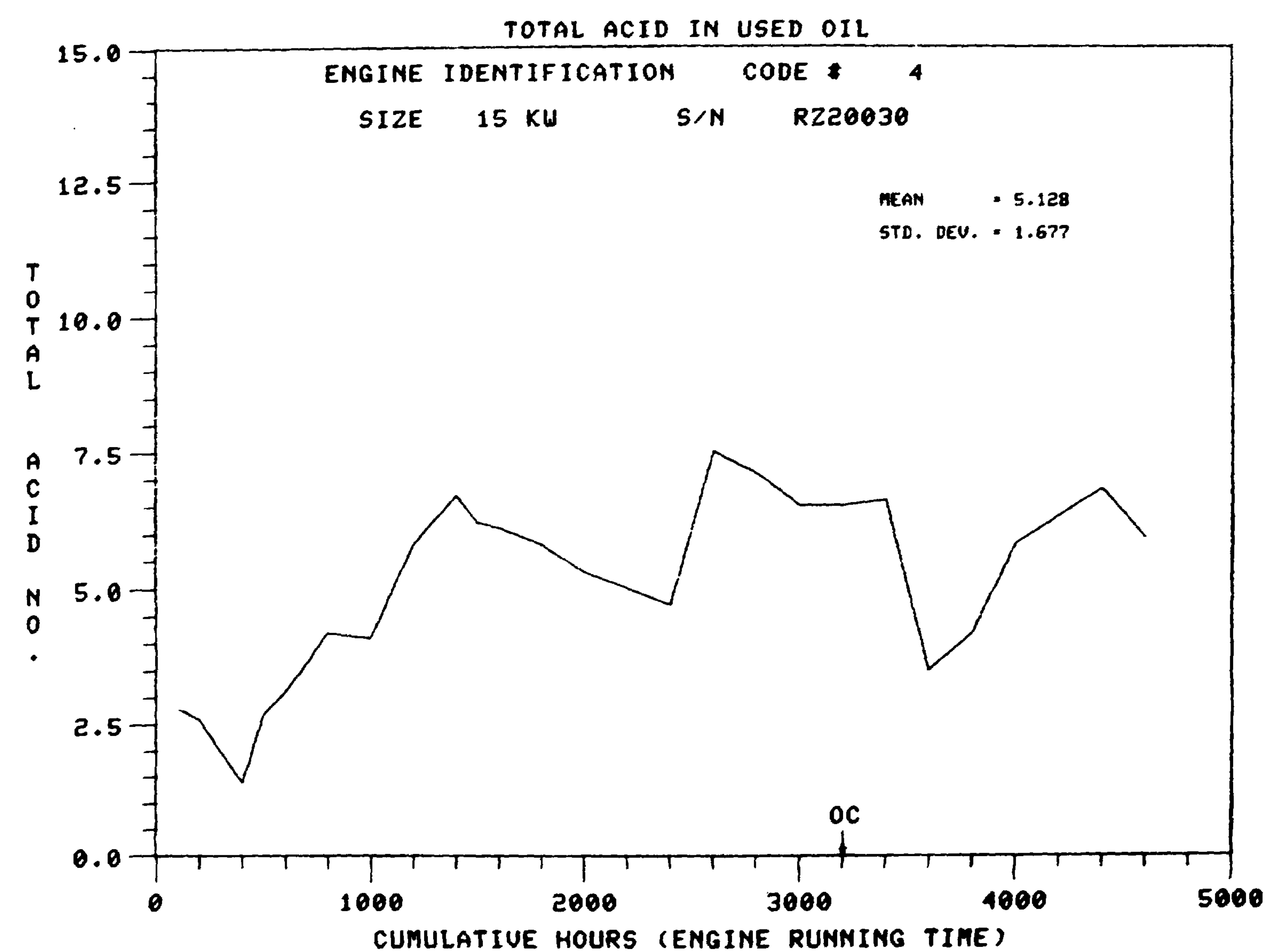
LEAD
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 143.837
STD. DEV. = 125.898
OC
0 1000 2000 3000 4000 5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0 50 100 150 200 250 300 350 400 450 500
WEAR METAL CONTENT PPM

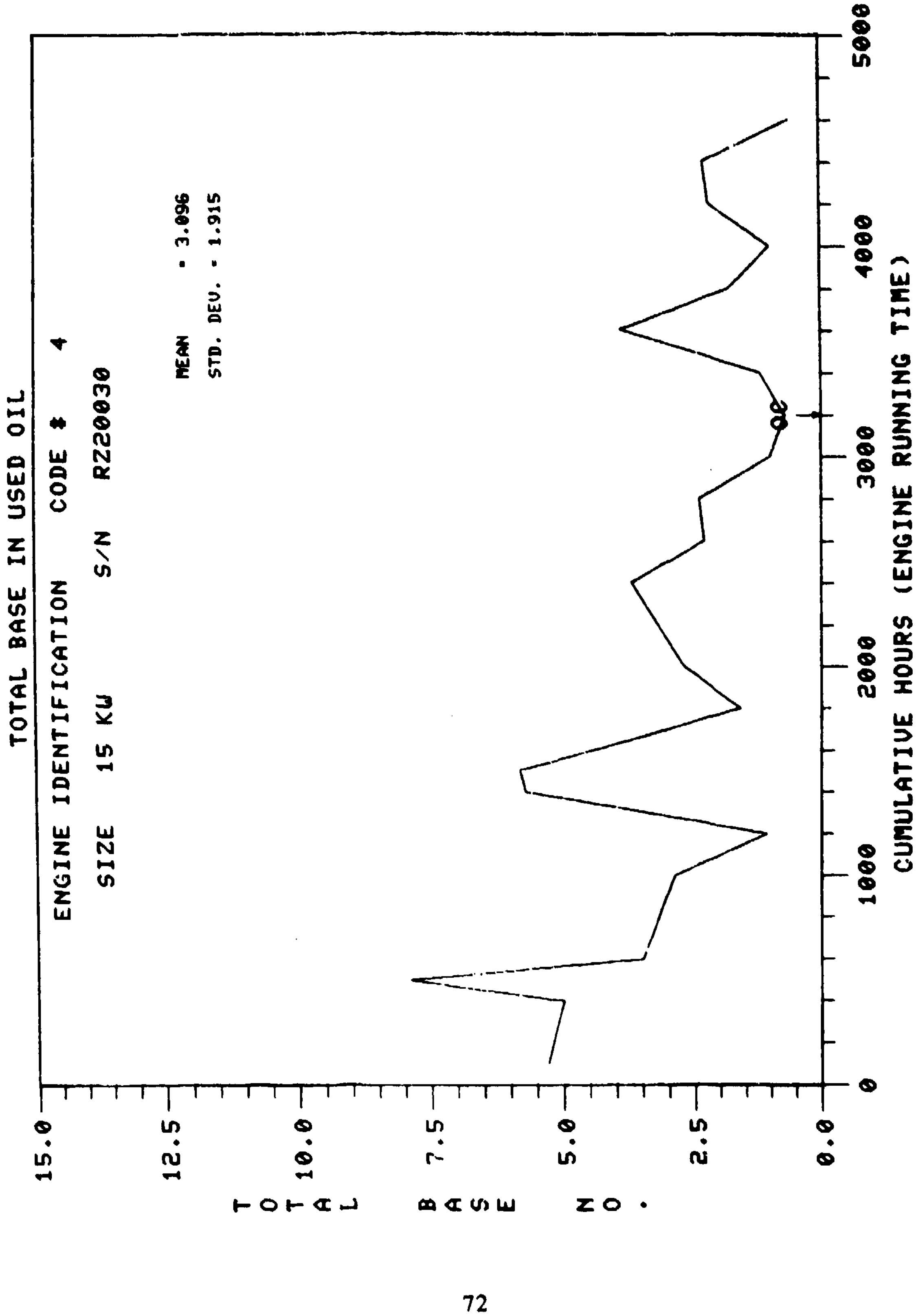

SILICON
ENGINE IDENTIFICATION CODE # 3
SIZE 30 KW S/N RZ51233
MEAN = 13.791
STD. DEV. = 8.587
OC
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

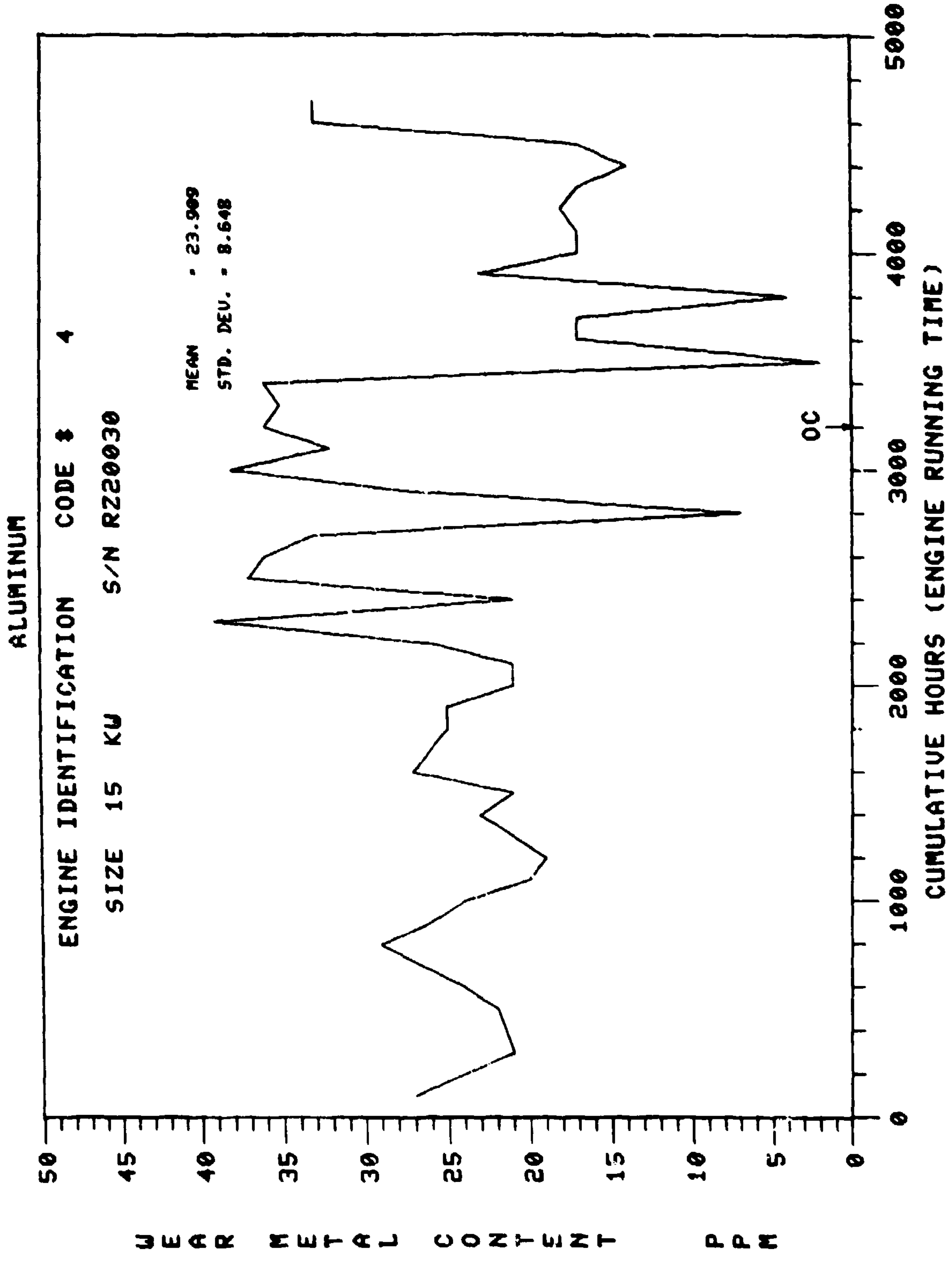

PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 0.208
STD. DEV. = 0.134
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
PENTANE INSOLUBLES
0.0
0.2
0.4
0.6
0.8
1.0

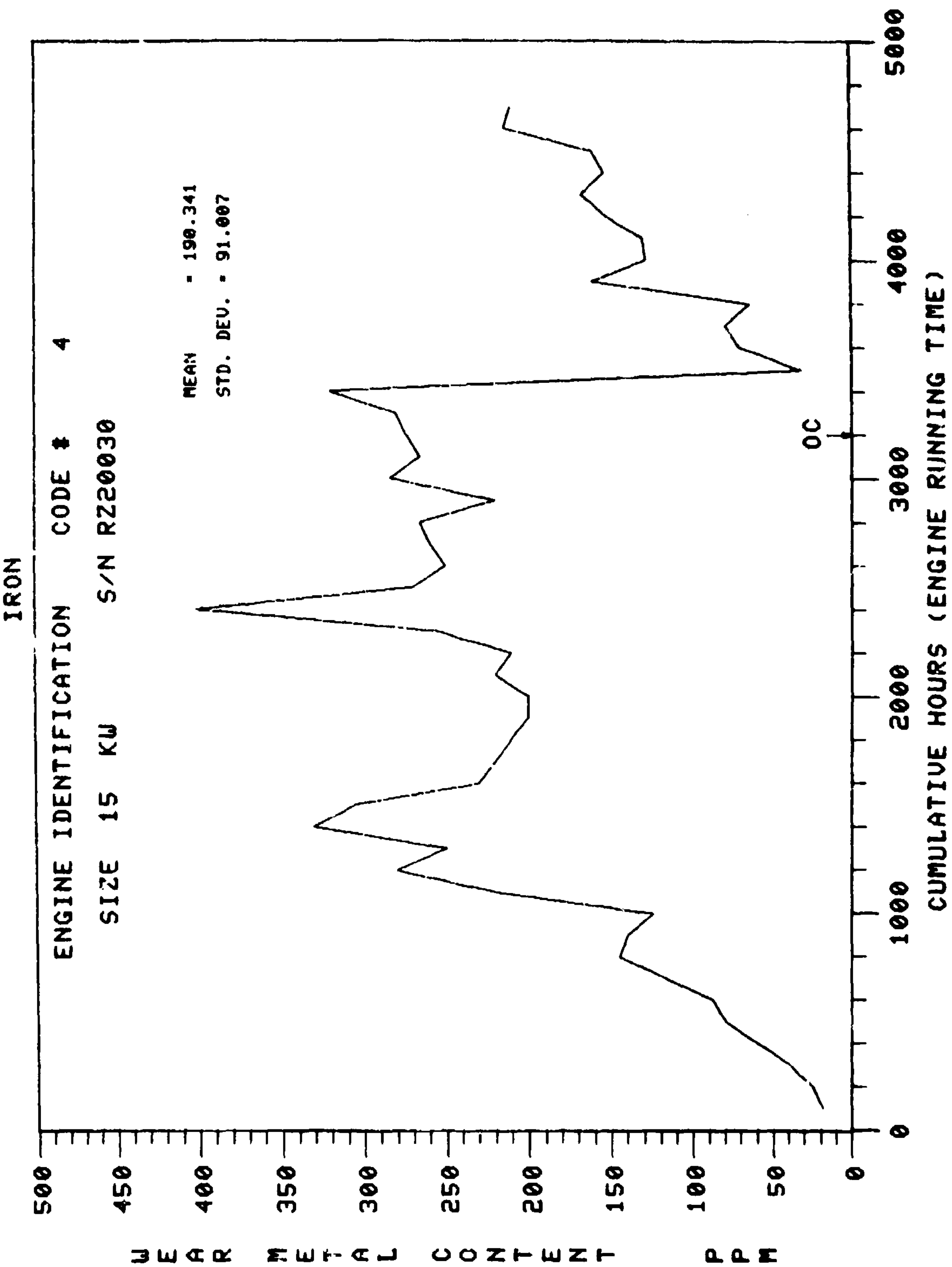

VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 11.448
STD. DEV. = 1.340
OC
VISCOSITY IN CS
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
0
1000
2000
3000
4000
5000

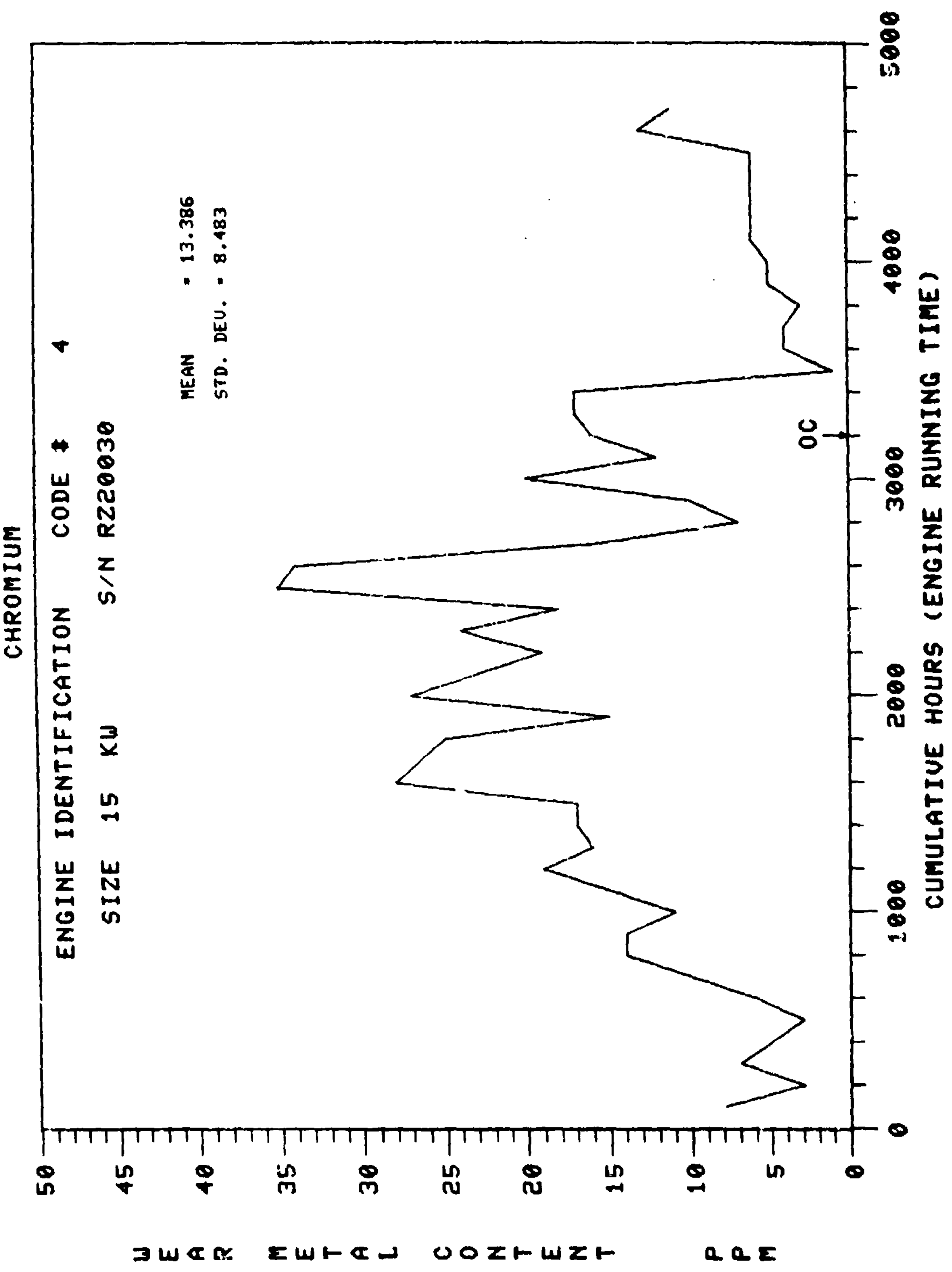

VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 92.652
STD. DEV. = 16.576
OC
150
125
100
75
50
VISCOSITY
CS
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 5.128
STD. DEV. = 1.677
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

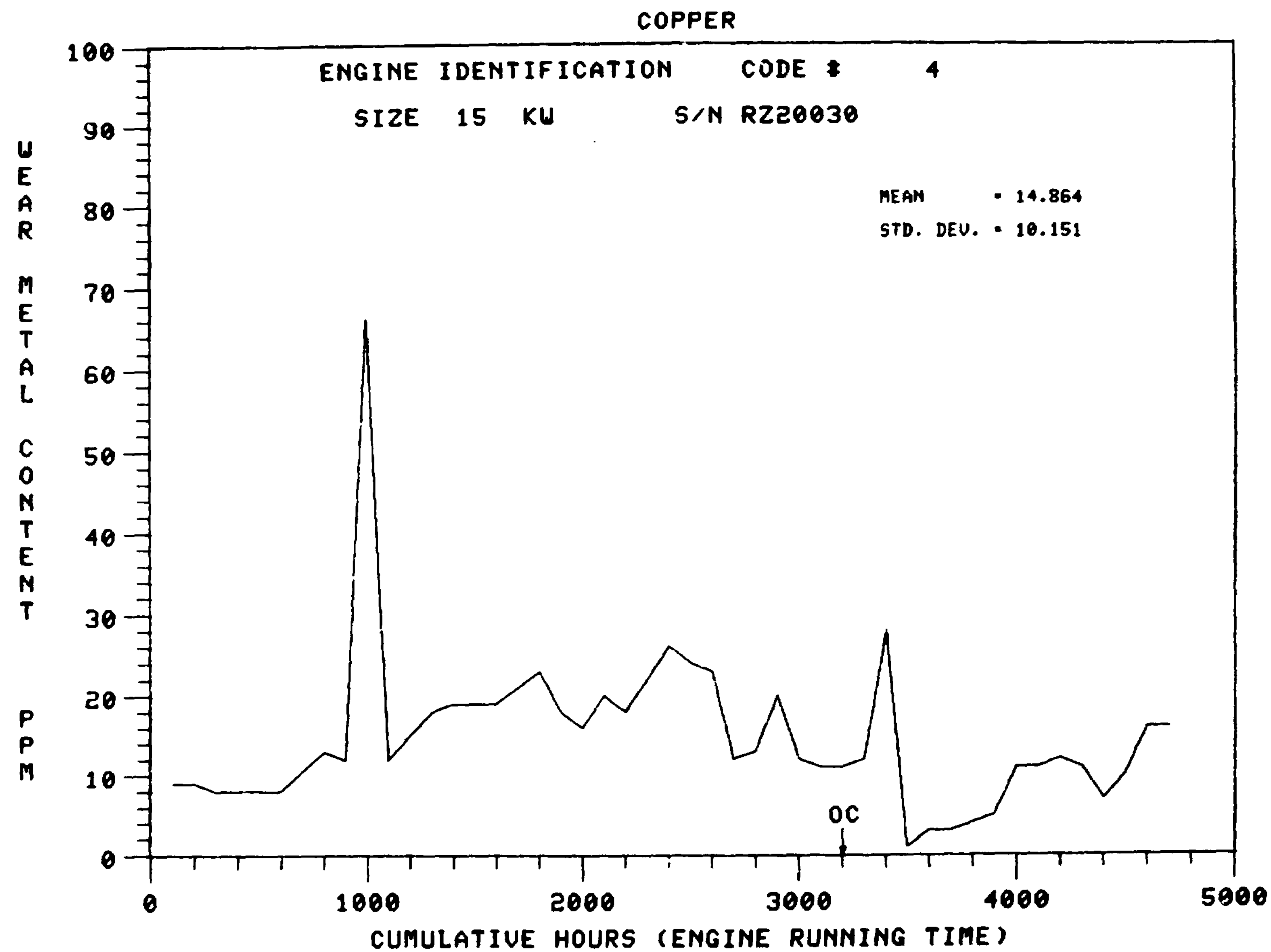

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 3.096
STD. DEV. = 1.915
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
OC

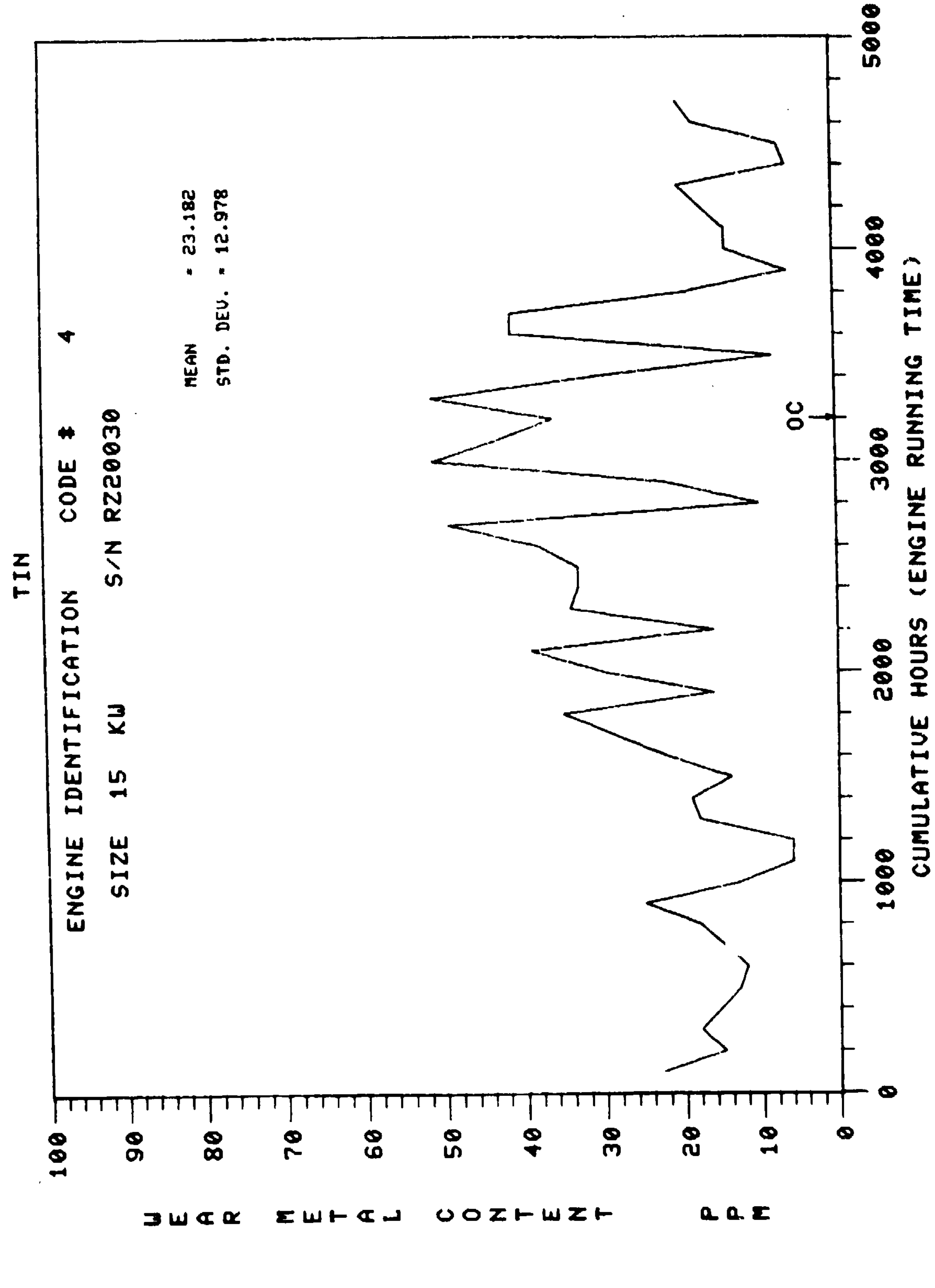

ALUMINUM
ENGINE IDENTIFICATION CODE $ 4
SIZE 15 KW S/N RZ20030
MEAN = 23.909
STD. DEV. = 8.648
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
25
30
35
40
45
50
WEAR METAL CONTENT PPM

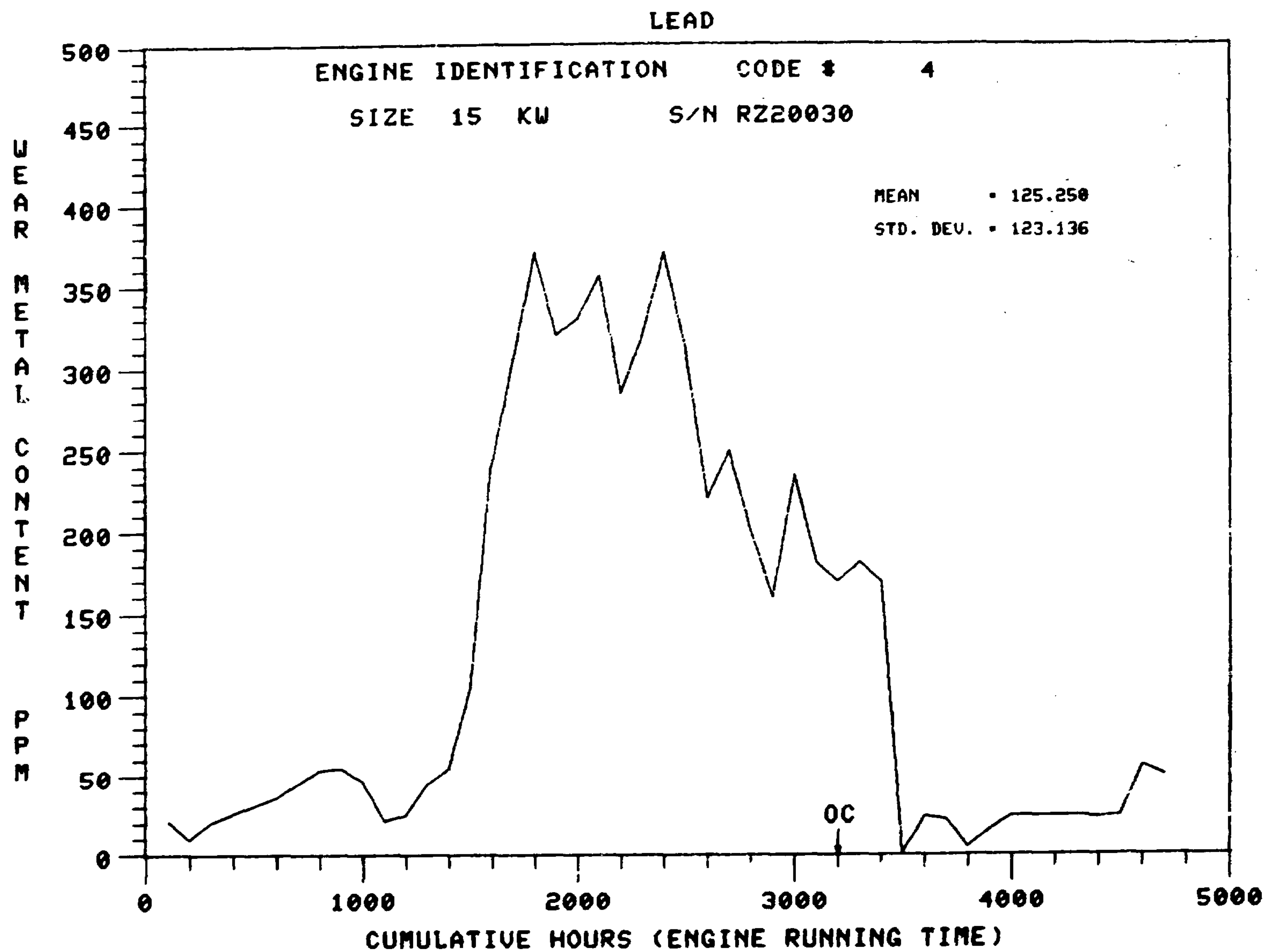

IRON
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 190.341
STD. DEV. = 91.007
OC
500
450
400
350
300
250
200
150
100
50
0
WEAR METAL CONTENT PPM
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

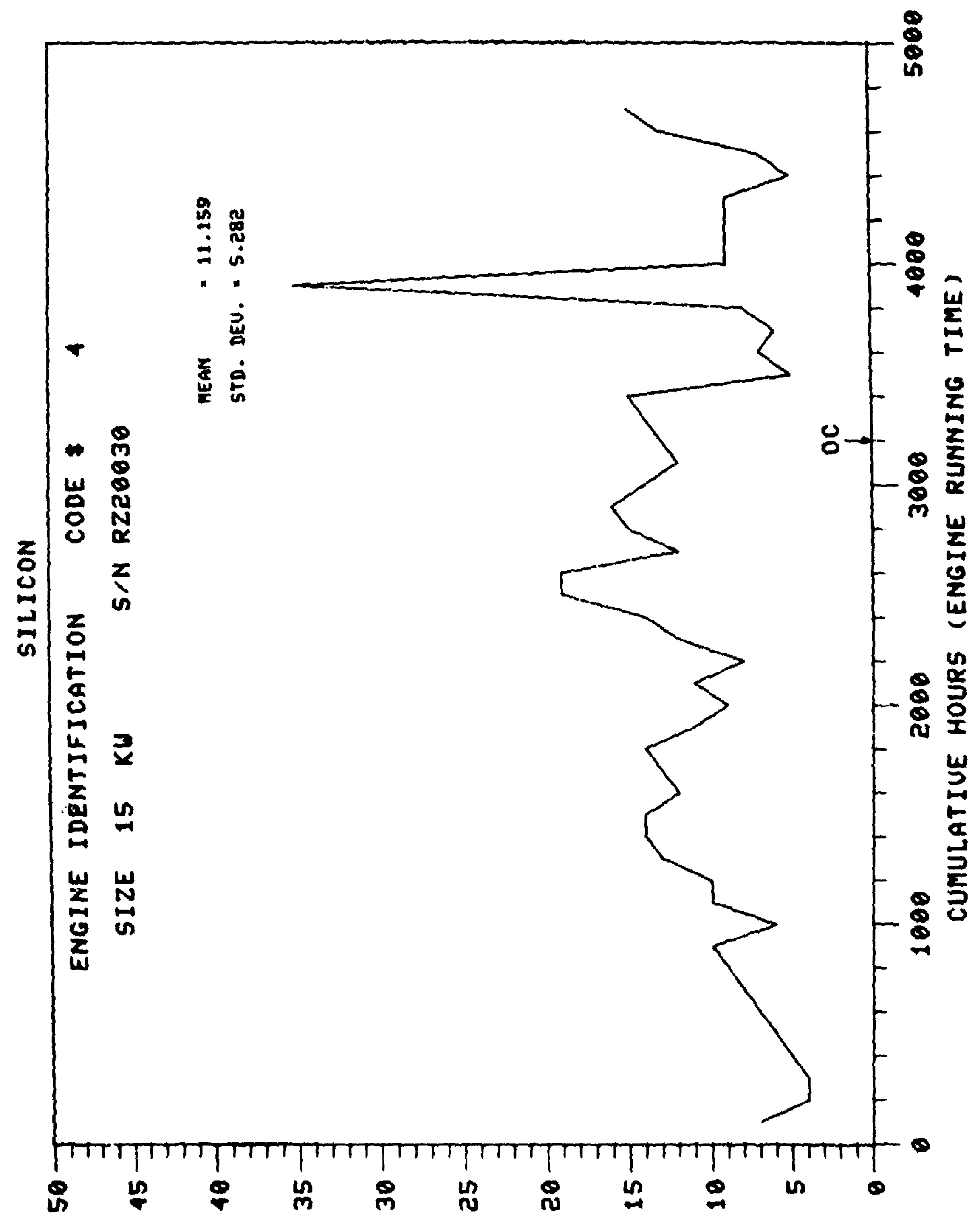


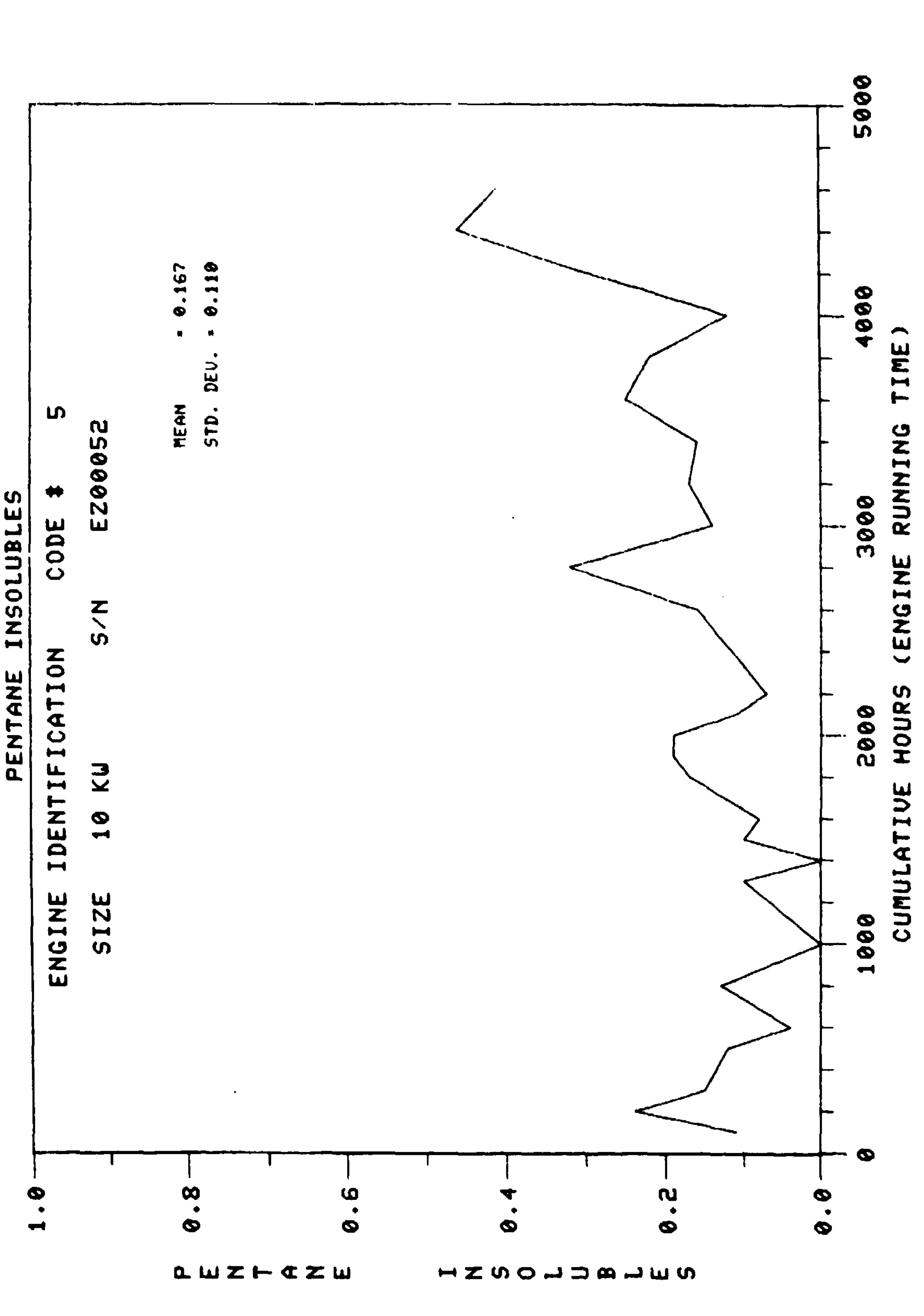
CHROMIUM
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 13.386
STD. DEV. = 8.483
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50

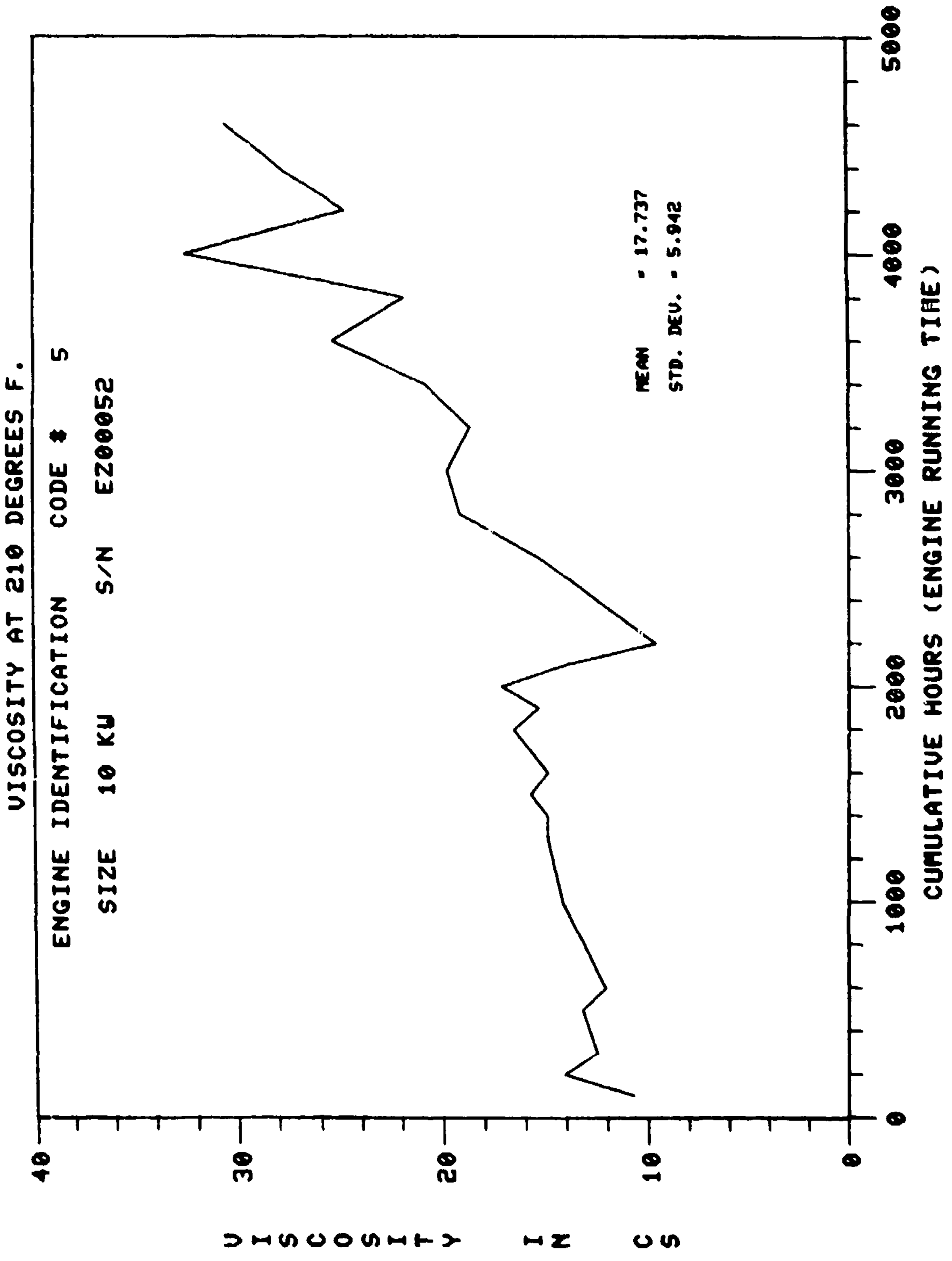

COPPER
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 14.864
STD. DEV. = 10.151
WEAR METAL CONTENT PPM
100
90
80
70
60
50
40
30
20
10
0
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

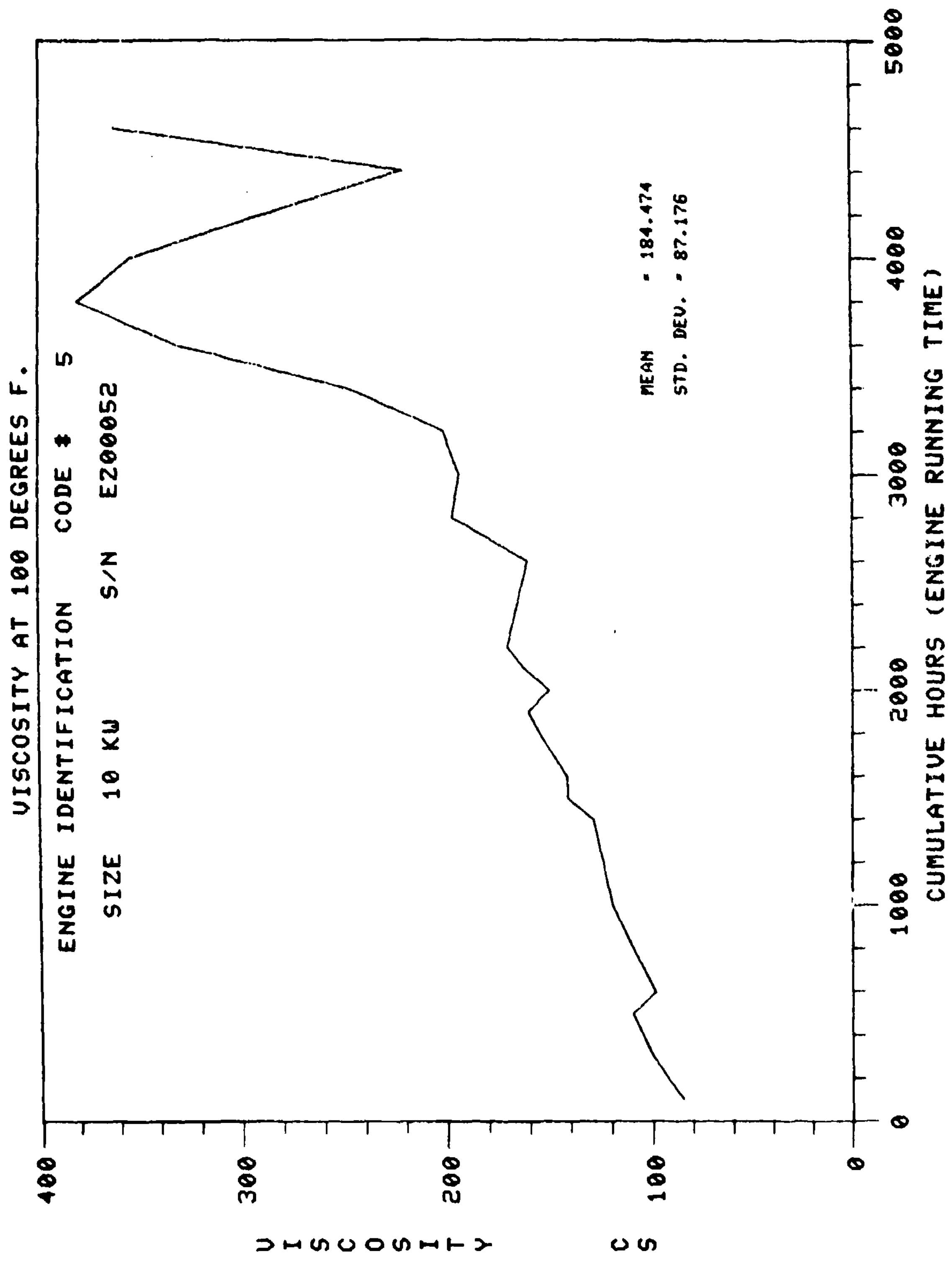

TIN
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ200030
MEAN = 23.182
STD. DEV. = 12.978
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
10
20
30
40
50
60
70
80
90
100
WEAR METAL CONTENT PPM


LEAD
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 125.250
STD. DEV. = 123.136
WEAR METAL CONTENT PPM
500
450
400
350
300
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)

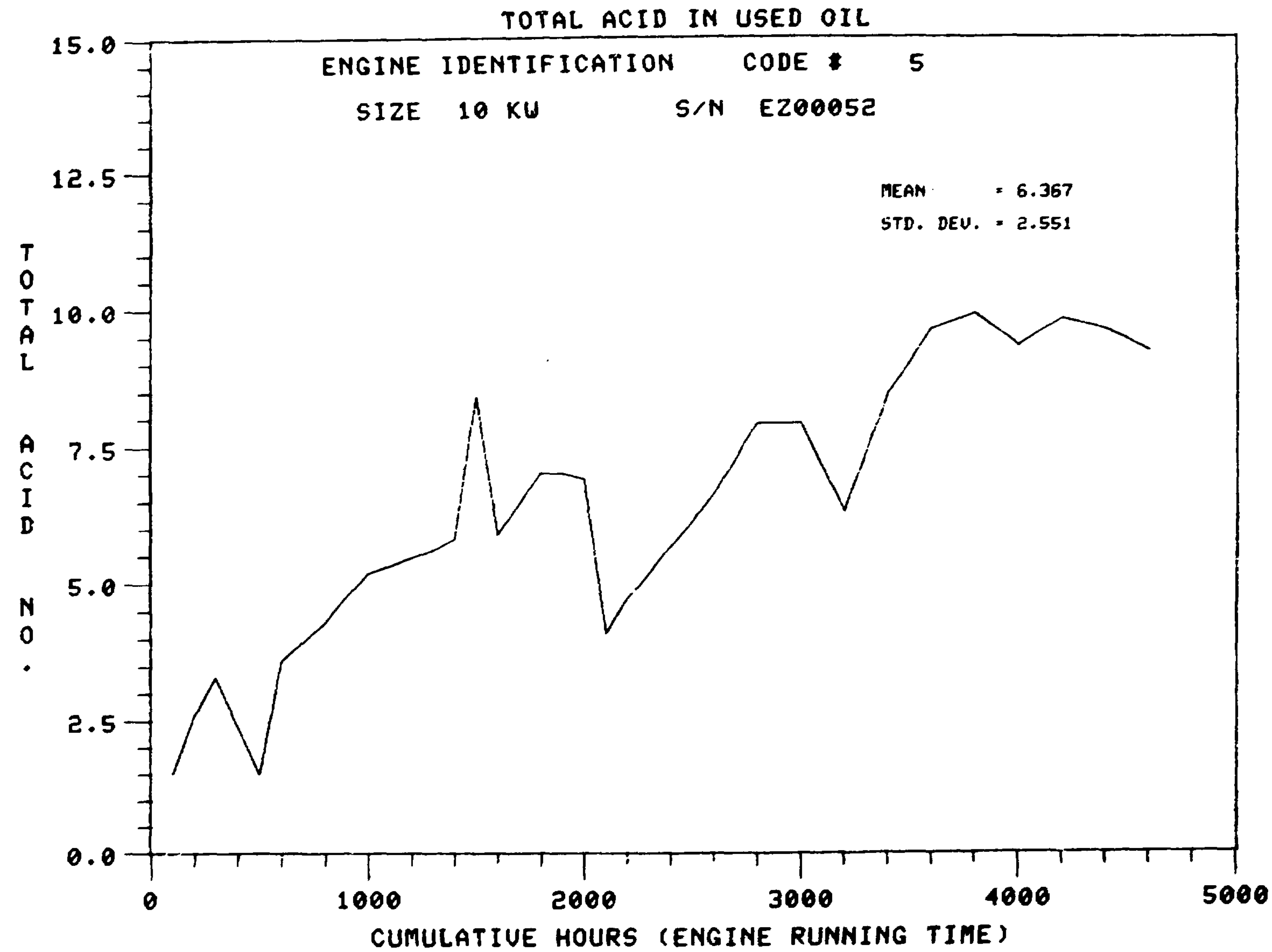

SILICON
ENGINE IDENTIFICATION CODE # 4
SIZE 15 KW S/N RZ20030
MEAN = 11.159
STD. DEV. = 5.282
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50

