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WATER SEPARATION METHODS STUDY

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WATER SEPARATION METHODS STUDY

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ABSTRACT

An aircraft turbine fuel Water Separation Methods validation program has been completed. In the study water separation methods measurements were for the first time experimentally compared against actual coalescence test results. This program was part of an extended study both of ways to improve the ASTM D 3948 MSEP test method and of the effectiveness of other water separation test methods. The effect of fuel quality on coalescence was measured in the Navy Coalescence Tester (NCT) using jet fuel field samples and jet fuel samples prepared to simulate additive and contamination effects. The jet fuels evaluated in the NCT were then tested using the various water separation test methods, and the results compared against the actual coalescence results.

The Interface Rating for the ASTM D 1094 Water Reaction Test was found to be non-responsive to any change in fuel coalescence quality. Thus, the D 1094 Interface rating results from this study clearly fail to show any evidence of test validity. The D 1094 Separation Rating and proposed Meniscus Geometry Rating were responsive to some but not all fuel quality variations, separately or in combination.

The other test methods evaluated all showed a response to variations in fuel coalescence quality. Results of regression analyses of the other water separation methods test results against NCT continuous coalescence times were used to statistically compare the effectiveness of various tests. The improved MSEP with the M Cell was found to be superior to the standard MSEP. Additional improvement can be achieved by using an Aluminum Syringe in conjunction with the M Cell. The test methods which produced numeric results were statistically ranked as follows: (1) MSEP with M Cell and Aluminum Syringe, (2) MSEP with M Cell, (3) Swift Kit, (4) MSEP with Aluminum Syringe, (5) Interfacial Tension ASTM D 971, (6) Standard MSEP ASTM D 3948, (7) IP 452 WASP test.

1. INTRODUCTION

Water and dirt contamination in jet fuel onboard an aircraft represents a potentially catastrophic threat to flight safety. A key element in preventing water and particulate contamination is the detection of surface active compounds. Surfactants are potentially deleterious because they can cause a number of problems e.g. they can absorb on and deactivate water coalescing surfaces, lift rust from storage tank and pipeline walls and/or reduce the size of dirt and water particles in the jet fuel and thus adversely affect settling, filtration and coalescence. Thus, tests are needed to insure that jet fuel as it is manufactured is free of surfactants, as well as to detect any surfactant pickup in transit.

Starting in 1995 an effort to both improve existing test methods and to encourage the development of new test methods to detect surfactants in jet fuel has been carried out by the ASTM Committee D-2 Subcommittee J Section 10 Water Separation Methods Task Force. The main effort of the Task force was directed toward developing an improved ASTM D 3948 "Standard Test Method for Determining the Water Separation Characteristics of Jet Fuel" (MSEP). After extensive work an improved MSEP method using a new M Cell was developed which demonstrated better reproducibility and reduced sensitivity to static dissipator additive. The improved MSEP was successfully tested in a round robin. However, acceptance of the improved MSEP was held up pending the development of a data base comparing the rating levels of the current and improved methods.

As a result, a number of programs including Air Force and Canadian studies were carried out comparing the current and improved MSEP. The Task Force finally concluded that it was also necessary to carry out a test method validation program. This test method validation program would for the first time obtain data comparing water separation methods test results against actual coalescence measurements using a series of carefully planned fuels. The Navy Coalescence Tester (NCT) unit at Patuxent River, Maryland was selected for this study. In addition to the primary goal of comparing the current and improved MSEP, a number of other established tests and tests under development were included for evaluation in the study. An additional goal was to help develop an improved understanding for test method users of the effect on actual fuel water coalescence of approved additives, contaminants and general fuel quality as measured by the various test methods.

2. CONCLUSIONS

The following conclusions resulted from the analysis of the data obtained in this study.

- The Interface Rating in the ASTM D 1094 Water Reaction Test was found to be non-responsive to any change in fuel coalescence quality. Results of this study, thus, clearly fail to show any evidence of test validity for the D 1094 Interface Rating. The D 1094 Separation Rating and the proposed Meniscus Geometry Rating were found to be responsive to some but not all differences in fuel quality, separately or in combination.

- The other test methods evaluated all showed a response to variations in fuel coalescence quality. Results of regression analyses of fuel quality tests which produced numeric results against NCT continuous coalescence times were used to statistically compare the effectiveness of the various tests. Test results with the new MSEP methods (use of the M Cell and use of the M Cell and Aluminum Syringe) corroborated the improvements seen in earlier studies. The majority of regression analyses produced correlation coefficients large enough to indicate that the regression lines were statistically significant at approximately the 90% confidence level or higher, demonstrating evidence of test validity.

- Statistical ranking of the test methods based on the percent of total variance explained by the linear correlation shows the following descending order: (1) MSEP with M Cell and Aluminum Syringe, (2) MSEP with M Cell, (3) Swift kit, (4) MSEP with Aluminum Syringe, (5) Interfacial Tension, (6) Standard MSEP, and (7) WASP test. The test methods were also compared using a Test Strength Index equal to the magnitude of the range of test results divided by the standard deviation of the regression. The Test Strength Index produced the same ranking order.

- The Navy Coalescence Tester unit provided excellent pass/fail and continuous coalescence time data.

3. NAVY COALESCENCE TESTER PROGRAM

3.1 EXPERIMENTAL EQUIPMENT AND TESTING

The Navy Coalescence tester (NCT) was designed and validated by Exxon Research and Engineering Company (ER&E) under contract to the Navy in the late 1980's (1). The goal of this program was to develop a simple laboratory coalescence test which duplicates actual field operational conditions at a scaled down flow rate, and which could be correlated against actual Single Element Test results. Critical design criteria included the ability to conduct testing on a once-through basis, utilization of coalescer materials similar to commercial filter/coalescers, operation at low inlet free water levels, and the ability to conduct long term testing. As part of the Navy contract, ER&E carried out a validation program, in which the laboratory unit results were compared against actual full scale single element tests, which concluded "Single Element Tests, conducted using full-scale military filter/coalescer elements, validated the results" (1). The NCT is a scaled down version of a full scale filter coalescer assembly. A schematic is shown in Figure 1. The NCT utilizes a miniature version of a full sized coalescer and separaror assembled in a capsule using state-of-the- art commercial media (Velcon I-6XX87). The capsule concept was developed prior to the Navy contract by ER&E during work to develop a test to evaluate the in-situ condition of full scale, in-use jet fuel handling equipment; and the concept was adopted for use in the NCT (2). The capsule is engineered to have the same flow per unit area as a full sized coalescer, but at a 800 fold reduction in total flow rate. The single pass fuel flow rate is 100 ml/min. In the NCT program a known amount of water (200 to 300 PPM free water) is injected into the inlet fuel. Run duration was 80 hours. Total water is measured by Karl Fischer at three points (tank effluent, coalescer influent and coalescer effluent). NCT failure criteria was based on when the coalescer inlet and effluent water levels first become equal.

Test fuels were selected to both cover a wide range of coalescence quality and to investigate a number of critical contamination issues. The test fuels used in the various NCT unit runs are listed in Table 1. Two base fuels were employed to which were added a variety of approved additives and unapproved contaminants.. Two naturally occurring "problem fuels" (fuels which exhibited evidence of surfactant related problems which were tested as-is) were also employed in the study. Base Fuel A was a hydrotreated Jet A fuel produced in the U.S, and Base Fuel B was a Merox treated Jet A-1 fuel produced in the U.K. The effects of approved additives were studied in the Merox treated base fuel since Merox fuels are often more sensitive to additive addition than hydrotreated fuels. The effect of a variety of unapproved contaminants were tested in the hydrotreated base fuel. In the run 3 fuel, sodium dodecyl benzene sulfonate (a strong surfactant contaminate representative of the type and boiling range potentially found in jet fuel, and which also is available in high chemical purity and thus is a reproducible compound rather than a variable batch reaction product) was used to produce a fuel expected to fail coalescence rapidly. In the run 6 fuel a film forming amine contaminant was added along with approved additive Stadis 450 since previous field experience had indicated this combination could be a problem. In the run 7 fuel a Diesel fuel lubricity additive (jet fuel contaminant) was added to investigate potential cross contamination effects when shipping jet fuel in multi-product pipelines. After the program was underway it was discovered that Base Fuel B contained a high particulate level and fuels 4F and 5F were prepared by micronic filtering to reduce particulate levels to the on-specification range.

Test methods investigated for their ability to predict coalescence effects are listed in Table 2. Both existing tests and tests under development were included in the study. In addition to the standard D 3948 MSEP and the improved MSEP with the M Cell, the use of an Aluminum Syringe rather than the standard plastic syringe (so as to reduce possible electrostatic effects) was investigated both with and without the use of the M Cell in a 2X2 factorial designed experimental program. Three ASTM D 1094 rating techniques were investigated including the current Interface rating widely cited in jet fuel specifications, the current Separation rating and the proposed Meniscus geometry rating in which the water/fuel meniscus is visually rated as either straight or curved (see Appendix I). Other coalescence related test included the IP 452 WASP test, the ASTM D 971 Interfacial Tension by the ring method test and the Velcon Swift Kit. Two tests not directly related to coalescence were also included: the ASTM D 5452 Particulate test and the ASTM D 6426 Filterability of Distillate Fuel Oil test which is under development for use with jet fuel.

3.2 DISCUSSION OF COALESCENCE TEST RESULTS

Detailed validation program data are shown in Table 3. Running logs for the various NCT runs are shown in the Appendix. Continuous Coalescence Time (CCT) was used as the given, X variable in carrying out statistical regression analyses against the various test method results as the Y variable. These regression analysis of various test method results against CCT values provide an objective, quantitative evaluation of the capability of the various test methods to predict the effect of fuel quality on coalescence. For NCT runs which went the full 80 hour run time without a coalescence failure (pass), the CCT is defined as 80 hours. For runs in which a coalescence failure occurred during the run (fail), the CCT is defined as the time in hours to first failure.

A summary of the data from runs used to compare NCT continuous coalescence times with the various test results is shown in Table 4. Average results from the replicate water separation method tests on various fuels were used in the linear regression of test results against CCT's for a number of reasons. First, since the primary goal of the NCT program was to validate test method results, the replicate test method data was averaged to minimize the influence of test reproducibility, and thus provide the best possible evaluation of the ability of each test to predict the effect of fuel quality on coalescence. In this way a comparison of the fraction of the total variance explained by each regression would reflect more strongly the ability of the test to predict fuel quality effects rather than reflect the influence of test reproducibility. Second, the NCT program was not designed to meet the rigorous requirements of an ASTM precision program, which in most cases had already been carried out. Lastly, this was done so that variations in the number of replicate tests which were run on the various fuels would not skew the analysis.

Linear regressions were carried out using the Origin 6.1 Scientific Graphing and Analysis Software produced by Origin Labs, Northhampton, MA. The Origin 6.1 program input data is shown in Table 5. Individual plots for the various water separation methods regressions are shown in Figures 2 through 11. Linear regression lines and upper and lower 95% confidence level curves are shown for those methods which produced true numeric results. These are not shown for D 1094 results since the Interface, Separation and Meniscus ratings are not true numeric results but are simply labels identifying different descriptive conditions. Thus, regression analyses could not be used to analyze the D 1094 test results.

Data from the runs which produced true numeric values were analyzed and compared using the results obtained from the regression analyses. Three approaches were used. (1) testing the regression line itself to see what level of statistical significance can be assigned to it (2) measuring how much of the total variance in the test results is explained by each test's regression line, and (3) measuring the "strength" of each test by calculating the ratio of the range of test values produced across all fuel coalescence qualities divided by the scatter in the data measured by the regression standard deviation (an ideal test would produce a large range of results and a small scatter in the data so that fuel quality effects would be measured and predicted with great confidence).

3.2.1 ANALYSES OF THE D 1094 WATER REACTION TEST RESULTS

A comparison of D 1094 test measurements against NCT run results is shown in Table 7. In making this comparison the NCT runs were organized into three arbitrary categories as follows: Fuels which ran the full 80 hours without a coalescence failure were classified as a "Low/No Surfactant" fuel; and it was expected that such fuels would produce a 1 Interface Rating, a 1 Separation Rating and a normal curved Meniscus. In contrast, fuels which produced a rapid NCT coalescence failure (< 3 hours) were classified as a "Strong Surfactant" fuel; and it was expected that they would produce Interface and Separation Ratings significantly greater than 1 and a non-normal straight Meniscus. Lastly, those fuels which failed coalescence in the NCT after 3 hours but before the 80 hour end of the run were classified as a "Weak Surfactant" fuel; and it was expected that these type fuels would show evidence of the weak surfactants by producing Interface and Separation Ratings greater than 1 but that the weak surfactants would still produce a normal curved Meniscus.

It can be seen in Table 7 that the D 1094 Interface Rating never changed from a 1 value regardless of the fuel's coalescence quality. No "Strong Surfactant" fuel or "Weak Surfactant" fuel was rated 1b, 2, 3 or 4. Thus, the D 1094 Interface Rating results from this study clearly fail to show any evidence of test validity. The D 1094 Separation Rating results are not much better. The D 1094 Separation Rating fails to identify the "Strong Surfactant" fuel in run 3 as a problem fuel, falsely identifies the "Low/No

Surfactant" fuel in run 8 as a problem fuel, and also fails to see the "Weak Surfactant" fuels in runs 9 and 4F. The Meniscus Geometry is not currently a part of the D 1094 test method, but was it's possible inclusion was suggested in a letter from the Association Francaise de Normalization; and the observation of a straight meniscus in the presence of diesel fuel lubricity additive contamination in the NCT study corroborates their reported straight meniscus observations (see Appendix I). The Meniscus Geometry observations correctly identified the four "Low/No Surfactant" fuels as normally curved; and the two "Strong Surfactant" fuels as straight. However, the Meniscus Geometry observations failed to identify two of the three "Weak Surfactant" fuels as potential problems. Thus, neither the Interface Rating, Separation Rating or Meniscus Geometry was able to correctly identify the full range of fuel coalescence qualities. In addition, combining the Separation rating with the Meniscus Geometry still does not provide a method which successfully deals with "Weak Surfactant" fuels.

3.2.2 STATISTICAL ANALYSIS OF TESTS PRODUCING NUMERIC RESULTS

3.2.2.1 STATISTICAL SIGNIFICANCE OF THE REGRESSION LINES

How statistically significant a regression line is can be determined from the magnitude of it's correlation coefficient. The NCT run regressions all had 8 degrees of freedom (9 data points), and for these regressions to be significant at the 95% confidence limit requires that the correlation coefficient be equal to or greater than 0.632 (3). As shown in Table 8 the MSEP with M Cell and Aluminum Syringe, MSEP with M Cell and Swift Kit tests produced correlation coefficients large enough to meet this criteria. The correlation coefficient for the Standard MSEP, Interfacial Tension and MSEP with aluminum Syringe indicate statistical significance at approximately the 90% level, while the WASP test correlation coefficient indicated a lower level.

3.2.2.2 PERCENT OF TOTAL VARIANCE EXPLAINED BY THE REGRESSIONS

The fraction of the total variance explained by the linear correlation is the correlation coefficient squared. The percentage of the total variance explained by the various regressions are shown in Table 8. The individual regressions ranged from explaining a high of 64% of the total variance to a low of 16%. The ranking of the test methods based on the percent of the total variance explained by the linear correlation shows the following descending order: (1) MSEP with M Cell and Aluminum Syringe, (2) MSEP with M Cell, (3) Swift Kit, (4) MSEP with Aluminum Syringe, (5) Interfacial Tension, (6) Standard MSEP, and (7) WASP test.

3.2.2.3 RELATIVE "STRENGTH" OF TEST METHODS

An ideal test should both product a wide range of results across the spectrum of fuel qualities which can occur and exhibit a small scatter in the data it produces, so that the test will measure and predict the effect of fuel quality on coalescence with great confidence. These two requirements were combined into a "Test Strength Index". The range of test results (i.e. predicted high value minus predicted low value) which the method produces was calculated by multiplying the slope of the linear regression line by length of the NCT run (80 hours). This value was then divided by the standard deviation of the regression to yield a "Test Strength Index". A good test which produces a wider range of results and a smaller standard deviation , thus, will yield a higher index than a poorer test with a smaller range of results and/or a larger standard deviation. Results of these calculations are shown in Table 9. The Test Strength Index ranged from a low of 0.9 to a high of 2.8, a factor of approximately three. The ranking of the test methods based on the Test Strength Index shows the following descending order (1) MSEP with M Cell and Aluminum Syringe, (2) MSEP with M Cell, (3) Swift Kit, (4) MSEP with Aluminum Syringe, (5) Interfacial Tension, (6) Standard MSEP, and (7) WASP test. This ranking is the same order as shown by the ranking based on the ability of the tests to explain a large proportion of the total variance.

3.2.2.4 COMPARISION OF MSEP METHODS

The various MSEP methods are compared in Table 10. The use of the M Cell in combination with the Aluminum Syringe produces a better method. A correlation of the MSEP with the M Cell and Aluminum Syringe against the Standard MSEP is shown in Figure 12. The slope and intercept parameters for this correlation are shown in Table 6.

3.3 THE EFFECT OF PARTICULATES ON COALESCENCE

In the initial phase of the NCT program runs 4 and 5, which used Merox Base Fuel B, were carried out before laboratory D 5452 particulate results were available. The Merox Base Fuel B fuel as-is passed the NCT coalescence test by running 80 hours without a failure (run 2); whereas the Merox additized fuels in runs 4 and 5 both failed the NCT test. Subsequently, D 5452 results indicated that Merox Treated Base Fuel B contained high levels of particulates (Table 3). As a result, fuels 4F and 5F were prepared by micronically filtering fuels 4 and 5 to reduce particulates to an on-specification range without removing other components, and these on-specification additized Merox fuels tested in the NCT.

Significant differences were seen with the Merox Base Fuel containing Stadis 450. The original run with Base Fuel B plus Stadis 450 (run 5) contained 1.17 mg/l average particulates and failed in the NCT test at 23 hours. The filtered Base Fuel B plus Stadis 450 (run 5F) contained only 0.3 mg/l average particulates and ran without failure in the NCT for 80 hours even with an increase in the Stadis 450 concentration from 1.0 to 2.0 mg/l at hour 42. The initial run with Base Fuel B plus Stadis 450, CI/LI and FSII (run 4) contained 2.67 mg/l average particulates and failed two NCT runs, the first run at hour 26 which was then terminated and the second run at hour 27 which was continued for the full 80 hours. These replicate runs demonstrated that NCT continuous coalescence times and pass/fail results are reproducible. Filtered fuel 4F contained an average particulate level of 0.4 mg/l but still produced a NCT run failure (at 8 hours) even though all three additives present are approved additives used in combination in military fuel, and thus would have been expected to perform better in the NCT.

These results indicate that high levels of fuel particulates can influence coalescence performance, and suggest a strong need for additional studies to better understand the effect of particulates in additized fuels on coalescence performance.

3.4 FILTERABILITY TEST RESULTS

In addition to tests designed to predict fuel coalescence quality, measurements with the ASTM D 6426 Filterability test using both 0.65u and 0.45u filter were also made on the NCT test fuels. In Figures 13 and 14 are shown plots of D 6426 Filterability 100 minus QF values versus D 5452 particulate levels. It can be seen that the use of the 0.45u filter compared to the 0.65u filter produced superior results.

4. RELATED PROGRAMS

A number of related programs were carried out under the direction of the ASTM Committee D-2 Subcommittee J Section 10 Water Separation Methods Task Force. Reports of this work are shown in the Appendix.

In 1998 the Air Force carried out a study of the MSEP with the M Cell compared to the Standard MSEP when testing military fuels (4). It was concluded that the improved MSEP produced smaller reproducibility and higher values when rating military fuels. Chevron Research reported on laboratory tests of strong surfactant doped fuels (2). In 1999 results of a Canadian fuel test program was reported by the CGSB (5). Fuels tested included refinery, terminal and airport samples. The CGSB concluded from this program that the MSEP with the M Cell showed a significant improvement in test method precision, and that the MSEP is the only test method capable of predicting a fuel's coalescing tendency. In 1999 the Air Force reported on a second study designed to obtain additional data on military fuels containing SDA additive (6). Again a lower standard deviation was seen for the MSEP with the M Cell.

5. RECOMMENDATIONS FOR FUTURE PROGRAMS

It is recommended that a program be carried out to study the effect of particulates on coalescence effects in the presence of fuels containing approved additives and contaminants.

6. REFERENCES

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(3) O. L. Davies, Ed. "Statistical Methods in Research and Production", Hafner Publishing Co., NY, 1958. Table E.
(4) Minutes of the ASTM D-2 Subcommittee J Section 10 Water Separation Methods Task Force, June 23, 1998, Toronto.
(5) Minutes of the ASTM D-2 Subcommittee J Section 10 Water Separation Methods Task Force, January 29, 1999, New Orleans.
(6) Minutes of the ASTM D-2 Subcommittee J Section 10 Water Separation Methods Task Force, July 12, 1999, St. Louis.

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TABLES AND FIGURES

Table 1 Navy Coalescence Tester Runs

Run 1 - Base Fuel A Hydrotreated JetA

Run 2 - Base Fuel B Merox Treated Jet A-1

Run 3 - Base Fuel A containing 1.0 mg/l sodium dodecyl benzene sulfonate (representative, reproducible strong surfactant contaminant)

Run 4 - Base Fuel B containing a combination of approved additives as follows:
1.0 mg/l Stadis 450, DCI-4A CI/LI at minimum allowed concentration (9 mg/l)
and 0.15 vol % DiEGME FSII.

Run 4F- Filtered (to on-spec particualtes) Base Fuel B used in Run 5F, which contained Stadis 450, and to which was added DCI-4A at 9 mg/l and 0.15 vol% DiEGME.

Run 5 - Base Fuel B containing 1.0 mg/l Stadis 450 approved additive

Run 5F – Filtered (to on-spec particulates) Base Fuel B to which was added 1.0 mg/l Stadis 450 initially, then increased to 2.0 mg/l Stadis 450 at hour 42.

Run 6 - Base Fuel A containing 1.0 mg/l Stadis 450 approved additive and 5.0 PPM FA-2 film forming amine additive (unapproved additive contaminant).

Run 7 - Base Fuel A containing 25 mg/l DLI Diesel fuel lubricity additive (unapproved additive contaminant).

Run 8 – Naturally occurring "Problem Fuel A" (from the field before transit).

Run 9 – Naturally occurring "Problem Fuel B" (from the field in transit).

