SHEAR STABILITY OF MULTIGRADE CRANKCASE OIL

Establishment of Field Data and Correlation with Laboratory Engine and Bench Test Results

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SHEAR STABILITY OF MULTIGRADE CRANKCASE OIL Establishment of Field Data and Correlation with Laboratory Engine and Bench Test Results

Prepared by the
Data Analysis Panel of
ASTM Committee D-2
Research and Development Division VII B-1
on the Shear Stability of Crankcase Oils

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I. SUMMARY

Extensive field test data have been obtained which can serve as a basis for evaluating the ability of various laboratory methods to predict the shear stability of multigrade crankcase oils. This basis was developed by determining the average viscosity changes of one single grade and twelve multigrade reference oils in six separate car fleets. The twelve multigrade oils were formulated with all of the chemical types of VI improvers currently in use, or likely to be used, in the near future.

As a second part of the program, four types of bench tests and three different laboratory engine tests were evaluated for their ability to predict the average viscosity changes of the thirteen reference oils observed in the fleet tests. Correlation of the laboratory methods' results with the field data was marred by the non-conformance of two multigrade oils. This non-conformance was more noticeable in the bench test results than in the laboratory engine test data.

The control oil (ARO-113) which did not contain a V.I. improver, showed a measurable viscosity increase in the 1500 mile field tests. This indicated that factors other than mechanical shear may have influenced the viscosity changes of the multigrade oils in the field tests. Consequently, these factors must be recognized in any attempt to adjust test conditions for a bench test so that its results agree with the field test data.

II. INTRODUCTION AND BACKGROUND

Evaluation of the viscosity stability of multigrade oils has been a major concern of Section B of ASTM R&D Div. VII since its organization in 1952. In 1955, six participants ran tests on two hydraulic fluids formulated with two different molecular weight V.I. improvers of the same chemical type (polyalkylmethacrylates). Techniques evaluated at that time included sonic (magnetostrictive) oscillators, pumps with sharp-edged orifices or pressure release valves, and a diesel fuel injector. On plotting percent viscosity loss of one reference fluid against percent viscosity loss of the other reference fluid under identical test conditions, members of the section found that data points from most of the shear methods studied fell reasonable well on a single curve. They therefore concluded (1)* that the various shear methods gave equivalent results under conditions of identical severity.

In 1957, R&D Div. VIIB conducted a cooperative program in which 12 laboratories evaluated a sonic oscillator method. This program led to a publication in 1961 (2) of a method for measuring the sonic shear stability of polymer-containing oils. The three reference oils used in this program were each prepared by adding sufficient V.I. improver to a 150 neutral base oil to double its viscosity at 100 F. Three different chemical types of V.I. improvers were selected for the program without regard for molecular weight and consequent shear stability. The sonic method, though somewhat lacking in precision and having unknown correlation with field performance, was published for information because it promised to be a useful tool for monitoring lot-to-lot variations in the manufacture of a given polymer concentrate or blend. While the simplicity and rapidity of the sonic

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* Numbers in parentheses designate References at end of paper.

shear method have appeal, attempts to extend its use to different chemical types of V.I. improvers have met with difficulties (3). For lack of a better method, R&D Div. VIIB voted in 1966 to republish the sonic method as a tentative (4) despite the evidence of poor correlation with tests designed to simulate specific service conditions.

In 1967, a new Subsection, B-1, was formed "to study ways of evaluating the shear stability of polymer-containing oils under conditions closely related to service". The Subsection circulated a questionnaire to representatives of industry, government and research organizations to find out what methods were being used for the measurement of shear stability. Response to the questionnaire led to the decision to obtain field data on a representative set of fully formulated multigrade crankcase oils containing all of the V.I. improver chemical types then available or likely to be available in the near future. These data would then be used by the Subsection to judge the relative merits of various laboratory engine tests and bench test devices for evaluating the shear stability of multigrade oils in automotive use.

Members of R&D DVII B-1 then selected a set of 13 test oils and, with the aid of a $5,000 appropriation from the American Petroleum Institute, blended and distributed appropriate quantities of the oils to field test and laboratory test participants in the U.S.A. and overseas. The U.S.A. portion of the initial program has been completed and is summarized in this report, but the overseas program will not be completed for some time.

III. PROGRAM

ASTM Reference Oils (ARO's) - Reference oils are a necessary link between field tests and bench tests. The following criteria were used for the formulation of the Reference Oils:

- Representation of all chemical types of polymers suitable for V.I. improver use. In this way, any sensitivity of a particular shear device to certain polymer types would become evident.
- Inclusion of V.I. improvers covering a broad range of shear stability.
- Inclusion of two V.I. improvers of the same chemical type but having appreciably different molecular weights to investigate the effect of molecular weight on shear stability.
- Inclusion of two sets of oils containing the same V.I. improver, but formulated to two different viscosity levels to determine the effect of viscosity level on breakdown.

- Formulation of all polymer-containing oils to SAE 10W/40 levels, with the exception of the two 10W/30 oils which were formulated to fulfill the requirements of the previous criterion, to maximize viscosity loss and to investigate a class of multi-grade oils that has grown in consumer acceptance.

- Inclusion of one oil for control purposes that does not contain any V.I. improver.

The V.I. improver types selected for this program are shown in Table 1. along with the viscosities of blends with and without their V.I. improver. In addition, the average 210 and 100 F viscosities determined by all of the participants are compared to those reported by laboratory "P".

The ARO's were all blended with two base stocks from the same commerical source* and the same batch of a commercial detergent-inhibitor additive package. Viscosity targets were set as follows:

ARO Nos.	101-110	111,112	113
Number of Oils	10	2	1
SAE Grades	10W/40	10W/30	20W/20
Viscosity Target at			
210°F, cSt	15.0	11.0	6.7
0°F, cP	2000	2000	2600

The ratio of the two base stocks had to be tailored to each V.I. improver. To determine the amount of viscosity contribution by the V.I. improver, the 210°F viscosity of each blend was determined both before and after V.I. improver was added.

A 400 gallon batch of each oil was blended not only to supply the proposed vehicle test, but also to provide a more than adequate inventory of these oils to evaluate bench shear devices.

An approval procedure, described in Appendix Table A-1, has been set up to control distribution of these valuable reference oils. All requests for ARO's must be approved by the Chairman of the Mechanical Shear Stability Subsection R&D Div. VII B-1. If the request is approved, a charge of $10 per gallon is made. Net proceeds from these charges are sent annually to API as reimbursement for their initial grant to cover additive and base stock costs. As a matter of policy, no approval will be granted for any bench test requiring an oil charge of more than one gallon per test. Approvals are also contingent upon disclosing all shear device data developed with ARO's to R&D Div. VII B-1.

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* Base stocks were 95 V.I. mid-continent origin, +5°F pour point with nominal viscosities of 100 SUS and 200 SUS at 100°F.

Field Test Design - The vehicle field test was composed of six individual fleets, with each fleet test being run by a different laboratory. (Laboratory participants are shown in Appendix Table A-2). Each test fleet consisted of thirteen passenger cars operated under typical owner driving conditions. Each car used only four of the thirteen reference oils according to a pre-determined 13X4 incomplete Latin (Youden) Square test design (6) which is outlined in Table 2. Other test designs were considered but this design was selected because it seemed the most appropriate for this program. While a greater number of test oils involving additional SAE viscosity grades, V.I. improvers and cars may have been desirable, it was felt that they were unnecessary.

Vehicle Selection - Each test vehicle fleet was envisioned as a "mini-population" of U.S. passenger vehicles driven under typical operating conditions, e.g., an employee car test fleet. The composition of the "ideal" mini-population would be as follows:

- Vehicle Make and Number

Manufacturer	No. of Vehicles
General Motors	5
Ford	4
Chrysler	3
AMC	1
	13

- Engine and Transmission - 11 of the 13 cars should have V-8 engines and automatic transmissions; the other two should have 6-cylinder engines and manual transmissions.

- Engine Condition - Cars having mileage accumulations between 8,000 to 50,000 miles and no external oil leakage were recommended for selection. Oil consumption rate should be 2,000 miles/quart or better to preclude the addition of oil during the 1,500 mile test period.

- Mileage Accumulation Rate - to complete the field test in a six month period, vehicles that accumulate at least 1,000 miles per month were sought.

Vehicle fleet tests that had other operating regimes were also welcomed. For example, a test is underway in a high-speed tire evaluation fleet that provides sustained turnpike driving without significant stop-and-go operation. This type of test must be analyzed separately because of its different nature.

Test Procedure - Vehicles selected for the test were to undergo the detailed procedure shown in Appendix Table A-3. The test procedure called for two flushes of the engine with test oil prior to the actual test oil charge. A one-ounce sample was taken after 1,000 miles of driving and was held in reserve against unexpected contingencies. Each 1,500-mile (nominal) drain sample was to be stripped of fuel dilution, as described in the subsequent section.

In general, test drivers were urged not to add oil during the test. If the oil level fell to one quart below full before 1,500 test miles was attained, the car was to be brought in, the oil drained, and the next test sequence initiated.

Stripping Procedure - Since fuel dilution affects the viscosity of the used oil significantly, it was necessary to remove fuel dilution from all samples prior to viscosity measurement. To accomplish this, several existing proprietary procedures were evaluated since no universally accepted method was available. The criteria for this evaluation were three-fold. The method should:

- Remove all dilution
- Not remove light ends from the lubricant
- Be repeatable.

To check on dilution removal, a special oil (ARO-100) was blended with 5% mineral spirits to simulate fuel dilution. The 210°F viscosity of this blend was as follows:

Mineral Spirits, Wt. %	210°F Viscosity, cSt
0	13.98
5	11.02 (ARO-100)

The goal was to strip to a viscosity level of 13.90 to 14.10 cSt.

To check on removal of light ends from the base stock, ARO-103 which contains the lowest viscosity base stock was stripped by each laboratory. If the 210°F viscosity of a fresh sample of ARO-103 increased from its initial value by more than 0.10 cSt., it was assumed that light ends were being removed from the lubricant. Evaluation of one technique that used a 240°F (116°C) temperature and 100 mmHg absolute pressure indicated that these conditions could remove light ends. However, when the temperature was lowered to 210°F (100°C), the method then attained the desired balance of removing fuel dilution, but not light ends of the base stock. The original development data for the method are shown in Appendix Table A-4.

This initial procedure was later found to vary in results from laboratory to laboratory. The variation was later attributed to the nitrogen sparging rate, which had not been quantitatively specified in the original procedure. The revised method (Appendix Table A-5) calls for a metered flow rate of one gram of nitrogen per minute.

The precision of the revised stripping procedure appears to be good, as shown by results on ARO-100 in Appendix Table A-6. The maximum differences within and between laboratories for the combined stripping and viscosity determination are roughly equivalent to the precision of the viscosity measurement alone, as summarized in the following table:

	Max. Difference in Vis. @ 210°F, cSt	
	Within Labs	Between Lab Means
Combined Stripping and Vis. Determination (Labs A,K,B,D,H*)	0.07	0.08
Vis. Determination (ASTM D445)	0.05 (or 0.35%)	0.10 (or 0.7%)

* Laboratory C data omitted.

Results from Lab C were omitted from the foregoing comparison because the viscosity levels are substantially higher than other laboratories. The viscosity measurement rather than the stripping procedure seems to be at fault since the viscosity before stripping is also higher for Lab C than for Labs K and D. Inter-laboratory viscometer effects can be minimized by comparing viscosity change, as follows:

	Avg. Viscosity @ 210°F for ARO-100, cSt		
Lab	Before Stripping	After Stripping	Viscosity Change
C	11.10	14.07	2.97
K	11.01	13.99	2.98
D	11.04	13.93	2.89

The 0.09 cSt maximum difference among labs in viscosity change is within the 0.10 cSt limit of viscosity reproducibility.

A different stripping method was used by one laboratory instead of the method developed by the Subsection. A copy of this method is shown in Appendix Table A-7. A single result on ARO-100 reported by this laboratory, 13.90 cSt at 210°F, is within the range of results obtained by other laboratories using the vacuum stripping technique.

European Field Test Program - A field test was also initiated in Europe to evaluate shear stability in European cars. Such a test will provide a direct comparison between U.S. and European cars in terms of shear severity.

The European test program is using two seven-car fleets. One fleet consists solely of cars that have a common sump for both the engine and manual transmission, whereas the other fleet is composed of conventional systems with separate sumps for engines and transmissions.

As of March, 1972, there were some incomplete portions of that test; hence, results from the European field test were not available for analysis.

IV. EXPERIMENTAL DATA

Car Data - The cars in each of the six car-fleets are listed in Appendix Tables B-1 through B-6. Make of car, number of cylinders, displacement, mileage at the start of the program and the program periods are included. In addition, the mileage interval and the oil consumption rate for each sample are shown if reported to the Data Analysis Panel.

Fleet Viscosity Data - The original field viscosity data, submitted by each processor of the used oil samples, are shown in Appendix Tables C-1 through C-13. The fresh oil viscosities at 210 and 100 F determined by each processor are shown along with their used oil viscosities after roughly 1,500 miles of use in each test car. Each used oil viscosity was measured after the drain sample was stripped and filtered by the revised stripping procedure. The calculated viscosity losses at 210°F for each processor are shown in Sections 1 and 2 of Appendix Tables D-1 through D-13. To minimize viscosity error, each viscosity loss was calculated by subtracting the used oil viscosity from its corresponding fresh oil viscosity as determined by the same laboratory. Viscosity losses for each fleet, corrected for car effect, are shown underscored at the bottom of Section 3 of the same tables just above the corresponding uncorrected viscosity losses. The viscosity losses at 100°F shown in Appendix Tables D-14 through D-25, were obtained so that used oil viscosity data at other temperatures could be predicted by extrapolation from mean viscosities at 210°F and 100°F if desired.

An analysis of variance, illustrated in Section 4 of these tables, was performed on each set of 210 and 100°F data to assess the significance of phase and car effects. Based on the viscosity losses at 210°F, the car effects were significant at the 95% confidence level in five of the six fleets;but the phase effect, or order of running, was generally not significant in any fleet. The results at 100°F lead to the same conclusions. A comparison of the corrected and uncorrected viscosity losses, shown at the bottom of Appendix Tables D-1 through D-13 indicated that the maximum overall car effect correction in viscosity at 210°F was 0.51 cSt.

Bench Test Data - The original bench test data submitted by each participant are shown in Appendix Tables E-1 through E-10. Both 210 and 100°F data are included where available. As with the fleet data, the bench test viscosity losses were obtained by subtracting the sheared oil viscosities from the fresh oil viscosities measured in the same lab-

oratory. The only exceptions were three cases where 15-laboratory average values were substituted for fresh oil viscosities that deviated too much from the average. These corrections appear in Appendix Tables E-3 and E-10.

Laboratory Engine Test Data - Three separate laboratory engine test programs were conducted to evaluate the shear stability of the reference oils. The engine test results shown in Appendix Table F-1 were obtained with a 327 CID V-8 engine motored at 2000 RPM. This method eliminates the need for stripping used oil samples. Appendix Table F-2 lists the viscosity losses obtained after 10 hours under L-38 engine test conditions. A special reference oil (REO-192) was run several times during this program to allow corrections for cylinder wall roughness to be made. This was necessary because the engine was not rebuilt between tests. Appendix Table F-3 shows the corrected viscosity losses obtained after 16 hours of use in a Ford MS Sequence VC test. Since the VC test engine was not always rebuilt between tests, these results were also corrected for cylinder wall condition by running ARO-104 frequently as a reference oil.

V. RESULTS AND DISCUSSION

Fleet Test Results - The average 210°F viscosity losses for each fleet are compared to the Six-Fleet average data in Table 3. Since each sample processor's data were corrected for car effect, the average losses for each fleet and the Six-Fleet average results are also corrected for car effect. The corrected viscosity losses obtained by all of the used oil sample processors are shown in Appendix Table G-1. All samples from each fleet except Fleet "F", were stripped by more than one processor. Fleet "F" did not retain enough of each drain sample for another laboratory to process.

Average viscosity losses for each fleet correlate* very well with the Six-Fleet average results, as shown in Table 4. As an example, Figure 1 illustrates graphically the close fit of data from Fleet "D" and the Six-Fleet average data to the regression equation line.

Car effects were found to be highly significant in individual thirteen-car fleets as shown in the analysis of variance calculations listed in the Appendix D Tables (Section 4). Additionally, an individual car effect was calculated** by a different method, the method of Natrella(12) This is the difference between the viscosity loss for a given oil in that car and the average viscosity loss on the same oil in all cars in that fleet. The

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* For a perfect linear correlation the standard error of estimate must be "zero" and the correlation coefficient must be "one". It is also desirable, but not essential, for the intercept to be "zero" and the slope to be "one".

** $c = \frac{4R - \Sigma T_j}{13}$ where c = individual car effect in a given fleet; R = row total for that car; ΣT_j = sum of column totals for each of 4 oils tested in that car } Section 2 of Appendix "D" Tables

Example: Car 1, Fleet A, Appendix Table D-1

$$c = \frac{4(3.47) = (6.53 + 8.59 + 1.28 - 0.68)}{13} = -0.14 \text{ cSt.}$$

magnitude and distribution of car effects for each fleet and all fleets, as calculated by the method of Natrella, are given in Table 5. A histogram (Figure 2) of the data for all fleets shows the overall distribution of car effect corrections to be fairly symmetrical with most corrections in the -0.3 to +0.4 cSt range. A review of individual fleet data indicates that large outliers (e.g. -1.2 or + 1.0 cSt) would significantly bias results. Consequently, car effect corrections are important for thirteen-car fleets.

The overall Six-Fleet viscosity results are essentially insensitive to car effects. As seen in Table 5 and Figure 2, as the sampling grows to a better 78 vehicle simulation of the true car population, car effect outliers on one side of the mean become balanced by those on the other side. As this process occurs, the corrected viscosity loss results should become equal to the uncorrected results. In Table 6, a comparison between uncorrected and corrected Six-Fleet results* confirms that the values have become virtually identical.

Thus, through use of the large number of cars in this cooperative field test, a set of reliable viscosity loss targets has been established for the ASTM Reference Oils. These viscosity loss criteria provide excellent standards for the evaluation of candidate bench test shear devices even though individual car results vary widely as shown in Table 7.

Laboratory Test Results - The viscosity losses for all of the bench test data and all of the laboratory engine test data are shown in Appendix Table G-3, along with the Six-Fleet average losses. Each set of these laboratory viscosity loss data was correlated with the Six-Fleet average results (Appendix Table G-4) to determine how well it predicted shear stability performance in the six car-fleets. The correlation obtained between the data from the best of each laboratory method and the Six-Fleet average results are summarized in Table 8. In addition, the correlations between the data from the best of each laboratory method and the Six-Fleet average results are shown graphically in Figures 3 through 9. The viscosity losses obtained using the best data from each bench test method and the best laboratory engine test data are found in Table 9 along with the Six-Fleet average losses.

All of the bench test methods predicted more viscosity loss for Oil ARO-109 and less viscosity loss for oil ARO-106 than was observed in the field tests. Of the laboratory engine tests, the Ford MS-VC did as well on these two problem oils as it did on several other oils, but the regression line intercept was more than one centistoke low. Both the L-38 and the motored engine tests predicted more viscosity loss for Oil ARO-109 than was obtained in field tests but they did fairly well on the rest of the oils.

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* See Appendix Tables G-1 and G-2 for individual values that make up the Six-Fleet Averages.

Many investigators (6, 7, 8) have reported the shear stability of multigrade crankcase oils in terms of % viscosity loss* and Shear Stability Index* (SSI). For comparison purposes, all ASTM viscosity loss data, i.e. bench test, lab engine test, and field test, have been converted to % viscosity loss and Shear Stability Index (See Appendix Table G-5).

Linear regression analyses were conducted using data in these three forms to determine if improved correlations between the various sets of laboratory test method data and the Six-Fleet average results could be found. The correlation coefficients from these regression analyses are summarized in Appendix Table G-6. These results show that viscosity losses generally gave the highest correlation coefficents, the % viscosity losses gave coefficients which were generally second and the Shear Stability Indices gave the lowest coefficients in several cases. The actual differences among the three sets were quite small. In only one instance did the correlation coefficient obtained using another parameter exceed that using the viscosity losses. These results justify the use of simple viscosity losses to evaluate the various laboratory methods in this program.

Summary of Best Correlations - The linear correlations obtained between the corrected Six-Fleet average viscosity losses and (a) the uncorrected Six-Fleet losses, (b) the best single set of fleet data, (c) the best set of bench test results and (d) the best laboratory engine data are all compared in Table 10. These results show that the uncorrected Six-Fleet losses and the best set of car fleet data both correlate very well with the corrected Six-Fleet target data; but the best laboratory engine data and the best bench test results have either intercepts or correlation coefficients that are unsatisfactory. The poor intercept obtained with the MS VC test data after 16 hours would probably improve if oil samples were taken earlier, e.g. at perhaps 10 hours; however, the regression analysis of the motored engine data shown in Appendix Table G-4 suggests that as the intercept improves, the slope may deteriorate. As shown in Figure 3, the best bench test method predicted the viscosity change of ARO-109 unsatisfactorily. The best diesel injector method correlation, shown in Figure 4, could not determine the viscosity change of either ARO-109 or 106 satisfactorily.

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* % Viscosity Loss is viscosity loss/fresh oil viscosity expressed in percent.

Shear Stability Index is viscosity loss/polymer-contributed viscosity expressed in percent.

If FOV = fresh oil viscosity, UOV = used oil viscosity and
BBV = viscosity before polymer addition

Then: $\%\ \text{Viscosity loss} = \frac{FOV - UOV}{FOV} \times 100$

$$SSI = \frac{FOV - UOV}{FOV - BBV} \times 100$$

Linear regression analyses relating laboratory test results to the fleet data were rerun omitting the ARO-109 data. These analyses, shown in Table 11, reflect the substantial improvements in correlation coefficients achieved by eliminating the ARO-109 results. However, at this time there is no justification for rejecting these data.

Effect of Viscosity Level on Shear Stability Index - To investigate the effect of viscosity level upon Shear Stability Index (SSI), two pairs of 10W/30 and 10W/40 reference oils were included in the ARO series. Field test results on these oils - - ARO's 101, 111, 103 and 112 - - indicate higher SSI results for each VI improver type in the higher viscosity 10W/40 blends (See Table 12).

This effect can also be noted in data published by Behrens et al (9) in which the used oil viscosity after 20 hours in a CLR engine was higher for a given multigrade test oil when the water jacket temperature was higher. At the higher ring belt temperature, the viscosity was lower and lower breakdown resulted in a higher used oil viscosity. One can hypothesize that at a constant shear rate, higher viscosity requires a higher shear stress which, in turn, would be expected to cause greater breakdown or SSI.

The sonic shear test, in which shear stress does not increase as viscosity increases, shows the reverse effect of lower SSI as viscosity increases. This result confirms observations of this defect by Goodson and Vick (10) and Pearce (11).

Laboratory engine tests and other mechanical shear bench tests showed a mixed pattern of SSI versus viscosity level. Further data are necessary to resolve this effect in these particular tests.

Effect of Polymer Molecular Weight on Viscosity Stability - In order to evaluate the effect of molecular weight on polymer shear stability, two of the test oils (ARO-101 and 102) were formulated from two polymethacrylate V.I. improvers that differed only in average molecular weight. The molecular weight of PMA-2 was about 1.8 times that of PMA-1. The Shear Stability Index data, summarized in Table 13, indicate that the molecular weight of V.I. improver consistently influenced its shear stability in the car fleets and the laboratory test methods. The SSI of the lower molecular weight V.I. improver was generally one-half of the SSI of the higher molecular weight one.

Precision of Program - This program was designed so that the precision of the viscosity determination method and the stripping procedure could be determined. The fleet test program also included some repeat tests to serve as a measure of a car's ability to shear the test oils repeatably.

The pooled reproducibility standard deviation for viscosity determinations at 210°F for fresh oils was calculated to be 0.08 cSt. This value was calculated from the fresh oil viscosities determined on

each of the ARO's by 15 laboratories (Appendix Table G-7). Three outliers were omitted from the averages and the pooled reproducibility standard deviation. The calculated ASTM reproducibility in centistokes is as follows:

$$\text{Reproducibility} = \sigma_R \cdot \sqrt{2} \cdot t_{175} = 0.08 \text{ X } 1.414 \text{ X } 1.96 = 0.22 \text{ cSt}$$

Where σ_R is the reproducibility standard deviation

t_{175} is the students t @ the 95% confidence level and 175 degrees of freedom.

The ASTM reproducibility in percent is calculated by dividing the reproducibility in cSt by the average oil viscosity in cSt.

Therefore:

$$\text{Reproducibility} = \frac{0.22}{15} \text{ X } 100 = 1.47\%$$

The reproducibility for the ASTM D445 viscosity determination method, 0.70%, is appreciably better than that achieved in this program. Fresh oil viscosities at 100°F obtained by 11 laboratories are shown in Appendix Table G-8. No reproducibility results were calculated.

The pooled reproducibility standard deviation obtained for the combined stripping operation and viscosity determinations at 210°F was found to be 0.10 cSt. This value was calculated from the results shown in Appendix Table G-1 where one, two or three laboratories each stripped the various used oil samples and determined their viscosities at 210°F. The calculated reproducibility of the combined operation is as follows:

$$\text{Reproducibility} = \sigma_R \cdot \sqrt{2} \cdot t_{78} = 0.10 \text{ X } 1.414 \text{ X } 1.96 = 0.28 \text{ cSt}$$

When this reproducibility is compared to the reproducibility obtained with the viscosity determinations alone, it shows that only about 0.06 cSt increase in reproducibility was contributed by the stripping operation.

The car fleet program included some repeat tests by adding a fifth phase to the original four-phase program. This fifth phase consisted of re-evaluating the shear stability of the various test oils in the same cars in which they were previously run. This part of the program was added to establish an independent measure of a car's ability to shear the various test oils repeatably. The pooled repeatability standard deviation calculated from the data shown in Appendix Table G-9 was 0.28 cSt. This value includes the stripping and viscosity determination variations in addition to the repeatability of a car's shearing ability. The calculated repeatability of the combined operation is as follows:

$$\text{Repeatability} = \sigma_R \cdot \sqrt{2} \cdot t_{16} = 0.28 \text{ X } 1.414 \text{ X } 2.12 = 0.84 \text{ cSt}$$

Role of Thickening - One oil (ARO-113) which contained no V.I. improver was included in the fleet test program for control purposes. This oil contained the same detergent and oxidation inhibitor package as the other oils and was blended with the same base stocks. The average viscosity increase at 210°F obtained with this oil after 1,500 miles of use in the test fleets was 0.31 cSt, with individual determinations ranging from 0.11 cSt viscosity decrease to 0.82 cSt viscosity increase. This is an indication that the additive package did only a fair job of preventing thickening. However, there is no evidence that any or all of the V.I. improved oils responded in the same manner as the control oil. Therefore, we know of no technique which would satisfactorily correct the field data for possible thickening effects.

VI. CONCLUSIONS

- Extensive field test data have been obtained which can serve as a basis for evaluating the ability of the various laboratory methods to predict the viscosity stability of multigrade crankcase oils.

- The high degree of correlation achieved between the data from each of the six car fleets and the Six-Fleet average viscosity losses indicates that if additional field data are needed, a single fleet test of an appropriate design rather than six fleets, would be adequate.

- A reliable fuel stripping method was developed which makes it possible to remove essentially all of the fuel from used oil samples without removing an appreciable amount of the light ends of the oils. This makes possible an accurate measure of viscosity change free from dilution.

- The current bench test results do not satisfactorily predict all of the viscosity changes observed in field test data.

- Laboratory engine tests were found to be better than the bench tests in predicting viscosity changes in the field test; however, these tests are considered to be impractical because of their large oil sample requirements and the high cost of such evaluations.

VII. RECOMMENDATIONS

Since the power steering pump tests and the Diesel injector pump tests appear to hold the most promise, it is the recommendation of the Data Analysis Panel that ASTM participants having this equipment should investigate ways of improving these tests. For example, the participants who submitted diesel injector pump test data might try running their tests at a variety of temperatures, pressures and pump speeds, passes and etc. These investigations should be implemented in an orderly manner by a Task Force to avoid duplication of effort and assure the maximum improvement for the effort spent.

In view of the thickening encountered with the control oil in the field tests, perhaps a reassessment of the goals of the subsection should be considered. It may be unrealistic to adapt a mechanical shear bench test to the extent required to predict all of the viscosity changes observed in the field tests.

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9. M. D. Behrens, S. W. Rein, G. W. Roth, and H. T. Marshall, "An Automated Fuel Injector Shear Stability Tester", SAE Paper No. 690158, January, 1969.

10. R. M. Goodson and G. K. Vick, "Viscosity Loss in Polymer-Thickened Oils During Use", ASTM STP 382, 1965.

11. A. F. Pearce, "A Laboratory Method for Predicting the Permanent Viscosity Loss of Polymeric Crankcase Oils in Field Service", SAE Paper 680069, presented at Detroit, January, 1968.

12. M. G. Natrella, "Experimental Statistics", NBS Handbook 91, pages 13-45, 13-46.

TABLE 1

VISCOSITIES OF ASTM REFERENCE OILS

ARO Oil No.	Blender	V.I. Improver Type	SAE Viscosity Grade	210°F Viscosity, cSt				100°F Viscosity, cSt		0°F Viscosity, cP
				15 Lab Avg. Finished Blend	Lab P Finished Blend	Lab P Without V.I. Improvers	Lab P Polymer Contributed	Finished Blend 11 Lab Avg	Finished Blend Lab P	Finished Blend Lab P
101	B	Polymethacrylate-1	10W/40	15.08	15.05	5.71	9.34	86.33	86.19	2040
102	B	Polymethacrylate-2	10W/40	15.03	15.02	5.83	9.19	85.92	85.93	2030
103	G	Polyisobutylene	10W/40	14.98	15.02	4.84	10.18	97.91	98.09	1970
104	G	Olefin Copolymer-1	10W/40	14.98	14.96	6.15	8.81	108.62	108.9	1960
105	G	Vinyl Copolymer	10W/40	14.87	15.05	5.67	9.38	83.94	84.54	1930
106	S	Polyacrylate	10W/40	14.96	15.01	5.65	9.36	76.27	76.95	1940
107	S	Polyalkylstyrene	10W/40	15.14	15.15	5.49	9.66	97.26	97.58	2000
108	S	Olefin Terpolymer	10W/40	14.96	15.00	5.47	9.53	104.84	105.1	1880
109	H	Styrene Polyester	10W/40	15.23	15.23	5.36	9.87	90.53	90.81	1940
110	J	Olefin Copolymer-2	10W/40	15.01	15.00	5.19	9.81	104.26	104.4	1950
111	B	Polymethacrylate-1	10W/30	10.97	10.97	5.93	5.04	66.31	66.29	2020
112	G	Polyisobutylene	10W/30	11.03	11.06	5.52	5.54	74.88	74.84	2100
113	H	None	20/20W	6.72	6.70	6.70	0.00	48.54	48.55	2600

TABLE 2

FIELD TEST DESIGN*

Car No.	ARO No. Used in Phase			
	I	II	III	IV
1	113	101	103	109
2	101	102	104	110
3	102	103	105	111
4	103	104	106	112
5	104	105	107	113
6	105	106	108	101
7	106	107	109	102
8	107	108	110	103
9	108	109	111	104
10	109	110	112	105
11	110	111	113	106
12	111	112	101	107
13	112	113	102	108

* Incomplete Latin Square, Cochran and Cox, "Experimental Designs", Second Edition, page 523, plan 13.5.