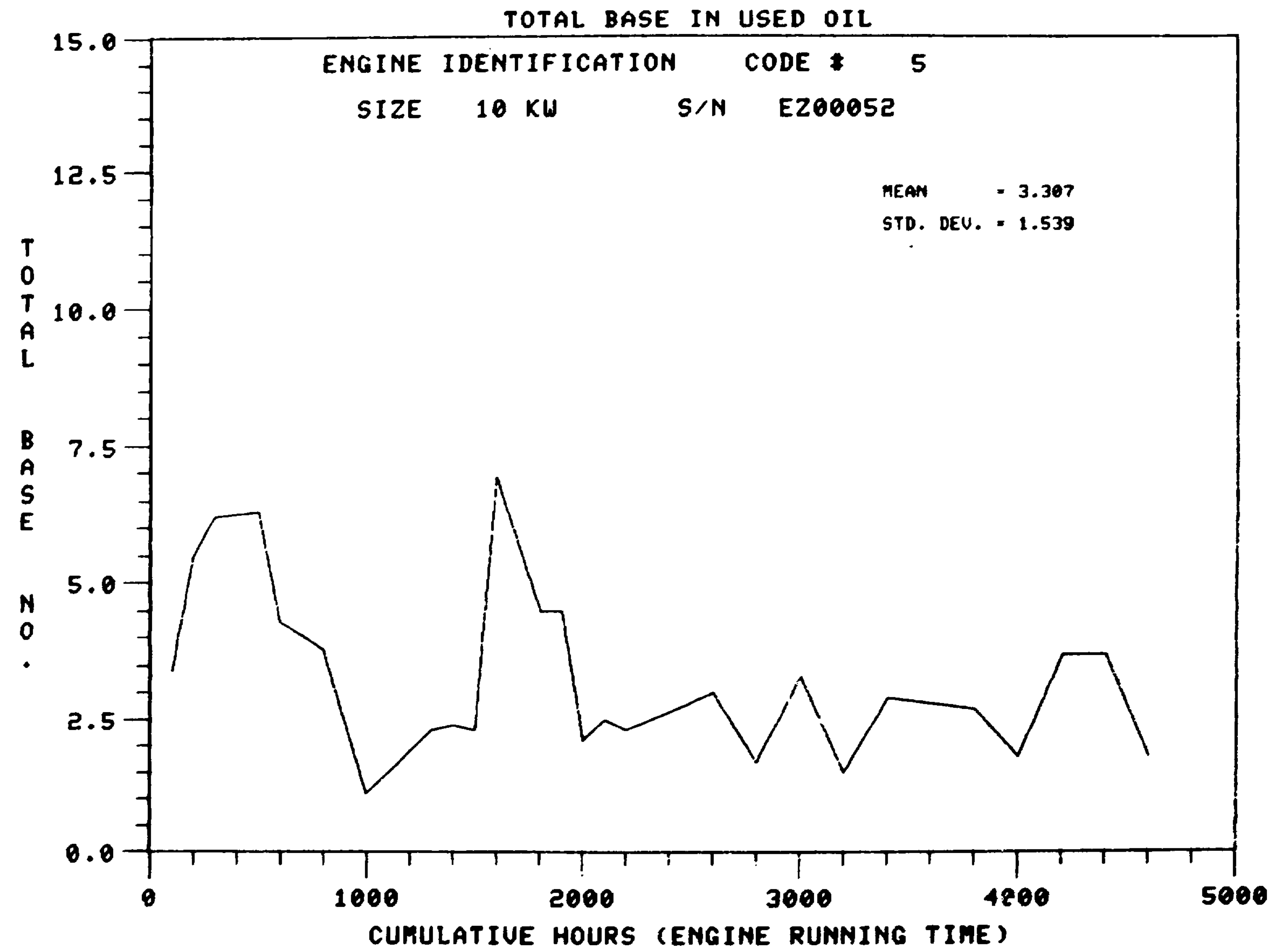

PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 0.167
STD. DEV. = 0.110
PENTANE INSOLUBLES
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

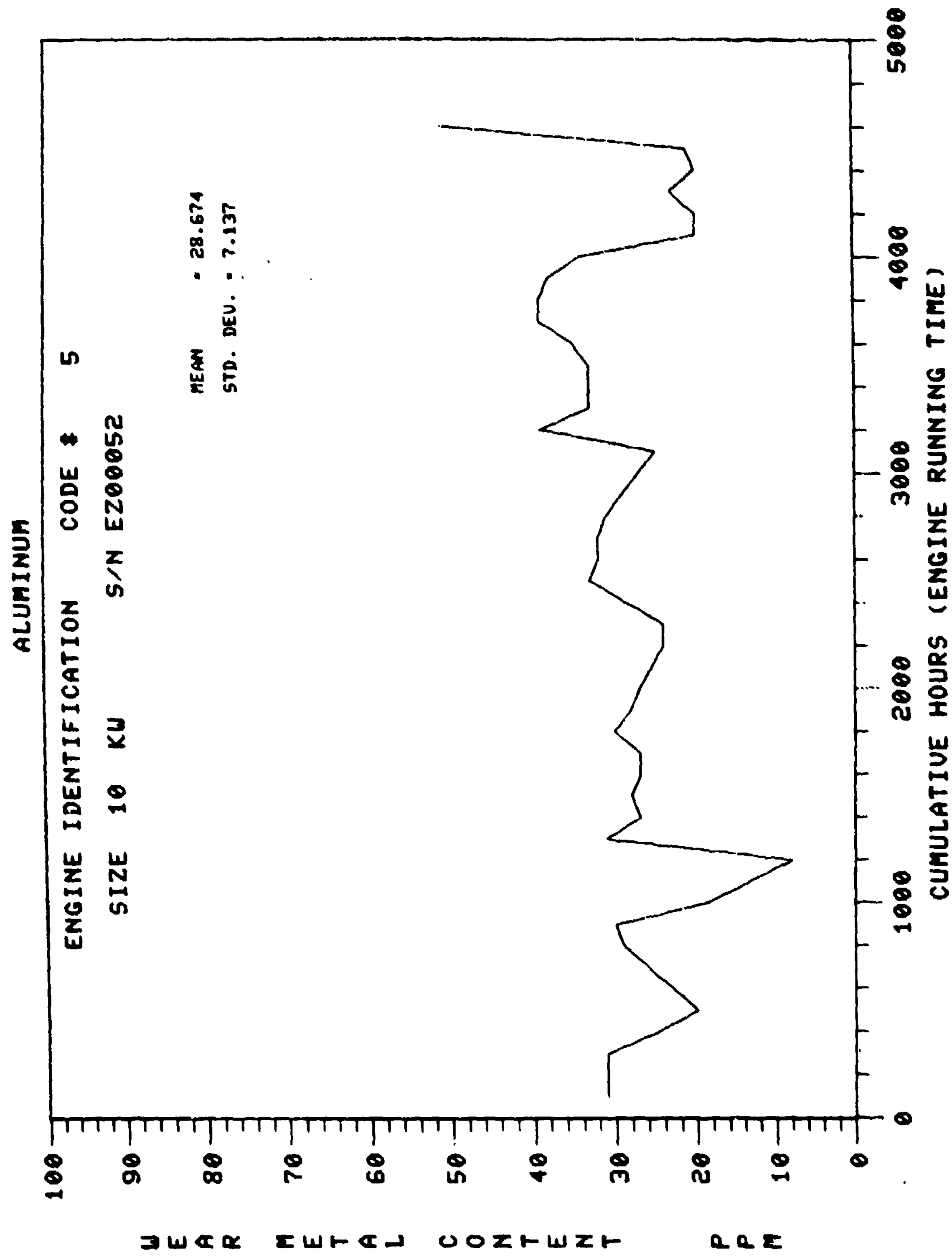

VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 17.737
STD. DEV. = 5.942
VISCOSITY IN CS
0
10
20
30
40
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

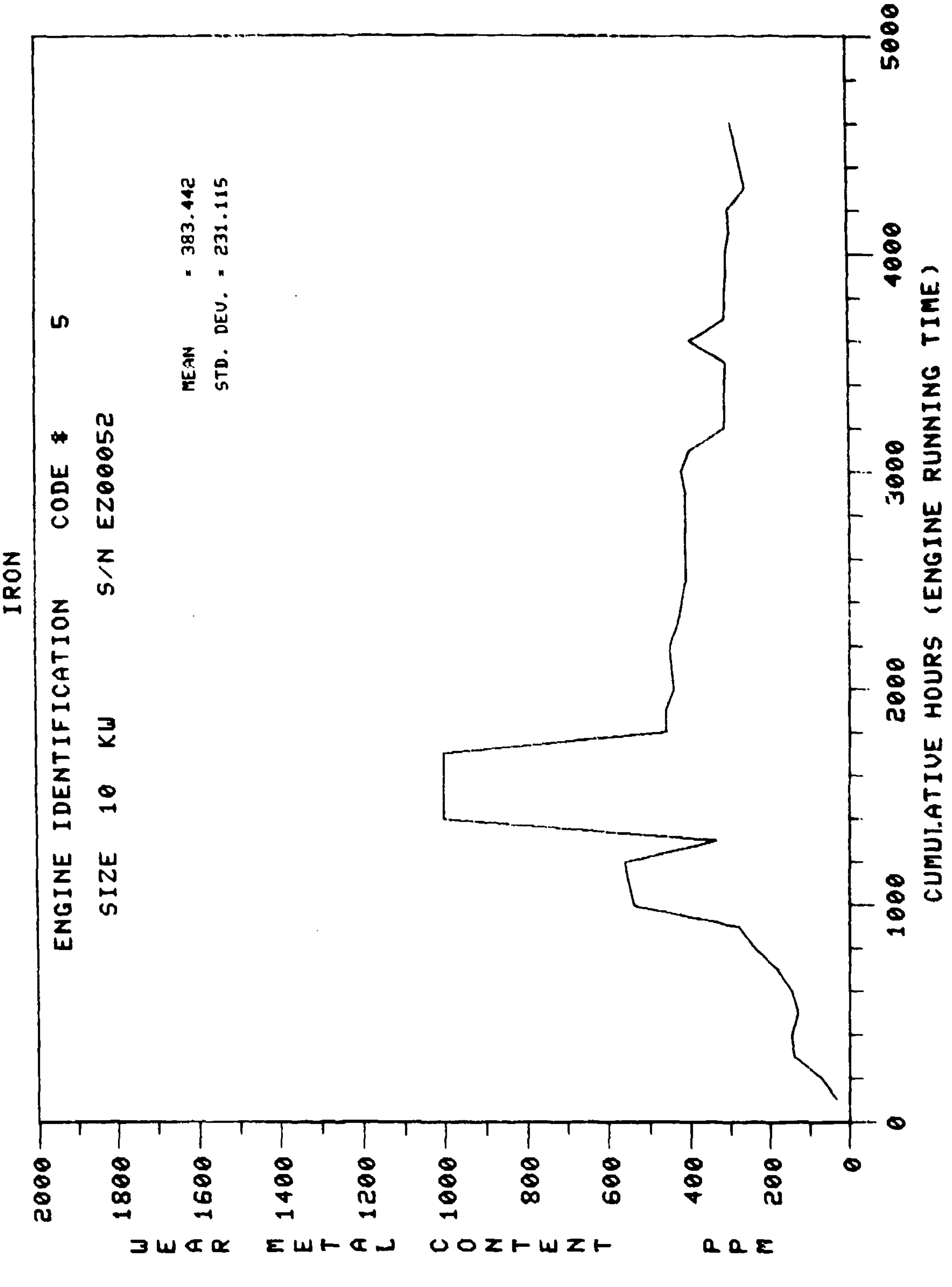


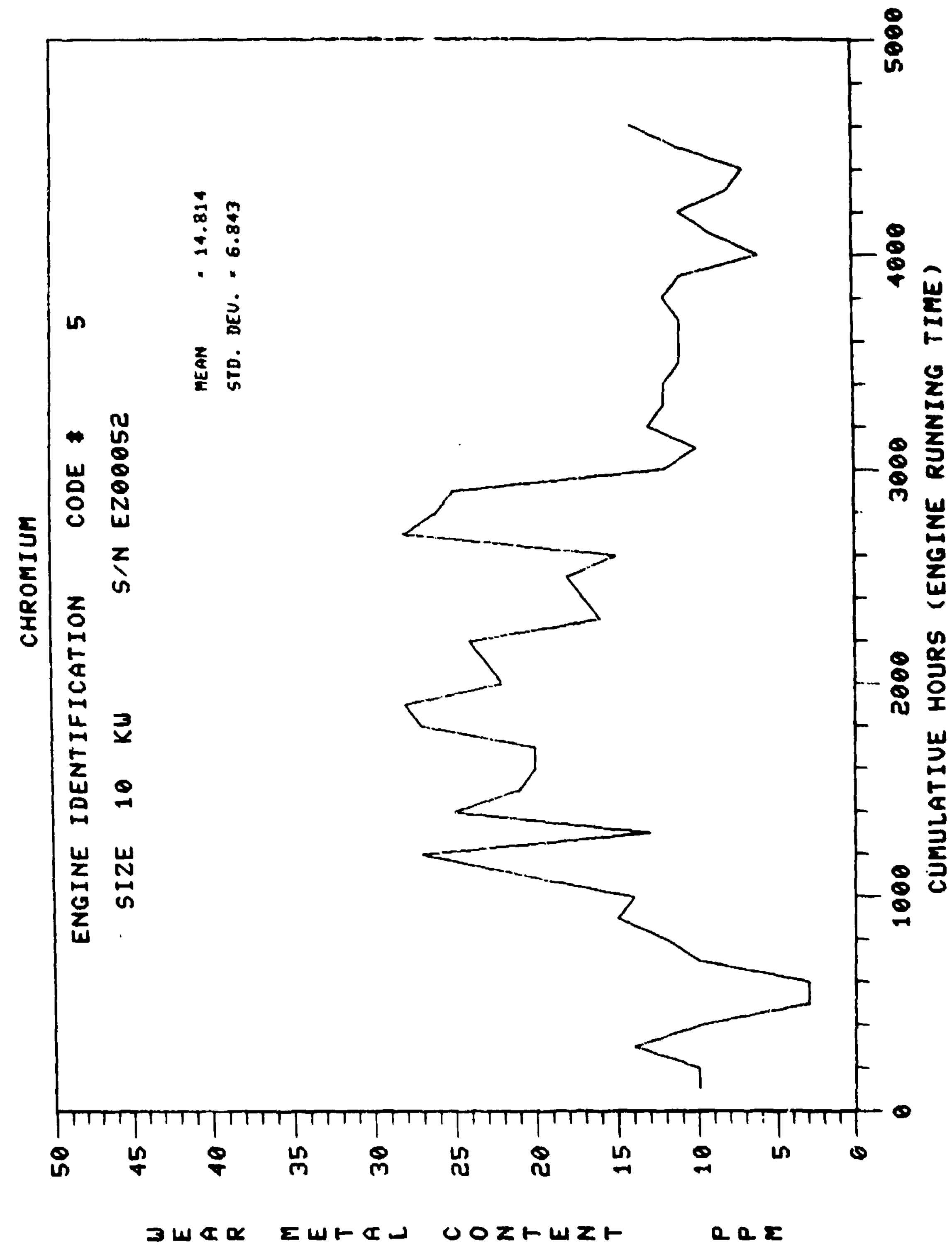
VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N E200052
MEAN = 184.474
STD. DEV. = 87.176
CUMULATIVE HOURS (ENGINE RUNNING TIME)
VISCOSITY CS
0
1000
2000
3000
4000
5000
100
200
300
400

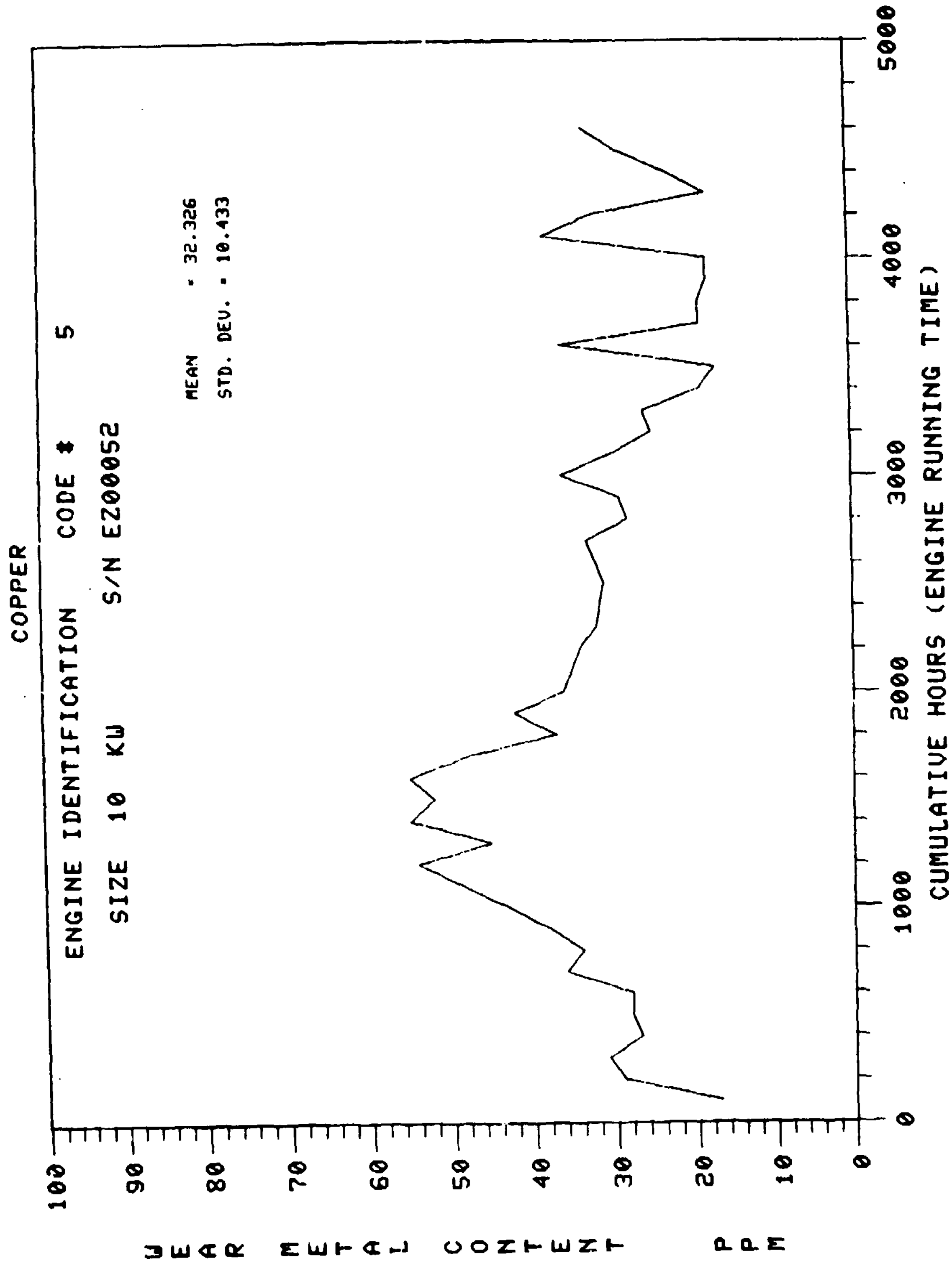

TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 6.367
STD. DEV. = 2.551
15.0
12.5
10.0
7.5
5.0
2.5
0.0
TOTAL ACID NO.
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

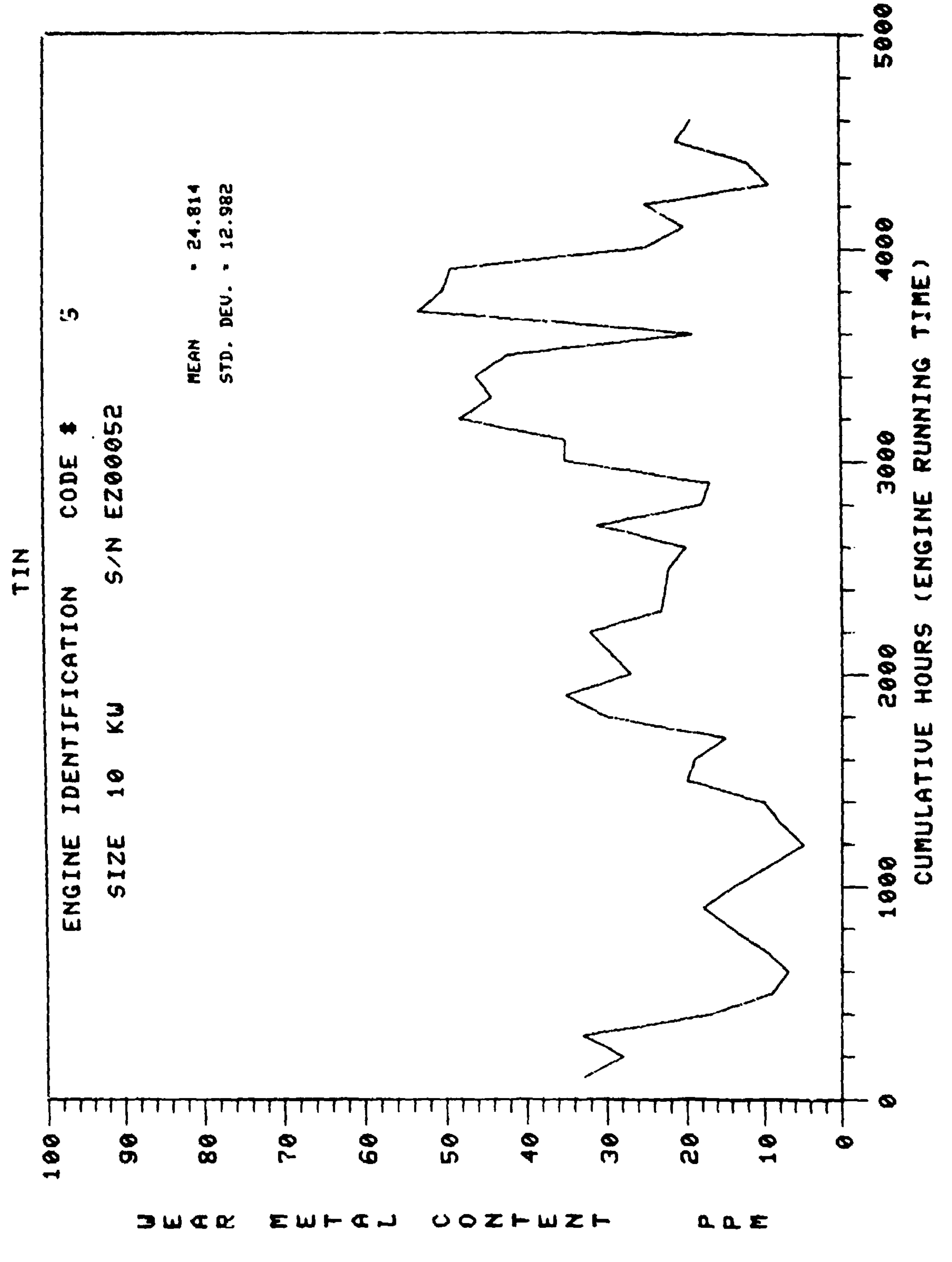

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 3.307
STD. DEV. = 1.539
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4200
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

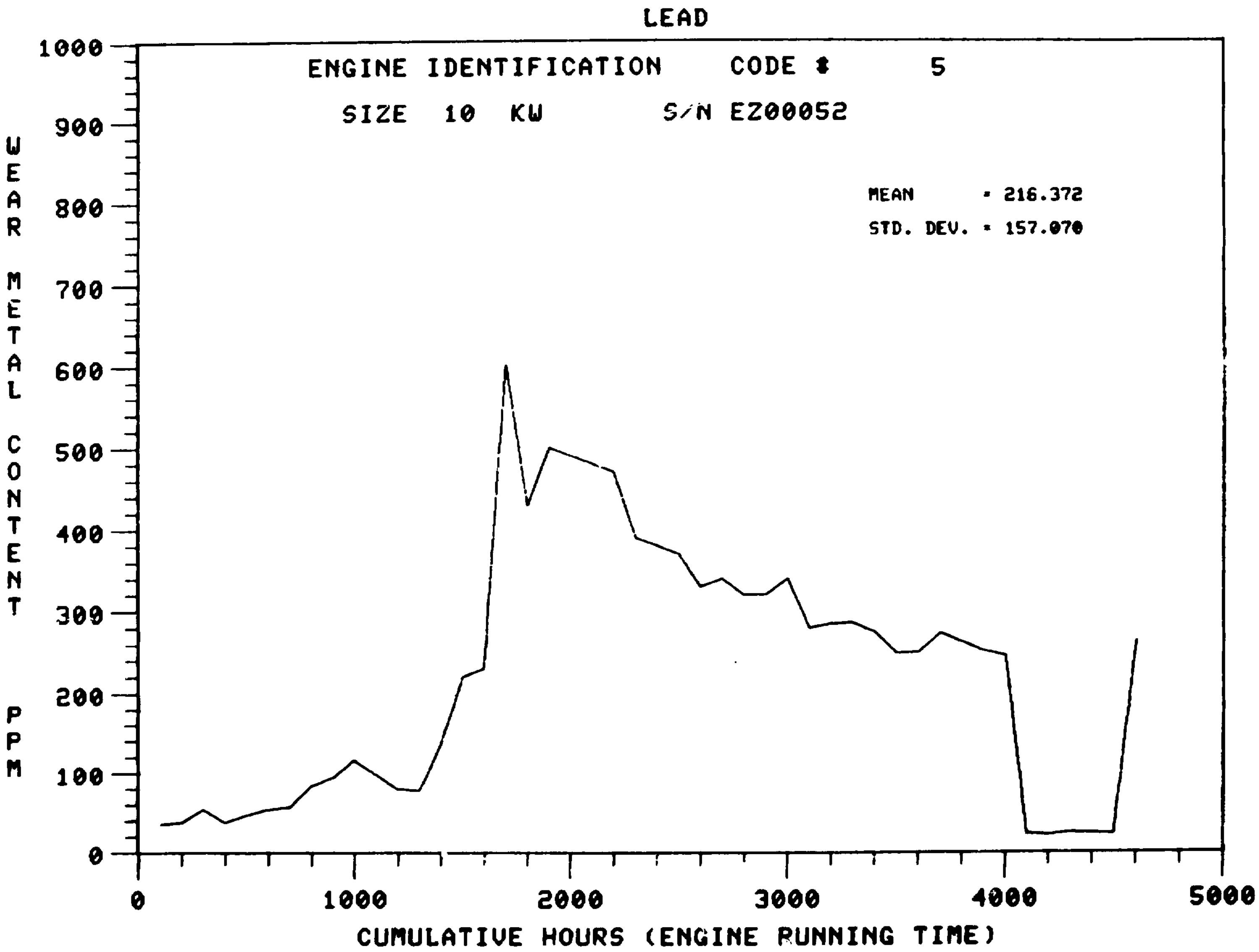

ALUMINUM
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 28.674
STD. DEV. = 7.137
WEAR METAL CONTENT PPM
100
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

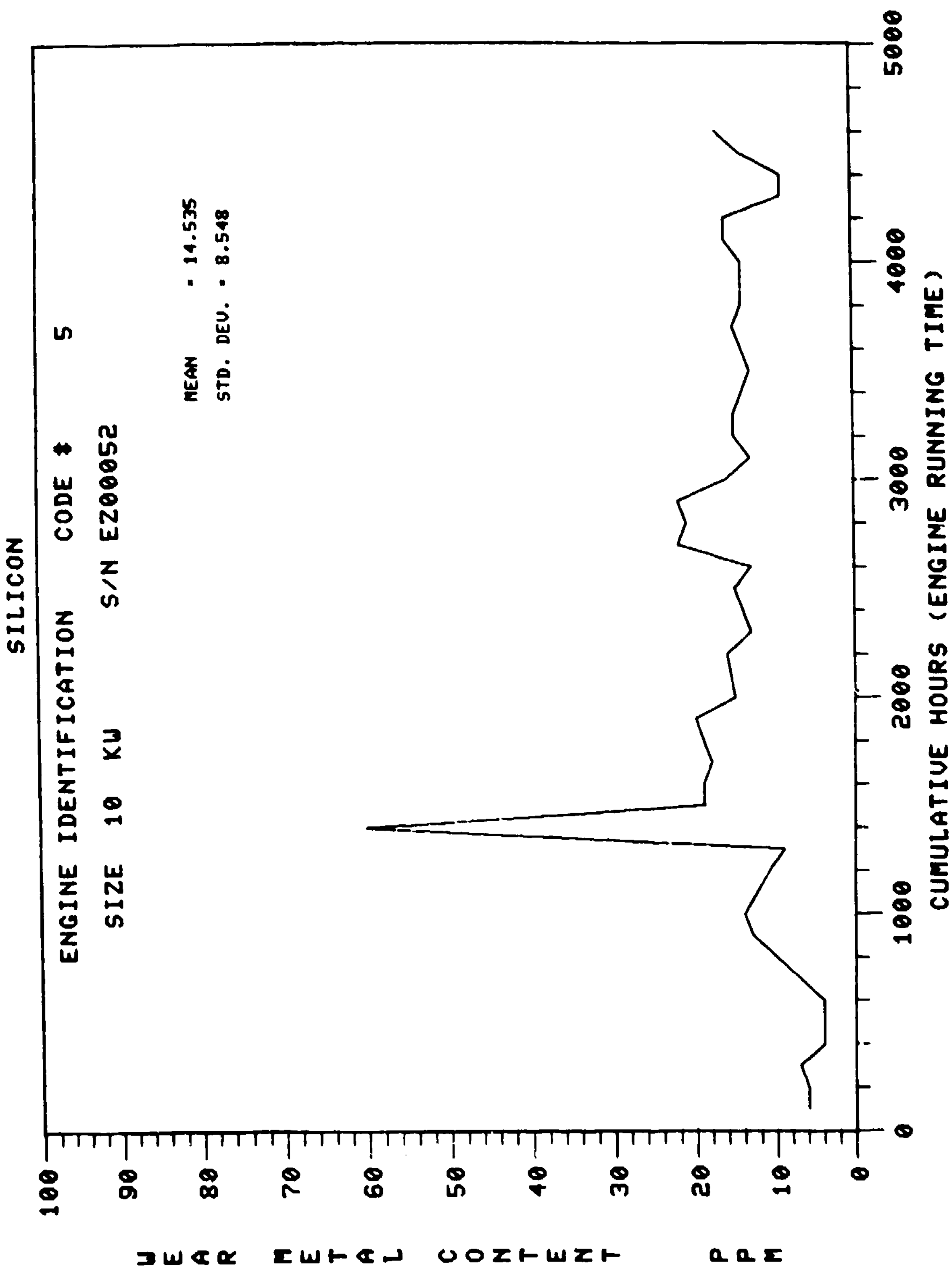

IRON
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 383.442
STD. DEV. = 231.115
WEAR METAL CONTENT PPM
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


CHROMIUM
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 14.814
STD. DEV. = 6.843
0
5
10
15
20
25
30
35
40
45
50
WEAR METAL CONTENT PPM
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

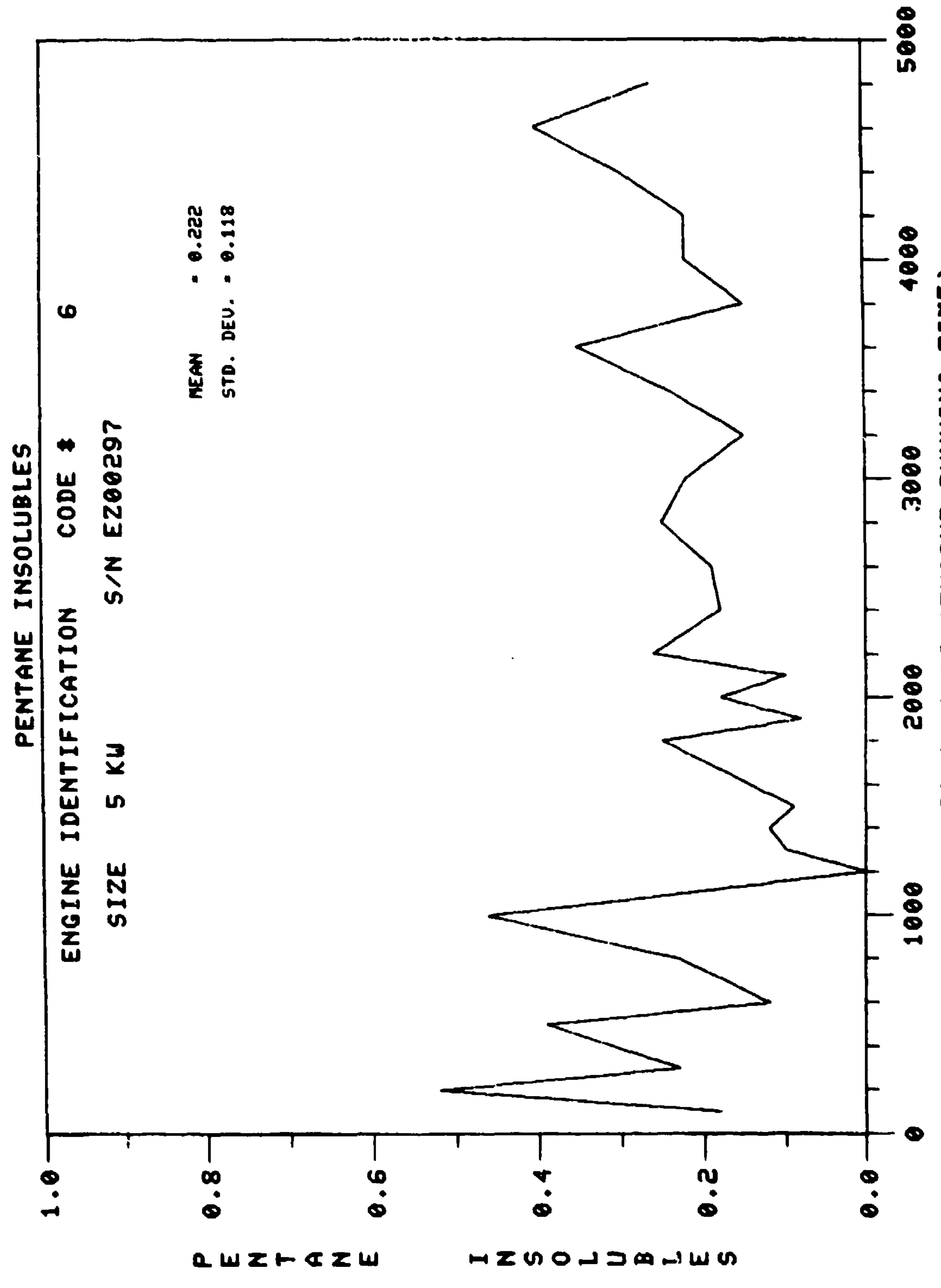

COPPER
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 32.326
STD. DEV. = 10.433
100
90
80
70
60
50
40
30
20
10
0
WEAR METAL CONTENT PPM
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

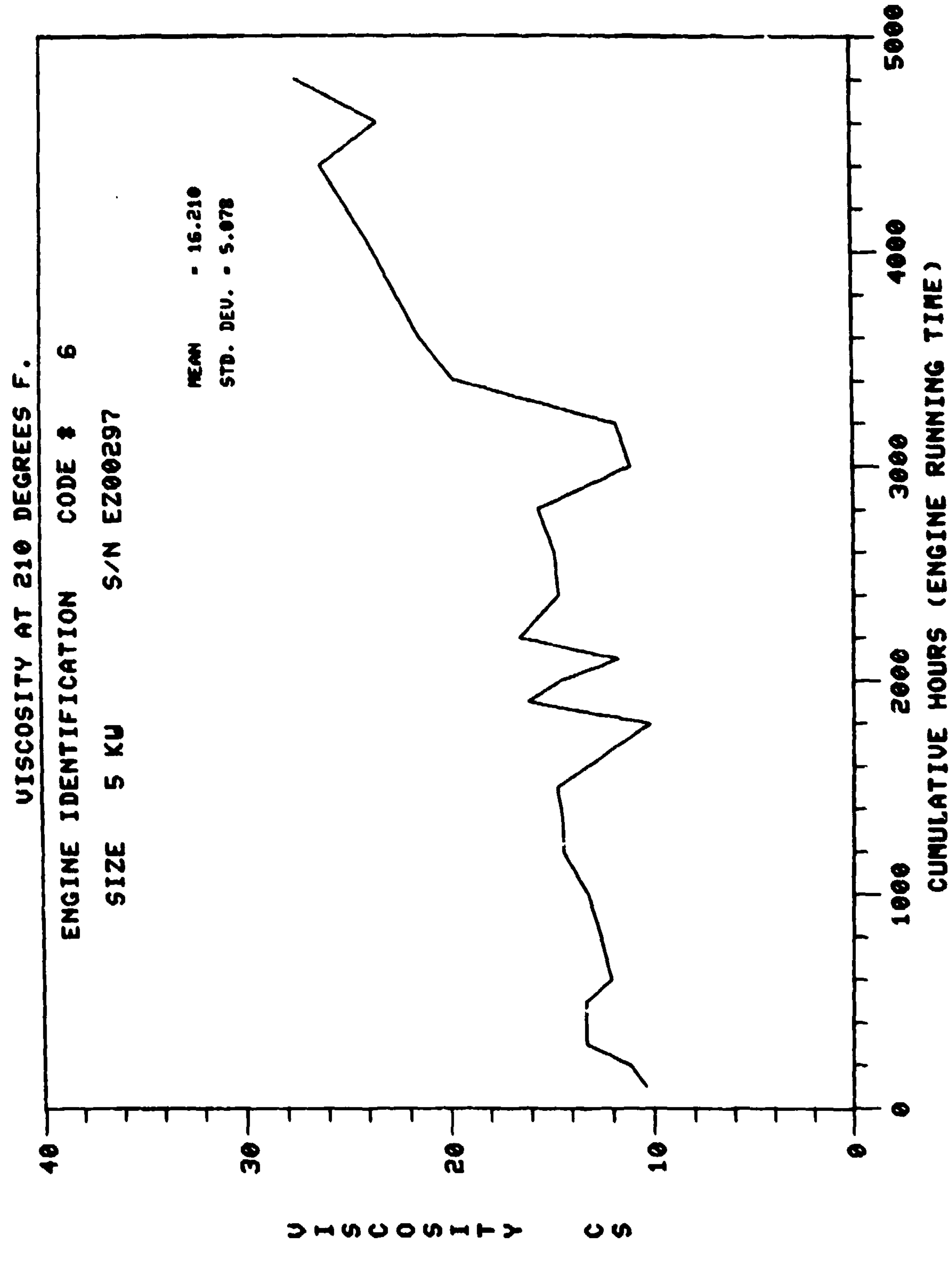

TIN
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 24.814
STD. DEV. = 12.982
WEAR METAL CONTENT PPM
100
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

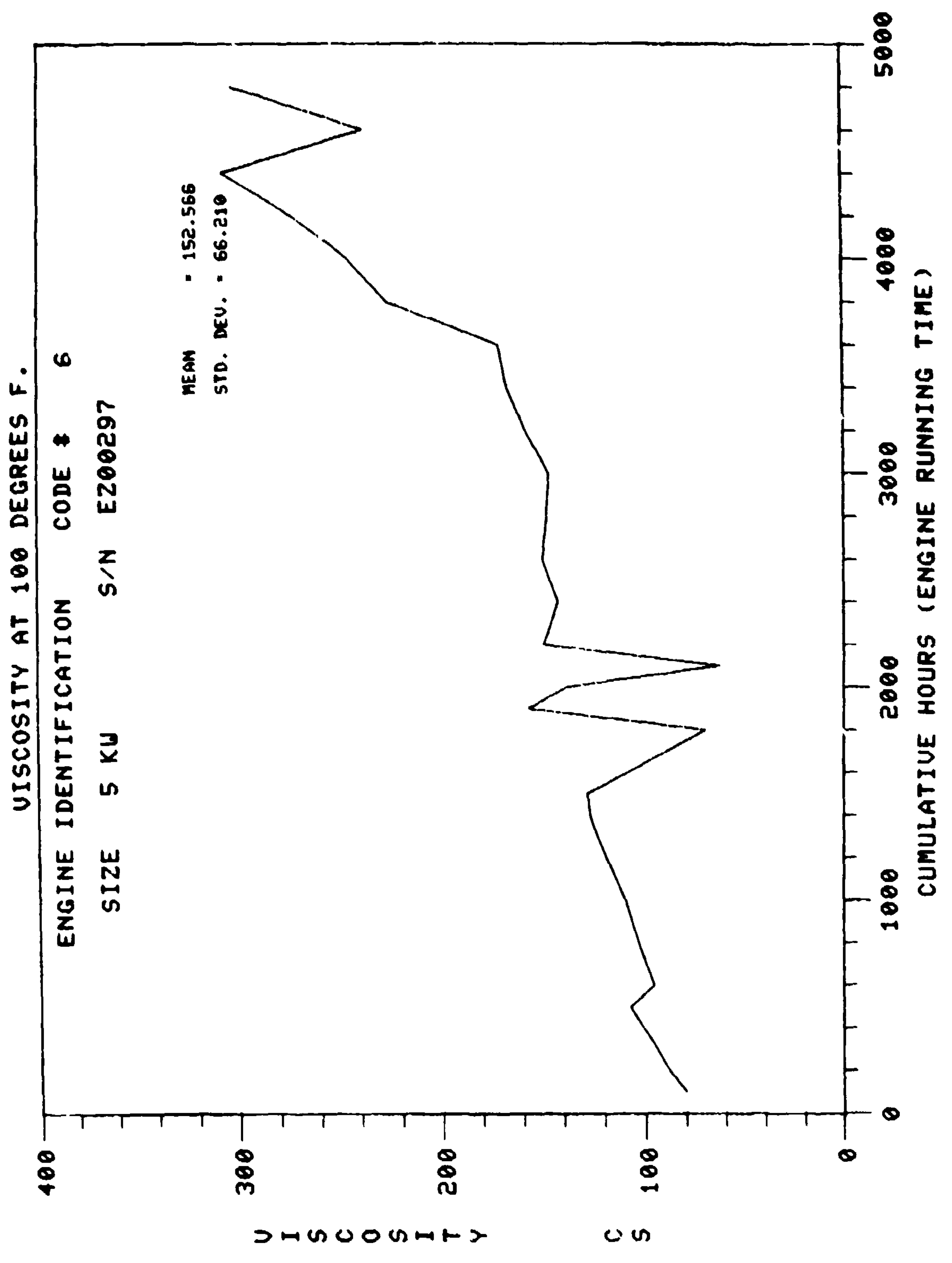

LEAD
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 216.372
STD. DEV. = 157.070
WEAR METAL CONTENT PPM
1000
900
800
700
600
500
400
300
200
100
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

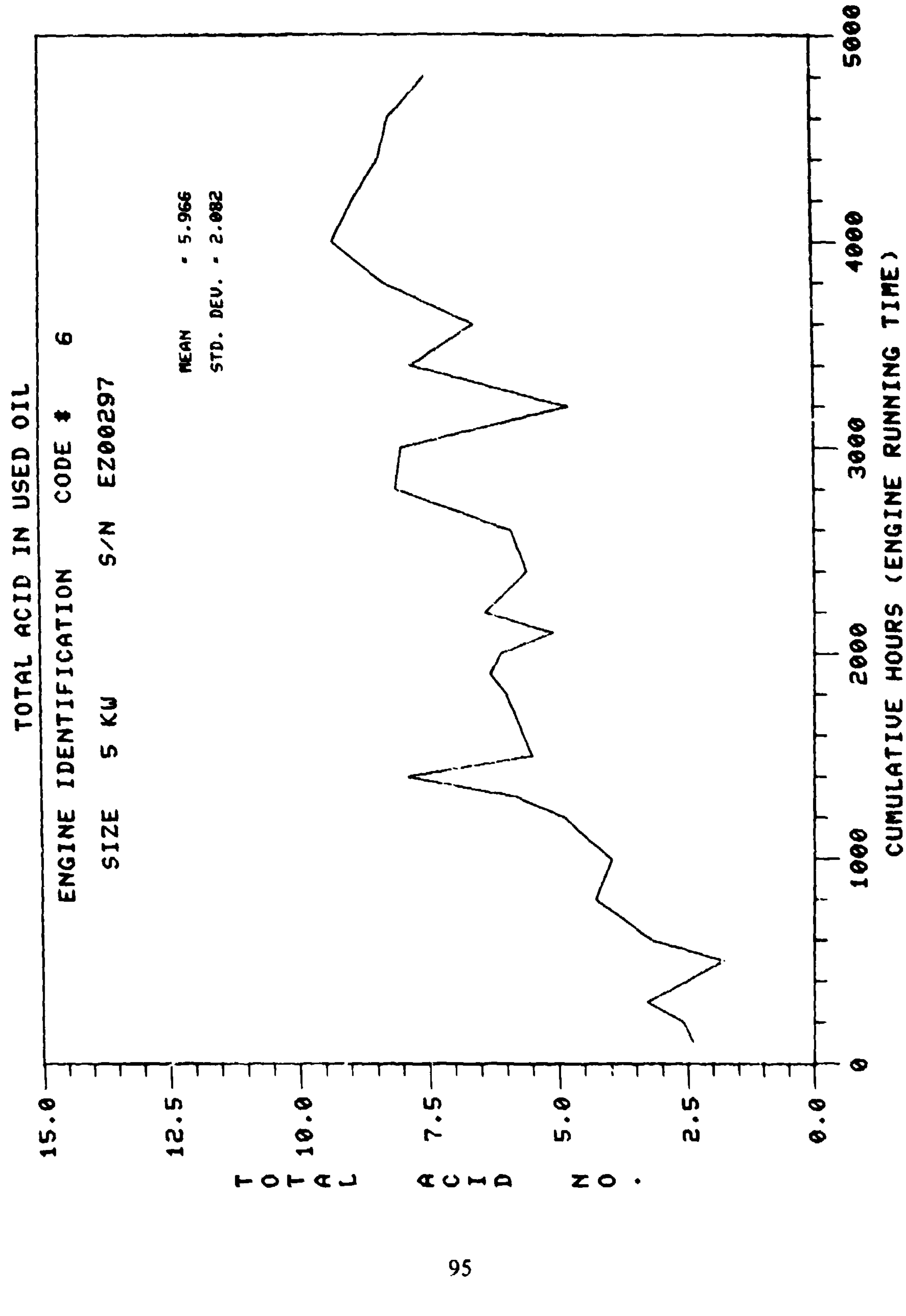


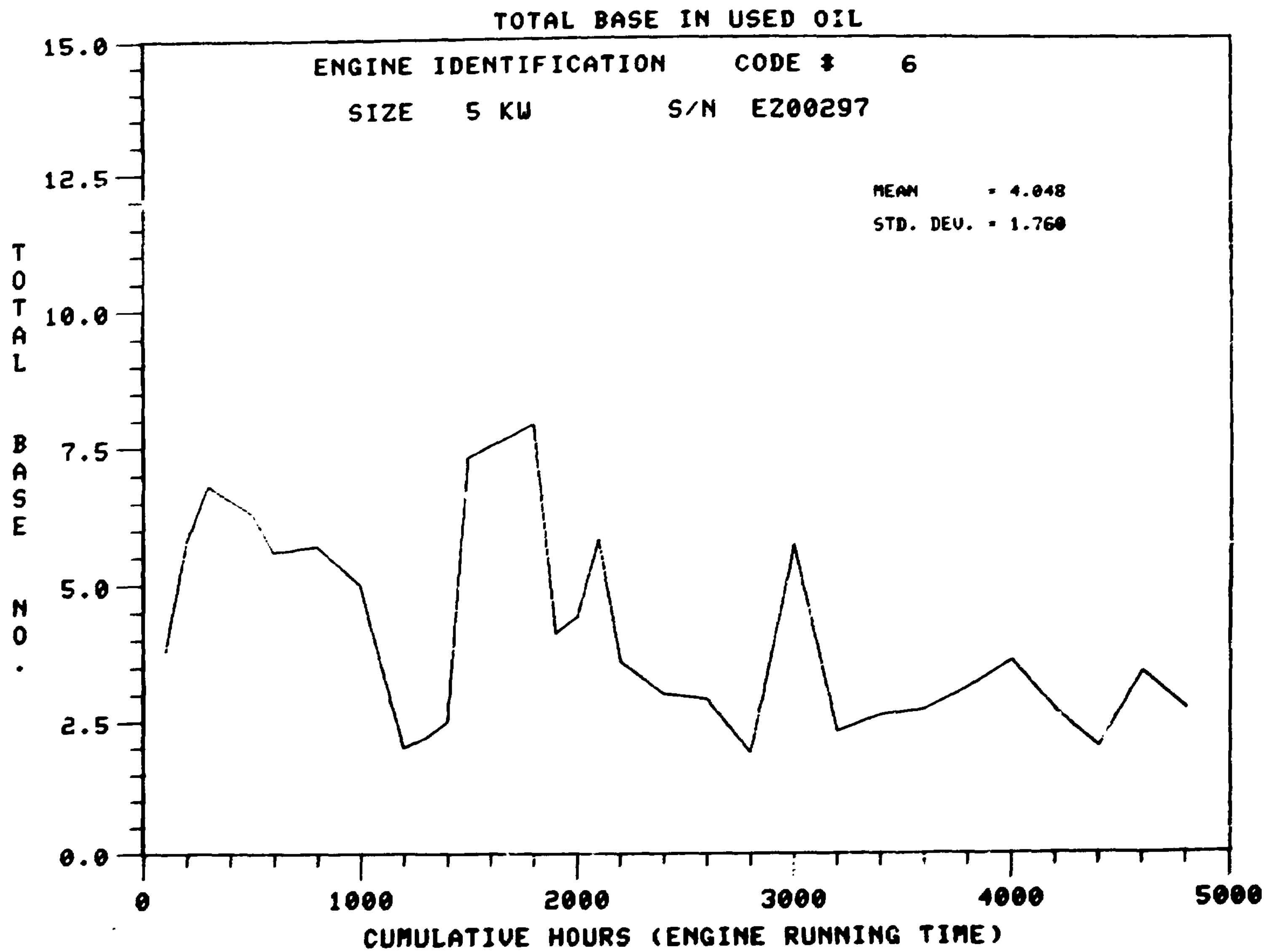
SILICON
ENGINE IDENTIFICATION CODE # 5
SIZE 10 KW S/N EZ00052
MEAN = 14.535
STD. DEV. = 8.548
WEAR METAL CONTENT PPM
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
10
20
30
40
50
60
70
80
90
100
1000
2000
3000
4000
5000


PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 0.222
STD. DEV. = 0.118
0.0
0.2
0.4
0.6
0.8
1.0
PENTANE INSOLUBLES
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