Table 2 Fuel Quality Tests

- **ASTM D 3948-99a MSEP (std Alumicel & plastic syringe)**
- **ASTM D 3948 MSEP using MCell (std plastic syringe)**
- **ASTM D 3948 MSEP using Aluminum syringe (std Alumicel)**
- **ASTM D 3948 MSEP using MCell and Aluminum Syringe**
- **ASTM D 1094 Water Reaction Test (vol change, interface, degree of separation)**
- **ASTM D 1094 with observation of meniscus geometry (straight or curved)**
- **IP 452 WASP Test (Shell)**
- **ASTM D 971 Interfacial Tension by Ring Method**
- **Velcon Swift Kit Test**
- **ASTM D 5452 Particulate Contamination**
- **ASTM D 6426 Filterability of Distillate Fuel Oil Test applied to jet fuel**

Table 3-1 Data Table

NCT Test #	Drum #	Pax River WSIM	Conductivity	NCT	IFT	Particulates	Wasp		Water React.	Emcee MSEP	MSEP
		Room 59	Room 59	Fail Time	Lab	Lab	Run 1	Run 2	Lab	St. Pl.	M-Cell Pl.
Run 2B	FF00-111-15	98	-		41.64	-	159.3	147.7	1.0/1/(1)	98	99
Run 2B	FF00-111-04	-	-		40.94	3.4	97.2	104.8	1.0/1/(1)	95	99
Run 2B	FF00-111-13	-	-		43.28	1.0	143.5	126.1	1.0/1/(1)	93	97
Run 2B	FF00-111-03	88	-	80	37.90	2.5	197.7	146.0	1.0/1/(1)-C	93	98
Run 4B	FF00-111-03	48	-		35.30	3.5	681.5	713.9	1.0/1/(1)-S	47	78
Run 4B	FF00-111-12	47	240	26	38.50	1.2	599.9	567.2	1.0/1/(1)-S	47	85
Run 4B(2)	FF00-111-09	55	320		38.20	4.0	510.0	550.0	1.0/1/(1)-S	60	76
Run 4B(2)	FF00-111-12	47	240		Same as Fuel.test.00505 above					47	85
Run 4B(2)	FF00-111-08	47	302	27	37.80	2.0	649.4	675.1	1.0/1/(1)-S	45	79
Run 3B	FF00-077-05	88	2		38.40	0.2	164.4	193.7	1.0/1/(2)-C	66	88
Run 3B	FF00-077-06	88	0		34.90	0.3	205.9	153.4	1.0/1/(2)-C	66	93
Run 3B	FF00-077-07	82	0	80	37.70	0.4	235.0	182.7	1.0/1/(2)-C	77	91
Run 5B	FF00-111-11	89	344		40.50	2.5	304.2	485.0	1.0/1/(1)-C	98	95
Run 5B	FF00-111-02	89	255		40.70	0.2	291.8	251.2	0.0/1/(1)-C	73	95
Run 5B	FF00-111-10	85	369	23	43.75	0.8	321.3	261.3	0.0/1/(1)-C	80	97
Run 9B		65	1	31	32.01	0.3	162.1	134.4	0.0/1/(1)-C	69	92
Run 5F	FF00-111-01	97	309		37.58	0.5	327.0	315.0	0.0/1/(1)-C	80	95
Run 5F	FF00-111-05	81	250		39.66	0.1	301.0	292.0	0.0/1/(1)-C	71	95
Run 5F	FF00-111-07	80	546		38.85	0.4	444.0	454.0	0.0/1/(1)-C	85	95
Run 5F	FF00-111-06	82	610	80	38.38	0.2	601.0	612.0	0.0/1/(1)-C	64	89
Run 4F	FF00-111-07	46	439		36.32	0.4	616.0	514.0	0.0/1/(1)-C	48	79
Run 4F	FF00-111-01	45	230		31.56	0.4	319.0	406.0	0.0/1/(1)-C	59	77
Run 4F	FF00-111-05	51	72	8	36.20	0.4	395.8	312.2	0.0/1/(1)-C	56	84
Run 1B	FF01-037-24	98	0		37.92	0.2	81.3	95.5	0.0/1/(1)-C	98	91
Run 1B	FF01-037-23	98	0		39.54	0.1	71.9	103.2	0.0/1/(1)-C	97	96
Run 1B	FF01-037-25	97	0	80	39.08	0.3	87.8	107.5	0.0/1/(1)-C	98	94
Run 3B	FF01-037-09	63	5		34.95	2.9	356.2	364.4	0.0/1/(1)-S	67	76
Run 3B	FF01-037-01	60	6		35.63	1.7	199.9	159.6	0.0/1/(1)-S	78	81
Run 3B	FF01-037-02	69	1	1	44.22	1.2	726.2	724.0	0.0/1/(1)-S	77	82
Run 6B	FF01-037-10	61	232		41.64	0.7	624.0	712.0	0.5/1/(2)-S	88	97
Run 6B	FF01-037-08	74	557		41.40	0.6	699.0	738.0	0.0/1/(2)-S	95	96
Run 6B	FF01-037-21	60	221	42	42.34	0.4	349.0	563.0	0.5/1/(2)-S	99	94
Run 7B	FF01-037-22	64	406		25.71	0.5	217.0	250.0	0.5/1/(2)-S	72	94
Run 7B	FF01-037-14	47	2		25.82	0.2	226.0	289.4	0.0/1/(2)-S	78	91
Run 7B	FF01-037-23	52	4	2	24.52	0.2	275.0	268.0	0.5/1/(2)-S	72	88

Water Reaction Test ASTM D 1094: Volume Change/Interface Rating/Separation Rating/Meniscus C=Curved, S=Straight

Table 3-2 Data Table

NCT Test #	Drum #	MSEP	MSEP	Conductivity	D 6426 Filterability (0.65 micron)			D 6426 Filterability (0.45 micron)			Swift Kit
		St. Al.	M-Cell Al.	Emcee	QF	psig	mls	QF	psig	mls	IFT
Run 2B	FF00-111-15	98	99	4	90	3.1	300	-	-	-	35
Run 2B	FF00-111-04	95	98	6	92	2.4	300	-	-	-	36
Run 2B	FF00-111-13	98	99	3	89	3.3	300	-	-	-	37
Run 2B	FF00-111-03	97	99	2	90	3.1	300	-	-	-	34
Run 4B	FF00-111-03	49	69	240	89	3.2	300	-	-	-	33
Run 4B	FF00-111-12	50	71	168	91	2.8	300	-	-	-	36
Run 4B(2)	FF00-111-09	52	78	294	90	2.9	300	-	-	-	30
Run 4B(2)	FF00-111-12	50	71	168	91	2.8	300	-	-	-	36
Run 4B(2)	FF00-111-08	46	79	270	89	3.3	300	-	-	-	36
Run 8B	FF00-077-05	68	88	2	85	4.4	300	-	-	-	37
Run 8B	FF00-077-06	59	88	0	85	4.4	300	-	-	-	37
Run 8B	FF00-077-07	54	82	1	83	5.1	300	73	8.2	300	32
Run 5B	FF00-111-11	99	93	307	90	3.0	300	84	4.8	300	37
Run 5B	FF00-111-02	84	97	141	91	2.7	300	87	4.0	300	36
Run 5B	FF00-111-10	69	91	71	90	3.1	300	86	4.3	300	32
Run 9B	[illegible]	66	87	3	86	4.3	300	74	7.7	300	33
Run 5F	FF00-111-01	80	92	35	90	3.1	300	85	4.6	300	31
Run 5F	FF00-111-05	78	95	30	91	2.3	300	85	4.6	300	35
Run 5F	FF00-111-07	78	91	79	90	3.0	300	85	4.6	300	33
Run 5F	FF00-111-06	67	86	135	91	2.7	300	87	4.0	300	35
Run 4F	FF00-111-07	48	78	61	90	3.1	300	82	5.3	300	27
Run 4F	FF00-111-01	52	71	49	90	3.0	300	83	5.1	300	28
Run 4F	FF00-111-05	57	75	51	88	3.5	300	84	4.9	300	26
Run 1B	FF01-037-24	96	89	2	89	3.6	300	83	5.1	300	37
Run 1B	FF01-037-23	98	93	2	88	3.7	300	78	6.5	300	37
Run 1B	FF01-037-25	98	95	1	88	3.7	300	83	5.1	300	37
Run 3B	FF01-037-09	65	69	42	83	5.1	300	79	6.4	300	30
Run 3B	FF01-037-01	69	81	4	84	4.7	300	78	6.5	300	37
Run 3B	FF01-037-02	71	76	64	49	15	295	80	6.1	300	29
Run 6B	FF01-037-10	96	95	74	89	3.3	300	82	5.5	300	36
Run 6B	FF01-037-08	98	89	120	84	4.7	300	78	6.5	300	34
Run 6B	FF01-037-21	99	100	150	86	4.2	300	79	6.4	300	36
Run 7B	FF01-037-22	54	83	3	89	3.2	300	82	5.6	300	33
Run 7B	FF01-037-14	48	75	2	88	3.6	300	82	5.4	300	34
Run 7B	FF01-037-23	51	82	2	87	3.8	300	83	5.1	300	33

Table 4 Summary of NCT Fuel Coalescence Quality Test Results

Fuel Tested	Run	Run Type	NCT- Pass/Fail	NCT Continous Coalescence Time, Hrs
Base Fuel A	1	HT Base Fuel	Pass	80
Base Fuel B	2	Merox Base fuel	Pass	80
Base B + Stadis 450	5F	Approved Additive	Pass	80
Base B + Stadis + CI +FSII	4F	Approved Additives	Fail	8
Base A + NaDBS	3	Unapproved Additive	Fail	1
Base A + Film Forming Amine + Stadis	6	Unapproved Additive	Fail	42
Base A + Diesel Lubricity Additive	7	Unapproved Additive	Fail	2
Problem Fuel A	8	As-is Fuel	Pass	80
Problem Fuel B	9	As-is Fuel	Fail	31

Table 5 -1 Origin 6.1 Program Input Data

	RunType	RunNumber	NCTHours(X)	MSEPSTDE(Y)	MSEPMCell(Y)	MSEPAlSyr(Y)	MSEPMAl(Y)
1	Base B(merox)	2	80	95.2	98.4	96.4	99
2	Base A (HT)	1	80	97.7	93.7	97.3	92.3
3	B plus Stadis	5F	80	75	93.5	75.8	91
4	B plus all additiv	4F	8	54.3	80	52.3	74.7
5	A plus NaDBS	3	1	74	79.7	68.3	75.3
6	A plus Amine/Stadi	6	42	94	95.7	97.7	94.7
7	A plus lubricity	7	2	74	91	51	80
8	Problem Fuel A	8	80	69.7	90.7	60.3	86
9	Problem Fuel B	9	31	69	92	66	87

NCT Hours = NCT Continuous Coalescence Time, Hrs
MSEPSTEDE = Average Standard MSEP
MSEPMCell = Average MSEP with M Cell
MSEPAlSyr = Average MSEP with Aluminum Syringe
MSEPMAl =Average MSEP with M Cell and Aluminum Syringe

Table 5 –2 Origin 6.1 Program Input Data

	SwiftKit(Y)	IFT(Y)	WASP(Y)	D1094Inter(Y)	D1094Separ(Y)	D1094Men(Y)
1	34.8	40.94	140.3	1	1	1
2	37	38.85	91.2	1	1	1
3	33.5	38.62	418.3	1	1	1
4	27	34.69	463.8	1	1	1
5	32	38.27	421.7	1	1	0
6	35.3	41.79	614.2	1	2	0
7	33.3	25.35	254.2	1	2	0
8	35.3	37	189.2	1	2	1
9	33	32.01	148.2	1	1	1

SwiftKit = Average Swift Kit
IFT = Average Interfacial Tension by D 971
WASP = Average WASP test
D1094Inter = Average D 1094 Interface Rating
D1094Separ = Average D 1094 Separation Rating
D1094Men = Average D 1094 Meniscus shape: 1=curved, 0 = straight

Table 5-3 Origin 6.1 Program Input

	RunType(Y)	RunNumber(Y)	D5452Partic(X1)	QF.65(Y1)	MQF(Y1)	QF.45(Y1)	MinusQF.45(Y1)
1	Base B (Merox)	2	2.3	90.2	9.8	41	59
2	Base A (HT)	1	0.2	88.3	11.7	81.3	18.7
3	B + Stadis(Fil	5F	0.3	90.5	9.5	85.5	14.5
4	B + All Add (F	4F	0.4	89.3	10.7	83	17
5	A + NaDBS	3	1.9	83.5	16.5	79	21
6	A + Amine/Stad	6	0.57	86.3	13.7	79.7	20.3
7	A + Lubricity	7	0.3	88	12	82.3	17.7
8	Problem Fuel A	8	0.3	84.3	15.7	73	27
9	Problem Fuel B	9	0.3	86	14	74	26
10	B + Stad (Unfi	5	1.17	90.3	9.7	85.7	14.3
11	B+All Add(Unfi	4	2.67	89.8	10.2		

D5452Partic = Average weight of particulates by ASTM D 5452
QF.65 = Average Filterability QF with 0.65u filter
MQF = Average (100 – QF) for Filterability with 0.65u filter
QF.45 = Average Filterability QF with 0.45u filter
MinusQF.45 = Average (100 – QF) for Filterability with 0.45u filter

Table 6 Linear Regression Summary

Y Value (1)	X Value (1)	Intercept, A	Slope, B	Corr. Coefficient, r	% Varience Explained	Reg. Std Dev., SD
Standard MSEP	NCT/CCT	68.48	0.214	0.528	27.8	13.2
MSEP + M Cell	NCT/CCT	84.81	0.127	0.701	49.2	4.95
MSEP + Al Syr	NCT/CCT	59.61	0.318	0.6	36	16.3
MSEP + MCell + Al Syr	NCT/CCt	78.1	0.191	0.799	63.9	5.49
Swift Kit	NCT/CCT	31.07	0.0534	0.669	44.8	2.27
Interfacial Tension	NCT/CCt	32.69	0.0823	0.577	33.3	4.46
WASP	NCT/CCT	395.98	-2.037	-0.404	16.3	176.5
MSEP +MCell + Al Syr	Standard MSEP	49.89	0.471	0.801	64.2	5.47

(1) $Y = A + B*X$

Table 7 ASTM D 1094 Results

NCT Performance Class	Fuel	NCT Run	Cont. Coalescence Time, Hours	D 1094 Interface	D 1094 Separation	D 1094 Meniscus Geometry
Low/No Surfactant (NCT=80 Hrs)	Base Fuel A	1	80	1	1	Curved
Low/No Surfactant	Base Fuel B	2	80	1	1	Curved
Low/No Surfactant	Base B + SDA	5F	80	1	1	Curved
Low/No Surfactant	Problem Fuel A	8	80	1	2 (a)	Curved
Strong Surfactant (NCT< 3 Hours)	Base A + NaDBS	3	1	1 (b)	1 (b)	Straight
Strong Surfactant	Base A + Diesel Lubricity Additive	7	2	1 (b)	2	Straight
Weak Surfactant (3 < NCT < 80 Hrs)	Base A + Film Form. Amine+SDA	6	42	1 (c)	2	Straight
Weak Surfactant	Problem Fuel B	9	31	1 (c)	1 (c)	Curved (c)
Weak Surfactant	Base B + SDA + FSII + CI	4F	8	1 (c)	1 (c)	Curved (c)

(a) Mis-identified Low/No Surfactant Fuel as problem
(b) Failed to signal Strong Surfactant Fuel
(c) Failed to signal Weak Surfactant Fuel

Table 8 Ability Of Tests To Predict Fuel Quality

Test	Correlation Coefficient r	% of Total Varience Explained by Correlation
Standard MSEP	0.528	28
MSEP with M Cell	0.701	49
MSEP with Al Syringe	0.6	36
MSEP + MCell + Al Syr	0.8	64
Swift Kit	0.67	45
Interfacial Tension	0.577	33
WASP	-0.404	16

Table 9 Test Strength Index

Test	Regression Slope, B	Range of Test Results, BX80	Reg. Standard Deviation SD	Test Strength Index, BX80/SD
Standard MSEP	0.214	17.1	13.2	1.3
MSEP + M Cell	0.127	10.2	4.95	2.1
MSEP + Al Syringe	0.318	25.4	16.3	1.6
MSEP + MCell + Al Syr	0.191	15.3	5.49	2.8
Swift Kit	0.0534	4.3	2.27	1.9
Interfacial Tension	0.0823	6.6	4.46	1.5
WASP	-2.037	163	176.5	0.9

Table 10 Comparison of MSEP Test Methods

	Percent Total Variance Explained		Test Strength Index	
	Alumicel	**M Cell**	**Alumicel**	**M Cell**
Plastic Syringe	28	49	1.3	2.1
Aluminum Syringe	36	64	1.6	2.8

FIGURE 1

Navy Coalescence Tester (NCT)

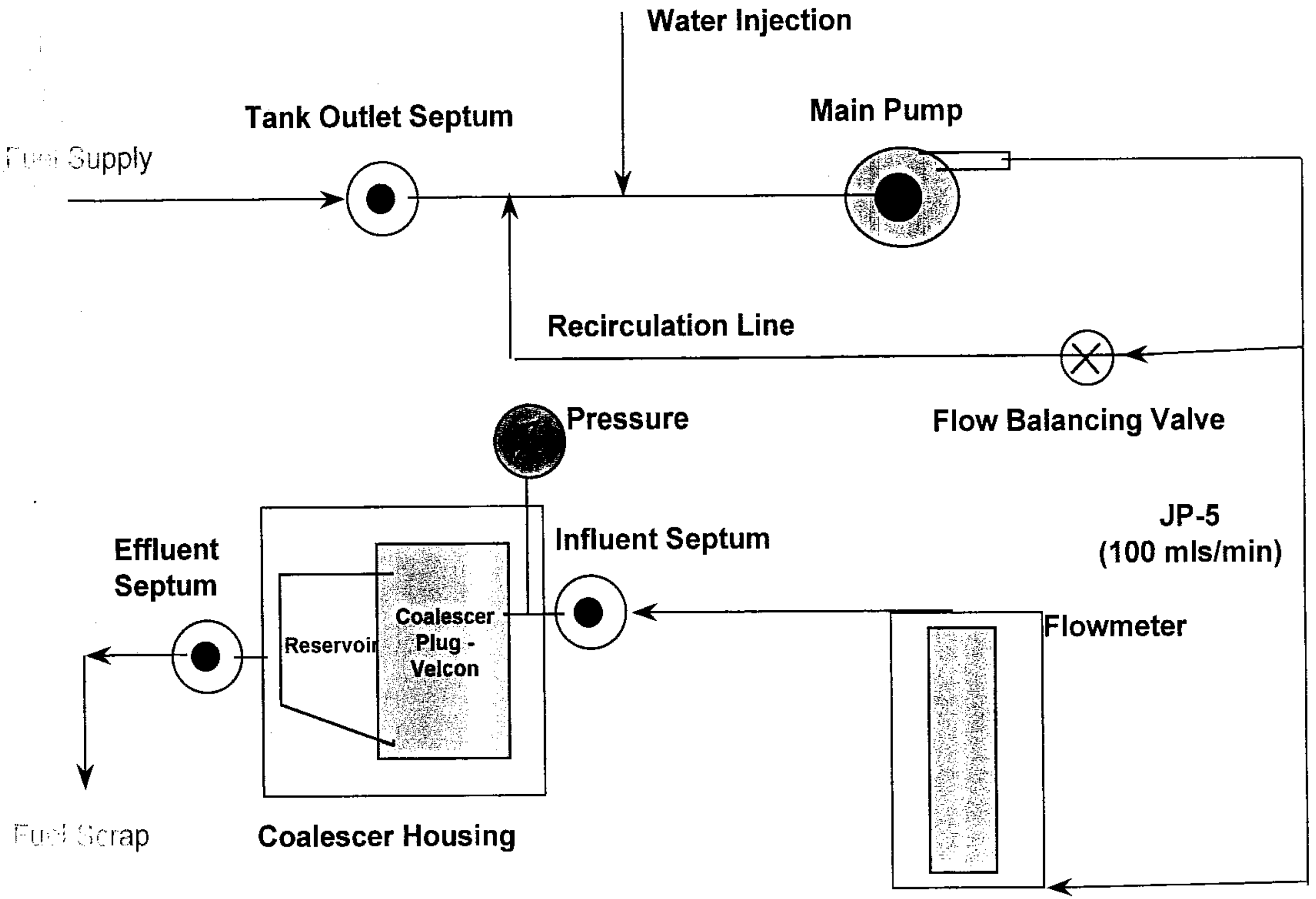
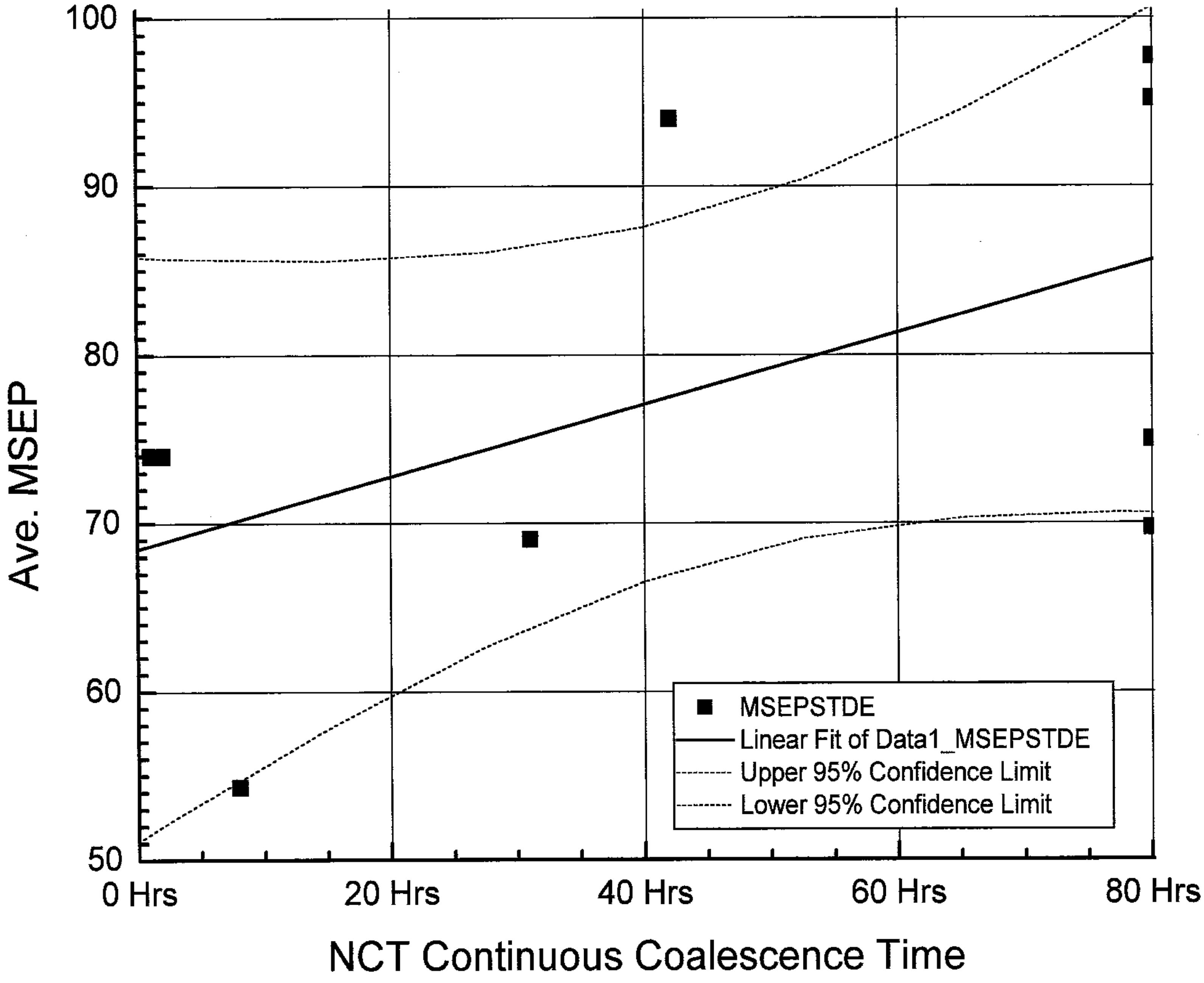