TABLE 3

ASTM SHEAR STABILITY FIELD TEST RESULTS

ARO Oil No.	Fleet -	Average 210 F Viscosity Losses, cSt., After 1,500 Miles of Use						Six-Fleet Avg.
		A	B	C	D	E	F	
101		1.65	1.54	1.49	1.76	1.78	1.60	1.64
102		3.12	3.20	2.55	3.24	3.48	2.57	3.03
103		2.06	1.44	1.42	1.95	1.75	1.87	1.75
104		2.28	2.07	1.67	2.29	2.12	1.80	2.04
105		3.94	3.97	3.71	4.13	4.62	3.99	4.06
106		4.05	3.74	3.39	3.88	4.11	3.94	3.85
107		2.36	2.12	1.89	2.15	2.47	2.05	2.17
108		2.51	2.18	2.14	2.34	2.62	2.42	2.37
109		0.41	-0.27	-0.01	0.21	-0.14	0.05	0.04
110		0.48	0.25	0.32	0.46	0.32	0.23	0.34
111		0.88	0.58	0.41	0.82	0.81	0.51	0.67
112		0.86	0.66	0.57	0.82	0.84	0.71	0.74
113		-0.20	-0.38	-0.45	-0.18	-0.07	-0.55	-0.31

TABLE 4

RESULTS OF REGRESSION ANALYSES RELATING
INDIVIDUAL FLEET RESULTS WITH THE SIX-FLEET AVERAGE

Equation Model: $Y = A+BX$ Where Y is the Six-Fleet average and X is individual fleet averages

FLEET -	A	B	C	D	E	F
Intercept (A)	-0.21	0.15	0.12	-0.14	0.01	0.12
Slope (B)	1.03	0.97	1.09	1.02	0.90	0.98
Std. Error	0.12	0.12	0.09	0.09	0.13	0.16
Corr. Coef.	0.997	0.996	0.998	0.998	0.996	0.994

TABLE 5

DISTRIBUTION OF CAR EFFECTS BY FLEET

Group Limits cSt. @ 210 F	Number of Cars in Car Fleets						Total
	A	B	C	D	E	F	
1.01 to 1.10		1					1
0.91 to 1.00							0
0.81 to 0.90							0
0.71 to 0.80			1				1
0.61 to 0.70			1		1		2
0.51 to 0.60	1						1
0.41 to 0.50	1		1			1	3
0.31 to 0.40		1	1	2	1	2	7
0.21 to 0.30		1	2	3	1	2	9
0.11 to 0.20	1	1		1	1	2	6
0.01 to 0.10	3	3	1	1	1	1	10
-0.09 to 0.00	2	1	2		2	1	8
-0.19 to -0.10	2	1	1	3	3	1	11
-0.29 to -0.20	2		1	1	2	1	7
-0.39 to -0.30	1	1			1		3
-0.49 to -0.40		1		1			2
-0.59 to -0.50		1		1			2
-0.69 to -0.60		1					1
-0.79 to -0.70						1	1
-0.89 to -0.80							0
-0.99 to -0.90			1				1
-1.09 to -1.00						1	1
-1.19 to -1.10							0
-1.29 to -1.20			1				1
Car Totals	13	13	13	13	13	13	78

TABLE 6

THE OVERALL CAR CORRECTION EFFECT AND CORRELATION WITH THE UNCORRECTED AVERAGE

ARO Oil No.	Six-Fleet Average Viscosity Loss, cSt. Corr. For Car Effect	Uncorrected
101	1.64	1.66
102	3.03	3.13
103	1.75	1.71
104	2.04	2.10
105	4.06	3.99
106	3.85	3.82
107	2.17	2.19
108	2.37	2.34
109	0.04	-0.04
110	0.34	0.35
111	0.67	0.74
112	0.74	0.68
113	-0.31	-0.23

REGRESSION ANALYSIS

Equation Model Y = A+BX where Y is the Six-Fleet Average viscosity loss (corrected for car effect and X is the uncorrected six-fleet average viscosity loss.

Intercept	Slope	Std. Error	Corr. Coef.
-0.01	1.00	0.06	0.999

TABLE 7

95% CONFIDENCE LIMITS
FOR UNCORRECTED FLEET DATA

	Viscosity Losses, cSt.			
		Standard	95% Confidence Limits*	
ARO	Average	Deviation	Upper	Lower
101	1.66	0.46	2.61	0.71
102	3.13	0.69	4.55	1.71
103	1.71	0.59	2.93	0.49
104	2.10	0.50	3.13	1.07
105	3.99	0.60	5.23	2.75
106	3.82	0.47	4.79	2.85
107	2.19	0.40	3.01	1.37
108	2.34	0.45	3.27	1.41
109	-0.04	0.76	1.53	-1.61
110	0.35	0.68	1.75	-1.05
111	0.74	0.32	1.40	0.08
112	0.68	0.33	1.36	0.00
113	-0.23	0.22	0.22	-0.68

* Individual uncorrected viscosity losses obtained in the six fleets fall within these limits 95% of the time.

TABLE 8

RESULTS OF REGRESSION ANALYSES RELATING THE BEST*
BENCH TEST AND LABORATORY ENGINE RESULTS TO THE SIX-FLEET DATA

Equation Model: $Y = A+BX$ Where Y is the Six-Fleet average and X is the Bench Test and Laboratory Engine Results

	Best Bench Tests				Best Laboratory Engine Tests		
	Power Steering Pump 1-Hr.	Diesel Injector Nozzle 10-Passes	Kady Dispersion Mill 6-Hr.	Sonic Shear 10 Min.	MS VC 16-Hrs.	Motored Engine 3-Hrs.	L-38 10 Hrs.
Intercept (A)	-0.32	-0.41	-0.07	0.12	-1.11	-0.16	-0.37
Slope (B)	1.06	0.98	1.09	0.84	1.00	1.40	1.23
Std. Error	0.63	0.66	0.72	0.84	0.34	0.43	0.48
Corr. Coef.	0.90	0.89	0.85	0.82	0.97	0.96	0.94

* The best results are based on their correlation coefficient when correlated with the Six-Fleet Average. In cases where correlation coefficients are essentially equal, standard error of estimate, slope and intercept are taken into consideration.

TABLE 9

SHEAR STABILITY OF ASTM OILS IN THE BEST* LABORATORY BENCH TESTS AND BEST* LABORATORY ENGINE TESTS COMPARED TO THE SIX-FLEET AVERAGE

	210 F Viscosity Losses, cSt., By the Various Test Methods							
ARO Oil No.	Diesel Injector Nozzle 10-Passes	Power Steering Pump 1-Hr.	Sonic Shear 10-Min.	Kady Dispersion Mill 6-Hr.	Motored Engine 3-Hr.	L-38 10-Hr.	MS VC 16-Hr.	Six-Fleet Average 1500 Miles
101	2.31	2.17	2.22	1.49	0.96	1.33	2.55	1.64
102	3.71	3.25	3.83	3.30	2.22	2.60	3.99	3.03
103	1.95	1.44	1.00	1.19	1.77	1.70	3.47	1.75
104	2.26	1.75	1.31	2.05	1.30	1.46	3.03	2.04
105	4.85	4.49	4.78	3.88	3.24	3.75	4.94	4.06
106	2.99	3.18	3.19	2.30	2.45	3.31	4.65	3.85
107	2.36	1.96	2.10	1.56	1.44	2.35	3.72	2.17
108	2.70	2.08	1.48	2.26	1.93	1.92	3.60	2.37
109	2.07	1.75	2.07	1.47	0.70	1.30	1.59	0.04
110	0.85	0.85	0.49	0.57	0.53	0.58	1.27	0.34
111	1.17	1.31	1.43	0.79	0.38	0.85	1.46	0.67
112	1.12	0.75	0.76	0.67	0.57	0.85	1.73	0.74
113	-0.07	0.03	0.07	-	-0.07	-	-	-0.31

* The best results are based on their correlation coefficient when correlated with the Six-Fleet Average. In cases where correlation coefficients are essentially equal, standard error of estimate, slope and intercept are taken into consideration.

TABLE 10

SUMMARY OF BEST REGRESSION ANALYSIS
RESULTS BY EACH METHOD

Equation Model: $Y = A+BX$ Where Y is the Six-Fleet Average and X is the various other results

	Uncorrected Six Fleet Average	Best Car Fleet	Best Lab Engine	Best Lab-Bench Test
Intercept (A)	-0.01	-0.14	-1.11	-0.26
Slope (B)	1.00	1.02	1.00	1.07
Std. Error	0.06	0.09	0.34	0.64
Corr. Coef.	0.999	0.998	0.97	0.90

TABLE 11

RESULTS OF REGRESSION ANALYSES RELATING THE BEST BENCH TEST AND LABORATORY ENGINE RESULTS TO THE SIX-FLEET DATA WITH OIL ARO-109 DATA OMITTED

Equation Model: $Y = A+BX$ Where Y is the Six-Fleet average and X is the Bench Test and Laboratory Engine Results

	Best Bench Tests				Best Laboratory Engine Tests		
	Power Steering Pump 1-Hr.	Diesel Injector Nozzle 10-Passes	Kady Dispersion Mill 6-Hr.	Sonic Shear 10 Min.	MS VC 16-Hrs.	Motored Engine 3-Hrs.	L-38 10 Hrs.
Intercept (A)	-0.17	-0.26	0.15	0.24	-0.93	-0.02	-0.14
Slope (B)	1.05	0.97	1.05	0.86	0.96	1.35	1.17
Std. Error	0.44	0.44	0.54	0.64	0.32	0.36	0.28
Corr. Coef.	0.95	0.95	0.91	0.89	0.97	0.97	0.98

TABLE 12

EFFECT OF VISCOSITY ON POLYMER BREAKDOWN

	Polymethacrylate-1		Polyisobutylene	
ARO No.	111	101	112	103
SAE Grades	10W/30	10W/40	10W/30	10W/40
Viscosity @ 210 F, cSt.	11.0	15.1	11.1	15.0
Shear Stability Index @ 210°F				
Six Fleet Average	13.3	17.6	13.4	17.2
MS-VC, 16 Hrs.	29.0	27.3	31.2	34.1
L-38, 10 Hrs.	16.9	14.2	15.3	16.7
Motored Engine	7.5	10.3	10.3	17.4
Power Steering Pump Test	26.0	23.2	13.5	14.1
Diesel Injector Rig	23.2	24.7	20.2	19.2
Kady Mill	15.7	16.0	12.1	11.7
Sonic Shear	28.4	23.8	13.7	9.8

TABLE 13

EFFECT OF MOLECULAR WEIGHT ON THE SHEAR STABILITY OF A POLYMETHACRYLATE VI IMPROVER

	Polymethacrylates	
	PMA-1	PMA-2
Relative Molecular Wt.	1.0	1.8
ARO No.	101	102
Shear Stability Index @ 210°F		
Six-Fleet Average	17.6	33.0
MS-VC, 16 Hrs.	27.3	43.4
L-38, 10 Hrs.	14.2	28.3
Motored Engine	10.3	24.2
Power Steering Pump Test	23.2	35.4
Diesel Injector Rig	24.7	40.4
Kady Mill	16.0	35.9
Sonic Shear	23.8	41.7