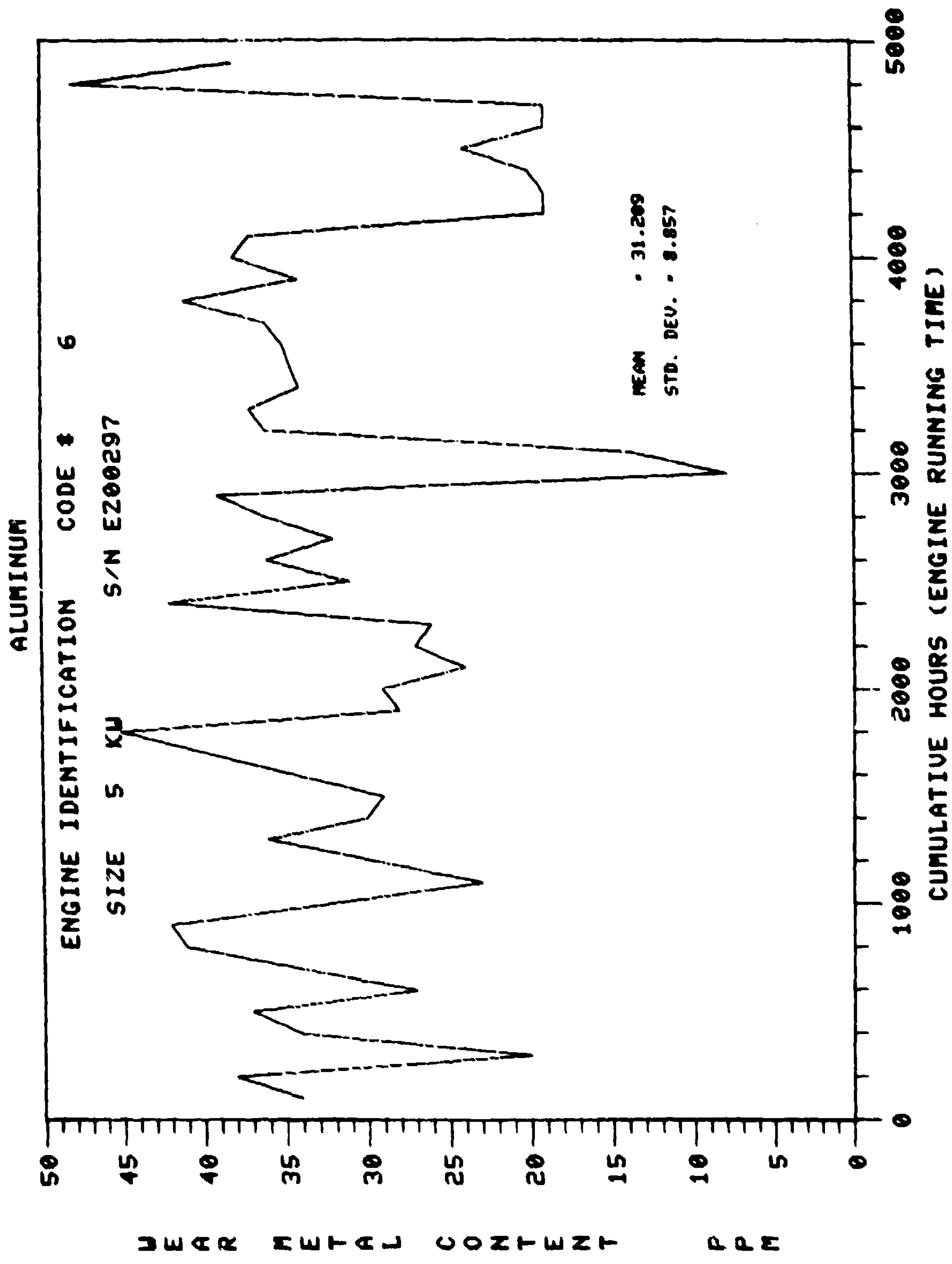

VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 16.210
STD. DEV. = 5.078
VISCOSITY CS
40
30
20
10
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N E200297
MEAN = 152.566
STD. DEV. = 66.210
VISCOSITY CS
400
300
200
100
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

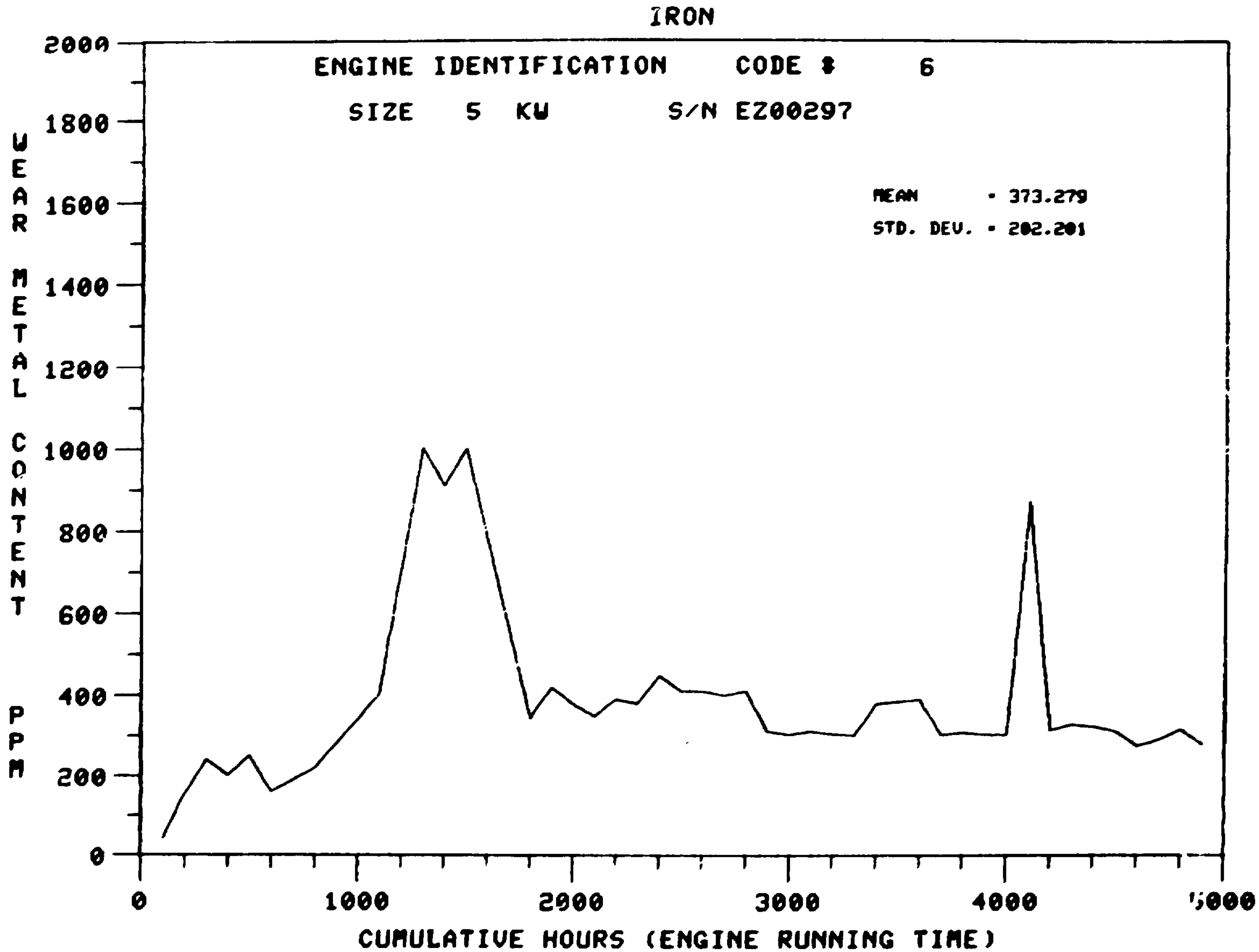

TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 5.966
STD. DEV. = 2.082
15.0
12.5
10.0
7.5
5.0
2.5
0.0
TOTAL ACID NO.
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

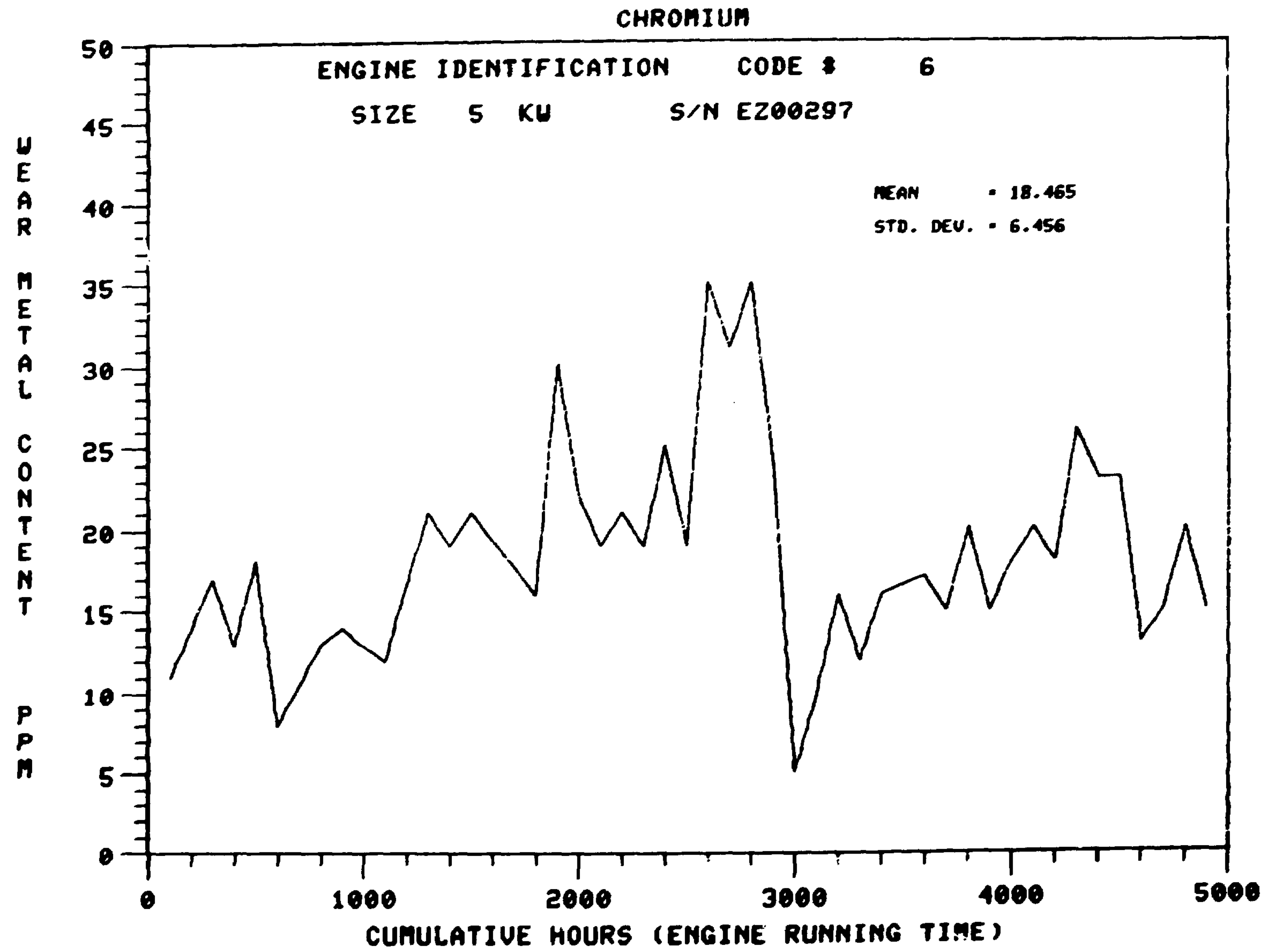


TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 4.048
STD. DEV. = 1.760
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

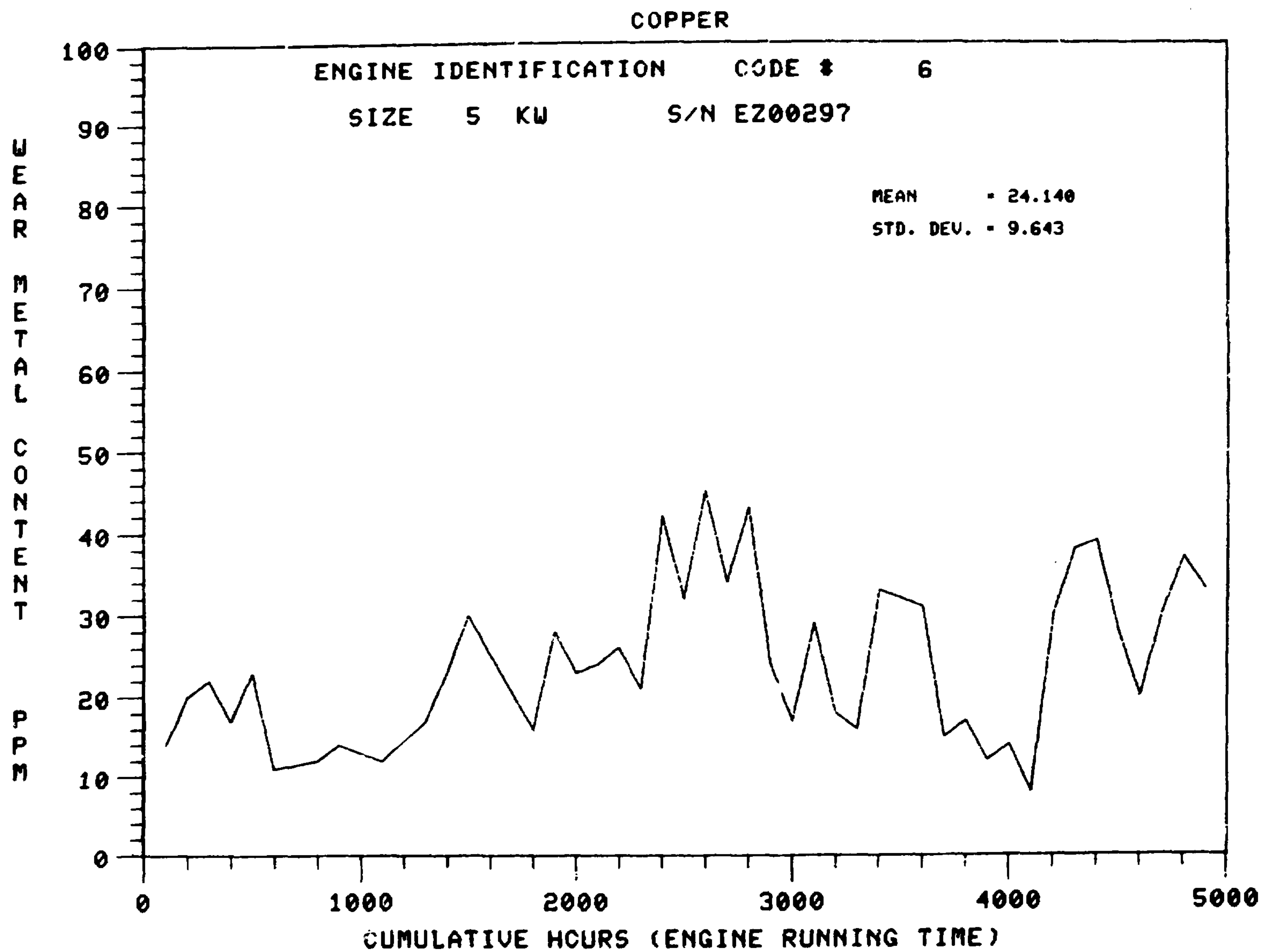


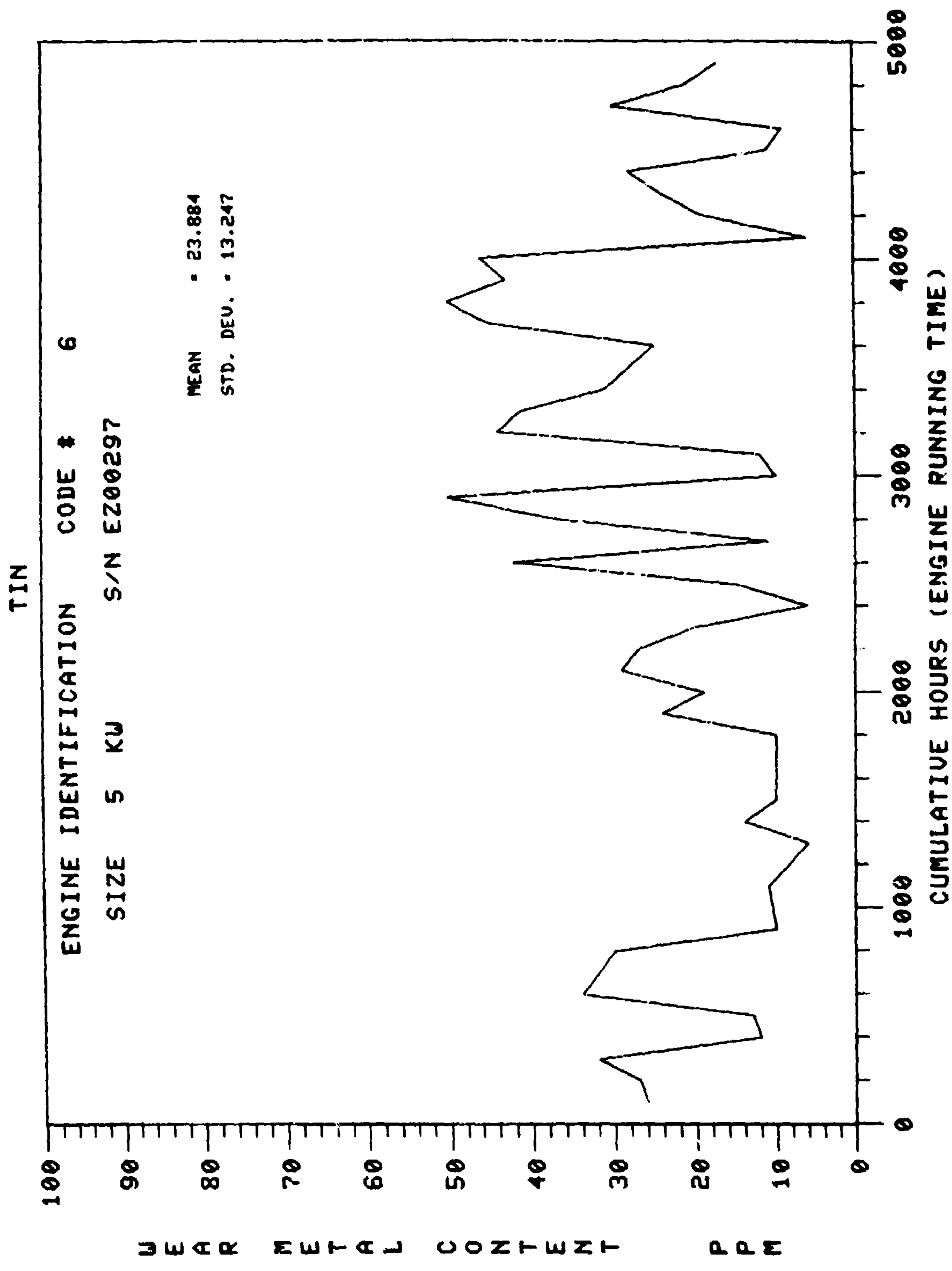
ALUMINUM
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 31.209
STD. DEV. = 8.857
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50


IRON
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 373.279
STD. DEV. = 202.201
WEAR METAL CONTENT PPM
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

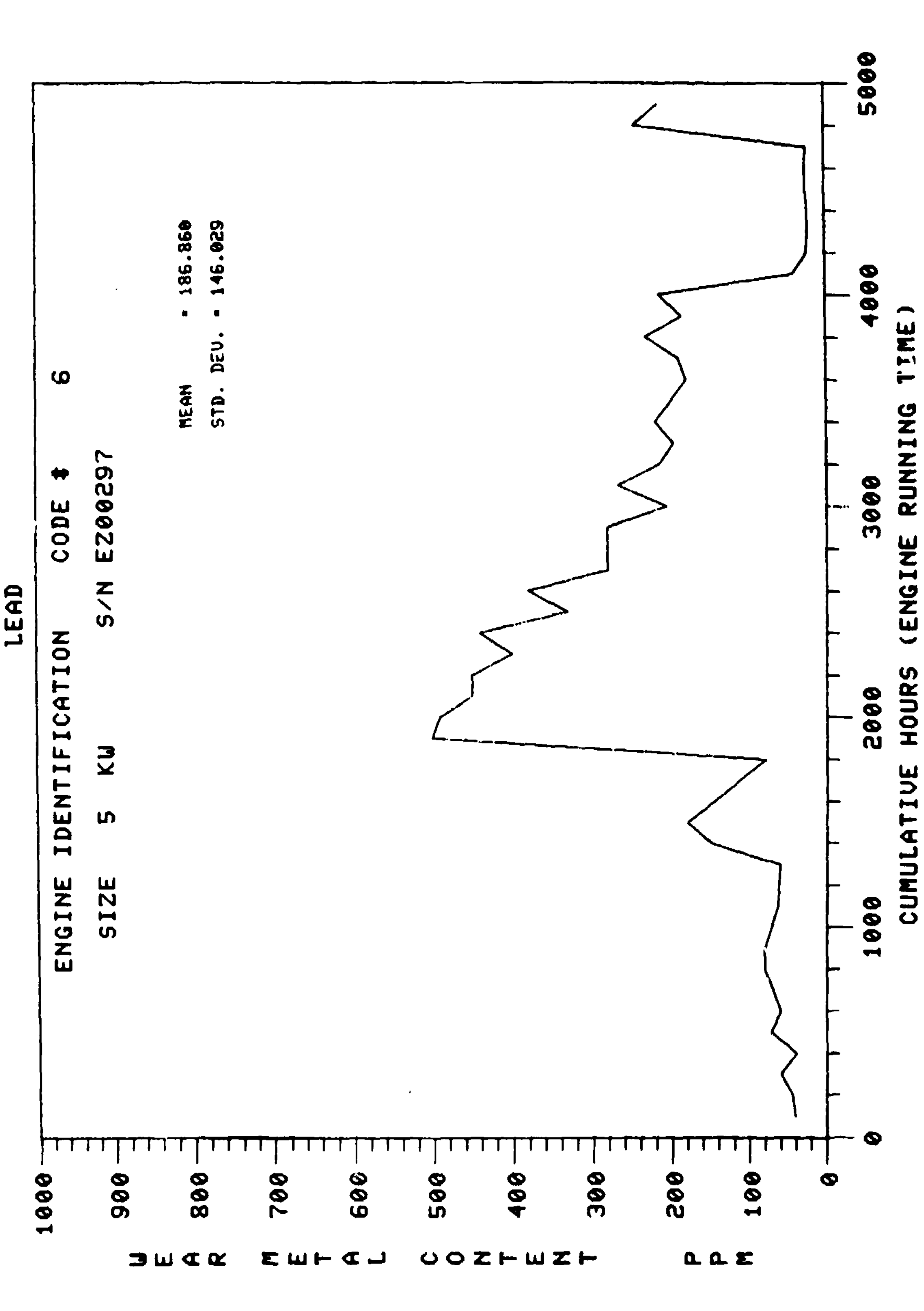


CHROMIUM
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 18.465
STD. DEV. = 6.456
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

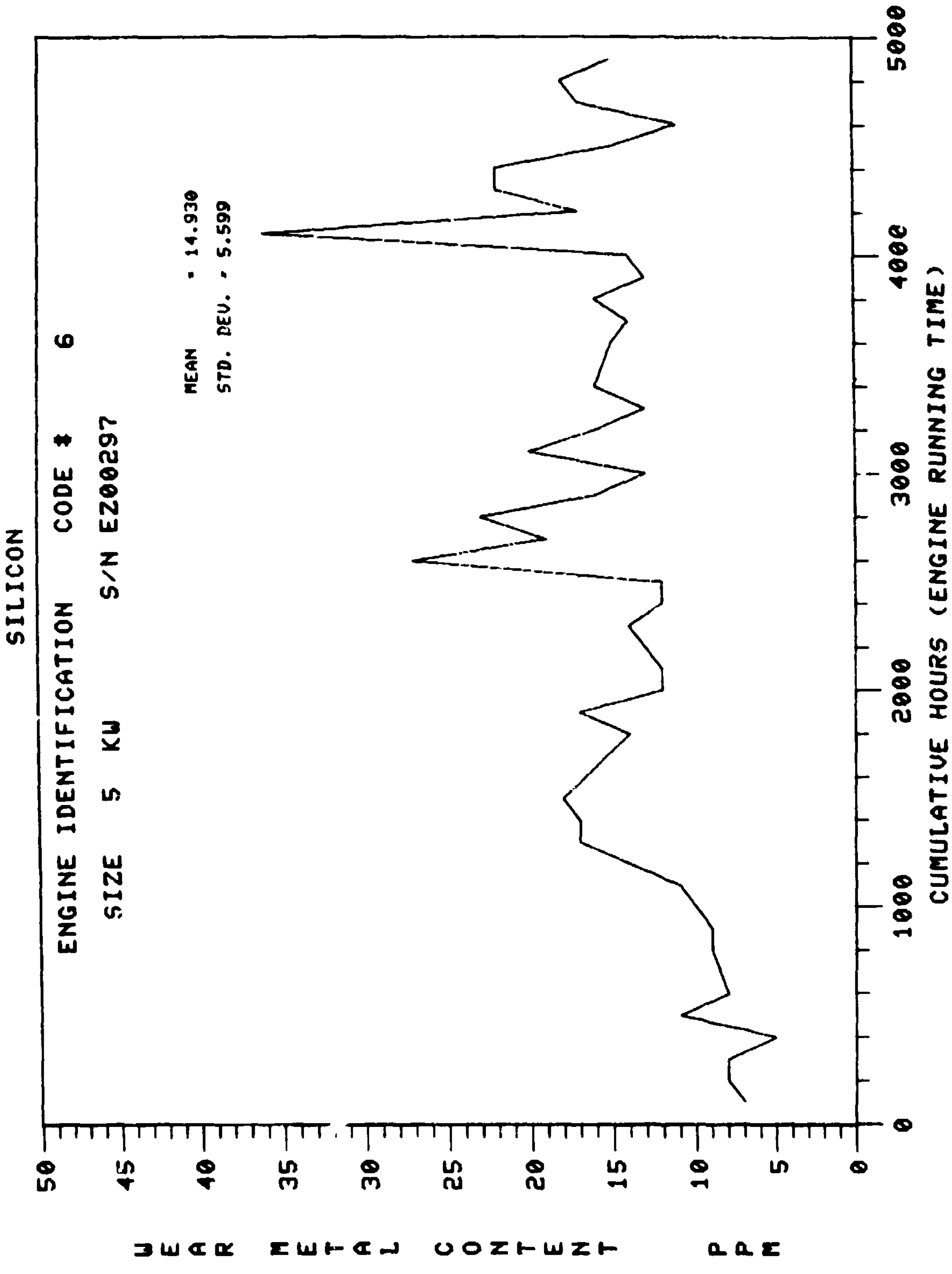

COPPER
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 24.140
STD. DEV. = 9.643
WEAR METAL CONTENT PPM
0
10
20
30
40
50
60
70
80
90
100
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)



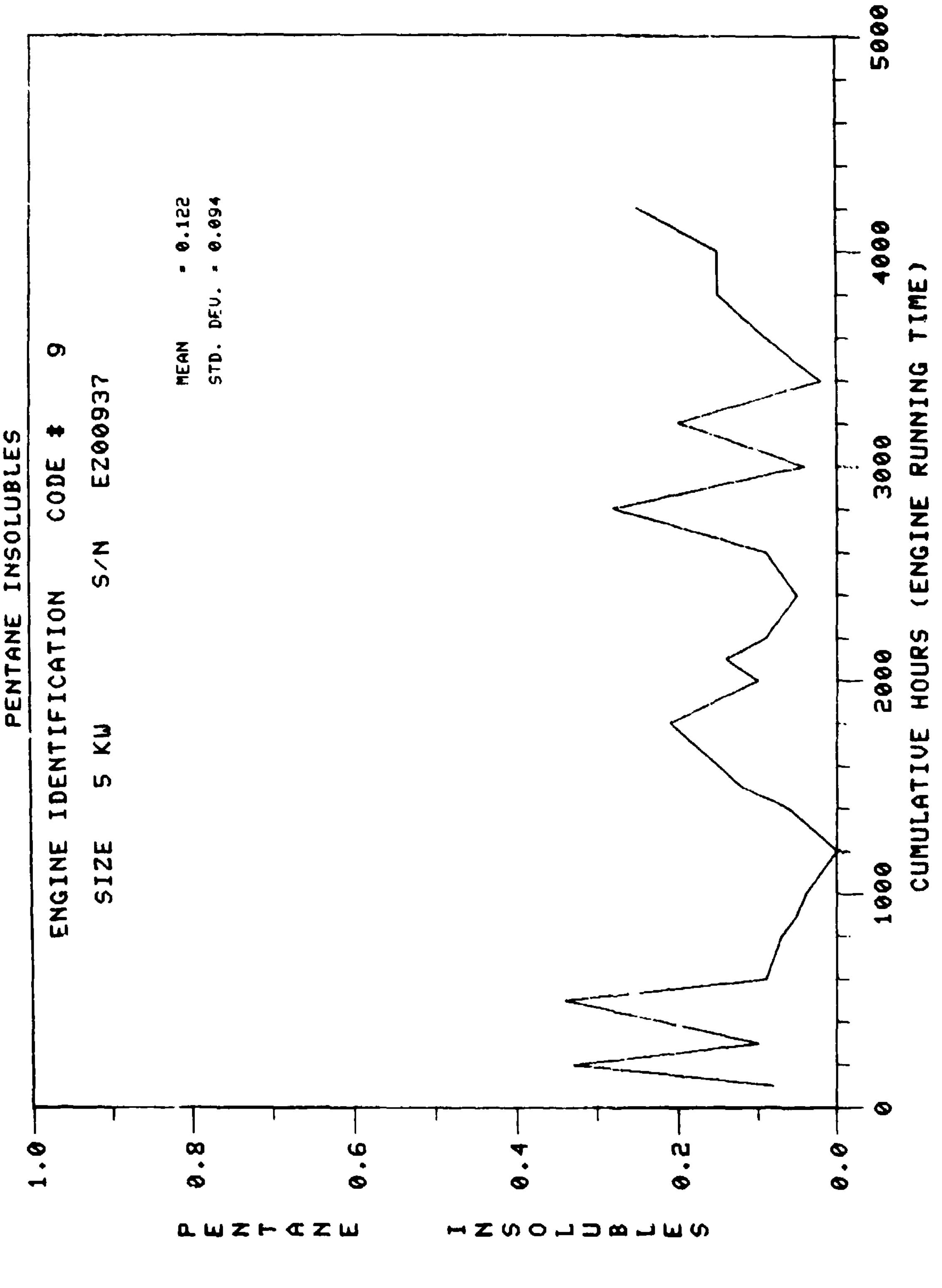
TIN
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 23.884
STD. DEV. = 13.247
WEAR METAL CONTENT PPM
0
10
20
30
40
50
60
70
80
90
100
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

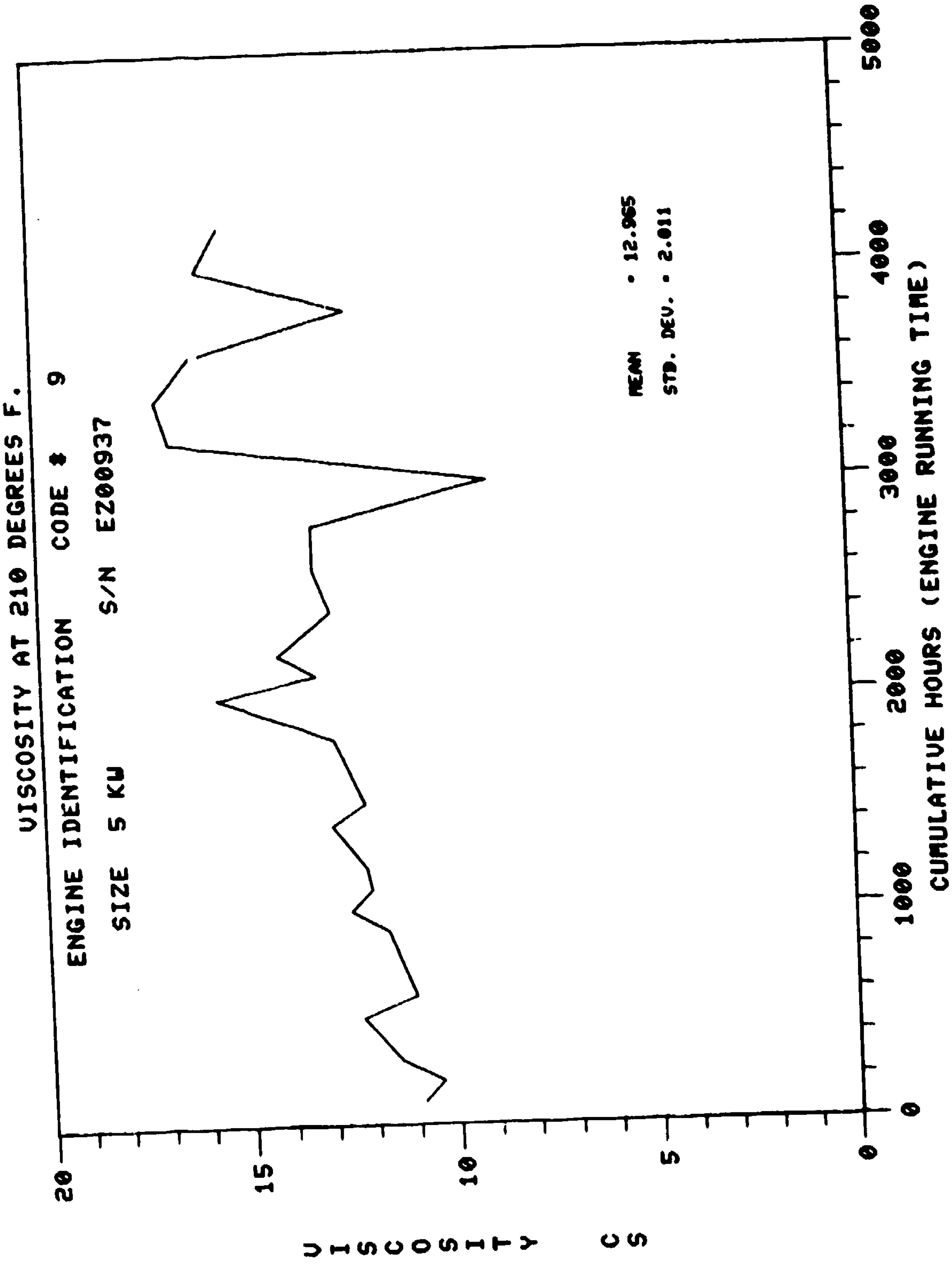


LEAD
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 186.860
STD. DEV. = 146.029
WEAR METAL CONTENT PPM
0
100
200
300
400
500
600
700
800
900
1000
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

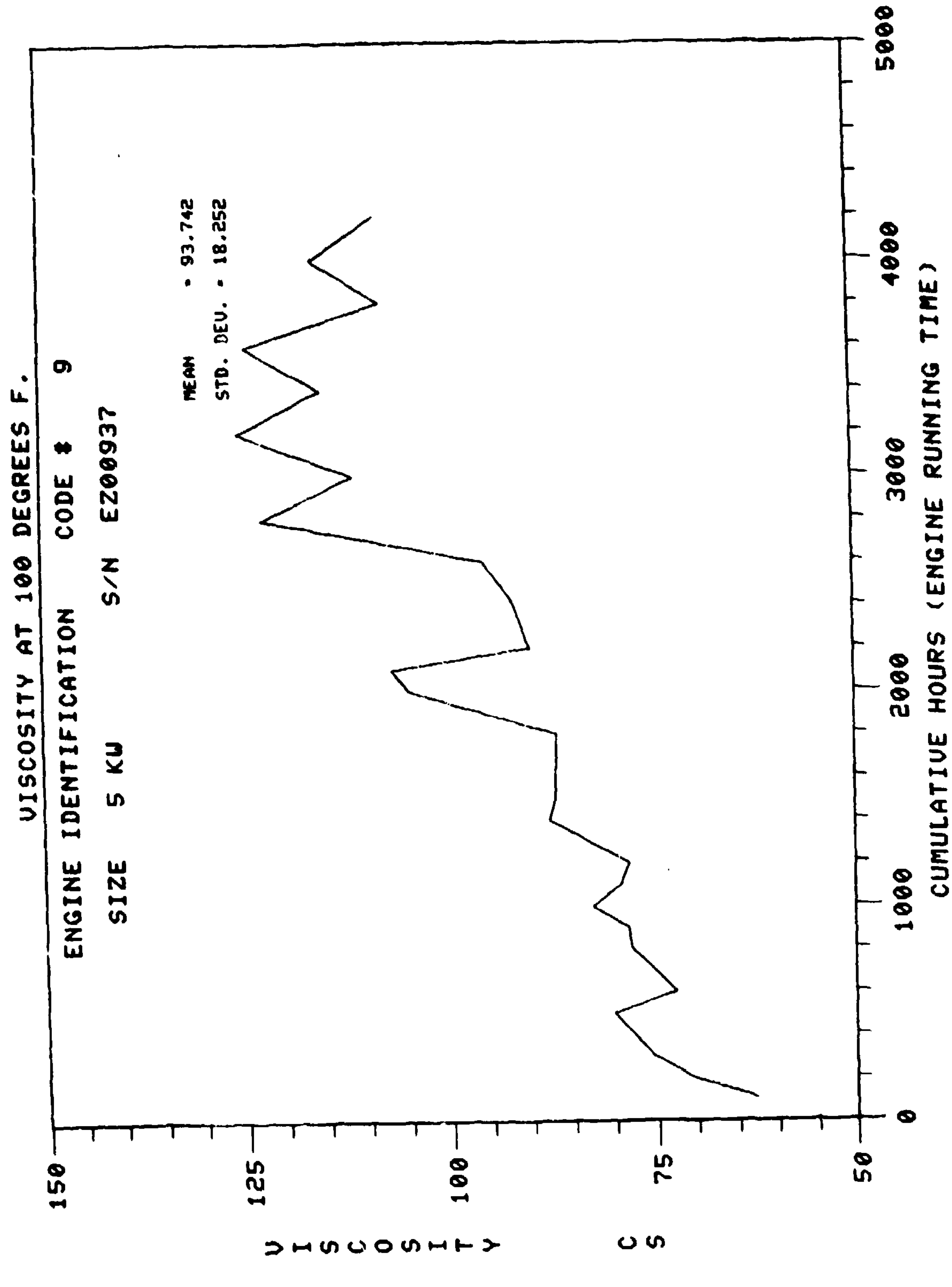


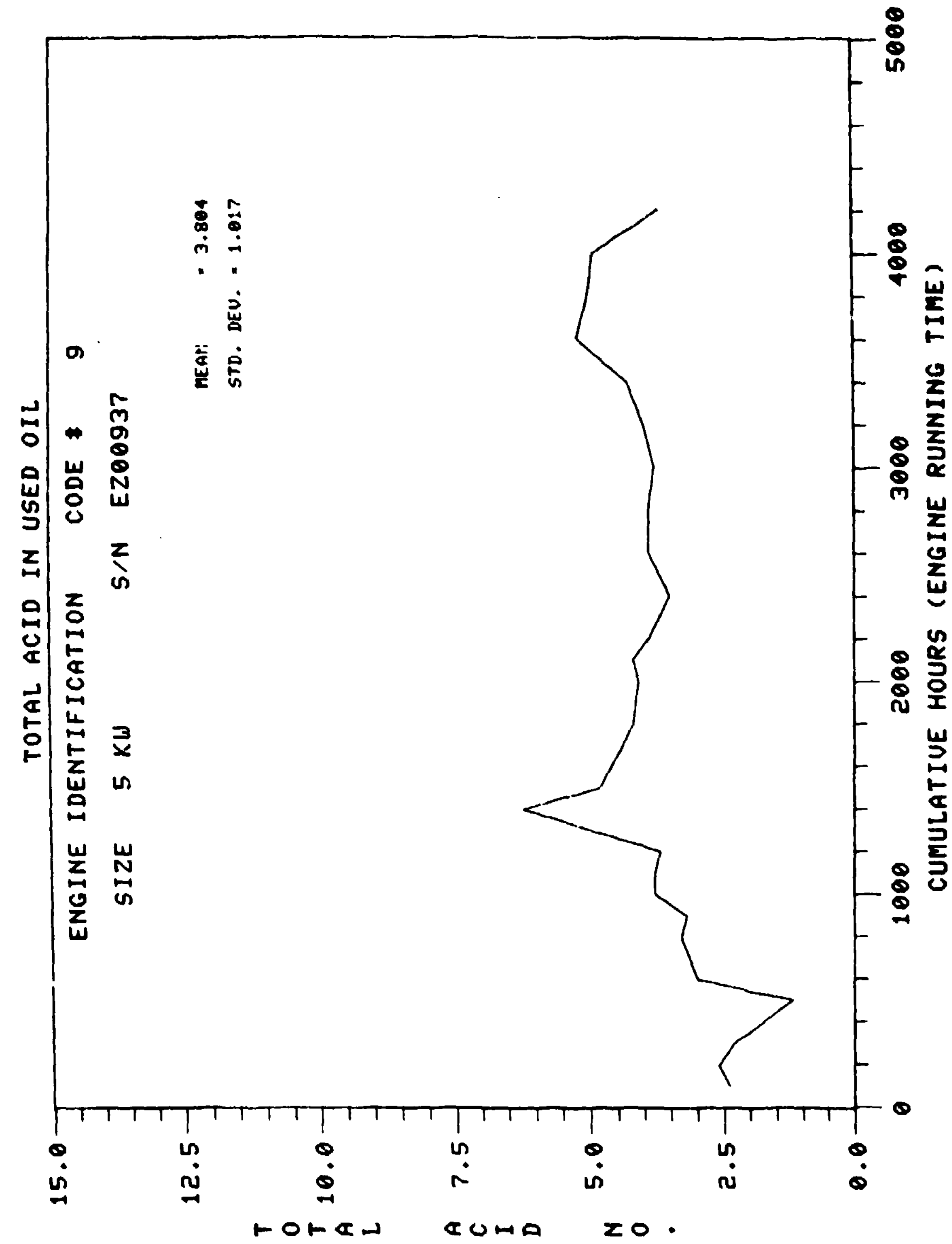
SILICON
ENGINE IDENTIFICATION CODE # 6
SIZE 5 KW S/N EZ00297
MEAN = 14.930
STD. DEV. = 5.599
0 1000 2000 3000 4000 5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0 5 10 15 20 25 30 35 40 45 50
WEAR METAL CONTENT PPM

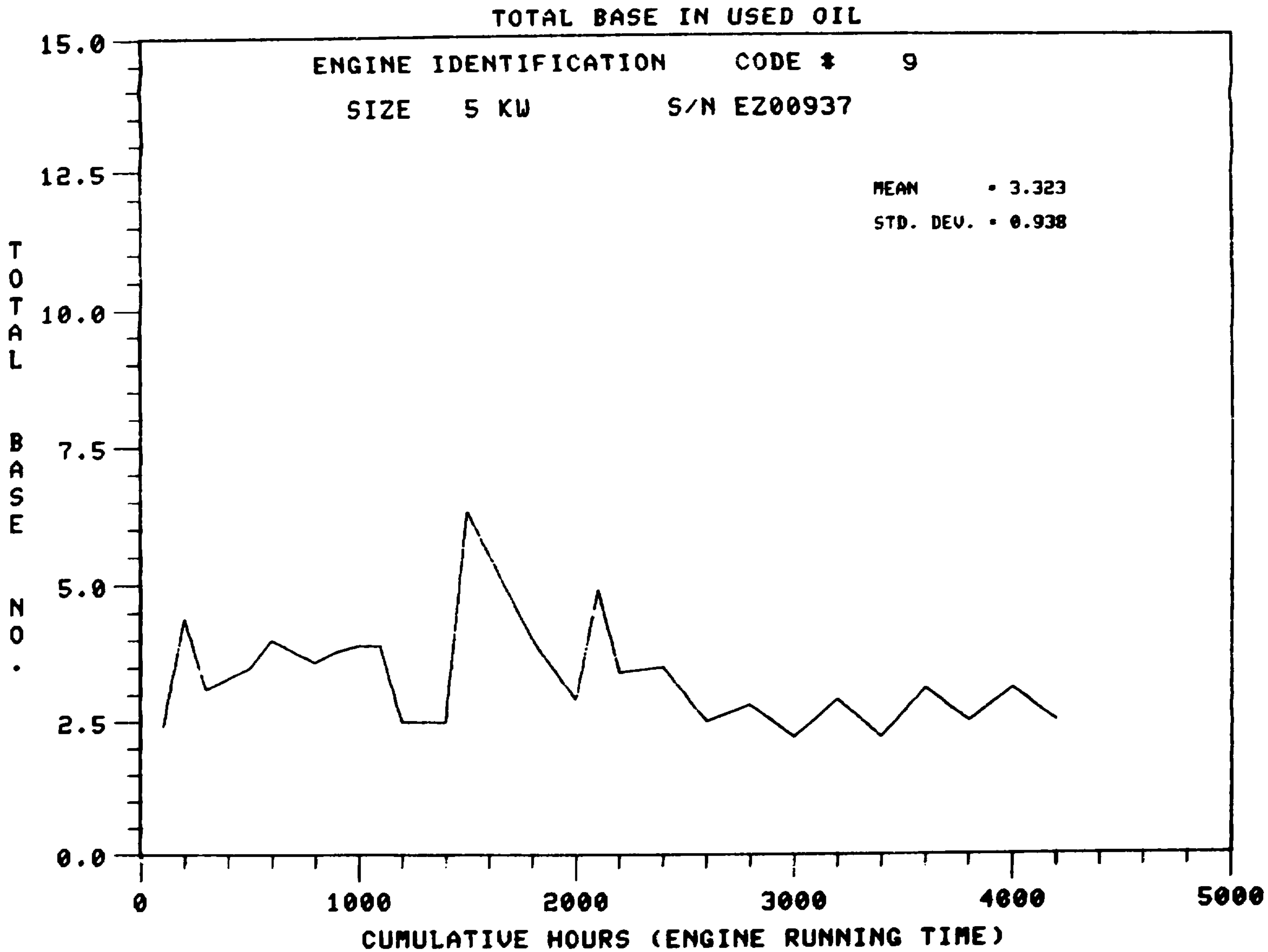

PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 0.122
STD. DEV. = 0.094
1.0
0.8
0.6
0.4
0.2
0.0
PENTANE INSOLUBLES
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

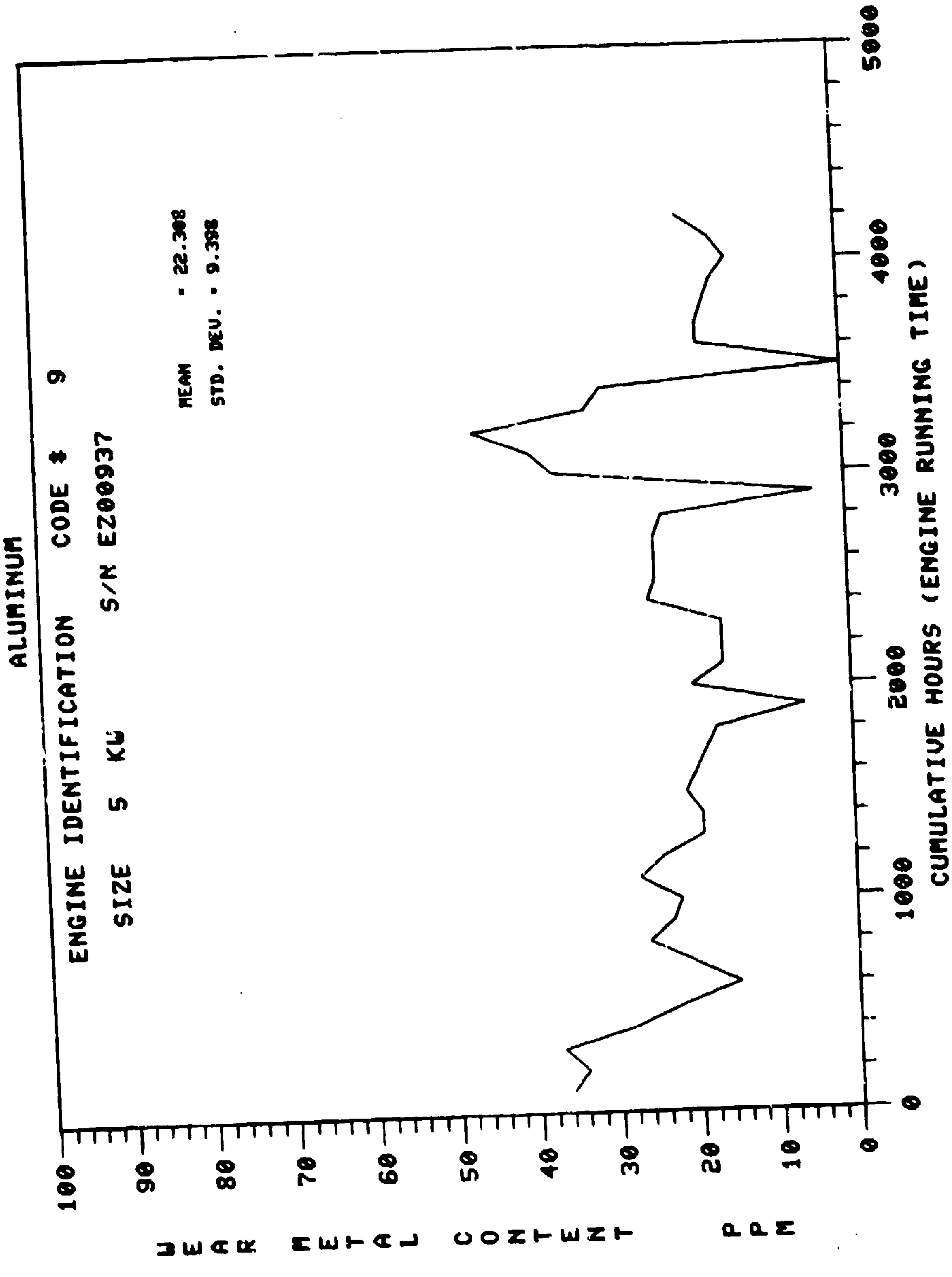


VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 12.965
STD. DEV. = 2.011
VISCOSITY CS
0
5
10
15
20
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

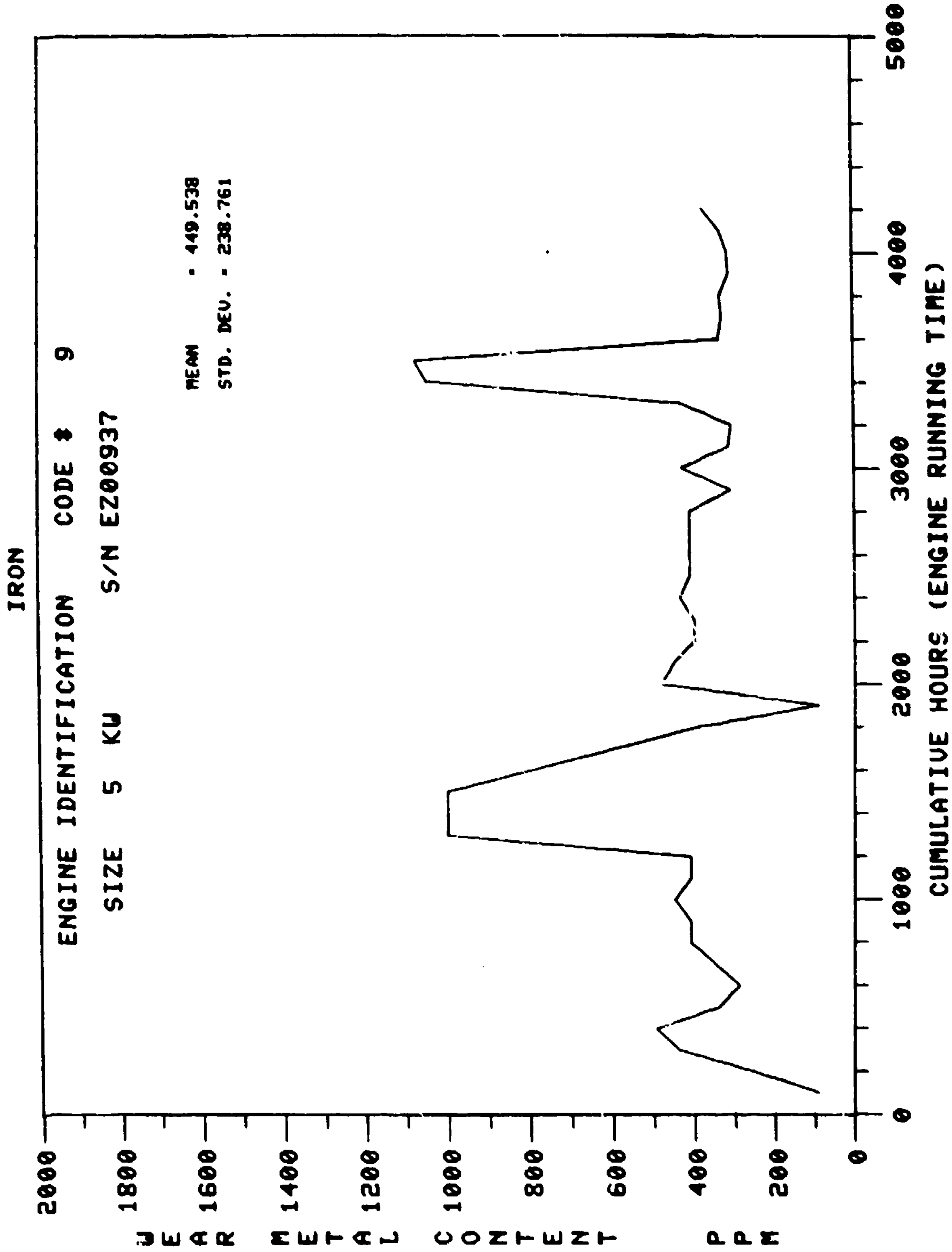

VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 93.742
STD. DEV. = 18.252
VISCOSITY CS
150
125
100
75
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 3.804
STD. DEV. = 1.017
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