Figure 2 NCT Versus Standard MSEP



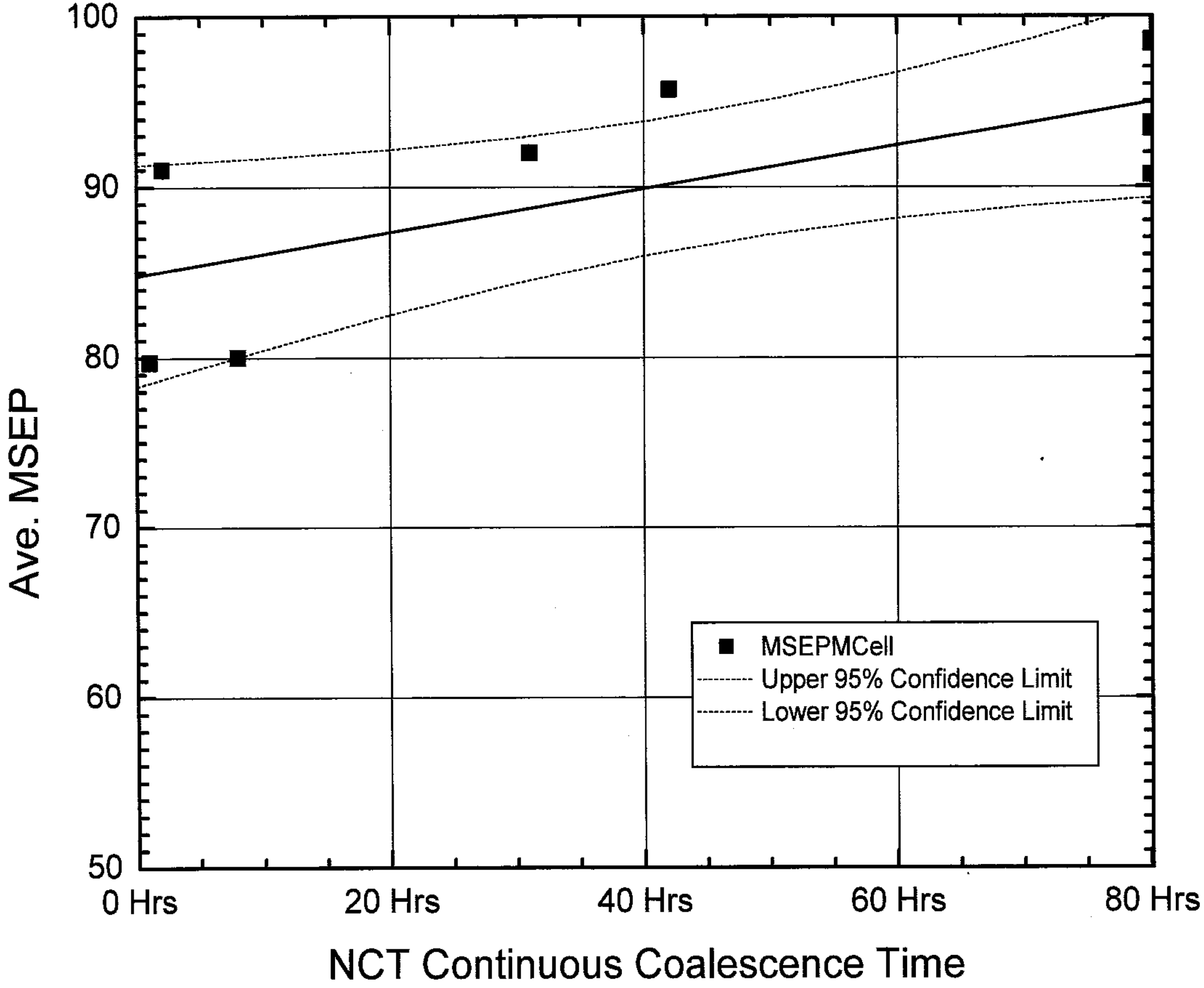


Figure 3 NCT Versus MSEP with MCell

Figure 4 NCT Versus MSEP With Aluminum Syringe

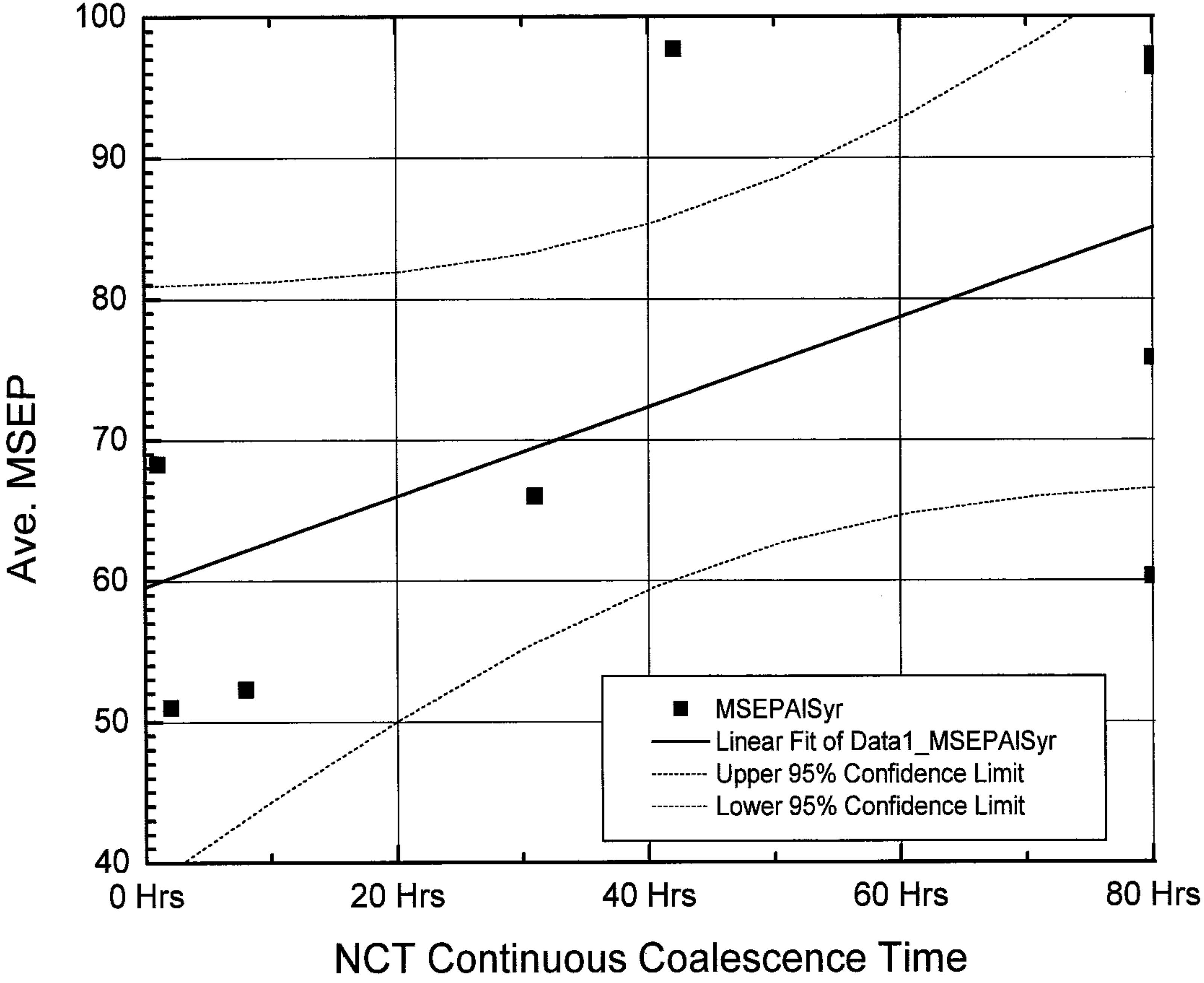


Figure 5 NCT Versus MSEP With MCell & Al Syringe

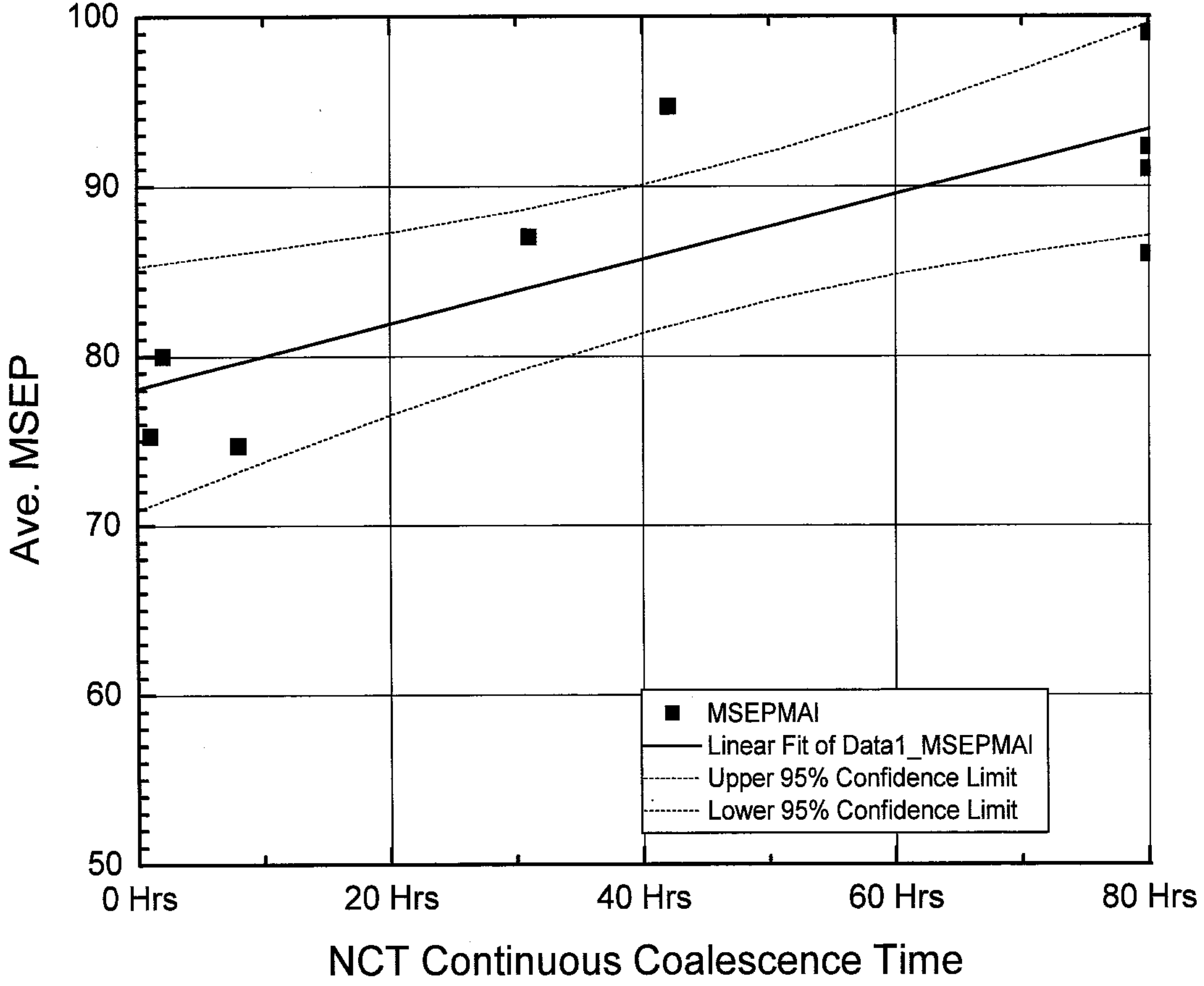


Figure 6 NCT Versus D 1094 Interface Condition

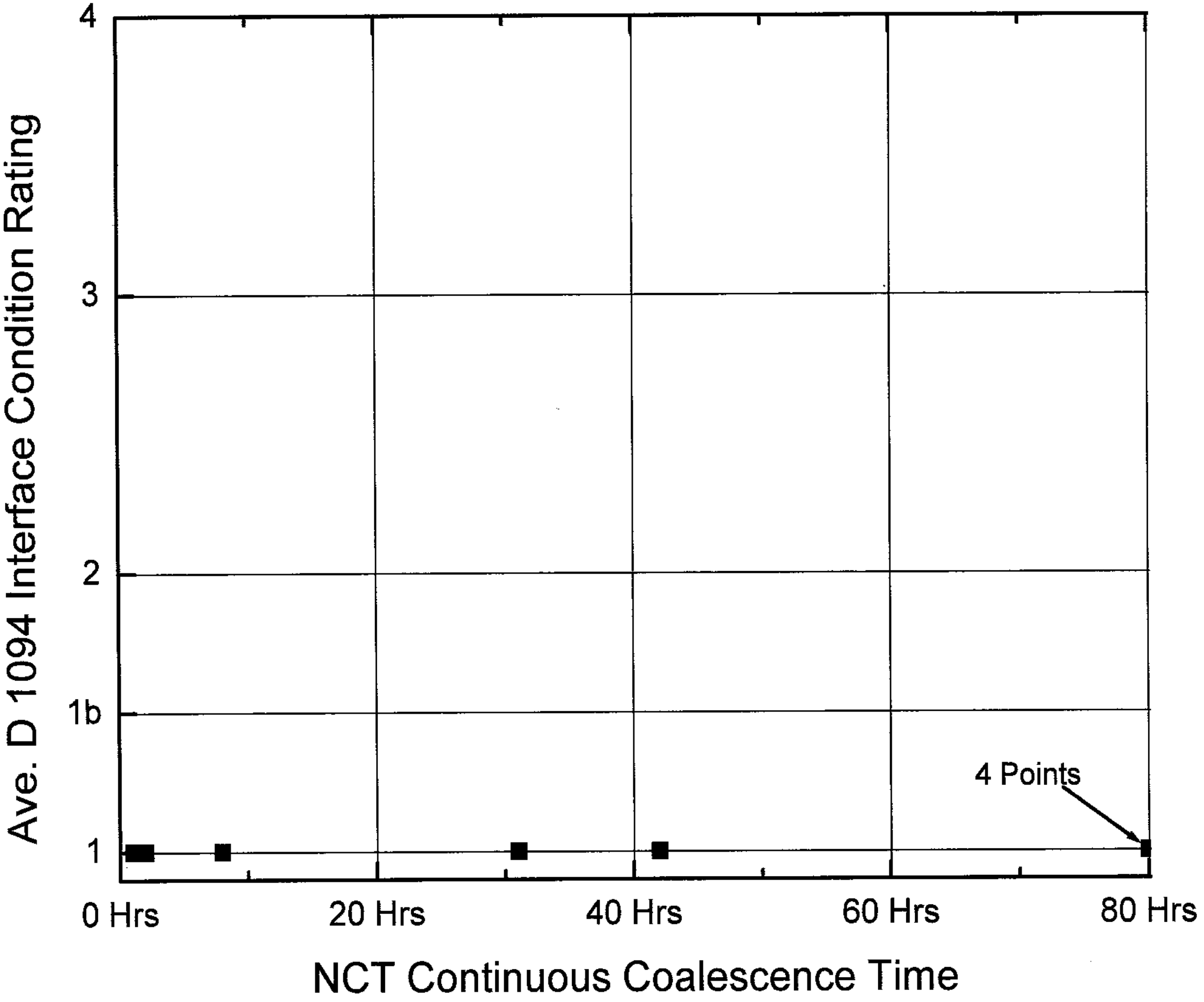


Figure 7 NCT Versus D 1094 Separation Rating

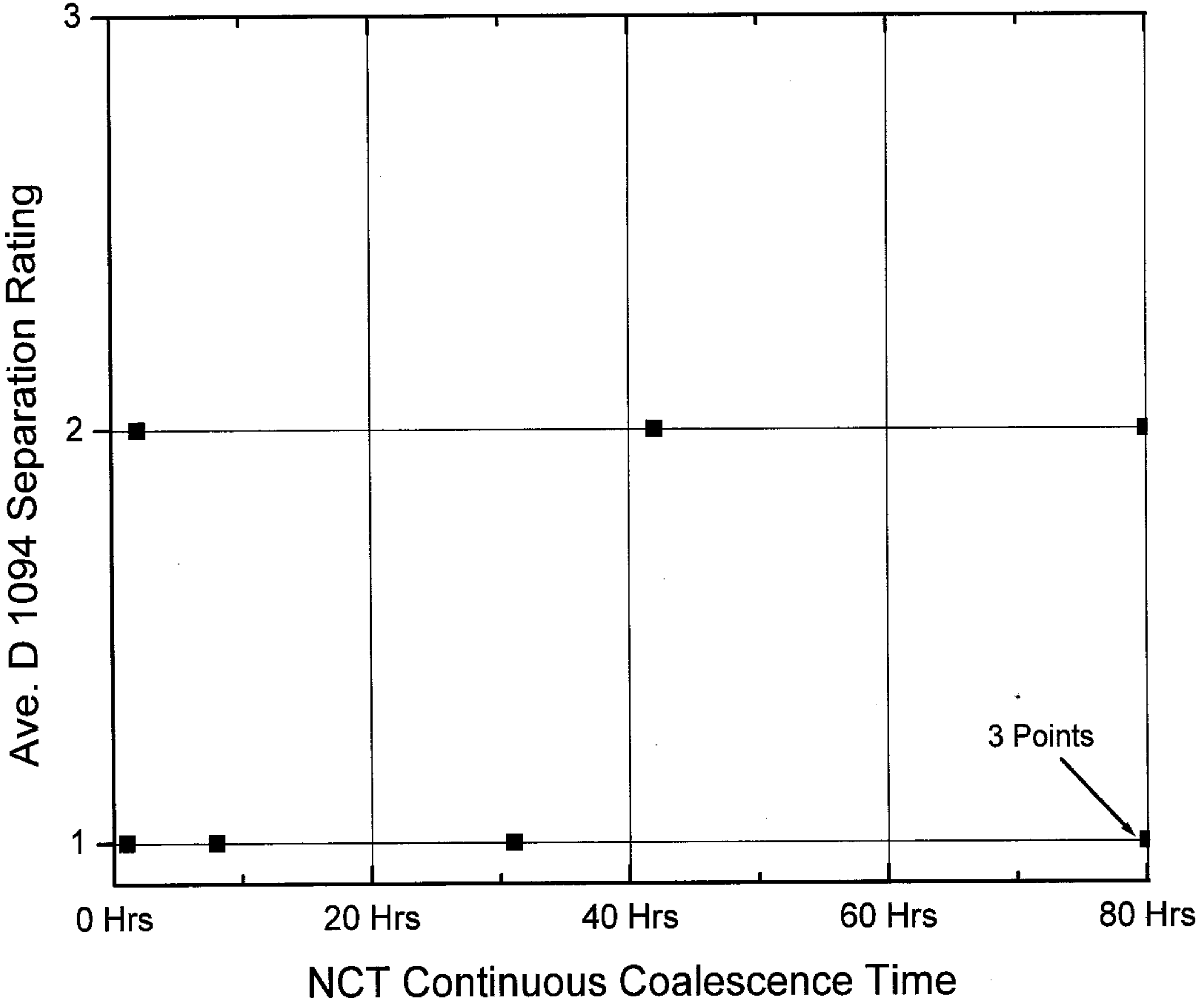


Figure 8 NCT Versus D 1094 Meniscus Shape

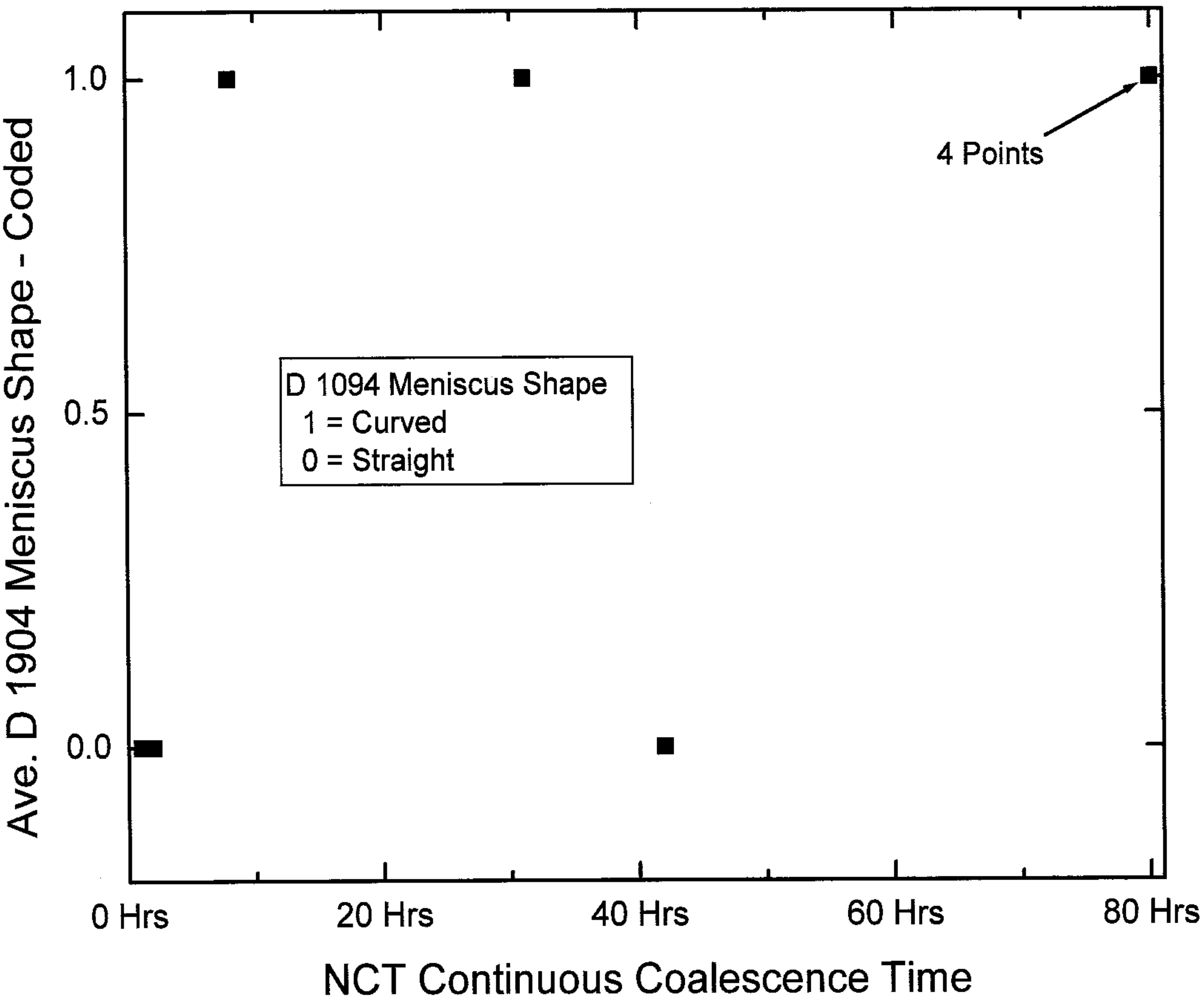


Figure 9 NCT Versus Swift Kit

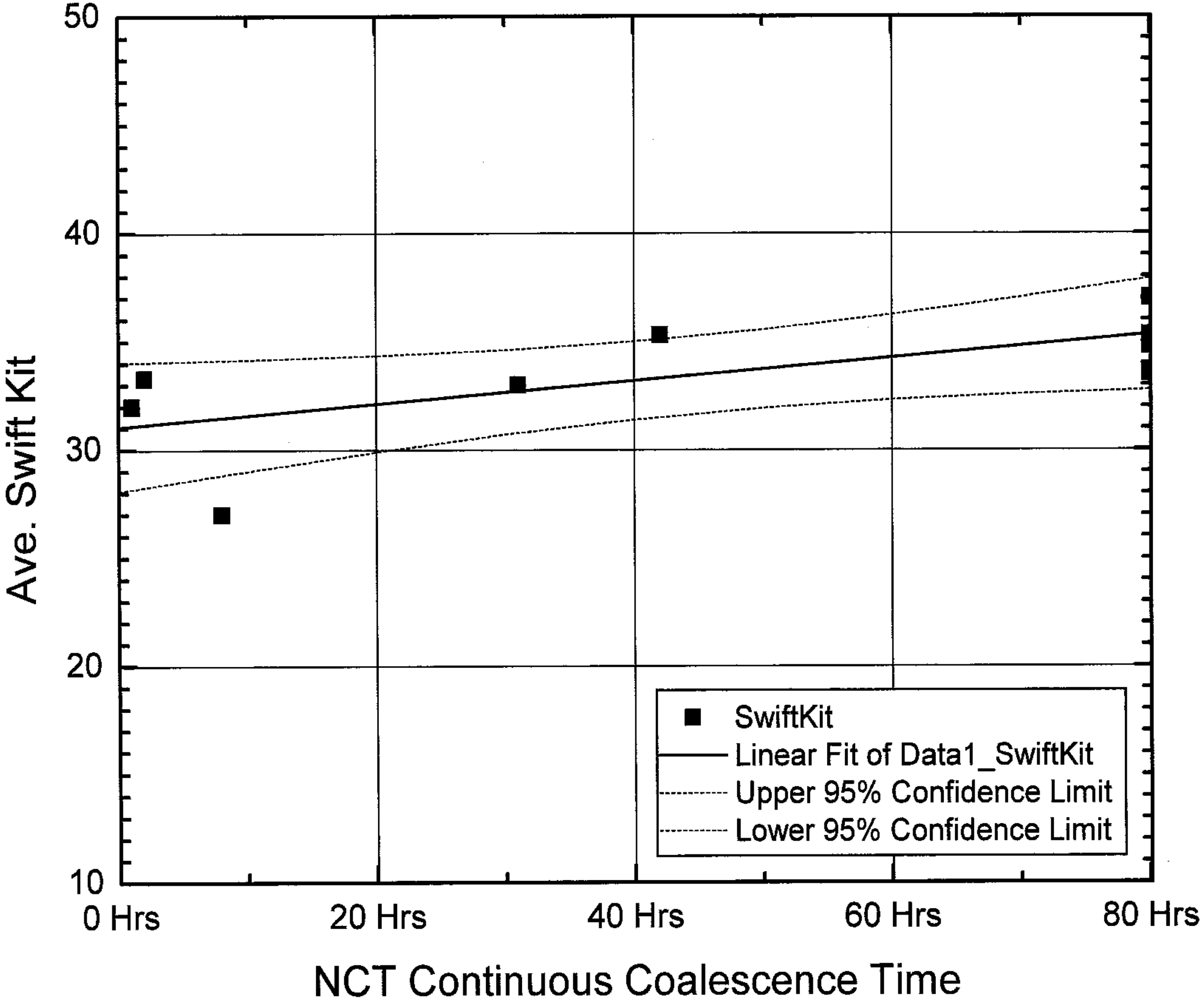


Figure 10 NCT Versus Interfacial Tension

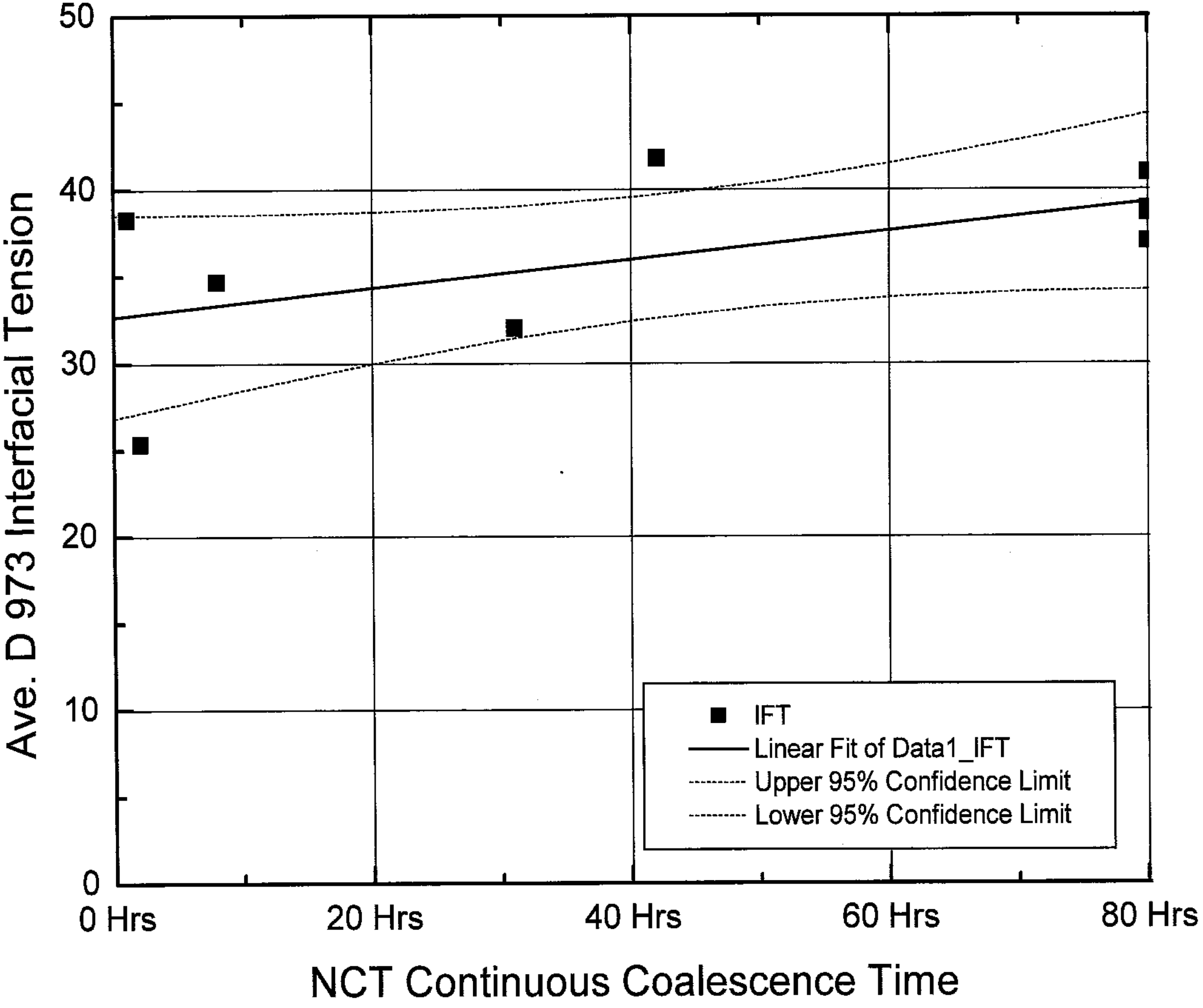


Figure 11 NCT Versus WASP

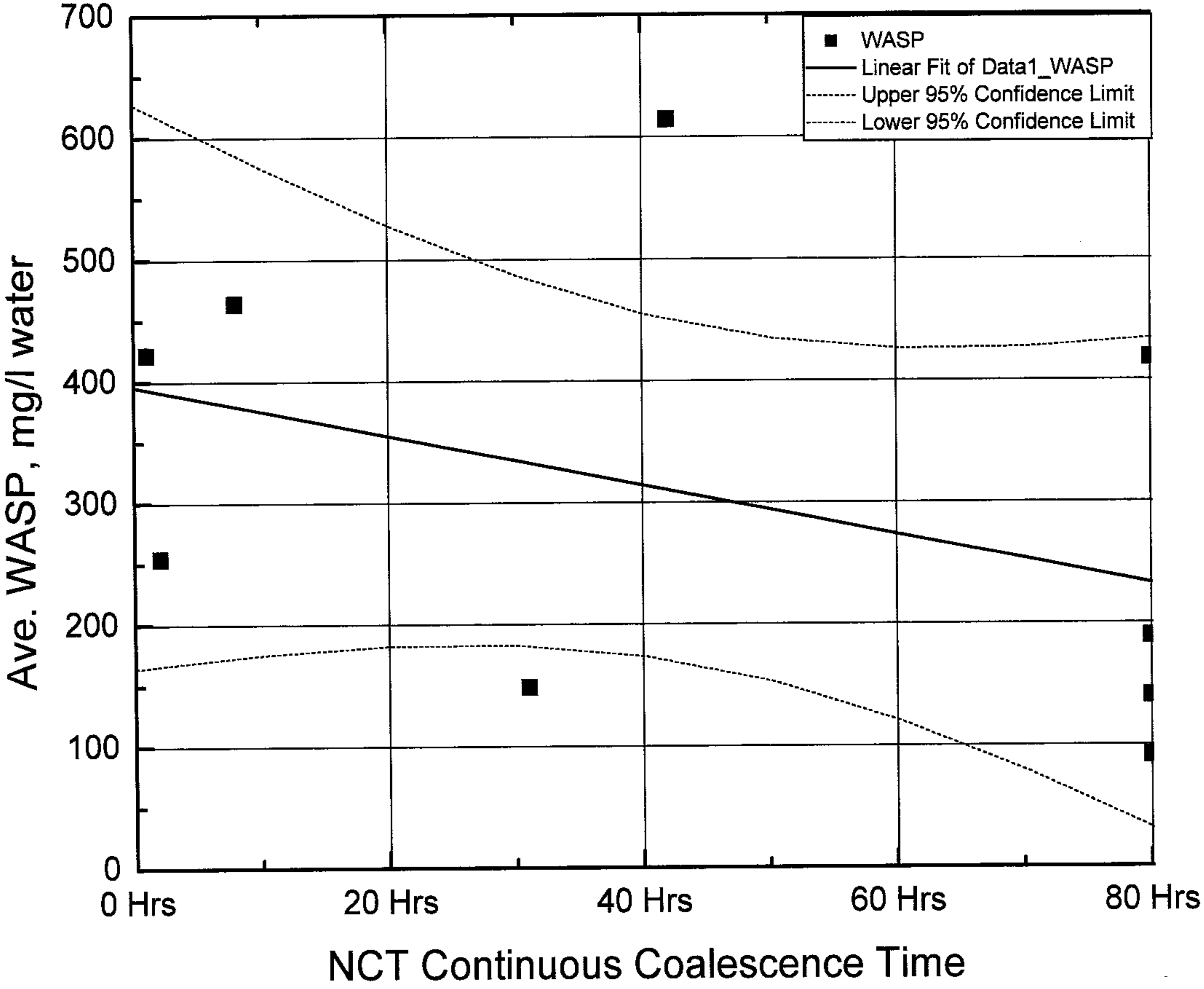


Figure 12 MSEP with M Cell & Al Syringe Versus Std. MSEP

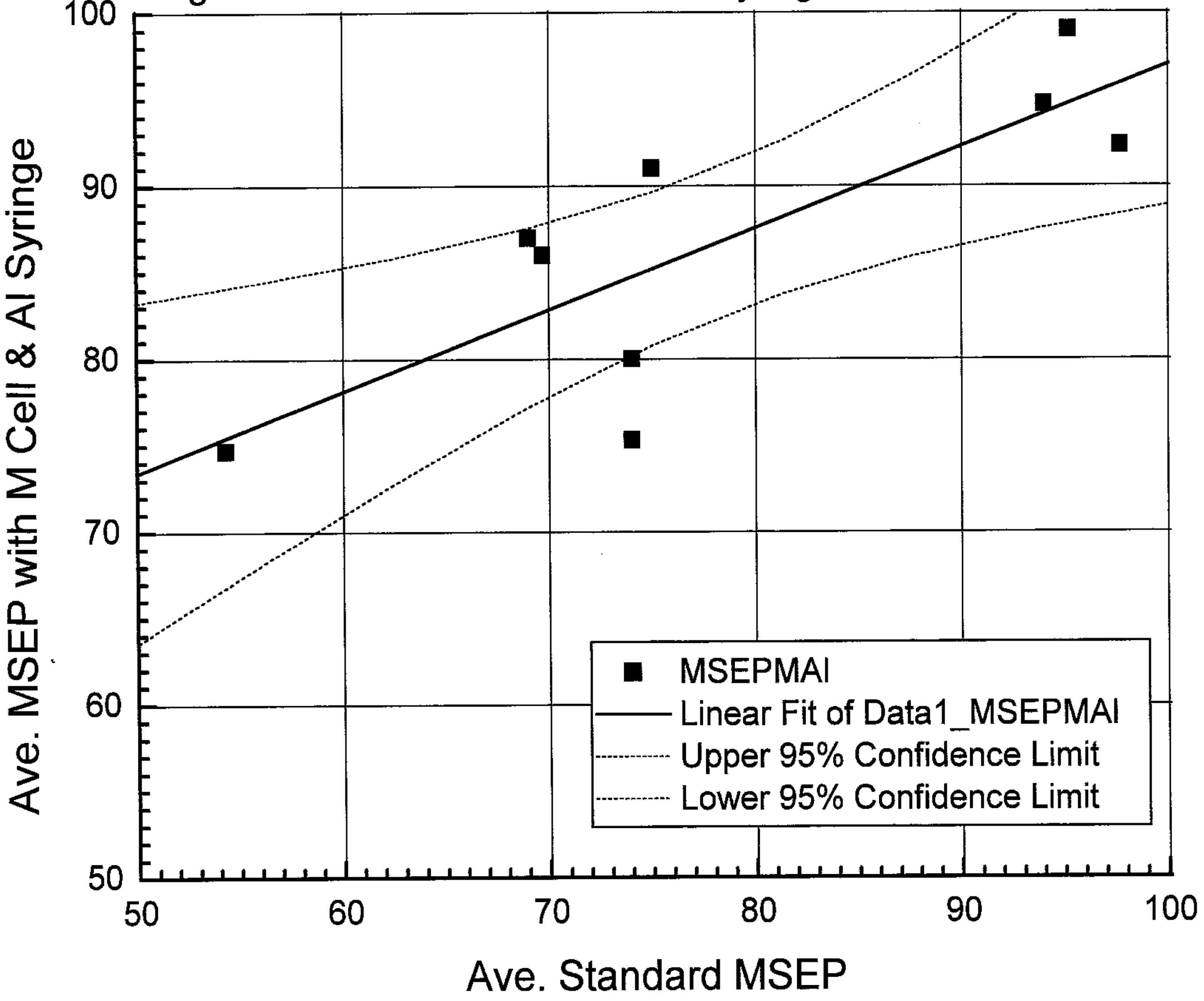


Figure 13 D 6426 Filterability(.65u) Vs. D 5452 Particulates