FIGURE 1
CORRELATION BETWEEN THE BEST FLEET DATA AND THE SIX-FLEET AVERAGE

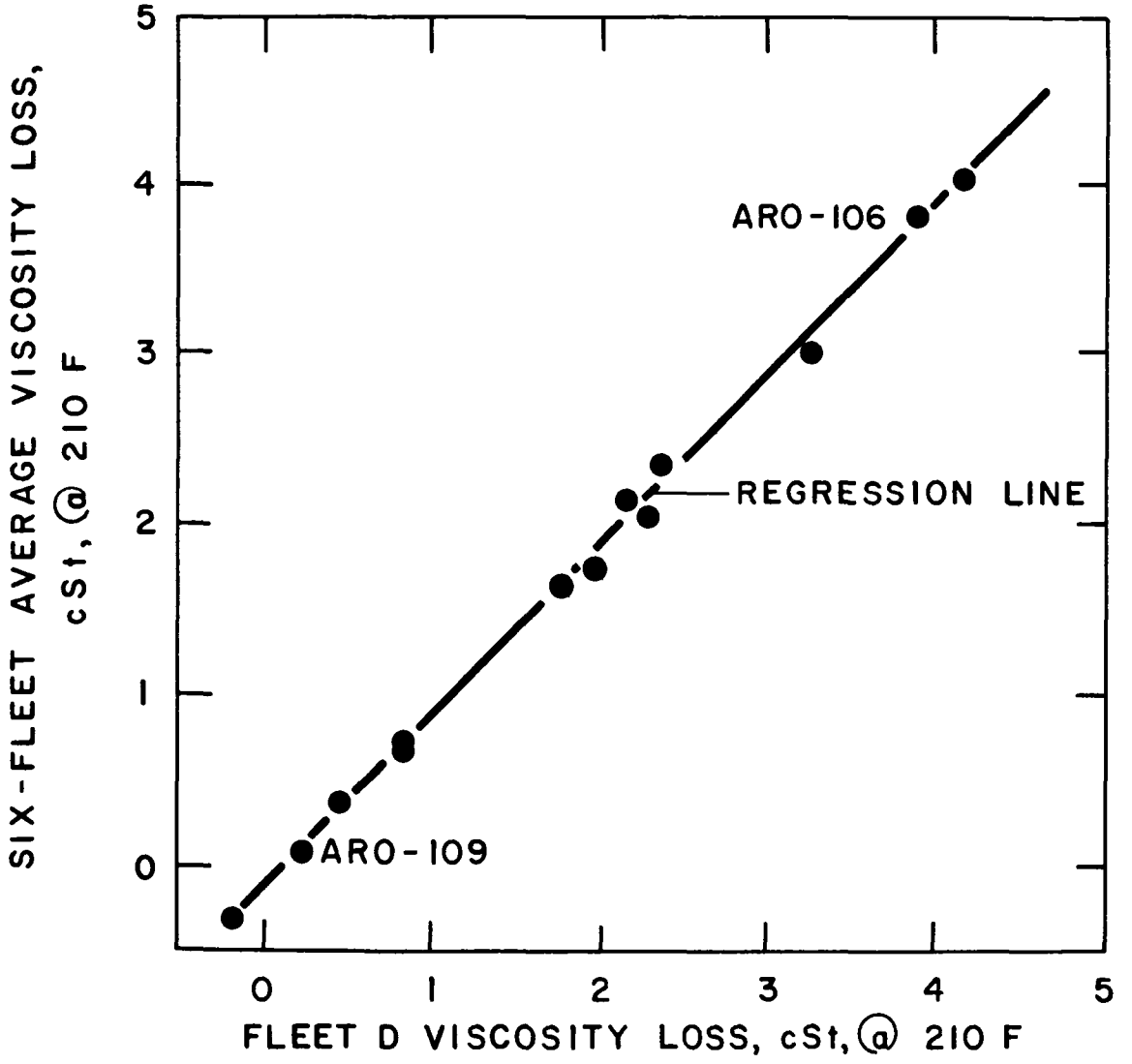


FIGURE 2
DISTRIBUTION OF CAR EFFECT CORRECTIONS FOR SIX FLEETS

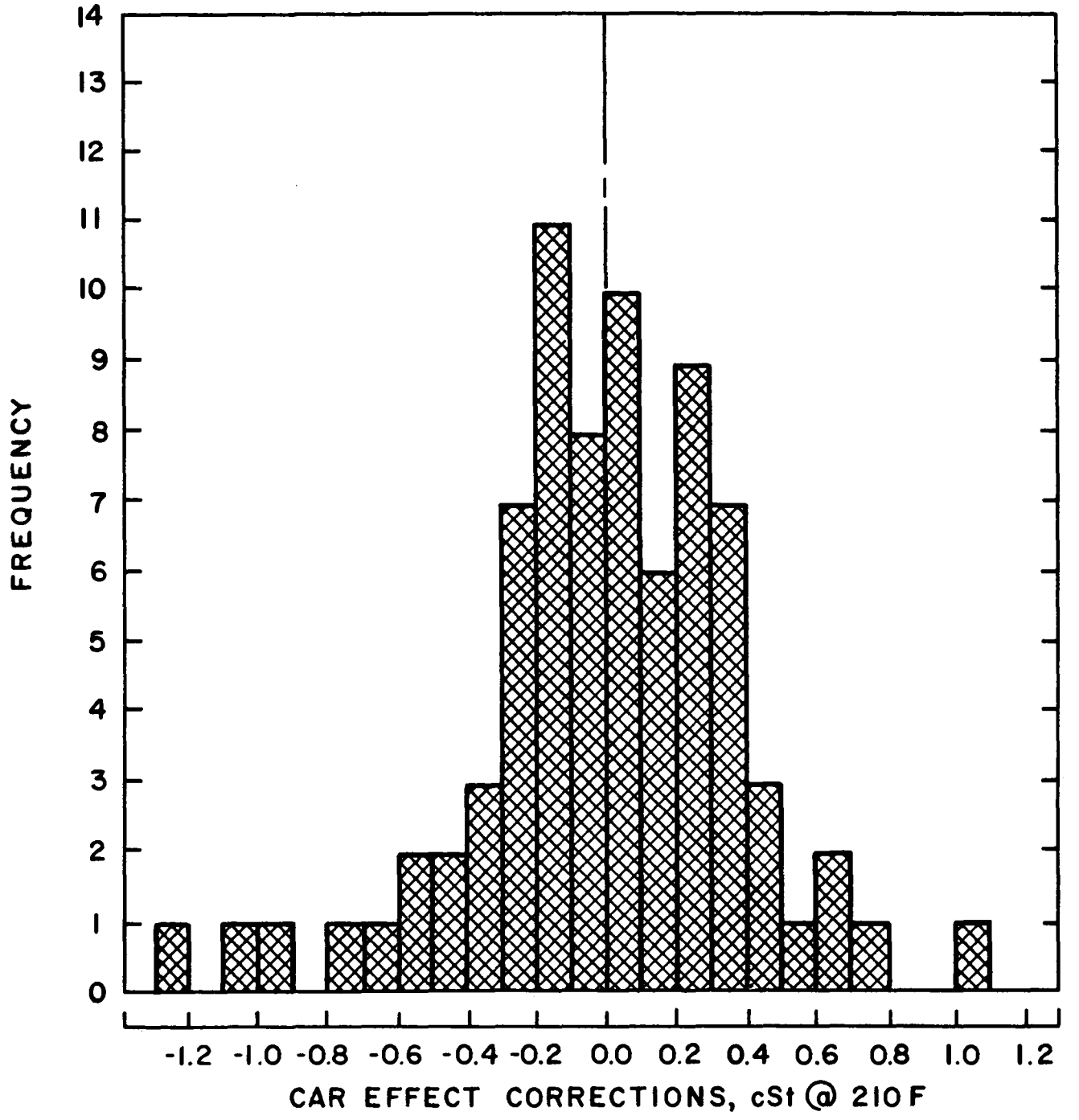


FIGURE 3
CORRELATION BETWEEN THE BEST POWER STEERING PUMP TEST DATA AND THE SIX-FLEET AVERAGE

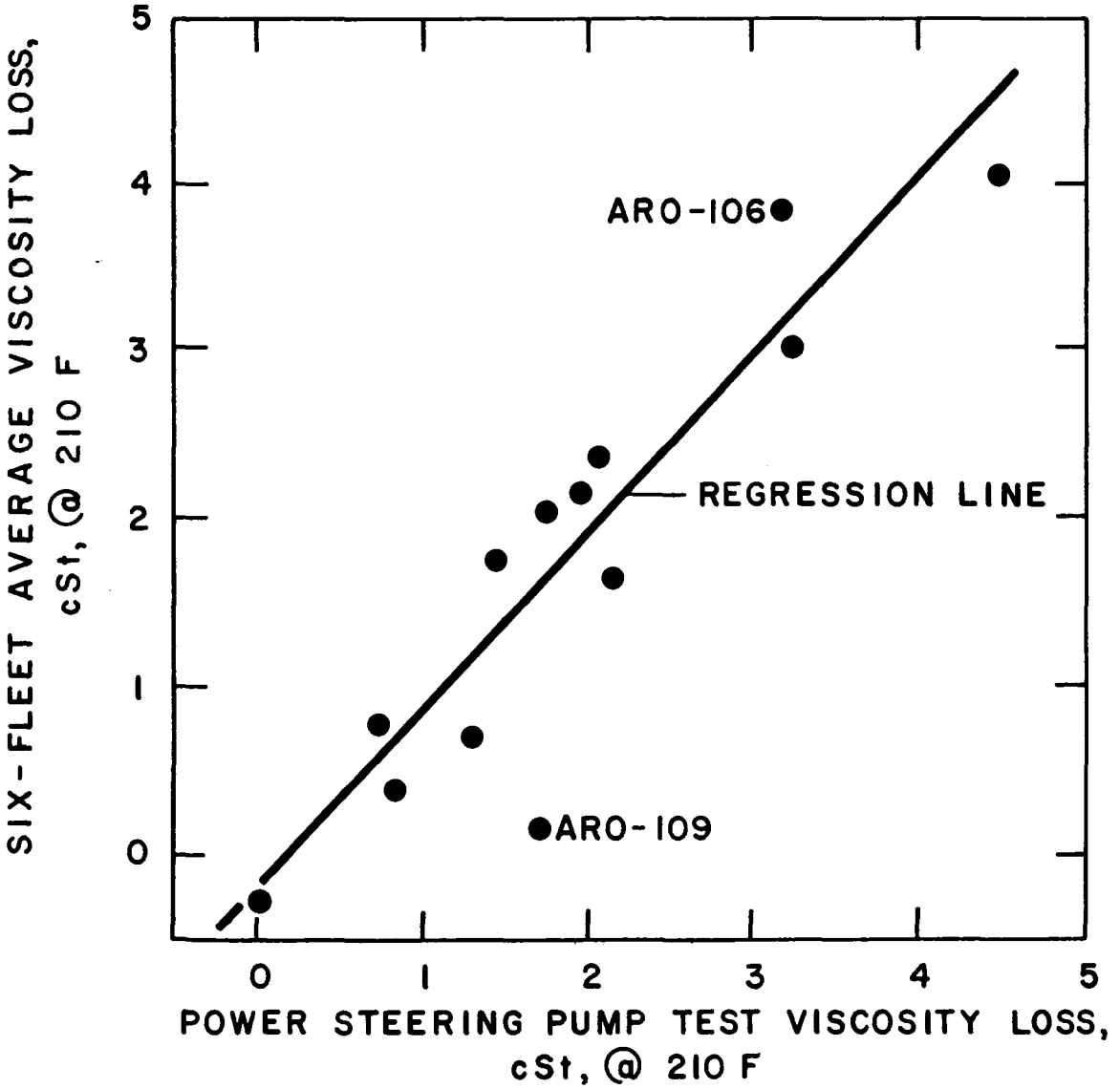


FIGURE 4
CORRELATION BETWEEN THE BEST DIESEL INJECTOR TEST DATA AND THE SIX-FLEET AVERAGE

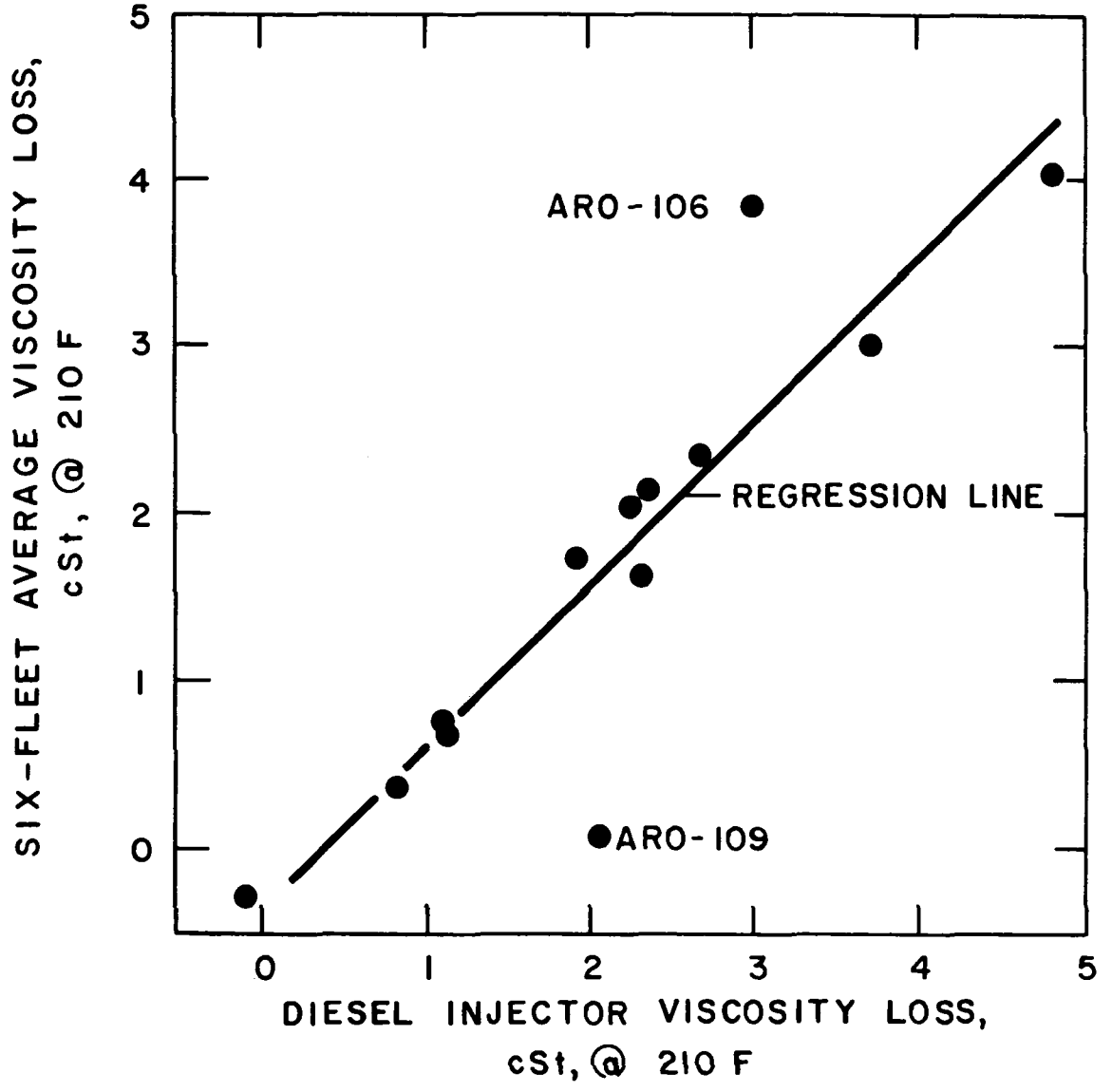


FIGURE 5
CORRELATION BETWEEN THE KADY MILL VISCOSITY LOSS DATA AND THE SIX-FLEET AVERAGE

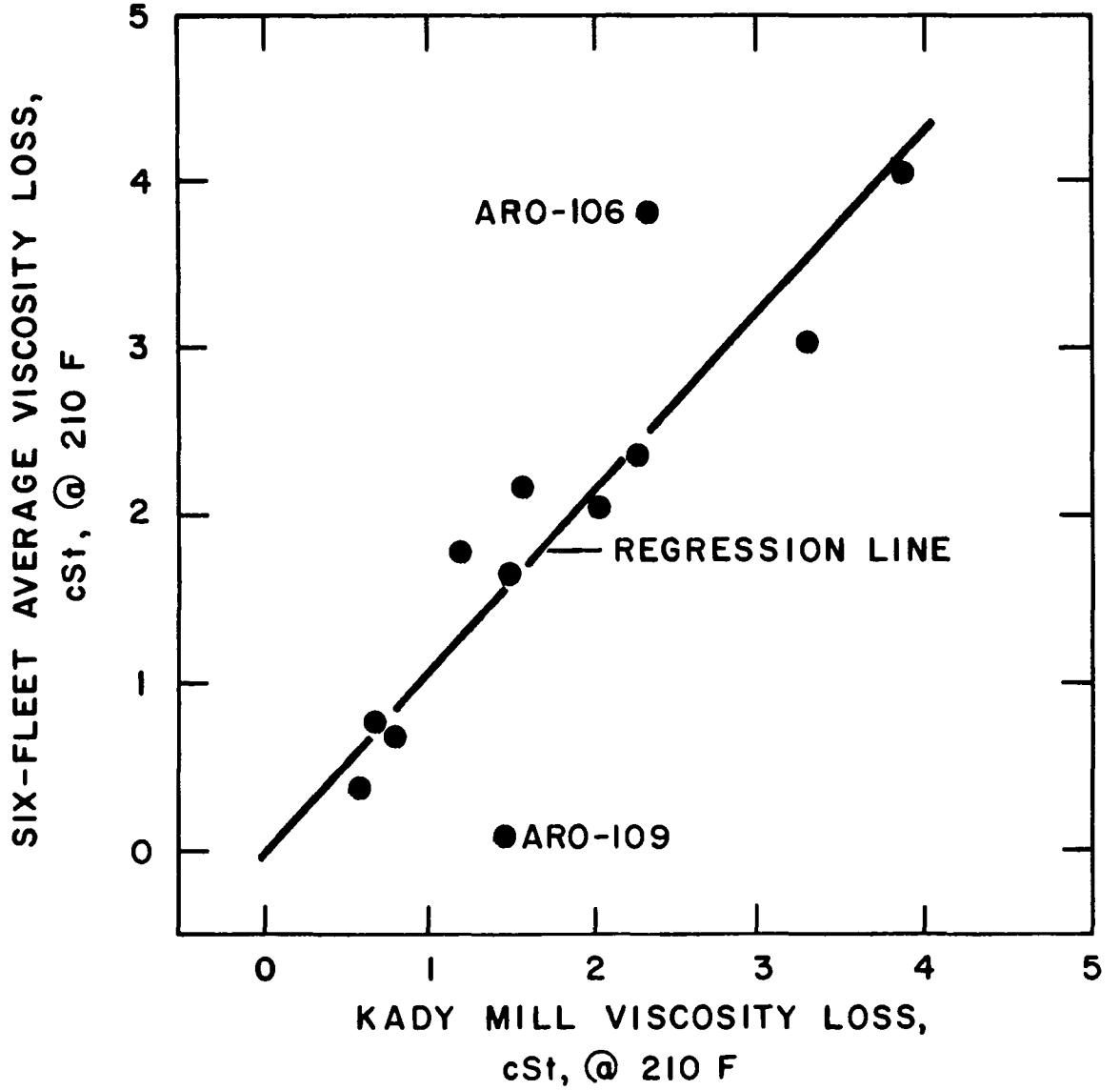


FIGURE 6
CORRELATION BETWEEN THE BEST SONIC SHEAR TEST DATA AND SIX-FLEET AVERAGE

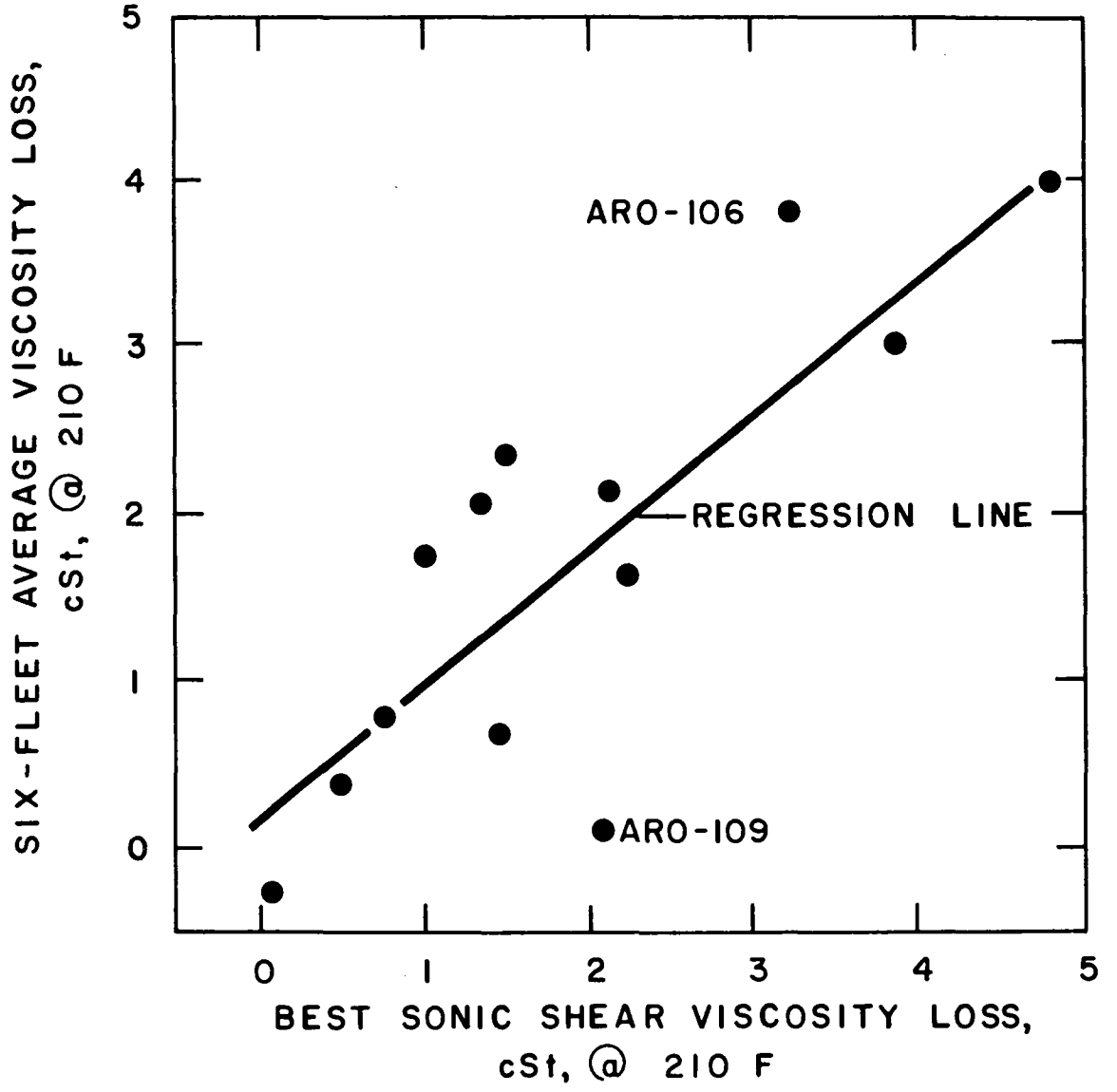


FIGURE 7
CORRELATION BETWEEN MS-VC DATA AND SIX-FLEET AVERAGE

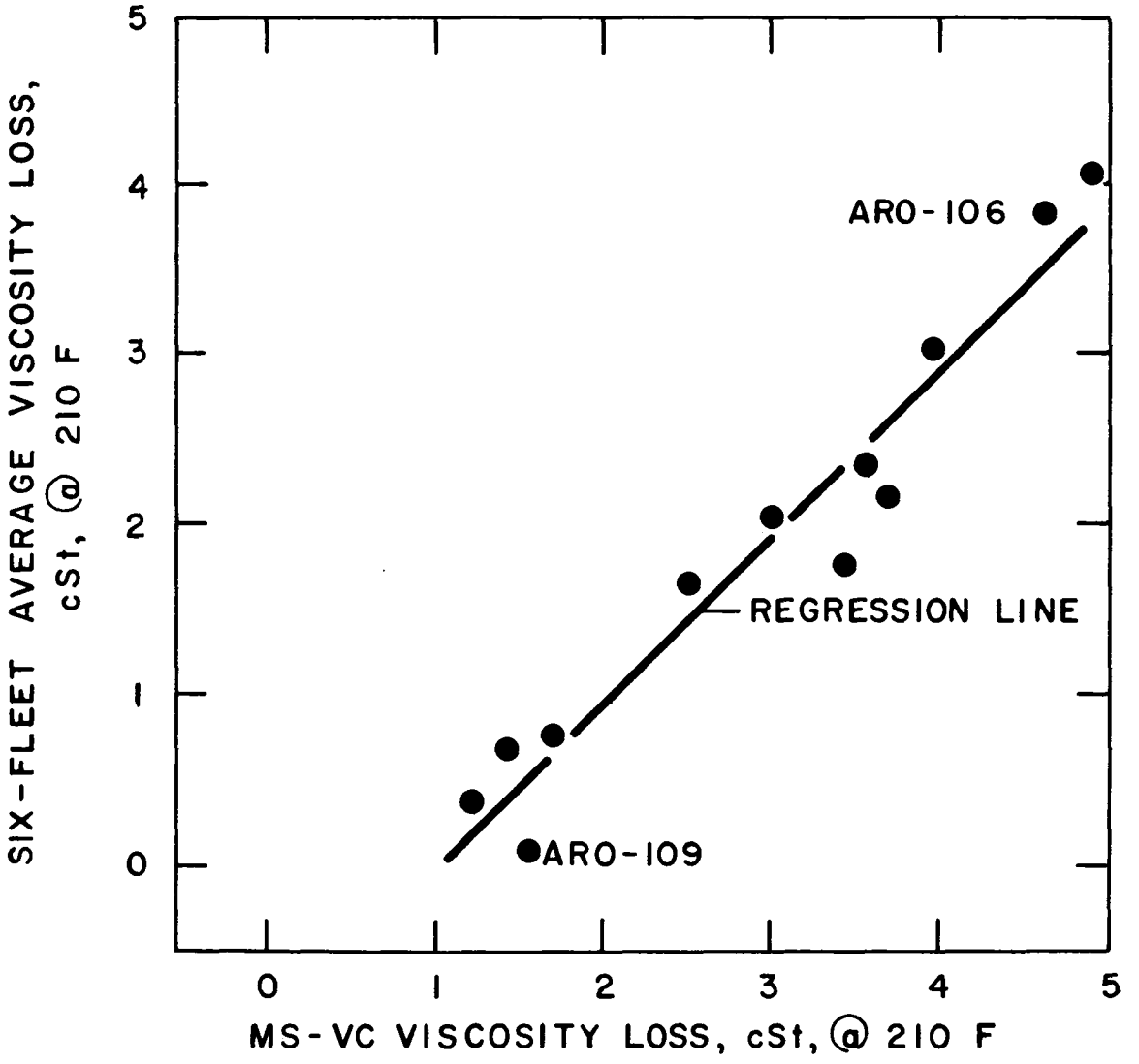


FIGURE 8
CORRELATION BETWEEN L-38 ENGINE TEST DATA AND SIX-FLEET AVERAGE

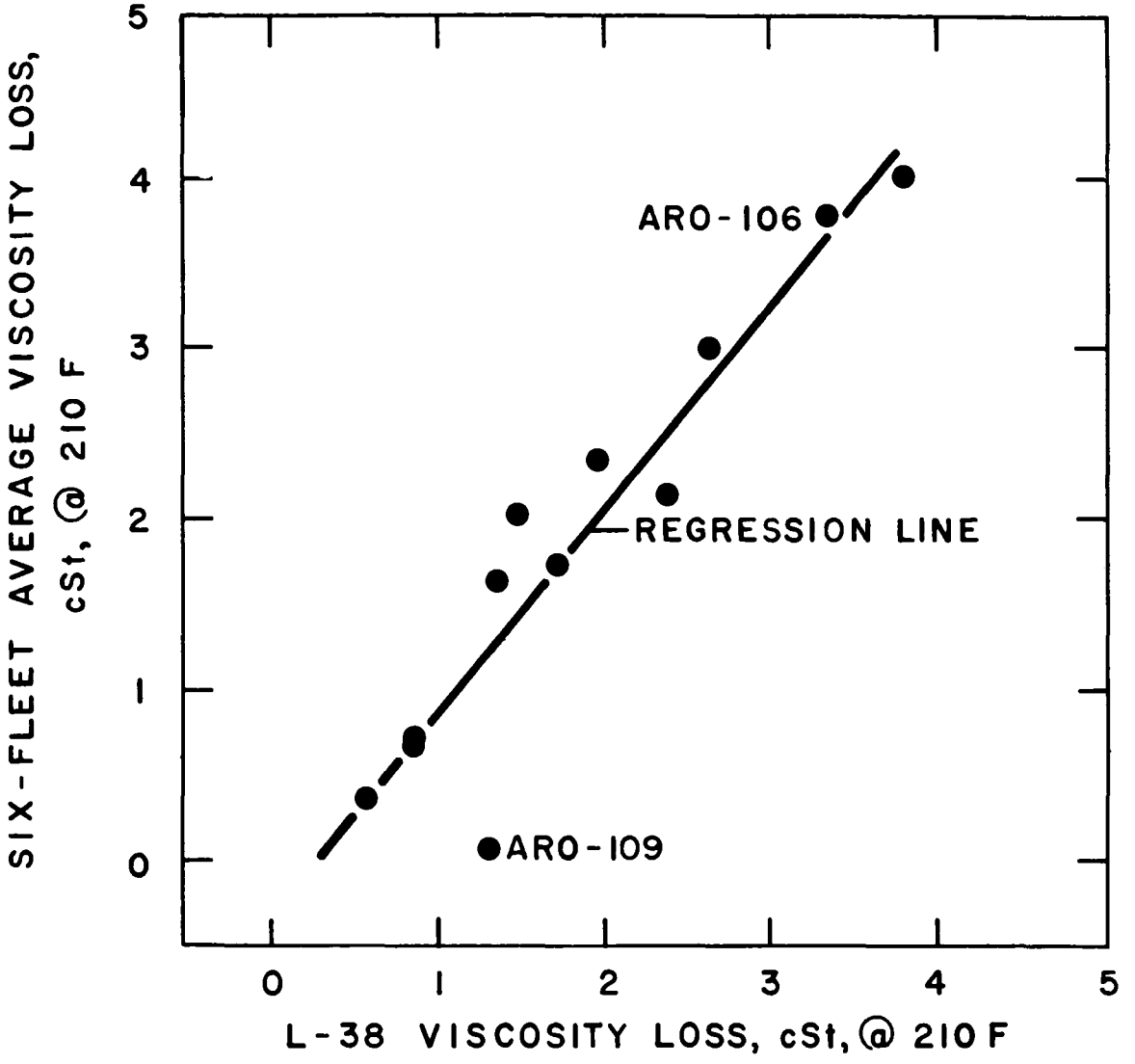
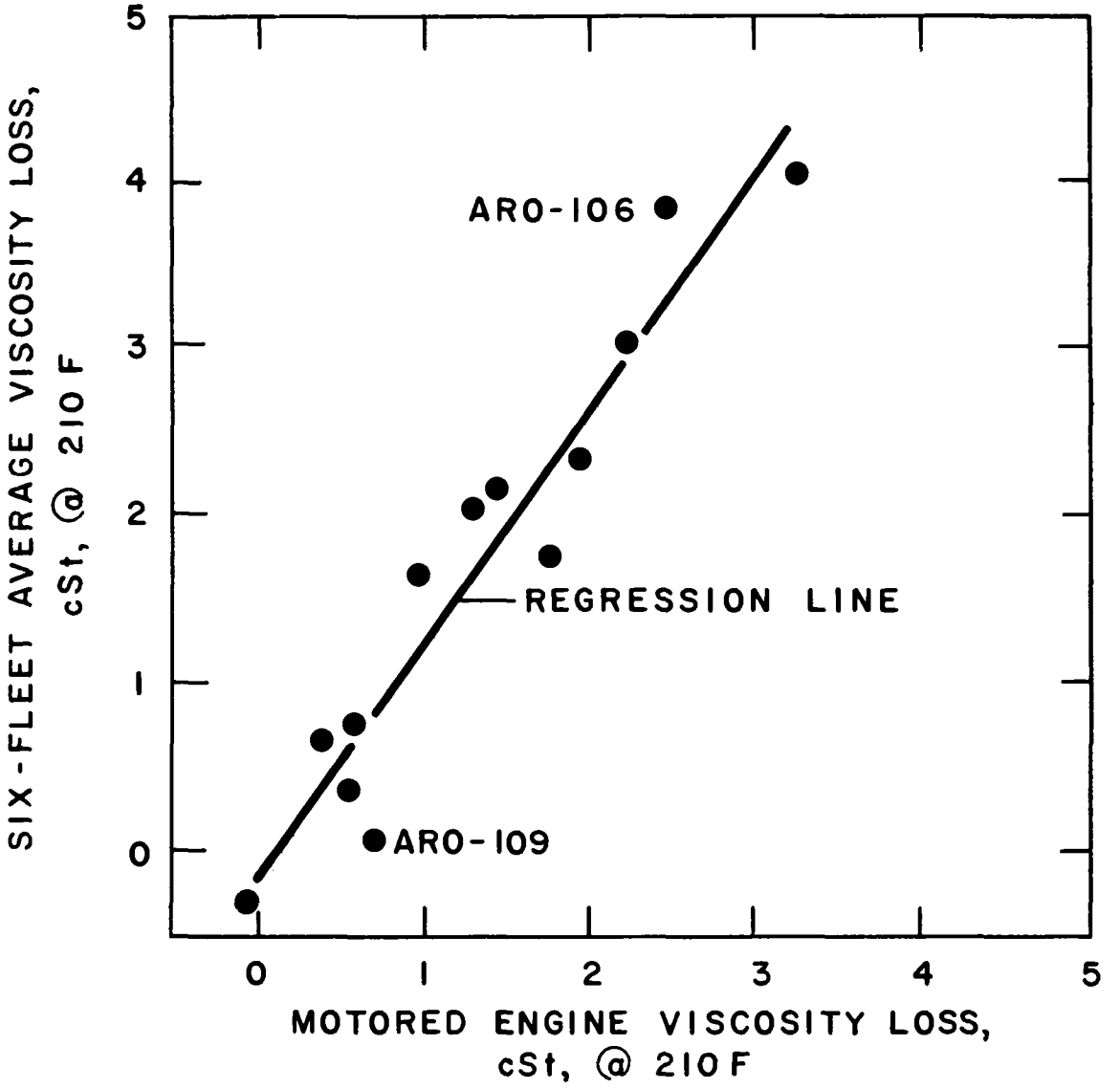


FIGURE 9
CORRELATION BETWEEN THE BEST MOTORED ENGINE TEST DATA AND THE SIX-FLEET AVERAGE



Appendix A

PROGRAM DETAILS

APPENDIX TABLE A-1

AUTHORIZATION PROCEDURE FOR

ASTM REFERENCE OILS (ARO's)

MARCH, 1972

1. Requestor writes a letter to Mechanical Shear Stability Subsection Chairman* stating the details of a proposed mechanical shear test, field correlation (if any), and ARO oil requirements.

2. If the request is granted, a letter of approval with an extra copy is sent to the requestor specifying the amount of each ARO that can be ordered.

3. The requestor attaches the copy of the approval letter to his purchase order for the specified ARO's. The purchase order is to be made out to and sent to SwRI.**. All ARO's will be billed at $10.00 per gallon FOB San Antonio. Hence, all shipments will be sent freight COLLECT. If air freight delivery is desired, the purchase order should specify so.

4. SwRI will send a shipping notice to the requestor (with a carbon copy to the Mechanical Shear Stability Subsection Chairman) and will bill the requestor accordingly.

---

* M. F. Smith, Jr.
Enjay Additives Laboratory
P. O. Box 536
Linden, New Jersey 07036

** Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78228
Attn: F. J. Westphal

APPENDIX TABLE A-2

PARTICIPANTS IN ASTM SHEAR STABILITY PROGRAM

Cooperating Agency	ARO Oil Blending	Car Fleet	Visc. of New Oils	Auxiliary Stripping	Bench Tests: Diesel Injector	Bench Tests: Steering Pump	Bench Tests: Sonic Shear	Bench Tests: Kady Mill	Lab. Engine Tests: Motored Engine	Lab. Engine Tests: 10-Hr. L-38	Lab. Engine Tests: MS VC
Army			●					●		●	
Cannon			●								
Chevron		●	●								
Chrysler		●	●			●					
Cities Service	●										
Dow		●	●								
DuPont			●	●							
Esso		●	●	●		●					
Esso Pet. (Ltd.)			●		●						
Enjay	●			●							●
Gulf		●	●	●		●	●				
Lubrizol	●		●	●							
Mobil		●	●	●	●						
NRC (Canada)			●		●						
Rohm & Haas	●	●	●	●			●				
Sun			●						●		
SWRI		●									
Texaco	●		●	●	●						

DATA ANALYSIS PANEL OF
ASTM R&D DIV. VII B-1

R. M. Stewart (Gulf), Chairman

H. R. Stringer (Rohm and Haas)

M. F. Smith, Jr. (Enjay)

APPENDIX TABLE A-3

TEST PROCEDURE FOR VEHICLES

After the test vehicles have been selected, the following steps should be taken:

Phase I

1. Check each engine for external oil leakage and PCV valve pluggage.
2. Warm up engine.
3. Drain oil.
4. Replace oil filter with adapter.
5. Charge three quarts of Phase I test lubricant (see Table) run engine and 10 minutes and drain.
6. Repeat step 5 for second flush.
7. Replace adapter with new oil filter.
8. Charge appropriate number of quarts of Phase I test oil and check dipstick level.
9. Run vehicle for 1000 miles; take one ounce sample at that point.
10. Terminate Phase I either at 1500 miles or when one quart low, whichever occurs first. Bring vehicle in for oil change.

Phase II

Repeat steps 1-10 with following changes:

- Step 3 - save oil drain; record actual drain mileage; vehicle number and date.
- Steps 5 and 8 - use Phase II test lubricant in place of Phase I lubricant.

Phase III and IV

- Repeat previous steps substituting proper phase where applicable.

APPENDIX TABLE A-4

EFFECT OF TEMPERATURE ON STRIPPING WITH INITIAL PROCEDURE

Oils*	Mineral Spirits Added, %	Treatment**	Stripping Temp. °C	Viscosity, cSt. 210 F	100 F
A	None	None	-	13.63	79.40
A	None	Stripped	120	13.73	79.17
A	5	Stripped	120	13.73	78.85
A	5	Stripped	120	13.73	79.40
B	None	None	-	13.86	79.89
B	None	Stripped	120	14.03	99.75
B	None	Stripped	100	13.90	98.58
B	None	Stripped	82	13.89	98.25
B	5	None	-	11.33	70.02
B	5	Stripped	120	14.06	99.78
B	5	Stripped	101	13.90	98.40
B	5	Stripped	82	13.81	97.47
Used C	None	Stripped	120	13.69	85.49
Used C	None	Stripped	100	13.49	83.45
Used D	None	Stripped	120	12.91	80.40
Used D	None	Stripped	100	12.87	78.28

* These are not ARO Reference Oils.

** Stripping procedure consisted of reducing absolute pressure to 100 mm Hg along with a nitrogen sparge for one hour.

APPENDIX TABLE A-5

METHOD FOR REMOVAL OF FUEL DILUTION FROM USED ENGINE OIL (1)

Apparatus

1. 200 or 250 ml R.B. flask with thermometer well (such as Corning No. 4323 or 93291).
2. Gas inlet adapter (such as Corning No. 96800 with 24/40 S joint).
3. Thermometer (ASTM 9F with 20 to 230°F. range).
4. Connecting tube (such as Corning No. 8920 24/40 joints).
5. Receiver adapter (such as Corning No. 8946).
6. 200 ml R.B. receiving flask (such as Corning No. 4320).
7. Dry ice trap (such as Corning No. 7728).
8. Manometer (0 to 130 mm).
9. Vacuum pump.
10. Glascol mantle for heating flask.
11. Powerstat.
12. Nitrogen cylinder with valve.
13. Seitz filter with 5μ filter pads.
14. Nitrogen flowmeter for 1.0 g/min rate ± 0.1 g/min, which is 860 cc/min at 760 mm Hg or 6500 cc/min at 100 mm Hg (such as rotameters*).

Procedure

1. Weight 50 g. of well-mixed sample into tared flask, recording weight to nearest 0.1 g.
2. Equip with thermometer, gas inlet tube and heating mantle.
3. Bubble nitrogen through the sample while reducing the absolute pressure to 100 mm Hg. Nitrogen flow rate must be maintained at 1.0 g/min. ± 0.1 g/min.
4. Heat to 210 ± 2°F. run for one hour at this temperature using special nitrogen flow rate.
5. Reweigh flask and oil (approximate % dilution = $100 \times \frac{\text{Wt. loss}}{\text{Wt. Sample}}$).
6. Filter oil through 5μ Seitz pad while warm.
7. Determine viscosity of filtered sample at 210°F. and 100°F. and, if desired, CCS viscosity at 0°F.

* Following rotameters are suitable for operating at 100 mm Hg pressure (e.g. control valve upstream; no valve between rotameter and sparger):

Make	Tube No.	Ball	Max. Air Rate cc/min at STP	Scale Reading (100 mm Hg)
Brooks	R-2-15-B	SS	4570	7.0
Fischer & Porter	1/8-25-G-5/54	SS	3660	20.0

(1) Revised 4/14/71.

APPENDIX TABLE A-6

STRIPPING RESULTS ON ARO-100 USING REVISED PROCEDURE (4/1/71)

Lab	Viscosity Results, cSt 210°F Individual (Mean)	100°F Individual (Mean)
Before Stripping		
K	11.01	--
D	11.04	65.94
C	11.13	66.03
	11.07 (11.10)	--
After Stripping		
A	13.99	97.75
	14.03 (14.01)	97.38 (97.57)
K	13.98	96.8
	13.99 (13.99)	97.4 (97.1)
B	13.89	97.43
	13.96 (13.93)	--
D	13.96	97.41
	13.89 (13.93)	97.89 (97.65)
H	13.90	--
	13.95 (13.93)	--
C	14.17	99.14
	14.03	98.45
	14.04	97.61
	14.04	97.99
	14.10	97.96
	14.08	98.37
	14.27	97.81
	14.04	98.67
	14.03	99.05
	14.12	98.31
	13.96	98.05
	14.02	98.33
	14.02 (14.07)	98.13 (98.30)
R*	13.90	99.0

* Different Stripping technique, see Appendix A-7.

APPENDIX TABLE A-7

STRIPPING METHOD USED BY LAB R

SUBJECT: STRIPPING OF DILUTED OIL SAMPLES (10% or LESS DILUTION)

EQUIPMENT: Aluminum Evaporating Dishes (4 oz. size)
Forced Air Drying Oven
Mettler Balance

PROCEDURE:

A - Stripping

1 - Weigh aluminum evaporating dish on Mettler Balance.

2 - Add 30 mls of the diluted used oil (approx. 20 grams) to the dish.

3 - Reweigh to determine weight of oil added. Call this weight Wu.

4 - Place in preheated oven for 4 hours under the following conditions:
a - Temperature controlled @ 190 F
b - Air Flow - 6 cu. ft. per minute on Precision Scientific Model 605 oven.

B - To approximate % dilution -

1 - Obtain a sample of the new (not diluted) oil.

2 - Prepare a dish as in A-1 and 2.

3 - Reweight the dish to determine weight of new oil added. Call this weight Wn.

4 - As in A-4, expose the new oil to the identical stripping procedure as the used oil.

5 - Reweigh the dishes, calculate the final weights of the new and used oils. Call the final weight of new oil Xn and the final weight of the used (stripped) oil Xu.

6 - The % dilution will be:

$$\left(\frac{(Wu-Xu) - \frac{(Wn-Xn)}{Wn} Wu}{Wu} \right) X\ 100$$

APPENDIX B

VEHICLE DETAILS

APPENDIX TABLE B-1

CAR DATA - FLEET A

Car No.	Make	Engine Cyl.	Engine CID	Mileage @ Start	Date of Program Start	Date of Program Finish	Miles on Each Used Oil Sample Phase I	II	III	IV	V	Oil Consumption Rate (Miles/Quart) Phase I	II	III	IV	V
1	Mercury	8	429	11,735	3/20/70	12/1/70	1,603	-	-	-	-	5,535	2,100	1,683	1,854	1,358
2	Plymouth	8	383	16,591	4/1/70	11/3/70	1,496	-	1,501	-	-	2,834	2,512	4,246	2,248	-
3	Ford	6	200	9,426	4/2/70	11/23/70	1,510	1,524	1,479	-	-	19,895	5,974	71,449	*	-
4	Dodge	8	383	34,094	3/13/70	8/24/70	1,505	1,451	1,507	-	-	1,570	2,184	1,089	1,614	-
5	Chevrolet	8	350	14,191	3/17/70	12/2/70	1,765	1,584	1,549	-	-	3,646	3,544	2,613	3,084	3,226
6	Chrysler	8	383	8,043	4/6/70	1/7/71	1,750	1,453	-	-	-	2,502	2,716	2,224	2,470	1,579
7	Ford	8	289	27,056	3/18/70	9/4/70	1,554	-	1,443	-	-	10,814	3,844	3,559	7,832	-
8	Chevrolet	6	250	16,613	3/18/70	8/7/70	1,506	1,489	1,507	-	-	2,617	1,819	2,482	2,742	-
9	Pontiac	8	428	22,846	3/18/70	6/16/70	1,548	1,651	1,508	-	-	1,719	1,951	1,971	1,636	-
10	Chevrolet	8	307	22,519	3/6/70	12/30/70	1,508	1,504	1,450	-	-	6,133	3,498	3,749	3,107	3,938
11	Ford	8	302	16,144	3/26/70	9/21/70	1,506	1,458	1,469	-	-	3,032	3,616	2,464	19,930	-
12	Buick	8	350	17,808	3/31/70	11/9/70	1,412	-	1,504	-	-	3,557	2,799	3,005	4,111	-
13	Rambler	6	232	39,157	3/31/70	7/6/70	1,497	1,530	1,541	-	-	4,190	3,949	6,683	4,243	-

* Oil Consumption Negative 0.445 Lbs.

APPENDIX TABLE B-2

CAR DATA - FLEET B

Car No.	Make	Engine Cyl.	Engine CID	Mileage @ Start	Date of Program Start	Date of Program Finish	Miles on Each Used Oil Sample Phase I	II	III	IV	V	Oil Consumption Rate (Miles/Quart) Phase I	II	III	IV	V
1	Ford	8	289	50,493	5/5/70	12/11/70	1,420	1,462	1,584	1,476	-					
2	Rambler	6	199	33,946	4/14/70	12/15/70	1,494	1,504	1,542	1,554	-					
3	Dodge	8	383	16,855	4/14/70	9/22/70	1,532	1,547	1,498	1,498	1,513					
4	Buick	8	350	21,115	4/14/70	9/21/70	1,551	1,632	1,577	1,409	1,754					
5	Ford	8	289	36,228	4/28/70	12/16/70	1,492	1,626	1,443	1,467	-					
6	Oldsmobile	8	425	32,351	4/28/70	11/30/70	1,511	1,683	1,566	1,645	-					
7	Plymouth	8	318	23,588	4/28/70	10/29/70	1,564	1,508	1,643	1,527	-					
8	Plymouth	8	318	10,284	4/28/70	9/8/70	1,594	1,735	1,499	1,789	1,493					
9	Pontiac	6	230	35,629	5/6/70	12/11/70	1,674	1,618	1,655	1,199	-					
10	Buick	8	340	41,502	5/5/70	12/3/70	1,680	1,475	1,595	1,494	-					
11	Ford	6	200	36,154	5/5/70	11/3/70	1,415	1,497	1,485	1,552						
12	Ford	8	289	49,205	10/13/70	3/8/71	1,501	1,450	1,381	1,627	-					
13	Oldsmobile	8	330	49,360	5/5/70	11/6/70	1,498	1,687	1,474	1,509	1,426					

APPENDIX TABLE B-3

CAR DATA - FLEET C

Car No.	Make	Engine Cyl.	Engine CID	Mileage @ Start	Date of Program Start	Date of Program Finish	Miles on Each Used Oil Sample Phase I	II	III	IV	V	Oil Consumption Rate (Miles/Quart) Phase I	II	III	IV	V
1	Pontiac	8	326	38,414	6/11/70	2/17/71	1,574	1,490	1,538	1,531	-					
2	Cadillac	8	429	30,627	5/5/70	12/31/70	1,499	1,501	1,514	1,495	1,484					
3	Buick	8	300	36,251	5/12/70	9/14/70	1,489	1,445	1,524	1,507	-					
4	Cadillac	8	472	37,044	5/8/70	7/1/70	1,613	1,468	1,565	1,536	-					
5	Chevrolet	6	250	59,170	5/4/70	10/15/70	1,623	1,499	1,610	1,607	-					
6	Lincoln	8	462	45,992	5/11/70	8/6/70	1,528	1,796	1,501	1,683	-					
7	Ford	8	390	49,573	5/5/70	11/3/70	1,460	1,228	1,447	2,089	2,806					
8	Ford	8	302	21,110	5/6/70	10/16/70	1,492	1,719	1,514	1,471	-					
9	Ford	6	240	60,941	5/7/70	9/21/70	1,426	1,549	1,649	1,511	1,455					
10	Dodge	8	318	33,291	5/7/70	8/14/70	1,761	1,683	1,848	1,405	-					
11	Chrysler	8	440	22,900	5/6/70	10/5/70	1,498	1,426	1,452	1,530	-					
12	Dodge	8	383	38,467	5/8/70	10/16/70	1,474	1,586	1,525	1,595	-					
13	Rambler	8	290	32,631	5/4/70	11/10/70	1,452	1,508	1,493	1,508	1,508					

APPENDIX TABLE B-4

CAR DATA - FLEET D

Car No.	Make	Engine Cyl.	Engine CID	Mileage @ Start	Date of Program Start	Date of Program Finish	Miles on Each Used Oil Sample Phase I	II	III	IV	V	Oil Consumption Rate (Miles/Quart) Phase I	II	III	IV	V
1	Chevrolet	8	283	34,446	4/7/70	1/9/71						1,357	1,021	1,832	1,438	
2	Ford	8	302	17,170	5/12/70	2/10/71						3,530	5,340	9,340	2,920	
3	Oldsmobile	8	455	24,353	4/9/70	8/3/70						964	2,365	4,155	4,340	
4	Plymouth	8	383	46,078	4/2/70	9/15/70						1,715	2,684	1,890	1,364	
5	Oldsmobile	8	350	19,083	4/2/70	11/24/70						4,675	4,350	4,925	4,060	
6	Plymouth	8	318	29,869	4/6/70	11/5/70						3,065	2,494	1,571	2,307	
7	Ford	8	390	33,607	4/9/70	10/28/70						1,928	2,123	-	2,100	
8	Chevrolet	8	327	16,326	4/7/70	12/11/70						2,896	2,058	2,398	2,200	
9	Chrysler	8	440	43,398	4/9/70	10/15/70						-	1,051	1,105	1,546	
10	Rambler	6	232	8,214	4/16/70	11/5/70						8,490	2,966	1,612	3,461	
11	Oldsmobile	8	330	18,363	4/14/70	4/27/71						7,185	3,280	2,224	4,450	
12	Plymouth	6	225	43,389	4/16/70	9/11/70						3,464	3,897	3,062	2,057	
13	Ford	8	390	16,543	4/14/70	7/15/70						-	1,154	1,450	1,850	

APPENDIX TABLE B-5

CAR DATA - FLEET E

Car No.	Make	Engine Cyl.	Engine CID	Mileage @ Start	Date of Program Start	Date of Program Finish	Miles on Fach Used Oil Sample Phase I	II	III	IV	V	Oil Consumption Rate (Miles/Quart) Phase I	II	III	IV	V
1	Chevrolet	8	307	14,850	5/1/70	9/18/70	1,563	1,516	1,461	1,490						
2	Chevrolet	6	250	29,840	5/4/70	8/31/70	1,473	1,516	1,529	1,526						
3	Pontiac	8	400	21,170	5/21/70		1,516	1,466	1,719	-						
4	Chrysler	8	383	2,715	5/12/70	9/21/70	1,678	1,235	1,533	1,206						
5	Plymouth	8	318	9,950	5/4/70	8/31/70	1,618	1,456	1,424	1,566						
6	Plymouth	8	383	18,670	5/5/70	8/22/70	1,670	1,523	1,501	1,502						
7	Ford	8	289	37,830	5/5/70	11/25/70	1,543	1,506	1,444	1,589						
8	Rambler	8	343	22,673	6/26/70	12/29/70	1,460	1,452	1,744	1,482						
9	Ford	8	302	50,107	7/2/70	10/21/70	1,521	1,515	1,500	1,480						
10	Ford	8	352	50,010	5/5/70	10/10/70	1,414	1,517	1,561	1,518						
11	Chevrolet	8	283	49,615	5/14/70	1/5/71	1,563	1,601	981	1,511						
12	Ford	8	289	49,850	5/12/70	11/10/70	1,543	1,515	1,482	1,486						
13	Chevrolet	8	283	27,170	5/13/70	12/3/70	1,542	1,514	1,453	1,466						

APPENDIX TABLE B-6

CAR DATA - FLEET F

Car No.	Make	Engine Cyl.	Engine CID	Mileage @ Start	Date of Program Start	Date of Program Finish	Miles on Each Used Oil Sample Phase I	II	III	IV	V	Oil Consumption Rate (Miles/Quart) Phase I	II	III	IV	V
1	Buick	8	310	49,488	4/22/70	10/7/70	1,584	1,516	1,519	-						
2	Cadillac	8	390	51,169	4/23/70	9/23/70	1,547	1,120	1,380	-						
3	Rambler	6	195	50,399	4/23/70	10/12/70	1,506	1,524	1,554	-						
4	Dodge	8	318	12,719	4/28/70	9/11/70	1,500	1,264	957	-						
5	Ford	8	292	2,000	4/28/70	2/21/71	1,488	1,546	1,497	-						
6	Ford	8	289	50,167	4/23/70	11/11/70	1,650	1,393	1,572	-						
7	Dodge	8	440	27,500	4/28/70	8/6/70	1,605	1,517	1,000	-						
8	Chevrolet	8	283	62,232	5/4/70	10/7/70	1,539	1,518	1,546	-						
9	Plymouth	8	383	14,902	5/4/70	11/4/70	1,484	1,464	2,636	-						
10	Ford	8	302	22,250	5/5/70	9/10/70	1,523	1,624	1,704	-						
11	Ford	8	390	27,706	5/6/70	11/20/70	1,487	1,503	982	-						
12	Chevrolet	8	350	8,887	5/7/70	2/21/71	766	1,525	1,435	-						
13	Chevrolet	6	292	44,833	5/8/70	5/3/71	1,937	1,524	1,440	-						