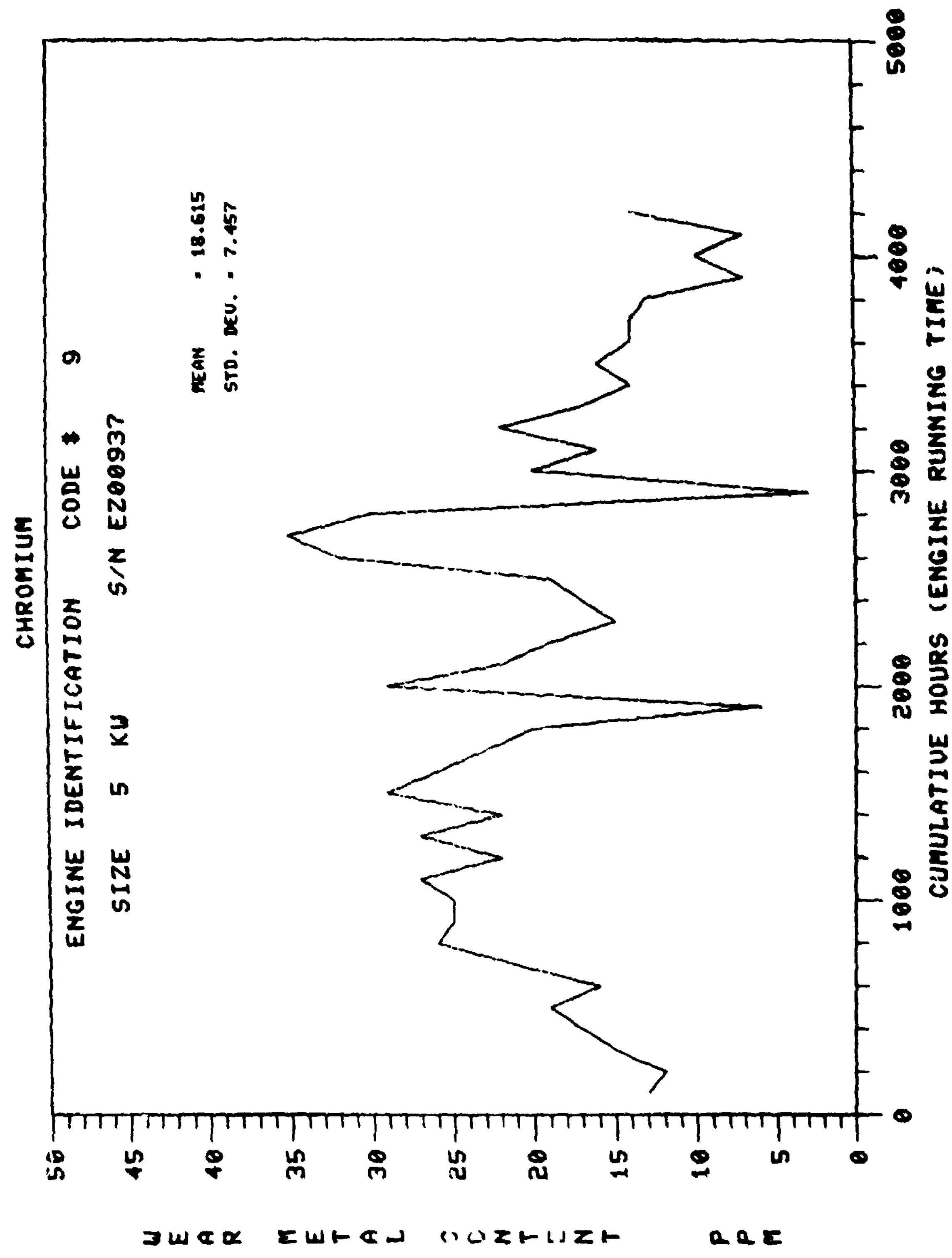

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 3.323
STD. DEV. = 0.938
15.0
12.5
10.0
7.5
5.0
2.5
0.0
TOTAL BASE NO.
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

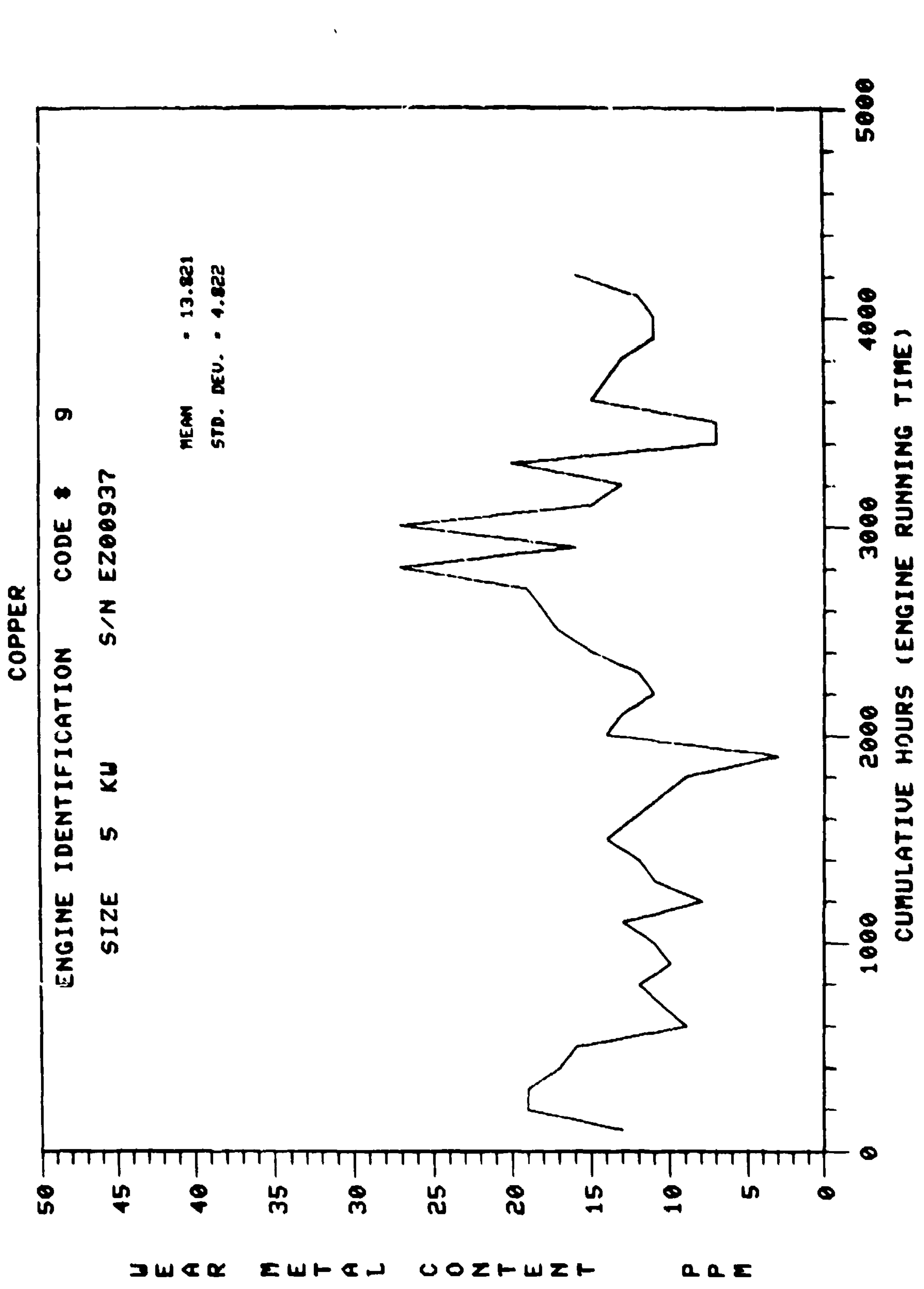


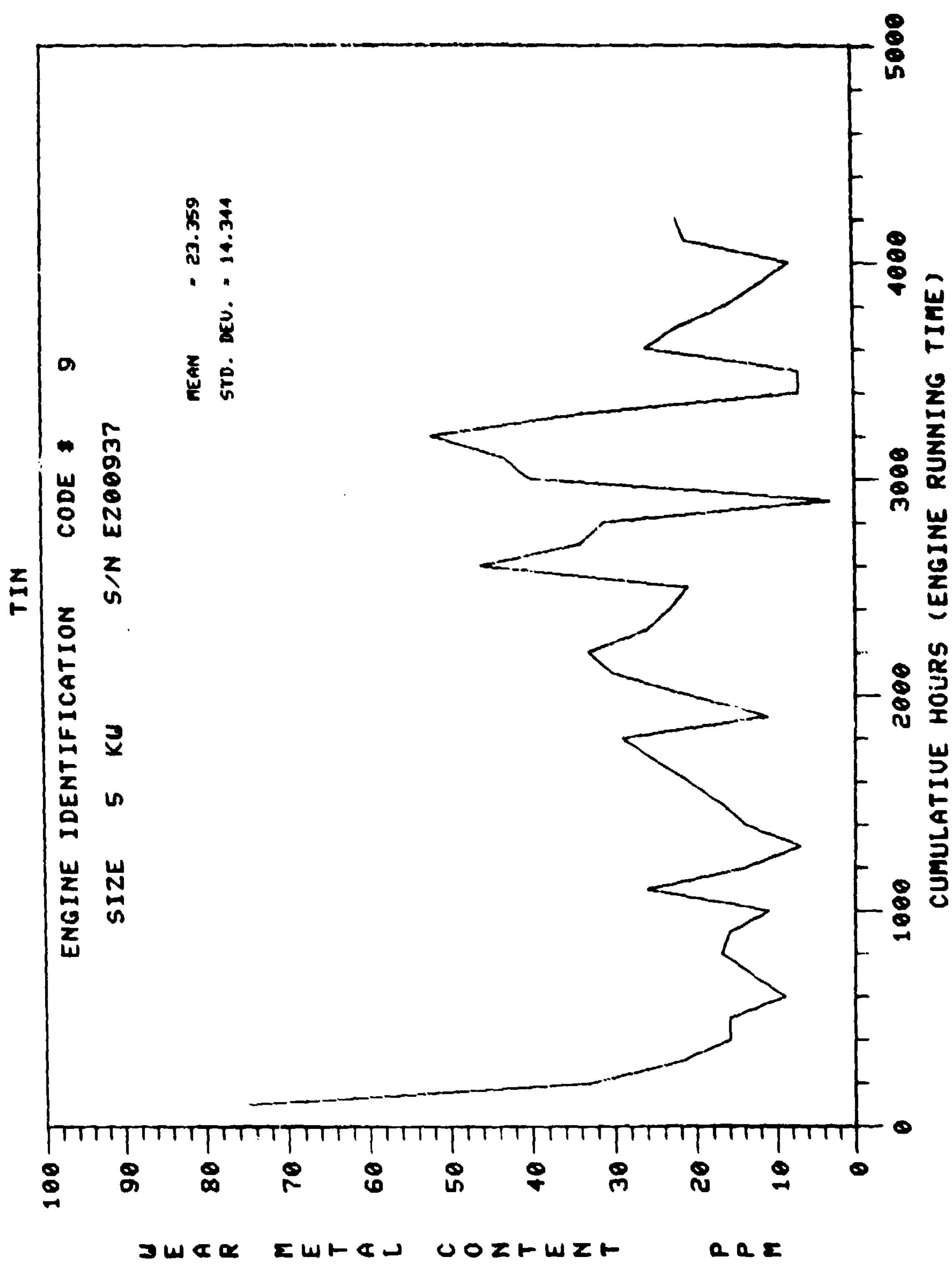
ALUMINUM
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 22.308
STD. DEV. = 9.398
WEAR METAL CONTENT PPM
0
10
20
30
40
50
60
70
80
90
100
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000

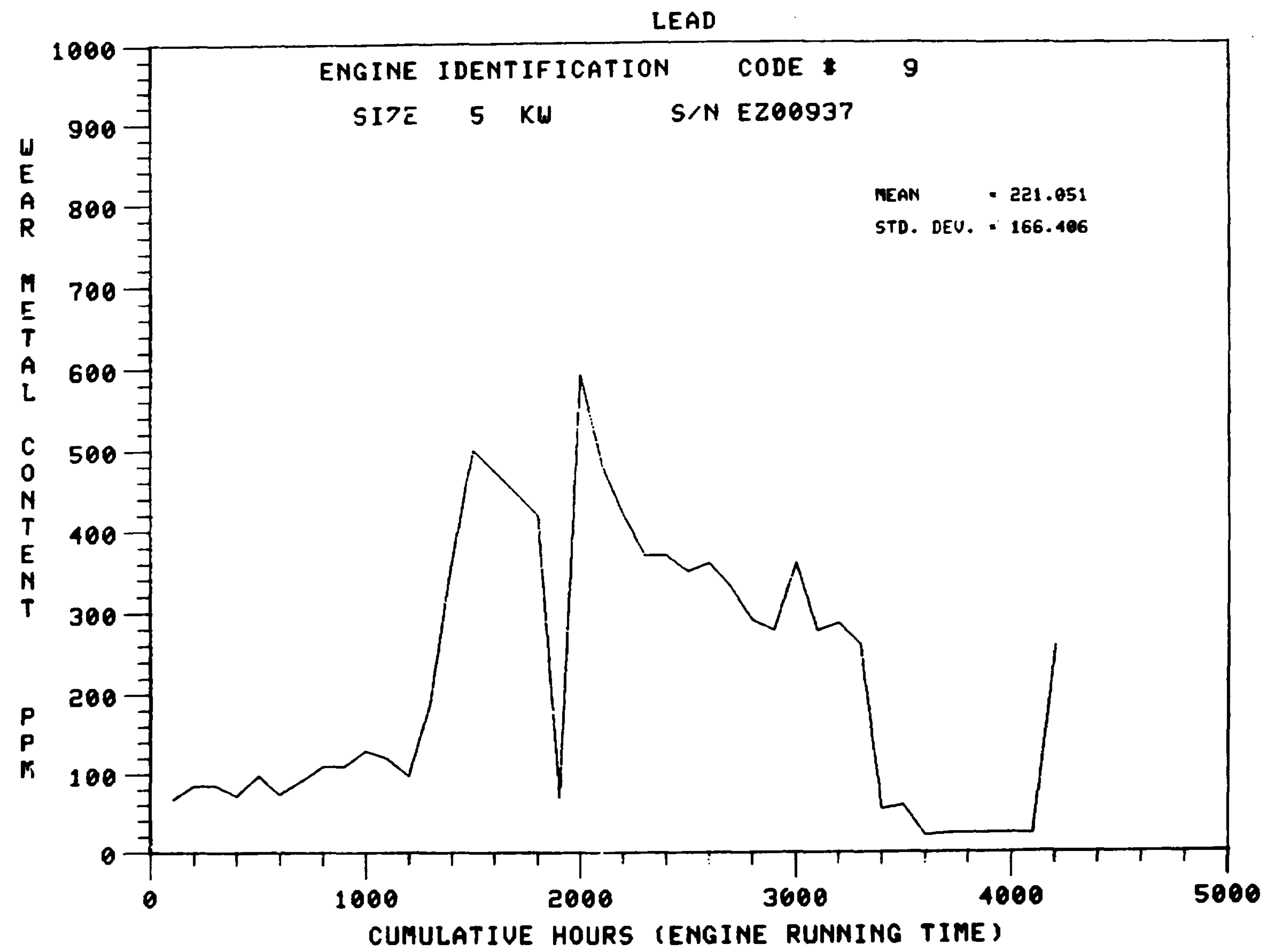


IRON
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 449.538
STD. DEV. = 238.761
WEAR METAL CONTENT PPM
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

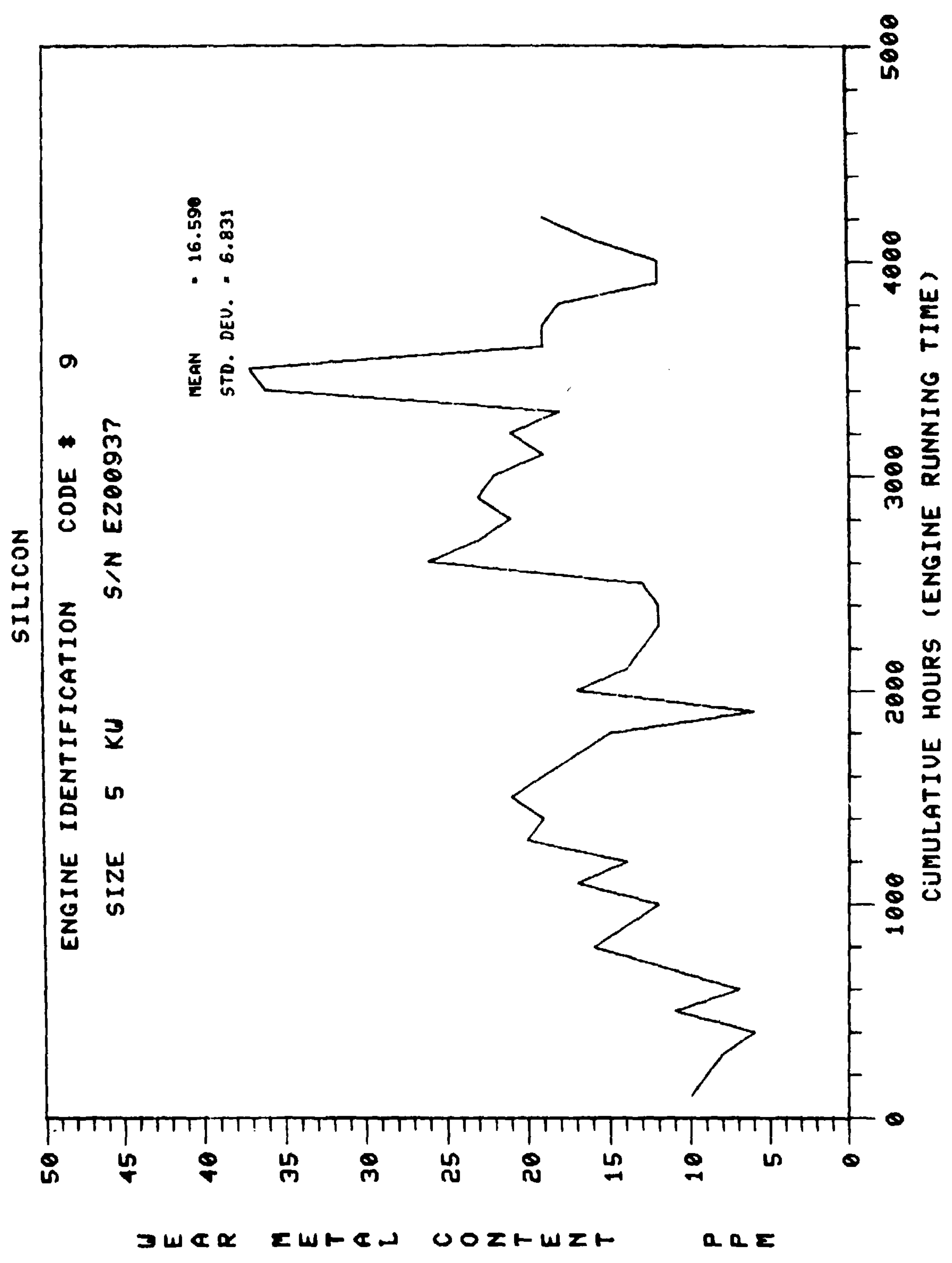

CHROMIUM
ENGINE IDENTIFICATION CODE $ 9
SIZE 5 KW S/N EZ00937
MEAN = 18.615
STD. DEV. = 7.457
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


COPPER
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N E200937
MEAN = 13.821
STD. DEV. = 4.822
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
25
30
35
40
45
50
WEAR METAL CONTENT PPM

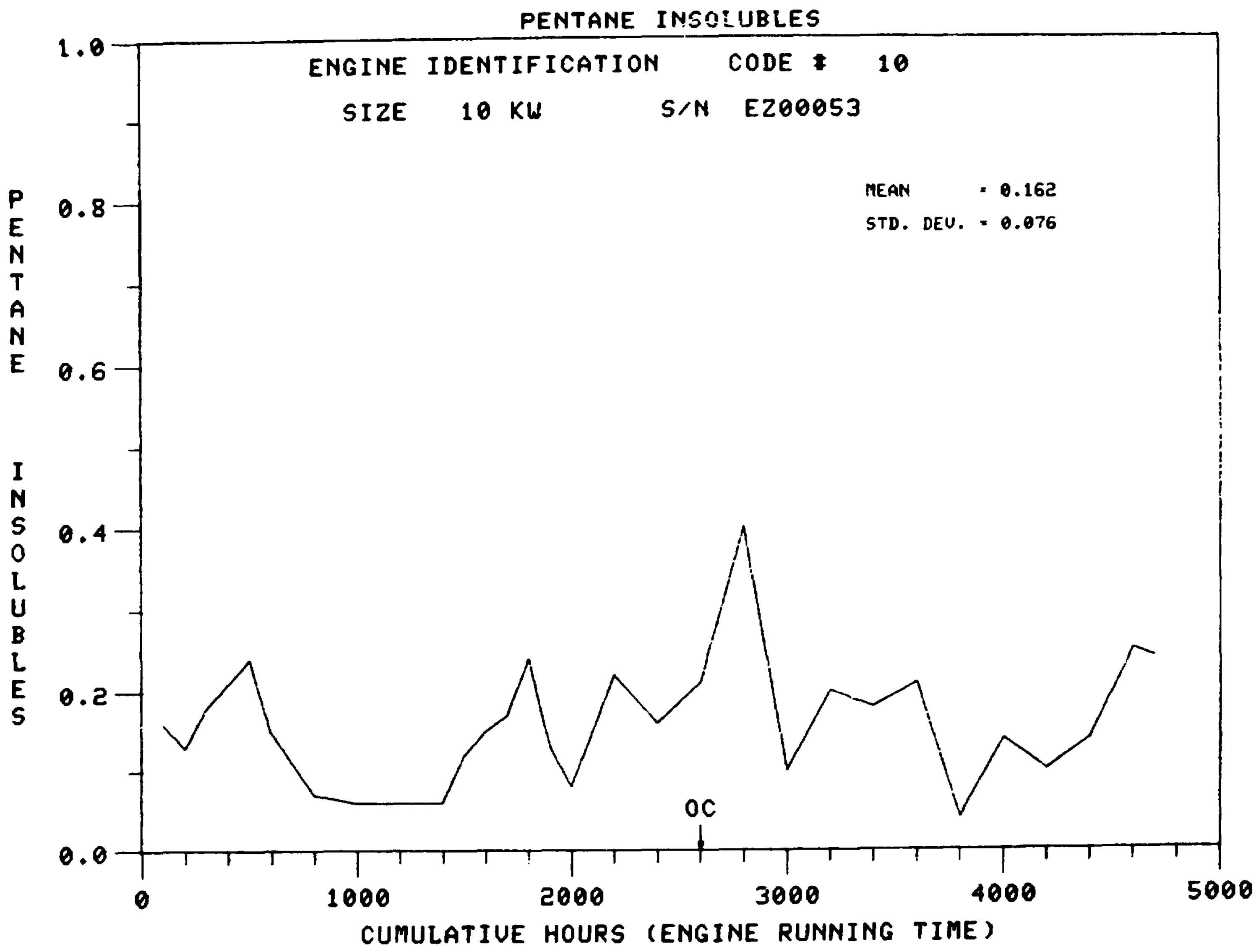

TIN
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N E200937
MEAN = 23.359
STD. DEV. = 14.344
WEAR METAL CONTENT PPM
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
10
20
30
40
50
60
70
80
90
100
1000
2000
3000
4000
5000

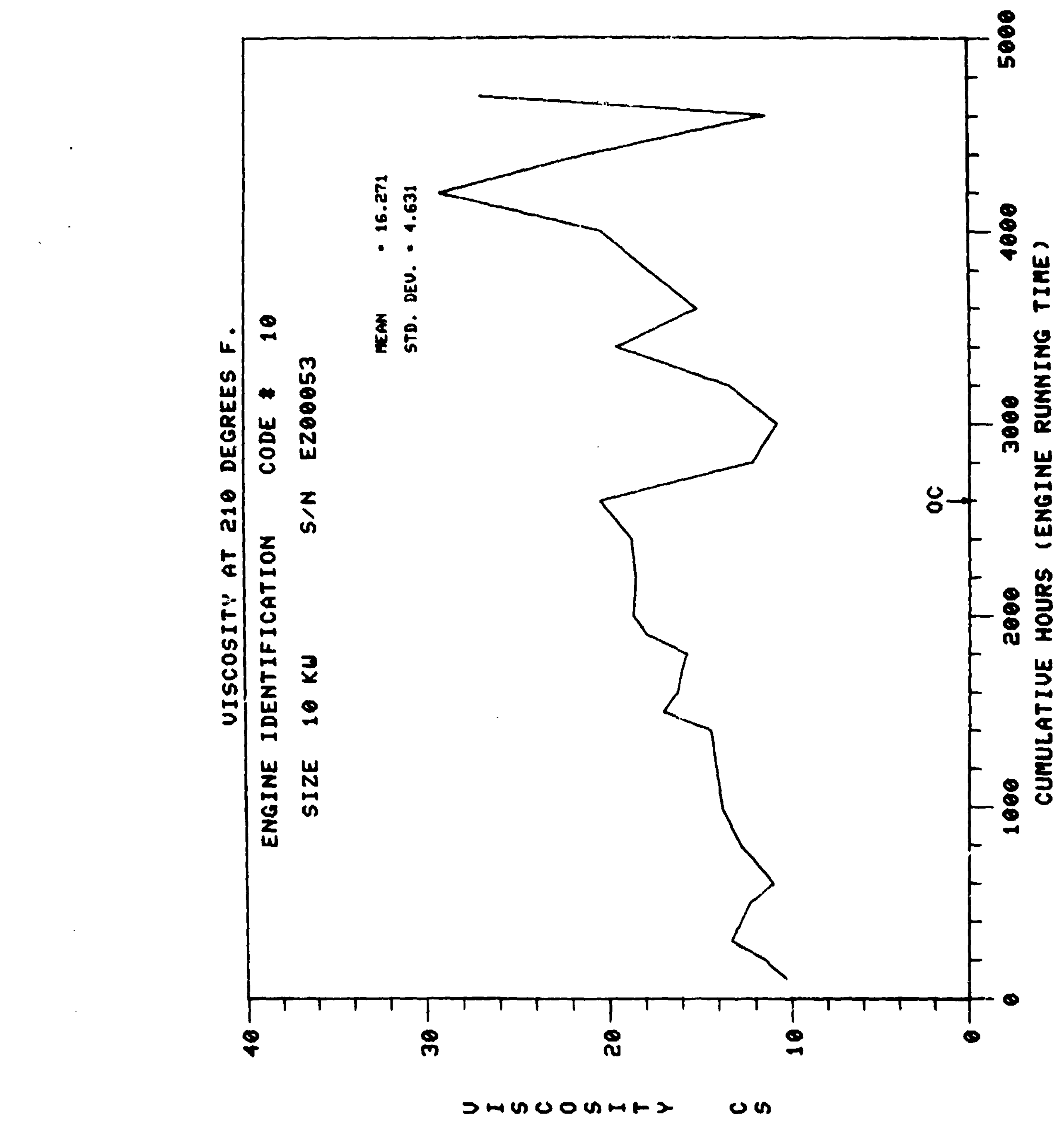


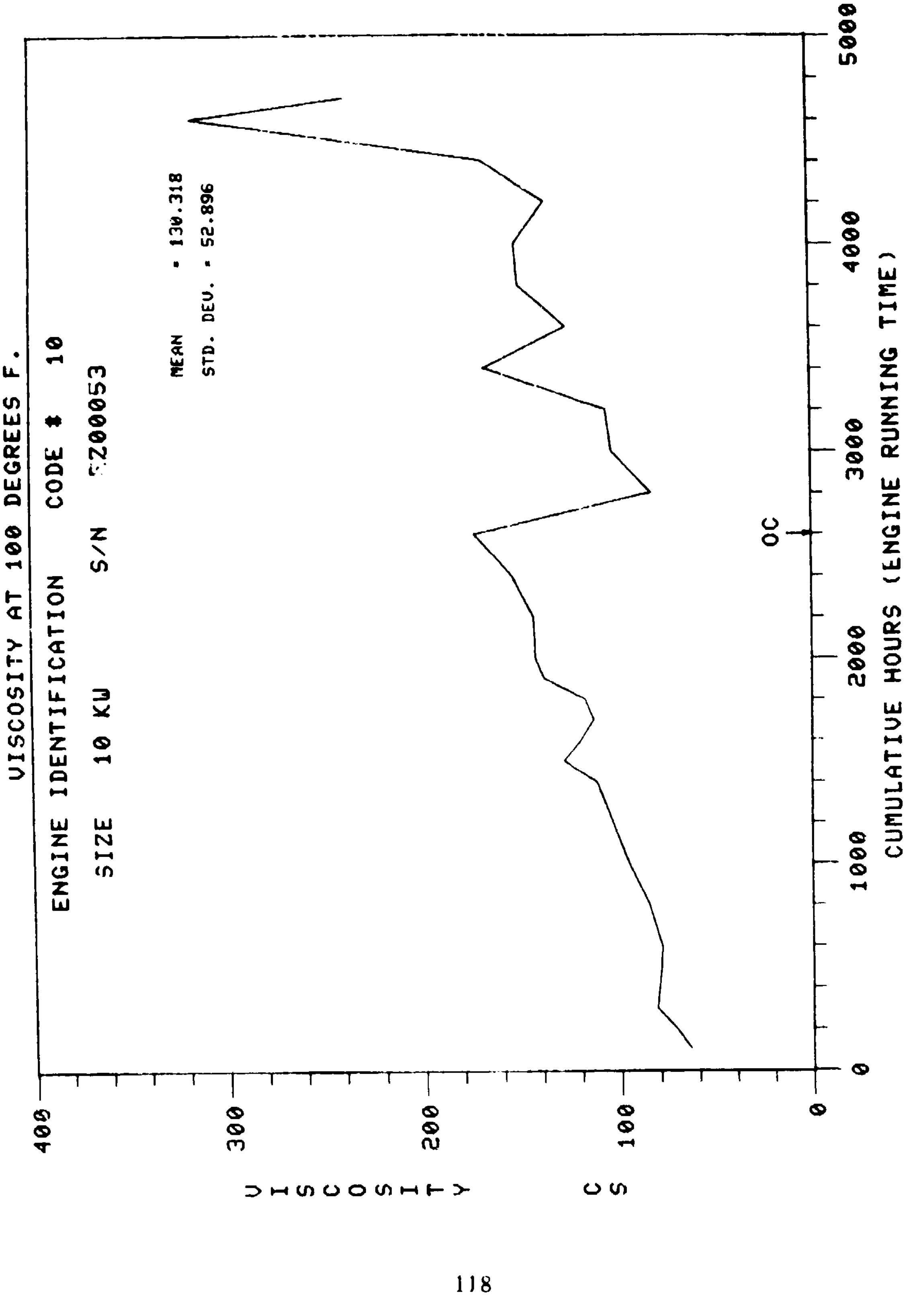
LEAD
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 221.051
STD. DEV. = 166.406
WEAR METAL CONTENT PPM
0
100
200
300
400
500
600
700
800
900
1000
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)



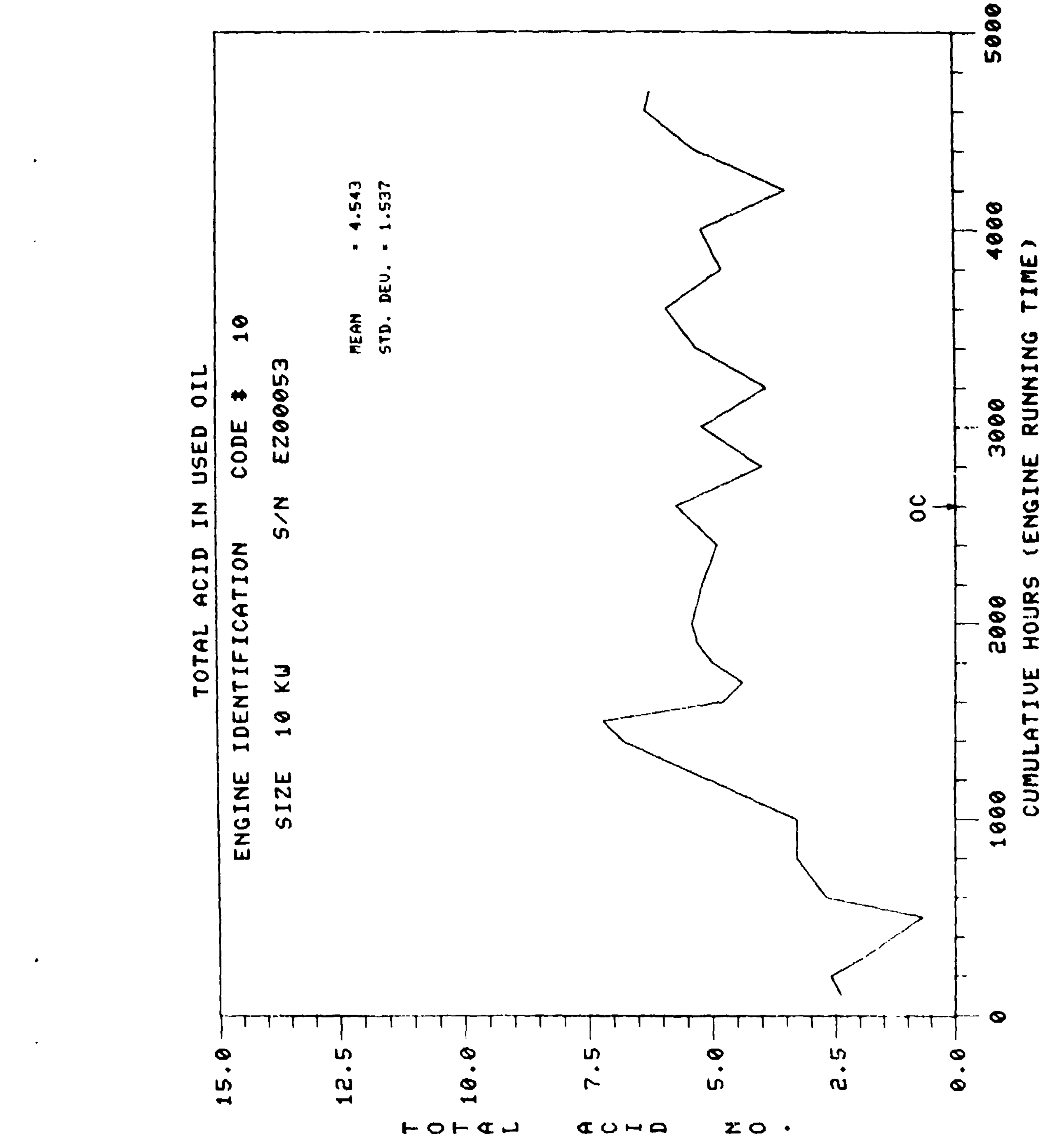
SILICON
ENGINE IDENTIFICATION CODE # 9
SIZE 5 KW S/N EZ00937
MEAN = 16.590
STD. DEV. = 6.831
WEAR METAL CONTENT PPM
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0 5 10 15 20 25 30 35 40 45 50
0 1000 2000 3000 4000 5000

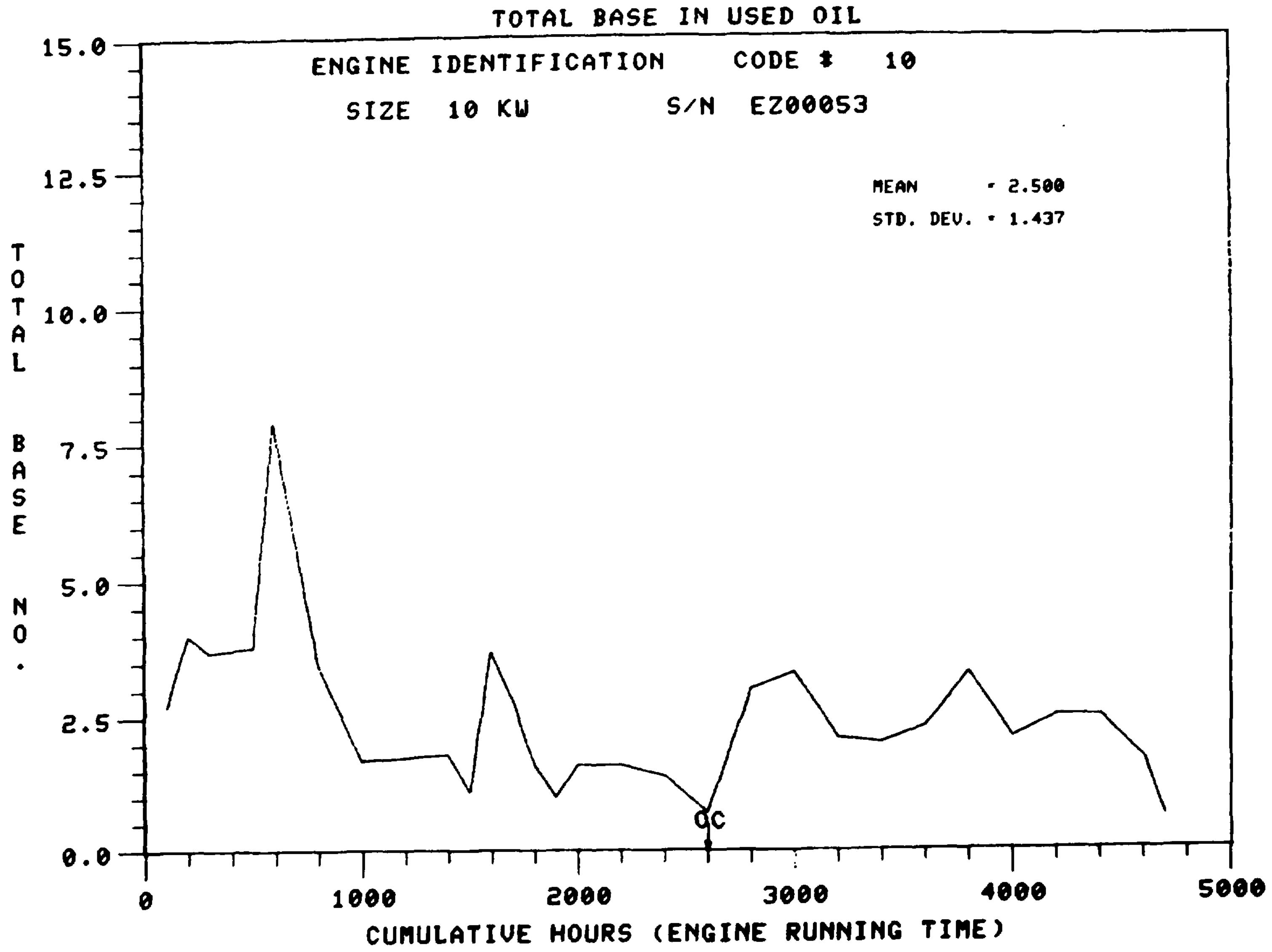

PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 0.162
STD. DEV. = 0.076
PENTANE INSOLUBLES
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)

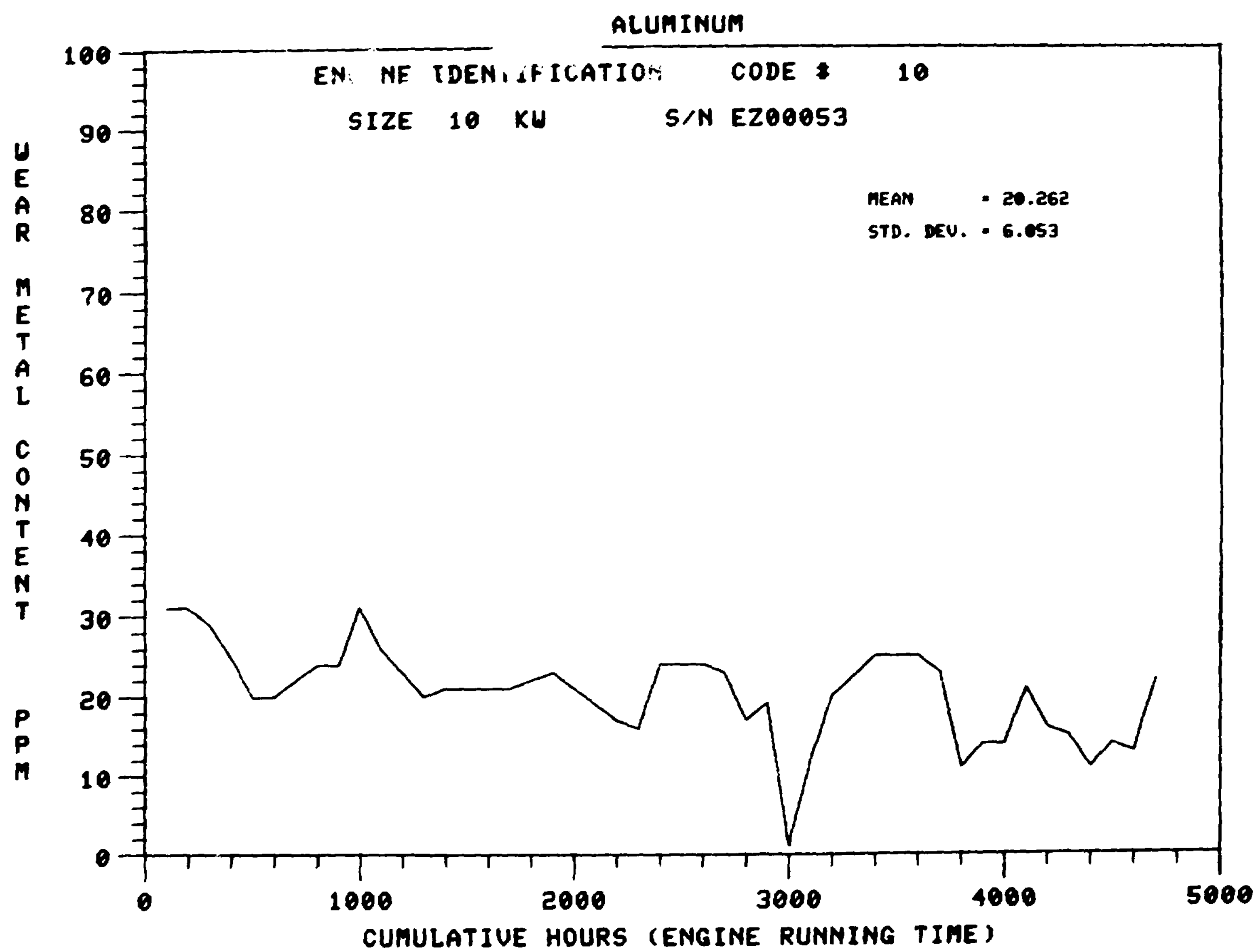

VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 16.271
STD. DEV. = 4.631
OC
VISCOSITY CS
40
30
20
10
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

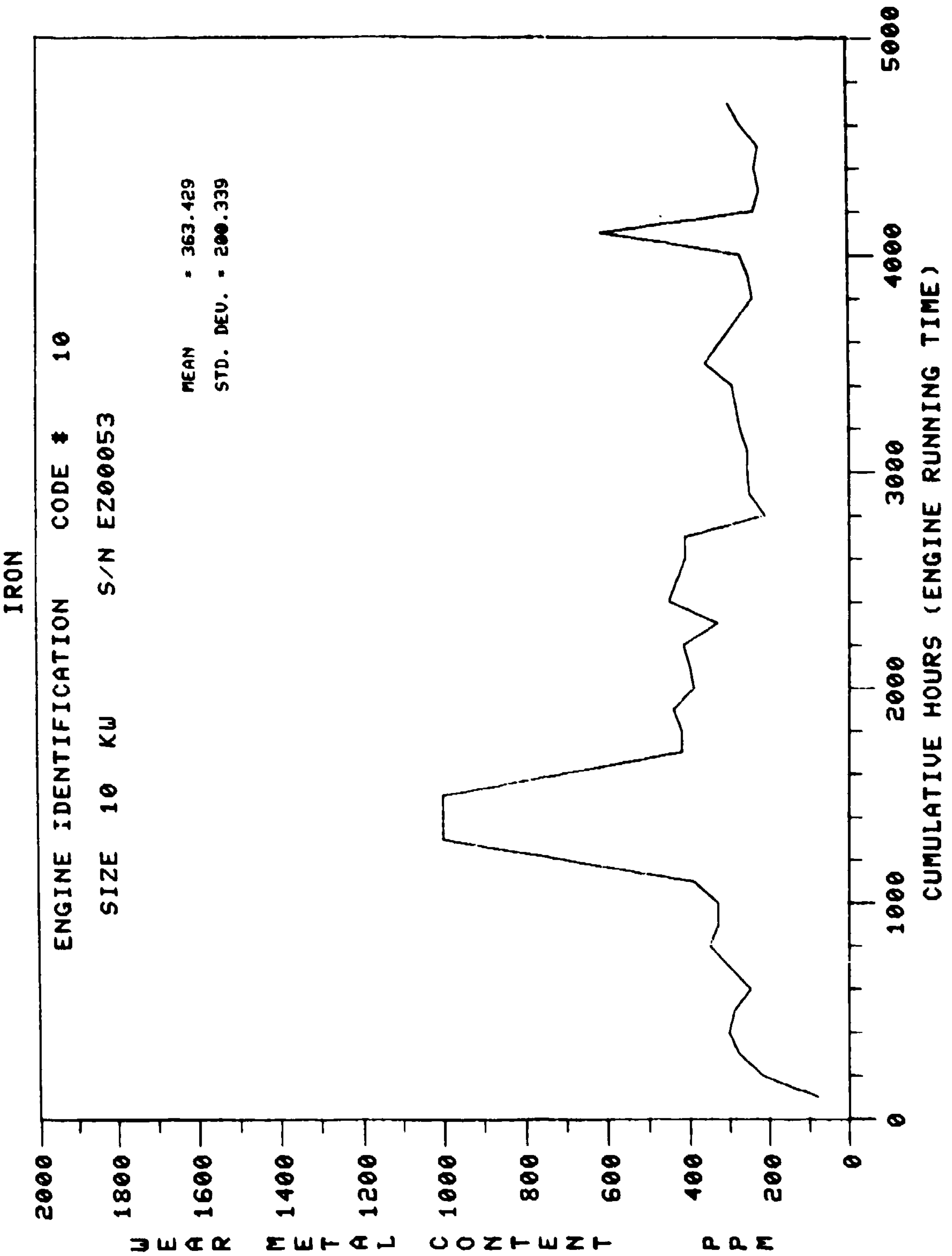


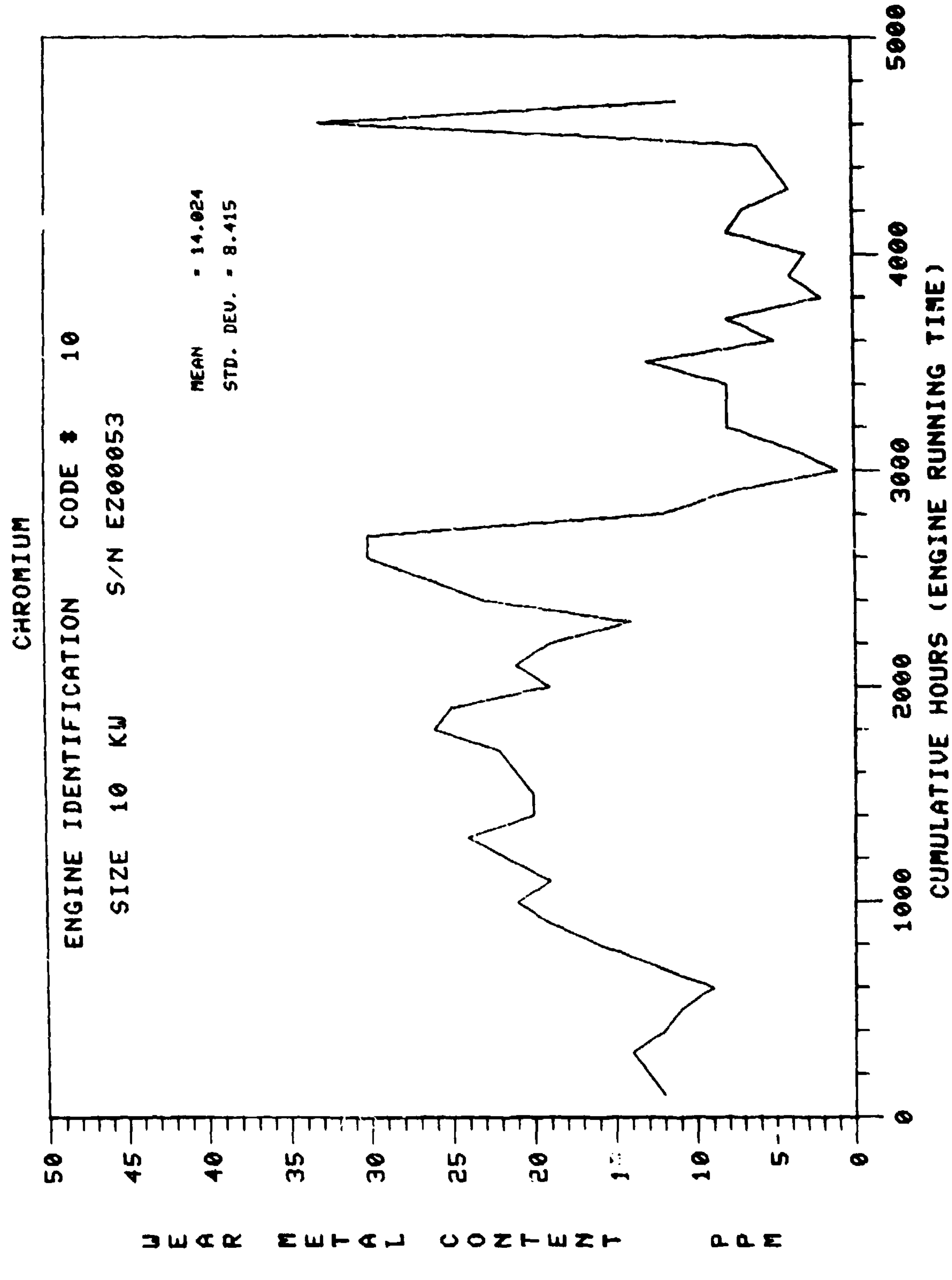
VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N Z00053
MEAN = 130.318
STD. DEV. = 52.896
OC
VISCOSITY CS
0
100
200
300
400
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