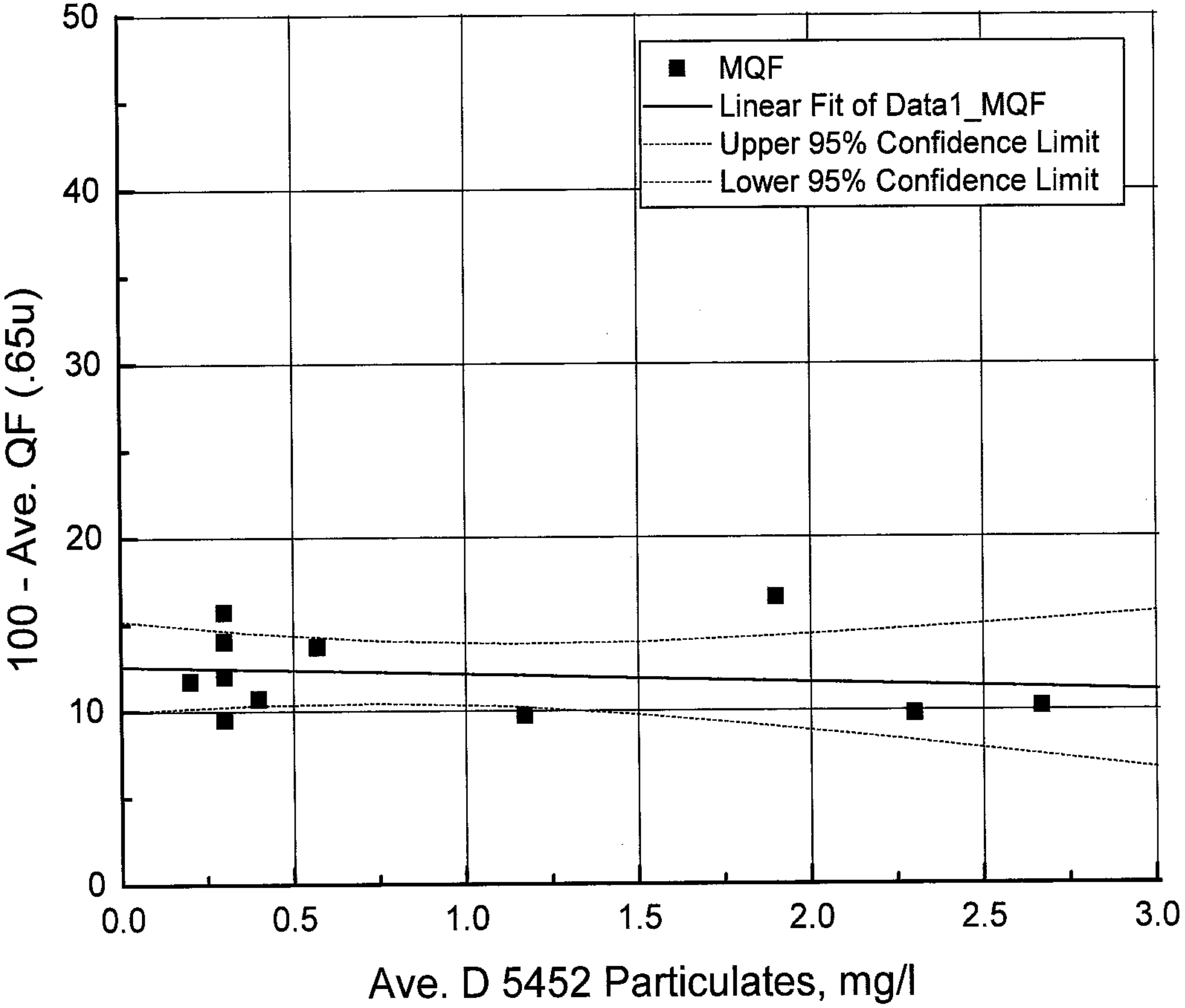
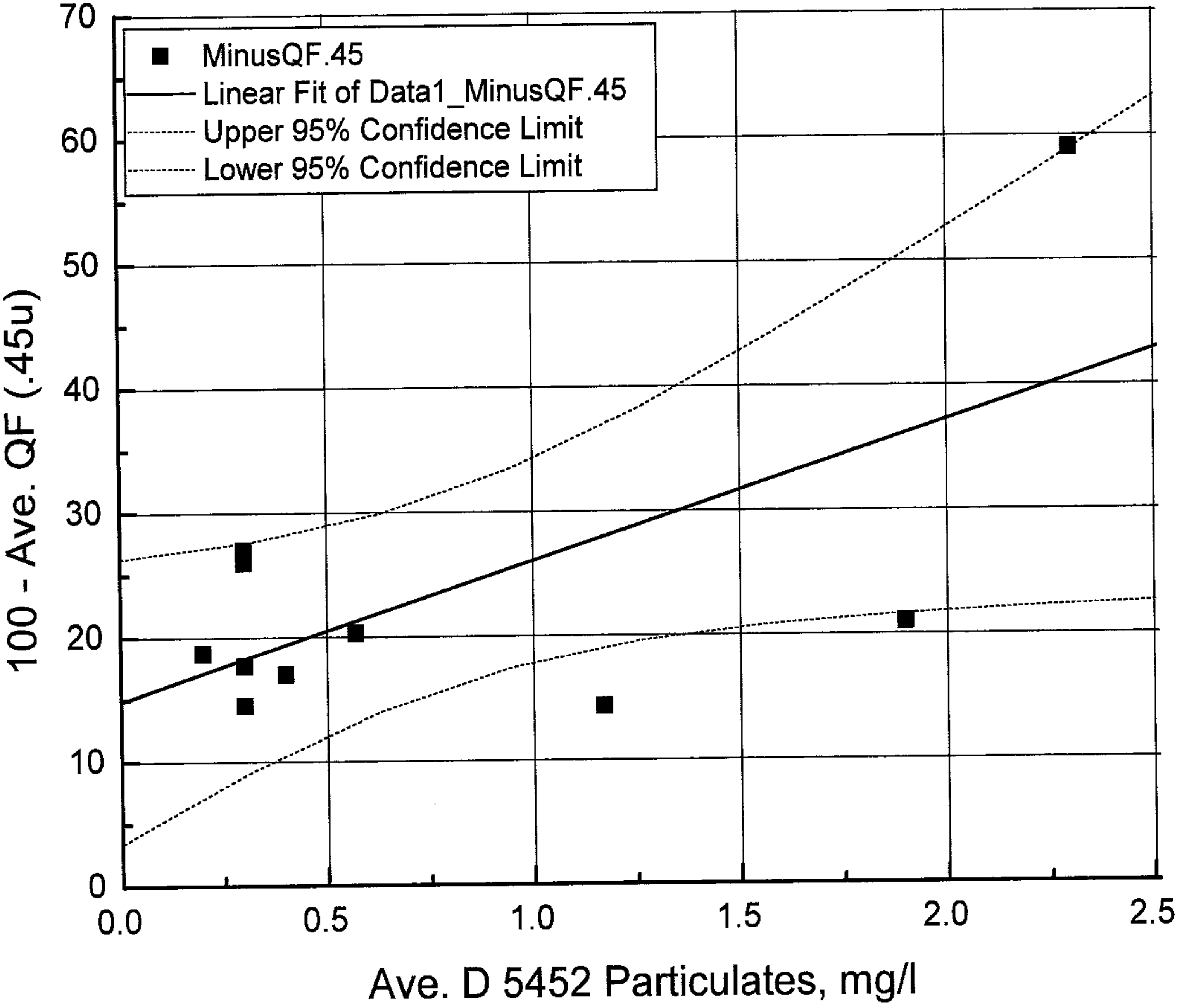


Figure 14 D 6426 Filterability(.45u) Vs. D 5452 Particulates



APPENDIX A

MEMBERS OF THE CRC AD HOC NCT PROGRAM PANEL

CRC Ad Hoc NCT Program Panel*

- Patricia Pierce - US Air Force -Panel Leader
- Regina Gray - DESC
- Peter Brook - UK MOD
- Rick Kamin - US Navy
- Brad Mathoney- CGSB
- Gretchen Wendtland - Pipeline Industry
- Cy Henry - International Spec Liaison Group

*Also ASTM S/C J Sect 10 Ad Hoc NCT Program Task Force

APPENDIX B

MSEP OF MILITARY FUELS

MSEP of Military Fuels

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23 June 98

Evaluation Parameters

- **Two Base Fuels**
  - **Hydrotreated Jet A with 25 mg/L Antioxidant (H)**
  - **Merox Jet A (M)**
- **Corrosion Inhibitor/Lubricity Improver Additive**
  - **DCI-4A (min 9 g/m³) (max 22.5 g/m³)**
  - **PRI-19 (min 18 g/m³) (max 22.5 g/m³)**
- **Fuel System Icing Inhibitor**
  - **0.15 Vol % DIEGME**

Evaluation Parameters (cont.)