APPENDIX C

FIELD TEST VISCOSITY RESULTS

APPENDIX TABLE C-1

FIELD TEST VISCOSITY RESULTS

FLEET A — DRAIN PROCESSOR A

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.05	86.11	12.89	13.40	13.88	13.50	78.48	82.66	83.67	81.59
102	15.02	86.04	11.43	11.43	11.78	12.35	68.71	70.28	71.54	74.29
103	14.97	97.09	12.71	12.58	13.23	12.77	86.58	81.98	88.91	84.10
104	15.02	109.2	12.31	12.78	12.26	12.77	90.31	93.37	89.55	92.47
105	14.70	83.40	10.74	10.95	10.28	11.04	66.66	67.80	62.05	67.73
106	15.01	75.82	11.12	11.14	11.02	10.71	64.60	66.05	65.57	62.85
107	15.15	96.82	12.84	13.15	12.85	12.83	85.81	87.19	86.01	85.09
108	14.98	104.4	12.06	12.46	12.93	12.46	84.51	86.73	91.08	86.74
109	15.23	89.63	14.63	14.87	15.39	14.75	94.36	100.5	95.40	98.96
110	15.00	104.0	14.82	14.80	14.57	13.96	103.4	103.9	101.9	97.56
111	10.99	66.13	10.30	10.29	10.03	9.45	65.30	63.88	62.88	57.50
112	11.05	74.86	10.04	10.43	10.31	10.27	68.48	71.71	70.63	72.99
113	6.72	48.15	7.12	6.81	6.80	6.83	53.05	49.18	48.64	49.55

PHASE V

ARO No.	Car No.	Repeat of Phase	cSt., @ 1,500 Miles @ 210 F	@ 100 F
103	1	III	13.13	88.74
107	5	III	12.88	86.50
112	10	III	10.24	70.18
101	6	IV	13.04	77.71

APPENDIX TABLE C-2

FIELD TEST VISCOSITY RESULTS

FLEET A — DRAIN PROCESSOR J

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.07	86.40	12.84	13.59	13.82	13.55				
102	15.00	86.00	11.42	11.39	11.77	12.24				
103	14.98	97.60	12.99	12.47	13.27	12.82				
104	14.87	108.10	12.58	12.70	12.13	12.89				
105	14.81	84.20	10.79	11.07	10.38	11.15				
106	14.94	75.80	11.21	11.55	11.06	10.77				
107	15.12	97.50	12.71	13.10	12.88	12.77				
108	14.92	104.50	12.02	12.37	12.98	12.36				
109	15.23	90.80	14.71	15.11	-	14.97				
110	15.05	104.90	14.32	14.82	14.46	13.86				
111	10.98	66.20	10.29	10.23	10.05	9.74				
112	11.01	74.80	9.96	10.36	10.28	10.25				
113	6.68	48.30	7.06	6.76	7.09	6.82				

PHASE V

ARO No.	Car No.	Repeat of Phase	cSt., @ 1,500 Miles @ 210 F	@ 100 F
103	1	III	13.11	-
107	5	III	13.02	-
112	10	III	9.98	-
101	6	IV	13.03	-

APPENDIX TABLE C-3

FIELD TEST VISCOSITY RESULTS

FLEET B — DRAIN PROCESSOR B

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.01	86.03	12.97	13.44	13.29	13.64	76.54	80.71	79.09	83.10
102	14.96	85.74	13.38	10.25	11.06	11.90	86.53	63.58	67.41	72.13
103	14.88	98.91	14.22	13.48	13.37	13.80	97.55	90.50	89.97	93.15
104	14.95	108.40	12.55	13.61	12.67	12.06	92.17	101.60	92.12	88.22
105	14.78	83.60	10.73	10.86	10.95	11.21	67.53	67.38	68.09	69.92
106	14.90	76.87	11.03	10.72	11.53	11.53	65.10	66.01	69.92	68.88
107	15.11	97.08	13.04	13.10	12.52	13.47	88.50	87.20	84.57	89.76
108	14.91	106.20	12.38	12.98	12.82	12.69	87.00	92.30	90.93	88.27
109	15.16	90.07	16.31	15.27	15.20	15.59	113.42	101.22	97.45	101.07
110	14.93	102.70	14.75	15.54	15.22	13.57	104.52	111.72	108.93	93.39
111	10.95	66.12	10.40	10.62	10.35	10.27	64.50	67.56	65.20	64.26
112	10.99	74.66	10.28	10.67	10.62	10.82	71.39	74.38	73.49	75.57
113	6.73	48.55	7.01	7.02	6.93	7.12	51.23	51.66	50.80	51.71

PHASE V

ARO No.	Car No.	Repeat of Phase	cSt., @ 1,500 Miles @ 210 F	@ 100 F
102	13	III	11.83	71.26
104	4	II	-	-
107	8	I	13.59	91.49
111	3	IV	10.19	64.11

APPENDIX TABLE C-4

FIELD TEST VISCOSITY RESULTS

FLEET B — DRAIN PROCESSOR A

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.05	86.11	12.88	13.42	13.29	13.62	74.98	80.02	78.64	82.59
102	15.02	86.04	13.43	10.18	10.89	11.93	86.46	62.77	66.79	72.10
103	14.97	97.09	14.18	13.42	13.46	13.72	97.16	89.70	89.67	93.41
104	15.02	100.2	12.74	13.55	12.58	12.28	94.39	100.8	91.24	88.43
105	14.70	83.40	10.69	10.78	10.90	11.10	67.36	66.59	67.34	68.99
106	15.01	75.82	11.12	11.21	12.06	11.36	64.54	67.03	70.75	67.41
107	15.15	96.82	13.12	13.08	12.38	13.53	88.19	86.29	82.13	90.07
108	14.98	104.4	12.33	13.08	12.70	12.59	85.69	92.51	88.89	86.95
109	15.23	89.63	16.12	15.16	14.97	15.12	115.1	101.0	95.55	97.67
110	15.00	104.0	14.67	15.56	15.23	13.15	104.1	111.22	108.2	88.04
111	10.99	66.13	10.44	10.73	10.36	10.26	64.78	67.03	64.79	63.67
112	11.05	74.86	10.28	10.29	10.58	10.83	71.12	70.16	72.62	75.17
113	6.72	48.15	7.00	7.01	6.90	7.09	50.74	51.56	50.52	50.93

PHASE V

ARO No.	Car No.	Repeat of Phase	cSt., @ 1,500 Miles @ 210 F	@ 100 F
102	13	III	11.66	69.78
104	4	II	13.81	103.1
107	8	I	13.60	91.05
111	3	IV	10.20	63.66

APPENDIX TABLE C-5

FIELD TEST VISCOSITY RESULTS

FLEET C — DRAIN PROCESSOR C

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.24	86.72	13.18	13.24	13.07	14.45	78.97	79.76	78.69	87.18
102	15.06	86.01	12.42	11.78	12.32	12.46	74.50	71.40	73.86	75.62
103	14.91	97.62	13.93	13.60	12.94	13.78	92.89	89.04	85.23	92.69
104	15.06	108.9	13.49	13.55	12.68	12.87	97.54	98.13	91.01	92.62
105	14.74	83.41	11.98	11.01	11.53	12.06	75.00	66.43	68.74	74.76
106	15.00	76.08	11.58	12.54	11.76	10.93	68.65	73.53	69.36	64.12
107	15.14	97.39	13.26	12.98	13.69	12.87	87.73	85.49	90.53	84.78
108	14.99	105.0	12.80	13.15	13.93	12.13	90.88	93.37	99.67	83.96
109	15.31	90.76	17.16	15.76	14.66	14.02	120.00	104.85	93.27	93.94
110	14.94	104.6	14.48	16.19	15.15	13.71	100.5	116.25	108.2	95.63
111	11.03	66.13	10.36	10.20	10.46	10.57	63.65	63.62	65.15	64.46
112	11.06	75.02	10.68	10.03	11.42	10.58	73.18	69.87	81.83	73.11
113	6.77	48.47	7.11	6.98	6.86	6.85	50.72	50.09	48.85	49.01

PHASE V

ARO No.	Car No.	Repeat of Phase	cSt., @ 1,500 Miles @ 210 F	@ 100 F
102	7	IV	11.76	73.78
104	10	IV	13.27	95.20
108	13	IV	12.18	84.91
110	2	IV	14.41	96.31

APPENDIX TABLE C-6

FIELD TEST VISCOSITY RESULTS

FLEET C — DRAIN PROCESSOR D

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.01	86.10	12.94	13.07	12.90	14.55	77.67	78.27	77.01	87.66
102	14.97	85.95	12.15	11.73	12.36	12.58	73.17	71.16	74.70	76.59
103	15.01	97.92	13.87	13.48	12.75	13.80	93.00	88.44	84.06	92.16
104	14.94	108.78	13.41	13.53	13.02	13.18	97.44	99.30	94.92	94.86
105	14.91	83.73	11.87	10.93	11.20	12.03	74.16	66.78	67.86	74.64
106	14.97	75.72	11.77	12.58	11.80	10.85	67.95	73.95	69.33	63.99
107	15.13	97.60	13.27	13.05	13.40	12.35	88.08	86.01	87.09	80.37
108	14.94	104.40	12.71	13.10	13.93	12.54	88.86	92.91	99.18	87.36
109	15.18	90.30	16.86	15.37	14.31	14.34	116.50	97.77	88.56	93.90
110	15.00	104.55	14.51	15.98	15.16	12.71	100.30	116.40	107.00	83.25
111	10.99	66.15	10.37	10.21	10.41	10.40	63.84	63.36	65.19	64.14
112	11.02	74.76	10.55	10.18	11.38	10.50	72.72	70.53	81.39	72.06
113	6.72	48.39	6.85	6.80	6.69	6.85	48.90	48.57	47.43	49.24

APPENDIX TABLE C-7

FIELD TEST VISCOSITY RESULTS

FLEET C — DRAIN PROCESSOR K

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.08	85.8	13.13	13.07	13.04	14.44	78.6	78.7	78.1	86.5
102	15.06	86.1	12.31	11.68	12.19	12.43	73.8	71.0	73.5	75.0
103	14.87	97.8	13.77	13.42	12.76	13.67	92.8	88.3	84.3	91.9
104	14.90	108.8	13.31	13.57	12.66	12.49	97.2	99.7	92.0	88.6
105	14.58	82.8	11.86	10.90	11.27	12.01	74.3	66.1	68.2	74.7
106	14.91	75.5	11.50	12.43	11.69	10.92	68.4	73.4	69.0	63.9
107	15.04	96.9	13.16	12.92	13.67	12.89	87.5	85.0	91.3	86.4
108	14.90	104.3	12.66	13.10	13.92	12.21	90.6	93.5	100.6	85.1
109	15.17	90.3	17.03	15.56	14.61	14.07	123.2	104.7	93.1	93.1
110	14.95	104.3	14.40	15.81	15.07	13.60	101.0	115.9	107.5	93.5
111	10.88	65.8	10.33	10.19	10.30	10.41	63.8	63.4	64.9	64.1
112	10.99	74.8	10.55	10.07	11.37	10.52	72.5	69.4	81.8	72.5
113	6.66	48.12	7.03	6.89	6.91	6.83	50.4	49.68	48.97	48.77

APPENDIX TABLE C-8

FIELD TEST VISCOSITY RESULTS

FLEET D — DRAIN PROCESSOR D

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.01	86.10	12.96	12.95	13.22	13.05	77.22	76.92	79.35	78.57
102	14.97	85.95	11.61	11.69	12.18	11.77	71.30	70.53	73.77	73.08
103	15.01	97.92	12.82	13.24	12.78	13.24	84.90	88.98	84.00	88.10
104	14.94	108.78	12.29	12.56	12.20	13.40	88.08	89.40	87.90	98.73
105	14.91	83.73	10.39	10.28	10.98	10.76	62.76	63.18	68.79	65.91
106	14.97	75.72	11.58	11.28	11.05	10.83	67.29	68.94	64.80	63.60
107	15.13	97.60	12.81	13.14	12.88	12.97	83.97	88.35	85.02	86.19
108	14.94	104.40	12.61	12.59	12.92	12.89	89.18	87.66	92.00	90.40
109	15.18	90.30	14.01	15.82	15.83	14.01	86.76	105.70	103.08	89.60
110	15.00	104.55	13.95	14.47	15.00	13.93	96.30	101.19	105.42	97.30
111	10.99	66.15	9.87	9.96	10.65	10.49	60.06	61.95	68.85	65.67
112	11.02	74.76	10.38	9.80	10.19	10.12	71.31	65.55	69.81	68.64
113	6.72	48.39	6.76	6.92	6.85	6.61	48.00	50.13	48.99	46.29

APPENDIX TABLE C-9

FIELD TEST VISCOSITY RESULTS

FLEET D — DRAIN PROCESSOR C

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.24	86.72	13.12	13.22	13.33	13.27	77.84	79.18	80.88	80.78
102	15.06	86.01	11.64	11.82	12.37	11.82	72.27	71.38	74.34	73.65
103	14.91	97.62	12.88	13.22	13.06	13.04	85.67	89.48	86.00	86.94
104	15.06	108.9	12.50	12.81	12.27	13.43	91.78	94.21	87.71	98.84
105	14.74	83.41	10.89	10.38	11.16	10.85	66.74	64.62	65.88	66.52
106	15.00	76.08	11.35	11.40	11.00	10.86	67.45	71.21	69.44	63.11
107	15.14	97.39	13.07	13.28	12.92	13.16	87.57	89.67	85.37	87.43
108	14.99	105.00	12.73	12.72	13.02	12.94	91.10	88.64	93.63	90.70
109	15.31	90.76	14.22	16.10	16.06	14.17	90.99	110.92	107.2	91.95
110	14.94	104.60	14.31	14.58	15.11	14.04	99.64	102.5	106.1	98.59
111	11.03	66.13	10.27	9.99	10.67	10.60	64.19	62.24	69.41	66.15
112	11.06	75.02	10.49	9.99	10.30	10.29	72.26	67.49	70.33	71.02
113	6.77	48.47	6.90	6.80	6.87	6.77	49.32	48.82	49.14	48.09

APPENDIX TABLE C-10

FIELD TEST VISCOSITY RESULTS

FLEET D — DRAIN PROCESSOR G

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.01	86.10	12.99	13.10	13.22	13.88	77.70	78.60	79.38	80.64
102	14.97	85.95	11.64	11.66	12.13	11.65	69.63	68.53	74.07	70.91
103	15.01	97.92	12.72	13.24	12.77	12.98	84.30	88.80	84.70	85.95
104	14.94	108.78	12.43	12.70	12.03	13.37	90.18	91.44	86.61	98.58
105	14.91	83.73	10.65	10.34	10.99	10.72	65.40	63.24	69.30	65.74
106	14.97	75.72	11.53	10.97	11.03	10.78	65.26	64.89	62.79	62.55
107	15.13	97.60	13.02	13.12	12.71	13.05	86.61	89.85	84.75	86.67
108	14.94	104.40	12.69	12.61	13.10	12.87	89.88	87.75	94.86	90.39
109	15.18	90.30	14.64	16.04	16.16	13.99	88.56	102.37	100.66	88.91
110	15.00	104.55	14.14	14.46	14.92	13.96	98.70	101.40	104.80	97.59
111	10.99	66.15	10.01	9.90	10.66	9.90	62.16	61.65	69.09	61.80
112	11.02	74.76	10.42	9.88	10.18	10.22	71.64	66.21	69.42	70.47
113	6.72	48.39	6.75	6.89	6.80	6.65	47.31	49.98	48.69	46.92

APPENDIX TABLE C-11

FIELD TEST VISCOSITY RESULTS

FLEET E

DRAIN PROCESSOR I

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.10	87.00	13.31	13.64	12.80	13.26	79.4	81.1	74.8	80.0
102	14.99	86.60	11.57	11.78	11.61	10.78	70.0	71.3	68.5	63.7
103	15.07	98.70	13.01	12.54	13.91	13.50	87.5	80.6	96.7	90.6
104	14.99	105.50	12.41	12.95	13.09	12.64	89.4	94.6	95.0	89.1
105	14.96	84.80	10.43	10.92	9.53	10.29	66.6	67.2	58.2	64.8
106	14.94	76.90	10.98	10.99	11.09	10.10	66.8	63.8	66.7	60.5
107	15.16	96.90	12.31	13.31	13.04	11.80	81.0	90.3	86.8	75.6
108	14.96	105.40	12.80	12.78	11.68	12.06	90.4	93.8	79.5	82.1
109	15.25	90.50	15.81	15.05	15.60	15.30	109.0	93.6	98.4	95.4
110	15.00	104.80	14.22	14.93	15.15	14.74	101.2	106.6	108.0	103.2
111	10.99	67.30	10.14	10.08	10.55	-	62.3	64.2	67.6	-
112	11.01	76.00	10.07	10.05	10.43	10.13	67.7	68.5	72.1	69.8
113	6.77	50.30	6.84	6.87	6.80	6.89	51.6	49.2	48.4	49.4

PHASE V

ARO No.	Car No.	Repeat of Phase	cSt., @ 1,500 Miles @ 210 F	@ 100 F
105	6	I	10.41	63.50
109	9	II	14.64	92.70
112	10	III	10.17	70.40
113	1	I	6.85	48.90

APPENDIX TABLE C-12

FIELD TEST VISCOSITY RESULTS

FLEET E — DRAIN PROCESSOR G

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	15.01	86.10	13.27	13.63	12.68	13.24	79.77	81.36	75.15	79.59
102	14.97	85.95	11.50	11.85	11.62	10.94	69.66	71.25	69.72	65.34
103	15.01	97.92	13.02	12.54	13.99	13.67	87.42	80.82	93.70	91.95
104	14.94	108.78	12.41	12.99	13.14	13.83	89.67	94.38	95.37	101.79
105	14.91	83.73	10.39	10.91	9.36	10.36	63.33	67.08	56.40	66.12
106	14.97	75.72	10.81	10.79	11.11	10.65	65.61	62.88	66.39	64.47
107	15.13	97.60	12.34	13.33	13.16	12.14	81.18	90.48	86.91	79.77
108	14.94	104.40	12.71	12.78	11.81	12.28	89.52	89.46	81.18	84.27
109	15.18	90.30	15.61	15.22	15.65	15.47	110.91	94.41	101.8	98.00
110	15.00	104.55	14.33	14.94	14.72	14.75	98.62	102.41	104.35	99.41
111	10.99	66.15	10.09	10.04	10.58	9.24	62.49	64.17	65.13	56.01
112	11.02	74.76	10.02	9.98	10.47	10.12	66.43	67.68	73.11	69.57
113	6.72	48.39	6.83	6.77	6.78	6.90	49.74	48.39	48.90	49.71

APPENDIX TABLE C-13

FIELD TEST VISCOSITY RESULTS

FLEET F — DRAIN PROCESSOR H

ARO Oil No.	Fresh Oil 210°F	Fresh Oil 100°F	210°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV	100°F Viscosity, cSt. Phase I	Phase II	Phase III	Phase IV
101	14.98	86.60	13.79	14.29	13.99	13.06	87.50	89.09	85.77	80.21
102	15.18	86.10	13.06	13.02	12.63*	11.81	73.17	80.19	75.23*	72.33
103	14.91	97.70	12.85	12.80	14.73	12.50	87.09	83.53	101.46	79.68
104	15.02	108.38	12.99	13.18	14.11	12.56	95.92	96.21	105.77	91.51
105	14.89	85.05	11.11	9.97	10.89	11.17	71.40	57.70	67.14	68.51
106	15.06	76.08	10.82	10.95*	11.43	10.61	66.51	64.95*	65.78	62.55
107	15.16	97.22	13.43	13.11	12.20	12.97	90.18	95.06	80.20	90.75
108	14.87	104.59	12.19	12.61	12.27	12.36*	84.86	89.07	86.15	86.69*
109	15.20	90.98	15.10	14.61	14.69	16.65	95.50	94.02	94.88	117.21
110	15.05	104.27	14.40	15.08	14.20	15.93	102.50	105.30	98.65	115.57
111	10.89	66.98	10.16*	9.95	10.64	9.89	62.34*	62.73	64.54	59.75
112	11.06	74.60	10.27	10.34*	10.44	10.32	69.57	70.82*	73.03	69.85
113	6.72	48.37	7.37	6.78	7.37	7.54	55.07	47.03	49.03	53.60

* Missing Data Filled in by Method of Cochran and Cox, Experimental Designs, Second Edition.

APPENDIX D

ANALYSIS OF FIELD TEST DATA

APPENDIX D

TABLE D-1

ANALYSIS OF FIELD TEST DATA

FLEET A — **DRAIN PROCESSOR A**

SECTION 1 — 210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.40	1.65	1.74	0.48
2	2.16	3.59	2.76	1.04
3	3.59	2.39	4.42	1.54
4	2.26	2.24	3.99	0.78
5	2.71	3.75	2.30	-0.11
6	3.96	3.87	2.05	1.55
7	3.89	2.00	-0.16	2.67
8	2.31	2.52	0.43	2.20
9	2.92	0.36	0.96	2.25
10	0.60	0.20	0.74	3.66
11	0.18	0.70	-0.08	4.30
12	0.69	0.62	1.17	2.32
13	1.01	-0.09	3.24	2.52
A_j (1)	25.88	23.80	23.56	25.20

SECTION 2 — 210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.65		1.74						0.48				-0.40	3.47
2	2.16	3.59		2.76						1.04				9.55
3		3.59	2.39		4.42						1.54			11.94
4			2.26	2.24		3.99						0.78		9.27
5				2.71	3.75		2.30						-0.11	8.65
6	1.55				3.96	3.87		2.05						11.43
7		2.67				3.89	2.00		-0.16					8.40
8			2.20				2.31	2.52		0.43				7.46
9				2.25				2.92	0.36		0.96			6.49
10					3.66				0.60	0.20		0.74		5.20
11						4.30				0.18	0.70		-0.08	5.10
12	1.17						2.32				0.69	0.62		4.80
13		3.24						2.52				1.01	-0.09	6.68
T_j (3)	6.53	13.09	8.59	9.96	15.79	16.05	8.93	10.01	1.28	1.85	3.89	3.15	-0.68	(4) 98.44

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	3.47		3.47						3.47				3.47
2	9.55	9.55		9.55						9.55			
3		11.94	11.94		11.94						11.94		
4			9.27	9.27		9.27						9.27	
5				8.65	8.65		8.65						8.65
6	11.43				11.43	11.43		11.43					
7		8.40				8.40	8.40		8.40				
8			7.46				7.46	7.46		7.46			
9				6.49				6.49	6.49		6.49		
10					5.20				5.20	5.20		5.20	
11						5.10				5.10	5.10		5.10
12	4.80						4.80				4.80	4.80	
13		6.68						6.68				6.68	6.68
B_j (6)	29.25	36.57	32.14	33.96	37.22	34.20	29.31	32.06	23.56	27.31	28.33	25.95	23.90
(7)	58.77	117.81	77.31	89.64	142.11	144.45	80.37	90.09	11.52	16.65	35.01	28.35	-6.12
(8)	-351.00	-438.84	-385.68	-407.52	-446.64	-410.40	-351.72	-384.72	-282.72	-327.72	-339.96	-311.40	-286.80
(9)	295.32	295.32	295.32	295.32	295.32	295.32	295.32	295.32	295.32	295.32	295.32	295.32	295.32
W_j (10)	3.09	-25.71	-13.05	-22.56	-9.21	29.37	23.97	0.69	24.12	-15.75	-9.63	12.27	2.40
Y_j	6.5976	12.5270	8.3043	9.4660	15.5884	16.6900	9.4549	10.0251	1.8082	1.5051	3.6792	3.4187	-0.6275
Corrected Avg. Visc. Losses ($Y_j/4$)	1.65	3.13	2.08	2.37	3.90	4.17	2.36	2.51	0.45	0.38	0.92	0.85	-0.16
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.63	3.27	2.15	2.49	3.95	4.01	2.23	2.50	0.32	0.46	0.97	0.79	-0.17

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	0.2862	3	0.0954	2.8392
(12) Cars Adj.	2.8142	12 E_b	0.2345	6.9791*
(13) Oils	89.7526	12	7.4793	222.5982*
(14) Error	0.8082	24 E_e	0.0336	
(5) Total	93.6612	51		

Uncorrected Sum Of Sq. = 280.0156

Correction Term C = 186.3544

$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mu = \frac{0.2345 - 0.0336}{9.1455}$

μ = 0.0219 (Car Correction Factor)

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-2

ANALYSIS OF FIELD TEST DATA

FLEET A — DRAIN PROCESSOR J

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.38	1.48	1.71	0.26
2	2.23	3.61	2.74	1.19
3	3.58	2.51	4.43	1.24
4	1.99	2.17	3.88	0.76
5	2.29	3.74	2.24	-0.14
6	4.02	3.39	1.94	1.52
7	3.73	2.02	0.00**	2.76
8	2.41	2.55	0.59	2.16
9	2.90	0.12	0.93	1.98
10	0.52	0.23	0.73	3.66
11	0.73	0.75	-0.41	4.17
12	0.69	0.65	1.25	2.35
13	1.05	-0.08	3.23	2.56
A_j (1)	25.76	23.14	23.26	24.47

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.48		1.71						0.26				-0.38	3.07
2	2.23	3.61		2.74						1.19				9.77
3		3.58	2.51		4.43						1.24			11.76
4			1.99	2.17		3.88						0.76		8.80
5				2.29	3.74		2.24						-0.14	8.13
6	1.52				4.02	3.39		1.94						10.87
7		2.76				3.73	2.02		0.00**					8.51
8			2.16				2.41	2.55		0.59				7.71
9				1.98				2.90	0.12		0.93			5.93
10					3.66				0.52	0.23		0.73		5.14
11						4.17				0.73	0.75		-0.41	5.24
12	1.25						2.35				0.69	0.65		4.94
13		3.23						2.56				1.05	-0.08	6.76
T_j (3)	6.48	13.18	8.37	9.18	15.85	15.17	9.02	9.95	0.90	2.74	3.61	3.19	-1.01 (4)	96.63

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	0.3467	3	0.1155	3.8245*
(12) Cars Adj.	2.8426	12 E_b	0.2368	7.8410*
(13) Oils	86.5085	12	7.2090	238.7086*
(14) Error	0.6964	23 Ee	0.0302	
(5) Total	90.3942	50		

Uncorrected Sum of Sq. = 269.9587

Correction Term C = 179.5645

μ = Eb-Ee / 39 Eb for Eb>Ee

μ = 0.2368-0.0302 / 9.2352

μ = 0.0223 (Car Correction Factor)

SECTION 3 -- OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	3.07		3.07						3.07				3.07
2	9.77	9.77		9.77						9.77			
3		11.76	11.76		11.76						11.76		
4			8.80	8.80		8.80						8.80	
5				8.13	8.13		8.13						8.13
6	10.87				10.87	10.87		10.87					
7		8.51				8.51	8.51		8.51				
8			7.71				7.71	7.71		7.71			
9				5.93				5.93	5.93		5.93		
10					5.14				5.14	5.14		5.14	
11						5.24				5.24	5.24		5.24
12	4.94						4.94				4.94	4.94	
13		6.76						6.76				6.76	6.76
(6)	28.65	36.80	31.34	32.63	35.90	33.42	29.29	31.27	22.65	27.86	27.87	25.64	23.20
(7)	58.32	118.62	75.33	82.62	142.65	136.53	81.18	89.55	8.10	24.66	32.49	28.71	-9.09
(8)	+343.80	+441.60	+376.08	+391.56	+430.80	+401.04	+351.48	+375.24	+271.80	+334.32	+334.44	+307.68	+278.40
(9)	289.89	289.89	289.89	289.89	289.89	289.89	289.89	289.89	289.89	289.89	289.89	289.89	289.89
W_j (10)	4.41	-33.09	-10.86	-19.05	1.74	25.38	19.59	4.20	26.19	-19.77	-12.06	10.92	2.40
Y_j	6.5783	12.4421	8.1279	8.7552	15.8888	15.7359	9.4568	10.0436	1.4840	2.2992	3.3411	3.4335	-0.9565
Corrected Avg. Visc. Losses (Y_j/4)	1.64	3.11	2.03	2.19	3.97	3.93	2.36	2.51	0.37	0.57	0.84	0.86	-0.24
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.62	3.30	2.09	2.30	3.96	3.79	2.26	2.49	0.23	0.69	0.90	0.80	-0.25

* Significant at the 95% Confidence Level.