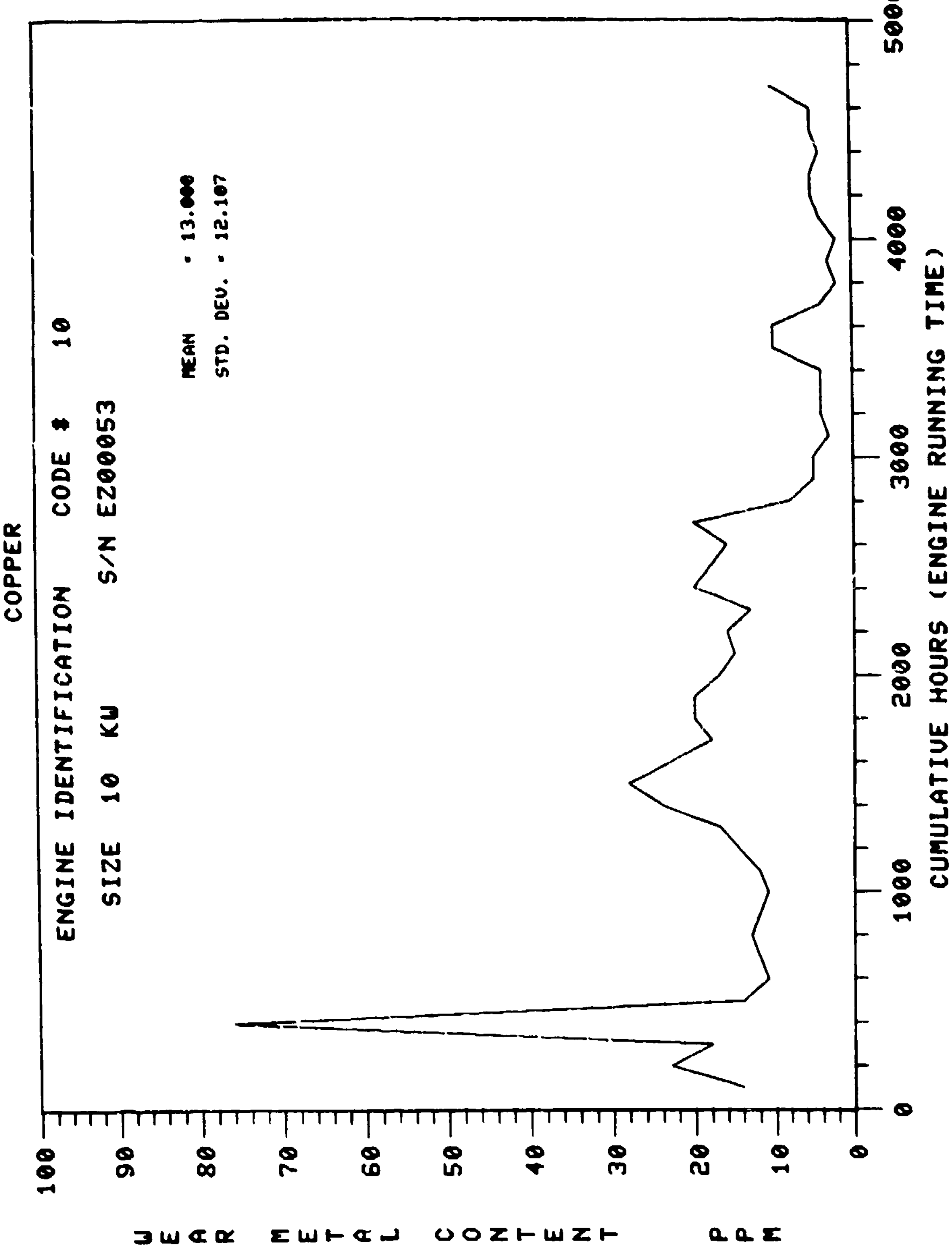

TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 4.543
STD. DEV. = 1.537
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)

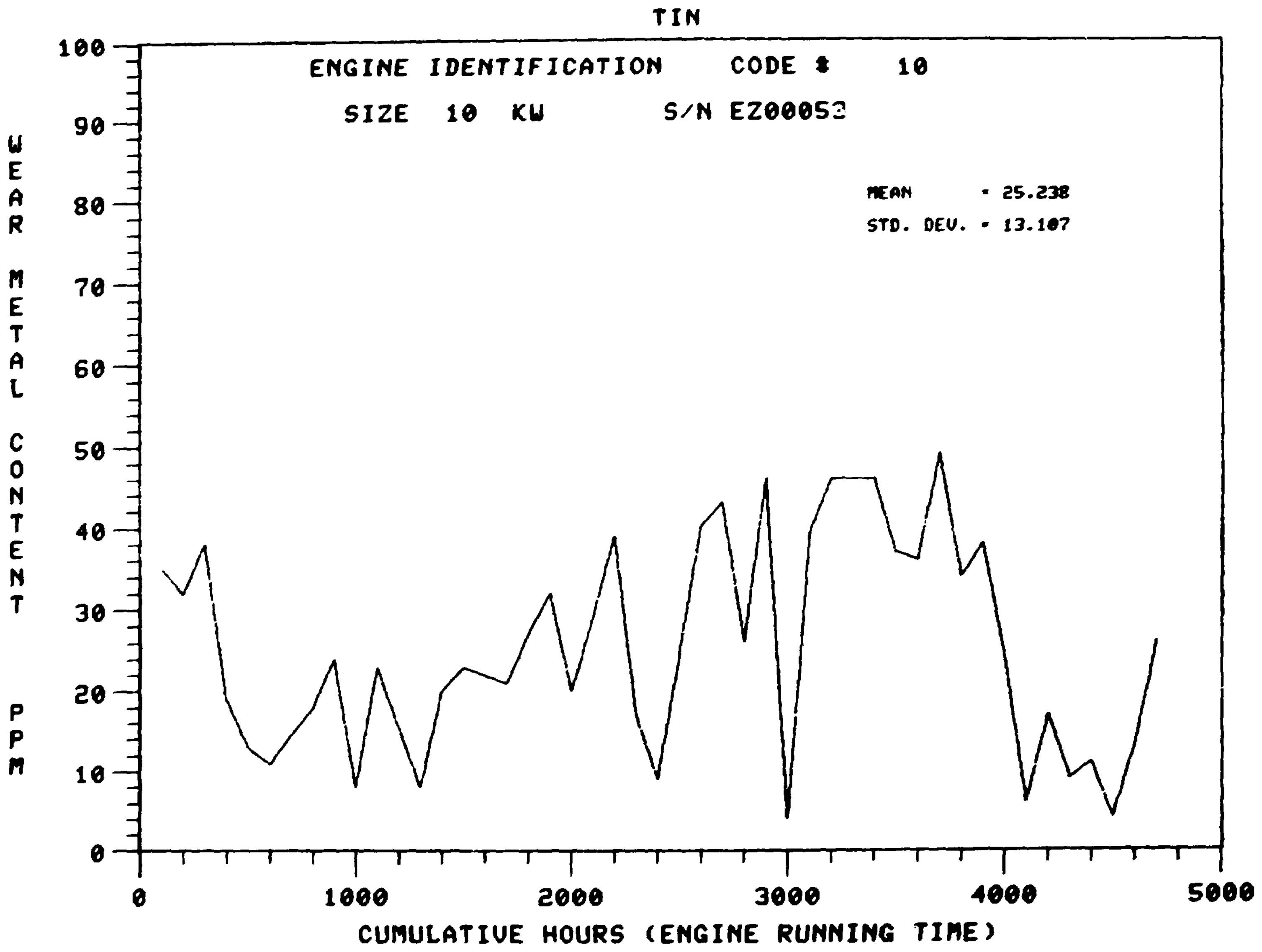

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 2.500
STD. DEV. = 1.437
QC
15.0
12.5
10.0
7.5
5.0
2.5
0.0
TOTAL BASE NO.
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

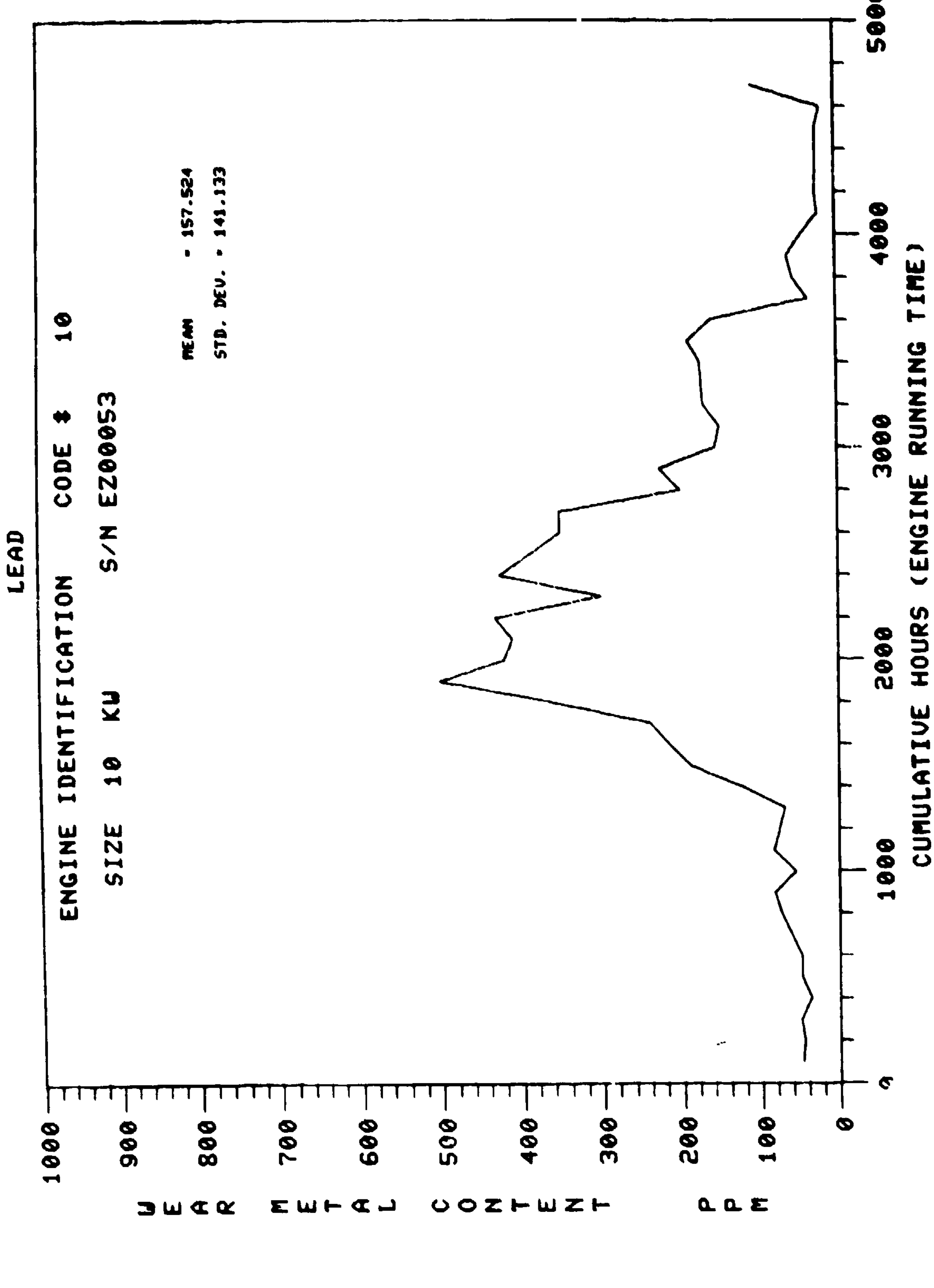

ALUMINUM
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 20.262
STD. DEV. = 6.053
WEAR METAL CONTENT PPM
100
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

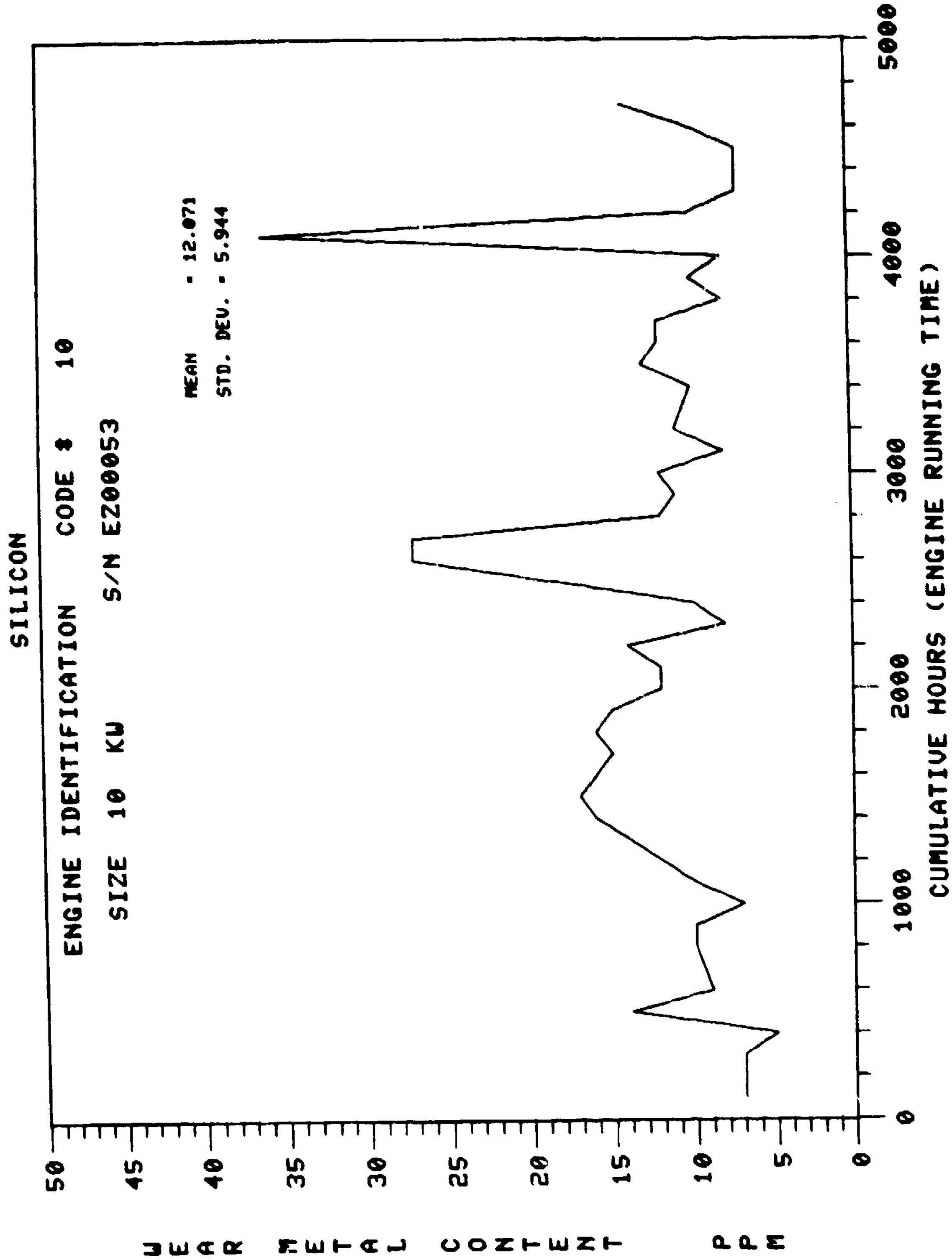

IRON
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 363.429
STD. DEV. = 200.339
WEAR METAL CONTENT PPM
0
200
400
600
800
1000
1200
1400
1600
1800
2000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000

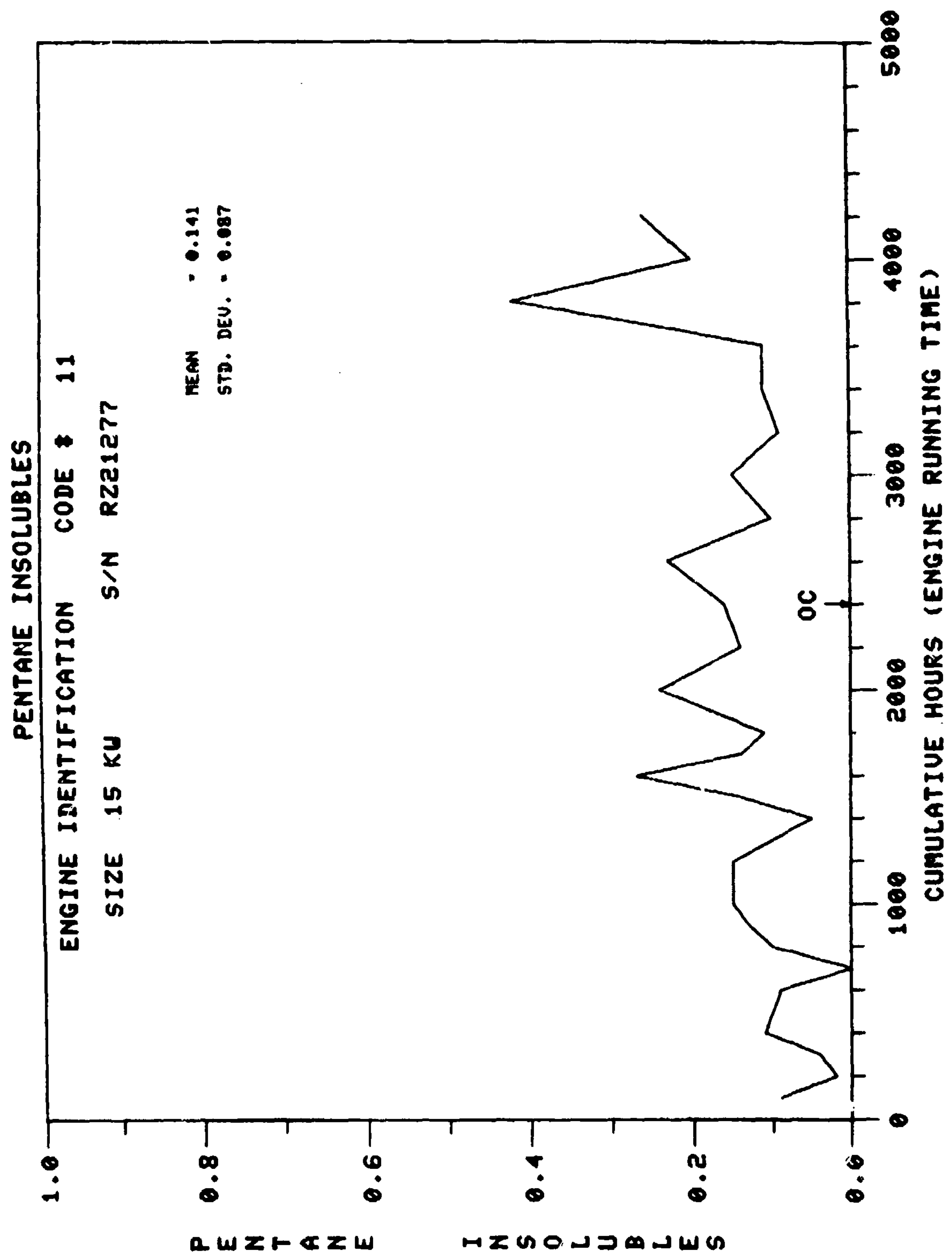

CHROMIUM
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ000053
MEAN = 14.024
STD. DEV. = 8.415
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
20
25
30
35
40
45
50

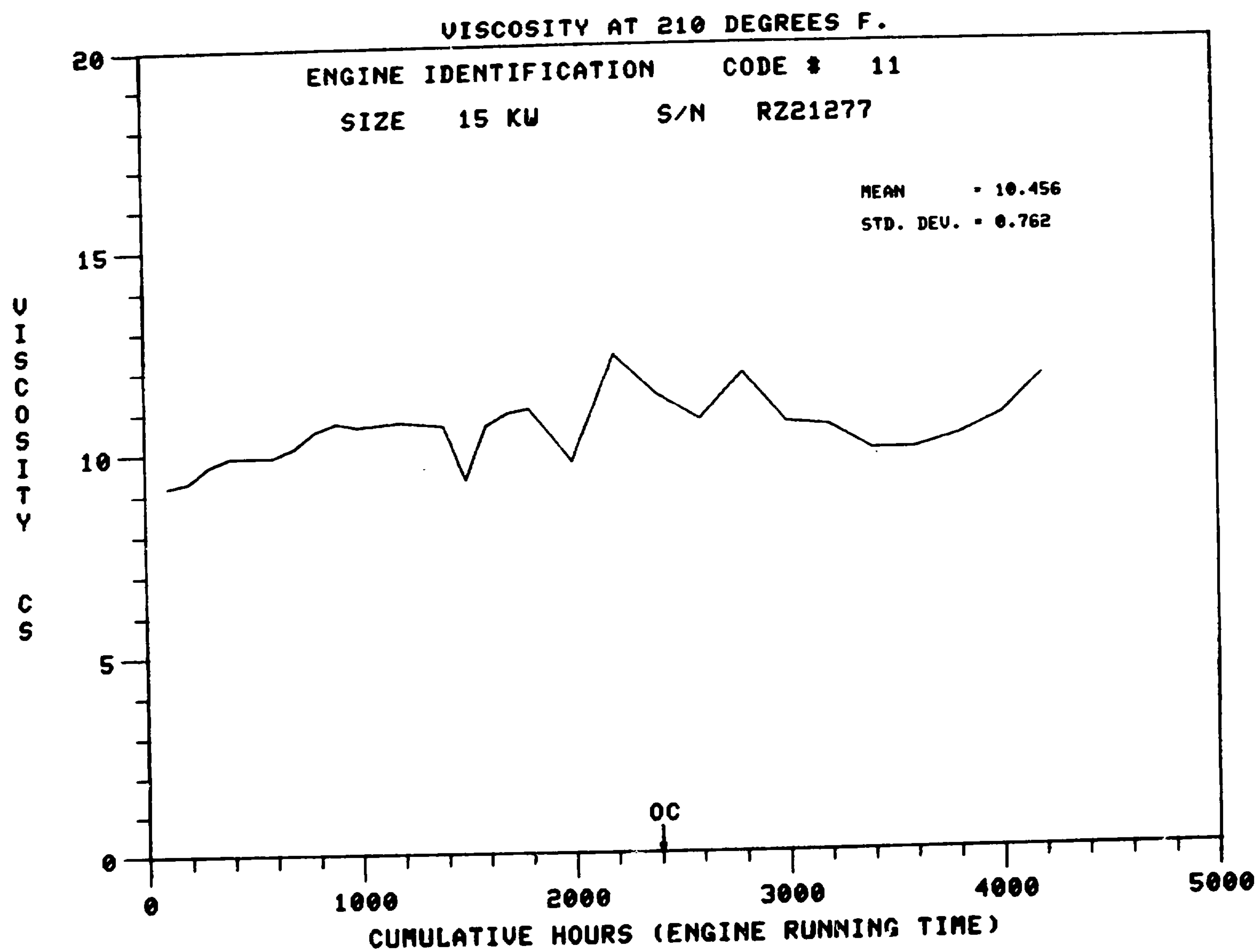

COPPER
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 13.000
STD. DEV. = 12.107
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
10
20
30
40
50
60
70
80
90
100
WEAR METAL CONTENT PPM

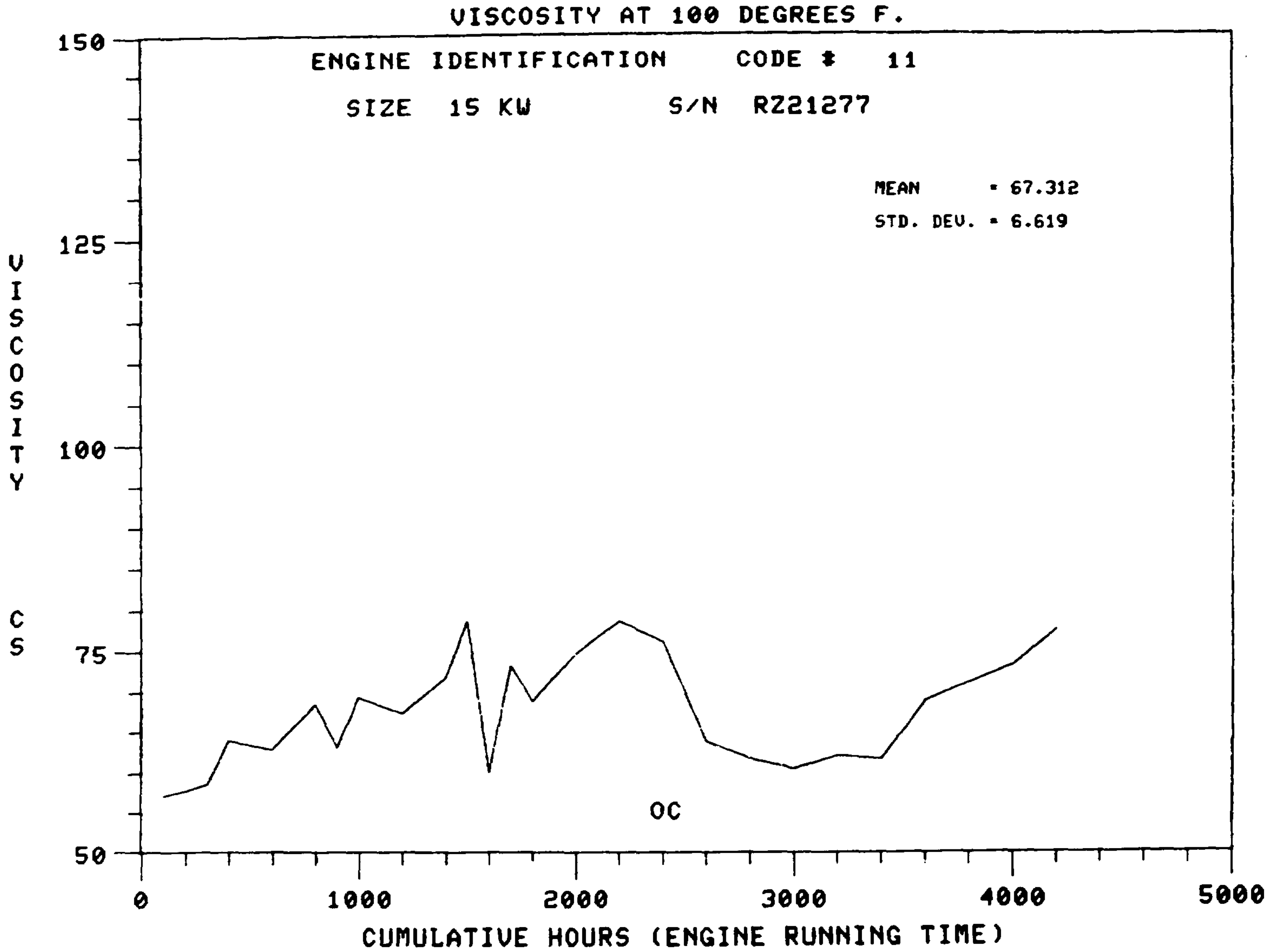

TIN
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 25.238
STD. DEV. = 13.107
WEAR METAL CONTENT PPM
100
90
80
70
60
50
40
30
20
10
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

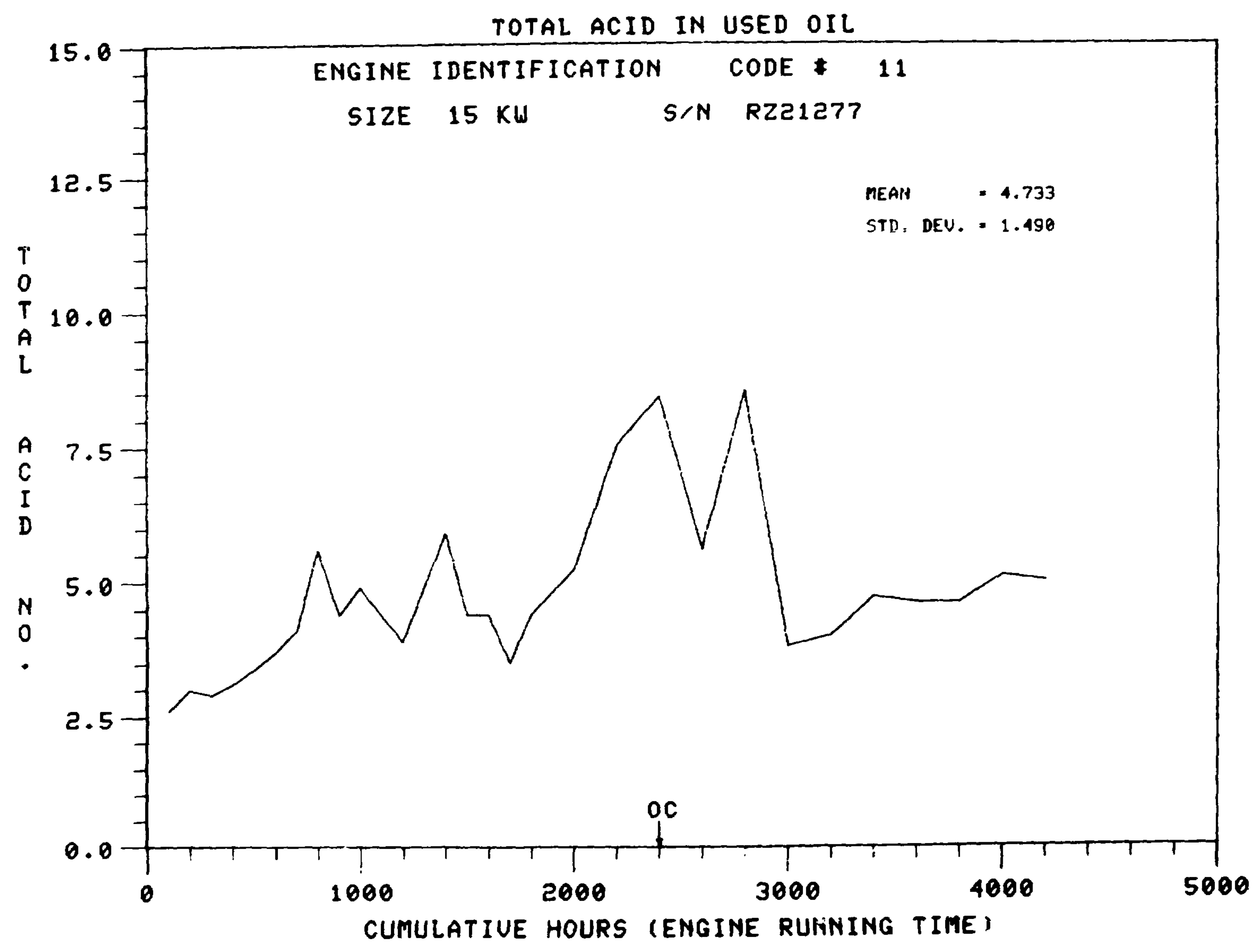

LEAD
ENGINE IDENTIFICATION CODE $ 10
SIZE 10 KW S/N EZ00053
MEAN = 157.524
STD. DEV. = 141.133
WEAR METAL CONTENT PPM
0
100
200
300
400
500
600
700
800
900
1000
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

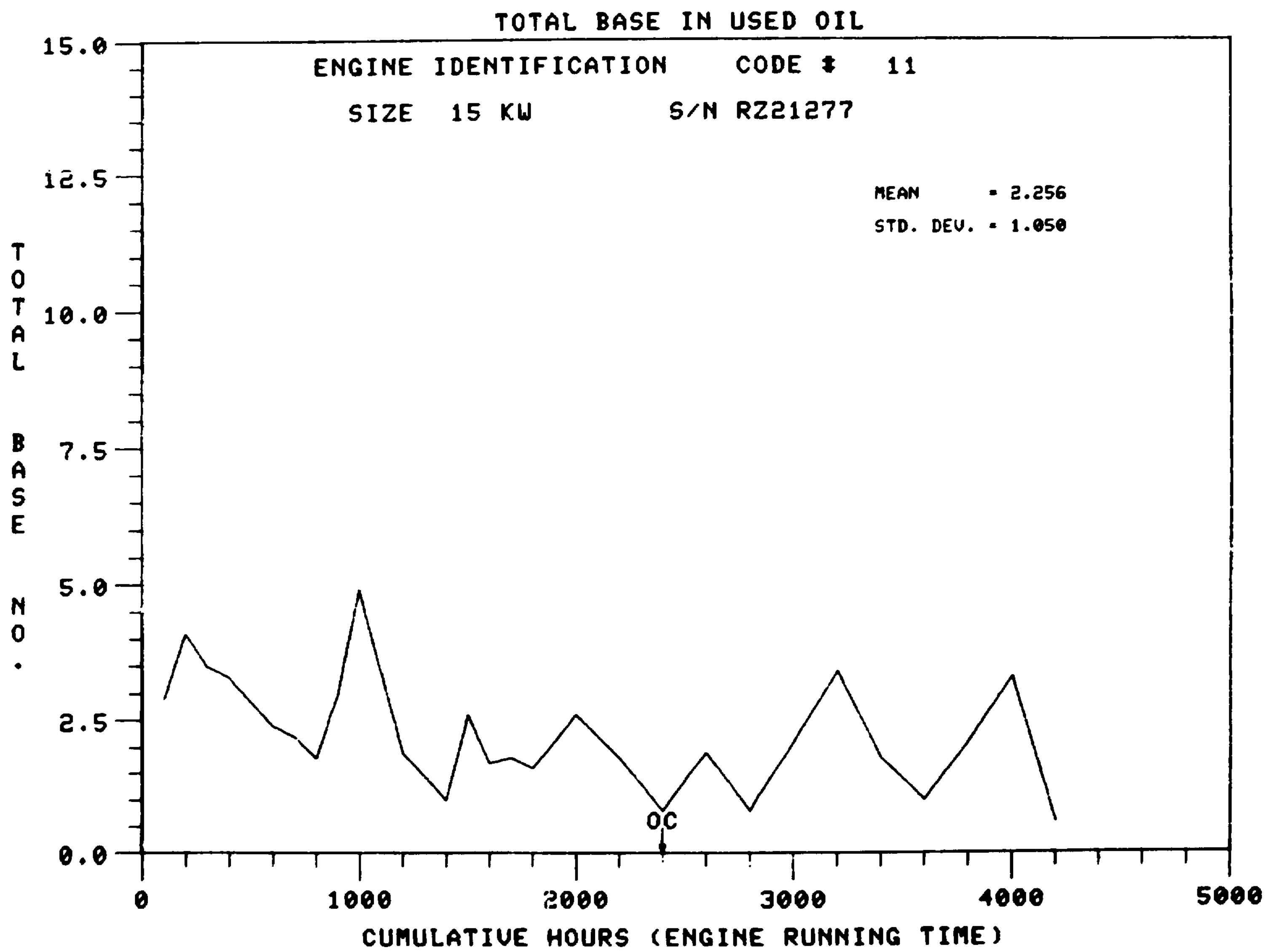

SILICON
ENGINE IDENTIFICATION CODE # 10
SIZE 10 KW S/N EZ00053
MEAN = 12.071
STD. DEV. = 5.944
WEAR METAL CONTENT PPM
50
45
40
35
30
25
20
15
10
5
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

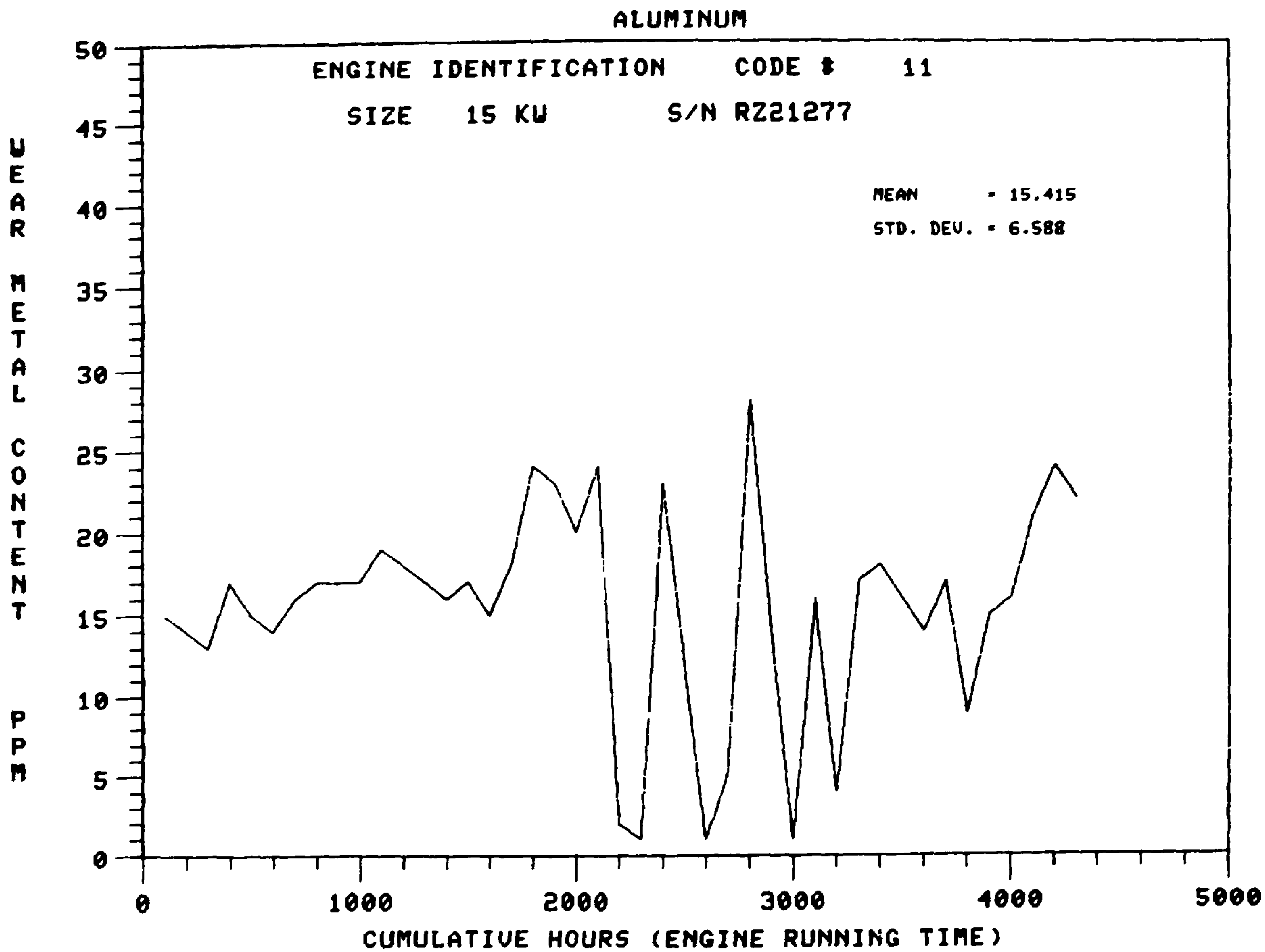

PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 0.141
STD. DEV. = 0.087
OC
CUMULATIVE HOURS (ENGINE RUNNING TIME)
PENTANE INSOLUBLES
0
1000
2000
3000
4000
5000
0.0
0.2
0.4
0.6
0.8
1.0

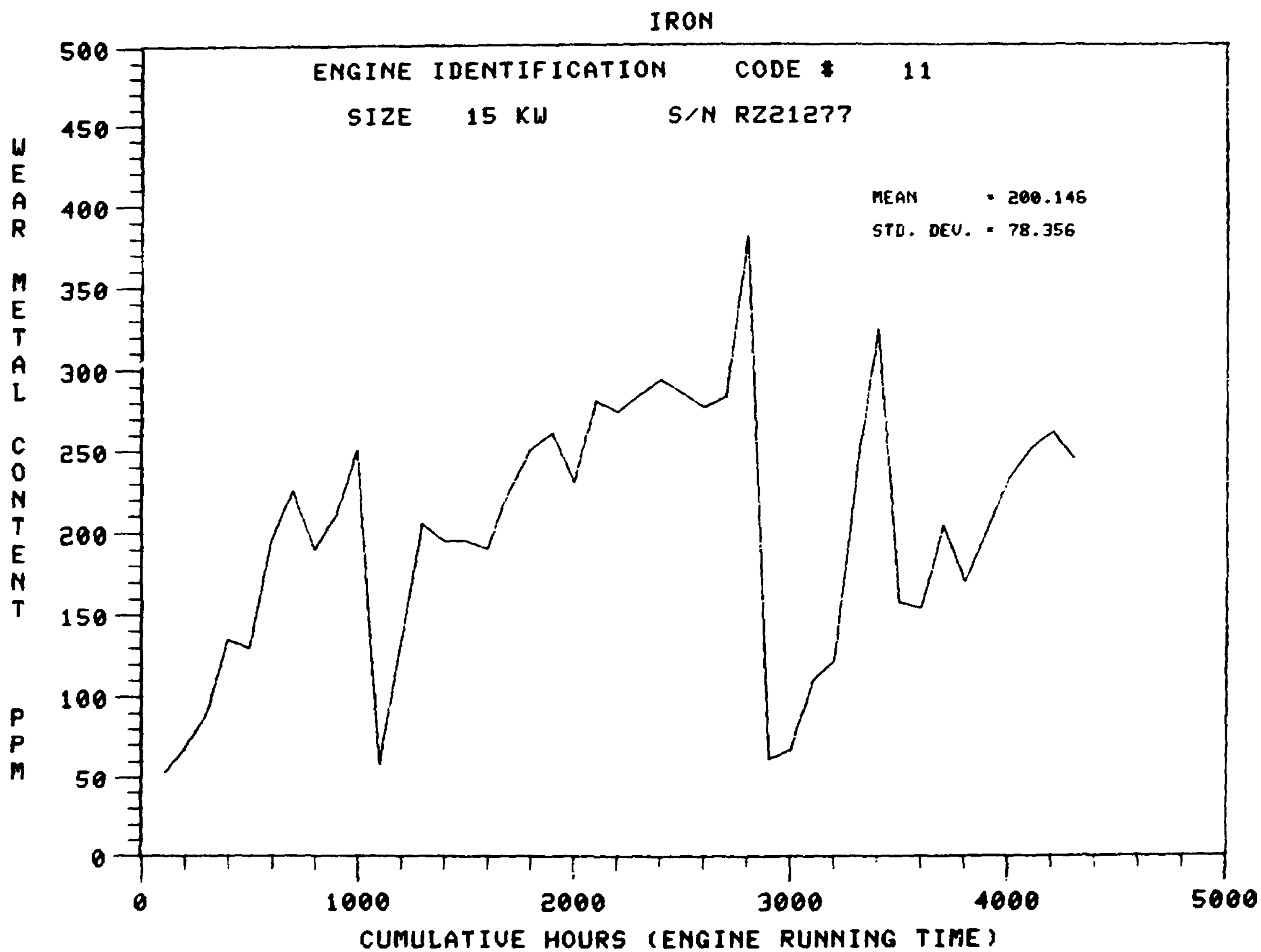

VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 10.456
STD. DEV. = 0.762
VISCOSITY CS
20
15
10
5
0
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

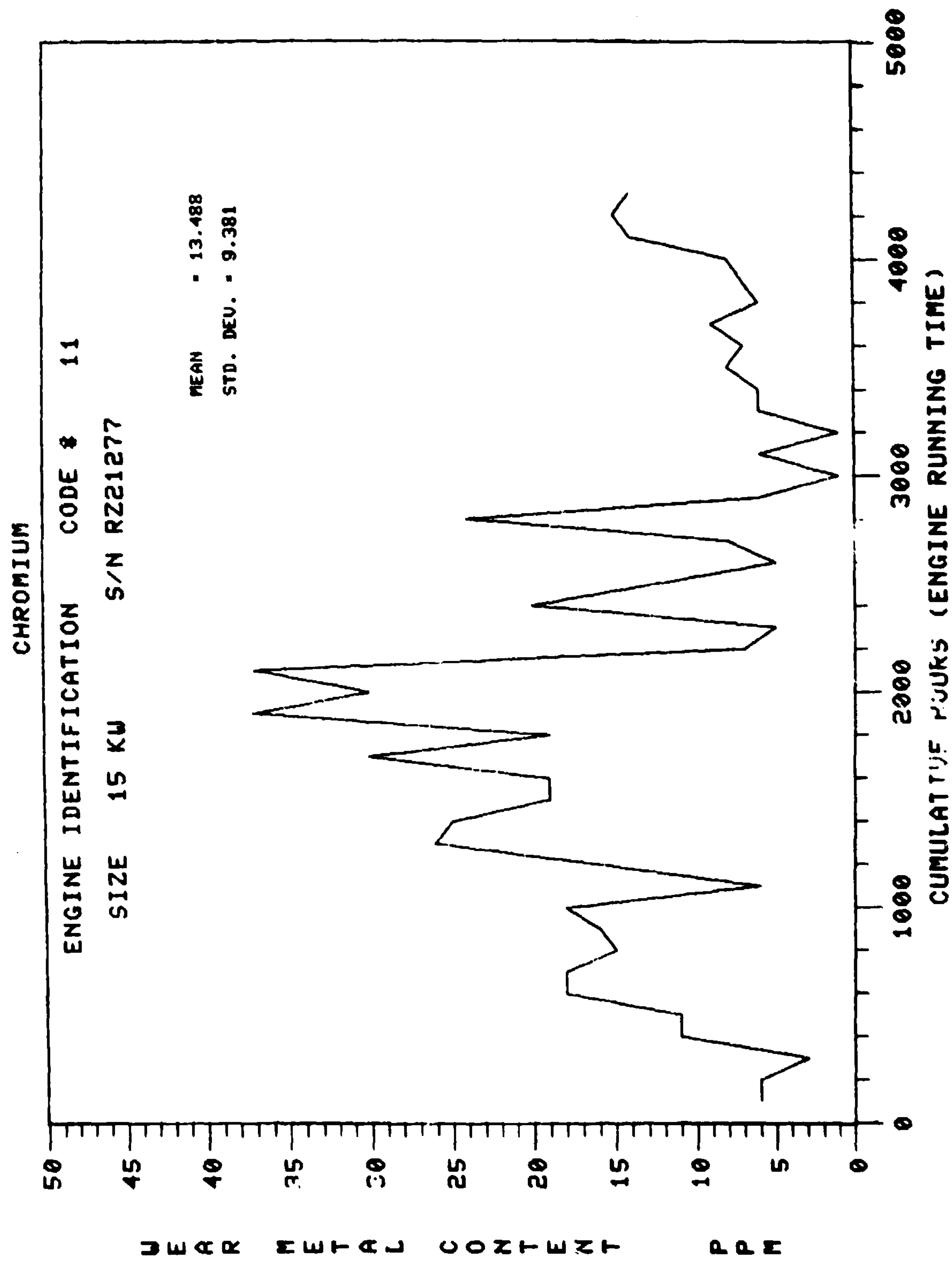

VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 67.312
STD. DEV. = 6.619
OC
150
125
100
75
50
VISCOSITY CS
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 4.733
STD. DEV. = 1.490
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

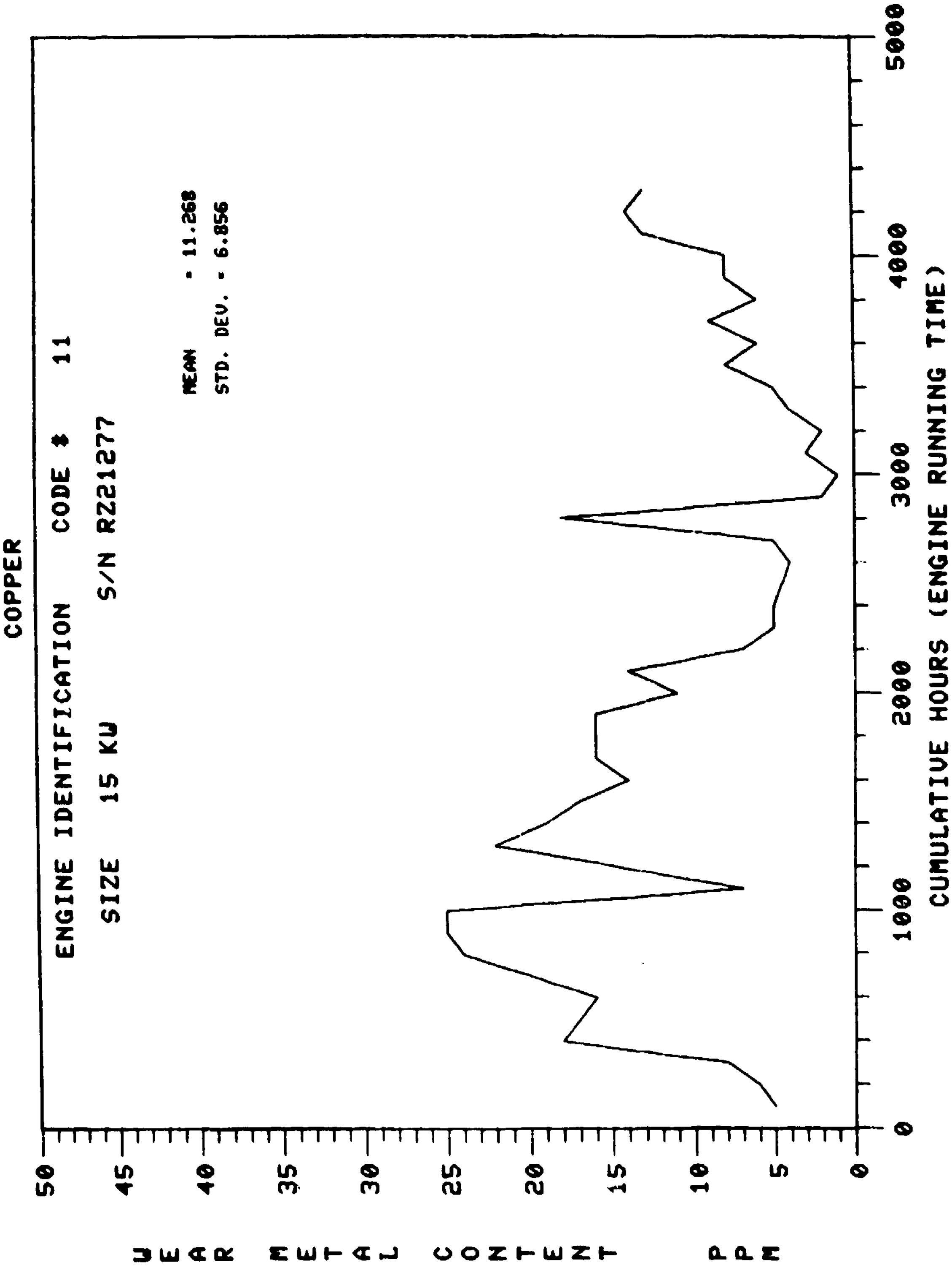

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 2.256
STD. DEV. = 1.050
OC
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