- **Static Disapator Additive**
  - **2 mg/L Stadis 450**
  - **Conductivity recorded prior to shipping and testing**
- **Thermal Stablity Improver Additive**
  - **256 mg/L Betz**
  - **280 mg/L Ethyl**
  - **458 mg/L Octel**

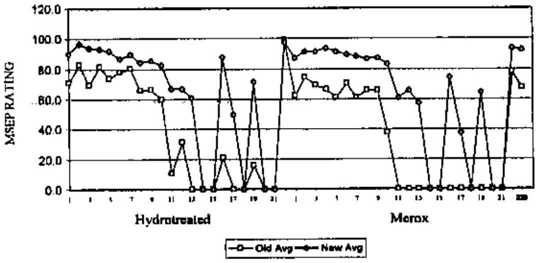
Evaluation Parameters (cont.)

- **Each Sample Run Twice Using Each Method**
- **Two Different Operators**
- **Total Eight Runs per Sample**
- **Testing Occurred 20-24 April 98**

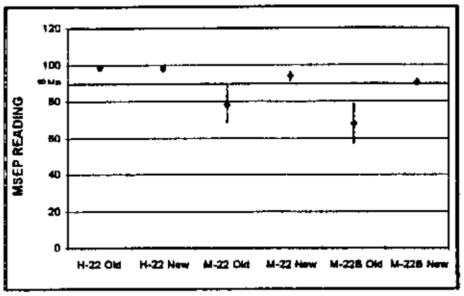
Data Key

Sample	DCI-4A	PRI-19	FSII	SDA	Betz	Ethyl	Octel	Comment
(H/M)-1			X					Base fuel, FSII
(H/M)-2	Min							Base fuel, CI/LI
(H/M)-3	Max							Base fuel, CI/LI
(H/M)-4		Min						Base fuel, CI/LI
(H/M)-5		Max						Base fuel, CI/LI
(H/M)-6	Min		X					Base fuel, CI/LI, FSII
(H/M)-7	Max		X					Base fuel, CI/LI, FSII
(H/M)-8		Min	X					Base fuel, CI/LI, FSII
(H/M)-9		Max	X					Base fuel, CI/LI, FSII
(H/M)-10				X				SDA/Jet A
(H/M)-11	Min		X	X				SDA/JP-8
(H/M)-12	Max		X	X				SDA/JP-8
(H/M)-13	Min		X	X	X			+100/JP-8
(H/M)-14	Min		X	X		X		+100/JP-8
(H/M)-15	Min		X	X			X	+100/JP-8
(H/M)-16					X			+100/Jet A
(H/M)-17						X		+100/Jet A
(H/M)-18							X	+100/Jet A
(H/M)-19			X		X			+100/FSII
(H/M)-20			X			X		+100/FSII
(H/M)-21			X				X	+100/FSII
(H/M)-22								Jet A

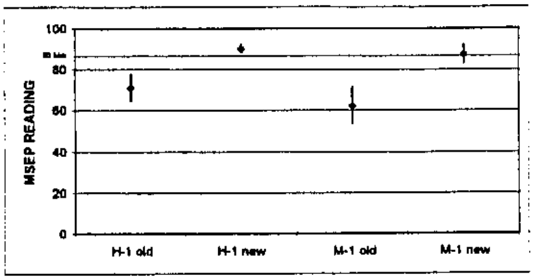
Data



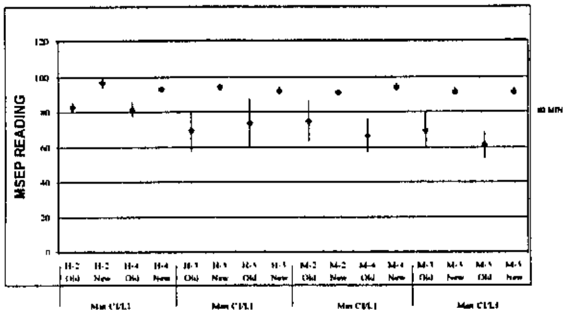
Base Fuel



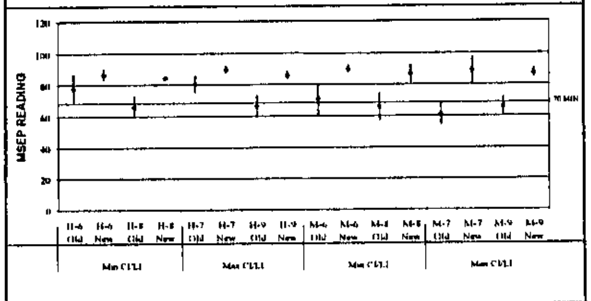
Base Fuel with FSII



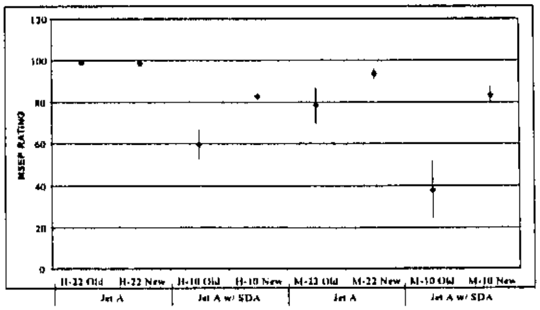
Base Fuel with Corrosion Inhibitor/Lubricity Improver (CI/LI)



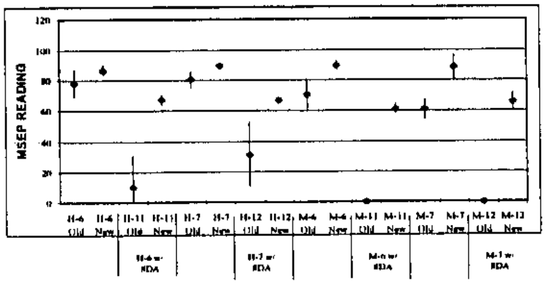
Base Fuel with CI/LI and FSII



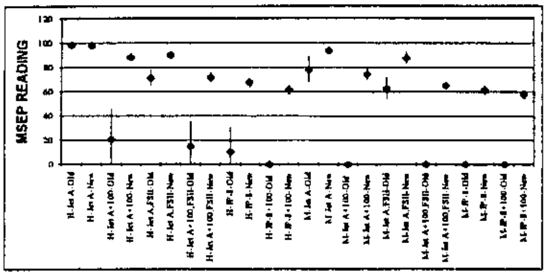
SDA in Base Fuel



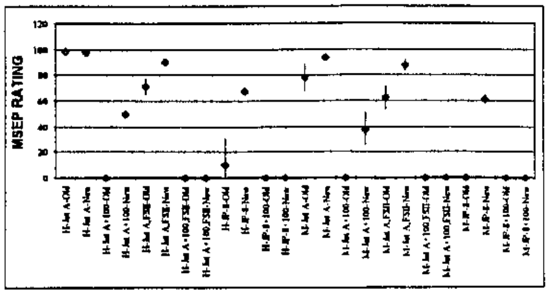
SDA in "JP-8"



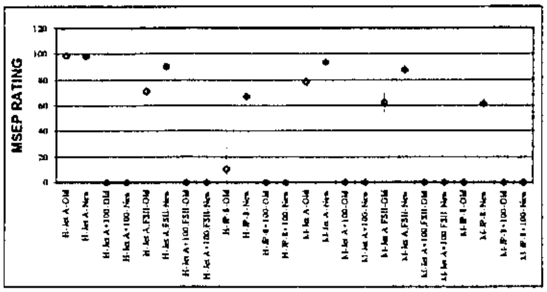
Betz +100 Additive



Ethyl +100 Additive



Octel +100 Additive



"ZEROs"

Old Cell	H-11 and M-11	SDA in JP-8
	H-12 and M-12	SDA in JP-8
	H-16 and M-16	Jet A +100 Betz
	H-19 and M-19	Jet A, FSII, +100 Betz
	H-13 and M-13	JP-8+100 Betz
	H-17 and M-17	Jet A +100 Ethyl
	H-20 and M-20	Jet A, FSII, +100 Ethyl
	H-14 and M-14	JP-8+100 Ethyl
	H-18 and M-18	Jet A +100 Octel
	H-21 and M-21	Jet A, FSII, +100 Octel
	H-15 and M-15	JP-8+100 Octel
New Cell	H-20 and M-20	Jet A, FSII, +100 Ethyl
	H-14 and M-14	JP-8+100 Ethyl
	H-18 and M-18	Jet A +100 Octel
	H-21 and M-21	Jet A, FSII, +100 Octel
	H-15 and M-15	JP-8+100 Octel

Conclusions (New Cell)

- Higher Rating when Compared to Old Cell
  - More Representative of Filter Coalescer Material Found in Field
- Less Variance in Data for each Sample when Compared to Old Cell
- Military Fuels (with FSII, CI/LI, FSII and CI/LI) can be Rated
- Shows Potential to Rate Fuels with SDA
- Different Thermal Stability Additives Effect the Test Differently

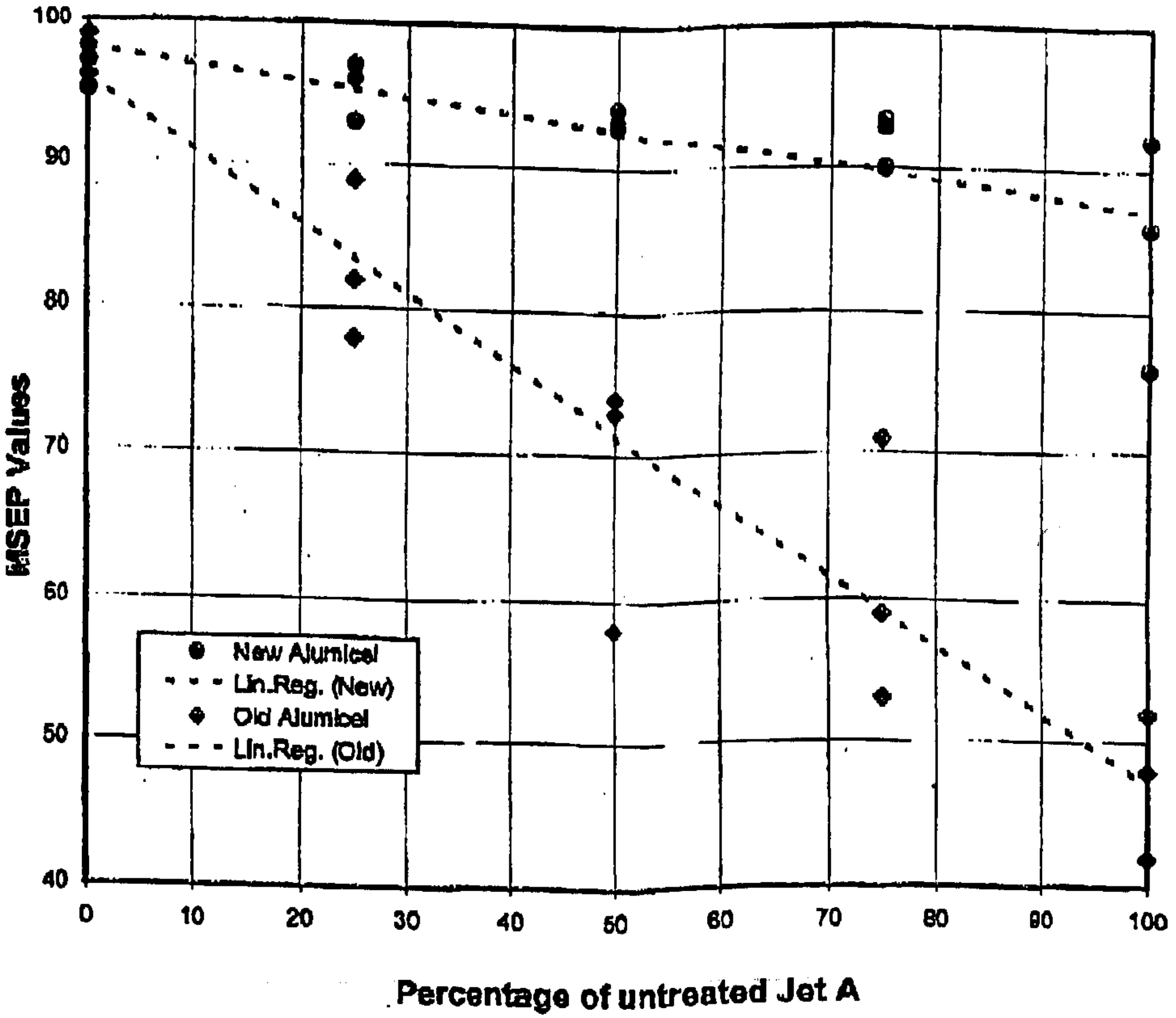
Summary

- Military needs to Re-evaluate our Specification Limits with New Cell
- Is there Interaction with Container?
  - Merox vs Hydrotreated?
- Future Testing
  - Problem Fuels from the Field
  - SDA
  - Thermal Stability Improver Additives
  - JP-4
  - Open to Suggestions

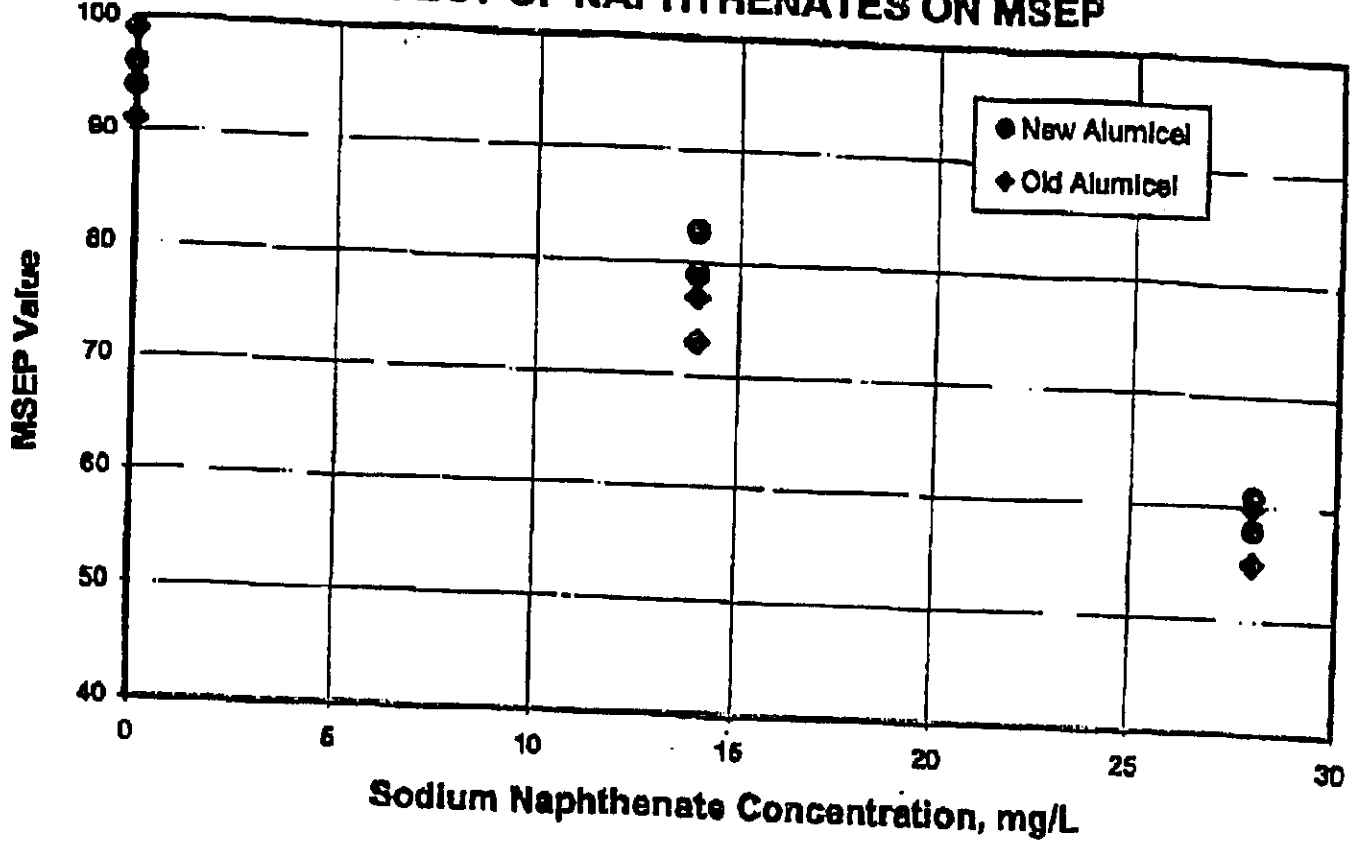
APPENDIX C

CHEVRON RESEARCH PROGRAM

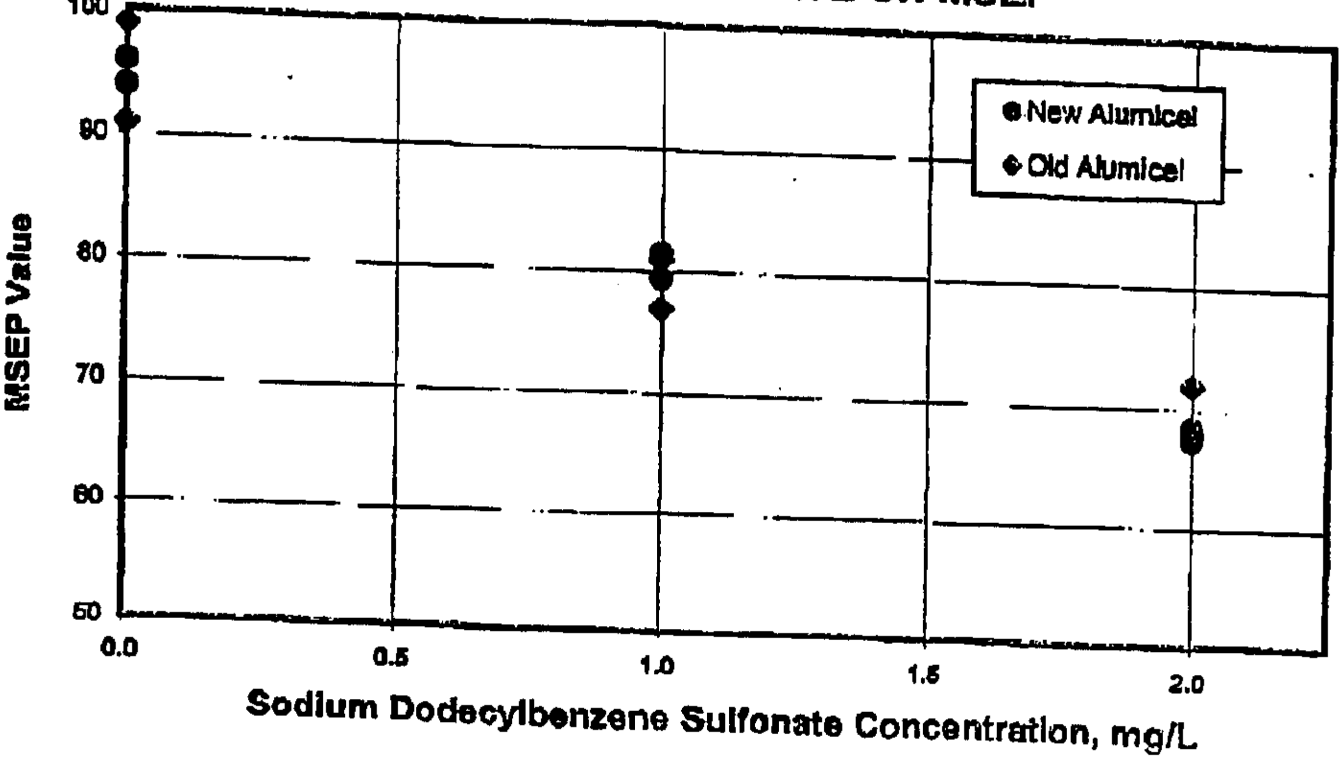
EFFECT OF CLAY TREATING ON MSEP
(Using an Unfinished Merox Treated JET A)



EFFECT OF NAPHTHENATES ON MSEP



EFFECT OF SULFONATE ON MSEP



Sodium Napthanates

Napthanates, mg/L	Old	New
0	99	96
0	91	94
14	73	79
14	77	83
28	60	58
28	55	61

Sodium Dodecylbenzine Sulfanate

Sulfanate, mg/L	Old	New
0	99	96
0	91	94
1	77	80
1	81	81
2	68	68
2	72	68

APPENDIX D

MSEP TESTING OF CANADIAN FUELS

MSEP TESTING
CANADIAN FUELS

- 32 SAMPLES
- 27 KEROSINE FUELS
- 15 CHEMICALLY TREATED
- 8 HYDROTREATED
- 4 COMMINGLED
- 5 WIDE CUT FUELS
- 3 CHEMICALLY TREATED
- 2 HYDROTREATED

SOURCES AND BACKGROUND

- REFINERY STORAGE, SHIPPING, AND RUNDOWN TANKS, WITH AND W/O SDA
- PIPELINE TERMINALS, BEFORE/AFTER CLAY TREATING, WITH AND W/O SDA
- COMMINGLED AIRPORT TANKS, WITH SDA (KEROSINE FUELS ONLY)
- ALL COMMERCIAL FUELS
- FUELS CONSUMED IN A/C

CGSB COMMENTS/OBSERVATIONS

- TEST RESULTS TO DATE SHOW SIGNIFICAN IMPROVEMENT IN TEST METHOD PRECISION

- SUPPORT RETENTION OF D-3948 AS REFERENCE NUMBER FOR REVISED TEST METHOD

- RETENTION OF CURRENT MSEP TEST LIMITS WITHIN THE CGSB JET FUEL SPECIFICATIONS DISCUSSED BUT NOT RESOLVED

- D-3948 IS THE ONLY TEST METHOD CITED IN THE CGSB JET FUEL SPECIFICATIONS CAPABLE OF PREDICTING A FUEL'S WATER-SHEDDING ABILITY WHEN THE FUEL IS PASSED THROUGH FIBERGLASS COALESCING MATERIAL

APPENDIX E

USAF JP-8 FUEL PROGRAM

USAF JP- 8 FUEL PROGRAM

Purpose: Determine the effect of additives on MSEP® rating using the new MCell® coalescers

A. Determine the cumulative effect of varying concentrations of JP-8 additives on the MSEP rating obtained using the new MCell coalescers

B. Determine if the current MSEP specification limits of 85 w/o additives and 70 w/additives, except Stadis® 450, are applicable to the MCell coalescer

C. Establish minimum specification requirement for MSEP rating for JP-8 fuels containing Stadis® 450 – No current requirement for MSEP rating for fuels containing Stadis® 450

TEST PROTOCOL

Test both merox and hydrotreated fuels containing varying amounts of additives typically used in JP-8. Measure the electrical conductivity, pS/m, of each sample. Use the proposed test procedure, without the electrostatic shield, to perform "blind" replicate MSEP rating tests with the current Alumicel® and new MCell® coalescers. Tests performed by 2 operators using 2 different Microseparometers on the same identical samples at a single site.