** Missing Data Filled in by Method of Cochran and Cox, Experimental Designs, Second Edition.

APPENDIX D

TABLE D-3

ANALYSIS OF FIELD TEST DATA

FLEET B — DRAIN PROCESSOR B

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.29	1.57	1.51	-0.43
2	2.04	4.71	2.28	1.36
3	1.58	1.40	3.83	0.68
4	0.66	1.34	3.37	0.17
5	2.40	3.92	2.59	-0.40
6	4.05	4.18	2.09	1.37
7	3.87	2.01	-0.04	3.06
8	2.07	1.93	-0.29	1.08
9	2.53	-0.11	0.60	2.89
10	-1.15	-0.61	0.37	3.57
11	0.18	0.33	-0.21	3.37
12	0.55	0.32	1.72	1.64
13	0.71	-0.30	3.90	2.22
A_j (1)	19.20	20.69	21.72	20.58

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.57		1.51						-0.43				-0.29	2.36
2	2.04	4.71		2.28						1.36				10.39
3		1.58	1.40		3.83						0.68			7.49
4			0.66	1.34		3.37						0.17		5.54
5				2.40	3.92		2.59						-0.40	8.51
6	1.37				4.05	4.18		2.09						11.69
7		3.06				3.87	2.01		-0.04					8.90
8			1.08				2.07	1.93		-0.29				4.79
9				2.89				2.53	-0.11		0.60			5.91
10					3.57				-1.15	-0.61		0.37		2.18
11						3.37				0.18	0.33		-0.21	3.67
12	1.72						1.64				0.55	0.32		4.23
13		3.90						2.22				0.71	-0.30	6.53
T_j (3)	6.70	13.25	4.65	8.91	15.37	14.79	8.31	8.77	-1.73	0.64	2.16	1.57	-1.20 (4)	82.19

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	0.2470	3	0.0823	0.4224
(12) Cars Adj.	6.8798	12 E_b	0.5733	2.9430 *
(13) Oils	103.6889	12	8.6407	44.3567 *
(14) Error	4.6752	24 E_e	0.1948	
(5) Total	115.4909	51		

Uncorrected Sum of Sq. = 245.3985

Correction Term C = 129.9076

$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mu = \frac{0.5733 - 0.1948}{22.3587}$

$\mu = 0.0169$ (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	2.36		2.36						2.36				2.36
2	10.39	10.39		10.39						10.39			
3		7.49	7.49		7.49						7.49		
4			5.54	5.54		5.54						5.54	
5				8.51	8.51		8.51						8.51
6	11.69				11.69	11.69		11.69					
7		8.90				8.90	8.90		8.90				
8			4.79				4.79	4.79		4.79			
9				5.91				5.91	5.91		5.91		
10					2.18				2.18	2.18		2.18	
11						3.67				3.67	3.67		3.67
12	4.23						4.23				4.23	4.23	
13		6.53						6.53				6.53	6.53
(6)	28.67	33.31	20.18	30.35	29.87	29.80	26.43	28.92	19.35	21.03	21.30	18.48	21.07
(7)	60.30	119.25	41.85	80.19	138.33	133.11	74.79	78.93	-15.57	5.76	19.44	14.13	-10.80
(8)	-344.04	-399.72	-242.16	-364.20	-358.44	-357.60	-317.16	-347.04	-232.20	-252.36	-255.60	-221.76	-252.84
(9)	246.57	246.57	246.57	246.57	246.57	246.57	246.57	246.57	246.57	246.57	246.57	246.57	246.57
W_j (10)	-37.17	-33.90	46.26	-37.44	26.46	22.08	4.20	-21.54	-1.20	-0.03	10.41	38.94	-17.07
Y_j	6.0719	12.6771	5.4317	8.2773	15.8171	15.1631	8.3809	8.4060	-1.7502	0.6395	2.3359	2.2280	-1.4884
Corrected Avg. Visc. Losses ($Y_j/4$)	1.52	3.17	1.36	2.07	3.95	3.79	2.10	2.10	-0.44	0.16	0.58	0.56	-0.37
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.68	3.31	1.16	2.23	3.84	3.70	2.08	2.19	-0.43	0.16	0.54	0.39	-0.30

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-4

ANALYSIS OF FIELD TEST DATA

FLEET B

DRAIN PROCESSOR A

SECTION 1

210°F Vis. Losses cSt, After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.28	1.63	1.51	0.11
2	2.17	4.84	2.44	1.85
3	1.59	1.55	3.80	0.73
4	0.79	1.47	2.95	0.22
5	2.28	3.92	2.77	-0.37
6	4.01	3.80	2.28	1.43
7	3.89	2.07	0.26	3.09
8	2.03	1.90	-0.23	1.25
9	2.65	0.07	0.63	2.74
10	-0.89	-0.56	0.47	3.60
11	0.33	0.26	-0.18	3.65
12	0.55	0.76	1.76	1.62
13	0.77	-0.29	4.13	2.39
A_j (1)	19.89	21.42	22.59	22.31

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.63		1.51						0.11				-0.28	2.97
2	2.17	4.84		2.44						1.85				11.30
3		1.59	1.55		3.80						0.73			7.67
4			0.79	1.47		2.95						0.22		5.43
5				2.28	3.92		2.77						-0.37	8.60
6	1.43				4.01	3.80		2.28						11.52
7		3.09				3.89	2.07		0.26					9.31
8			1.25				2.03	1.90		-0.23				4.95
9				2.74				2.65	0.07		0.63			6.09
10					3.60				-0.89	-0.56		0.47		2.62
11						3.65				0.33	0.26		-0.18	4.06
12	1.76						1.62				0.55	0.76		4.69
13		4.13						2.39				0.77	-0.29	7.00
T_j (3)	6.99	13.65	5.10	8.93	15.33	14.29	8.49	9.22	-0.45	1.39	2.17	2.22	-1.12 (4)	86.21

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	2.97		2.97						2.97				2.97
2	11.30	11.30		11.30						11.30			
3		7.67	7.67		7.67						7.67		
4			5.43	5.43		5.43						5.43	
5				8.60	8.60		8.60						8.60
6	11.52				11.52	11.52		11.52					
7		9.31				9.31	9.31		9.31				
8			4.95				4.95	4.95		4.95			
9				6.09				6.09	6.09		6.09		
10					2.62				2.62	2.62		2.62	
11						4.06				4.06	4.06		4.06
12	4.69						4.69				4.69	4.69	
13		7.00						7.00				7.00	7.00
B_j (6)	30.48	35.28	21.02	31.42	30.41	30.32	27.55	29.56	20.99	22.93	22.51	19.74	22.63
(7)	62.91	122.85	45.90	80.37	137.97	128.61	76.41	82.98	-4.05	12.51	19.53	19.98	-10.08
(8)	-365.76	-423.36	-252.24	-377.04	-364.92	-363.84	-330.60	-354.72	-251.88	-275.16	-270.12	-236.88	-271.56
(9)	258.63	258.63	258.63	258.63	258.63	258.63	258.63	258.63	258.63	258.63	258.63	258.63	258.63
W_j (10)	-44.22	-41.88	52.29	-38.04	31.68	23.40	4.44	-13.11	2.70	-4.02	8.04	41.73	-23.01
Y_j	6.18	12.88	6.06	8.23	15.91	14.72	8.57	8.98	-0.40	1.32	2.32	2.98	-1.54
Corrected Avg. Visc. Losses ($Y_j/4$)	1.55	3.22	1.51	2.06	3.98	3.68	2.14	2.25	-0.10	0.33	0.58	0.75	-0.39
Uncorrected Avg. Visc. Losses (Raw Avg)	1.75	3.41	1.28	2.23	3.83	3.57	2.12	2.31	-0.11	0.35	0.54	0.56	-0.28

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	0.3409	3	0.1136	0.5629
(12) Cars Adj.	8.5415	12 E_b	0.7117	3.5267*
(13) Oils	94.6401	12	7.8866	39.0812*
(14) Error	4.8438	24 E_e	0.2018	
(5) Total	108.3663	51		

Uncorrected Sum Of Sq. = 251.2925

Correction Term C = 142.9262

μ = $\frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

μ = $\frac{0.7117 - 0.2018}{39(0.7117)}$

μ = 0.0183 (Car Correction Factor)

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-5

ANALYSIS OF FIELD TEST DATA

FLEET C — DRAIN PROCESSOR C

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	I	II	III	IV	CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	-0.34	2.00	1.97	1.29	1	2.00		1.97						1.29				-0.34	4.92
2	2.06	3.28	2.38	1.23	2	2.06	3.28		2.38						1.23				8.95
3	2.64	1.31	3.21	0.46	3		2.64	1.31		3.21						0.46			7.62
4	0.98	1.51	3.24	0.48	4			0.98	1.51		3.24						0.48		6.21
5	1.57	3.73	1.45	-0.08	5				1.57	3.73		1.45						-0.08	6.67
6	2.76	2.46	1.06	0.79	6	0.79				2.76	2.46		1.06						7.07
7	3.42	2.16	0.65	2.60	7		2.60				3.42	2.16		0.65					8.83
8	1.88	1.84	-0.21	1.13	8			1.13				1.88	1.84		-0.21				4.64
9	2.19	-0.45	0.57	2.19	9				2.19				2.19	-0.45		0.57			4.50
10	-1.85	-1.25	-0.36	2.68	10					2.68				-1.85	-1.25		-0.36		-0.78
11	0.46	0.83	-0.09	4.07	11						4.07				0.46	0.83		-0.09	5.27
12	0.67	1.03	2.17	2.27	12	2.17						2.27				0.67	1.03		6.14
13	0.38	-0.21	2.74	2.86	13		2.74						2.86				0.38	-0.21	5.77
A_j (1)	16.82	18.24	18.78	21.97	T_j (3)	7.02	11.26	5.39	7.65	12.38	13.19	7.76	7.95	-0.36	0.23	2.53	1.53	-0.72	(4) 75.81

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio	
(11) Phases	1.0915	3	0.3638	3.8660	*
(12) Cars Adj.	13.5478	12 E_b	1.1289	11.9968	*
(13) Oils	70.4142	12	5.8678	62.3570	*
(14) Error	2.2606	24 E_e	0.0941		
(5) Total	87.3141	51			

Uncorrected Sum of Sq. = 197.8363

Correction Term C = 110.5222

$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mu = \frac{1.1289 - 0.0941}{44.0271}$

μ = 0.0235 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	4.92		4.92						4.92				4.92
2	8.95	8.95		8.95						8.95			
3		7.62	7.62		7.62						7.62		
4			6.21	6.21		6.21						6.21	
5				6.67	6.67		6.67						6.67
6	7.07				7.07	7.07		7.07					
7		8.83				8.83	8.83		8.83				
8			4.64				4.64	4.64		4.64			
9				4.50				4.50	4.50		4.50		
10					-0.78				-0.78	-0.78		-0.78	
11						5.27				5.27	5.27		5.27
12	6.14						6.14				6.14	6.14	
13		5.77						5.77				5.77	5.77
(6)	27.08	31.17	23.39	26.33	20.58	27.38	26.28	21.98	17.47	18.08	23.53	17.34	22.63
(7)	63.18	101.34	48.51	68.85	111.42	118.71	69.84	71.55	-3.24	2.07	22.77	13.77	-6.48
(8)	-324.96	-374.04	-280.68	-315.96	-246.96	-328.56	-315.36	-263.76	-209.64	-216.96	-282.36	-208.08	-271.56
(9)	227.43	227.43	227.43	227.43	227.43	227.43	227.43	227.43	227.43	227.43	227.43	227.43	227.43
W_j (10)	-34.35	-45.27	-4.74	-19.68	91.89	17.58	-18.09	35.22	14.55	12.54	-32.16	33.12	-50.61
Y_j	6.2128	10.1962	5.2787	7.1876	14.5394	13.6031	7.3349	8.7776	-0.0181	0.5246	1.7743	2.3083	-1.9093
Corrected Avg. Visc. Losses ($Y_j/4$)	1.55	2.55	1.32	1.80	3.63	3.40	1.83	2.19	0.00	0.13	0.44	0.58	-0.48
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.76	2.82	1.35	1.91	3.10	3.30	1.94	1.99	-0.09	0.06	0.63	0.38	-0.18

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-6

ANALYSIS OF FIELD TEST DATA

FLEET C

DRAIN PROCESSOR D

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

CARS	PHASES I	II	III	IV
1	-0.13	1.94	2.26	0.84
2	2.07	3.24	1.92	2.29
3	2.82	1.53	3.71	0.59
4	1.14	1.41	3.17	0.52
5	1.53	4.01	1.73	-0.13
6	3.04	2.39	1.01	0.46
7	3.20	2.08	0.87	2.39
8	1.86	1.84	-0.16	1.21
9	2.23	-0.19	0.58	1.76
10	-1.68	-0.98	-0.36	2.88
11	0.49	0.78	0.03	4.12
12	0.62	0.84	2.11	2.78
13	0.47	-0.08	2.61	2.40
T_j (3)				
A_j (1)	17.66	18.81	19.48	22.11

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

CARS	OILS 101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.94		2.26						0.84				-0.13	4.91
2	2.07	3.24		1.92						2.29				9.52
3		2.82	1.53		3.71						0.59			8.65
4			1.14	1.41		3.17						0.52		6.24
5				1.53	4.01		1.73						-0.13	7.14
6	0.46				3.04	2.39		1.01						6.90
7		2.39				3.20	2.08		0.87					8.54
8			1.21				1.86	1.84		-0.16				4.75
9				1.76				2.23	-0.19		0.58			4.38
10					2.88				-1.68	-0.98		-0.36		-0.14
11						4.12				0.49	0.78		0.03	5.42
12	2.11						2.78				0.62	0.84		6.35
13		2.61						2.40				0.47	-0.08	5.40
T_j (3)	6.58	11.06	6.14	6.62	13.64	12.88	8.45	7.48	-0.16	1.64	2.57	1.47	-0.31(4)	78.06

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phase	0.8210	3	0.2736	2.3565
(12) Cars Adj.	14.7355	12 E_b	1.2279	10.5762*
(13) Oils	67.3245	12	5.6103	48.3229*
(14) Error	2.7882	24 E_e	0.1161	
(5) Total	85.6692	51		

Uncorrected Sum Of Sq. = 202.8492

Correction Term C = 117.1800

μ = $\frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

μ = $\frac{1.2279 - 0.1161}{47.8881}$

μ = 0.0232 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	4.91		4.91						4.91				4.91
2	9.52	9.52		9.52						9.52			
3		8.65	8.65		8.65						8.65		
4			6.24	6.24		6.24						6.24	
5				7.14	7.14		7.14						7.14
6	6.90				6.90	6.90		6.90					
7		8.54				8.54	8.54		8.54				
8			4.75				4.75	4.75		4.75			
9				4.38				4.38	4.38		4.38		
10					-0.14				-0.14	-0.14		-0.14	
11						5.42				5.42	5.42		5.42
12	6.35						6.35				6.35	6.35	
13		5.40						5.40				5.40	5.40
(6)	27.68	32.11	24.55	27.28	22.55	27.10	26.78	21.43	17.69	19.55	24.80	17.85	22.87
(7)	59.22	99.54	55.26	59.58	122.76	115.92	76.05	67.32	-1.44	14.76	23.13	13.23	-2.79
(8)	+332.16	+385.32	+294.60	+327.36	+270.60	+325.20	+321.36	+257.16	+212.28	+234.60	+297.60	+214.20	+274.44
(9)	234.18	234.18	234.18	234.18	234.18	234.18	234.18	234.18	234.18	234.18	234.18	234.18	234.18
(10)	-38.76	-51.60	-5.16	-33.60	86.34	24.90	-11.13	44.34	20.46	14.34	-40.29	33.21	-43.05
Y_j	5.6808	9.8629	6.0203	5.8405	15.6430	13.4576	8.1918	8.5086	0.3146	1.9726	1.6353	2.2404	-1.3087
Corrected Avg. Visc. Losses ($Y_j/4$)	1.42	2.47	1.51	1.46	3.91	3.36	2.05	2.13	0.08	0.49	0.41	0.56	-0.33
Uncorrected Avg. Visc. Losses Raw Avg.	1.65	2.77	1.54	1.66	3.41	3.22	2.11	1.87	-0.04	0.41	0.64	0.37	-0.08

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-7

ANALYSIS OF FIELD TEST DATA

FLEET C

DRAIN PROCESSOR K

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.37	2.01	2.11	1.10
2	1.95	3.38	2.24	1.35
3	2.75	1.45	3.31	0.47
4	1.10	1.33	3.22	0.47
5	1.59	3.68	1.37	-0.17
6	2.72	2.48	0.98	0.64
7	3.41	2.12	0.56	2.63
8	1.88	1.80	-0.12	1.20
9	2.24	-0.39	0.58	2.41
10	-1.86	-0.86	-0.38	2.57
11	0.55	0.69	-0.25	3.99
12	0.55	0.92	2.04	2.15
13	0.44	-0.23	2.87	2.69
A_j (1)	16.95	18.38	18.53	21.50

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	2.01		2.11						1.10				-0.37	4.85
2	1.95	3.38		2.24						1.35				8.92
3		2.75	1.45		3.31						0.47			7.98
4			1.10	1.33		3.22						0.47		6.12
5				1.59	3.68		1.37						-0.17	6.47
6	0.64				2.72	2.48		0.98						6.82
7		2.63				3.41	2.12		0.56					8.72
8			1.20				1.88	1.80		-0.12				4.76
9				2.41				2.24	-0.39		0.58			4.84
10					2.57				-1.86	-0.86		-0.38		-0.53
11						3.99				0.55	0.69		-0.25	4.98
12	2.04						2.15				0.55	0.92		5.66
13		2.87						2.69				0.44	-0.23	5.77
T_i (3)	6.64	11.63	5.86	7.57	12.28	13.10	7.52	7.71	-0.59	0.92	2.29	1.45	-1.02 (4)	75.36

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	4.85		4.85						4.85				4.85
2	8.92	8.92		8.92						8.92			
3		7.98	7.98		7.98						7.98		
4			6.12	6.12		6.12						6.12	
5				6.47	6.47		6.47						6.47
6	6.82				6.82	6.82		6.82					
7		8.72				8.72	8.72		8.72				
8			4.76				4.76	4.76		4.76			
9				4.84				4.84	4.84		4.84		
10					-0.53				-0.53	-0.53		-0.53	
11						4.98				4.98	4.98		4.98
12	5.66						5.66				5.66	5.66	
13		5.77						5.77				5.77	5.77
B_j (6)	26.25	31.39	23.71	26.35	20.74	26.64	25.61	22.19	17.88	18.13	23.46	17.02	22.07
(7)	59.76	104.67	52.74	68.13	110.52	117.90	67.68	69.39	-5.31	8.28	20.61	13.05	-9.18
(8)	-315.00	-376.68	-284.52	-316.20	-248.88	-319.68	-307.32	-266.28	-214.56	-217.56	-281.52	-204.24	-264.84
(9)	226.08	226.08	226.08	226.08	226.08	226.08	226.08	226.08	226.08	226.08	226.08	226.08	226.08
W_j (10)	-29.16	-45.93	-5.70	-21.99	87.72	24.30	-13.56	29.19	6.21	16.80	-34.83	34.89	-47.94
Y_j	5.9577	10.5553	5.7267	7.0555	14.3361	13.6686	7.2027	8.3930	-0.4447	1.3131	1.4750	2.2664	-2.1417
Corrected Avg. Visc. Losses ($Y_j/4$)	1.49	2.64	1.43	1.76	3.58	3.42	1.80	2.10	-0.11	0.33	0.37	0.57	-0.54
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.66	2.91	1.47	1.89	3.07	3.28	1.88	1.93	-0.15	0.23	0.57	0.36	-0.26

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	0.8427	3	0.2809	3.1073
(12) Cars Adj.	12.7112	12 E_b	1.0592	11.7168 *
(13) Oils	70.5298	12	5.8774	65.0154 *
(14) Error	2.1719	24 E_e	0.0904	
(5) Total	86.2556	51		

Uncorrected Sum Of Sq. = 195.4696

Correction Term C = 109.2140

$\mu = \frac{E_b - E_e}{39\,E_b}$ for $E_b > E_e$

$\mu = \frac{1.0592 - 0.0904}{39(1.0592)}$

$\mu = \frac{0.9688}{41.3088} = 0.0234$ (Car Correction Factor)

* Significant at the 95% confidence level.

APPENDIX D

TABLE D-8

ANALYSIS OF FIELD TEST DATA

FLEET D — DRAIN PROCESSOR D

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.04	2.06	2.23	1.17
2	2.05	3.28	2.74	1.07
3	3.36	1.77	3.93	0.50
4	2.19	2.38	3.92	0.90
5	2.65	4.63	2.25	0.11
6	4.52	3.69	2.02	1.96
7	3.39	1.99	-0.65	3.20
8	2.32	2.35	0.00	1.77
9	2.33	-0.64	0.34	1.54
10	1.17	0.53	0.83	4.15
11	1.05	1.03	-0.13	4.14
12	1.12	1.22	1.79	2.16
13	0.64	-0.20	2.79	2.05
A_j (1)	26.75	24.09	22.06	24.72

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	2.06		2.23						1.17				-0.04	5.42
2	2.05	3.28		2.74						1.07				9.14
3		3.36	1.77		3.93						0.50			9.56
4			2.19	2.38		3.92						0.90		9.39
5				2.65	4.63		2.25						0.11	9.64
6	1.96				4.52	3.69		2.02						12.19
7		3.20				3.39	1.99		-0.65					7.93
8			1.77				2.32	2.35		0.0				6.44
9				1.54				2.33	-0.64		0.34			3.57
10					4.15				1.17	0.53		0.83		6.68
11						4.14				1.05	1.03		-0.13	6.09
12	1.79						2.16				1.12	1.22		6.29
13		2.79						2.05				0.64	-0.20	5.28
T_j (3)	7.86	12.63	7.96	9.31	17.23	15.14	8.72	8.75	1.05	2.65	2.99	3.59	-0.26(4)	97.62

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phase	0.8613	3	0.2871	3.2477
(12) Cars Adj.	3.8699	12 E_b	0.3224	3.6470 *
(13) Oils	86.7494	12	7.2291	81.7771 *
(14) Error	2.1219	24 E_e	0.0884	
(5) Total	93.6025	51		

Uncorrected Sum Of Sq. = 276.8652

Correction Term C = 183.2627

$\mu = \frac{E_b - E_e}{39\ E_b}$ For $E_b > E_e$

$\mu = \frac{0.3224 - 0.0884}{12.5736}$

μ = 0.0186 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	5.42		5.42						5.42				5.42
2	9.14	9.14		9.14						9.14			
3		9.56	9.56		9.56						9.56		
4			9.39	9.39		9.39						9.39	
5				9.64	9.64		9.64						9.64
6	12.19				12.19	12.19		12.19					
7		7.93				7.93	7.93		7.93				
8			6.44				6.44	6.44		6.44			
9				3.57				3.57	3.57		3.57		
10					6.68				6.68	6.68		6.68	
11						6.09				6.09	6.09		6.09
12	6.29						6.29				6.29	6.29	
13		5.28						5.28				5.28	5.28
(6)	33.04	31.91	30.81	31.74	38.07	35.60	30.30	27.48	23.60	28.35	25.51	27.64	26.43
(7)	70.74	113.67	71.64	83.79	155.07	136.26	78.48	78.75	9.45	23.85	26.91	32.31	-2.34
(8)	-396.48	-382.92	-369.72	-380.88	-456.84	-427.20	-363.60	-329.76	-283.20	-340.20	-306.12	-331.68	-317.16
(9)	292.86	292.86	292.86	292.86	292.86	292.86	292.86	292.86	292.86	292.86	292.86	292.86	292.86
W_j (10)	-32.88	23.61	-5.22	-4.23	-8.91	1.92	7.74	41.85	19.11	-23.49	13.65	-6.51	-26.64
Y_j	7.2485	13.0691	7.8630	9.2314	17.0643	15.1757	8.8639	9.5284	1.4054	2.2131	3.2438	3.4690	-0.7555
Corrected Avg. Visc. Losses ($Y_j/4$)	1.81	3.27	1.97	2.31	4.27	3.79	2.22	2.38	0.35	0.55	0.81	0.87	-0.19
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.97	3.16	1.99	2.33	4.31	3.79	2.18	2.19	0.26	0.66	0.75	0.90	-0.07

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-9

ANALYSIS OF FIELD TEST DATA

FLEET D

DRAIN PROCESSOR C

SECTION 1
210°F Vis. Losses cSt. After 1500 Miles

SECTION 2
210°F Viscosity Losses cSt. After 1500 Miles

CARS	PHASES I	II	III	IV		OILS 101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	-0.13	2.02	1.85	1.14	1	2.02		1.85						1.14				-0.13	4.88
2	2.12	3.24	2.79	0.90	2	2.12	3.24		2.79						0.90				9.05
3	3.42	1.69	3.58	0.43	3		3.42	1.69		3.58						0.43			9.12
4	2.03	2.25	4.00	0.77	4			2.03	2.25		4.00						0.77		9.05
5	2.56	4.36	2.22	0.00	5				2.56	4.36		2.22						0.00	9.14
6	3.85	3.60	1.97	1.97	6	1.97				3.85	3.60		1.97						11.39
7	3.65	1.86	-0.75	3.24	7		3.24				3.65	1.86		-0.75					8.00
8	2.07	2.27	-0.17	1.87	8			1.87				2.07	2.27		-0.17				6.04
9	2.26	-0.79	0.36	1.63	9				1.63				2.26	-0.79		0.36			3.46
10	1.09	0.36	0.76	3.89	10					3.89				1.09	0.36		0.76		6.10
11	0.63	1.04	-0.10	4.14	11						4.14				0.63	1.04		-0.10	5.71
12	0.76	1.07	1.91	1.98	12	1.91						1.98				0.76	1.07		5.72
13	0.57	-0.03	2.69	2.05	13		2.69						2.05				0.57	-0.03	5.28
A_j (1)	24.88	22.94	21.11	24.01	T_j (3)	8.02	12.59	7.44	9.23	15.68	15.39	8.13	8.55	0.69	1.72	2.59	3.17	-0.26 (4)	92.94

SECTION 4
ANALYSIS OF VARIANCE

SECTION 3 - OILS

Source	S.S.	D.F.	Mean Sq.	F Ratio	CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
(11) Phases	0.6084	3	0.2028	1.8639	1	4.88		4.88						4.88				4.88
(12) Cars Adj.	3.2021	12 E_b	0.2668	2.4522*	2	9.05	9.05		9.05						9.05			
(13) Oils	85.2747	12	7.1062	65.3143*	3		9.12	9.12		9.12						9.12		
(14) Error	2.6125	24 E_e	0.1088		4			9.05	9.05		9.05						9.05	
(5) Total	91.6941	51			5				9.14	9.14		9.14						9.14
					6	11.39				11.39	11.39		11.39					
Uncorrected Sum of Sq. =				257.8064	7		8.00				8.00	8.00		8.00				
					8			6.04				6.04	6.04		6.04			
Correction Term C =				166.1123	9				3.46				3.46	3.46		3.46		
					10					6.10				6.10	6.10		6.10	
$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b \geq E_e$					11						5.71				5.71	5.71		5.71
					12	5.72						5.72				5.72	5.72	
					13		5.28						5.28				5.28	5.28
$\mu = \frac{0.2268 - 0.1088}{10.4052}$					(6)	31.04	31.45	29.09	30.70	35.75	34.15	28.90	26.17	22.44	26.90	24.01	26.15	25.01
μ = 0.0151 (Car Correction Factor)					(7)	72.18	113.31	66.96	83.07	141.12	138.51	73.17	76.95	6.21	15.48	23.31	28.53	-2.34
					(8)	-372.48	-377.40	-349.08	-368.40	-429.00	-409.80	-346.80	-314.04	-269.28	-322.80	-288.12	-313.80	-300.12
					(9)	278.82	278.82	278.82	278.82	278.82	278.82	278.82	278.82	278.82	278.82	278.82	278.82	278.82
					W_j (10)	-21.48	14.73	-3.30	-6.51	-9.06	7.53	5.19	41.73	15.75	-28.50	14.01	-6.45	-23.64
					Y_j	7.6957	12.8124	7.3902	9.1317	15.5432	15.5037	8.2083	9.1801	0.9278	1.2897	2.8015	3.0727	-0.6169
Corrected Avg. Visc. Losses					(Y_j/4)	1.92	3.20	1.85	2.28	3.89	3.88	2.05	2.30	0.23	0.32	0.70	0.77	-0.15
Uncorrected Avg. Visc. Losses					(Raw Avg.)	2.01	3.15	1.86	2.31	3.92	3.85	2.03	2.14	0.17	0.43	0.65	0.79	-0.07

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-10

ANALYSIS OF FIELD TEST DATA

FLEET D

DRAIN PROCESSOR G

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.03	1.91	2.24	1.19
2	2.02	3.31	2.91	1.04
3	3.33	1.77	3.92	1.09
4	2.29	2.24	3.94	0.80
5	2.51	4.57	2.42	0.07
6	4.26	4.00	1.84	1.13
7	3.44	2.01	-0.98	3.32
8	2.11	2.33	0.08	2.03
9	2.25	-0.86	0.33	1.57
10	0.54	0.54	0.84	4.19
11	0.86	1.09	-0.08	4.19
12	0.98	1.14	1.79	2.08
13	0.60	-0.17	2.84	2.07
A_j (1)	25.16	23.88	22.09	24.77

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.91		2.24						1.19				-0.03	5.31
2	2.02	3.31		2.91						1.04				9.28
3		3.33	1.77		3.92						1.09			10.11
4			2.29	2.24		3.94						0.80		9.27
5				2.51	4.57		2.42						0.07	9.57
6	1.13				4.26	4.00		1.84						11.23
7		3.32				3.44	2.01		-0.98					7.79
8			2.03				2.11	2.33		0.08				6.55
9				1.57				2.25	-0.86		0.33			3.29
10					4.19				0.54	0.54		0.84		6.11
11						4.19				0.86	1.09		-0.08	6.06
12	1.79						2.08				0.98	1.14		5.99
13		2.84						2.07				0.60	-0.17	5.34
T_j (3)	6.85	12.80	8.33	9.23	16.94	15.57	8.62	8.49	-0.11	2.52	3.49	3.38	-0.21(4)	95.90

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	0.4306	3	0.1435	1.4364
(12) Cars Adj.	4.2217	12 E_b	0.3518	3.5215*
(13) Oils	90.9204	12	7.5767	75.8428*
(14) Error	2.3982	24 E_e	0.0999	
(5) Total	97.9709	51		

Uncorrected Sum of Sq. = 274.8326

Correction Term C = 176.8617

$t = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$t = \frac{0.3518 - 0.0999}{13.7202}$

t = 0.0183 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	5.31		5.31						5.31				5.31
2	9.28	9.28		9.28						9.28			
3		10.11	10.11		10.11						10.11		
4			9.27	9.27		9.27						9.27	
5				9.57	9.57		9.57						9.57
6	11.23				11.23	11.23		11.23					
7		7.79				7.79	7.79		7.79				
8			6.55				6.55	6.55		6.55			
9				3.29				3.29	3.29		3.29		
10					6.11				6.11	6.11		6.11	
11						6.06				6.06	6.06		6.06
12	5.99						5.99				5.99	5.99	
13		5.34						5.34				5.34	5.34
(6)	31.81	32.52	31.24	31.41	37.02	34.35	29.90	26.41	22.50	28.00	25.45	26.71	26.28
(7)	61.65	115.20	74.97	83.07	152.46	140.13	77.58	76.41	-0.99	22.68	31.41	30.42	-1.89
(8)	-381.72	-390.24	-374.88	-376.92	-444.24	-412.20	-358.80	-316.92	-270.00	-336.00	-305.40	-320.52	-315.36
(9)	287.70	287.70	287.70	287.70	287.70	287.70	287.70	287.70	287.70	287.70	287.70	287.70	287.70
W_j (10)	-32.37	12.66	-12.21	-6.15	-4.08	15.63	6.48	47.19	16.71	-25.62	13.71	-2.40	-29.55
Y_j	6.2577	13.0316	8.1066	9.1175	16.8654	15.8560	8.7385	9.3535	0.1957	2.0512	3.7408	3.3361	-0.7507
Corrected Avg. Visc. Losses ($Y_j/4$)	1.56	3.26	2.03	2.28	4.22	3.96	2.18	2.34	0.05	0.51	0.94	0.83	-0.19
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.71	3.20	2.08	2.31	4.24	3.89	2.16	2.12	-0.03	0.63	0.87	0.85	-0.05

* Significant st the 95% Confidence level.