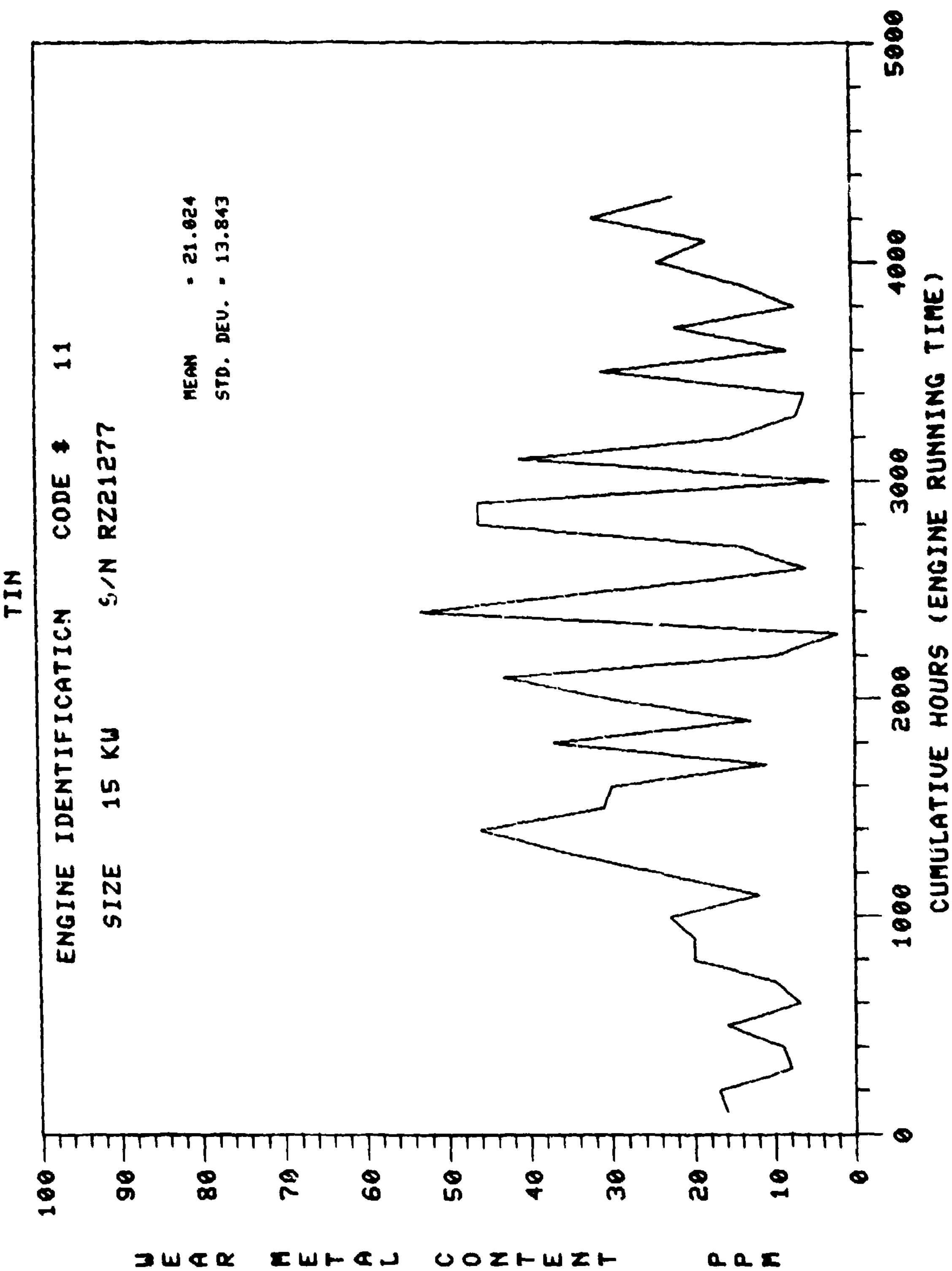

ALUMINUM
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 15.415
STD. DEV. = 6.588
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

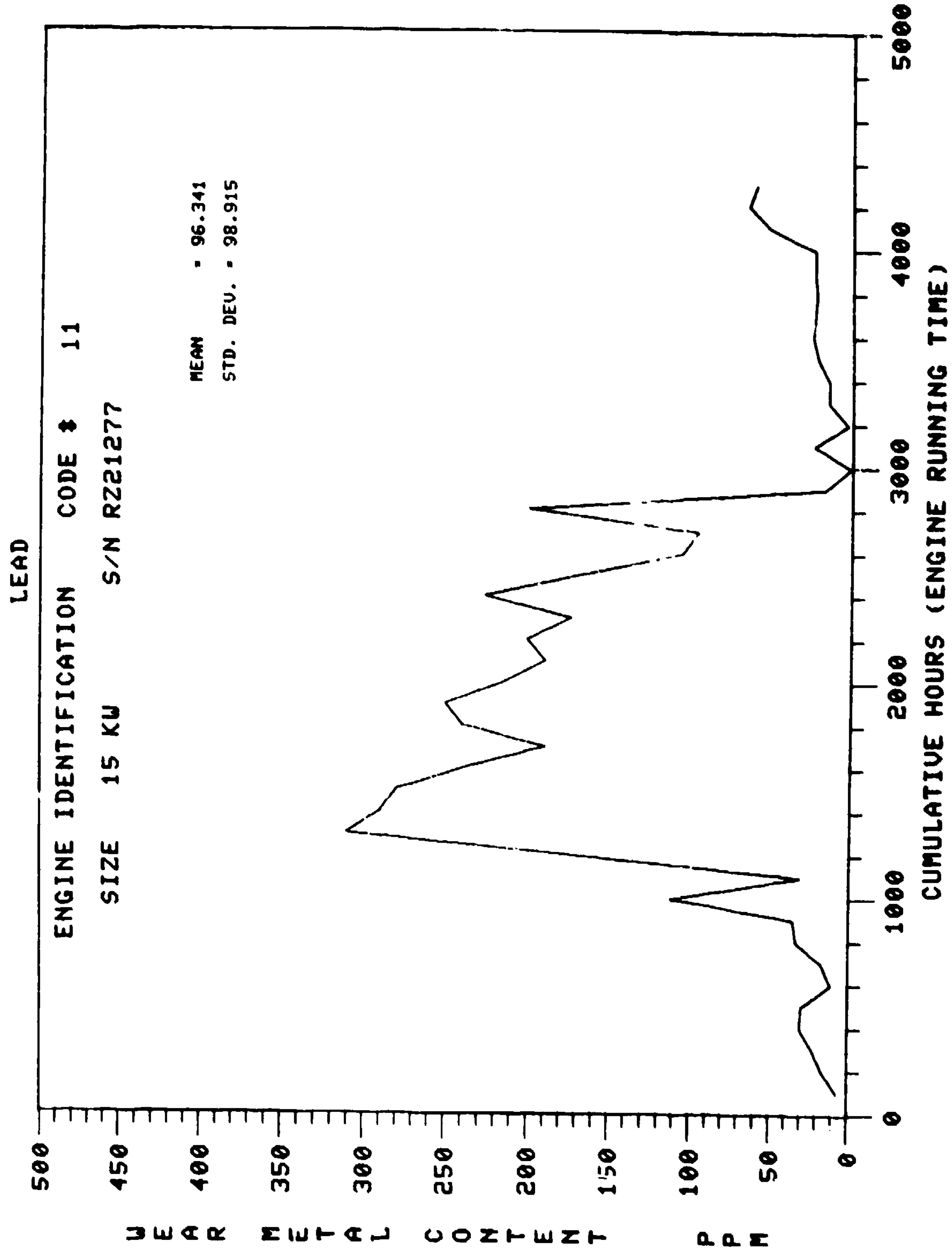

IRON
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 200.146
STD. DEV. = 78.356
WEAR METAL CONTENT PPM
0
50
100
150
200
250
300
350
400
450
500
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

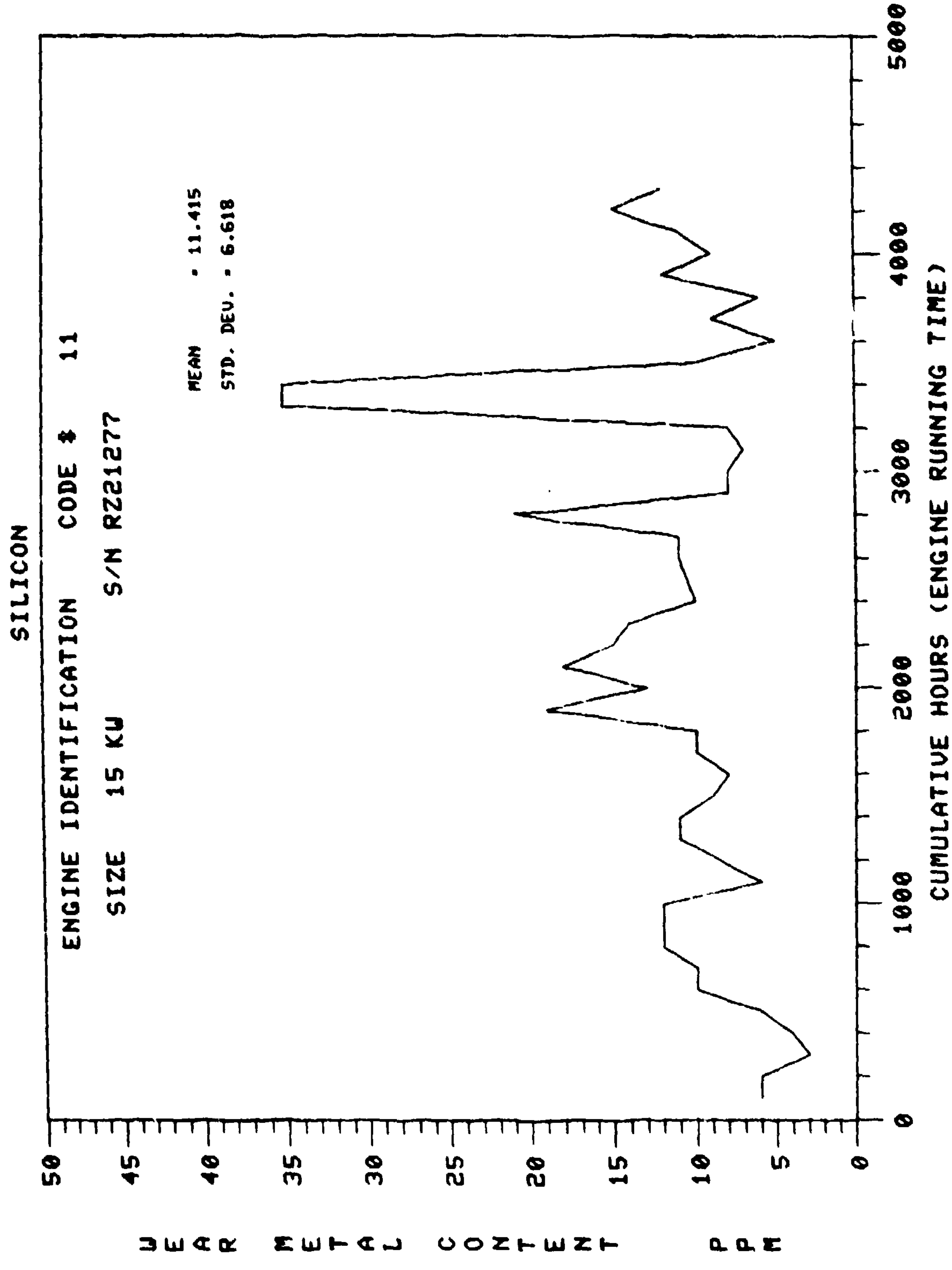


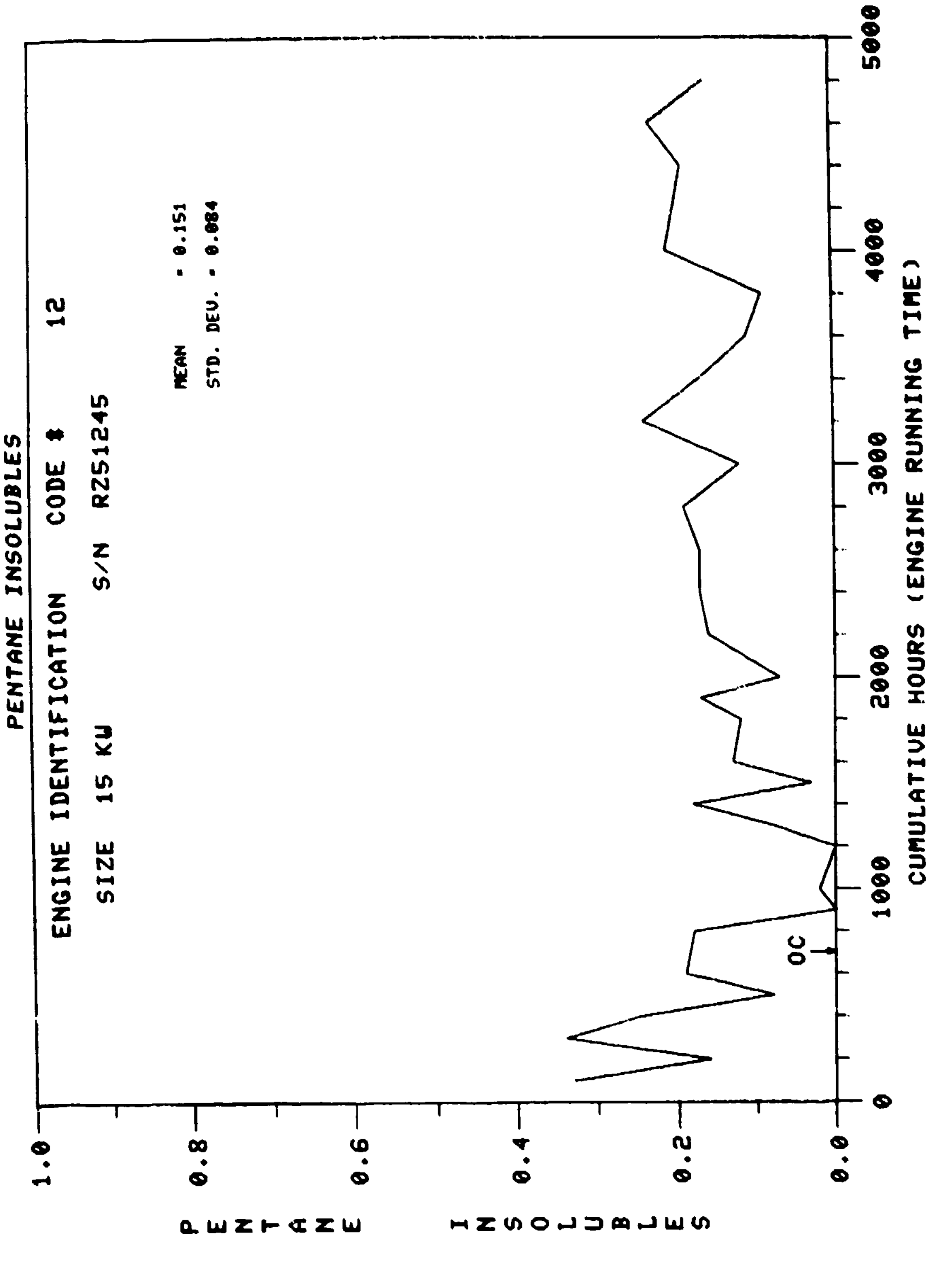
CHROMIUM
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 13.488
STD. DEV. = 9.381
WEAR METAL CONTENT PPM
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000


COPPER
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 11.268
STD. DEV. = 6.856
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
25
30
35
40
45
50
WEAR METAL CONTENT PPM

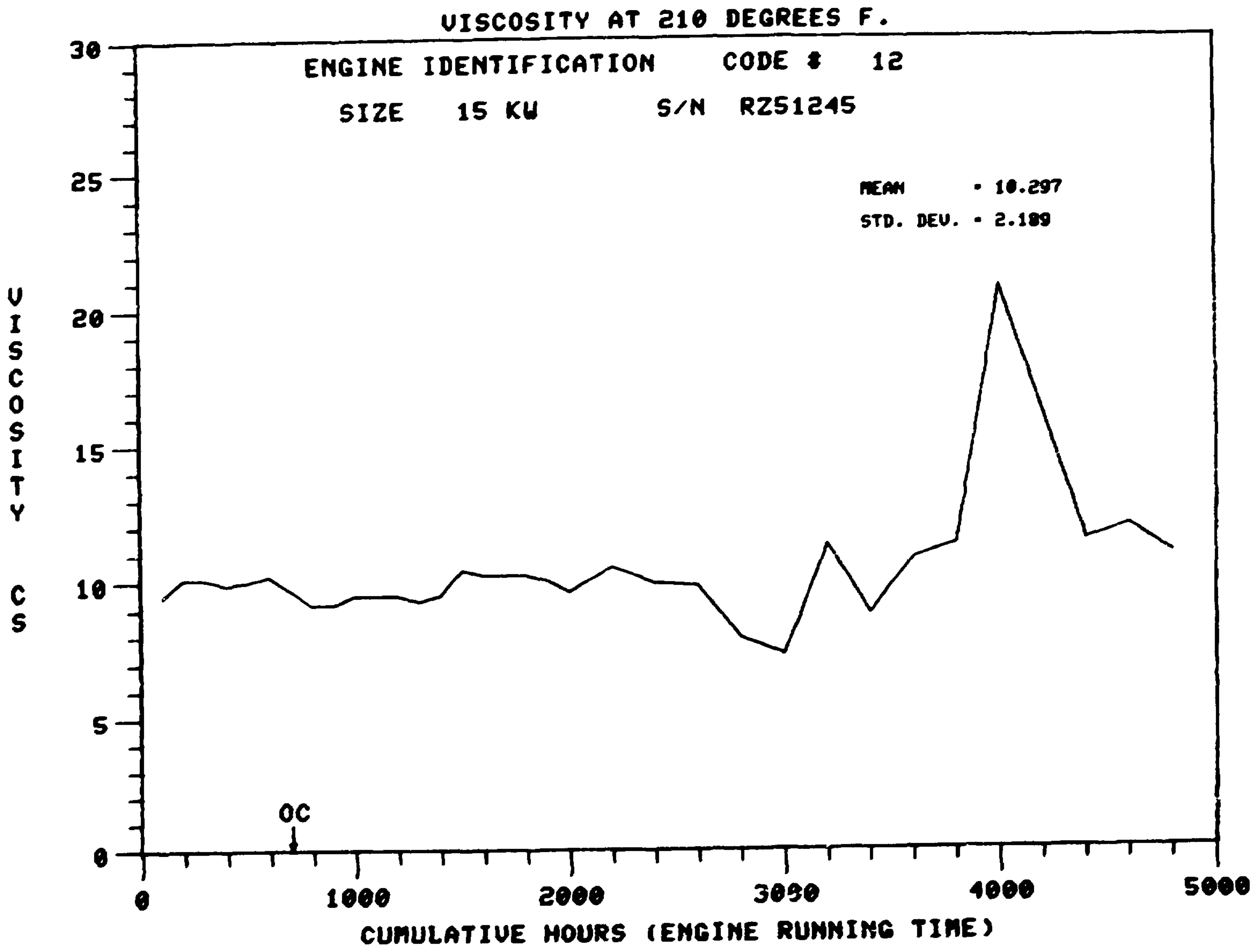

TIN
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 21.024
STD. DEV. = 13.843
WEAR METAL CONTENT PPM
0 10 20 30 40 50 60 70 80 90 100
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0 1000 2000 3000 4000 5000

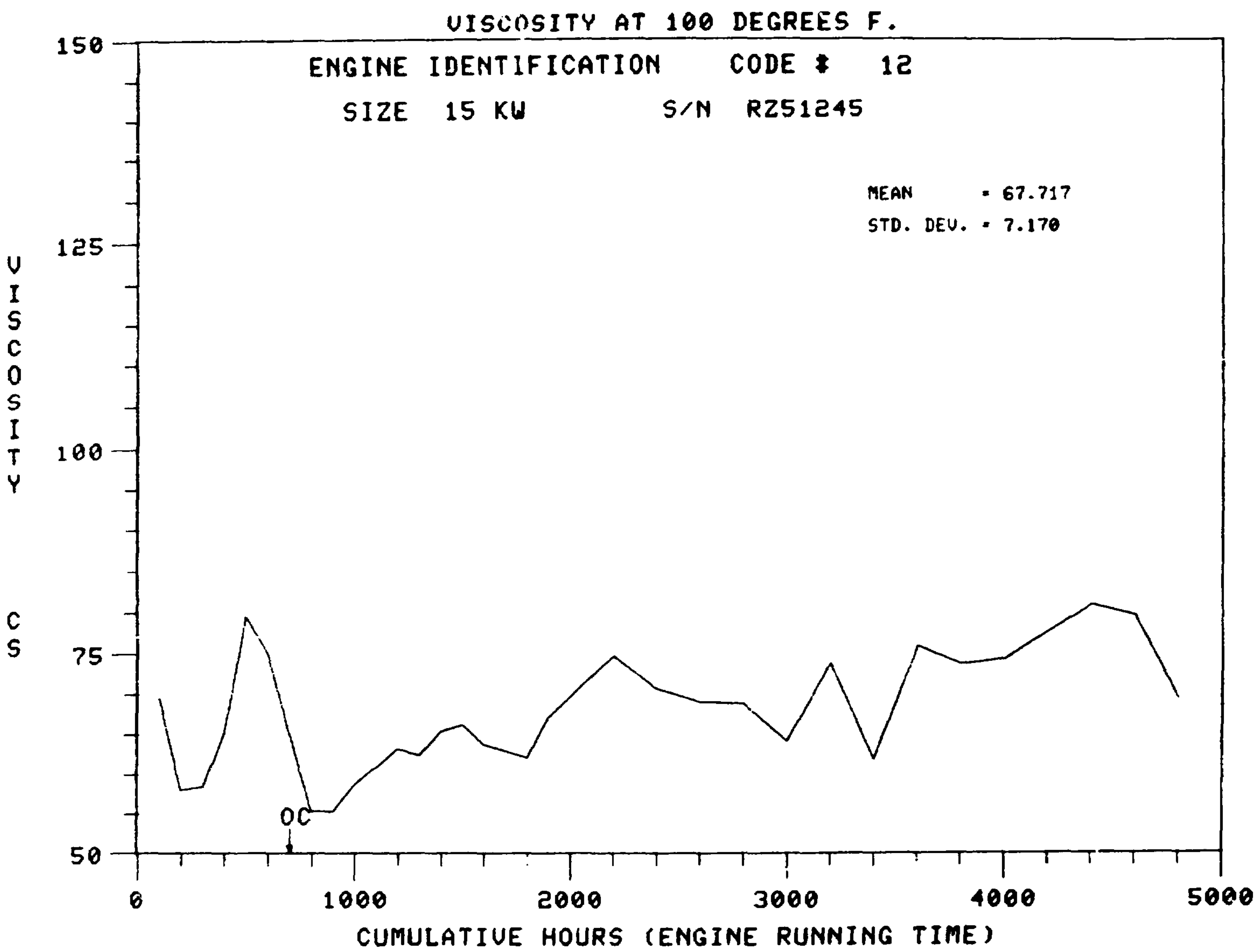

LEAD
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ221277
MEAN = 96.341
STD. DEV. = 98.915
0
50
100
150
200
250
300
350
400
450
500
WEAR METAL CONTENT PPM
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

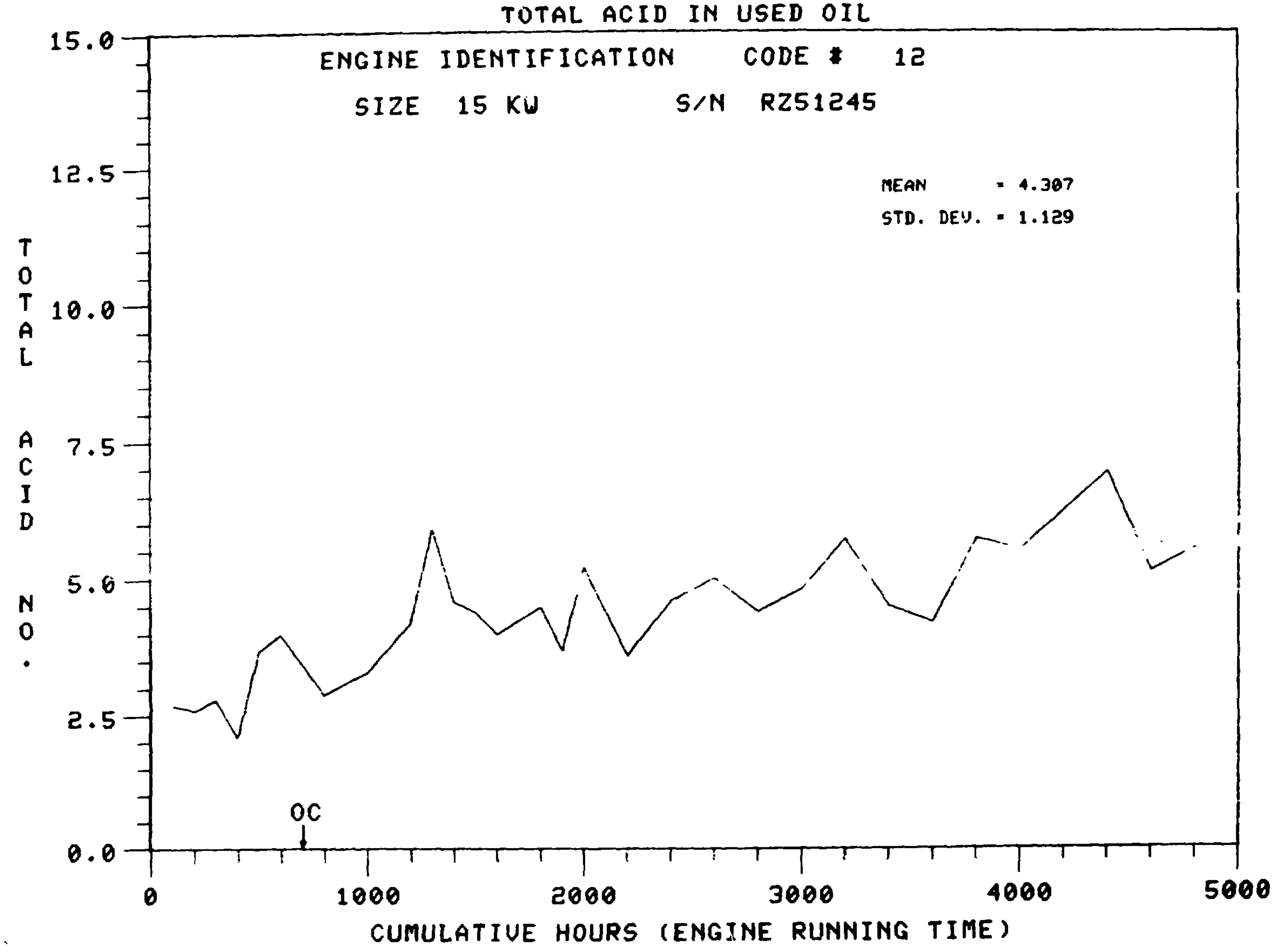

SILICON
ENGINE IDENTIFICATION CODE # 11
SIZE 15 KW S/N RZ21277
MEAN = 11.415
STD. DEV. = 6.618
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)



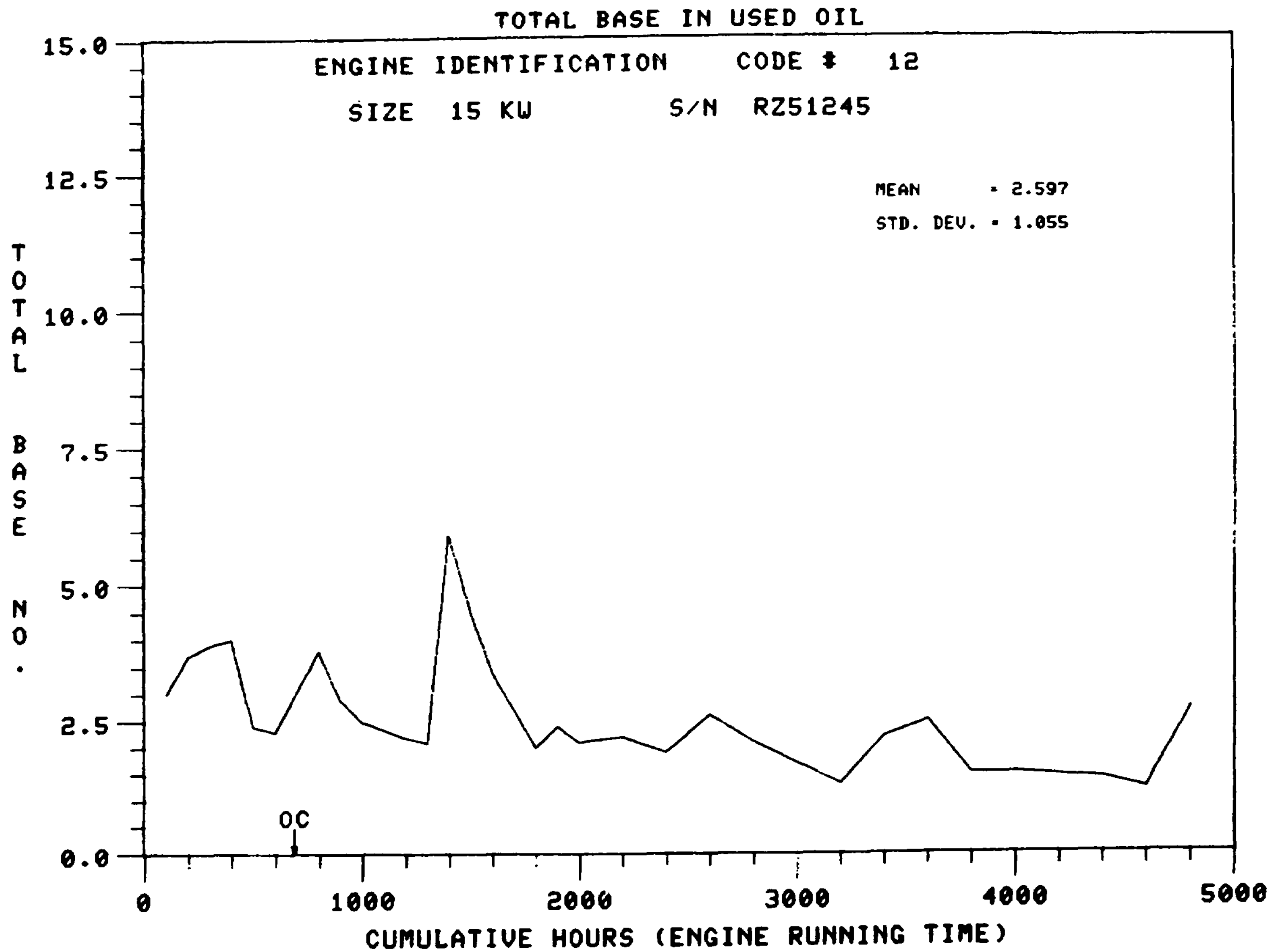
PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 12
SIZE 15 KW S/N RZ51245
MEAN = 0.151
STD. DEV. = 0.084
OC
PENTANE INSOLUBLES
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

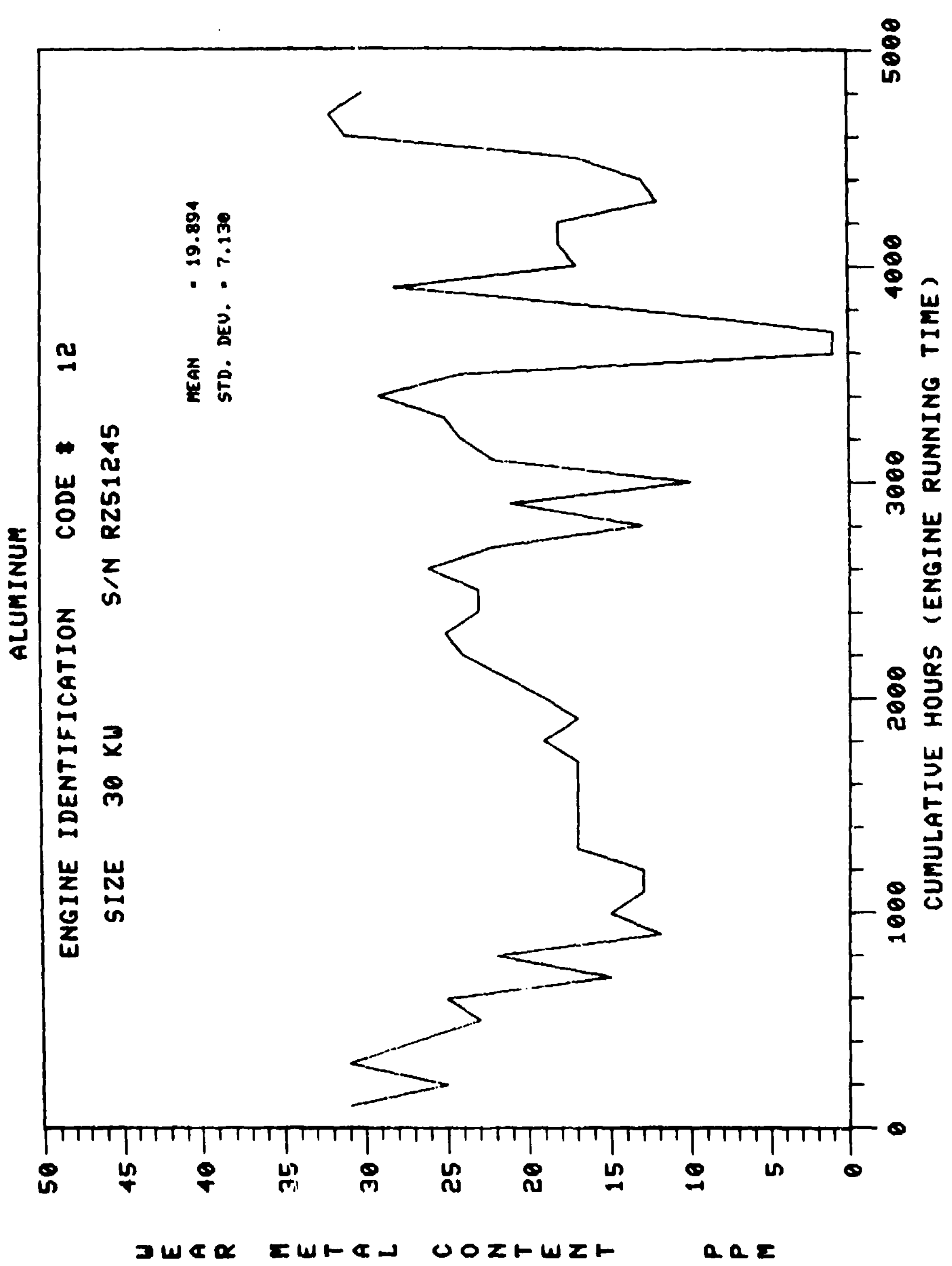

VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 12
SIZE 15 KW S/N RZ51245
MEAN = 10.297
STD. DEV. = 2.189
OC
VISCOSITY CS
0
5
10
15
20
25
30
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 12
SIZE 15 KW S/N RZ51245
MEAN = 67.717
STD. DEV. = 7.170
VISCOSITY CS
150
125
100
75
50
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

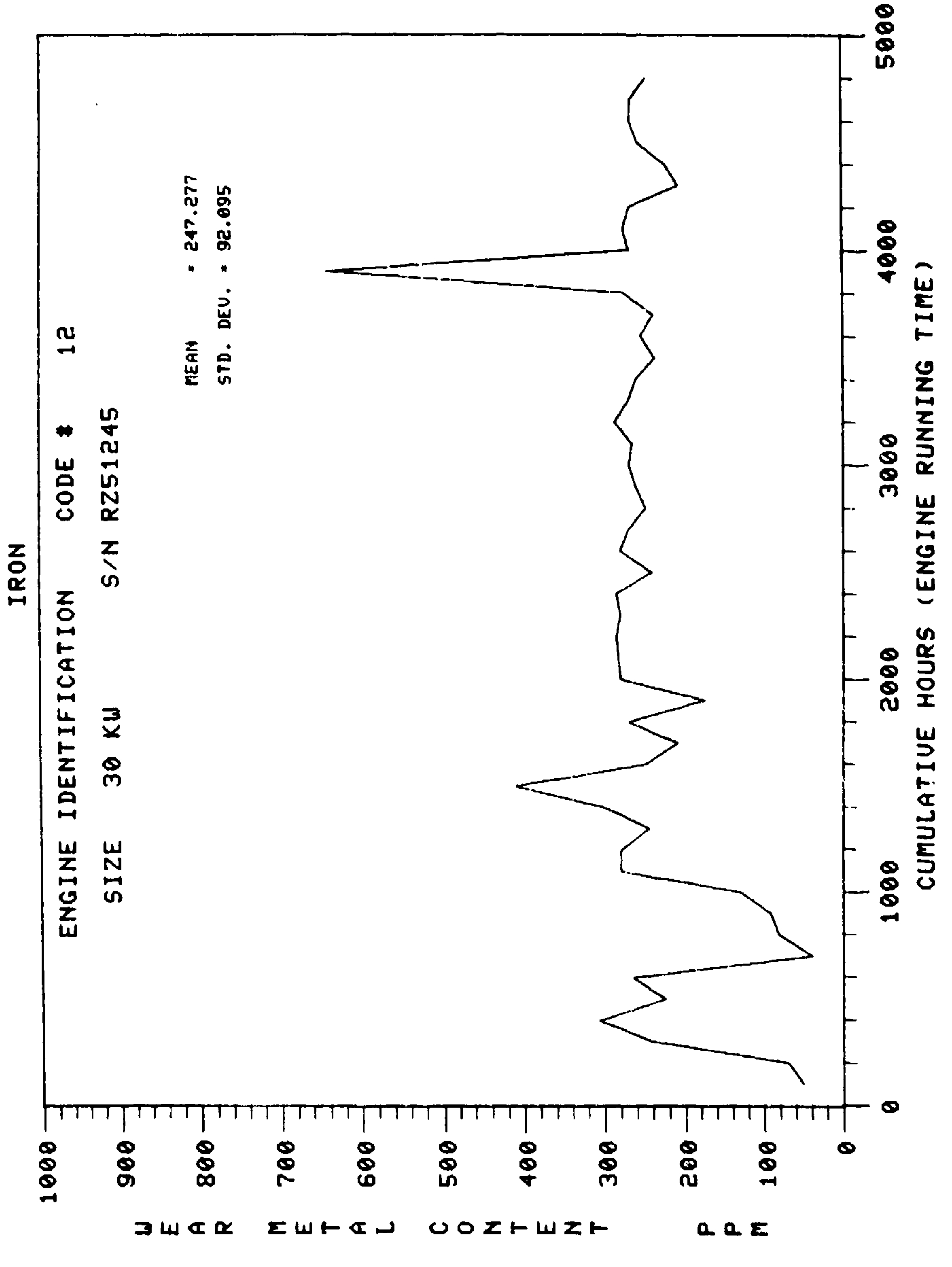


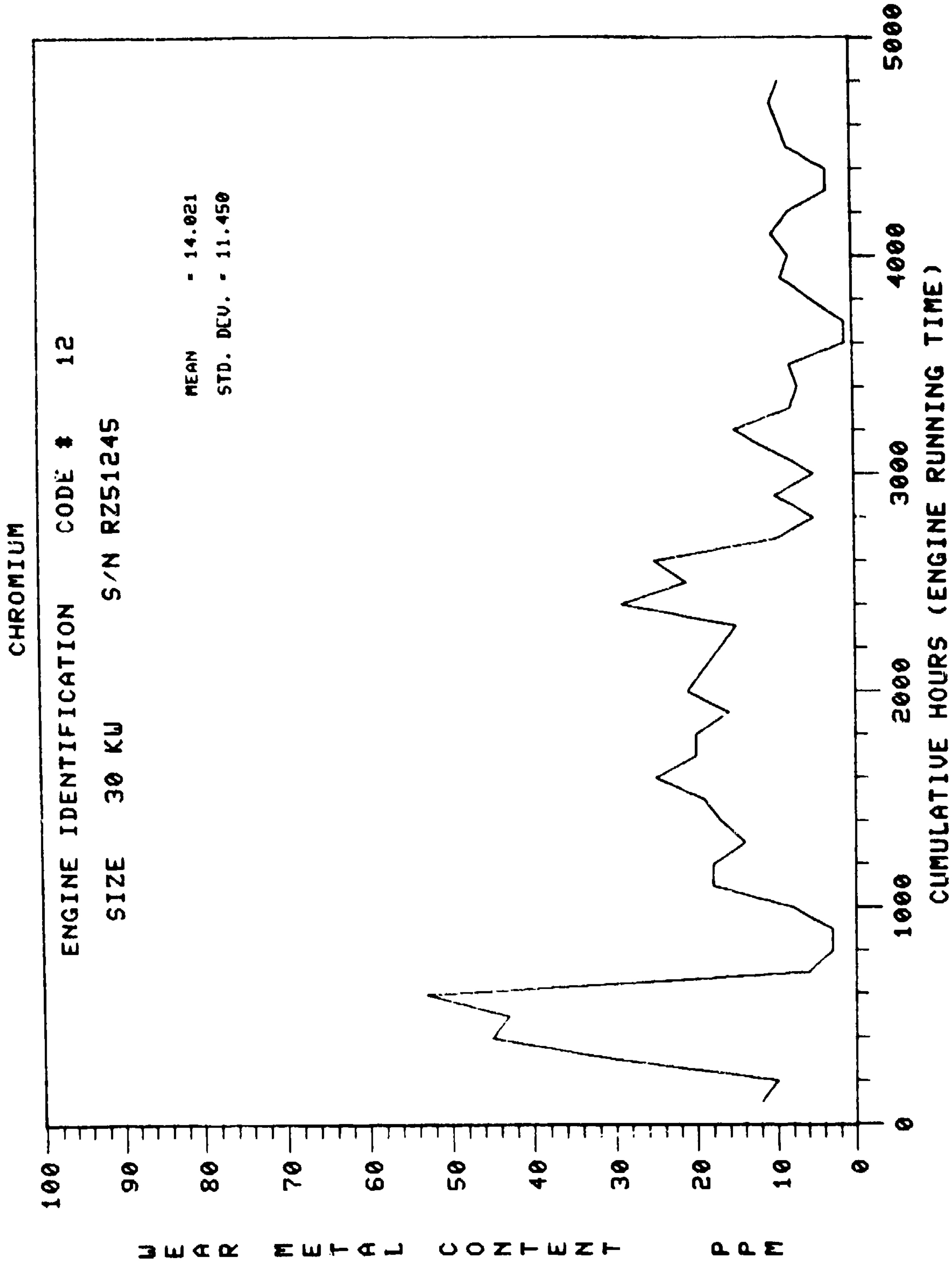
TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 12
SIZE 15 KW S/N RZ51245
MEAN = 4.307
STD. DEV. = 1.129
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

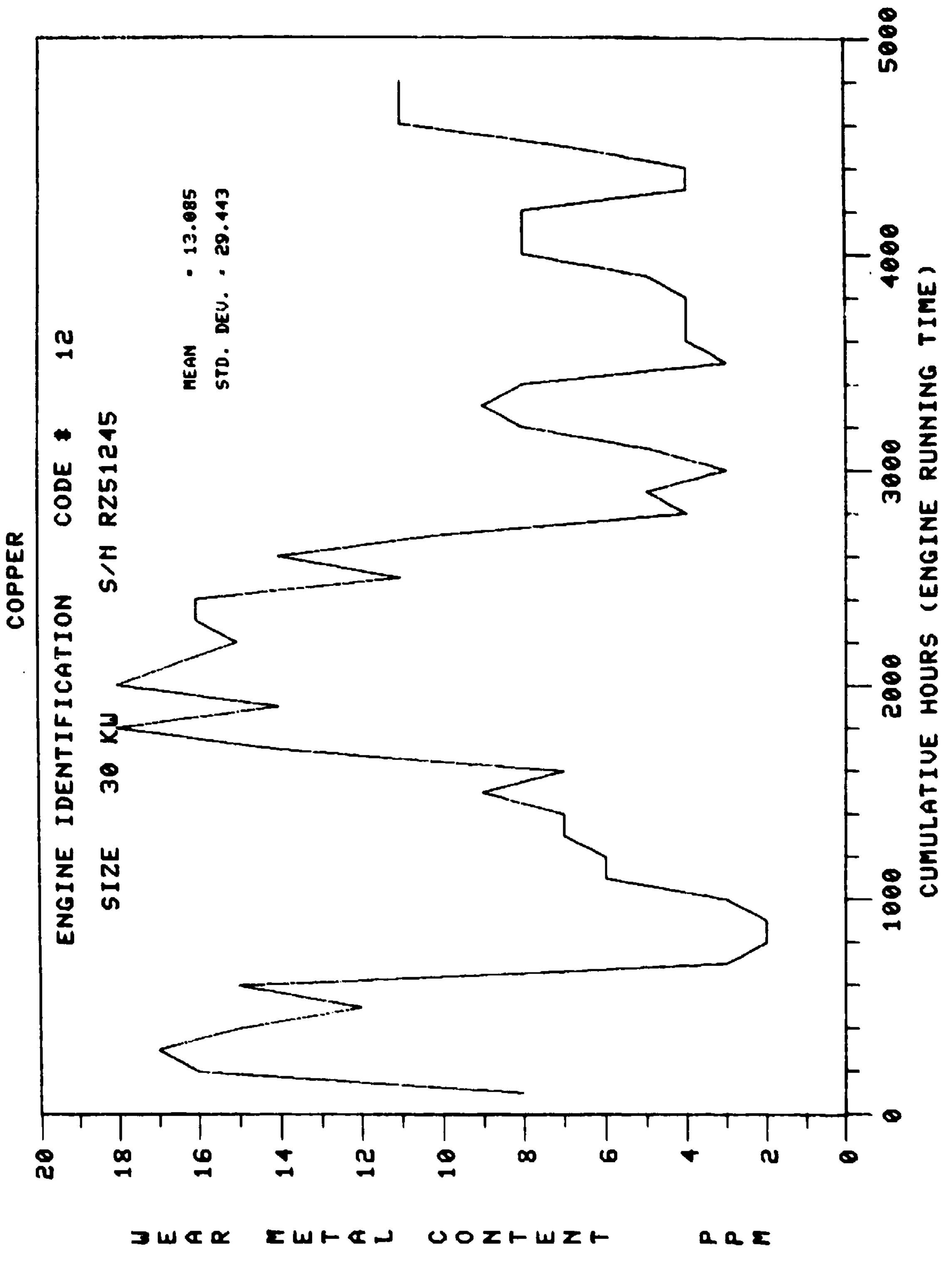

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 12
SIZE 15 KW S/N RZ51245
MEAN = 2.597
STD. DEV. = 1.055
15.0
12.5
10.0
7.5
5.0
2.5
0.0
TOTAL BASE NO.
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)



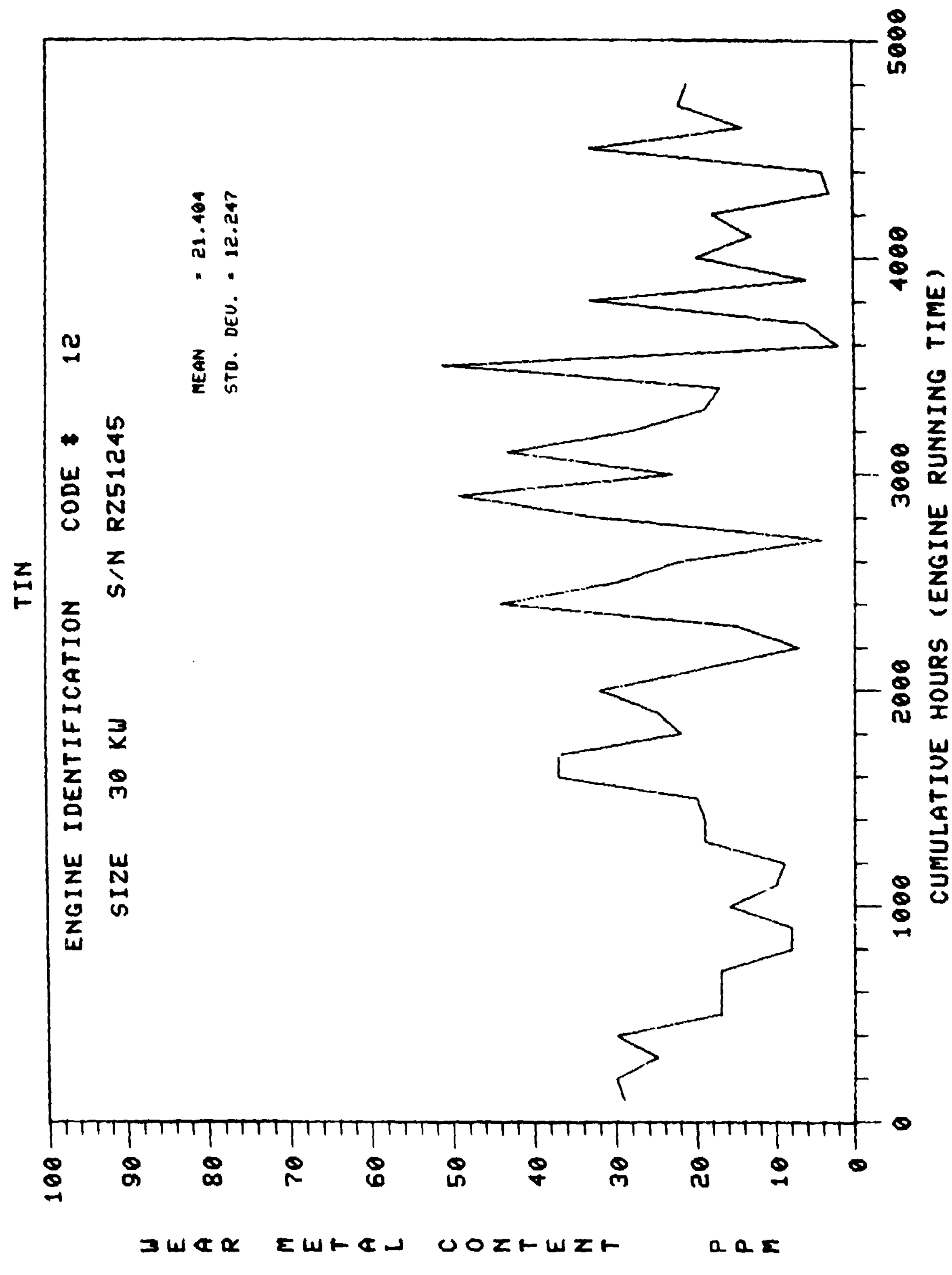
ALUMINUM
ENGINE IDENTIFICATION CODE # 12
SIZE 30 KW S/N RZ51245
MEAN = 19.894
STD. DEV. = 7.130
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50


IRON
ENGINE IDENTIFICATION CODE # 12
SIZE 30 KW S/N RZ51245
MEAN = 247.277
STD. DEV. = 92.095
WEAR METAL CONTENT PPM
1000
900
800
700
600
500
400
300
200
100
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