EFFORT TO DATE

The USAF, Patti Leberio, recently supplied 2 batches of coded samples of unknown content to Emcee Electronics, Inc. for testing. The samples, 9 per batch, had been prepared from a common base merox treated and a hydrotreated fuel. Each sample was blended with additives commonly used in JP-8 fuel. The samples contained min/max amounts of corrosion inhibitors, DCI-4A & PRI-19; 1.0 & 2.0 ppm Stadis® 450; and FSII. The merox samples were tested according to the test protocol approximately 5 weeks and the hydrotreated fuels approximately 2 weeks from the date of blending with additives. The test results were furnished to the USAF who then identified the content of each sample. The USAF considered all of the samples as being acceptable for use.

SUMMARY OF TEST RESULTS

- Both coalescer types yielded approximately the same MSEP rating for the base fuel
- MSEP ratings obtained by both coalescers, decreased proportionately to the amount of additive present – more additive content – lower MSEP rating
- Both coalescers exhibited the same footprint except the Alumicel® coalescer yielded an average lower MSEP rating
- All of the samples, except one hydrotreated sample (marginal), passed the current MSEP spec limit (70) using the MCell, whereas, only 2 of the merox and 3 of the hydrotreated samples passed using the Alumicel® coalescer – 13 of 18 good fuels rejected
- The standard deviation for the MCell is approximately 2:1 better than that of the Alumicel coalescer – compares favorably with the round robin test results
- The addition of a corrosion inhibitor and FSII appears to depress the conductivity level of the fuels containing equal amounts of Stadis® 450®.
- PRI-19 appears to affect the MSEP rating more than DCI-4A.

CONCLUSIONS & FUTURE ACTIVITY

The USAF test program yielded results indicating that the goals of the ASTM task force are being met. Both coalescers produce MSEP ratings that reflect the presence of surfactants with the MCell being less sensitive to additives. This decreases the probability of rejecting good fuels. In contrast, previous Chevron data showed a close correlation at all levels of surfactants known to cause filter separator failure. The inference being that MCell coalescers do not yield low MSEP ratings for benign additives even in the presence of SDA, whereas, both coalescers yield approximately the same results for malignant surfactants.

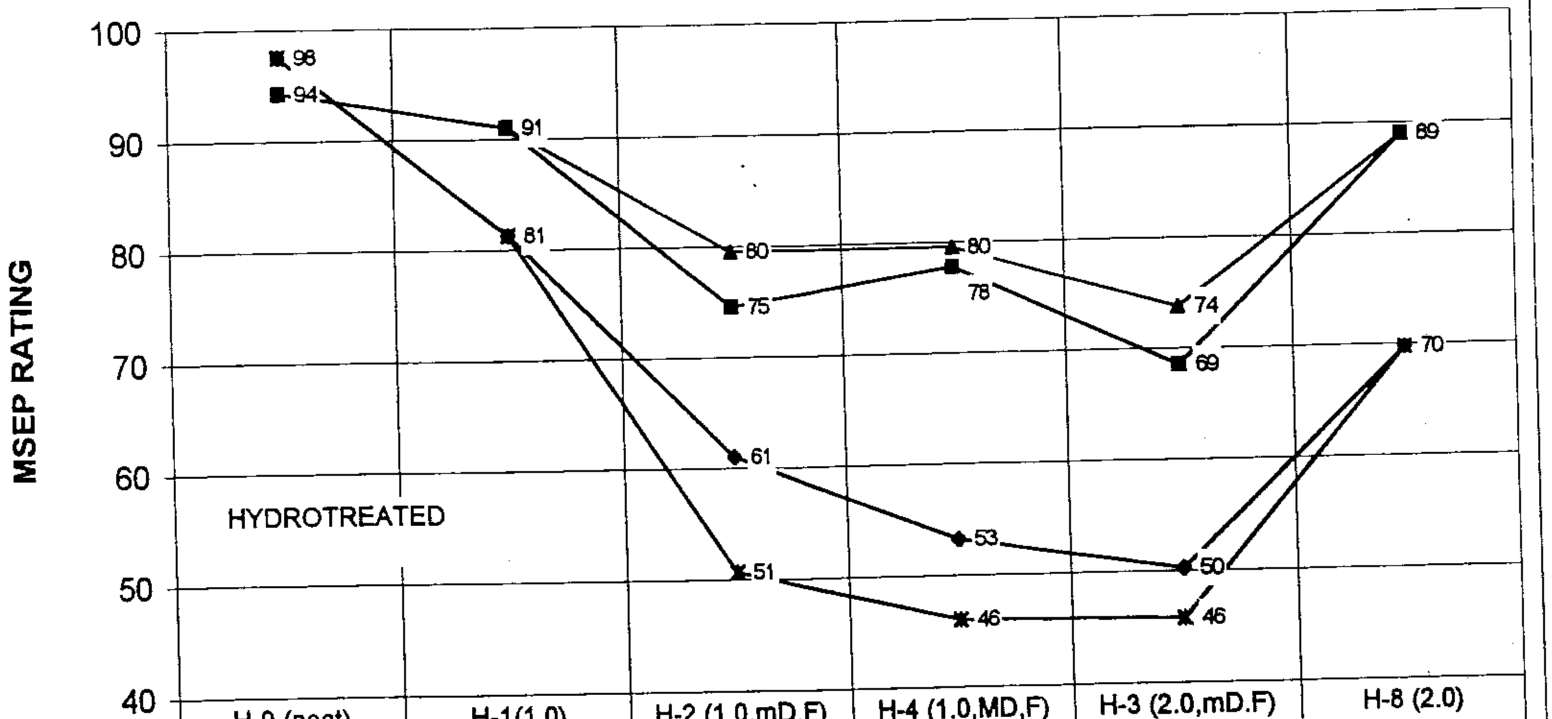
The USAF is planning to conduct additional tests using the Navy Coalescence Tester (NCT) to obtain experimental data on the effect of various surfactants on jet fuel coalesce. These tests will include the current (Alumicel) and improved (MCell) MSEP tests, the Water Reaction Test, the Shell WASP Test, and the IFT test. Surfactant classes to be evaluated include strong surfactants known to potentially be present in jet fuel; weak surfactants resulting from the use of approved additives alone or in combination, and weak surfactants, other than additives, that are potentially present in jet fuel. A draft test protocol has been written by Bill Taylor, Chairman of MSEP task force.

The time frame to complete these activities is by year-end.

USAF JET FUELS
HYDROTREATED
MAY 4, 1999

MSEP RESPONSE TO ADDITIVES

Stadis 450 + Corrosion Inhibitors (DCI-4A & PRI-19) + FSII

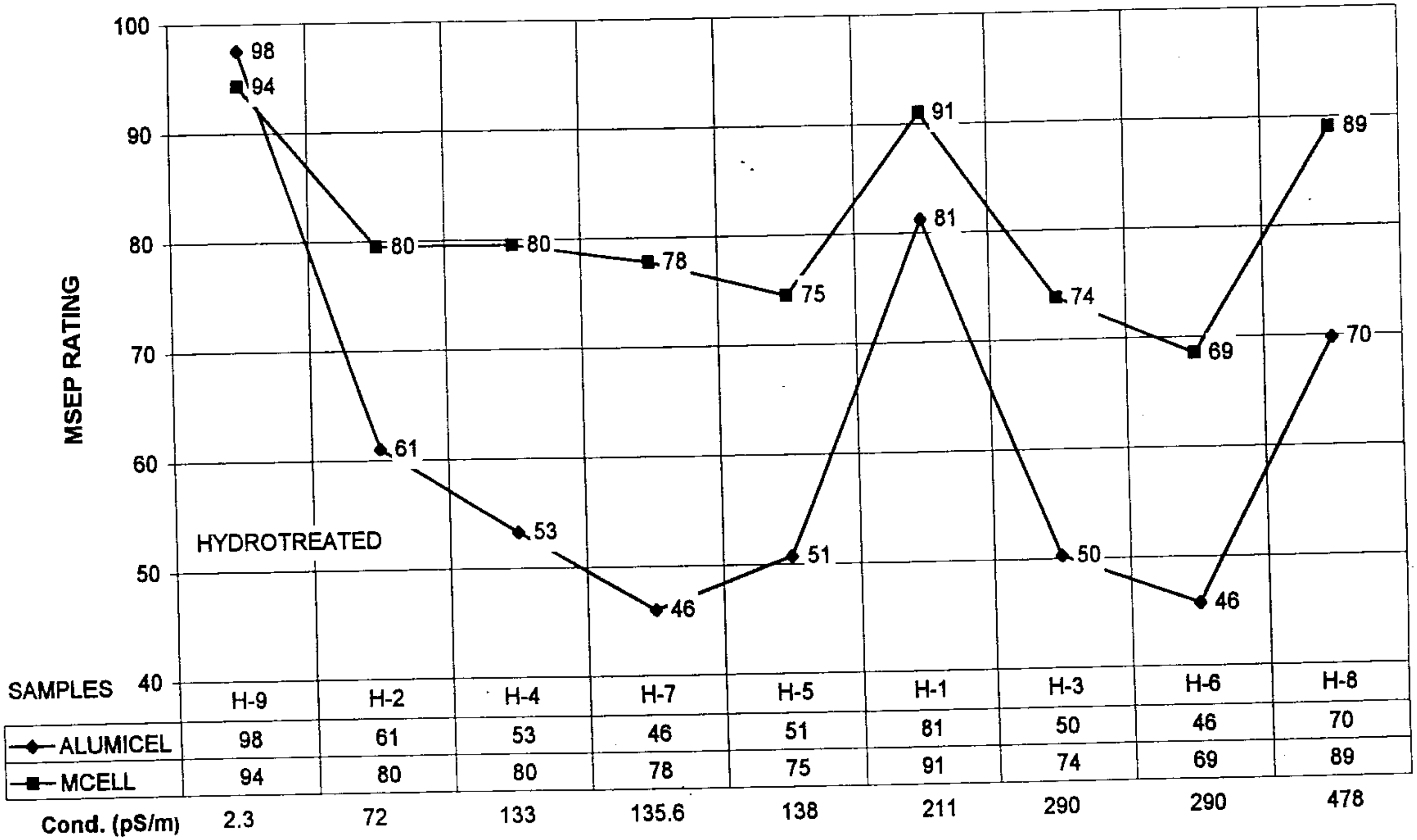


*SAMPLES	H-9 (neat) H-9 (neat)	H-1(1.0) H-1(1.0)	H-2 (1.0,mD,F) H-5 (1.0,mP,F)	H-4 (1.0,MD,F) H-7 (1.0,MP,F)	H-3 (2.0,mD.F) H-6 (2.0,mP,F)	H-8 (2.0) H-8 (2.0)
◆ Alumicel - DCI-4A	98	81	61	53	50	70
▲ MCell - DCI-4A	94	91	80	80	74	89
✱ Alumicel - PRI-19	98	81	51	46	46	70
■ MCell - PRI-19	94	91	75	78	69	89

***Sample Legend: SDA (1.0 or 2.0 ppm), Corrosion Inhibitor (m=min. M=max, D=DCI-4A, P=PRI-19),F=FSII**

MSEP RATING - CURRENT (Alummicel) VS NEW (MCell) COALESCERS
(AVERAGE OF REPLICATE DATA - SORTED BY INCREASING CONDUCTIVITY)

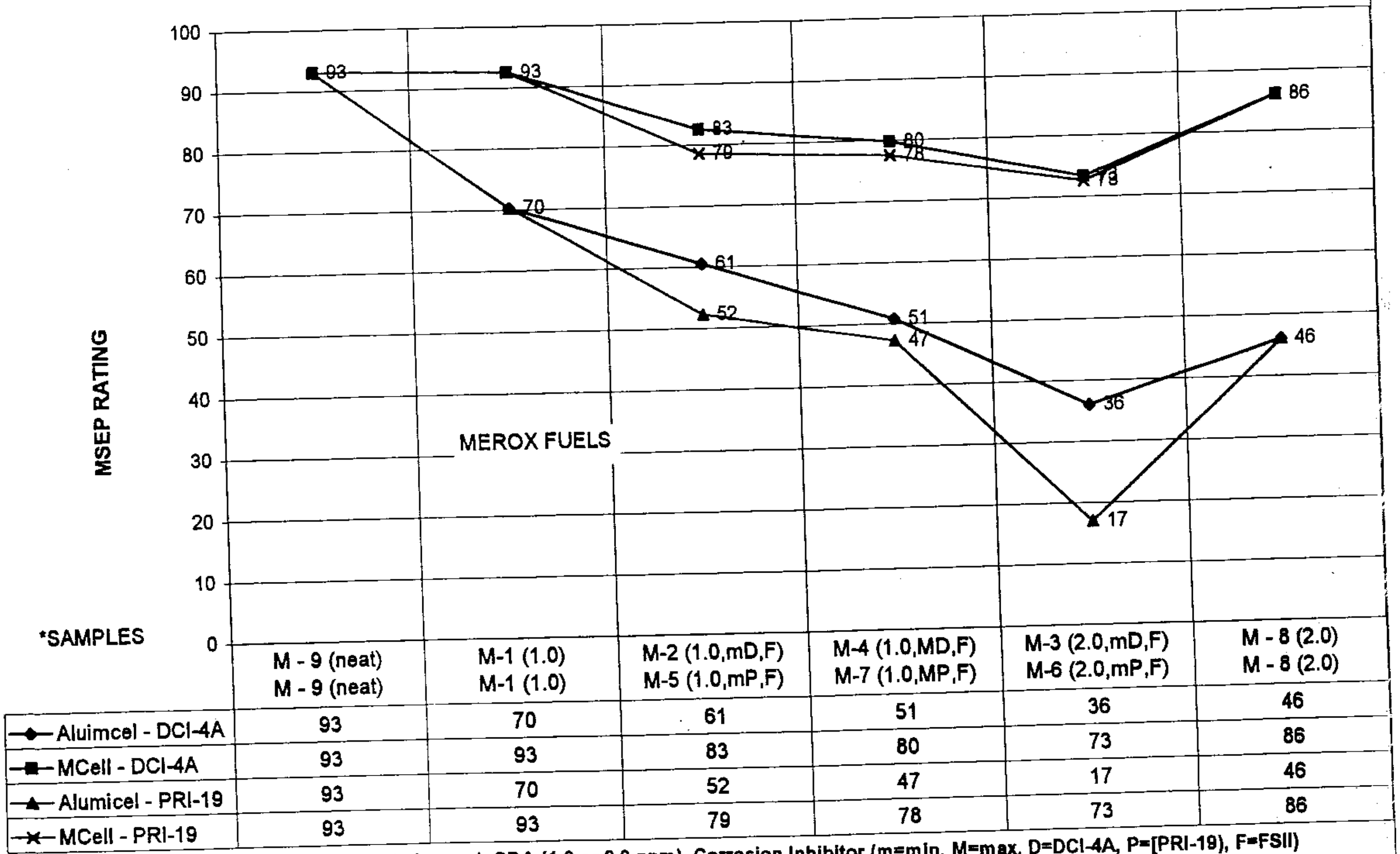
USAF JET FUELS
HYDROTREATED
MAY 4,1999



SAMPLES	H-9	H-2	H-4	H-7	H-5	H-1	H-3	H-6	H-8
◆ ALUMICEL	98	61	53	46	51	81	50	46	70
■ MCELL	94	80	80	78	75	91	74	69	89
Cond. (pS/m)	2.3	72	133	135.6	138	211	290	290	478

USAF JET FUEL
MEROX
March 11, 1999

MSEP RESPONSE TO ADDITIVES
Stadis 450 + Corrosion Inhibitors (DCI-4A & PRI-19) + FSII

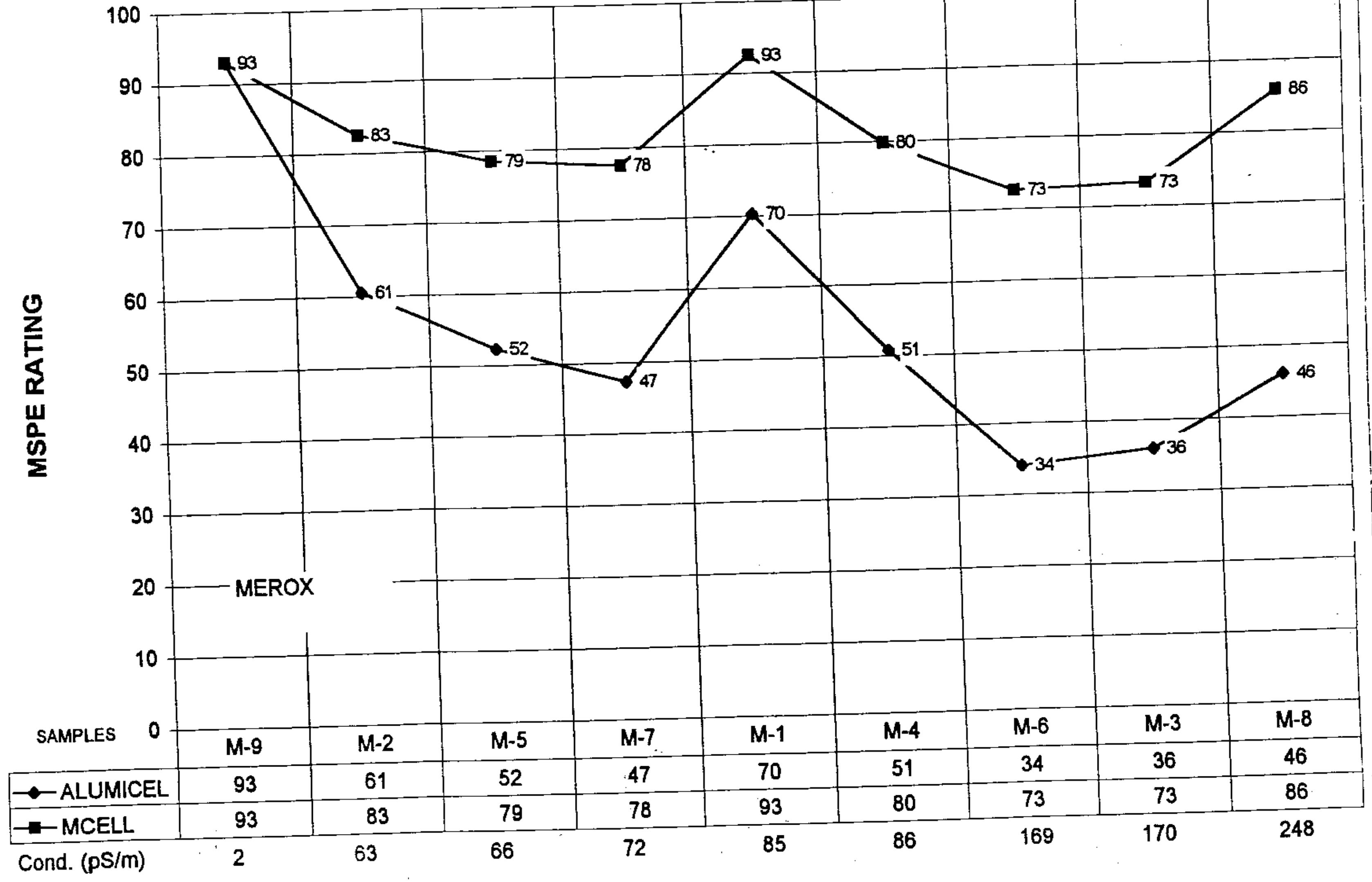


*SAMPLES	M - 9 (neat) M - 9 (neat)	M-1 (1.0) M-1 (1.0)	M-2 (1.0,mD,F) M-5 (1.0,mP,F)	M-4 (1.0,MD,F) M-7 (1.0,MP,F)	M-3 (2.0,mD,F) M-6 (2.0,mP,F)	M - 8 (2.0) M - 8 (2.0)
◆ Aluimcel - DCI-4A	93	70	61	51	36	46
■ MCell - DCI-4A	93	93	83	80	73	86
▲ Alumicel - PRI-19	93	70	52	47	17	46
✕ MCell - PRI-19	93	93	79	78	73	86

*Sample Legend: SDA (1.0 or 2.0 ppm), Corrosion Inhibitor (m=min. M=max, D=DCI-4A, P=[PRI-19), F=FSII)

MSEP RATING - CURRENT (Alumicel(VS NEW (MCell) COALESCERS
(AVERAGE OF REPLICATE DATA - SORTED BY INCREASING CONDUCTIVITY)