APPENDIX D

TABLE D-11

ANALYSIS OF FIELD TEST DATA

FLEET E — DRAIN PROCESSOR G

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.11	1.38	1.02	-0.29
2	1.74	3.12	1.80	0.25
3	3.47	2.47	5.55	1.75
4	1.99	1.95	3.86	0.90
5	2.53	4.00	1.97	-0.18
6	4.52	4.18	3.13	1.77
7	4.16	1.80	-0.47	4.03
8	2.79	2.16	0.28	1.34
9	2.23	-0.04	0.41	1.11
10	-0.43	0.06	0.55	4.55
11	0.67	0.95	-0.06	4.32
12	0.90	1.04	2.33	2.99
13	1.00	-0.05	3.35	2.66
A_j (1)	25.46	23.02	23.72	25.20

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.38		1.02						-0.29				-0.11	2.00
2	1.74	3.12		1.80						0.25				6.91
3		3.47	2.47		5.55						1.75			13.24
4			1.99	1.95		3.86						0.90		8.70
5				2.53	4.00		1.97						-0.18	8.32
6	1.77				4.52	4.18		3.13						13.60
7		4.03				4.16	1.80		-0.47					9.52
8			1.34				2.79	2.16		0.28				6.57
9				1.11				2.23	-0.04		0.41			3.71
10					4.55				-0.43	0.06		0.55		4.73
11						4.32				0.67	0.95		-0.06	5.88
12	2.33						2.99				0.90	1.04		7.26
13		3.35						2.66				1.00	-0.05	6.96
T_j (3)	7.22	13.97	6.82	7.39	18.62	16.52	9.55	10.18	-1.23	1.26	4.01	3.49	-0.40	(4) 97.40

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	0.3170	3	0.1056	0.7106
(12) Cars Adj.	3.7285	12 E_b	0.3107	2.0908
(13) Oils	116.1584	12	9.6798	65.1399*
(14) Error	3.5677	24 E_e	0.1486	
(5) Total	123.7716	51		

Uncorrected Sum of Sq. = 306.2092

Correction Term C = 182.4376

μ = $\frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

μ = $\frac{0.3107 - 0.1486}{12.1176}$

μ = 0.0133 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	2.00		2.00						2.00				2.00
2	6.91	6.91		6.91						6.91			
3		13.24	13.24		13.24						13.24		
4			8.70	8.70		8.70						8.70	
5				8.32	8.32		8.32						8.32
6	13.60				13.60	13.60		13.60					
7		9.52				9.52	9.52		9.52				
8			6.57				6.57	6.57		6.57			
9				3.71				3.71	3.71		3.71		
10					4.73				4.73	4.73		4.73	
11						5.88				5.88	5.88		5.88
12	7.26						7.26				7.26	7.26	
13		6.96						6.96				6.96	6.96
(6)	29.77	36.63	30.51	27.64	39.89	37.70	31.67	30.84	19.96	24.09	30.09	27.65	23.16
(7)	64.98	125.73	61.38	66.51	167.58	148.68	85.95	91.62	-11.07	11.34	36.09	31.41	-3.60
(8)	+357.24	+439.56	+366.12	+331.68	+478.68	+452.40	+380.04	+370.08	+239.52	+289.08	+361.08	+331.80	-277.92
(9)	292.20	292.20	292.20	292.20	292.20	292.20	292.20	292.20	292.20	292.20	292.20	292.20	292.20
(10)	-0.06	-21.63	-12.54	27.03	-18.90	-11.52	-1.89	13.74	41.61	14.46	-32.79	-8.19	10.68
Y_j	7.2193	13.6824	6.6533	7.7494	18.3687	16.3668	9.5249	10.3627	-0.6766	1.4523	3.5739	3.3811	-0.2580
Corrected Avg. Visc. Losses (Y_j/4)	1.80	3.42	1.66	1.94	4.59	4.09	2.38	2.59	-0.17	0.36	0.89	0.85	-0.06
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.81	3.49	1.71	1.85	4.66	4.13	2.39	2.55	-0.31	0.32	1.00	0.87	-0.10

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-12

ANALYSIS OF FIELD TEST DATA

FLEET E

DRAIN PROCESSOR R

SECTION 1

210°F Viscosity Losses cSt. After 1500 Miles

CARS	PHASES I	II	III	IV
1	-0.07	1.37	1.16	-0.05
2	1.70	3.21	1.90	0.26
3	3.42	2.53	5.43	1.26**
4	2.06	2.04	3.85	0.88
5	2.58	4.04	2.12	-0.12
6	4.53	3.95	3.28	1.75
7	3.96	1.85	-0.35	4.21
8	2.85	2.18	-0.15	1.57
9	2.16	0.20	0.44	2.35
10	-0.56	0.07	0.58	4.67
11	0.78	0.91	-0.03	4.84
12	0.85	0.96	2.21	3.36
13	0.94	-0.10	3.38	2.90
T_j (3)				
A_j (1)	25.20	23.21	23.82	27.88

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

CARS	OILS 101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	1.37		1.16						-0.05				-0.07	2.41
2	1.70	3.21		1.90						0.26				7.07
3		3.42	2.53		5.43						1.26**			12.64
4			2.06	2.04		3.85						0.88		8.83
5				2.58	4.04		2.12						-0.12	8.62
6	1.75				4.53	3.95		3.28						13.51
7		4.21				3.96	1.85		-0.35					9.67
8			1.57				2.85	2.18		-0.15				6.45
9				2.35				2.16	0.20		0.44			5.15
10					4.67				-0.56	0.07		0.58		4.76
11						4.84				0.78	0.91		-0.03	6.50
12	2.21						3.36				0.85	0.96		7.38
13		3.38						2.90				0.94	-0.10	7.12
T_j (3)	7.03	14.22	7.32	8.87	18.67	16.60	10.18	10.52	-0.76	0.96	3.46	3.36	-0.32 (4)	100.11

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S	D.F.	Mean Sq.	F Ratio
(11) Phase	0.9944	3	0.3314	2.2498
(12) Cars Adj.	3.1318	12 E_b	0.2609	1.7712
(13) Oils	119.0647	12	9.9220	67.3591*
(14) Error	3.3900	23 E_e	0.1473	
(5) Total	126.5809	50		

Uncorrected Sum of Sq. = 319.3119

Correction Term C = 192.7310

μ = $\frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

μ = $\frac{0.2609 - 0.1473}{10.1751}$

μ = 0.0111 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	2.41		2.41						2.41				2.41
2	7.07	7.07		7.07						7.07			
3		12.64	12.64		12.64						12.64		
4			8.83	8.83		8.83						8.83	
5				8.62	8.62		8.62						8.62
6	13.51				13.51	13.51		13.51					
7		9.67				9.67	9.67		9.67				
8			6.45				6.45	6.45		6.45			
9				5.15				5.15	5.15		5.15		
10					4.76				4.76	4.76		4.76	
11						6.50				6.50	6.50		6.50
12	7.38						7.38				7.38	7.38	
13		7.12						7.12				7.12	7.12
(6)	30.37	36.50	30.33	29.67	39.53	38.51	32.12	32.23	21.99	24.78	31.67	28.09	24.65
(7)	63.27	127.98	65.88	79.83	168.03	149.40	91.62	94.68	-6.84	8.64	31.14	30.24	-2.88
(8)	-364.44	-438.00	-363.96	-356.04	-474.36	-462.12	-385.44	-386.76	-263.88	-297.36	-380.04	-337.08	-295.80
(9)	300.33	300.33	300.33	300.33	300.33	300.33	300.33	300.33	300.33	300.33	300.33	300.33	300.33
W_j (10)	-0.84	-9.69	2.25	24.12	-6.00	-12.39	6.51	8.25	29.61	11.61	-48.57	-6.51	1.65
Y_j	7.02	14.11	7.34	9.14	18.60	16.46	10.25	10.61	-0.43	1.09	2.92	3.29	-0.30
Corrected Avg. Visc. Losses ($Y_j/4$)	1.76	3.53	1.84	2.29	4.65	4.12	2.56	2.65	-0.11	0.27	0.73	0.82	-0.08
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.76	3.56	1.83	2.22	4.67	4.15	2.55	2.63	-0.19	0.24	0.87	0.84	-0.08

* Significant at the 95% Confidence level.

** Missing Data Filled in By Method of Cochran and Cox, Experimental Designs, Second Edition.

APPENDIX D

TABLE D-13

ANALYSIS OF FIELD TEST DATA

FLEET F — DRAIN PROCESSOR H

SECTION 1

210°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.65	0.69	0.18	-1.45
2	1.19	2.16	0.91	-0.88
3	2.12	2.11	4.00	1.00
4	2.06	1.84	3.63	0.74
5	2.03	4.92	2.96	-0.82
6	3.78	4.16**	2.60	1.92
7	4.24	2.05	0.51	3.37
8	1.73	2.26	0.85	2.41
9	2.68	0.59	0.25	2.46
10	0.10	-0.03	0.62	3.72
11	0.65	0.94	-0.65	4.45
12	0.30**	0.63**	0.99	2.19
13	0.79	-0.06	2.67**	2.94**
T_j (3)	4.79	10.32	6.76	7.24
A_j (1)	21.02	22.26	19.52	22.05

SECTION 2

210°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	0.69		0.18						-1.45				-0.65	-1.23
2	1.19	2.16		0.91						-0.88				3.38
3		2.12	2.11		4.00						1.00			9.23
4			2.06	1.84		3.63						0.74		8.27
5				2.03	4.92		2.96						-0.82	9.09
6	1.92				3.78	4.16**		2.60						12.46
7		3.37				4.24	2.05		0.51					10.17
8			2.41				1.73	2.26		0.85				7.25
9				2.46				2.68	0.59		0.25			5.98
10					3.72				0.10	-0.03		0.62		4.41
11						4.45				0.65	0.94		-0.65	5.39
12	0.99						2.19				0.30**	0.63**		4.11
13		2.67**						2.94**				0.79	-0.06	6.34
T_j (3)	4.79	10.32	6.76	7.24	16.42	16.48	8.93	10.48	-0.25	0.59	2.49	2.78	-2.18(4)	84.85

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mesn Sq.	F Ratio
(11) Phases	0.3616	3	0.1205	0.4088
(12) Cars Adj.	7.9990	12 E_b	0.6665	2.2612*
(13) Oils	105.9065	12	8.8255	29.9474*
(14) Error	5.6011	19 E_e	0.2947	
(5) Total	119.8682	46		

Uncorrected Sum of Sq. = 258.3205

Correction Term C = 138.4523

μ = $\frac{E_b - E_e}{39\ E_b}$ for $E_b > E_d$

μ = $\frac{2.2616 - 0.2947}{88.2024}$

μ = 0.0222 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	-1.23		-1.23						-1.23				-1.23
2	3.38	3.38		3.38						3.38			
3		9.23	9.23		9.23						9.23		
4			8.27	8.27		8.27						8.27	
5				9.09	9.09		9.09						9.09
6	12.46				12.46	12.46		12.46					
7		10.17				10.17	10.17		10.17				
8			7.25				7.25	7.25		7.25			
9				5.98				5.98	5.98		5.98		
10					4.41				4.41	4.41		4.41	
11						5.39				5.39	5.39		5.39
12	4.11						4.11				4.11	4.11	
13		6.34						6.34				6.34	6.34
(6)	18.72	29.12	23.52	26.72	35.19	36.29	30.62	32.03	19.33	20.43	24.71	23.13	19.59
(7)	43.11	92.88	60.84	65.16	147.78	148.32	80.37	94.32	-2.25	5.31	22.41	25.02	-19.62
(8)	-224.64	-349.44	-282.24	-320.64	-422.28	-435.48	-367.44	-384.36	-231.96	-245.16	-296.52	-277.56	-235.08
(9)	254.55	254.55	254.55	254.55	254.55	254.55	254.55	254.55	254.55	254.55	254.55	254.55	254.55
(10)	73.02	-2.01	33.15	-0.93	-19.95	-32.61	-32.52	-35.49	20.34	14.70	-19.56	2.01	-0.15
Y_j	6.4110	10.2754	7.4959	7.2194	15.9772	15.7561	8.2081	9.6922	0.2015	0.9163	2.0558	2.8246	-2.1833
Corrected Avg. Visc. Losses ($Y_j/4$)	1.60	2.57	1.87	1.80	3.99	3.94	2.05	2.42	0.05	0.23	0.51	0.71	-0.55
Uncorrected Avg. Visc. Losses (Raw Avg.)	1.20	2.58	1.69	1.81	4.11	4.12	2.23	2.62	-0.06	0.15	0.62	0.70	-0.55

* Significant at the 95% Confidence Level.

** Missing Data Filled in by Method of Cochran and Cox, Experimental Designs, Second Edition.

APPENDIX D

TABLE D-14

ANALYSIS OF FIELD TEST DATA

FLEET A

DRAIN PROCESSOR A

SECTION 1

100° F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-4.90	3.45	8.18	-9.33
2	7.63	15.76	19.65	6.44
3	17.33	15.11	21.35	8.63
4	10.51	15.83	10.25	1.87
5	18.89	15.60	10.81	-1.40
6	16.74	9.77	13.32	4.52
7	11.22	9.63	-5.77	11.75
8	11.01	17.67	2.10	12.99
9	19.89	-10.87	3.25	16.73
10	-4.73	0.10	4.23	15.67
11	0.60	2.25	-0.49	12.97
12	0.83	3.15	2.44	11.73
13	6.38	-1.03	14.50	17.66
A_j (1)	111.40	96.42	103.82	110.23

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	3.45		8.18						-9.33				-4.90	-2.60
2	7.63	15.76		19.65						6.44				49.48
3		17.33	15.11		21.35						8.63			62.42
4			10.51	15.83		10.25						1.87		38.46
5				18.89	15.60		10.81						-1.40	43.90
6	4.52				16.74	9.77		13.32						44.35
7		11.75				11.22	9.63		-5.77					26.83
8			12.99				11.01	17.67		2.10				43.77
9				16.73				19.89	-10.87		3.25			29.00
10					15.67				-4.73	0.10		4.23		15.27
11						12.97				0.60	2.25		-0.49	15.33
12	2.44						11.73				0.83	3.15		18.15
13		14.50						17.66				6.38	-1.03	37.51
T_j (3)	18.04	59.34	46.79	71.10	69.36	44.21	43.18	68.54	-30.70	9.24	14.96	15.63	-7.824)	421.87

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	10.9575	3	3.6525	1.4979
(12) Cars Adj	160.2631	12 E_b	13.3552	5.4770*
(13) Oils	3071.3992	12	255.9491	104.9660*
(14) Error	58.5235	24 E_e	2.4384	
(5) Total	3301.1333	51		

Uncorrected Sum of Sq. = 6723.7159

Correction Term C = 6422.5826

$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mu = \frac{13.3552 - 2.4384}{520.8528}$

$\mu =$ 0.0209 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	-2.60		-2.60						-2.60				-2.60
2	49.48	49.48		49.48						49.48			
3		62.42	62.42		62.42						62.42		
4			38.46	38.46		38.46						38.46	
5				43.90	43.90		43.90						43.90
6	44.35				44.35	44.35		44.35					
7		26.83				26.83	26.83		26.83				
8			43.77				43.77	43.77		43.77			
9				29.00				29.00	29.00		29.00		
10					15.27				15.27	15.27		15.27	
11						15.33				15.33	15.33		15.33
12	18.15						18.15				18.15	18.15	
13		37.51						37.51				37.51	37.51
(6)	109.38	176.24	142.05	160.84	165.94	124.97	132.65	154.63	68.50	123.85	124.90	109.39	94.14
(7)	162.36	534.06	421.11	639.90	624.24	397.89	388.62	616.86	-276.30	83.16	134.64	140.67	-70.38
(8)	-1312.56	-2114.88	-1704.60	-1930.08	-1991.28	-1499.64	-1591.80	-1855.56	-822.00	-1486.20	-1498.80	-1312.68	-1129.68
(9)	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61	1265.61
W_j (10)	115.41	-315.21	-17.88	-24.57	-101.43	163.86	62.43	26.91	167.31	-137.43	-98.55	93.60	65.55
Y_j	20.4520	52.7524	46.4164	70.5865	67.2402	47.6346	44.4847	69.1024	-27.2033	6.3678	12.9004	17.5862	-6.4501
Corrected Avg. Visc. Losses (Y_j/4)	5.11	13.19	11.60	17.65	16.81	11.91	11.12	17.28	-6.80	1.59	3.23	4.40	-1.61
Uncorrected Avg. Visc. Losses (Raw Avg.)	4.51	14.84	11.70	17.78	17.34	11.05	10.80	17.14	-7.68	2.31	3.74	3.91	-1.96

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-15

ANALYSIS OF FIELD TEST DATA

FLEET 8 — DRAIN PROCESSOR B

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-2.68	5.32	8.94	-11.00
2	9.49	22.16	16.28	9.31
3	-0.79	8.41	15.51	1.86
4	1.36	6.80	6.95	-0.91
5	16.23	16.22	12.51	-3.16
6	16.07	10.86	15.27	2.93
7	11.77	9.88	-7.38	13.61
8	8.58	13.90	-6.23	5.76
9	19.20	-11.15	0.92	20.18
10	-23.45	-9.02	1.17	13.68
11	-1.82	-1.44	-2.25	7.99
12	1.62	0.28	6.94	7.32
13	3.27	-3.11	18.33	17.93
A_j (1)	58.85	69.11	86.96	85.50

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	5.32		8.94						-11.00				-2.68	0.58
2	9.49	22.16		16.28						9.31				57.24
3		-0.79	8.41		15.51						1.86			24.99
4			1.36	6.80		6.95						-0.91		14.20
5				16.23	16.22		12.51						-3.16	41.80
6	2.93				16.07	10.86		15.27						45.13
7		13.61				11.77	9.88		-7.38					27.88
8			5.76				8.58	13.90		-6.23				22.01
9				20.18				19.20	-11.15		0.92			29.15
10					13.68				-23.45	-9.02		1.17		-17.62
11						7.99				-1.82	-1.44		-2.25	2.48
12	6.94						7.32				1.62	0.28		16.16
13		18.33						17.93				3.27	-3.11	36.42
T_j (3)	24.68	53.31	24.47	59.49	61.48	37.57	38.29	66.30	-52.98	-7.76	2.96	3.81	-11.20(4)	300.42

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	42.2125	3	14.0708	1.1674
(12) Cars Adj.	538.8913	12 E_b	44.9076	3.7258*
(13) Oils	3678.8374	12	306.5697	25.4359*
(14) Error	289.2625	24 E_e	12.0526	
(5) Total	4549.2037	51		

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	0.58		0.58						0.58				0.58
2	57.24	57.24		57.24						57.24			
3		24.99	24.99		24.99						24.99		
4			14.20	14.20		14.20						14.20	
5				41.80	41.80		41.80						41.80
6	45.13				45.13	45.13		45.13					
7		27.88				27.88	27.88		27.88				
8			22.01				22.01	22.01		22.01			
9				29.15				29.15	29.15		29.15		
10					-17.62				-17.62	-17.62		-17.62	
11						2.48				2.48	2.48		2.48
12	16.16						16.16				16.16	16.16	
13		36.42						36.42				36.42	36.42
(6)	119.11	146.53	61.78	142.39	94.30	89.69	107.85	132.71	39.99	64.11	72.78	49.16	81.28
(7)	22.12	479.79	220.23	535.41	553.32	338.13	344.61	596.70	-476.82	-69.84	26.64	34.29	-100.80
(8)	-1429.32	-1758.36	-741.36	-1708.68	-1131.60	-1076.28	-1294.20	-1592.52	-479.88	-769.32	-873.36	-589.92	-975.36
(9)	901.26	901.26	901.26	901.26	901.26	901.26	901.26	901.26	901.26	901.26	901.26	901.26	901.26
W_j (10)	-305.94	-377.31	380.13	-272.01	322.98	163.11	-48.33	-94.56	-55.44	62.10	54.54	345.63	-174.90
Y_j	18.9590	46.2544	31.5784	54.4035	67.5197	40.6201	37.3863	64.5318	-54.0167	-6.5988	3.9798	10.2732	-14.4706
Corrected Avg. Visc. Losses ($Y_j/4$)	4.74	11.56	7.89	13.60	16.88	10.16	9.35	16.13	-13.50	-1.65	0.99	2.57	-3.62
Uncorrected Avg. Visc. Losses (Raw Avg.)	6.17	13.33	6.12	14.87	15.37	9.39	9.57	16.58	-13.25	-1.94	0.74	0.95	-2.80

Uncorrected Sum of Sq. = 6284.8224

Correction Term C = 1735.6187

$t = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$t = \frac{44.9076 - 12.0526}{1751.3964}$

t = 0.0187 (Car Correction Factor)

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-16

ANALYSIS OF FIELD TEST DATA

FLEET B — DRAIN PROCESSOR A

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-2.59	6.09	7.42	-8.04
2	11.13	23.27	17.96	15.96
3	-0.42	7.39	16.06	2.46
4	-0.07	8.40	5.07	-0.31
5	14.81	16.81	14.69	-2.78
6	16.04	8.79	15.51	3.52
7	11.28	10.53	-5.92	13.94
8	8.63	11.89	-4.20	3.68
9	18.71	-11.37	1.34	20.77
10	-25.47	-7.22	2.24	14.41
11	-0.10	-0.90	-2.37	8.41
12	1.35	4.70	7.47	6.75
13	3.74	-3.41	19.25	17.45
A_j (1)	57.04	74.97	94.52	96.22

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	6.09		7.42						-8.04				-2.59	2.88
2	11.13	23.27		17.96						15.96				68.32
3		-0.42	7.39		16.06						2.46			25.49
4			-0.07	8.40		5.07						-0.31		13.09
5				14.81	16.81		14.69						-2.78	43.53
6	3.52				16.04	8.79		15.51						43.86
7		13.94				11.28	10.53		-5.92					29.83
8			3.68				8.63	11.89		-4.20				20.00
9				20.77				18.71	-11.37		1.34			29.45
10					14.41				-25.47	-7.22		2.24		-16.04
11						8.41				-0.10	-0.90		-2.37	5.04
12	7.47						6.75				1.35	4.70		20.27
13		19.25						17.45				3.74	-3.41	37.03
T_j (3)	28.21	56.04	18.42	61.94	63.32	33.55	40.60	63.56	-50.80	4.44	4.25	10.37	-11.15 (4)	322.75

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	78.8070	3	26.2690	1.9309
(12) Cars Adj.	726.1729	12 E_b	60.5144	4.4482*
(13) Oils	3443.1976	12	286.9331	21.0918*
(14) Error	326.4967	24 E_e	13.6040	
(5) Total	4574.6742	51		

Uncorrected Sum of Sq. = 6577.8965

Correction Term C = 2003.2223

$\mathcal{L}_c = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mathcal{L}_c = \frac{60.5144 - 13.6040}{2360.0616}$

$\mathcal{L}_c$ = 0.0198 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	2.88		2.88						2.88				2.88
2	68.32	68.32		68.32						68.32			
3		25.49	25.49		25.49						25.49		
4			13.09	13.09		13.09						13.09	
5				43.53	43.53		43.53						43.53
6	43.86				43.86	43.86		43.86					
7		29.83				29.83	29.83		29.83				
8			20.00				20.00	20.00		20.00			
9				29.45				29.45	29.45		29.45		
10					-16.04				-16.04	-16.04		-16.04	
11						5.04				5.04	5.04		5.04
12	20.27						20.27				20.27	20.27	
13		37.03						37.03				37.03	37.03
(6)	135.33	160.67	61.46	154.39	96.84	91.82	113.63	130.34	46.12	77.32	80.25	54.35	88.48
(7)	253.89	504.36	165.78	557.46	569.88	301.95	365.40	572.04	-457.20	39.96	38.25	93.33	-100.35
(8)	-1623.96	-1928.04	-737.52	-1852.68	-1162.08	-1101.84	-1363.56	-1564.08	-553.44	+927.84	-963.00	+652.20	-1061.76
(9)	968.25	968.25	968.25	968.25	968.25	968.25	968.25	968.25	968.25	968.25	968.25	968.25	968.25
W_j (10)	-401.82	-455.43	396.51	-326.97	376.05	168.36	-29.91	-23.79	-42.39	80.37	43.50	409.38	-193.86
Y_j	20.2540	47.0225	26.2708	55.4660	70.7657	36.8835	40.0078	63.0890	-51.6393	6.0313	5.1113	18.4757	-14.9884
Corrected Avg. Visc. Losses ($Y_j/4$)	5.06	11.76	6.57	13.87	17.69	9.22	10.00	15.77	-12.91	1.51	1.28	4.62	-3.75
Uncorrected Avg. Visc. Losses (Raw Avg.)	7.05	14.01	4.61	15.49	15.83	8.39	10.15	-15.89	-12.70	1.11	1.06	2.59	-2.79

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-17

ANALYSIS OF FIELD TEST DATA

FLEET C — DRAIN PROCESSOR C

SECTION 1
100°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-2.25	6.96	12.34	-3.18
2	7.75	14.61	17.89	8.97
3	11.51	8.58	14.67	1.67
4	4.73	10.77	6.72	1.91
5	11.36	16.98	6.86	-0.54
6	8.41	2.55	5.33	-0.46
7	7.43	11.90	-2.51	10.39
8	9.66	11.63	-3.60	4.93
9	14.12	-14.09	0.98	16.28
10	-29.24	-11.65	-6.81	8.65
11	4.10	2.51	-0.38	11.96
12	2.48	5.15	8.03	12.61
13	1.84	-1.62	12.15	21.04
A_j (1)	51.90	64.28	71.67	94.23

SECTION 2
100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	6.96		12.34						-3.18				-2.25	13.87
2	7.75	14.61		17.89						8.97				49.22
3		11.51	8.58		14.67						1.67			36.43
4			4.73	10.77		6.72						1.91		24.13
5				11.36	16.98		6.86						-0.54	34.66
6	-0.46				8.41	2.55		5.33						15.83
7		10.39				7.43	11.90		-2.51					27.21
8			4.93				9.66	11.63		-3.60				22.62
9				16.28				14.12	-14.09		0.98			17.29
10					8.65				-29.24	-11.65		-6.81		-39.05
11						11.96				4.10	2.51		-0.38	18.19
12	8.03						12.61				2.48	5.15		28.27
13		12.15						21.04				1.84	-1.62	33.41
T_j (3)	22.28	48.66	30.58	56.30	48.71	28.66	41.03	52.12	-49.02	-2.18	7.64	2.09	-4.794	282.08

SECTION 4
ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	73.0099	3	24.3366	3.2873
(12) Cars Adj.	928.4484	12 Eb	77.3707	10.4512*
(13) Oils	2733.9320	12	227.8276	30.7750*
(14) Error	177.6734	24 Ee	7.4030	
(5) Total	3913.0637	51		

Uncorrected Sum of Sq. = 5443.2392

Correction Term C = 1530.1755

$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mu = \frac{77.3707 - 7.4030}{3017.4573}$

$\mu = 0.0231$ (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	13.87		13.87						13.87				13.87
2	49.22	49.22		49.22						49.22			
3		36.43	36.43		36.43						36.43		
4			24.13	24.13		24.13						24.13	
5				34.66	34.66		34.66						34.66
6	15.83				15.83	15.83		15.83					
7		27.21				27.21	27.21		27.21				
8			22.62				22.62	22.62		22.62			
9				17.29				17.29	17.29		17.29		
10					-39.05				-39.05	-39.05		-39.05	
11						18.19				18.19	18.19		18.19
12	28.27						28.27				28.27	28.27	
13		33.41						33.41				33.41	33.41
(6)	107.19	146.27	97.05	125.30	47.87	85.36	112.76	89.15	19.32	50.98	100.18	46.76	100.13
(7)	200.52	437.94	275.22	506.70	438.39	257.94	369.27	469.08	-441.18	-19.62	68.76	18.81	-43.11
(8)	-1286.28	-1755.24	-1164.60	-1503.60	-574.44	-1024.32	-1353.12	-1069.80	-231.84	-611.76	-1202.16	-561.12	-1201.56
(9)	846.24	846.24	846.24	846.24	846.24	846.24	846.24	846.24	846.24	846.24	846.24	846.24	846.24
W_j (10)	-239.52	-471.06	-43.14	-150.66	710.19	79.86	-137.61	245.52	173.22	214.86	-287.16	303.93	-398.43
Y_j	16.7471	37.7786	29.5835	52.8198	65.1153	30.5047	37.8513	57.7915	-45.0187	2.7832	1.0067	9.1107	-13.9937
Corrected Avg. Visc. Losses ($Y_j/4$)	4.19	9.44	7.40	13.20	16.28	7.63	9.46	14.45	-11.25	0.70	0.25	2.28	-3.50
Uncorrected Avg. Visc. Losses — Raw Avg.	5.57	12.17	7.65	14.08	12.18	7.17	10.26	13.03	-12.26	-0.55	1.91	0.52	-1.20

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-18

ANALYSIS OF FIELD TEST DATA

FLEET C — DRAIN PROCESSOR D

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.51	7.83	13.86	-3.60
2	8.43	14.79	13.86	21.30
3	12.78	9.48	15.87	2.01
4	4.92	9.48	6.39	2.07
5	11.34	16.95	10.51	-0.85
6	9.57	1.77	5.22	-1.56
7	7.77	11.59	1.74	9.36
8	9.52	11.49	-2.45	5.76
9	15.54	-7.47	0.96	13.92
10	-26.20	-11.85	-6.63	9.09
11	4.25	2.79	0.96	11.73
12	2.31	4.23	9.09	17.23
13	2.04	-0.18	11.25	17.04
A_j (1)	61.76	70.90	80.63	103.50

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	7.83		13.86						-3.60				-0.51	17.58
2	8.43	14.79		13.86						21.30				58.38
3		12.78	9.48		15.87						2.01			40.14
4			4.92	9.48		6.39						2.07		22.86
5				11.34	16.95		10.51						-0.85	37.95
6	-1.56				9.57	1.77		5.22						15.00
7		9.36				7.77	11.59		1.74					30.46
8			5.76				9.52	11.49		-2.45				24.32
9				13.92				15.54	-7.47		0.96			22.95
10					9.09				-26.20	-11.85		-6.63		-35.59
11						11.73				4.25	2.79		0.96	19.73
12	9.09						17.23				2.31	4.23		32.86
13		11.25						17.04				2.04	-0.18	30.15
T_j (3)	23.79	48.18	34.02	48.60	51.48	27.66	48.85	49.29	-35.53	11.25	8.07	1.71	-0.58 (4)	316.79

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	74.2753	3	24.7584	2.1916
(12) Cars Adj.	1133.2673	12 E_b	94.4389	8.3599*
(13) Oils	2093.8333	12	174.4861	15.4458*
(14) Error	271.1201	24 E_e	11.2966	
(5) Total	3572.4960	51		

Uncorrected Sum of Sq. = 5502.4172

Correction Term C = 1929.9212

$\mu = \frac{E_b - E_e}{39\ E_b}$

$\mu = \frac{94.4389 - 11.2966}{3683.1171}$

$\mu = 0.0225$ (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	17.58		17.58						17.58				17.58
2	58.38	58.38		58.38						58.38			
3		40.14	40.14		40.14						40.14		
4			22.86	22.86		22.86						22.86	
5				37.95	37.95		37.95						37.95
6	15.00				15.00	15.00		15.00					
7		30.46				30.46	30.46		30.46				
8			24.32				24.32	24.32		24.32			
9				22.95				22.95	22.95		22.95		
10					-35.59				-35.59	-35.59		-35.59	
11						19.73				19.73	19.73		19.73
12	32.86						32.86				32.86	32.86	
13		30.15						30.15				30.15	30.15
(6)	123.82	159.13	104.90	142.14	57.50	88.05	125.59	92.42	35.40	66.84	115.68	50.28	105.41
(7)	214.11	433.62	306.18	437.40	463.32	248.94	439.65	443.61	-319.77	101.25	72.63	15.39	-5.22
(8)	-1485.84	-1909.56	-1258.80	-1705.68	-690.00	-1056.60	-1507.08	-1109.04	-424.80	-802.08	-1388.16	-603.36	-1264.92
(9)	950.37	950.37	950.37	950.37	950.37	950.37	950.37	950.37	950.37	950.37	950.37	950.37	950.37
W_j (10)	-321.36	-525.57	-2.25	-317.91	723.69	142.71	-117.06	284.94	205.80	249.54	-365.16	362.40	-319.77
Y_j	16.5594	36.3547	33.9694	41.4471	67.7630	30.8709	46.2162	55.7011	-30.8995	16.8646	-0.1461	9.8640	-7.7748
Corrected Avg. Visc. Losses ($Y_j/4$)	4.14	9.09	8.49	10.36	16.94	7.72	11.55	13.93	-7.72	4.22	-0.04	2.47	-1.94
Uncorrected Avg. Visc. Losses (Raw Avg.)	5.95	12.05	8.51	12.15	12.87	6.92	12.21	12.32	-8.88	2.81	2.02	0.43	-0.15

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-19

ANALYSIS OF FIELD TEST DATA

FLEET C — DRAIN PROCESSOR K

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

CARS	PHASES I	II	III	IV
1	-2.28	7.10	13.50	-2.80
2	7.20	15.10	16.80	10.80
3	12.30	9.50	14.60	1.70
4	5.00	9.10	6.50	2.30
5	11.60	16.70	5.60	-0.65
6	8.50	2.10	3.70	-0.70
7	7.10	11.90	-2.80	11.10
8	9.40	10.80	-3.20	5.90
9	13.70	-14.40	0.90	20.20
10	-32.90	-11.60	-7.00	8.10
11	3.30	2.40	-0.85	11.60
12	2.00	5.40	7.70	10.50
13	2.30	-1.56	12.60	19.20
A_j (1)	47.22	62.54	68.05	97.25

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

CARS	OILS 101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	7.10		13.50						-2.80				-2.28	15.52
2	7.20	15.10		16.80						10.80				49.90
3		12.30	9.50		14.60						1.70			38.10
4			5.00	9.10		6.50						2.30		22.90
5				11.60	16.70		5.60						-0.65	33.25
6	-0.70				8.50	2.10		3.70						13.60
7		11.10				7.10	11.90		-2.80					27.30
8			5.90				9.40	10.80		-3.20				22.90
9				20.20				13.70	-14.40		0.90			20.40
10					8.10				-32.90	-11.60		-7.00		-43.40
11						11.60				3.30	2.40		-0.85	16.45
12	7.70						10.50				2.00	5.40		25.60
13		12.60						19.20				2.30	-1.56	32.54
T_j (3)	21.30	51.10	33.90	57.70	47.90	27.30	37.40	47.40	-52.90	-0.70	7.00	3.00	-5.34	(4) 275.06

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	101.1418	3	33.7139	3.3217
(12) Cars Adj.	1048.5600	12 E_b	87.3800	8.6096 *
(13) Oils	2823.5473	12	235.2956	23.1832 *
(14) Error	243.5863	24 E_e	10.1494	
(5) Total	4216.8354	51		