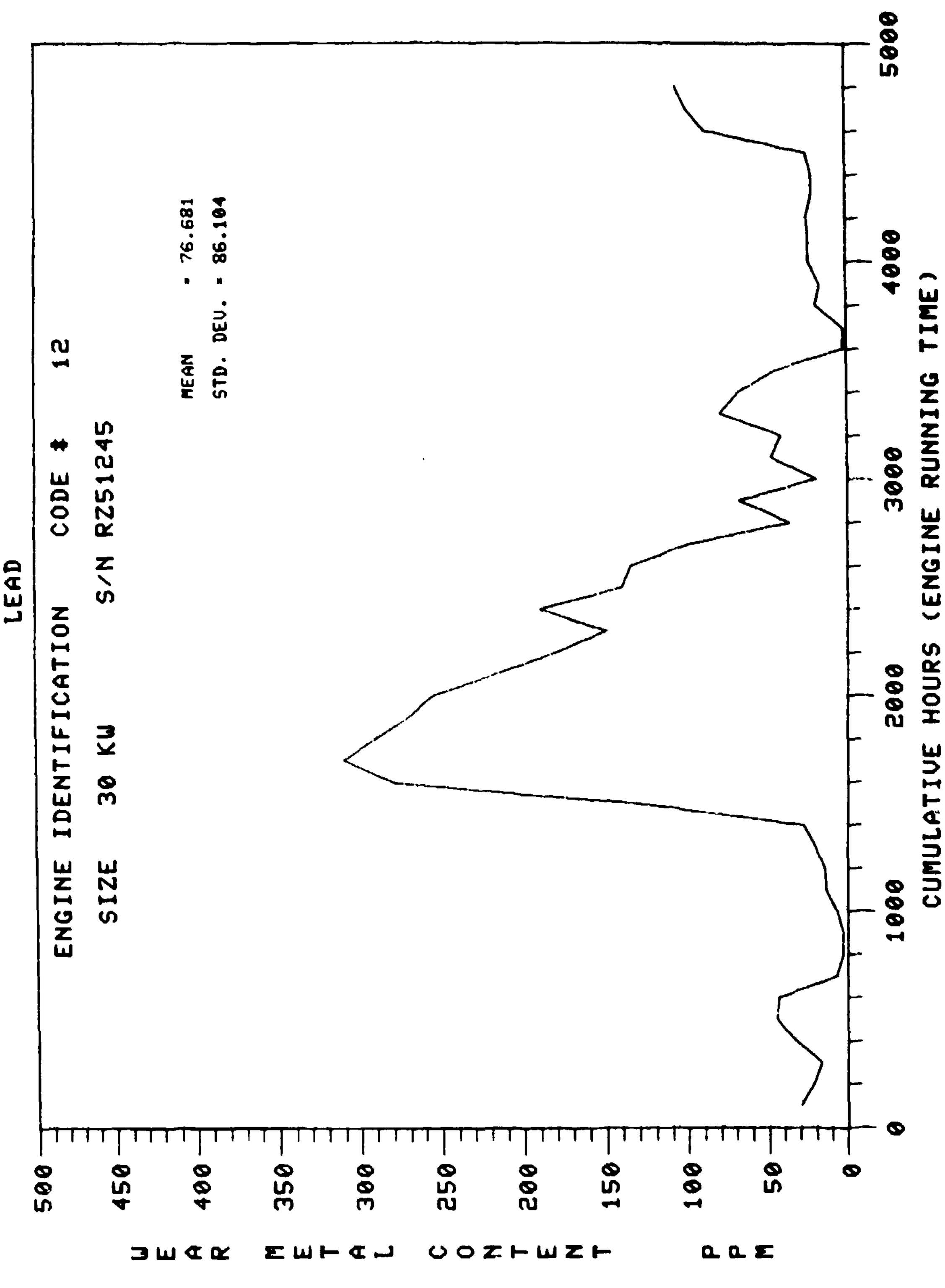

CHROMIUM
ENGINE IDENTIFICATION CODE # 12
SIZE 30 KW S/N RZ51245
MEAN = 14.021
STD. DEV. = 11.450
0
10
20
30
40
50
60
70
80
90
100
WEAR METAL CONTENT PPM
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)



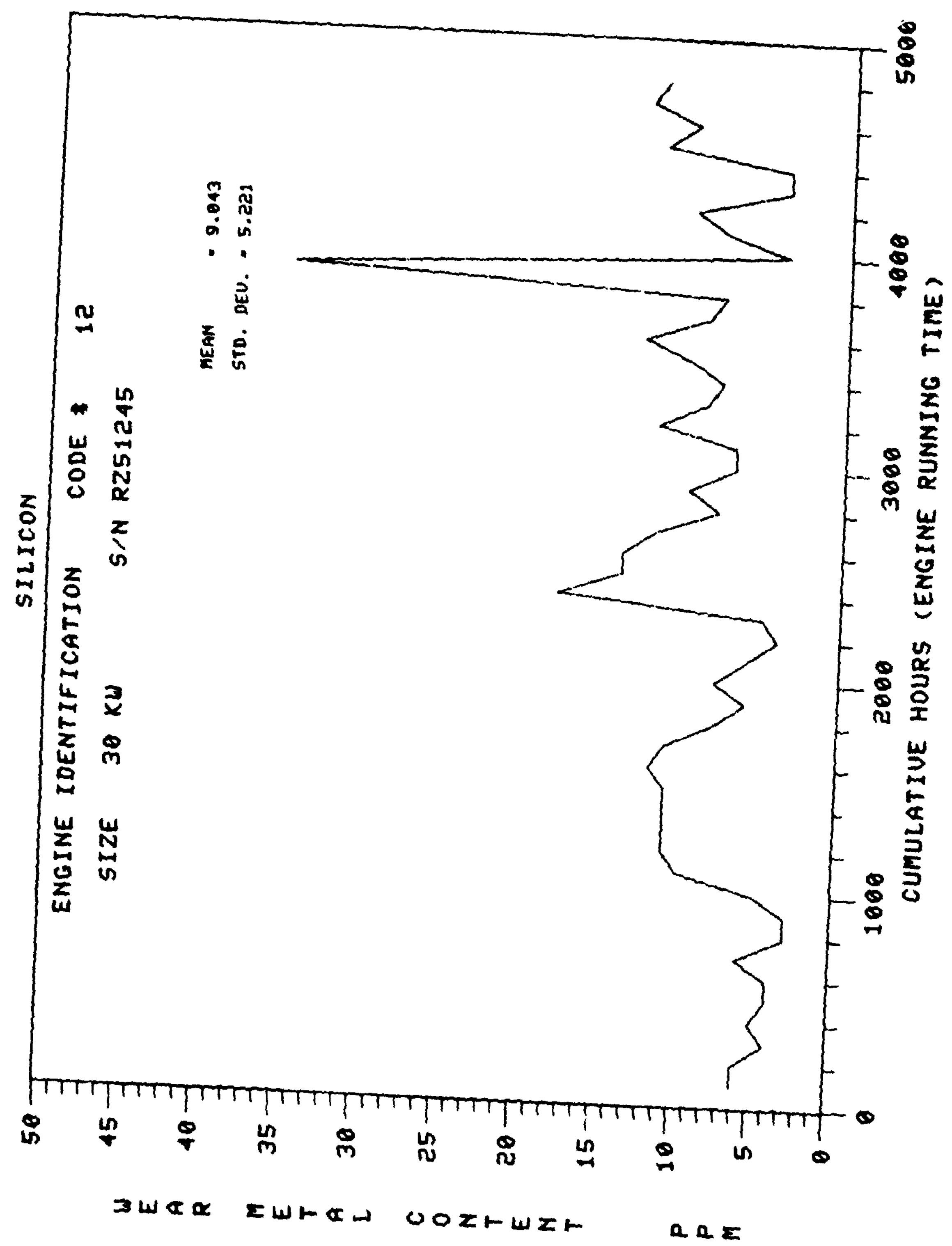
COPPER
ENGINE IDENTIFICATION CODE # 12
SIZE 30 KW S/N RZ51245
MEAN = 13.085
STD. DEV. = 29.443
WEAR METAL CONTENT PPM
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0 2 4 6 8 10 12 14 16 18 20
0 1000 2000 3000 4000 5000

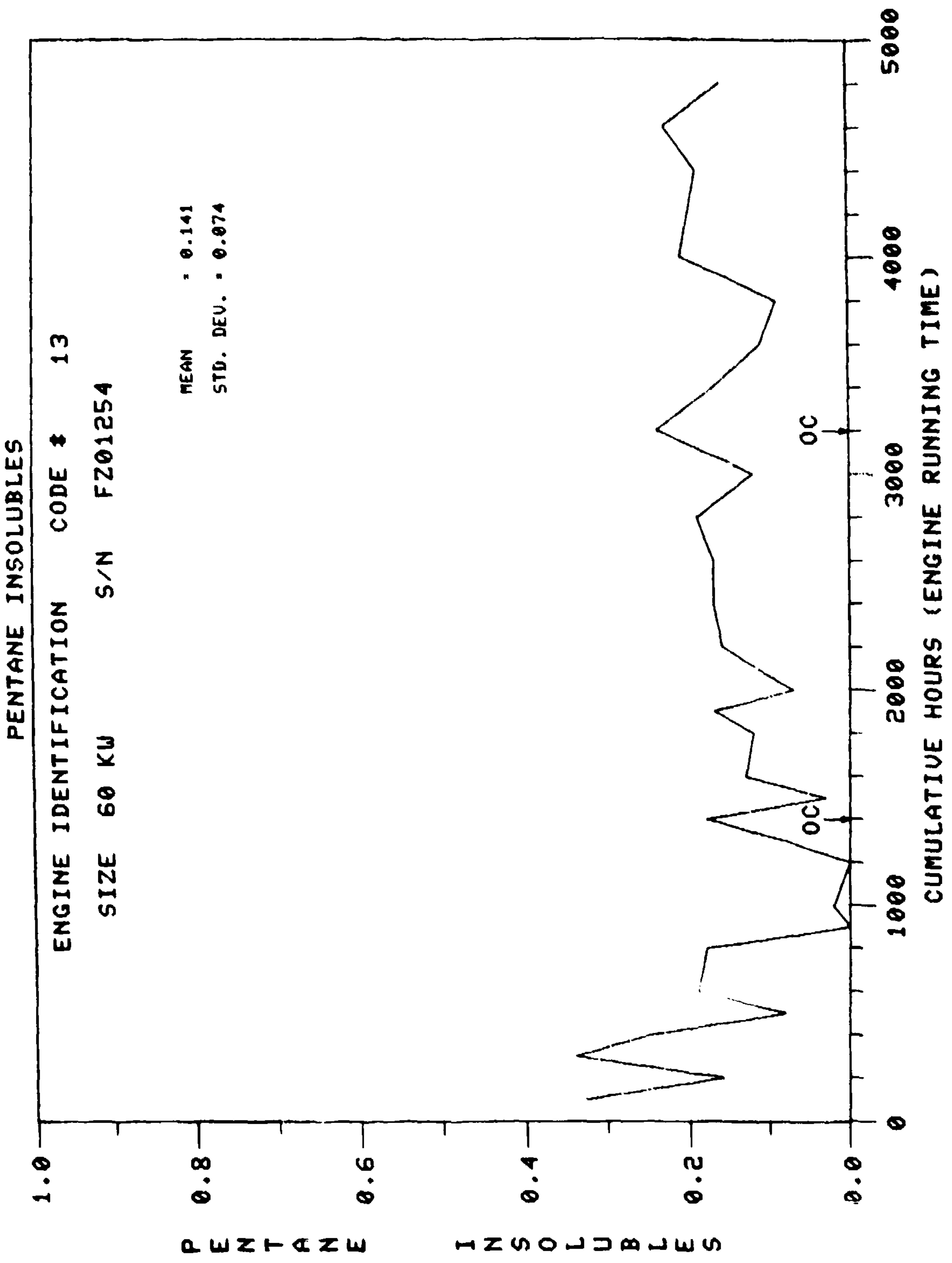


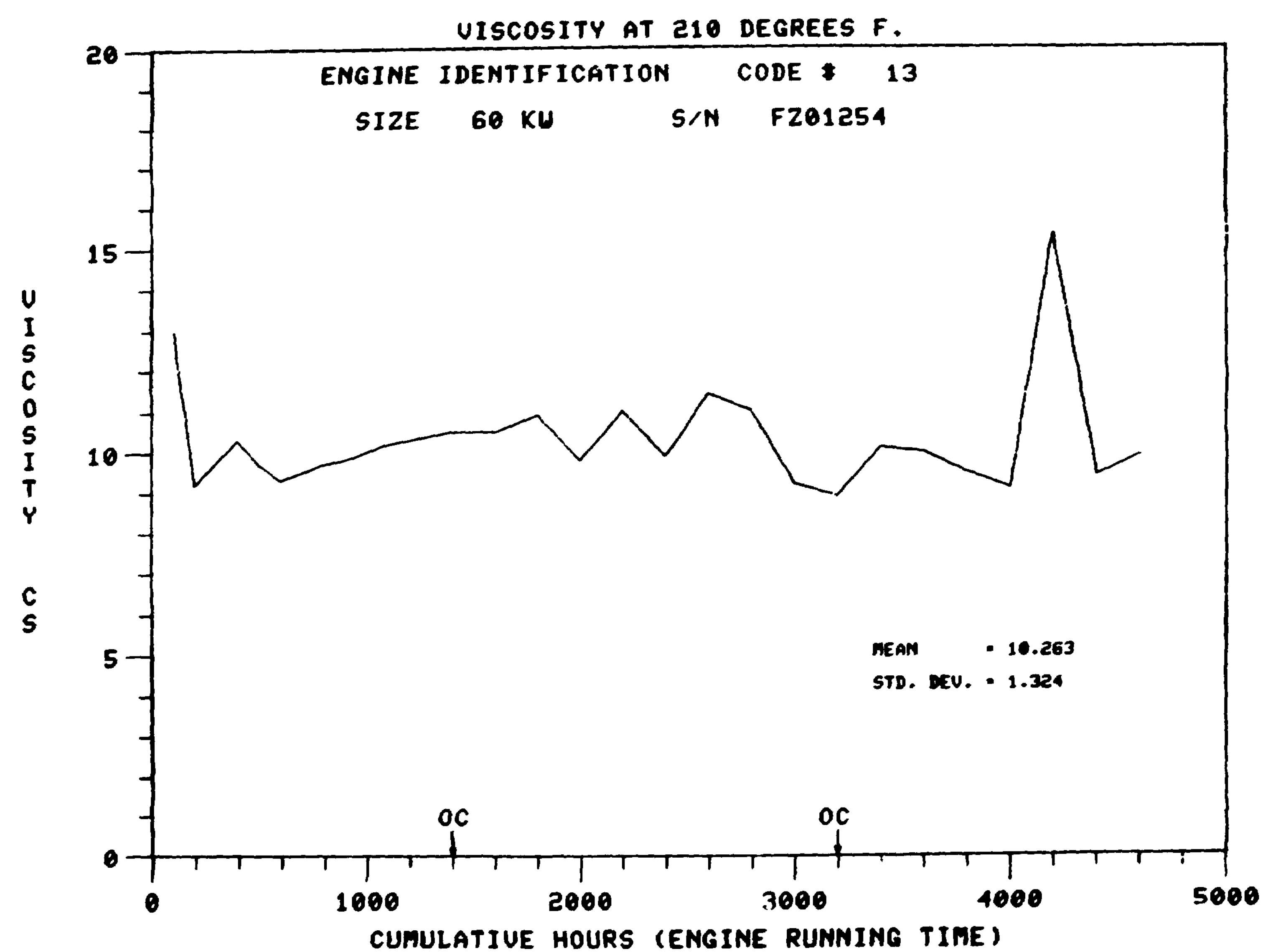
TIN
ENGINE IDENTIFICATION CODE # 12
SIZE 30 KW S/N RZ51245
MEAN = 21.404
STD. DEV. = 12.247
WEAR METAL CONTENT PPM
0
10
20
30
40
50
60
70
80
90
100
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

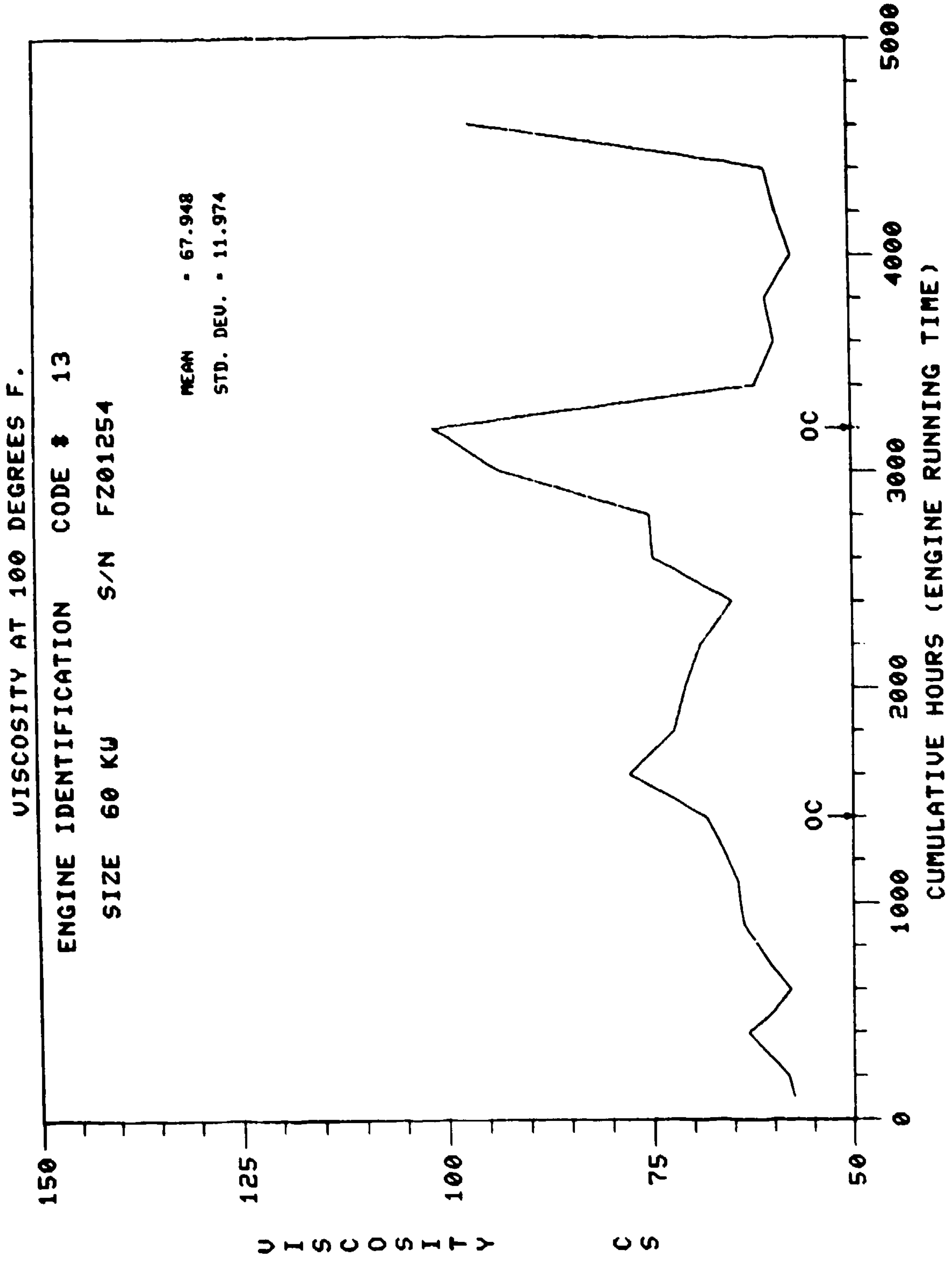


LEAD
ENGINE IDENTIFICATION CODE # 12
SIZE 30 KW S/N RZ51245
MEAN = 76.681
STD. DEV. = 86.104
WEAR METAL CONTENT PPM
500
450
400
350
300
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

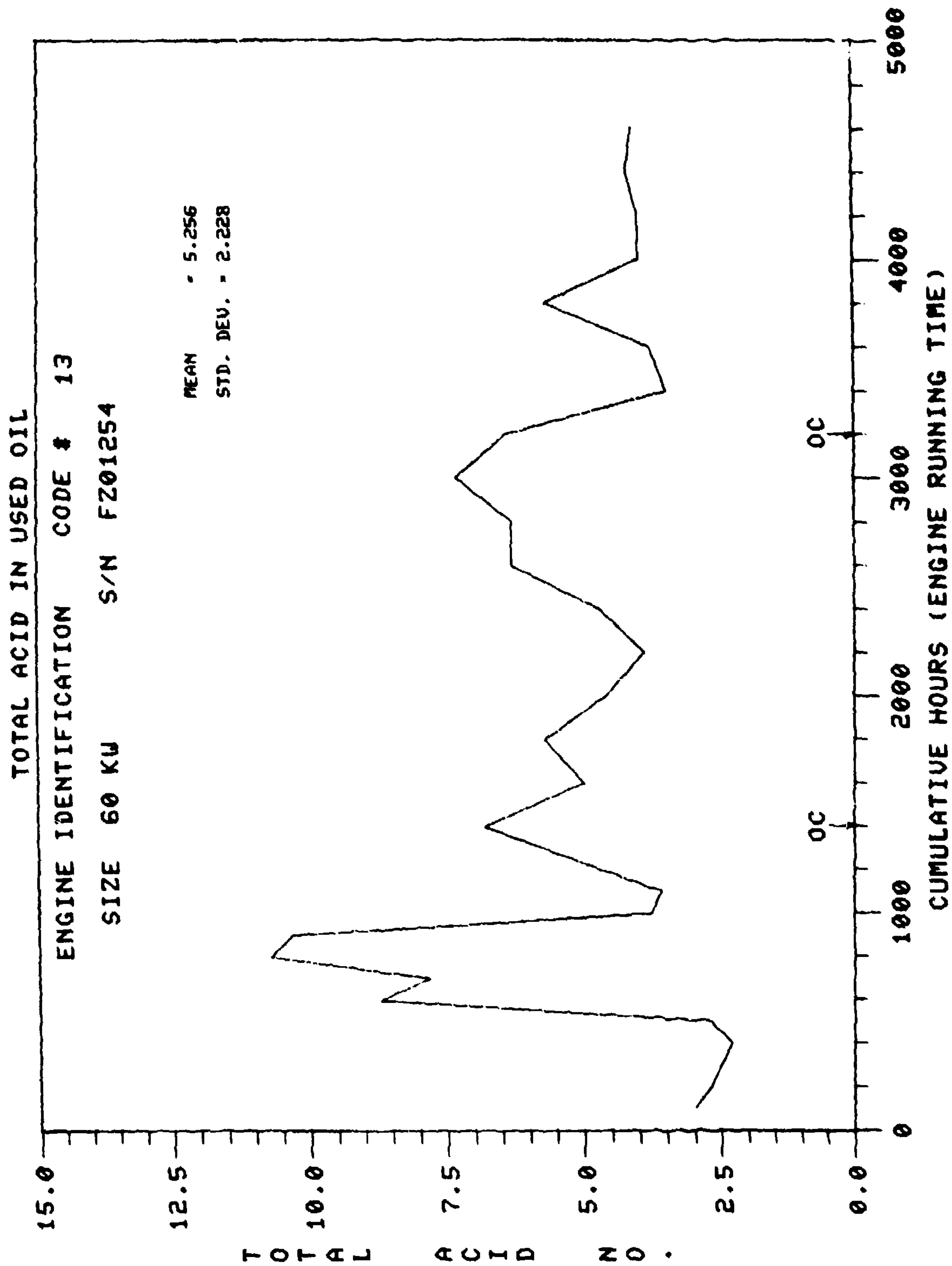

SILICON
ENGINE IDENTIFICATION CODE # 12
SIZE 30 KW S/N R251245
MEAN = 9.043
STD. DEV. = 5.221
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

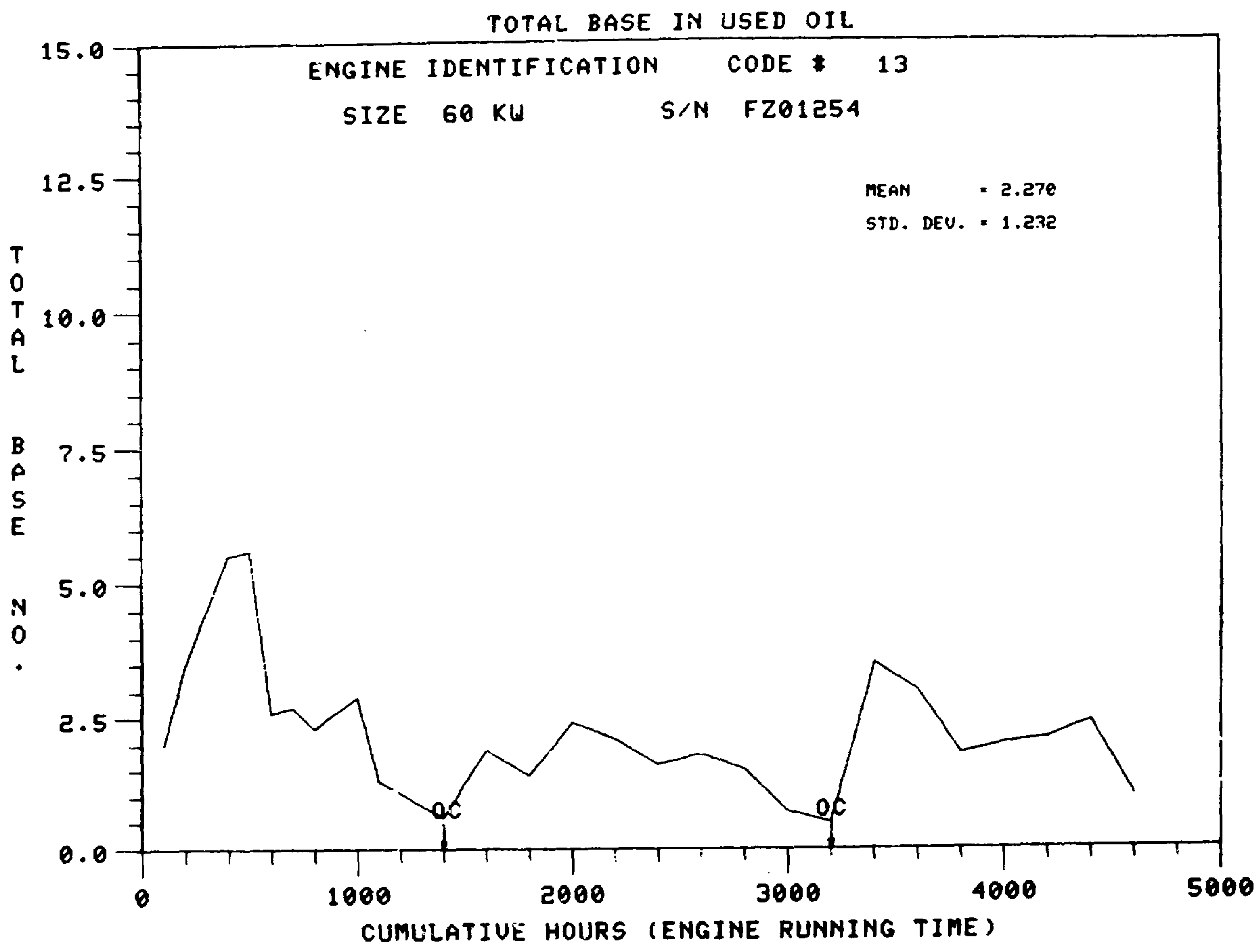

PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 0.141
STD. DEV. = 0.074
OC
OC
PENTANE INSOLUBLES
0.0
0.2
0.4
0.6
0.8
1.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
VISCOSITY CS
20
15
10
5
0
1000
2000
3000
4000
5000
OC
OC
MEAN = 10.263
STD. DEV. = 1.324
CUMULATIVE HOURS (ENGINE RUNNING TIME)

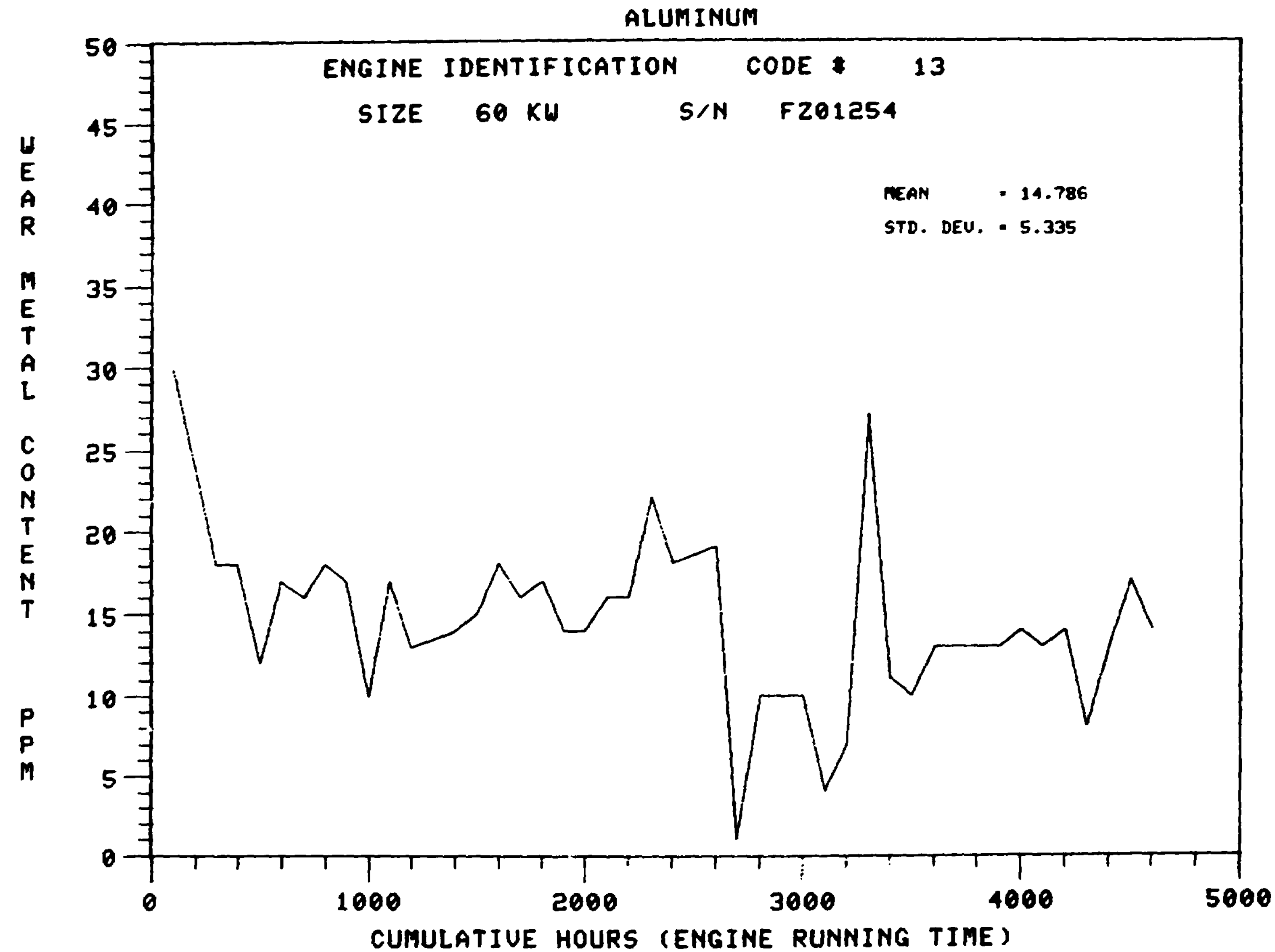


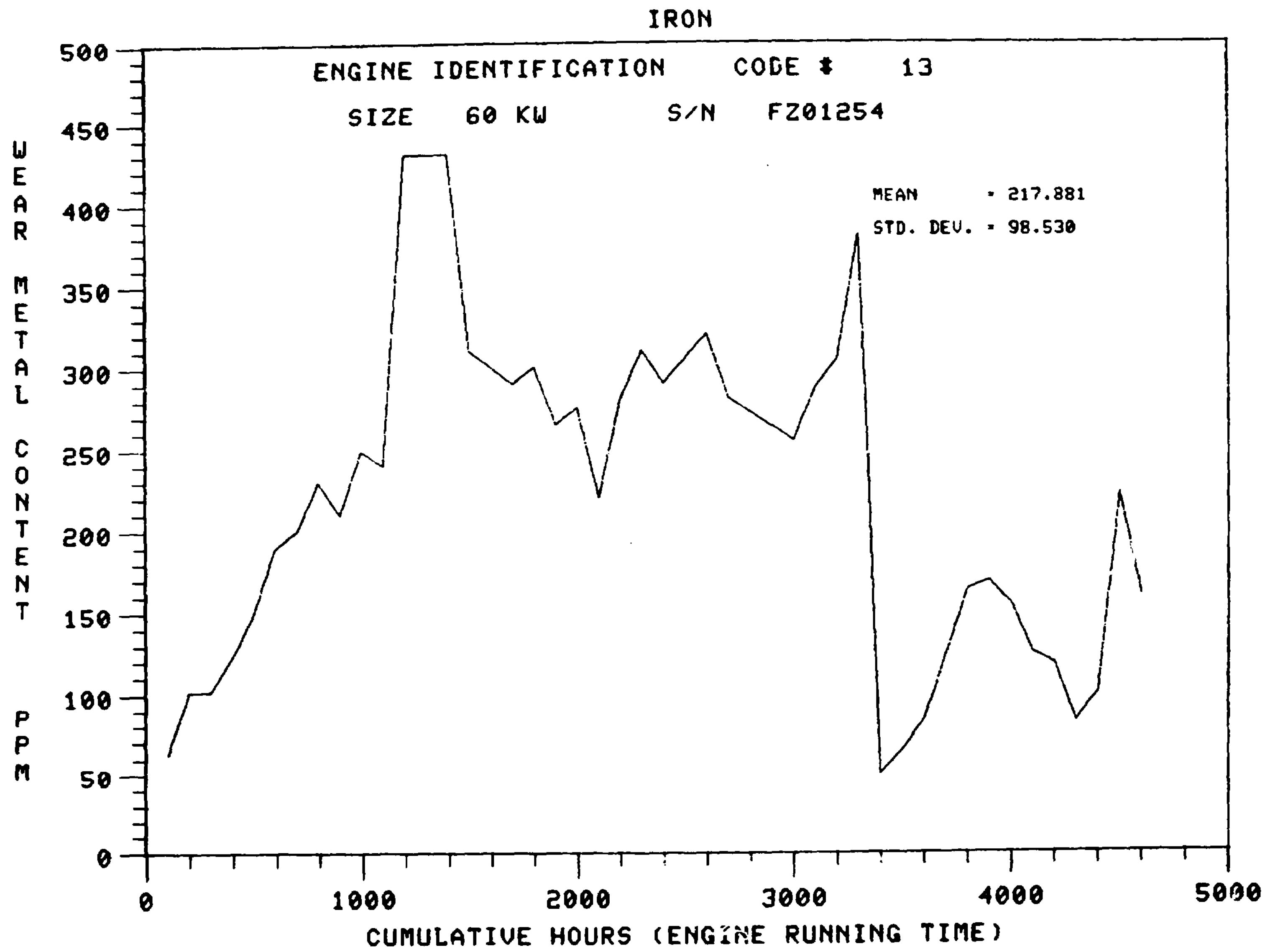
VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 67.948
STD. DEV. = 11.974
OC
OC
V I S C O S I T Y
C S
150
125
100
75
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

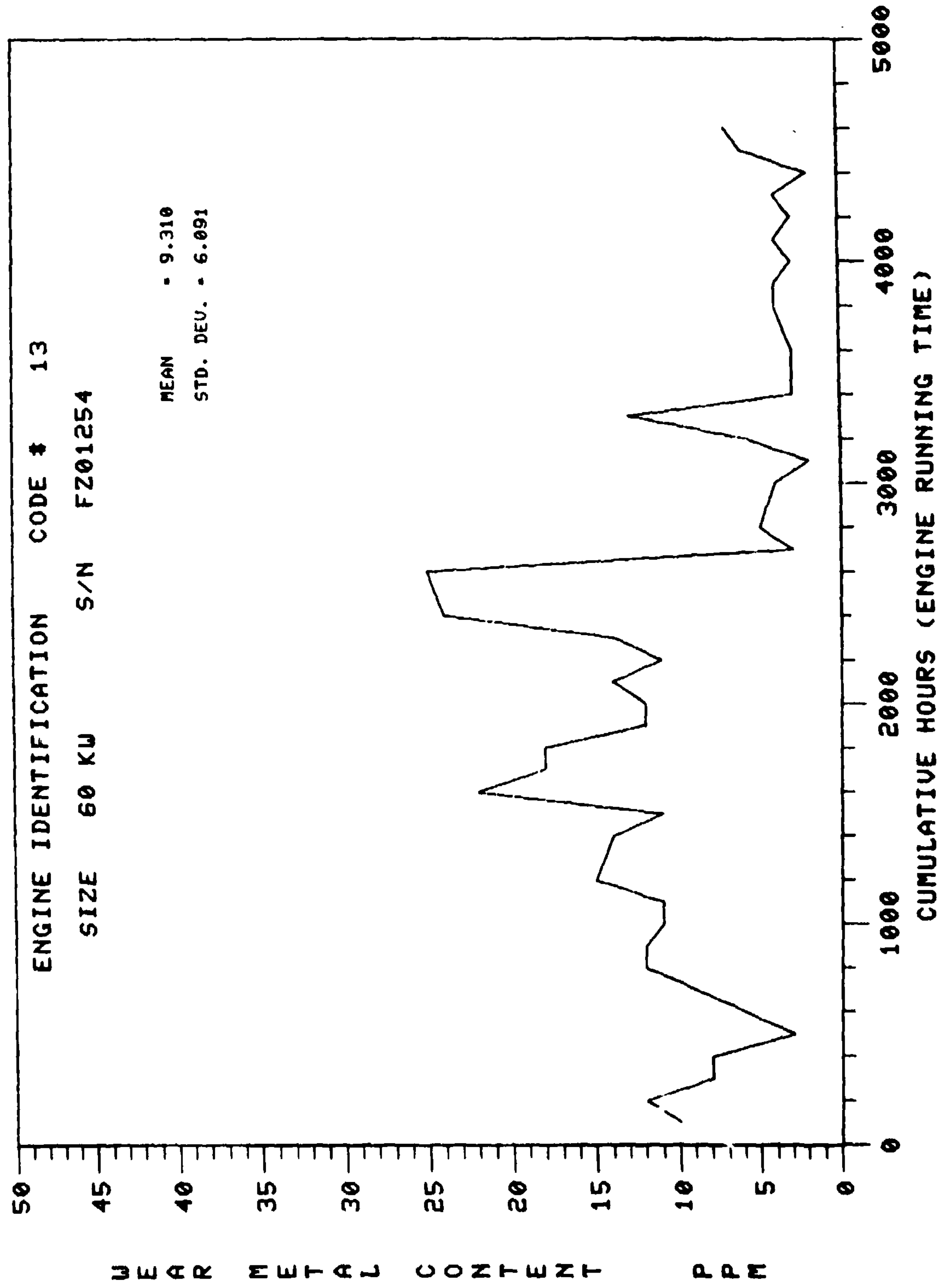

TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 5.256
STD. DEV. = 2.228
OC
OC
15.0
12.5
10.0
7.5
5.0
2.5
0.0
TOTAL ACID NO.
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

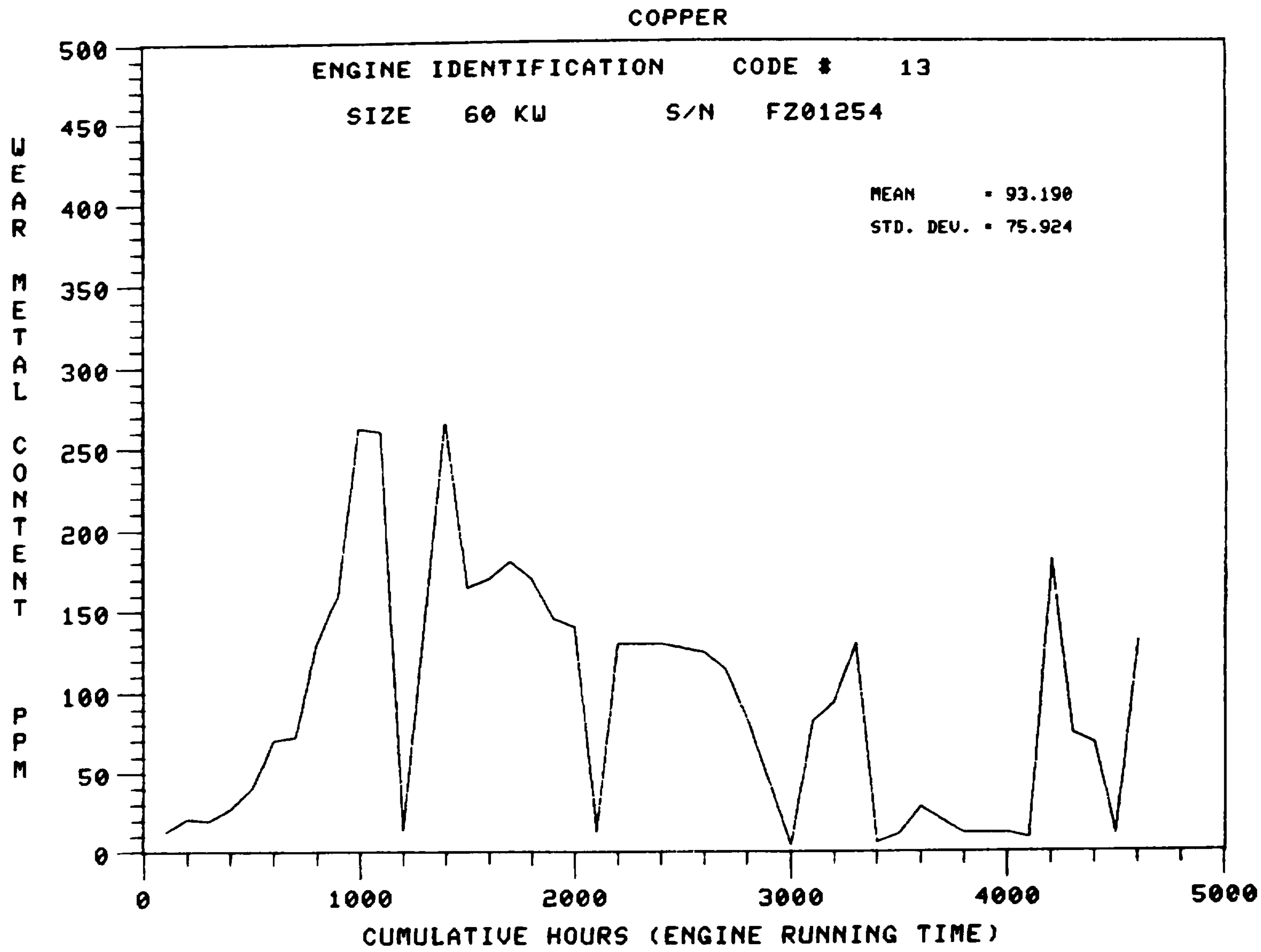


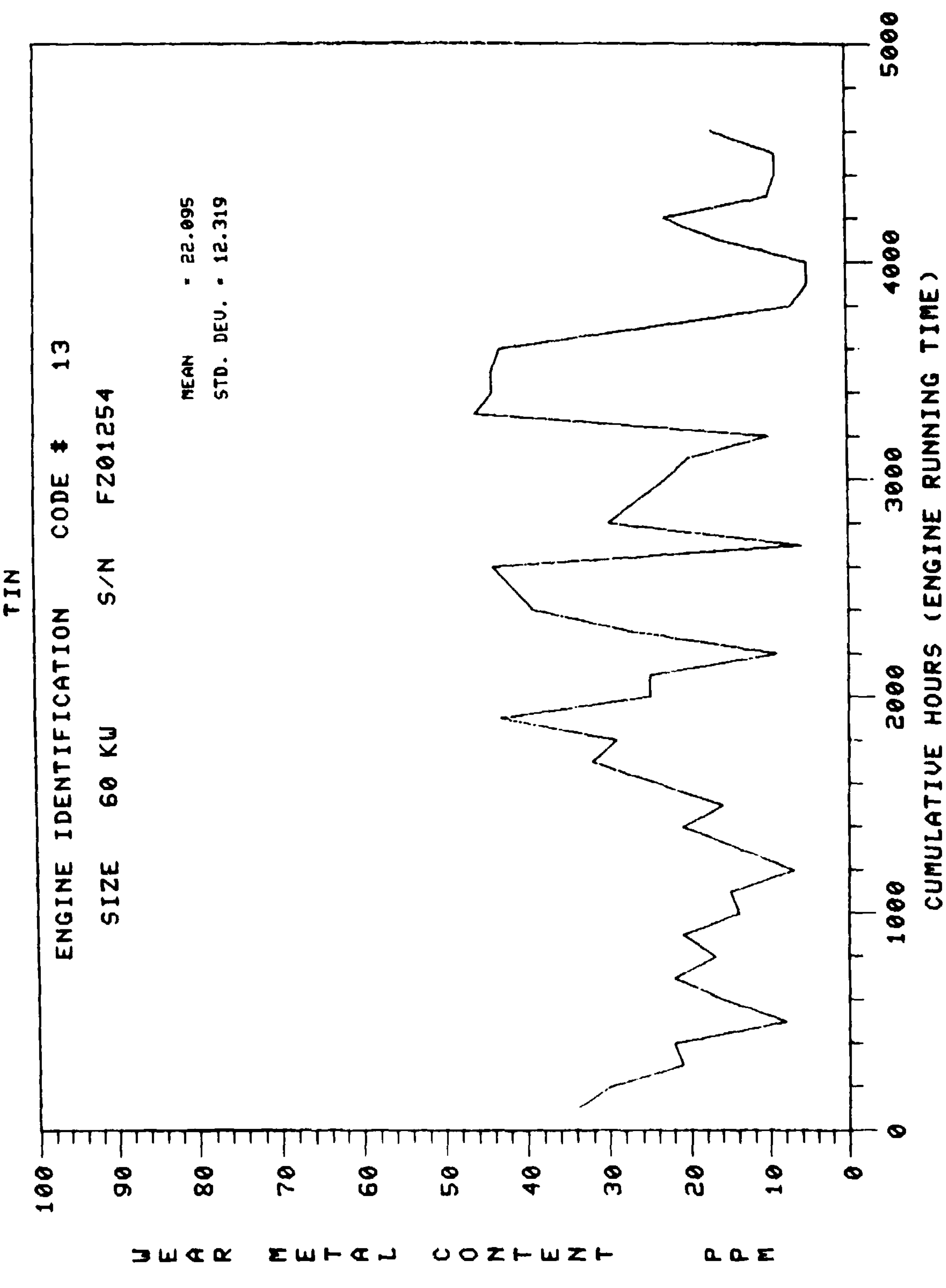
TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 2.270
STD. DEV. = 1.232
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
OC
OC
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


ALUMINUM
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 14.786
STD. DEV. = 5.335
WEAR METAL CONTENT PPM
50
45
40
35
30
25
20
15
10
5
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

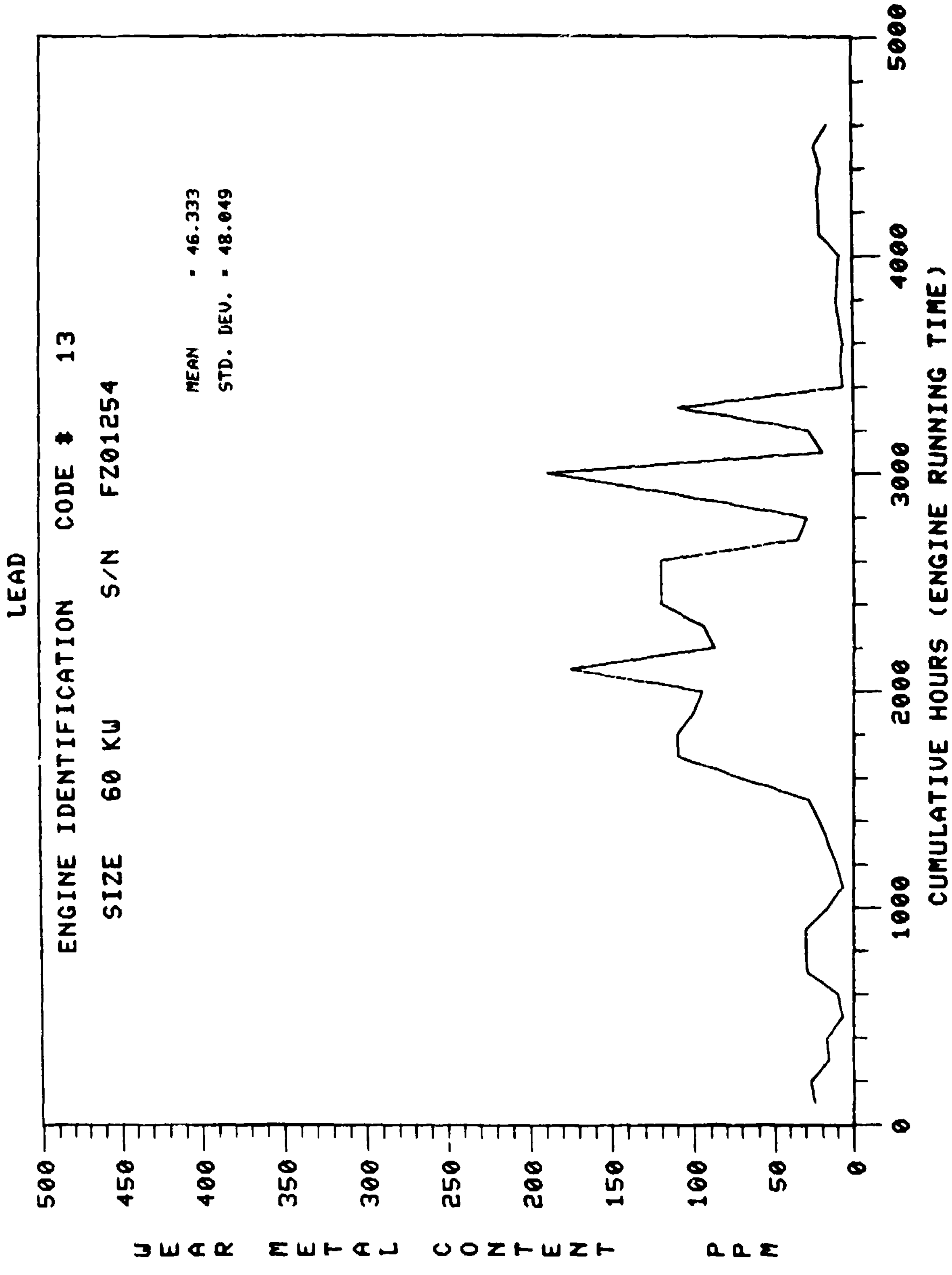

IRON
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 217.881
STD. DEV. = 98.530
WEAR METAL CONTENT PPM
0
50
100
150
200
250
300
350
400
450
500
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


CHROMIUM
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 9.310
STD. DEV. = 6.091
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50