USAF JET FUELS
MEROX
MARCH 11, 1999



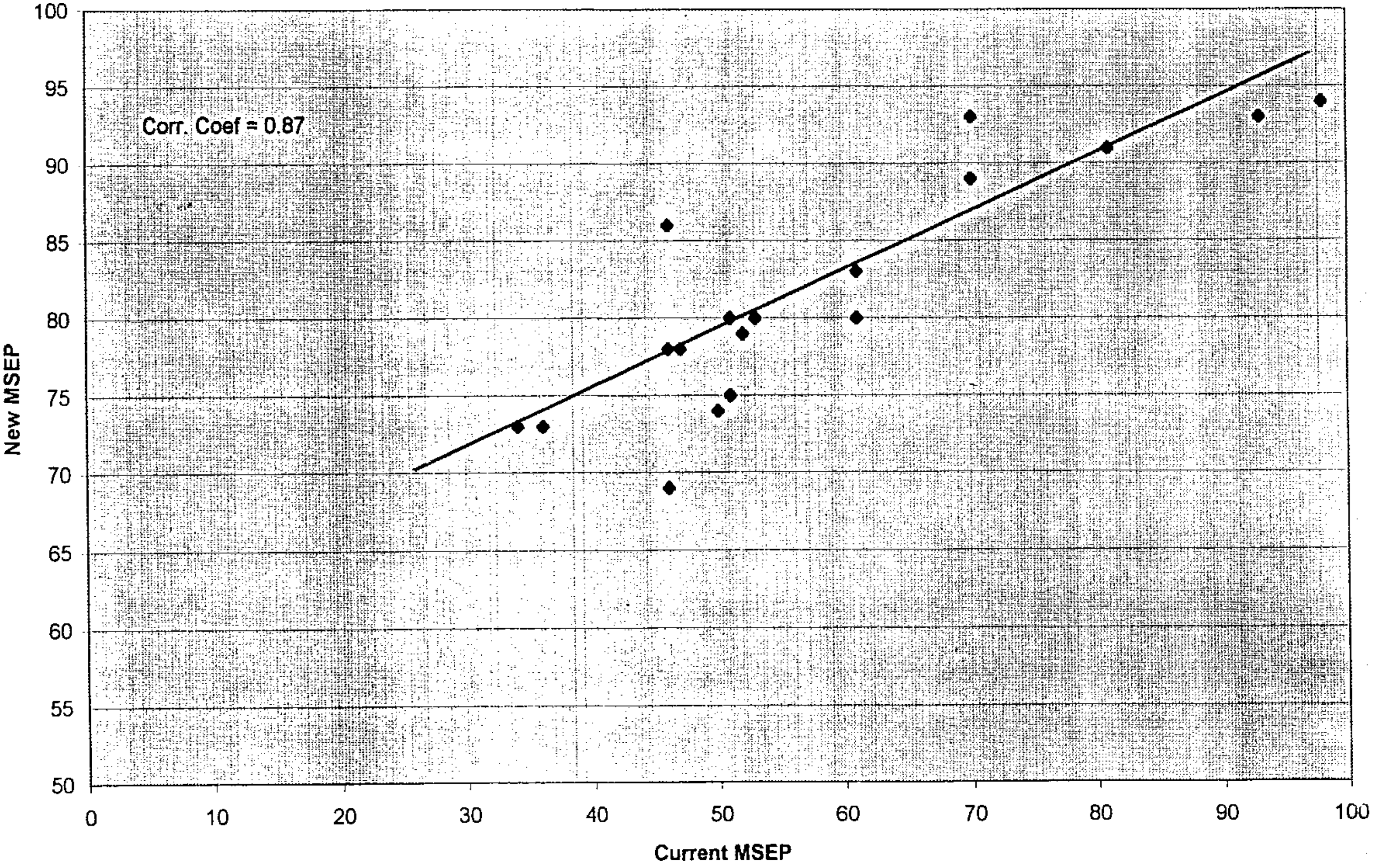
SAMPLES	M-9	M-2	M-5	M-7	M-1	M-4	M-6	M-3	M-8
◆ ALUMICEL	93	61	52	47	70	51	34	36	46
■ MCELL	93	83	79	78	93	80	73	73	86
Cond. (pS/m)	2	63	66	72	85	86	169	170	248

usaf_tst.xls								
		Old Cell	Old Cell		New Cell	New Cell		Old Cell
		Karin	Karin		Karin	Karin		Dan
Sample		**Test-1**	**Test-2**		**Test-1**	**Test-2**	**PS/M**	**Test-1**
H-	1	64	70		88	93	2	80
H-	2	87	83		98	99	8	81
H-	3	73	62		92	94	3	84
H-	4	83	85		94	93	3	83
H-	5	68	60		92	93	3	92
H-	6	65	84		85	83	4	79
H-	7	80	73		87	92	2	83
H-	8	56	70		83	84	3	70
H-	9	67	56		87	87	4	70
H-	10	50	62		82	81	820	66
H-	11	0	0		69	62	568	0
H-	12	43	0		65	66	353	39
H-	13	0	0		63	66	710	0
H-	14	0	0		0	0	1260	0
H-	15	0	0		0	0	130	0
H-	16	0	0		89	88	96	42
H-	17	0	0		51	48	74	0
H-	18	0	0		0	0	23	0
H-	19	3	15		75	66	94	0
H-	20	0	0		0	0	60	0
H-	21	0	0		0	0	56	0
H-	22	99	99		99	99	0.5	99
M-	1	55	55		83	94	0	73
M-	2	63	67		91	92	0	84
M-	3	66	56		93	93	0	80
M-	4	63	55		94	94	21	70
M-	5	55	54		93	93	0	69
M-	6	62	62		86	91	0	77
M-	7	52	62		83	81	0	68
M-	8	56	60		81	83	0	73
M-	9	60	61		91	84	0	69
M-	10	18	43		85	87	268	44
M-	11	0	0		64	64	291	0
M-	12	0	0		65	58	331	0
M-	13	0	0		57	54	541	0
M-	14	0	0		0	0	940	0
M-	15	0	0		0	0	482	0
M-	16	0	0		75	73	106	0
M-	17	0	0		43	19	97	0
M-	18	0	0		0	0	163	0
M-	19	0	0		67	65	102	0
M-	20	0	0		0	0	85	0
M-	21	0	0		0	0	152	0
M-	22	93	71		97	95	2	70
M-	22r	75	58		92	89	7	59

								DCI-4A
Old Cell		New Cell	New Cell					9g/m
Dan		Dan	Dan	Old Cell	Old Cell	New Cell	New Cell	22.5g/m
Test-2		**Test-1**	**Test-2**	**Old Avg**	**Std-Dev**	**New Avg**	**Std-Dev**	**CI/L1-1**
71		91	89	71.3	6.6	90.3	2.2	
81		92	98	83.0	2.8	96.8	3.2	Min
58		93	96	69.3	11.7	93.8	1.7	Max
75		94	92	81.5	4.4	93.3	1.0	
75		94	89	73.8	13.6	92.0	2.2	
84		90	89	78.0	9.0	86.8	3.3	Min
86		91	89	80.5	5.6	89.8	2.2	Max
68		85	86	66.0	6.7	84.5	1.3	
72		82	87	66.3	7.1	85.8	2.5	
61		83	84	59.8	6.8	82.5	1.3	
41		69	69	10.3	20.5	67.3	3.5	Min
44		67	69	31.5	21.1	66.8	1.7	Max
0		56	60	0.0	0.0	61.3	4.3	Min
0		0	0	0.0	0.0	0.0	0.0	Min
0		0	0	0.0	0.0	0.0	0.0	Min
42		86	89	21.0	24.2	88.0	1.4	
0		52	49	0.0	0.0	50.0	1.8	
0		0	0	0.0	0.0	0.0	0.0	
44		74	71	15.5	20.1	71.5	4.0	
0		0	0	0.0	0.0	0.0	0.0	
0		0	0	0.0	0.0	0.0	0.0	
98		97	97	98.8	0.5	98.0	1.2	
67		86	87	62.5	9.0	87.5	4.7	
85		91	91	74.8	11.4	91.3	0.5	Min
75		89	90	69.3	10.6	91.3	2.1	Max
78		96	91	66.5	9.8	93.8	2.1	
66		90	89	61.0	7.6	91.3	2.1	
81		92	91	70.5	9.9	90.0	2.7	Min
62		91	100	61.0	6.6	88.8	8.7	Max
74		90	93	65.8	9.1	86.8	5.7	
73		86	88	65.8	6.3	87.3	3.0	
47		84	77	38.0	13.4	83.3	4.3	
0		61	56	0.0	0.0	61.3	3.8	Min
0		73	67	0.0	0.0	65.8	6.2	Max
0		63	57	0.0	0.0	57.8	3.8	Min
0		0	0	0.0	0.0	0.0	0.0	Min
0		0	0	0.0	0.0	0.0	0.0	Min
0		69	81	0.0	0.0	74.5	5.0	
0		41	49	0.0	0.0	38.0	13.1	
0		0	0	0.0	0.0	0.0	0.0	
0		64	62	0.0	0.0	64.5	2.1	
0		0	0	0.0	0.0	0.0	0.0	
0		0	0	0.0	0.0	0.0	0.0	
79		92	91	78.3	10.6	93.8	2.8	
79		92	89	67.8	10.8	90.5	1.7	

PRI-19						
18g/m	Diegme		Betz	Ethyl	Octel	
22.5g/m	.15v%	2mg/L	256mg/L	280mg/L	458mg/L	
CI/L1-2	**FSII**	**SDA**	**+100-1**	**+100-2**	**+100-3**	**Comment**
	x					Current
						Current
						Current
Min						Current
Max						Current
	x					Current
	x					Current
Min	x					Current
Max	x					Current
		x				SDA/Jet-A
	x	x				SDA/JP-8
	x	x				SDA/JP-8
	x	x	x			+100/JP-8
	x	x		x		+100/JP-8
	x	x			x	+100/JP-8
			x			+100/Jet-A
				x		+100/Jet-A
					x	+100/Jet-A
	x		x			+100/FSII
	x			x		+100/FSII
	x				x	+100/FSII
						Base
	x					Current
						Current
						Current
Min						Current
Max						Current
	x					Current
	x					Current
Min	x					Current
Max	x					Current
		x				SDA/Jet-A
	x	x				SDA/JP-8
	x	x				SDA/JP-8
	x	x	x			+100/JP-8
	x	x		x		+100/JP-8
	x	x			x	+100/JP-8
			x			+100/Jet-A
				x		+100/Jet-A
					x	+100/Jet-A
	x		x			+100/FSII
	x			x		+100/FSII
	x				x	+100/FSII
						Base
						Base

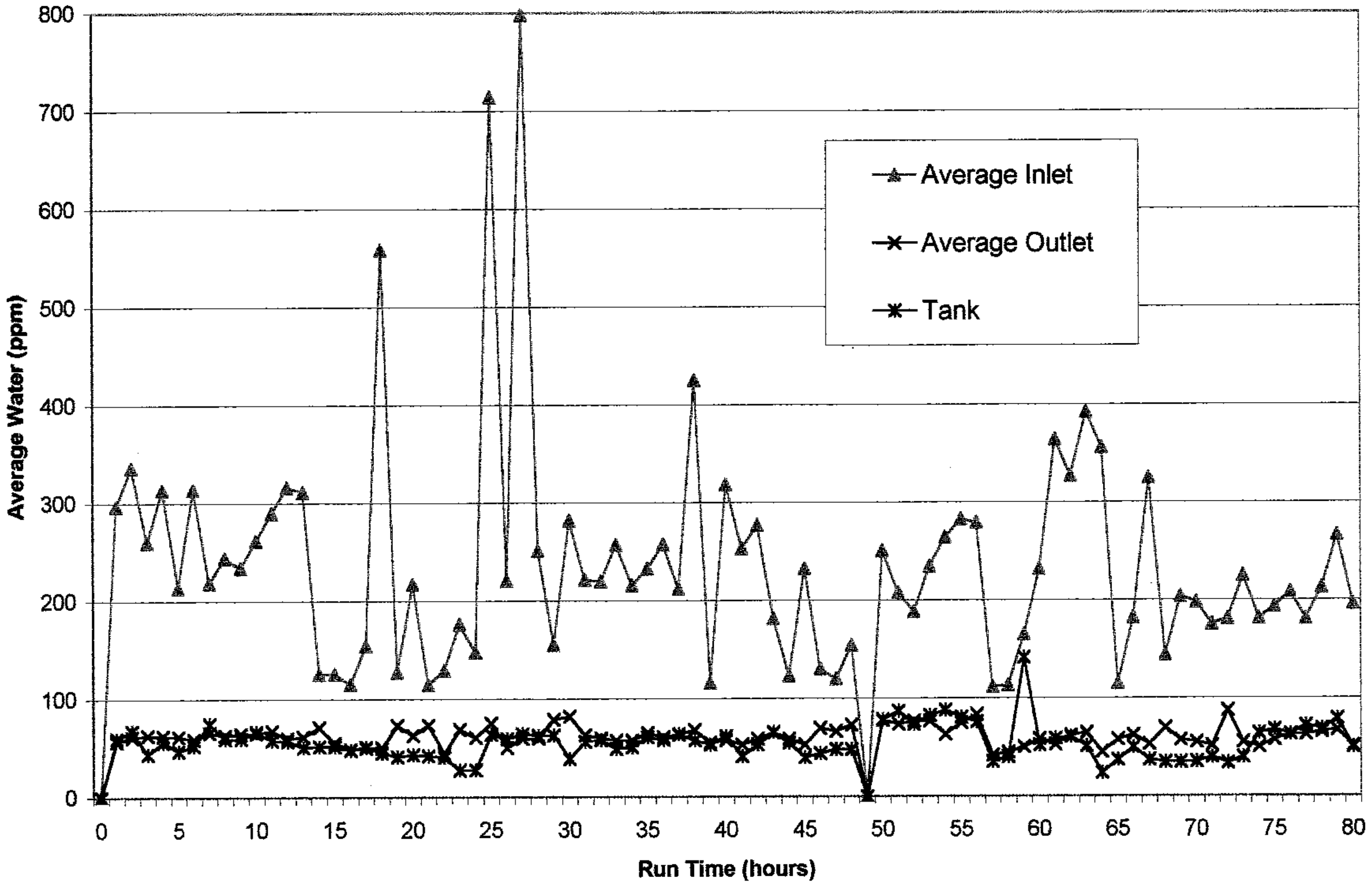
Second USAF/Emcee Test Program



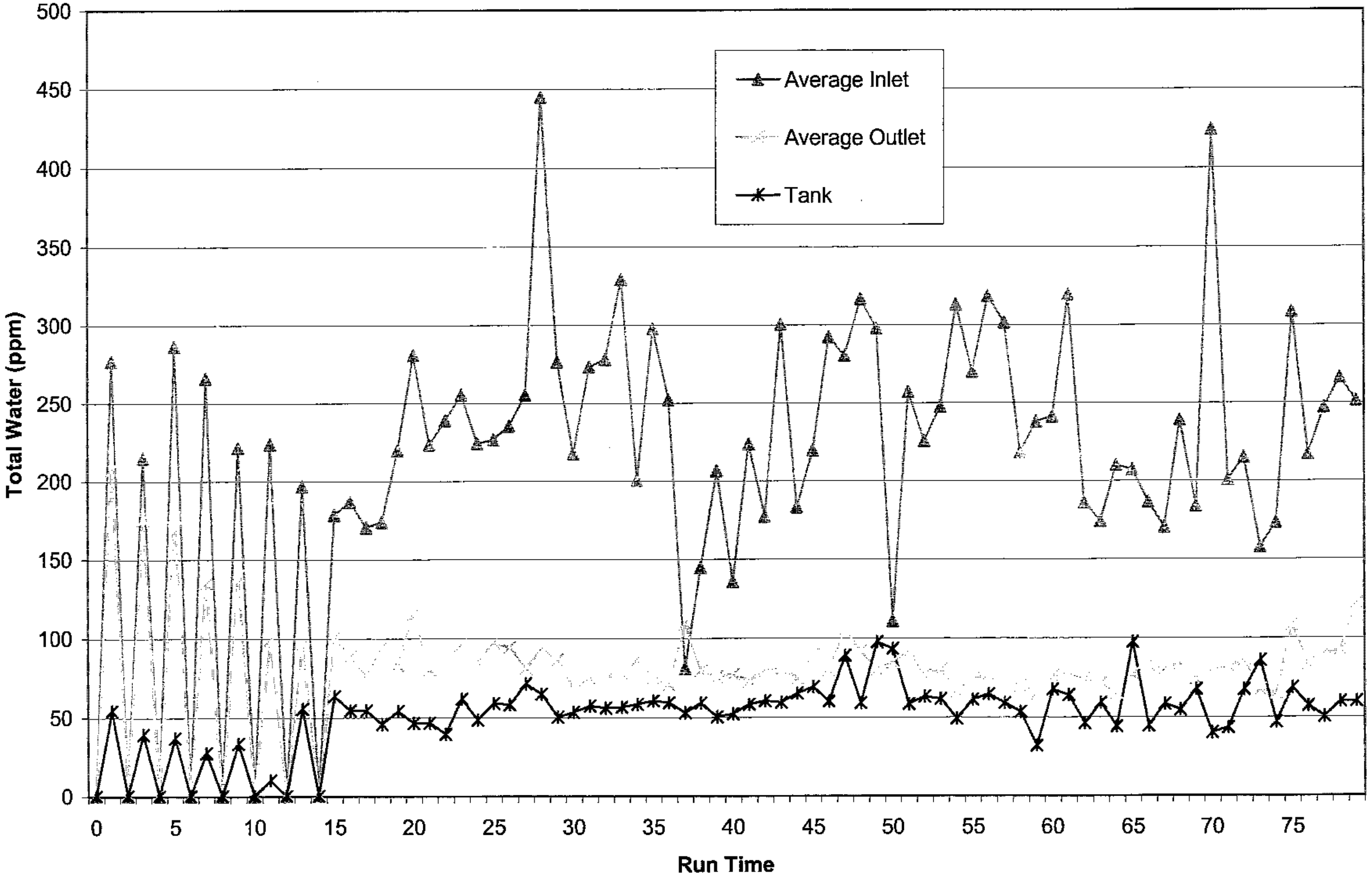
APPENDIX F

NCT RUN LOGS

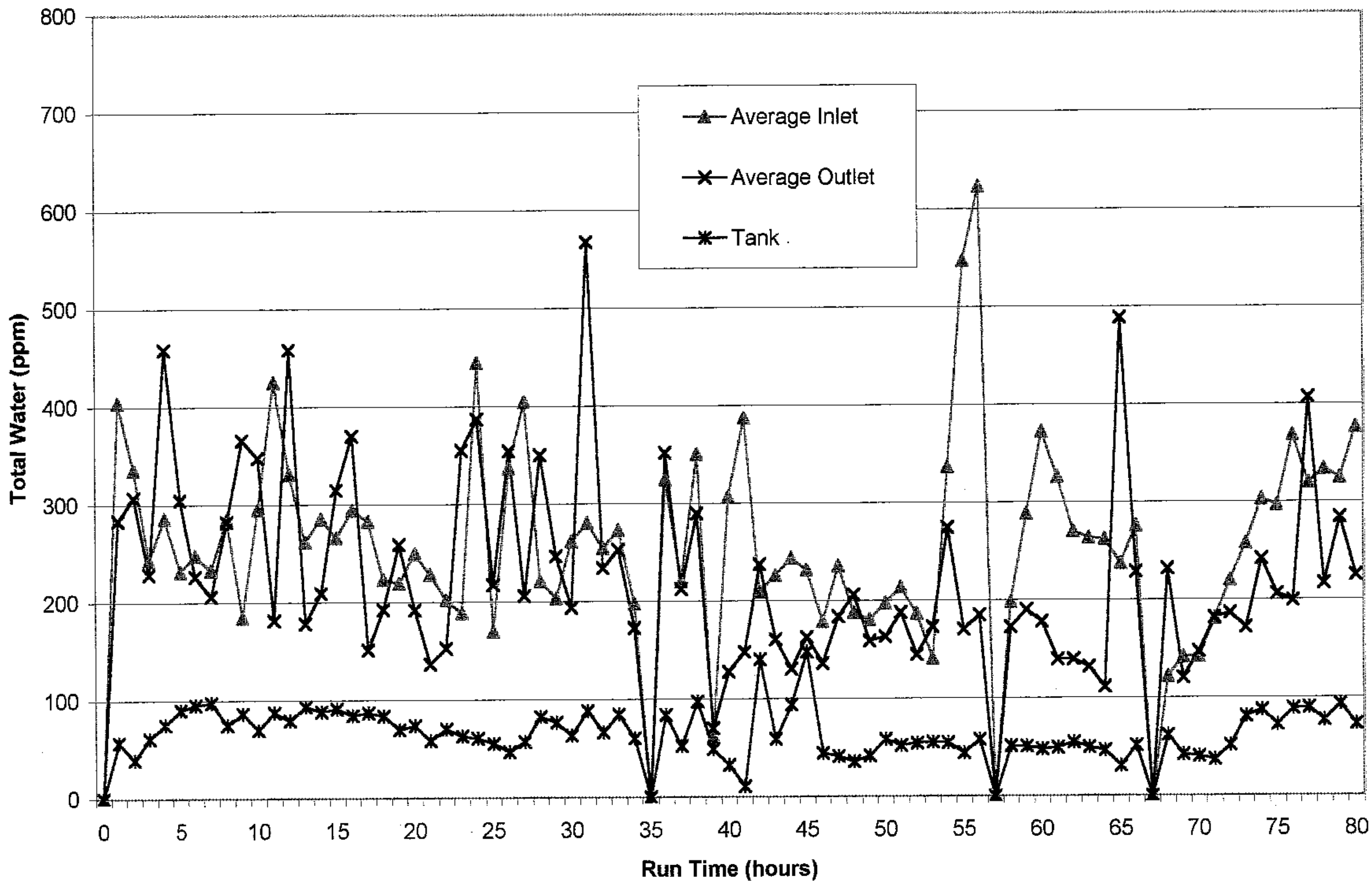
Average Total Water for DESC NCT Run 1B



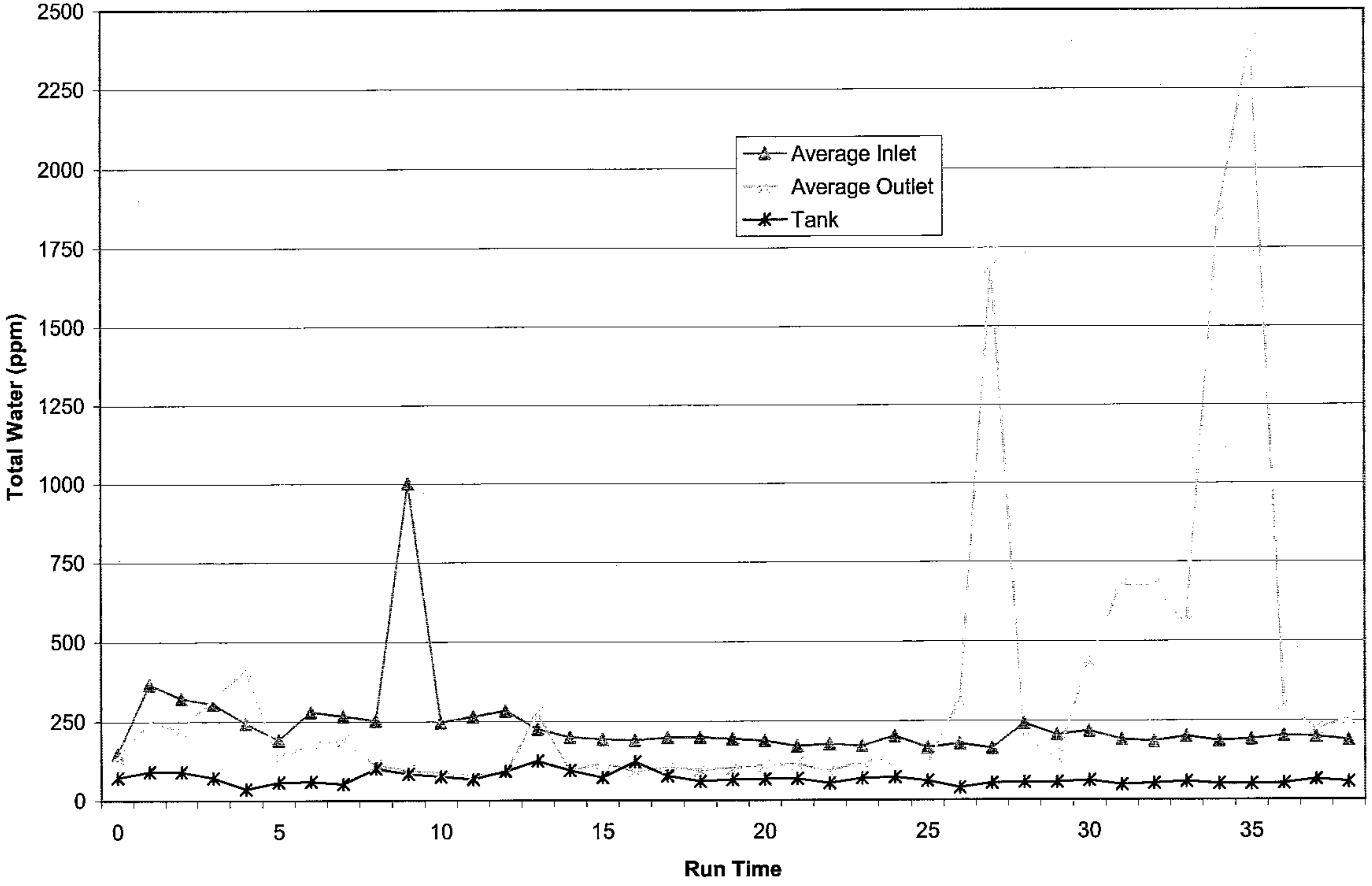
Total Average Water (ppm) DESC NCT Run 2B