Uncorrected Sum of Sq. = 5671.7970

Correction Term C = 1454.9616

μ = $\frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

μ = $\frac{87.3800 - 10.1494}{3407.8200}$

μ = 0.0226 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	15.52		15.52						15.52				15.52
2	49.90	49.90		49.90						49.90			
3		38.10	38.10		38.10						38.10		
4			22.90	22.90		22.90						22.90	
5				33.25	33.25		33.25						33.25
6	13.60				13.60	13.60		13.60					
7		27.30				27.30	27.30		27.30				
8			22.90				22.90	22.90		22.90			
9				20.40				20.40	20.40		20.40		
10					-43.40				-43.40	-43.40		-43.40	
11						16.45				16.45	16.45		16.45
12	25.60						25.60				25.60	25.60	
13		32.54						32.54				32.54	32.54
(6)	104.62	147.84	99.42	126.45	41.55	80.25	109.05	89.44	19.82	45.85	100.55	37.64	97.76
(7)	191.70	459.90	305.10	519.30	431.10	245.70	336.60	426.60	-476.10	-6.30	63.00	27.00	-48.06
(8)	-1255.44	-1774.08	-1193.04	-1517.40	-498.60	-963.00	-1303.60	-1073.28	-237.84	-550.20	-1206.60	-451.68	-1173.12
(9)	825.18	825.18	825.18	825.18	825.18	825.18	825.18	825.18	825.18	825.18	825.18	825.18	825.18
W_j (10)	-238.56	-489.00	-62.76	-172.92	757.68	107.88	-146.82	178.50	111.24	268.68	-318.42	400.50	-396.00
Y_j	15.9086	40.0486	32.4817	53.7921	65.0235	29.7380	34.0819	51.4341	-50.3860	5.3721	-0.1962	12.0513	-14.2896
Corrected Avg. Visc. Losses ($Y_j/4$)	3.98	10.01	8.12	13.45	16.26	7.43	8.52	12.86	-12.60	1.34	-0.05	3.01	-3.57
Uncorrected Avg. Visc. Losses (Raw Avg.)	5.33	12.78	8.48	14.43	11.98	6.83	9.35	11.85	-13.23	-0.18	1.75	0.75	-1.34

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-20

ANALYSIS OF FIELD TEST DATA

FLEET D — DRAIN PROCESSOR D

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

CARS	I	II	III	IV
1	0.39	9.18	13.92	0.70
2	8.88	15.42	20.88	7.25
3	14.65	8.94	14.94	0.48
4	13.02	19.38	10.92	6.12
5	20.70	20.55	12.58	2.10
6	20.97	6.78	12.40	7.53
7	8.43	9.25	-12.78	12.87
8	13.63	16.74	-0.87	9.82
9	14.62	-15.40	-2.70	10.05
10	3.54	3.36	4.95	17.82
11	8.25	4.20	-0.60	12.12
12	6.09	9.21	6.75*	11.41
13	3.45	-1.74	12.18	14.00
A_j (1)	136.62	105.87	92.57	112.27

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

CARS	OILS 101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	9.18		13.92						0.70				0.39	24.19
2	8.88	15.42		20.88						7.25				52.43
3		14.65	8.94		14.94						0.48			39.01
4			13.02	19.38		10.92						6.12		49.44
5				20.70	20.55		12.58						2.10	55.93
6	7.53				20.97	6.78		12.40						47.68
7		12.87				8.43	9.25		-12.78					17.77
8			9.82				13.63	16.74		-0.87				39.32
9				10.05				14.62	-15.40		-2.70			6.57
10					17.82				3.54	3.36		4.95		29.67
11						12.12				8.25	4.20		-0.60	23.97
12	6.75						11.41				6.09	9.21		33.46
13		12.18						14.00				3.45	-1.74	27.89
T_j (3)	32.34	55.12	45.70	71.01	74.28	38.25	46.87	57.76	-23.94	17.99	8.07	23.73	0.156	447.33

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	78.5544	3	26.1846	4.3225*
(12) Cars Adj.	339.6790	12 E_b	28.3065	4.6728*
(13) Oils	2465.2485	12	205.4373	33.9134*
(14) Error	145.3869	24 E_e	6.0577	
(5) Total	3028.8688	51		

Uncorrected Sum of Sq. = 3028.8688

Correction Term C = 3848.1563

$\lambda = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\lambda = \frac{28.3065 - 6.0577}{1103.9535}$

λ = 0.0201 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	24.19		24.19						24.19				24.19
2	52.43	52.43		52.43						52.43			
3		39.01	39.01		39.01						39.01		
4			49.44	49.44		49.44						49.44	
5				55.93	55.93		55.93						55.93
6	47.68				47.68	47.68		47.68					
7		17.77				17.77	17.77		17.77				
8			39.32				39.32	39.32		39.32			
9				6.57				6.57	6.57		6.57		
10					29.67				29.67	29.67		29.67	
11						23.97				23.97	23.97		23.97
12	33.46						33.46				33.46	33.46	
13		27.89						27.89				27.89	27.89
(6)	157.76	137.10	151.96	164.37	172.29	138.86	146.48	121.46	78.20	145.39	103.01	140.46	131.98
(7)	291.06	496.08	411.30	639.09	668.52	344.25	421.83	519.84	-215.46	161.91	72.63	213.57	1.35
(8)	-1893.12	-1645.20	-1823.52	-1972.44	-2067.48	-1666.32	-1757.76	-1457.52	-938.40	-1744.68	-1236.12	-1685.52	-1583.76
(9)	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99	1341.99
W_j (10)	-260.07	192.87	-70.23	8.64	-56.97	19.92	6.06	404.31	188.13	-240.78	178.50	-129.96	-240.42
Y_j	27.1126	58.9966	44.2884	71.1836	73.1350	38.6503	46.9918	65.8866	-20.1586	13.1503	11.6578	21.1179	-4.6824
Corrected Avg. Visc. Losses (Y_j/4)	6.78	14.75	11.07	17.80	18.28	9.66	11.75	16.47	-5.04	3.29	2.91	5.28	-1.17
Uncorrected Avg. Visc. Losses Raw Avg.	8.09	13.78	11.43	17.75	18.57	9.56	11.72	14.44	-5.99	4.50	2.02	5.93	0.04

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-21

ANALYSIS OF FIELD TEST DATA

FLEET D — DRAIN PROCESSOR G

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	1.08	7.50	13.22	1.39
2	8.40	17.42	22.17	6.96
3	16.32	9.12	14.43	4.35
4	13.62	17.34	12.93	4.29
5	18.60	20.49	12.85	1.47
6	18.33	10.83	9.54	5.46
7	10.46	7.75	-10.36	15.04
8	10.99	16.65	-0.25	11.97
9	14.52	-12.07	-2.94	10.20
10	1.74	3.15	5.34	17.99
11	5.85	4.50	-0.30	13.17
12	3.99	8.55	6.72	10.93
13	3.12	-1.59	11.88	14.01
A_j (1)	127.02	109.64	95.23	117.23

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	7.50		13.22						1.39				1.08	23.19
2	8.40	17.42		22.17						6.96				54.95
3		16.32	9.12		14.43						4.35			44.22
4			13.62	17.34		12.93						4.29		48.18
5				18.60	20.49		12.85						1.47	53.41
6	5.46				18.33	10.83		9.54						44.16
7		15.04				10.46	7.75		-10.36					22.89
8			11.97				10.99	16.65		-0.25				39.36
9				10.20				14.52	-12.07		-2.94			9.71
10					17.99				1.74	3.15		5.34		28.22
11						13.17				5.85	4.50		-0.30	23.22
12	6.72						10.93				3.99	8.55		30.19
13		11.88						14.01				3.12	-1.59	27.42
T_j (3)	28.08	60.66	47.93	68.31	71.24	47.39	42.52	54.72	-19.30	15.71	9.90	21.30	0.66 (4)	449.12

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	41.4956	3	13.8318	2.9748
(12) Cars Adj	279.0358	12 E_b	23.2529	5.0010 *
(13) Oils	2302.5530	12	191.8794	41.2679 *
(14) Error	111.5926	24 E_e	4.6496	
(5) Total	2734.6770	51		

Uncorrected Sum of Sq. = 5613.6918

Correction Term C = 3879.0148

$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mu = \frac{23.2529 - 4.6496}{906.8631}$

$\mu = 0.0205$ (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	23.19		23.19						23.19				23.19
2	54.95	54.95		54.95						54.95			
3		44.22	44.22		44.22						44.22		
4			48.18	48.18		48.18						48.18	
5				53.41	53.41		53.41						53.41
6	44.16				44.16	44.16		44.16					
7		22.89				22.89	22.89		22.89				
8			39.36				39.36	39.36		39.36			
9				9.71				9.71	9.71		9.71		
10					28.22				28.22	28.22		28.22	
11						23.22				23.22	23.22		23.22
12	30.19						30.19				30.19	30.19	
13		27.42						27.42				27.42	27.42
(6)	152.49	149.48	154.95	166.25	170.01	138.45	145.85	120.65	84.01	145.75	107.34	134.01	127.24
(7)	252.72	545.94	431.37	614.79	641.16	426.51	382.68	492.48	-173.70	141.39	89.10	191.70	5.94
(8)	-1829.88	-1793.76	-1859.40	-1995.00	-2040.12	-1661.40	-1750.20	-1447.80	-1008.12	-1749.00	-1288.08	-1608.12	-1526.88
(9)	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36	1347.36
W_j(10)	-229.80	99.54	-80.67	-32.85	-51.60	112.47	-20.16	392.04	165.54	-260.25	148.38	-69.06	-173.58
Y_j	23.3691	62.7005	46.2763	67.6366	70.1822	49.6956	42.1068	62.7568	-15.9065	10.3749	12.9417	19.8843	-2.8983
Corrected Avg. Visc. Losses ($Y_j/4$)	5.84	15.68	11.57	16.91	17.55	12.42	10.53	15.69	-3.98	2.59	3.24	4.97	-0.72
Uncorrected Avg. Visc. Losses (Raw Avg.)	7.02	15.17	11.98	17.08	17.81	11.85	10.63	13.68	-4.83	3.93	2.48	5.33	0.17

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-22

ANALYSIS OF FIELD TEST DATA

FLEET D — DRAIN PROCESSOR C

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-0.85	7.54	11.62	-1.19
2	8.88	14.63	21.19	6.01
3	13.74	8.14	17.53	-0.02
4	11.95	14.69	6.64	4.00
5	17.12	18.79	12.02	0.38
6	16.67	4.87	11.37	5.94
7	8.63	7.72	-16.44	12.36
8	9.82	16.36	-1.50	10.68
9	13.90	-20.16	-3.28	10.06
10	-0.23	2.10	4.69	16.89
11	4.96	3.89	-0.67	12.97
12	1.94	7.53	5.84	9.96
13	2.76	-0.35	11.67	14.03
A_j (1)	109.29	85.75	80.68	102.07

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	7.54		11.62						-1.19				-0.85	17.12
2	8.88	14.63		21.19						6.01				50.71
3		13.74	8.14		17.53						-0.02			39.39
4			11.95	14.69		6.64						4.00		37.28
5				17.12	18.79		12.02						0.38	48.31
6	5.94				16.67	4.87		11.37						38.85
7		12.36				8.63	7.72		-16.44					12.27
8			10.68				9.82	16.36		-1.50				35.36
9				10.06				13.90	-20.16		-3.28			0.52
10					16.89				-0.23	2.10		4.69		23.45
11						12.97				4.96	3.89		-0.67	21.15
12	5.84						9.96				1.94	7.53		25.27
13		11.67						14.03				2.76	-0.35	28.11
T_j (3)	28.20	52.40	42.39	63.06	69.88	33.11	39.52	55.66	-38.02	11.57	2.53	18.98	-1.49 (4)	377.79

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	41.8148	3	13.9382	1.8100
(12) Cars Adj.	311.6717	12 E_b	25.9726	3.3728 *
(13) Oils	2730.8017	12	227.5668	29.5525 *
(14) Error	184.8099	24 E_e	7.7004	
(5) Total	3269.0981	51		

Uncorrected Sum of Sq. = 2744.7170

$4 = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$4 = \frac{25.9726 - 7.7004}{1012.9314}$

$4 = 0.0180$ (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	17.12		17.12						17.12				17.12
2	50.71	50.71		50.71						50.71			
3		39.39	39.39		39.39						39.39		
4			37.28	37.28		37.28						37.28	
5				48.31	48.31		48.31						48.31
6	38.85				38.85	38.85		38.85					
7		12.27				12.27	12.27		12.27				
8			35.36				35.36	35.36		35.36			
9				0.52				0.52	0.52		0.52		
10					23.45				23.45	23.45		23.45	
11						21.15				21.15	21.15		21.15
12	25.27						25.27				25.27	25.27	
13		28.11						28.11				28.11	28.11
(6)	131.95	130.48	129.15	136.82	150.00	109.55	121.21	102.84	53.36	130.67	86.33	114.11	114.69
(7)	253.80	471.60	381.51	567.54	628.92	297.99	355.68	500.94	-342.18	104.13	22.77	170.82	-13.41
(8)	-1583.40	-1565.76	-1549.80	-1641.84	-1800.00	-1314.60	-1454.52	-1234.08	-640.32	-1568.04	-1035.96	-1369.32	-1376.28
(9)	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37	1133.37
W_j(10)	0196.23	39.21	-34.92	59.07	-37.71	116.76	34.53	400.23	150.87	-330.54	120.18	-65.13	-256.32
Y_j	24.6679	53.1057	41.7615	64.1232	69.2013	35.2116	40.1415	62.8641	-35.3044	5.6203	4.6932	17.8077	-6.1037
Corrected Avg. Visc. Losses ($Y_j/4$)	6.17	13.28	10.44	16.03	17.30	8.80	10.04	15.72	-8.83	1.41	1.17	4.45	-1.53
Uncorrected Avg. Visc. Losses (Raw Avg.)	7.05	13.10	10.60	15.77	17.47	8.28	9.88	13.92	-9.51	2.89	0.63	4.75	-0.37

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-23

ANALYSIS OF FIELD TEST DATA

FLEET E

DRAIN PROCESSOR G

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

CARS	PHASES I	II	III	IV
1	-1.35	4.74	4.22	-7.70
2	6.33	14.70	13.41	5.14
3	16.29	17.10	27.33	10.14
4	10.50	14.40	9.33	5.19
5	19.11	16.65	10.69	-1.32
6	20.40	12.84	23.22	6.51
7	10.11	7.12	-11.50	20.61
8	16.42	14.94	0.20	5.97
9	14.88	-4.11	1.02	6.99
10	-20.61	2.14	1.65	17.61
11	5.93	1.98	-0.51	11.25
12	3.66	7.08	10.95	17.83
13	8.33	0.00	16.23	20.13
A_j (1)	110.00	109.58	106.24	118.35

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

CARS	OILS 101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	4.74		4.22						-7.70				-1.35	-0.09
2	6.33	14.70		13.41						5.14				39.58
3		16.29	17.10		27.33						10.14			70.86
4			10.50	14.40		9.33						5.19		39.42
5				19.11	16.65		10.69						-1.32	45.13
6	6.51				20.40	12.84		23.22						62.97
7		20.61				10.11	7.12		-11.50					26.34
8			5.97				16.42	14.94		0.20				37.53
9				6.99				14.88	-4.11		1.02			18.78
10					17.61				-20.61	2.14		1.65		0.79
11						11.25				5.93	1.98		-0.51	18.65
12	10.95						17.83				3.66	7.08		39.52
13		16.23						20.13				8.33	0.00	44.69
T_j (3)	28.53	67.83	37.79	53.91	81.99	43.53	52.06	73.17	-43.92	13.41	16.80	22.25	-3.18 (4)	444.17

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11)Phases	6.1300	3	2.0433	0.1362
(12)Cars Adj.	300.3216	12 E_b	25.0268	1.6691
(13)Oils	3537.7107	12	294.8092	19.6616*
(14)Error	359.8599	24 E_e	14.9941	
(5)Total	4204.0222	51		

Uncorrected Sum of Sq. = 7998.0027

Correction Term C = 3793.9805

$\mu = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mu = \frac{25.0268 - 14.9941}{976.0452}$

μ = 0.0102 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	-0.09		-0.09						-0.09				-0.09
2	39.58	39.58		39.58						39.58			
3		70.86	70.86		70.86						70.86		
4			39.42	39.42		39.42						39.42	
5				45.13	45.13		45.13						45.13
6	62.97				62.97	62.97		62.97					
7		26.34				26.34	26.34		26.34				
8			37.53				37.53	37.53		37.53			
9				18.78				18.78	18.78		18.78		
10					0.79				0.79	0.79		0.79	
11						18.65				18.65	18.65		18.65
12	39.52						39.52				39.52	39.52	
13		44.69						44.69				44.69	44.69
(6)	141.98	181.47	147.72	142.91	179.75	147.38	148.52	163.97	45.82	96.55	147.81	124.42	108.38
(7)	256.77	610.47	340.11	485.19	737.91	391.77	468.54	658.53	-395.28	120.69	151.20	200.25	-28.62
(8)	-1703.76	-2177.64	-1772.64	-1714.92	-2157.00	-1768.56	-1782.24	-1967.64	-549.84	-1158.60	-1773.72	-1493.04	-1300.56
(9)	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51	1332.51
Wj (10)	-114.48	-234.66	-100.02	102.78	-86.58	-44.28	18.81	23.40	387.39	294.60	-290.01	39.72	3.33
Y_j	27.3624	65.4365	36.7698	54.9583	81.1069	43.0784	52.2518	73.4086	-39.9687	16.4149	13.8419	22.6551	-3.1461
Corrected Avg. Visc. Losses ($Y_j/4$)	6.84	16.36	9.19	13.74	20.28	10.78	13.06	18.35	-9.99	4.10	3.46	5.66	-0.79
Uncorrected Avg. Visc. Losses (Raw Avg.)	7.13	16.96	9.45	13.48	20.50	10.88	13.02	18.29	-10.98	3.35	4.20	5.56	-0.80

* Significant at the 95% Confidence level.

APPENDIX D

TABLE D-24

ANALYSIS OF FIELD TEST DATA

FLEET E — DRAIN PROCESSOR R

SECTION 1

100°F Vis. Losses cSt, After 1500 Miles

CARS	PHASES I	II	III	IV
1	-1.30	5.90	2.00	-4.90
2	7.60	15.30	10.50	1.60
3	16.60	18.10	26.60	8.80**
4	11.20	10.90	10.20	6.20
5	16.10	17.60	10.10	0.90
6	18.20	13.10	25.90	7.00
7	10.10	6.60	-7.90	22.90
8	15.90	11.60	-3.20	8.10
9	15.00	-3.10	-0.30	16.40
10	-18.50	-1.80	3.90	20.00
11	3.60	3.10	1.90	16.40
12	5.00	7.50	12.20	21.30
13	8.30	1.10	18.10	23.30
A_j (1)	107.80	105.90	110.00	148.00

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

CARS	OILS 101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	5.90		2.00						-4.90				-1.30	1.70
2	7.60	15.30		10.50						1.60				35.00
3		16.60	18.10		26.60						8.80**			70.10
4			11.20	10.90		10.20						6.20		38.50
5				16.10	17.60		10.10						0.90	44.70
6	7.00				18.20	13.10		25.90						64.20
7		22.90				10.10	6.60		-7.90					31.70
8			8.10				15.90	11.60		-3.20				32.40
9				16.40				15.00	-3.10		-0.30			28.00
10					20.00				-18.50	-1.80		3.90		3.60
11						16.40				3.60	3.10		1.90	25.00
12	12.20						21.30				5.00	7.50		46.00
13		18.10						23.30				8.30	1.10	50.80
T_j (3)	32.70	72.90	39.40	53.90	82.40	49.80	53.90	75.80	-34.40	0.20	16.60	25.90	2.60(4)	471.70

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	93.2361	3	31.0787	2.1491
(12) Cars Adj.	326.5646	12 E_b	27.2137	1.8819
(13) Oils	3486.5679	12	290.5473	20.0922 *
(14) Error	332.5968	23 E_e	14.4607	
(5) Total	4238.9654	50		

Uncorrected Sum of Sq. = 8518.0100

Correction Term C = 4279.0446

$t = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$t = \frac{27.2137 - 14.4607}{1061.3343}$

t = 0.0120 (Car Correction Factor)

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	1.70		1.70						1.70				1.70
2	35.00	35.00		35.00						35.00			
3		70.10	70.10		70.10						70.10		
4			38.50	38.50		38.50						38.50	
5				44.70	44.70		44.70						44.70
6	64.20				64.20	64.20		64.20					
7		31.70				31.70	31.70		31.70				
8			32.40				32.40	32.40		32.40			
9				28.00				28.00	28.00		28.00		
10					3.60				3.60	3.60		3.60	
11						25.00				25.00	25.00		25.00
12	46.00						46.00				46.00	46.00	
13		50.80						50.80				50.80	50.80
(6)	146.90	187.60	142.70	146.20	182.60	159.40	154.80	175.40	65.00	96.00	169.10	138.90	122.20
(7)	294.30	656.10	354.60	485.10	741.60	448.20	485.10	682.20	-309.60	1.80	149.40	233.10	23.40
(8)	-1762.80	-2251.20	-1712.40	-1754.40	-2191.20	-1912.80	-1857.60	-2104.80	-780.00	-1152.00	-2029.20	-1666.80	-1466.40
(9)	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10	1415.10
W_j (10)	-53.40	-180.00	57.30	145.80	-34.50	-49.50	42.60	-7.50	325.50	264.90	-464.70	-18.60	-27.90
Y_j	320592	70.7400	40.0876	55.6494	81.9860	49.2060	54.4112	75.7100	-30.4940	3.3788	11.0236	25.6768	2.2652
Corrected Avg. Visc. Losses ($Y_j/4$)	8.01	17.69	10.02	13.91	20.50	12.30	13.60	18.93	-7.62	0.84	2.76	6.42	0.57
Uncorrected Avg. Visc. Losses (Raw Avg.)	8.18	18.23	9.85	13.48	20.60	12.45	13.48	18.95	-8.60	0.05	4.15	6.48	0.65

* Significant at the 95% Confidence Level.

** Missing Data Filled in by Method of Cochran and Cox, Experimental Designs, Second Edition.

APPENDIX D

TABLE D-25

ANALYSIS OF FIELD TEST DATA

FLEET F — DRAIN PROCESSOR H

SECTION 1

100°F Vis. Losses cSt. After 1500 Miles

PHASES

CARS	I	II	III	IV
1	-6.70	-2.49	-3.76	-26.23
2	-0.90	5.90	2.61	-11.30
3	12.93	14.17	17.91	7.23
4	10.61	12.17	10.30	4.75
5	12.46	27.35	17.02	-5.23
6	13.65	10.29**	18.44	6.39
7	9.57	2.16	-3.90	13.77
8	7.04	15.52	5.62	18.02
9	19.73	-3.04	2.44	16.87
10	-4.52	-1.03	1.57	16.54
11	1.77	4.25	-0.66	13.53
12	-1.94**	-0.57**	0.83	6.47
13	5.03	1.34	16.45**	18.47**
A_j (1)	78.73	86.02	84.87	79.28

SECTION 2

100°F Viscosity Losses cSt. After 1500 Miles

OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113	(2)
1	-2.49		-3.76						-26.23				-6.70	-39.18
2	-0.90	5.90		2.61						-11.30				-3.69
3		12.93	14.17		17.91						7.23			52.24
4			10.61	12.17		10.30						4.75		37.83
5				12.46	27.35		17.02						-5.23	51.60
6	6.39				13.65	10.29**		18.44						48.77
7		13.77				9.57	2.16		-3.90					21.60
8			18.02				7.04	15.52		5.62				46.20
9				16.87				19.73	-3.04		2.44			36.00
10					16.54				-4.52	-1.03		1.57		12.56
11						13.53				1.77	4.25		-0.66	18.89
12	0.83						6.47				-1.94**	-0.57**		4.79
13		16.45**						18.47**				5.03	1.34	41.29
T_j (3)	3.83	49.05	39.04	44.11	75.45	43.69	32.69	72.16	-37.69	-4.94	11.98	10.78	-11.25	(4)328.90

SECTION 4

ANALYSIS OF VARIANCE

Source	S.S.	D.F.	Mean Sq.	F Ratio
(11) Phases	3.2527	3	1.0842	0.0495
(12) Cars Adj.	953.3719	12 E_b	79.4476	3.6344 *
(13) Oils	3319.4166	12	276.6180	12.6544 *
(14) Error	415.3301	19 E_e	21.8594	
(5) Totsl	4691.3713	46		

SECTION 3 - OILS

CARS	101	102	103	104	105	106	107	108	109	110	111	112	113
1	-39.18		-39.18						-39.18				-39.18
2	-3.69	-3.69		-3.69						-3.69			
3		52.24	52.24		52.24						52.24		
4			37.83	37.83		37.83						37.83	
5				51.60	51.60		51.60						51.60
6	48.77				48.77	48.77		48.77					
7		21.60				21.60	21.60		21.60				
8			46.20				46.20	46.20		46.20			
9				36.00				36.00	36.00		36.00		
10					12.56				12.56	12.56		12.56	
11						18.89				18.89	18.89		18.89
12	4.79						4.79				4.79	4.79	
13		41.29						41.29				41.29	41.29
(6)	10.69	111.44	97.09	121.74	165.17	127.09	124.19	172.26	30.98	73.96	111.92	96.47	72.60
(7)	34.47	441.45	351.36	396.99	679.05	393.21	294.21	649.44	-339.21	-44.46	107.82	97.02	-101.25
(8)	-128.28	-1337.28	-1165.08	-1460.88	-1982.04	-1525.08	-1490.28	-2067.12	-371.76	-887.52	-1343.04	-1157.64	-871.20
(9)	986.70	986.70	986.70	986.70	986.70	986.70	986.70	986.70	986.70	986.70	986.70	986.70	986.70
W_j (10)	892.89	90.87	172.98	-77.19	-316.29	-145.17	-209.37	-430.98	275.73	54.72	-248.52	-73.92	14.25
Y_j	20.3484	50.7310	42.2401	42.6820	69.5987	41.0044	28.8167	64.1869	-32.5890	-3.9277	7.3824	9.4125	-10.9864
Corrected Avg. Visc. Losses ($Y_j/4$)	5.09	12.68	10.56	10.67	17.40	10.25	7.20	16.05	-8.15	-0.98	1.85	2.35	-2.75
Uncorrected Avg. Visc. Losses (Rsw Avg.)	0.96	12.26	9.76	11.03	18.86	10.92	8.17	18.04	-9.42	-1.24	3.00	2.70	-2.81

Uncorrected Sum of Sq. = 6771.6638

Correction Term C = 2080.2925

$\mathcal{M} = \frac{E_b - E_e}{39\ E_b}$ for $E_b > E_e$

$\mathcal{M} = \frac{79.4476 - 21.8594}{3098.4564}$

$\mathcal{M} = 0.0185$ (Car Correction Factor)

* Significant at the 95% Confidence Level.

** Missing Data Filled in by Method of Cochran and Cox, Experimental Designs, Second Edition.

APPENDIX E

BENCH TEST DATA

APPENDIX TABLE E-1

BENCH TEST DATA - LAB. C

(DIESEL INJECTOR RIG)

ARO Oil No.	Fresh Oil Viscosity, cSt.		Sheared Oil Viscosity, cSt.					
			1 Pass		5 Passes		10 Passes	
	210°F	100°F	210°F	100°F	210°F	100°F	210°F	100°F
101	15.24	86.72	12.64	74.06	11.39	68.39	10.97	66.13
102	15.06	86.01	11.29	67.00	9.92	61.02	9.53	58.89
103	14.87	97.83	12.96	84.05	11.51	73.97	11.13	71.87
104	15.06	108.90	13.01	93.52	11.68	83.96	11.40	81.37
105	14.74	83.41	10.03	60.30	8.89	54.93	8.55	53.49
106	15.00	76.08	11.64	64.44	10.17	59.03	9.75	57.43
107	15.14	97.39	12.71	82.27	10.87	70.57	10.33	67.37
108	14.99	105.00	12.48	86.13	10.99	74.66	10.70	72.30
109	15.31	90.76	12.84	77.27	11.69	70.94	11.25	68.49
110	14.94	104.60	14.03	96.77	13.18	90.56	12.95	88.60
111	11.03	66.13	9.61	59.50	9.01	55.88	8.71	54.63
112	11.06	75.02	9.78	65.80	9.12	60.60	8.90	59.29
113	6.77	48.47	6.74	48.41	6.73	48.55	6.73	48.38

APPENDIX TABLE E-2

BENCH TEST DATA - LAB. L

(DIESEL INJECTOR RIG)

ARO Oil No.	Fresh Oil Viscosity cSt. 210°F	Sheared Oil Viscosity cSt. @ 210°F (20 Passes)
101	15.14	12.22
102	15.06	10.66
103	15.06	12.63
104	14.99	12.13
105	14.78	9.54
106	14.91	10.92
107	15.06	12.30
108	14.98	11.83
109	15.22	12.65
110	15.05	13.83
111	-	-
112	-	-
113	-	-

APPENDIX TABLE E-3

BENCH TEST DATA - LAB, M

(DIESEL INJECTOR RIG)

ARO Oil No.	Fresh Oil Viscosity, cSt.		Sheared Oil Viscosity, cSt.					
			5 Passes		10 Passes		20 Passes	
	210°F	100°F	210°F	100°F	210°F	100°F	210°F	100°F
101	15.14	86.37	13.46	77.49	12.83	74.82	12.17	71.70
102	15.06	85.99	12.34	70.67	11.35	67.81	10.57	65.30
103	14.87	97.45	13.31	86.61	12.92	83.58	12.49	80.64
104	14.89	108.10	13.05	93.76	12.63	90.36	12.24	86.90
105	14.87*	84.03	10.53	63.40	10.02	61.12	9.74	59.04
106	14.77	75.79	12.41	65.44	11.78	63.19	11.23	61.45
107	15.10	97.26	13.26	85.58	12.74	82.18	12.06	78.14
108	14.89	104.70	12.50	85.71	12.19	82.41	11.84	79.60
109	15.21	91.01	13.57	81.73	13.14	78.80	12.57	75.79
110	14.98	103.90	14.27	90.40	14.13	96.26	13.81	94.86
111	10.96	66.30	10.00	61.30	9.79	59.99	9.47	59.07
112	10.98	74.53	9.82	67.87	9.86	66.13	9.61	64.77
113	6.68	48.41	6.71	48.44	6.75	48.48	6.75	48.65

* This is the 15-Lab. average that was substituted for the reported value.

APPENDIX TABLE E-4

BENCH TEST DATA - LAB. J

(DIESEL INJECTOR RIG)

ARO Oil No.	Fresh Oil Viscosity, cSt.		Sheared Oil Viscosity, cSt. 5 Passes		Sheared Oil Viscosity, cSt. 20 Passes	
	210°F	100°F	210°F	100°F	210°F	100°F
101	15.07	86.40	12.91	75.60	11.84	70.20
102	15.00	86.00	11.10	66.90	10.29	62.70
103	14.98	97.60	12.50	80.70	12.11	77.80
104	14.87	108.10	12.43	88.90	12.03	85.70
105	14.81	84.20	10.09	61.30	9.35	57.20
106	14.94	75.80	11.66	63.70	10.48	60.80
107	15.12	97.50	12.77	82.60	11.28	73.50
108	14.92	104.50	11.69	-	11.16	-
109	15.23	90.80	13.05	79.10	12.21	74.40
110	15.05	104.90	13.94	96.30	13.73	94.20
111	10.98	66.20	9.70	60.10	9.22	57.70
112	11.01	74.80	9.93	66.50	9.56	63.90
113	6.68	48.30	6.79	48.70	6.75	48.80

APPENDIX TABLE E-5

BENCH TEST DATA - LAB. D

(POWER STEERING PUMP TEST)

ARO Oil No.	Fresh Oil Viscosity cSt. @ 210°F	4-Hour Test Viscosity, cSt. @ 210°F
101	15.01	11.57
102	14.97	10.07
103	15.01	12.31
104	14.94	12.35
105	14.91	9.34
106	14.97	10.22
107	15.13	11.30
108	14.94	11.65
109	15.18	11.89
110	15.00	13.57
111	10.99	9.22
112	11.02	9.49
113	6.72	6.76

APPENDIX TABLE E-6

BENCH TEST DATA - LAB. R

(POWER STEERING PUMP TEST)

ARO Oil No.	Fresh Oil Viscosity cSt. @ 210°F	1-Hour Test Viscosity, cSt. @ 210°F
101	15.01	12.39
102	14.99	11.02
103	15.07	12.28
104	14.99	12.88
105	14.96	9.80
106	14.94	10.67
107	15.16	12.18
108	14.96	12.63
109	15.25	12.60
110	15.00	14.01
111	10.99	9.63
112	11.01	9.74
113	6.77	6.94

APPENDIX TABLE E-7

BENCH TEST DATA - LAB. A

(POWER STEERING PUMP TEST)

ARO Oil No.	Fresh Oil Viscosity, cSt.		Sheared Oil Viscosity, cSt.									
			5-Min.*		1-Hr.		2-Hr.		4-Hr.		6-Hr.	
	210°F	100°F	210°F	100°F	210°F	100°F	210°F	100°F	210°F	100°F	210°F	100°F
101	15.05	86.11	14.26	81.36	12.88	75.17	12.07	70.39	11.37	67.27	11.09	65.40
102	15.02	86.04	13.82	80.14	11.77	69.77	11.07	66.45	10.41	63.22	10.01	61.18
103	14.92	97.09	14.50	94.47	13.53	88.05	13.09	84.48	12.51	80.39	12.09	77.69
104	15.02	109.20	14.09	101.90	13.27	95.46	12.88	92.41	12.36	88.27	11.98	85.22
105	14.70	83.40	13.01	71.78	10.21	61.89	9.72	59.52	9.30	57.23	8.98	55.74
106	15.01	75.82	13.91	72.33	11.83	65.04	11.15	62.63	10.43	60.03	10.01	58.37
107	15.15	96.82	14.51	92.94	13.19	84.82	12.50	80.37	11.58	74.75	10.96	70.53
108	14.98	104.40	13.62	93.79	12.90	87.80	12.34	84.06	11.77	80.03	11.43	77.13
109	15.28	89.63	14.71	87.75	13.48	80.80	12.94	77.44	12.14	73.29	11.64	70.41
110	15.00	104.00	14.34	99.32	14.15	97.70	13.49	95.71	13.53	93.03	13.28	90.71
111	10.99	66.13	10.68	63.78	9.68	59.38	9.39	57.73	9.02	56.12	8.80	54.74
112	11.05	74.86	10.85	72.95	10.30	68.29	9.82	65.94	9.48	63.58	9.29	62.06
113	6.72	48.15	6.73	48.25	6.69	48.02	6.74	48.08	6.69	47.98	6.72	48.05

* Sample taken as soon as test conditions were achieved (usually about 5-min. from start of test).