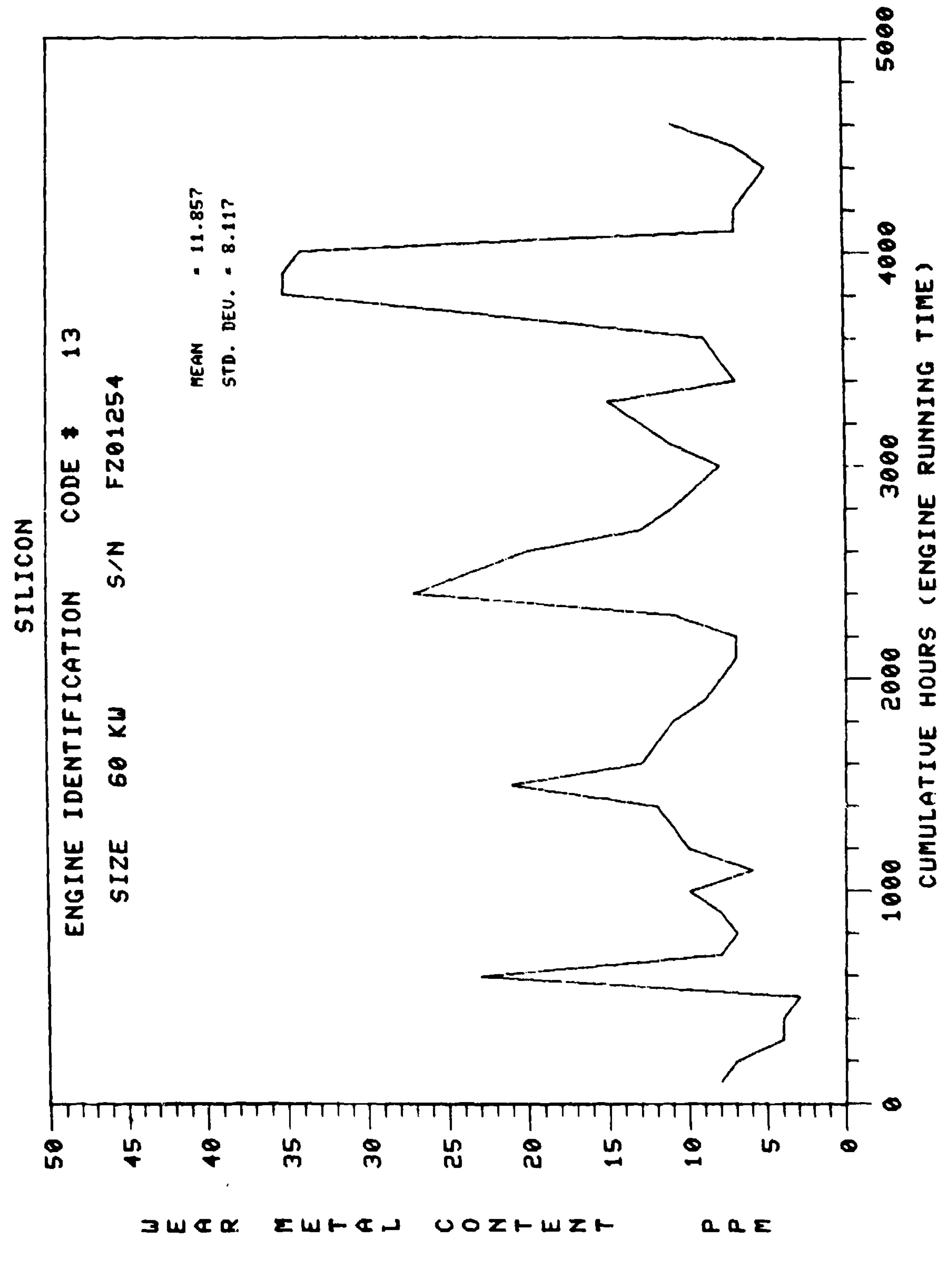

COPPER
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 93.190
STD. DEV. = 75.924
WEAR METAL CONTENT PPM
0
50
100
150
200
250
300
350
400
450
500
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

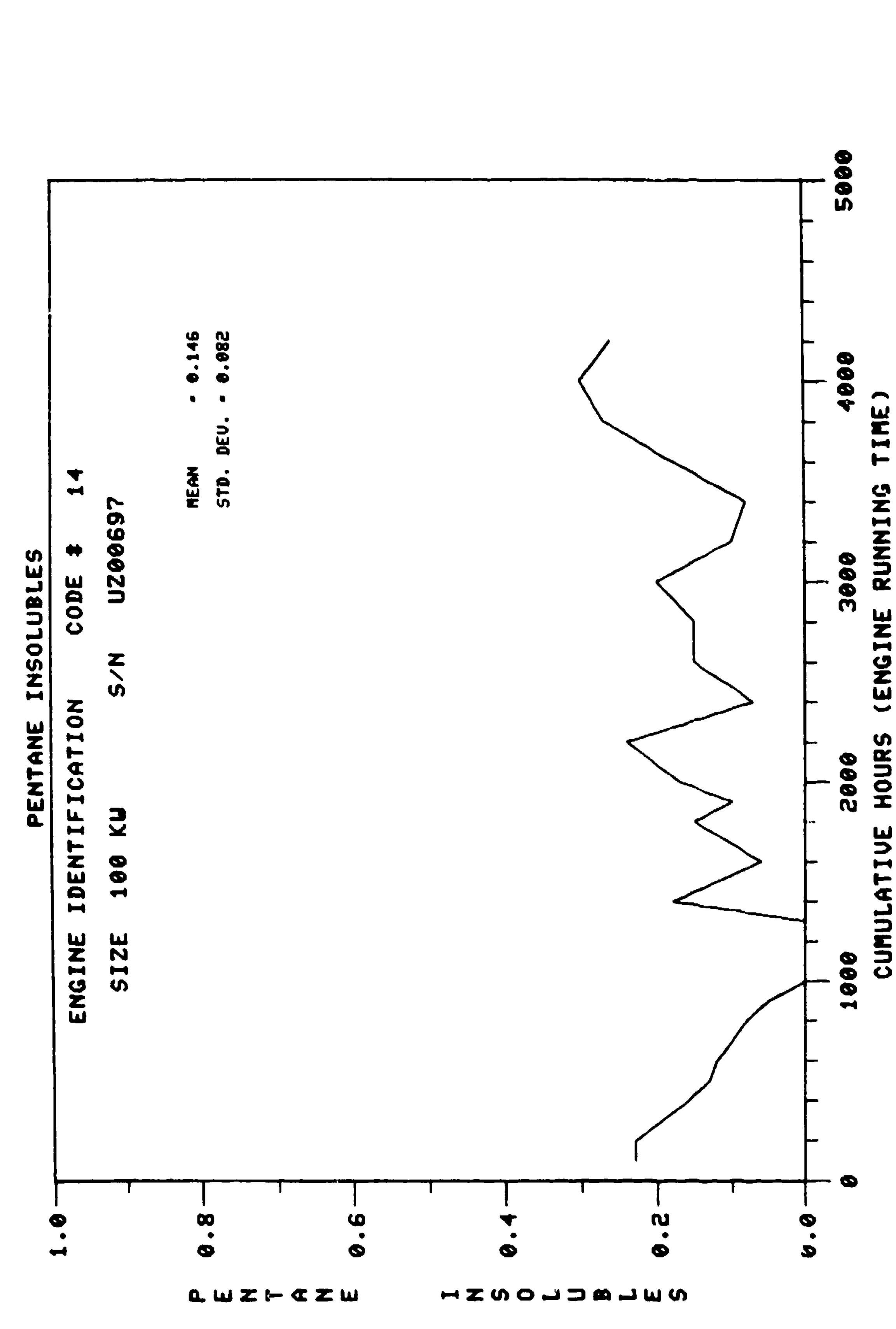


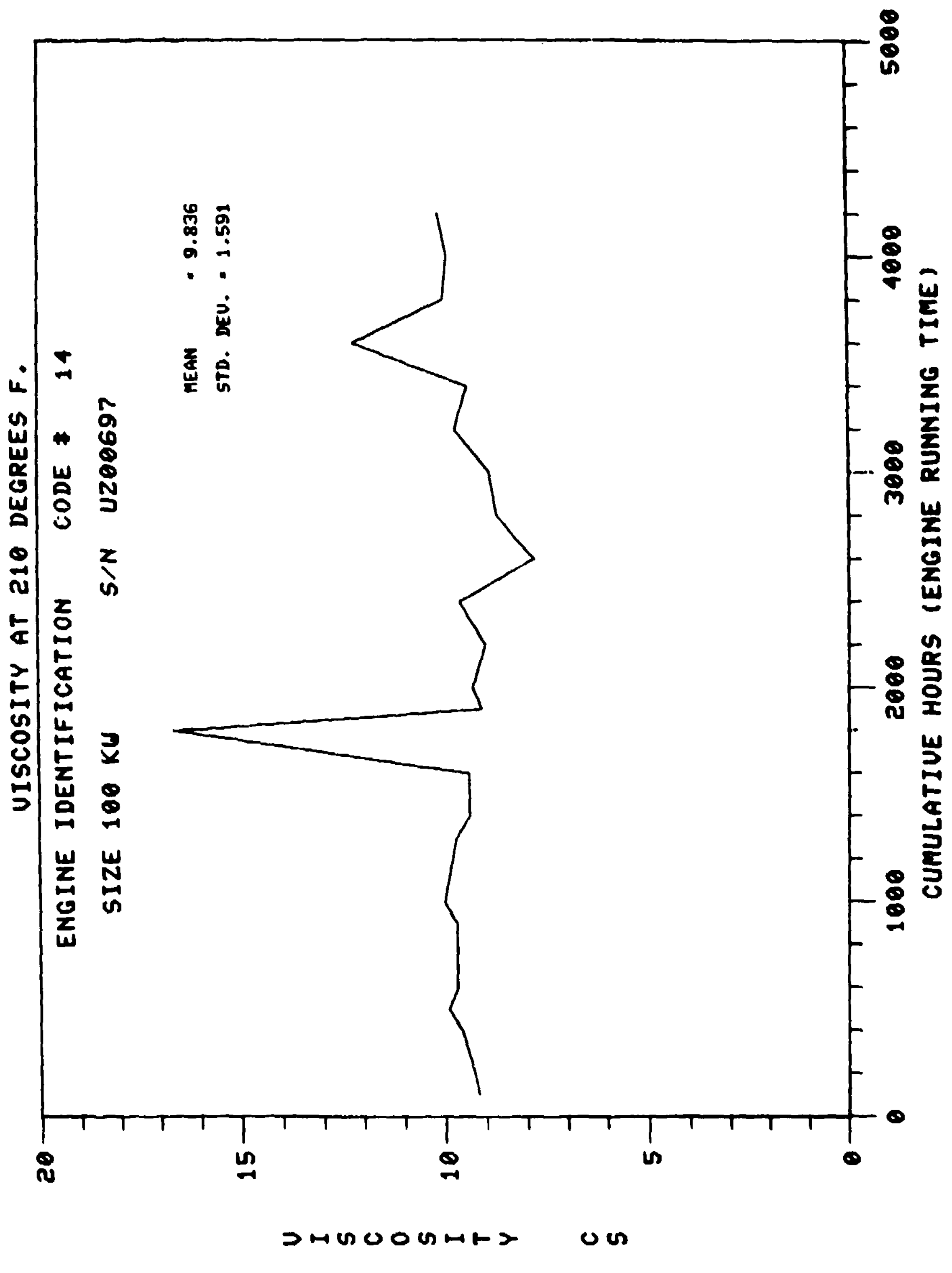
TIN
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 22.095
STD. DEV. = 12.319
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
10
20
30
40
50
60
70
80
90
100
WEAR METAL CONTENT PPM



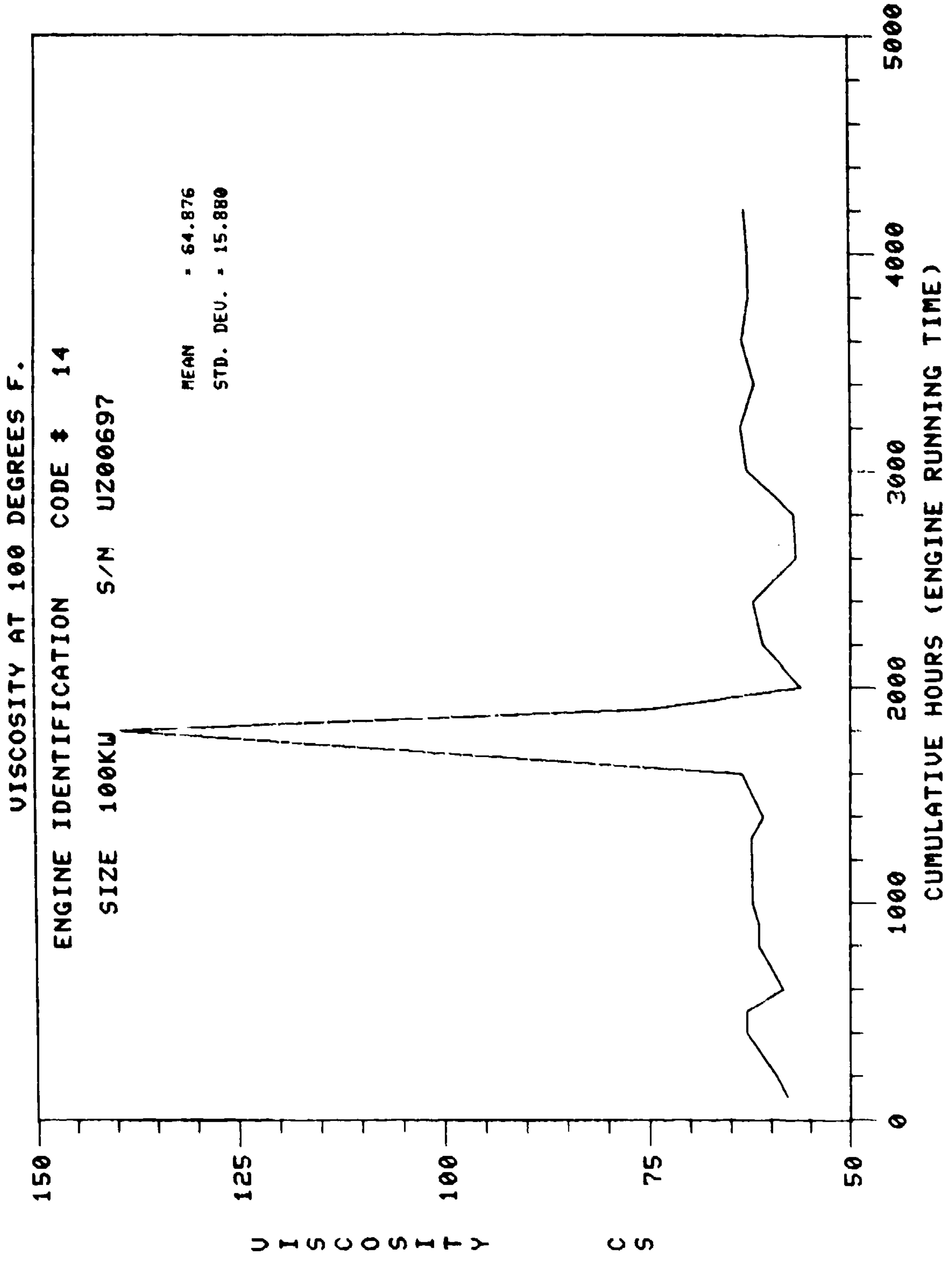
LEAD
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 46.333
STD. DEV. = 48.049
WEAR METAL CONTENT PPM
0
50
100
150
200
250
300
350
400
450
500
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000

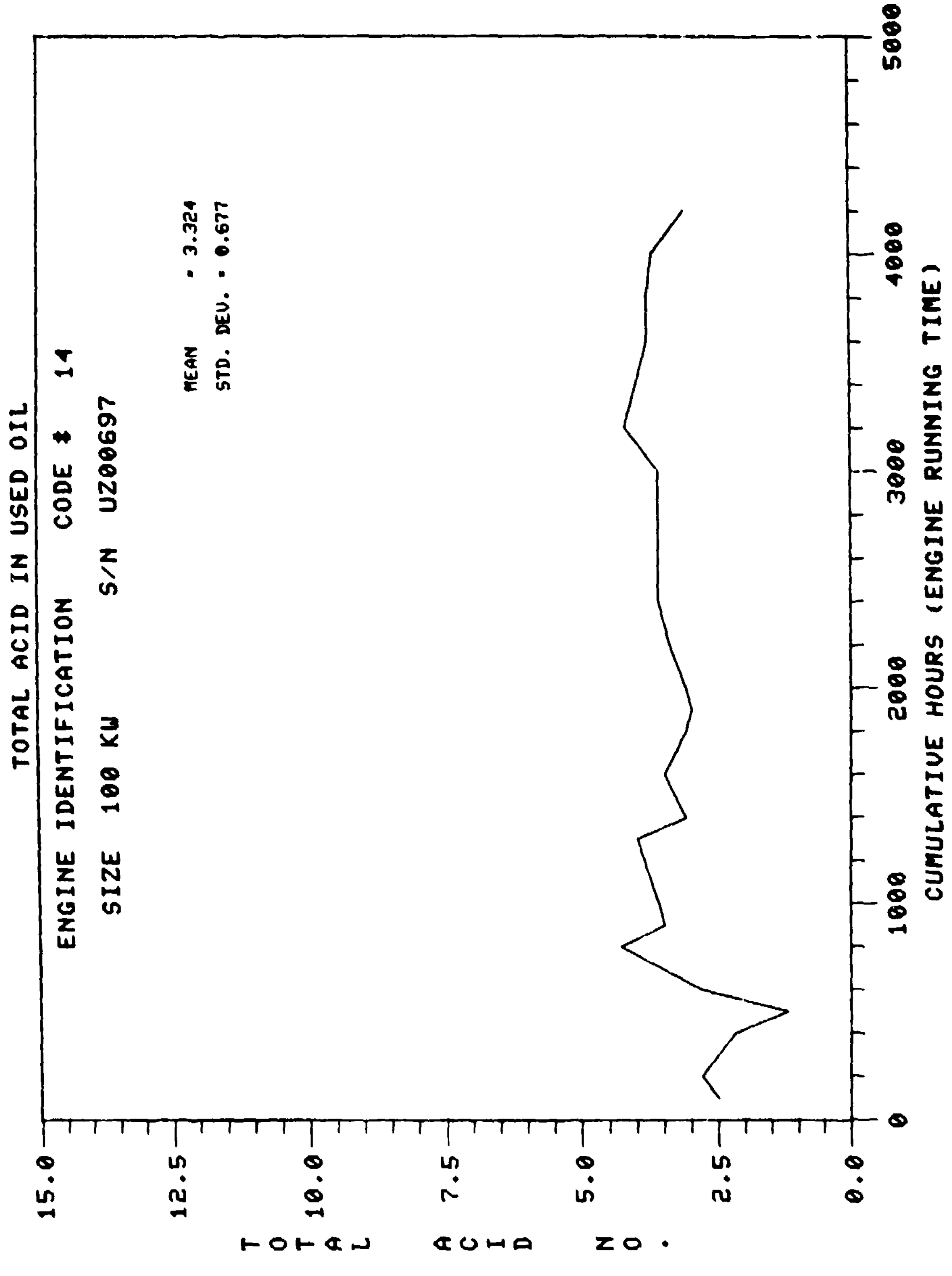

SILICON
ENGINE IDENTIFICATION CODE # 13
SIZE 60 KW S/N FZ01254
MEAN = 11.857
STD. DEV. = 8.117
WEAR METAL CONTENT PPM
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
5
10
15
20
25
30
35
40
45
50
1000
2000
3000
4000
5000


PENTANE INSOLUBLES
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 0.146
STD. DEV. = 0.082
PENTANE INSOLUBLES
0.0
0.2
0.4
0.6
0.8
1.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

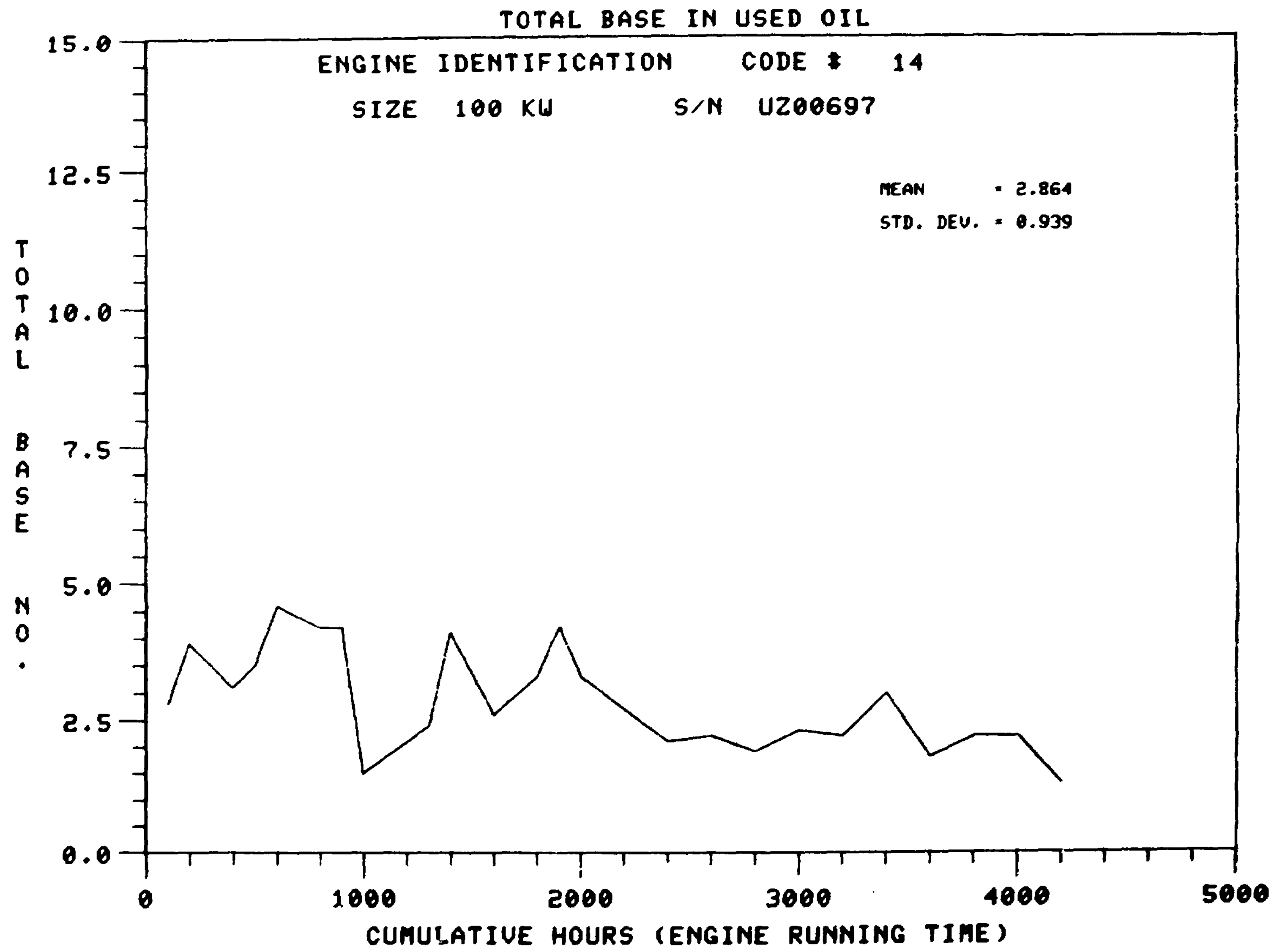


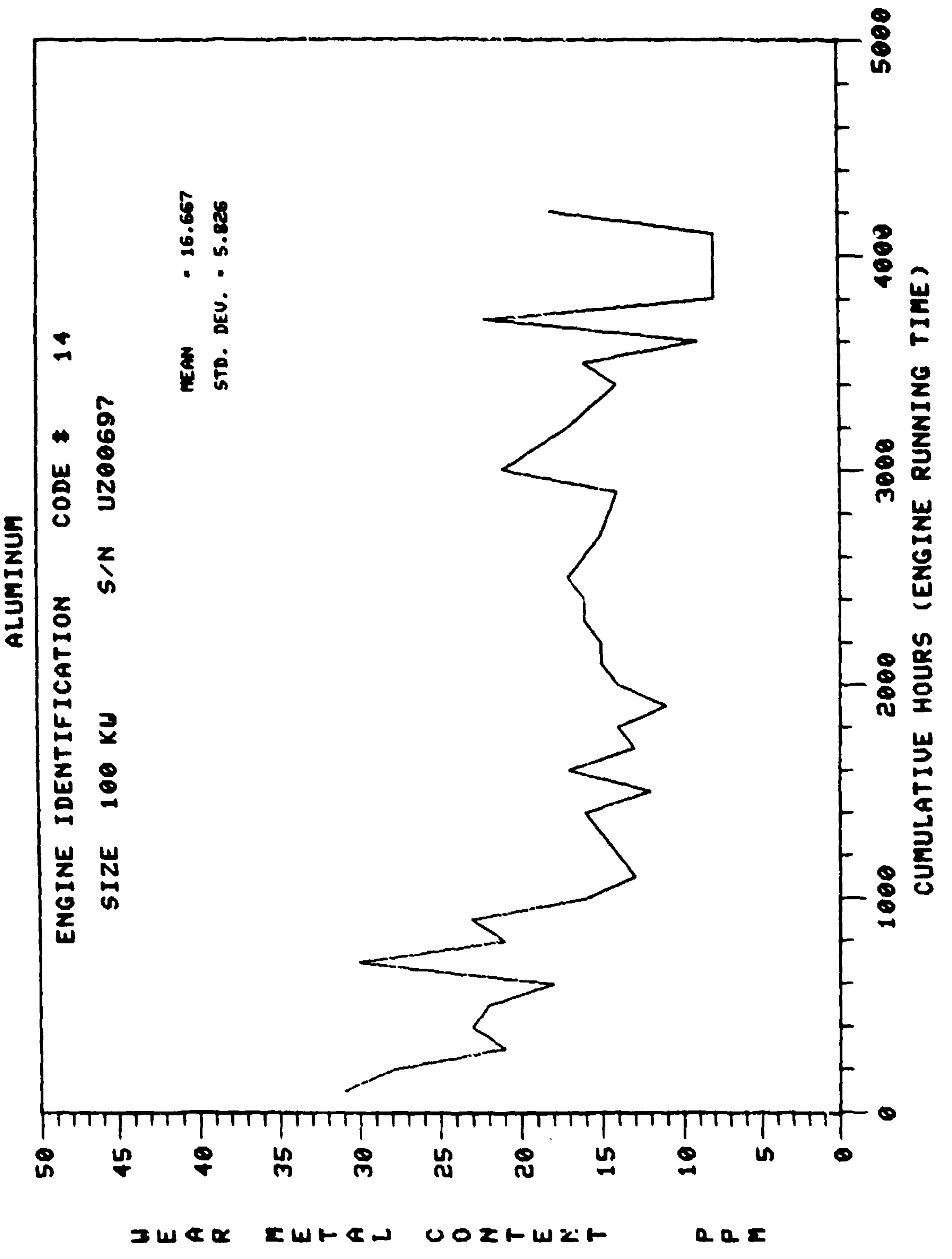
VISCOSITY AT 210 DEGREES F.
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N U200697
MEAN = 9.836
STD. DEV. = 1.591
20
15
10
5
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
VISCOSITY CS

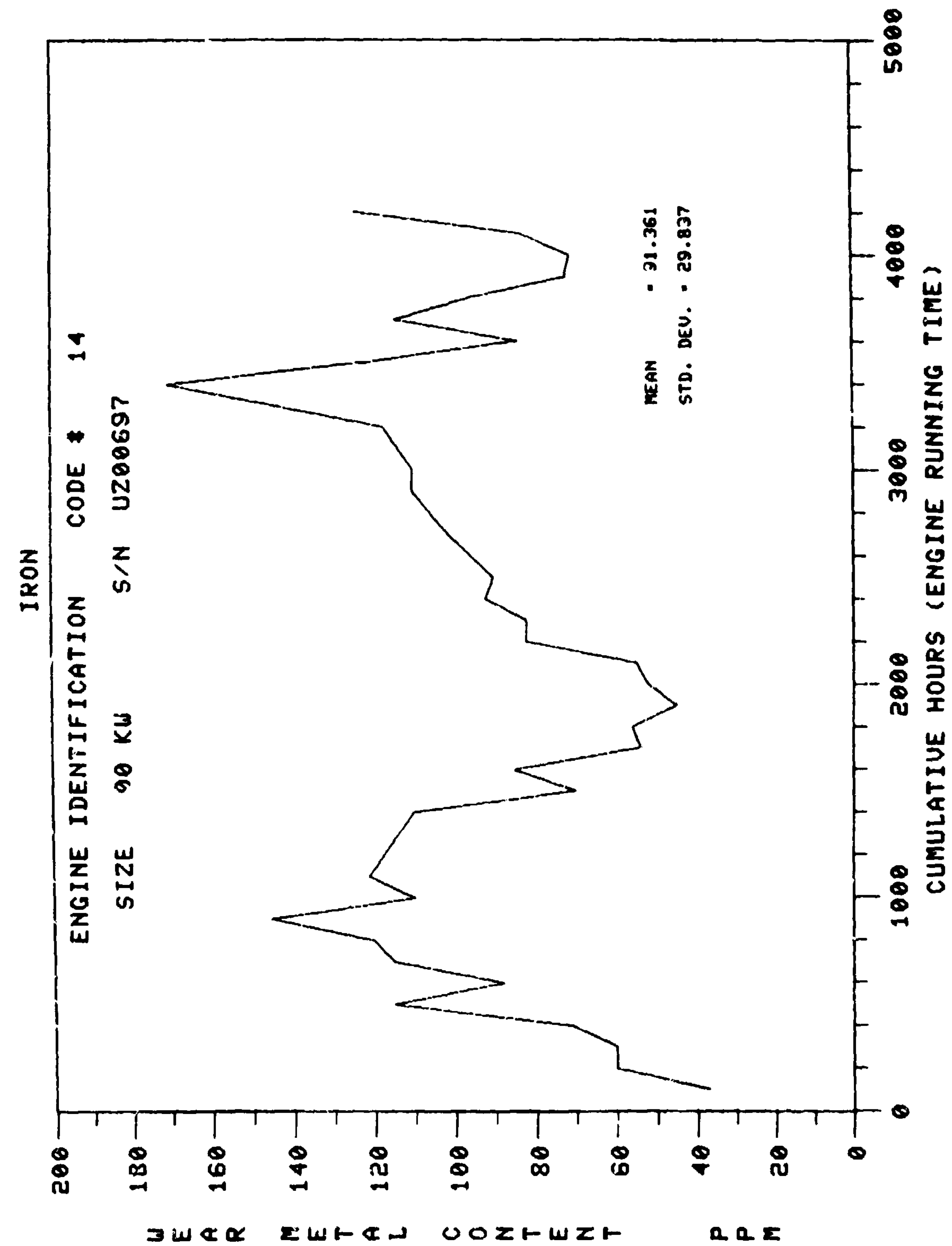

VISCOSITY AT 100 DEGREES F.
ENGINE IDENTIFICATION CODE # 14
SIZE 100KW S/N UZ00697
MEAN = 64.876
STD. DEV. = 15.880
150
125
100
75
50
VISCOSITY
CS
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

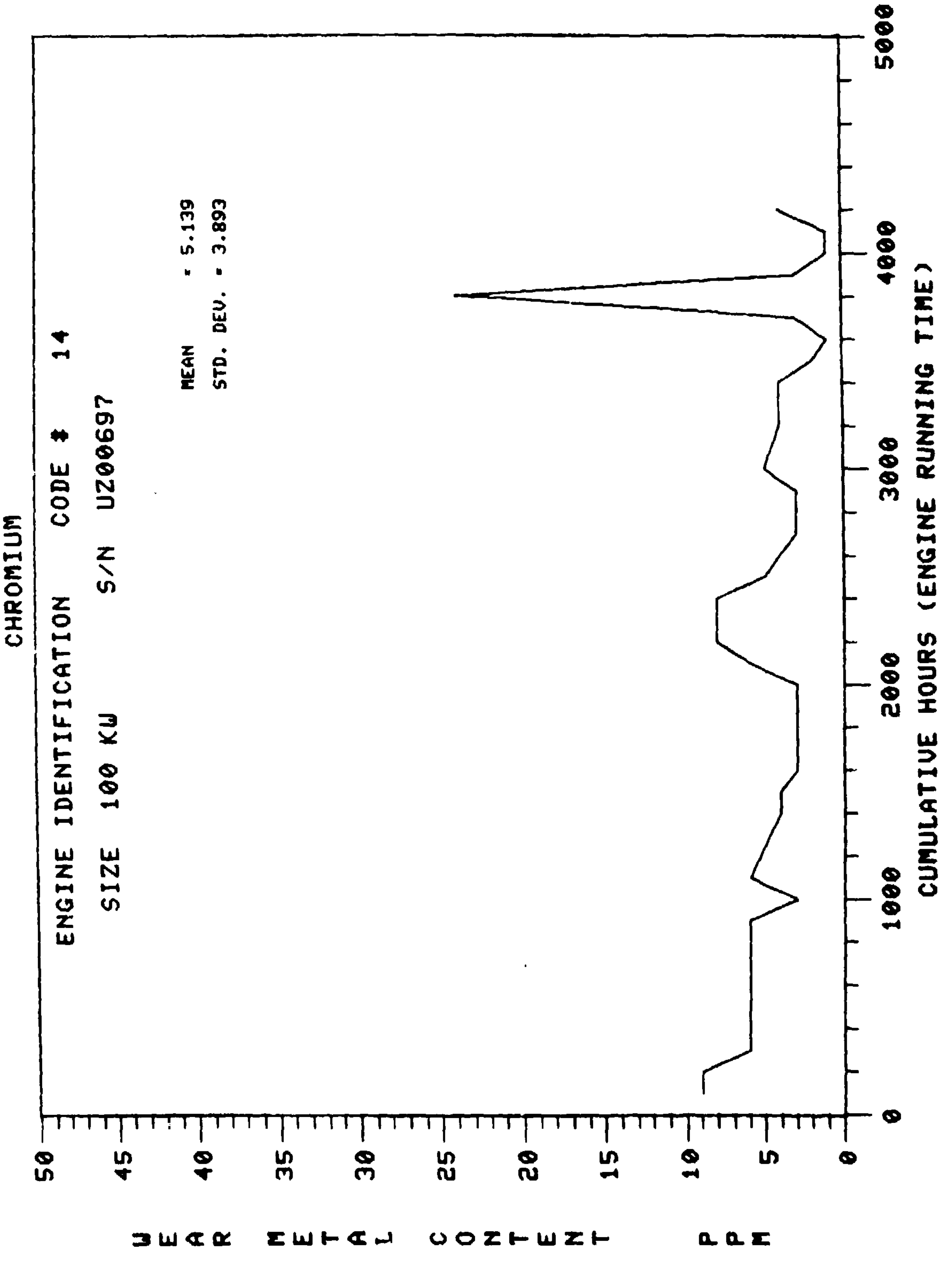


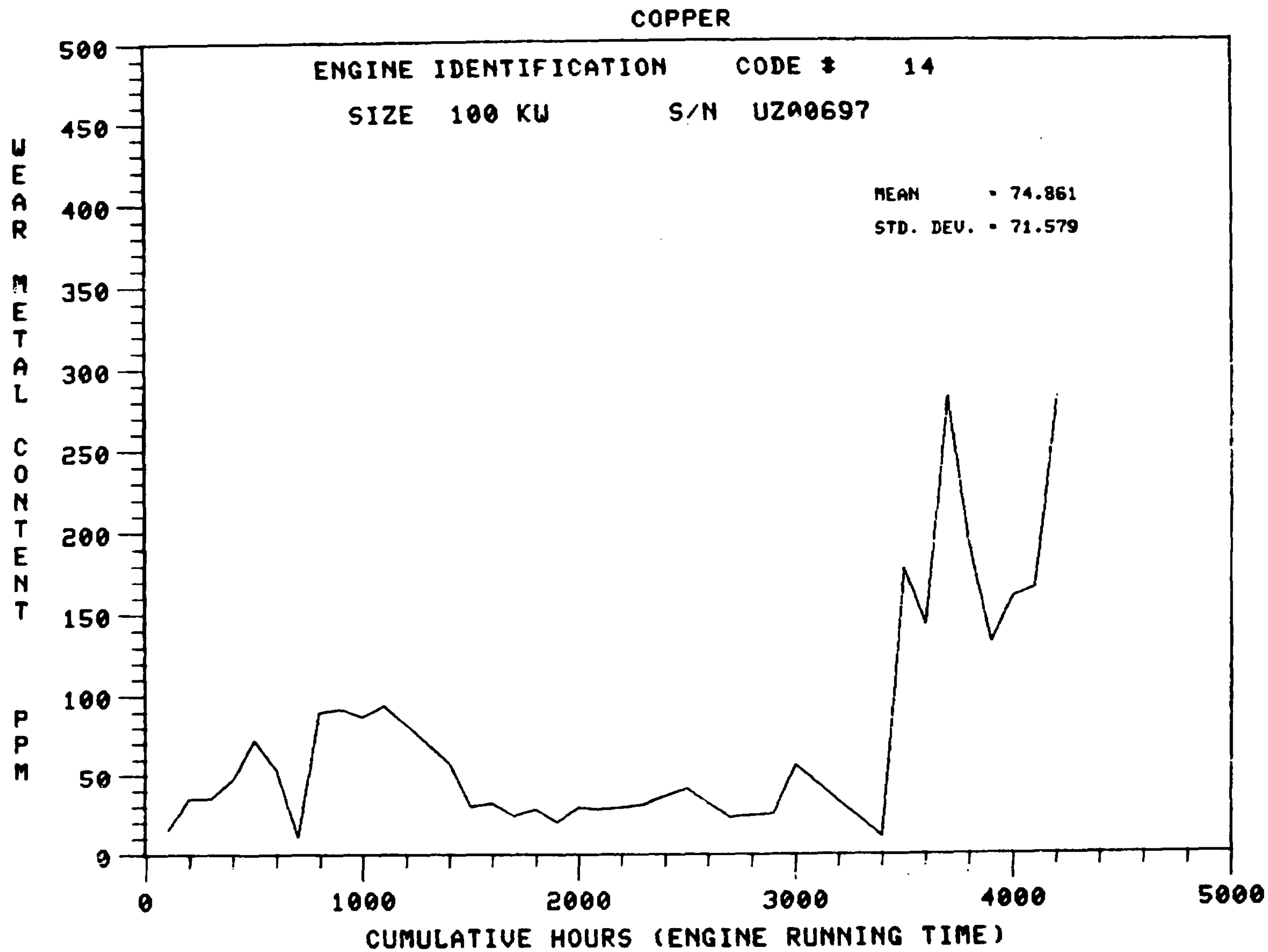
TOTAL ACID IN USED OIL
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 3.324
STD. DEV. = 0.677
TOTAL ACID NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

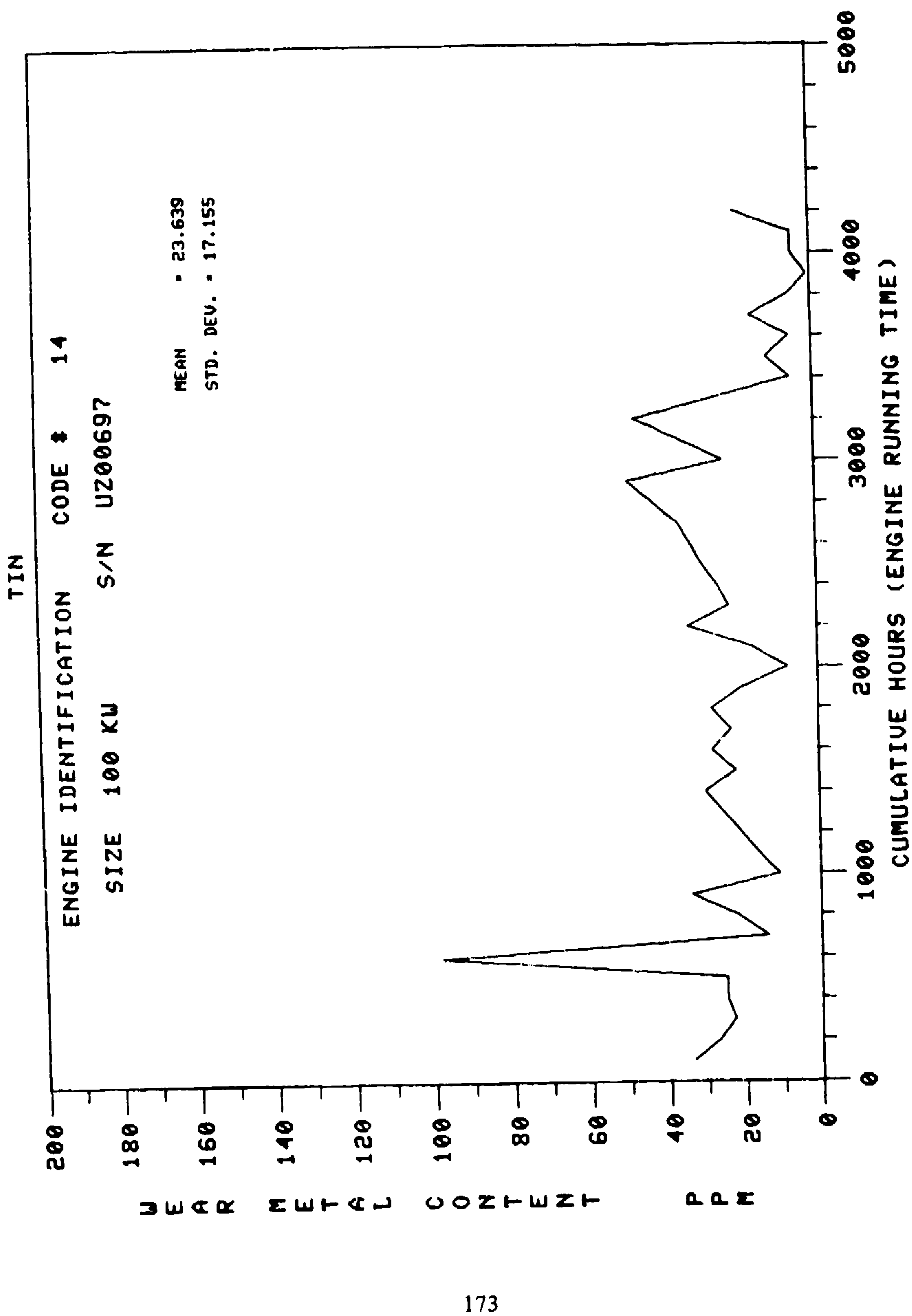

TOTAL BASE IN USED OIL
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 2.864
STD. DEV. = 0.939
TOTAL BASE NO.
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

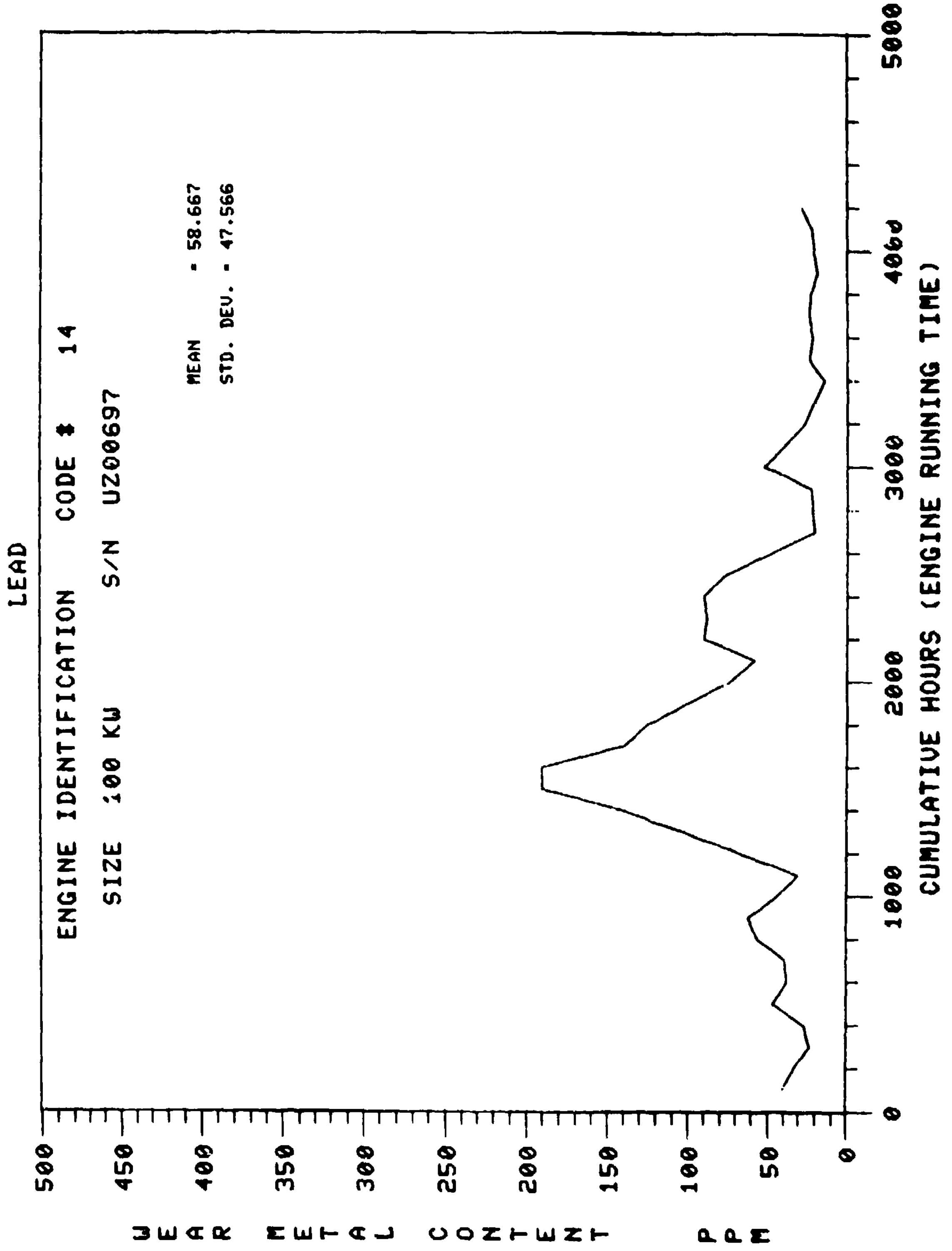

ALUMINUM
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 16.667
STD. DEV. = 5.826
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50

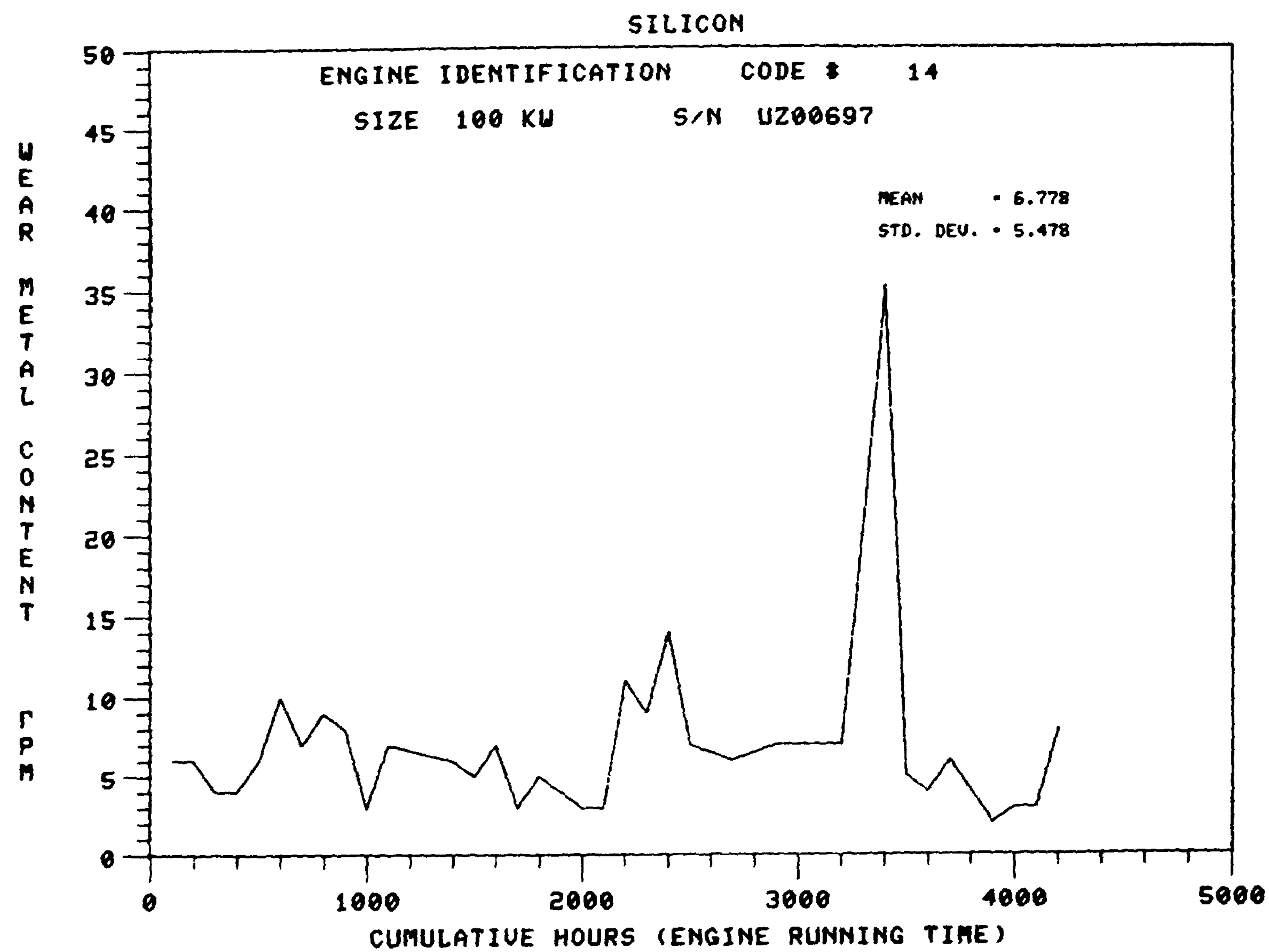

IRON
ENGINE IDENTIFICATION CODE # 14
SIZE 90 KW S/N UZ00697
MEAN = 31.361
STD. DEV. = 29.837
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
1000
2000
3000
4000
5000
WEAR METAL CONTENT PPM
0
20
40
60
80
100
120
140
160
180
200


CHROMIUM
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 5.139
STD. DEV. = 3.893
WEAR METAL CONTENT PPM
0 5 10 15 20 25 30 35 40 45 50
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0 1000 2000 3000 4000 5000


COPPER
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZA0697
MEAN = 74.861
STD. DEV. = 71.579
WEAR METAL CONTENT PPM
0
50
100
150
200
250
300
350
400
450
500
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


TIN
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 23.639
STD. DEV. = 17.155
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)
0
20
40
60
80
100
120
140
160
180
200
WEAR METAL CONTENT PPM


LEAD
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 58.667
STD. DEV. = 47.566
WEAR METAL CONTENT PPM
500
450
400
350
300
250
200
150
100
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)


SILICON
ENGINE IDENTIFICATION CODE # 14
SIZE 100 KW S/N UZ00697
MEAN = 6.778
STD. DEV. = 5.478
WEAR METAL CONTENT PPM
0
5
10
15
20
25
30
35
40
45
50
0
1000
2000
3000
4000
5000
CUMULATIVE HOURS (ENGINE RUNNING TIME)

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