APPENDIX TABLE E-8

BENCH TEST DATA - LAB. B

(5-MIN. SONIC SHEAR TEST)

ARO Oil No.	Fresh Oil Viscosity cSt.		Visc. cSt. after 5-Min. Sonic Shear Test	
	210°F	100°F	210°F	100°F
101	15.01	86.03	13.08	76.24
102	14.96	85.74	11.46	68.44
103	14.88	98.91	13.91	90.60
104	14.95	108.40	13.76	98.19
105	14.78	83.60	10.12	60.80
106	14.90	76.87	12.22	64.87
107	15.11	97.08	13.30	85.87
108	14.91	106.20	13.40	92.90
109	15.16	90.07	13.42	80.81
110	14.93	102.70	14.50	100.40
111	10.95	66.12	9.57	59.04
112	10.99	74.66	10.16	68.79
113	6.72	48.55	-	-

APPENDIX TABLE E-9

BENCH TEST DATA - LAB. A

(10-MIN. SONIC SHEAR TEST)

ARO Oil No.	Fresh Oil Viscosity cSt. 210°F	Fresh Oil Viscosity cSt. 100°F	Viscosity, cSt. @ 210 F After 10-Min. Sonic Shear	Viscosity Loss
101	15.05	86.11	12.83	2.22
102	15.02	86.04	11.19	3.83
103	14.97	97.09	15.97	1.00
104	15.02	109.20	13.71	1.31
105	14.70	83.40	9.92	4.78
106	15.01	75.82	11.82	3.19
107	15.15	96.82	13.05	2.10
108	14.98	104.40	13.50	1.48
109	15.23	89.63	13.16	2.07
110	15.00	104.00	14.51	0.49
111	10.99	66.13	9.56	1.43
112	11.05	74.86	10.29	0.76
113	6.72	48.15	6.65	0.07

APPENDIX TABLE E-10

BENCH TEST DATA - LAB. T

(6-HOUR KADY DISPERSION MILL)

ARO Oil No.	Fresh Oil Viscosity cSt. @ 210°F	Sheared Oil Viscosity cSt. @ 210°F
101	15.13	13.64
102	15.03*	11.73
103	14.87	13.68
104	14.96	12.91
105	14.78	10.90
106	14.96*	12.66
107	15.12	13.56
108	14.95	12.69
109	15.26	13.79
110	14.96	14.39
111	11.00	10.21
112	10.96	10.29
113	-	-

* These are the 15-Lab. average values that were substituted for the reported values.

APPENDIX F

LABORATORY ENGINE TEST DATA

APPENDIX TABLE F-1

LABORATORY ENGINE TEST DATA - LAB. N

(327 CID V-8 ENGINE)

ARO Oil No.	Fresh Oil Visc. cSt.	Viscosity cSt. @ 210 F After Use in Motored Engine			
		1/2 Hr.	3 Hrs.	10 Hrs.	24 Hrs.
101	15.16	14.87	14.20	13.36	12.52
102	15.15	14.29	12.93	11.76	11.19
103	15.15	14.63	13.38	12.58	12.00
104	15.14	14.40	13.84	13.07	12.64
105	15.10	13.52	11.86	10.72	10.14
106	15.12	13.92	12.67	11.60	10.99
107	15.30	14.72	13.86	12.60	11.72
108	15.10	14.13	13.17	12.31	12.13
109	15.36	15.10	14.66	13.84	13.63
110	15.19	14.90	14.66	14.41	14.24
111	11.06	10.97	10.68	10.31	10.02
112	11.14	10.94	10.57	10.17	9.95
113	6.76	6.81	6.83	6.84	6.90

APPENDIX TABLE F-2

LABORATORY ENGINE TEST DATA - LABS, T & G

(SINGLE CYLINDER CLR ENGINE - 10 HOUR TEST)

Test No.	Oil Code	Viscosity at 210°F, cSt. Fresh Oil	After 10-Hr. L-38 Test Unstripped	Stripped	Viscosity Loss (a) Actual	Corrected (b)
1	REO 192	16.10	13.30	13.34	2.80	2.20
2	ARO 101	15.15	13.51	13.55	1.60	1.33
3	ARO 102	14.92	11.95	11.97	2.95	2.60
4	ARO 103	15.12	13.31	13.31	1.81	1.70
5	ARO 104	15.01	13.55	13.56	1.45	1.46
6	ARO 105	14.90	11.35	11.42	3.48	3.75
7	ARO 106	15.12	12.18	12.29	2.83	3.31
8	REO 192	16.10	14.37	- -	1.73	2.20
(Rebuilt Engine)						
1	REO 192	16.10	13.54	13.54	2.56	2.20
2	ARO 107	15.31	12.66	12.77	2.54	2.35
3	GRO 108	(c)	(c)	(c)	(c)	(c)
4	REO 192 (d)	16.10	14.34	14.25	1.76	2.20
5	REO 192 (d)	16.10	14.20	14.17	1.90	2.20
6	REO 192 (d)	16.10	14.23	14.23	1.87	2.20
7	ARO 109	15.28	14.31	14.40	0.88	1.30
8	GRO 110	(c)	(c)	(c)	(c)	(c)
9	ARO 111	11.05	10.53	10.61	0.44	0.85
(Rebuilt Engine)						
1	REO 192 (d)	16.10	12.92	12.99	3.18	2.20
2	ARO 108	15.01	12.29	12.41	2.60	1.92
3	ARO 110	15.04	14.26	14.31	0.73	0.58
4	ARO 112	11.00	9.94	10.01	0.99	0.85
5	REO 192 (d)	16.10	13.74	- -	2.36	2.20

(a) Unstripped viscosities were used for the reference oils (REO-Oils) since not all stripped viscosities were available.

(b) Viscosities of the stripped used oils were adjusted based on an average of 13.9 cSt. for the REO 192 used oil.

(c) No results obtained since these were Gear Reference Oils.

(d) Viscosities of these reference oils were supplied by Organization F.

APPENDIX TABLE F-3

LABORATORY ENGINE TEST DATA - LAB. D

(16-HOUR FORD MS VC ENGINE TEST)

MS-VC Test No.	ARO Oil No.	Viscosity at 210°F, cSt.				
			Blend after 16-Hr. MS-VC		Viscosity Loss	
		Fresh Oil	Unstripped	Stripped	Actual	Corrected *
1	104	15.01	10.06	11.90	3.11	3.11
2	109	15.28	11.93	13.76	1.52	1.54
3	101	15.15	11.00	12.63	2.52	2.58
4	102	14.92	9.65	11.07	3.85	3.98
5	103	15.12	10.16	11.79	3.33	3.47
6	106	15.12	9.30	10.71	4.41	4.65
7	107	15.31	10.25	11.82	3.49	3.72
8	104	15.07	10.56	12.27	2.80	3.03
9	**					
10	**					
11	111	11.05	8.45	9.74	1.31	1.46
12	112	11.00	8.07	9.47	1.53	1.73
13	105	14.90	9.00	10.44	4.46	5.10
14	104	15.06	10.58	12.32	2.74	3.17
15	108	15.01	10.31	11.94	3.07	3.60
16	110	15.04	12.15	13.97	1.07	1.27
17	105	14.92	9.48	10.71	4.21	5.05
18	104	15.07	10.74	12.50	2.57	3.12
(Rebuilt Engine)						
19	104	15.04	10.38	11.85	3.19	3.19
20	109	15.24	12.43	13.67	1.57	1.60
21	101	15.12	11.20	12.68	2.44	2.49
22	102	14.96	9.65	11.01	3.92	4.04
23	105	14.92	9.16	10.33	4.59	4.81

* Engine severity decreased for each succeeding 16-Hr. test.

** No results obtained since Gear Reference Oils were tested by mistake.

APPENDIX G

MISCELLANEOUS DATA SUMMARIES

APPENDIX TABLE G-1

SUMMARY OF CORRECTED* VISCOSITY LOSS DATA FROM THE ASTM SHEAR STABILITY FLEET TESTS

ARO Oil No.	Fleet - Processor -	210 F Viscosity Losses, cSt., After 1,500 Miles of Use																		Six-Fleet** Average
		A A	A J	A Avg.	B A	B B	B Avg.	C K	C C	C D	C Avg.	D C	D D	D G	D Avg.	E R	E G	E Avg.	F H	
101		1.65	1.64	1.65	1.55	1.52	1.54	1.49	1.55	1.42	1.49	1.92	1.81	1.56	1.76	1.76	1.80	1.78	1.60	1.64
102		3.13	3.11	3.12	3.22	3.17	3.20	2.64	2.55	2.47	2.55	3.20	3.27	3.26	3.24	3.53	3.42	3.48	2.57	3.03
103		2.08	2.03	2.06	1.51	1.36	1.44	1.43	1.32	1.51	1.42	1.85	1.97	2.03	1.95	1.84	1.66	1.75	1.87	1.75
104		2.37	2.19	2.28	2.06	2.07	2.07	1.76	1.80	1.46	1.67	2.28	2.31	2.28	2.29	2.29	1.94	2.12	1.80	2.04
105		3.90	3.97	3.94	3.98	3.95	3.97	3.58	3.63	3.91	3.71	3.89	4.27	4.22	4.13	4.65	4.59	4.62	3.99	4.06
106		4.17	3.93	4.05	3.68	3.79	3.74	3.42	3.40	3.36	3.39	3.88	3.79	3.96	3.88	4.12	4.09	4.11	3.94	3.85
107		2.36	2.36	2.36	2.14	2.10	2.12	1.80	1.83	2.05	1.89	2.05	2.22	2.18	2.15	2.56	2.38	2.47	2.05	2.17
108		2.51	2.51	2.51	2.25	2.10	2.18	2.10	2.19	2.13	2.14	2.30	2.38	2.34	2.34	2.65	2.59	2.62	2.42	2.37
109		0.45	0.37	0.41	-0.10	-0.44	-0.27	-0.11	0.00	0.08	-0.01	0.23	0.35	0.05	0.21	-0.11	-0.17	-0.14	0.05	0.04
110		0.38	0.57	0.48	0.33	0.16	0.25	0.33	0.13	0.49	0.32	0.32	0.55	0.51	0.46	0.27	0.36	0.32	0.23	0.34
111		0.92	0.84	0.88	0.58	0.58	0.58	0.37	0.44	0.41	0.41	0.70	0.81	0.94	0.82	0.73	0.89	0.81	0.51	0.67
112		0.85	0.86	0.86	0.75	0.56	0.66	0.57	0.58	0.56	0.57	0.77	0.87	0.83	0.82	0.82	0.85	0.84	0.71	0.74
113		-0.16	-0.24	-0.20	-0.39	-0.37	-0.38	-0.54	-0.48	-0.33	-0.45	-0.15	-0.19	-0.19	-0.18	-0.08	-0.06	-0.07	-0.55	-0.31

Overall Pooled Reproducibility Standard Deviation = 0.10 cSt.

* Viscosity losses for each fleet and processor corrected for car effect.

** Six-fleet average obtained by averaging the average values from each of the six-fleets.

APPENDIX TABLE G-2

SUMMARY OF THE UNCORRECTED VISCOSITY LOSS DATA FROM THE ASTM SHEAR STABILITY FLEET TESTS

ARO Oil No.	Fleet - Processor -	210 F Viscosity Losses, cSt., After 1,500 Miles of Use																		Uncorrected Six-Fleet Average
		A A	A J	Avg.	B A	B B	Avg.	C K	C C	C D	Avg.	D C	D D	D G	Avg.	E R	E G	Avg.	F H	
101		1.63	1.62	1.63	1.75	1.68	1.72	1.66	1.76	1.65	1.69	2.01	1.97	1.71	1.90	1.76	1.81	1.79	1.20	1.66
102		3.27	3.30	3.29	3.41	3.31	3.36	2.91	2.82	2.77	2.83	3.15	3.16	3.20	3.17	3.56	3.49	3.53	2.58	3.13
103		2.15	2.09	2.12	1.28	1.16	1.22	1.47	1.35	1.54	1.45	1.86	1.99	2.08	1.98	1.83	1.71	1.77	1.69	1.71
104		2.49	2.30	2.40	2.23	2.23	2.23	1.89	1.91	1.66	1.82	2.31	2.33	2.31	2.32	2.22	1.85	2.04	1.81	2.10
105		3.95	3.96	3.96	3.83	3.84	3.84	3.07	3.10	3.41	3.19	3.92	4.31	4.24	4.16	4.67	4.66	4.67	4.11	3.99
106		4.01	3.79	3.90	3.57	3.70	3.64	3.28	3.30	3.22	3.27	3.85	3.79	3.89	3.84	4.15	4.13	4.14	4.12	3.82
107		2.23	2.26	2.25	2.12	2.08	2.10	1.88	1.94	2.11	1.98	2.03	2.18	2.16	2.12	2.55	2.39	2.47	2.23	2.19
108		2.50	2.49	2.50	2.31	2.19	2.25	1.93	1.99	1.87	1.93	2.14	2.19	2.12	2.15	2.63	2.55	2.59	2.62	2.34
109		0.32	0.23	0.28	-0.11	-0.43	-0.27	-0.15	-0.09	-0.04	-0.09	0.17	0.26	-0.03	0.13	-0.19	-0.31	-0.25	-0.06	-0.04
110		0.46	0.69	0.58	0.35	0.16	0.26	0.23	0.06	0.41	0.23	0.43	0.66	0.63	0.57	0.24	0.32	0.28	0.15	0.35
111		0.97	0.90	0.94	0.54	0.54	0.54	0.57	0.63	0.64	0.61	0.65	0.75	0.87	0.76	0.87	1.00	0.94	0.62	0.74
112		0.79	0.80	0.80	0.56	0.39	0.48	0.36	0.38	0.37	0.37	0.79	0.90	0.85	0.85	0.84	0.87	0.86	0.70	0.68
113		-0.17	-0.25	-0.21	-0.28	-0.30	-0.29	-0.26	-0.18	-0.08	-0.17	-0.07	-0.07	-0.05	-0.06	-0.08	-0.10	-0.09	-0.55	-0.23

APPENDIX TABLE G-3

MECHANICAL SHEAR STABILITY OF ASTM OILS IN LABORATORY BENCH TEST, LABORATORY ENGINE TESTS AND FLEET TESTS

210 F Viscosity Losses, cSt., by the Various Shear Stability Test Methods

ARO Oil No.	Lab.-	Diesel Injector Nozzle Type									Power Steering Pump Type Tests							Sonic Shear		Kady Mill	Laboratory Engine Type Tests						Six-Fleet Avg.
		J		C			L	M			A					D	R	A	B	T	Motored Engine Test N				L-38 T	MS VC G	
		5 Passes	20 Passes	1 Pass	5 Passes	10 Passes	20 Passes	5 Passes	10 Passes	20 Passes	5 Min.	1 Hr.	2 Hr.	4 Hr.	6 Hr.	4 Hr.	1 Hr.	10 Min.	5 Min.	6 Hr.	1/2 Hr.	3 Hr.	10 Hr.	24 Hr.	10 Hr.	16 Hr.	
101		2.16	3.23	2.60	3.85	4.27	2.92	1.68	2.31	2.97	0.79	2.17	2.98	3.68	3.96	3.44	2.62	2.22	1.93	1.49	0.29	0.96	1.80	2.64	1.33	2.55	1.64
102		3.90	4.71	3.77	5.14	5.53	4.40	2.72	3.71	4.49	1.20	3.25	3.95	4.61	5.01	4.90	3.97	3.83	3.50	3.30	0.86	2.22	3.39	3.96	2.60	3.99	3.03
103		2.48	2.87	1.91	3.36	3.74	2.43	1.56	1.95	2.38	0.47	1.44	1.88	2.46	2.88	2.70	2.97	1.00	0.97	1.19	0.52	1.77	2.57	3.15	1.70	3.47	1.75
104		2.44	2.84	2.05	3.38	3.66	2.85	1.84	2.26	2.65	0.93	1.75	2.14	2.66	3.04	2.59	2.11	1.31	1.19	2.05	0.74	1.30	2.07	2.50	1.46	3.03	2.04
105		4.72	5.46	4.71	5.85	6.19	5.24	4.34	4.85	5.13	1.69	4.49	4.98	5.40	5.72	5.57	5.16	4.78	4.66	3.88	1.58	3.24	4.38	4.96	3.75	4.94	4.06
106		3.28	4.46	3.36	4.83	5.25	3.99	2.36	2.99	3.54	1.10	3.18	3.86	4.58	5.00	4.75	4.27	3.19	2.68	2.30	1.20	2.45	3.52	4.13	3.31	4.65	3.85
107		2.35	3.84	2.43	4.27	4.81	2.77	1.84	2.36	3.04	0.64	1.96	2.65	3.57	4.19	3.83	2.98	2.10	1.81	1.56	0.58	1.44	2.70	3.58	2.35	3.72	2.17
108		3.23	3.76	2.51	4.00	4.29	3.15	2.39	2.70	3.05	1.36	2.08	2.64	3.21	3.55	3.29	2.33	1.48	1.51	2.26	0.97	1.93	2.79	2.97	1.92	3.60	2.37
109		2.18	3.02	2.47	3.62	4.06	2.56	1.64	2.07	2.64	0.52	1.75	2.31	3.09	3.59	3.29	2.65	2.07	1.74	1.47	0.26	0.70	1.52	1.73	1.30	1.59	0.04
110		1.11	1.32	0.91	1.76	1.99	1.22	0.71	0.85	1.17	0.66	0.85	1.51	1.47	1.72	1.43	0.99	0.49	0.43	0.57	0.29	0.53	0.78	0.95	0.58	1.27	0.34
111		1.28	1.76	1.42	2.02	2.32	-	0.96	1.17	1.49	0.31	1.31	1.60	1.97	2.19	1.77	1.36	1.43	1.38	0.79	0.09	0.38	0.75	1.04	0.85	1.46	0.67
112		1.08	1.45	1.28	1.94	2.16	-	1.16	1.12	1.37	0.20	0.75	1.23	1.57	1.76	1.53	1.27	0.76	0.83	0.67	0.20	0.57	0.97	1.19	0.85	1.73	0.74
113		-0.11	-0.07	0.03	0.04	0.04	-	-0.03	-0.07	-0.07	-0.01	0.03	-0.02	0.03	0.00	0.04	-0.17	0.07	-	-	-0.05	-0.07	-0.08	-0.14	-	-	-0.31

APPENDIX TABLE G-4

RESULTS OF LINEAR REGRESSION ANALYSES USING ALL BENCH TEST AND LABORATORY ENGINE DATA

Equation Model: $Y = A+BX$

Where Y is Six-Fleet Average and X is Bench Test and Laboratory Engine Data

		Intercept (A)	Slope (B)	Std. Error	Corr. Coef.
Diesel Injector Nozzle					
Lab. J	5 Passes	-0.53	0.97	0.63	0.84
	20 Passes	-0.69	0.81	0.64	0.90
Lab. C	1 Pass	-0.51	0.99	0.72	0.87
	5 Passes	-0.88	0.77	0.70	0.88
	10 Passes	-0.91	0.71	0.74	0.86
Lab. L	20 Passes	-1.07	1.02	0.68	0.87
Lab. M	5 Passes	-0.33	1.15	0.69	0.88
	10 Passes	-0.41	0.98	0.66	0.89
	20 Passes	-0.57	0.88	0.69	0.88
Power Steering Pump					
Lab. A	5 Min.	-0.14	2.46	0.76	0.86
	1 Hour	-0.26	1.07	0.64	0.90
	2 Hours	-0.59	0.95	0.66	0.89
	4 Hours	-0.72	0.83	0.70	0.88
	6 Hours	-0.77	0.76	0.74	0.86
Lab. D	4 Hours	-0.63	0.78	0.74	0.88
Lab. R	1 Hour	-0.41	0.86	0.68	0.89
Kady Mill					
Lab. T	6 Hours	-0.07	1.09	0.72	0.85
Sonic Shear					
Lab. A	10 Min.	0.12	0.84	0.84	0.82
Lab. B	5 Min.	0.28	0.85	0.86	0.78
Motored Engine					
Lab. N	0.5 Hour	0.12	2.77	0.50	0.94
	3 Hours	-0.16	1.40	0.43	0.96
	10 Hours	-0.43	1.03	0.45	0.95
	24 Hours	-0.51	0.89	0.47	0.95
L-38 Engine Test					
Lab. T	10 Hours	-0.37	1.23	0.48	0.94
MS VC Engine Test					
Lab. G	16 Hours	-1.11	1.00	0.34	0.97

APPENDIX TABLE G-5

COMPARISON OF VISCOSITY LOSSES, % LOSSES AND SHEAR STABILITY INDEXES % OF THE ARO OILS BY THE DIFFERENT MECHANICAL SHEARING METHODS

Viscosity Losses,[b] cSt., % Loss[c] and Shear Stability Index[d] % of Blended Oils Obtained By Various Methods of Shearing

ARO Oil No.	Six-Fleet Avg. @ 1500 Miles			16-Hr. Ford MS VC Test			10-Hr. L-38 Engine Test			3-Hr. Motored Engine Test			1-Hr. Power Steering Test			Diesel Injector 10 Passes			6-Hr. Kady Mill Test			10-Min. Sonic Shear Test		
	Loss		Shear Stability Index	Loss		Shear Stability Index	Loss		Shear Stability Index	Loss		Shear Stability Index	Loss		Shear Stability Index	Loss		Shear Stability Index	Loss		Shear Stability Index	Loss		Shear Stability Index
	cSt.	%		cSt.	%		cSt.	%		cSt.	%		cSt.	%		cSt.	%		cSt.	%		cSt.	%	
101	1.6	10.9	17.6	2.6	16.9	27.3	1.3	8.8	14.2	1.0	6.4	10.3	2.2	14.4	23.2	2.3	15.3	24.7	1.5	9.9	16.0	2.2	14.8	23.8
102	3.0	20.2	33.0	4.0	26.6	43.4	2.6	17.3	28.3	2.2	14.8	24.2	3.3	21.6	35.4	3.7	24.7	40.4	3.3	22.0	35.9	3.8	25.5	41.7
103	1.8	11.7	17.2	3.5	23.1	34.1	1.7	11.3	16.7	1.8	11.8	17.4	1.4	9.6	14.1	2.0	13.0	19.2	1.2	7.9	11.7	1.0	6.7	9.8
104	2.0	13.6	23.2	3.0	20.3	34.4	1.5	9.8	16.6	1.3	8.7	14.8	1.8	11.7	19.9	2.3	15.1	25.7	2.1	13.7	23.3	1.3	8.8	14.9
105	4.1	27.0	43.2	4.9	32.8	52.7	3.8	24.9	40.0	3.2	21.5	34.5	4.5	29.8	47.9	4.9	32.2	51.7	3.9	25.8	41.4	4.8	31.8	51.0
106	3.9	25.6	41.1	4.7	31.0	49.7	3.3	22.1	35.4	2.5	16.3	26.2	3.2	21.2	34.0	3.0	19.9	31.9	2.3	15.3	24.6	3.2	21.3	34.1
107	2.2	14.3	22.5	3.7	24.6	38.5	2.4	15.5	24.3	1.4	9.5	14.9	2.0	12.9	20.3	2.4	15.6	24.4	1.6	10.3	16.1	2.1	13.9	21.7
108	2.4	15.8	24.9	3.6	24.0	37.8	1.9	12.8	20.1	1.9	12.9	20.3	2.1	13.9	21.8	2.7	18.0	28.3	2.3	15.1	23.7	1.5	9.9	15.5
109	0.0	0.3	0.4	1.6	10.4	16.1	1.3	8.5	13.2	0.7	4.6	7.1	1.8	11.5	17.7	2.1	13.6	21.0	1.5	9.7	14.9	2.1	13.6	21.0
110	0.3	2.3	3.5	1.3	8.5	12.9	0.6	3.9	5.9	0.5	3.5	5.4	0.9	5.7	8.7	0.9	5.7	8.7	0.6	3.8	5.8	0.5	3.3	5.0
111	0.7	6.1	13.3	1.5	13.3	29.0	0.9	7.7	16.9	0.4	3.5	7.5	1.3	11.9	26.0	1.2	10.7	23.2	0.8	7.2	15.7	1.4	13.0	28.4
112	0.7	6.7	13.4	1.7	15.6	31.2	0.9	7.7	15.3	0.6	5.2	10.3	0.8	6.8	13.5	1.1	10.1	20.2	0.7	6.1	12.1	0.8	6.9	13.7
113	-0.3	-4.6	-	-	-	-	-	-	-	-0.1	-1.0	-	0.0	0.4	-	-0.1	-1.0	-	-	-	-	0.1	1.0	-

(a) Fresh oil viscosities determined by Lab. P.

(b) Viscosity losses, cSt., obtained by subtracting sheared oil viscosities from fresh oil viscosities.

(c) % loss is the viscosity loss divided by blended fresh oil viscosity.

(d) Shear stability index is calculated by dividing viscosity loss by the new oil polymer contributed viscosity.

APPENDIX TABLE G-6

RESULTS OF LINEAR REGRESSION ANALYSES USING VISCOSITY LOSSES, % LOSSES AND SHEAR STABILITY INDICES

Equation Model: $Y = A+BX$

Where Y is the Six-Fleet Average Data and
X is the Laboratory Data

		Correlation Coefficients		
		Visc. Loss	% Visc. Loss	Shear Stability Index
Laboratory Engine Tests				
MS VC	16 Hours	0.97	0.97	0.97
Motored Engine	3 Hours	0.96	0.96	0.94
L-38	10 Hours	0.94	0.93	0.93
Bench Tests				
Power Steering Pump		0.90	0.90	0.84
Diesel Injector		0.89	0.90	0.86
Kady Mill		0.85	0.84	0.84
Sonic Shear		0.82	0.80	0.74

APPENDIX TABLE G-7

ASTM REFERENCE OILS
NEW OIL VISCOSITIES, cSt., AT 210 F

ARO Oil No.	Lab.- A	B	C	E	G	H	R	J	K	L	M	N	T	P	Q	15-Lab. Average
101	15.05	15.01	15.24	15.11	15.01	14.98	15.01	15.07	15.08	15.14	15.14	15.16	15.13	15.05	14.99	15.08
102	15.02	14.96	15.06	14.78	14.97	15.18	14.99	15.00	15.06	15.06	15.06	15.15	14.27*	15.02	15.04	15.03
103	14.97	14.88	14.91	15.10	15.01	14.91	15.07	14.98	14.87	15.06	14.87	15.15	14.87	15.02	15.02	14.98
104	15.02	14.95	15.06	14.95	14.94	15.02	14.99	14.87	14.90	14.99	14.89	15.14	14.96	14.96	15.00	14.98
105	14.70	14.78	14.74	15.00	14.91	14.89	14.96	14.81	14.58	14.78	14.44*	15.10	14.78	15.05	14.94	14.87
106	15.01	14.90	15.00	15.08	14.97	15.06	14.94	14.94	14.91	14.91	14.77	15.12	14.63*	15.01	14.85	14.96
107	15.15	15.11	15.14	15.15	15.13	15.16	15.16	15.12	15.04	15.06	15.10	15.30	15.12	15.15	15.17	15.14
108	14.98	14.91	14.99	15.05	14.94	14.87	14.96	14.92	14.90	14.98	14.89	15.10	14.95	15.00	14.97	14.96
109	15.23	15.16	15.31	15.28	15.18	15.20	15.25	15.23	15.17	15.22	15.21	15.36	15.26	15.23	15.19	15.23
110	15.00	14.93	14.94	15.00	15.00	15.05	15.00	15.05	14.95	15.05	14.98	15.19	14.96	15.00	15.06	15.01
111	10.99	10.95	11.03	10.97	10.99	10.89	10.99	10.98	10.88	-	10.96	11.06	11.00	10.97	10.95	10.97
112	11.05	10.99	11.06	11.06	11.02	11.06	11.01	11.01	10.99	-	10.98	11.14	10.96	11.06	11.09	11.03
113	6.72	6.72	6.77	6.73	6.72	6.72	6.77	6.68	6.66	-	6.68	6.76	-	6.70	6.69	6.72

Pooled Reproducibility Standard Deviation = 0.08 cSt.

* Outlier omitted from average and pooled reproducibility standard deviation.

APPENDIX TABLE G-8

ASTM REFERENCE OILS
NEW OIL VISCOSITIES, cSt., AT 100 F

ARO Oil No.	Lab - A	B	C	E	G	H	R	J	K	M	P	11-Lab. Average
101	86.11	86.03	86.72	86.35	86.10	86.60	87.00	86.40	85.80	86.37	86.19	86.33
102	86.04	85.74	86.01	84.64	85.95	86.10	86.60	86.00	86.10	85.99	85.93	85.92
103	97.09	98.91	97.62	98.09	97.92	97.70	98.70	97.60	97.80	97.45	98.09	97.91
104	109.20	108.40	108.90	108.60	108.78	108.38	105.50*	108.10	108.80	108.10	108.90	108.62
105	83.40	83.60	83.41	83.83	83.73	85.05	84.80	84.20	82.80	84.03	84.54	83.94
106	75.82	76.87	76.08	77.44	75.72	76.08	76.90	75.80	75.50	75.79	76.95	76.27
107	96.82	97.08	97.39	97.63	97.60	97.22	96.90	97.50	96.90	97.26	97.58	97.26
108	104.40	106.20	105.00	104.65	104.40	104.59	105.40	104.50	104.30	104.70	105.10	104.84
109	89.63	90.07	90.76	90.69	90.30	90.98	90.50	90.80	90.30	91.01	90.81	90.53
110	104.00	102.70	104.60	104.41	104.55	104.27	104.80	104.90	104.30	103.90	104.40	104.26
111	66.13	66.12	66.13	65.99	66.15	66.98	67.30	66.20	65.80	66.30	66.29	66.31
112	74.86	74.66	75.02	74.82	74.76	74.60	76.00	74.80	74.80	74.53	74.84	74.88
113	48.15	48.55	48.47	48.30	48.39	48.37	50.30	48.30	48.12	48.41	48.55	48.54

*Outlier omitted from average

APPENDIX TABLE G-9

REPEATABILITY OF COMBINED ENGINE TEST,
STRIPPING PROCEDURE AND VISCOSITY DETERMINATION

Fleet	ARO Oil No.	Processor	210 F Viscosity Loss, cSt., @ 1,500 Miles	
			1st Test	2nd Test
	101		1.55	2.01
A	103	A	1.74	1.84
	107		2.30	2.27
	112		0.74	0.81
	102		4.13	3.36
B	104	A	1.47	1.21
	107		2.03	1.55
	111		0.73	0.79
	102		2.60	3.30
C	104	C	2.19	1.79
	108		2.86	2.81
	110		1.22	0.53
	105		4.53	4.55
E	109	R	0.20	0.61
	112		0.58	0.84
	113		-0.07	-0.08

Pooled Repeatability Standard Deviation = 0.28 cSt.