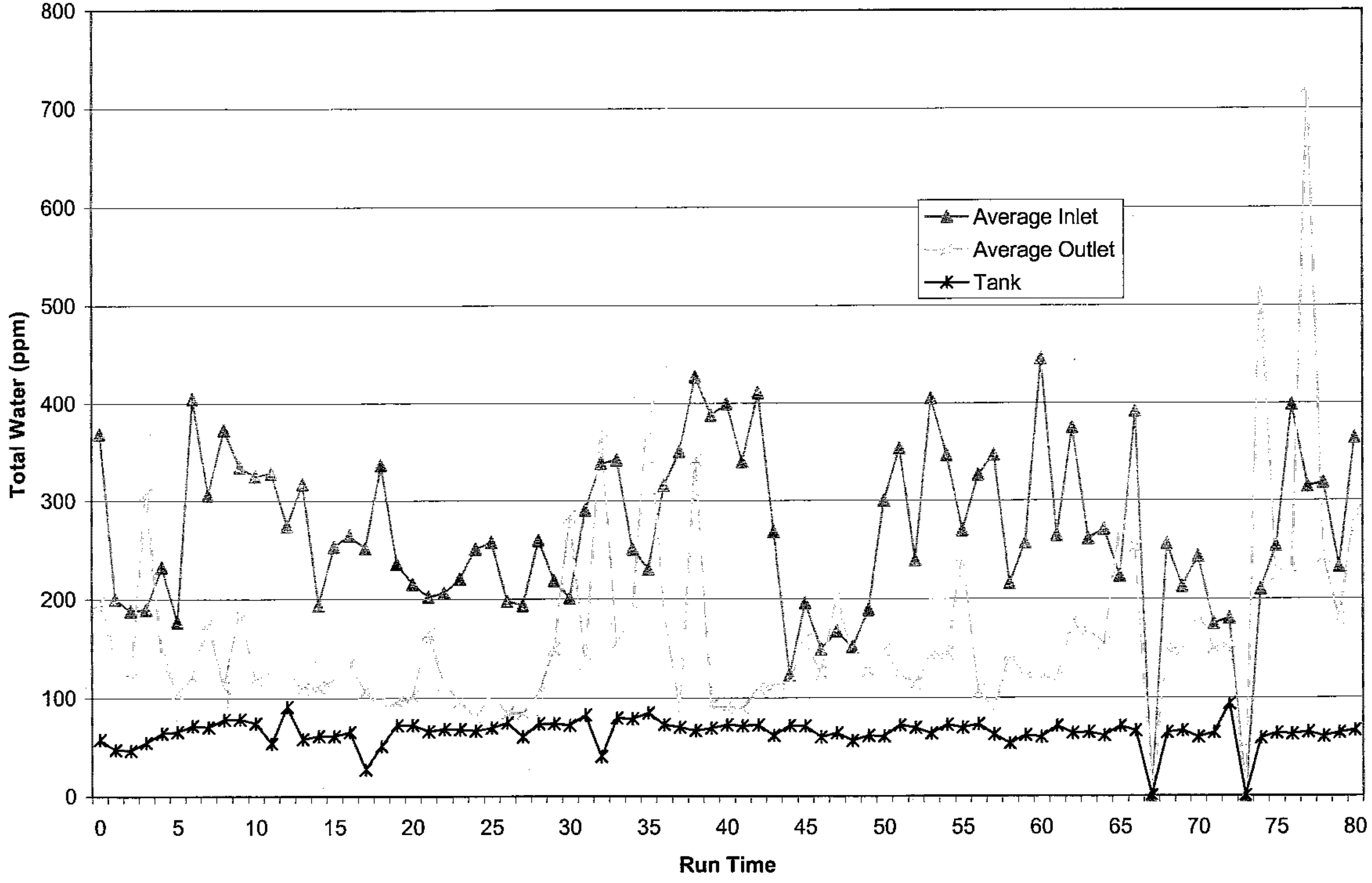
Average Total Water for DESC NCT Run 3B

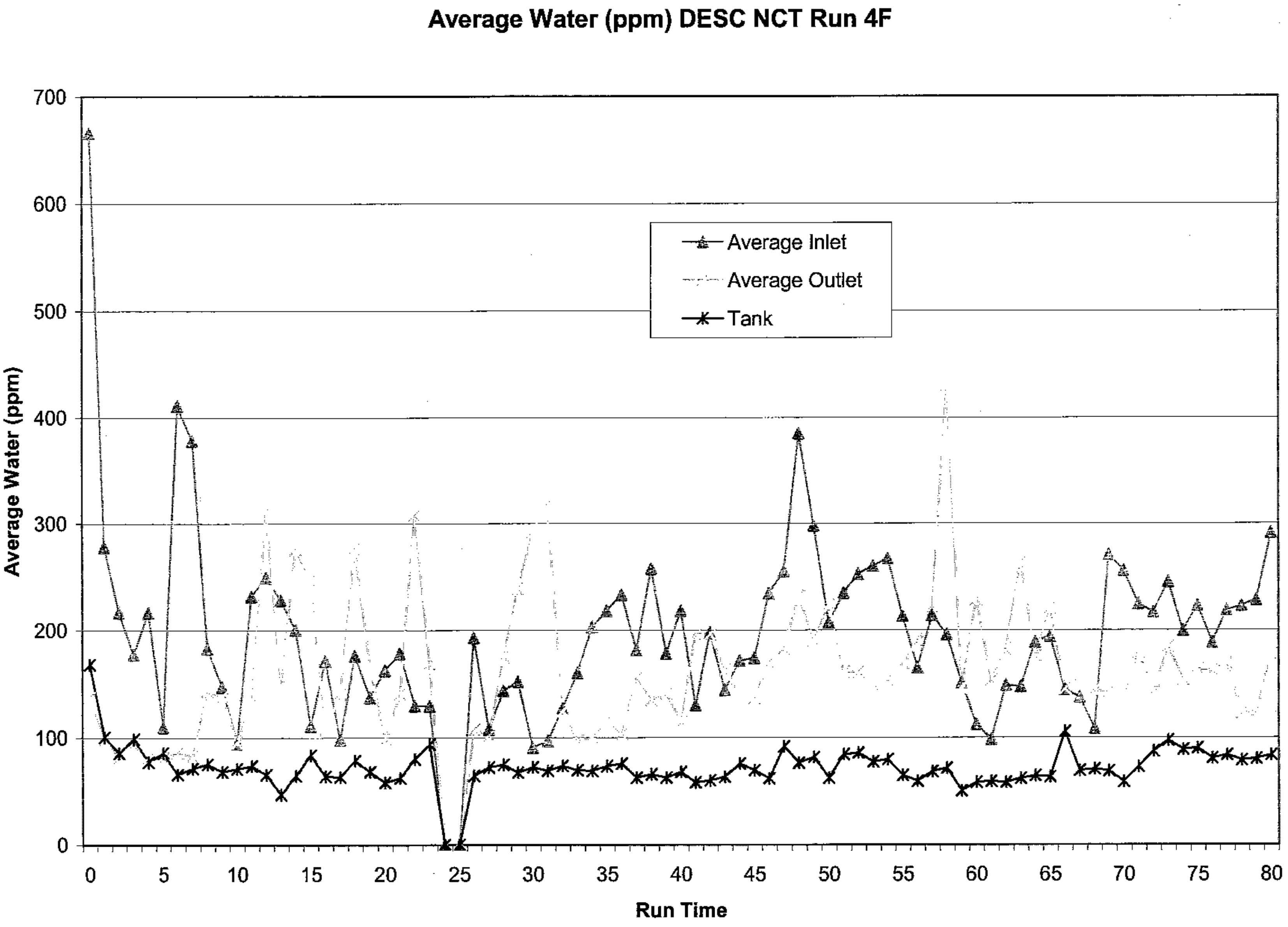


Total Average Water (ppm) DESC NCT Run 4B

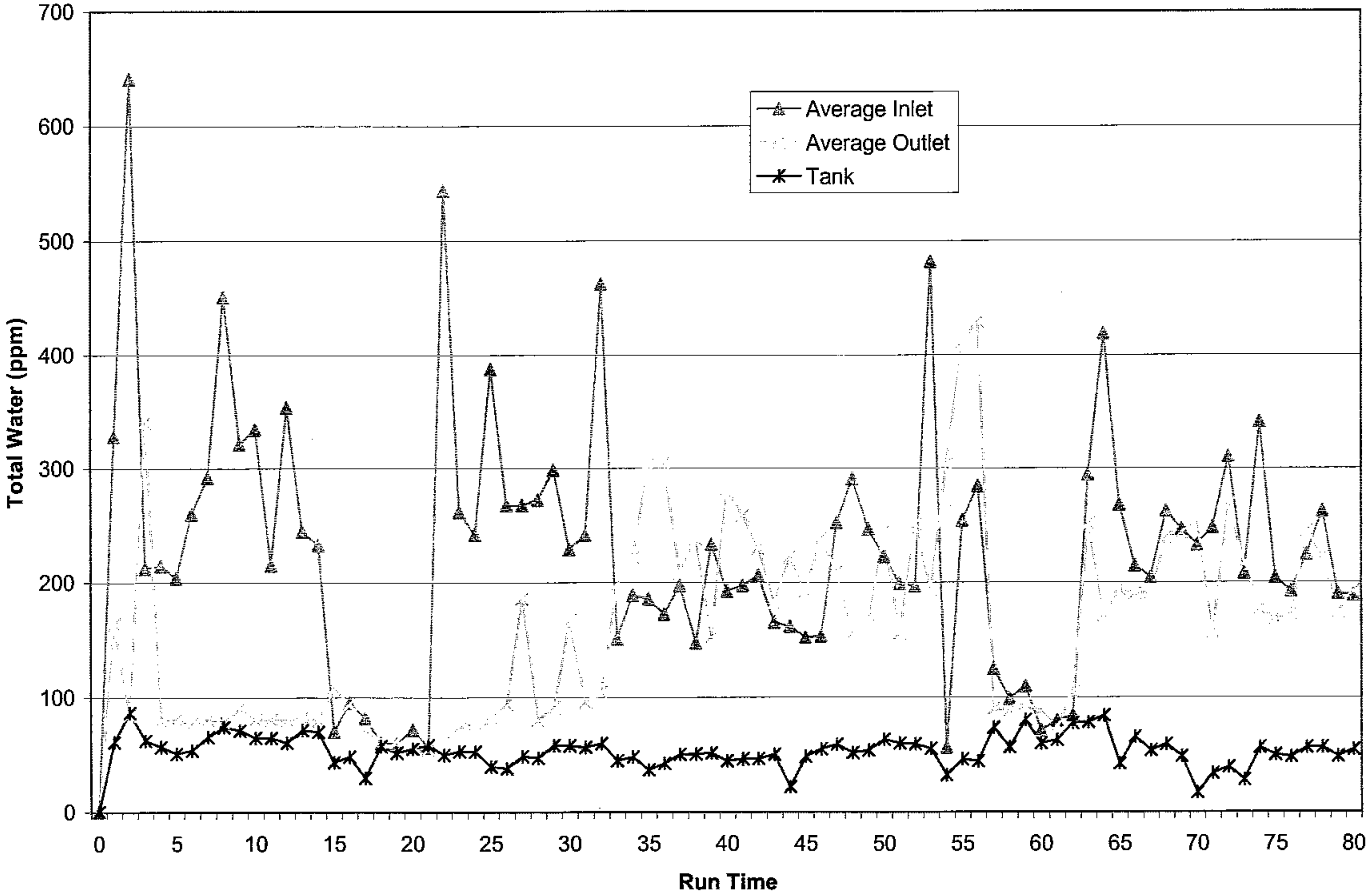


Total Average Water (ppm) DESC NCT Run 4B(2)

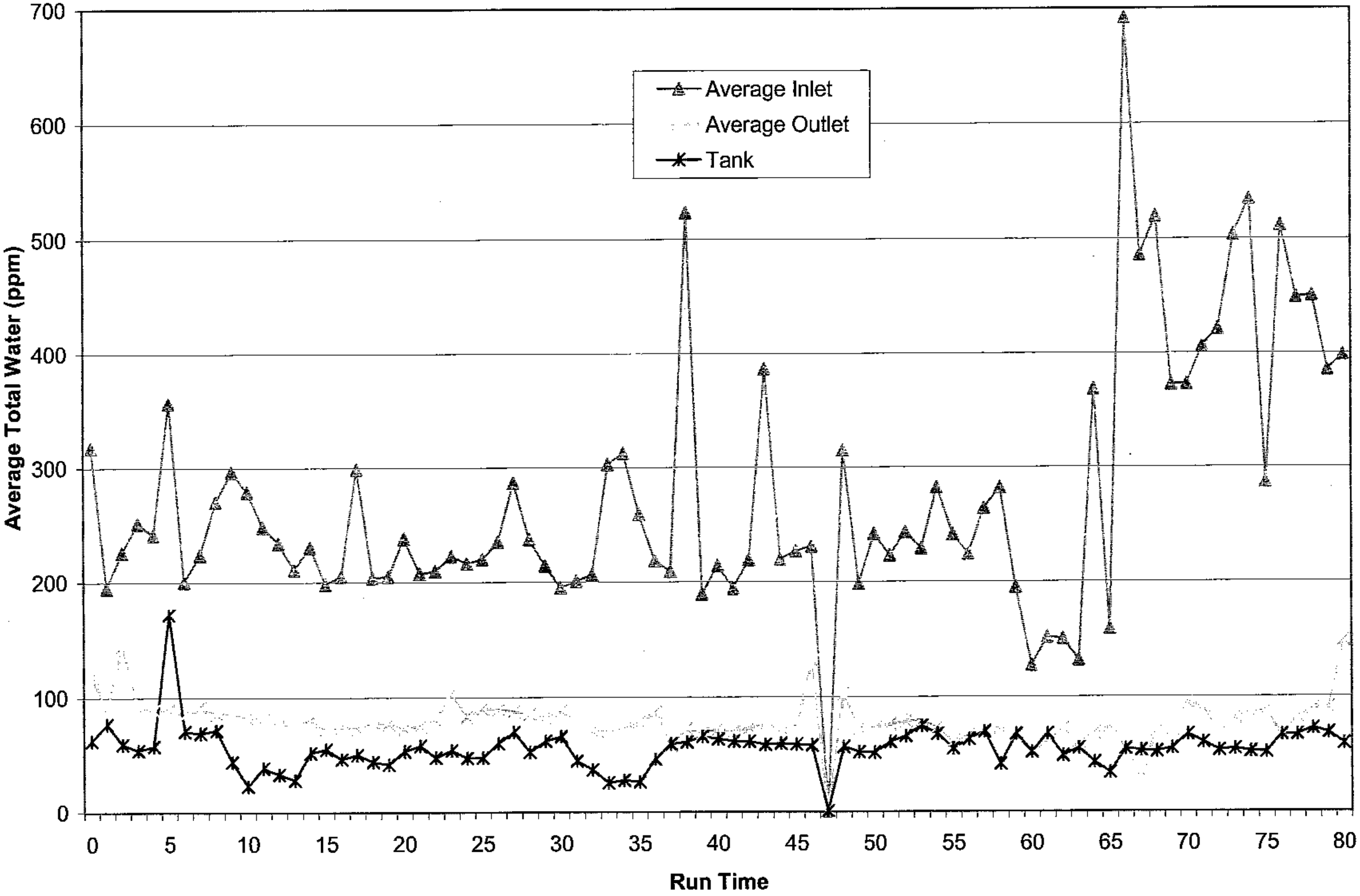



Average Water (ppm) DESC NCT Run 4F
Average Inlet
Average Outlet
Tank
Average Water (ppm)
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Run Time

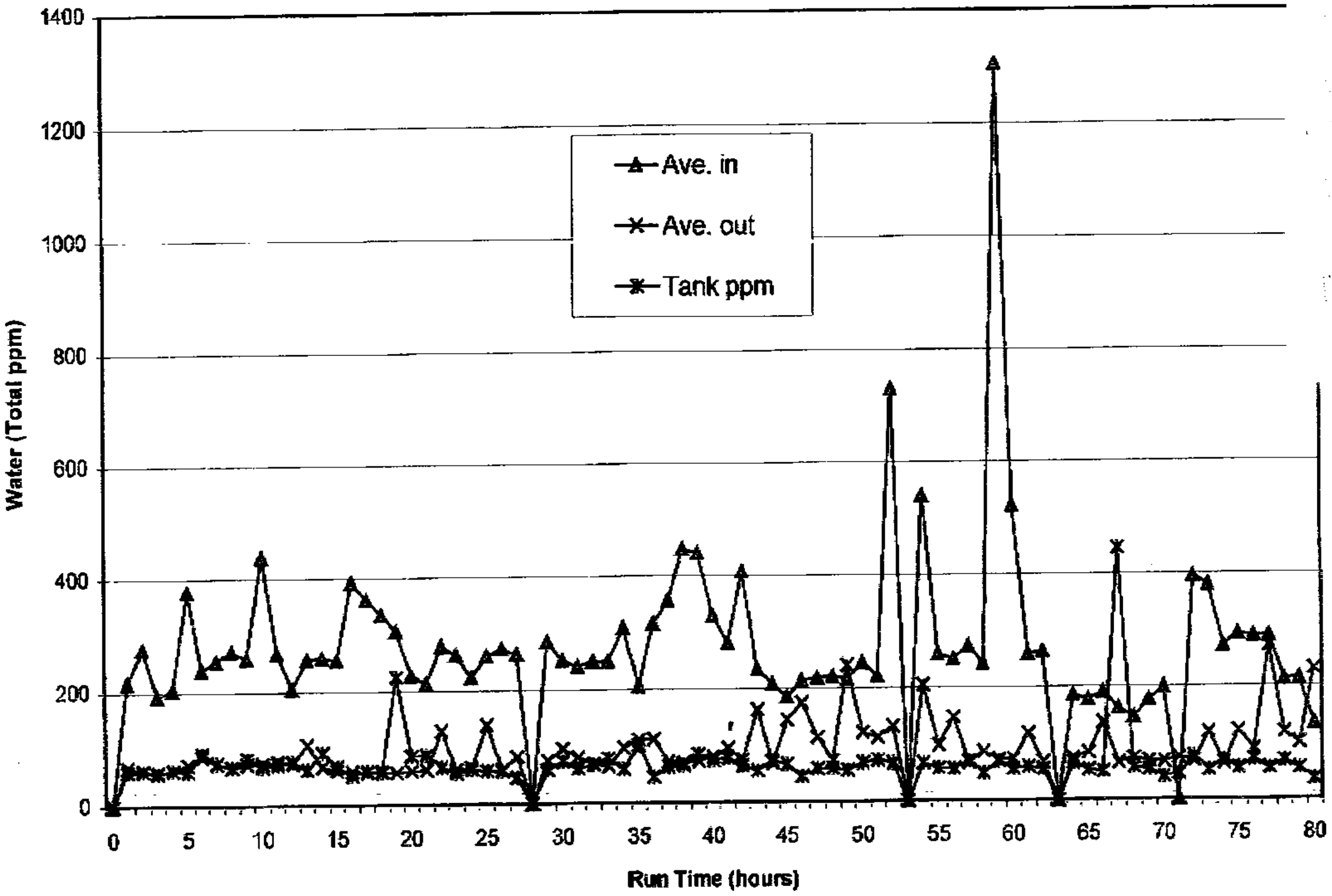
Total Average Water (ppm) DESC NCT Run 5B

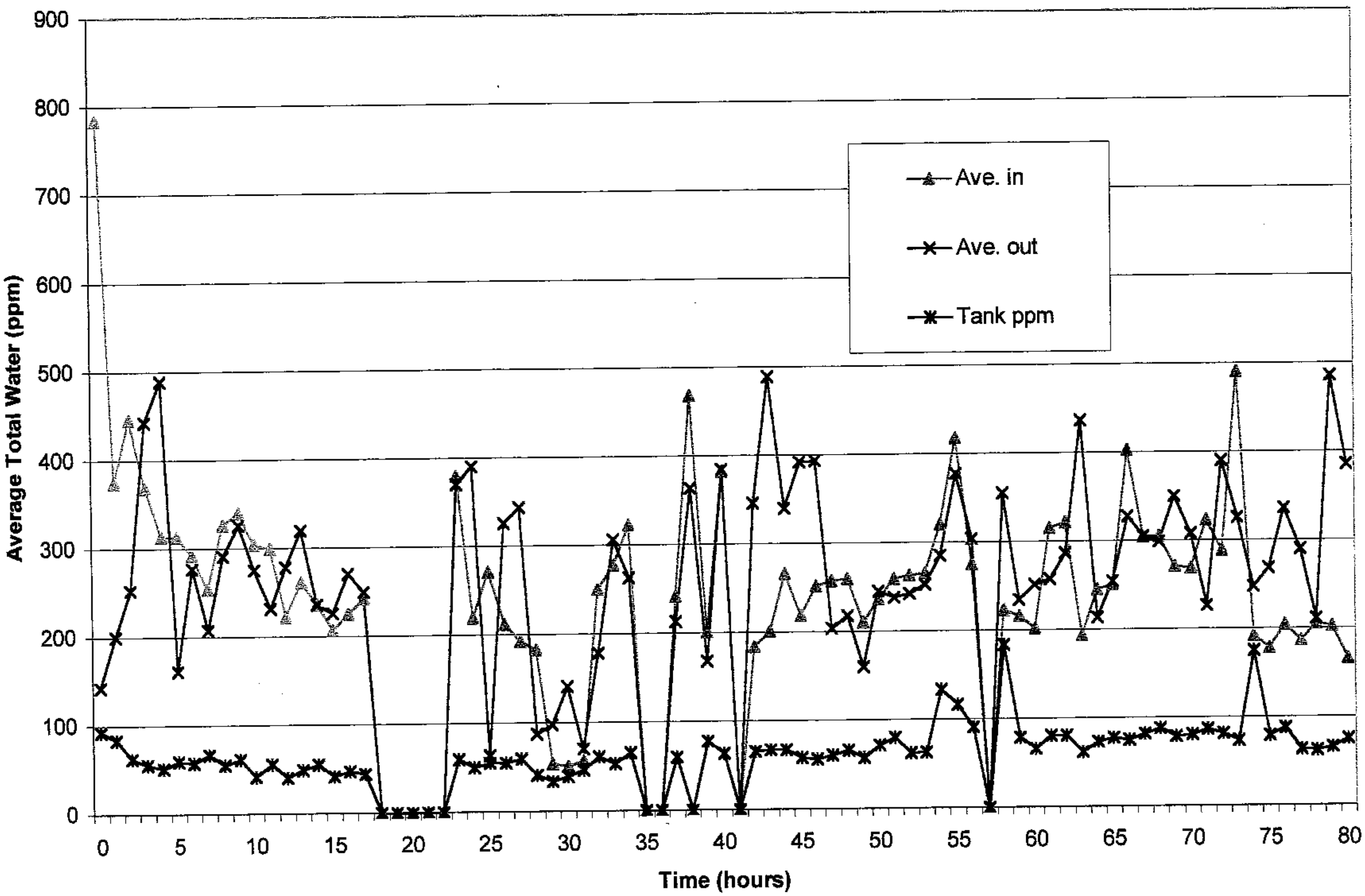


Total Water (ppm) DESC NCT Test Run 5F



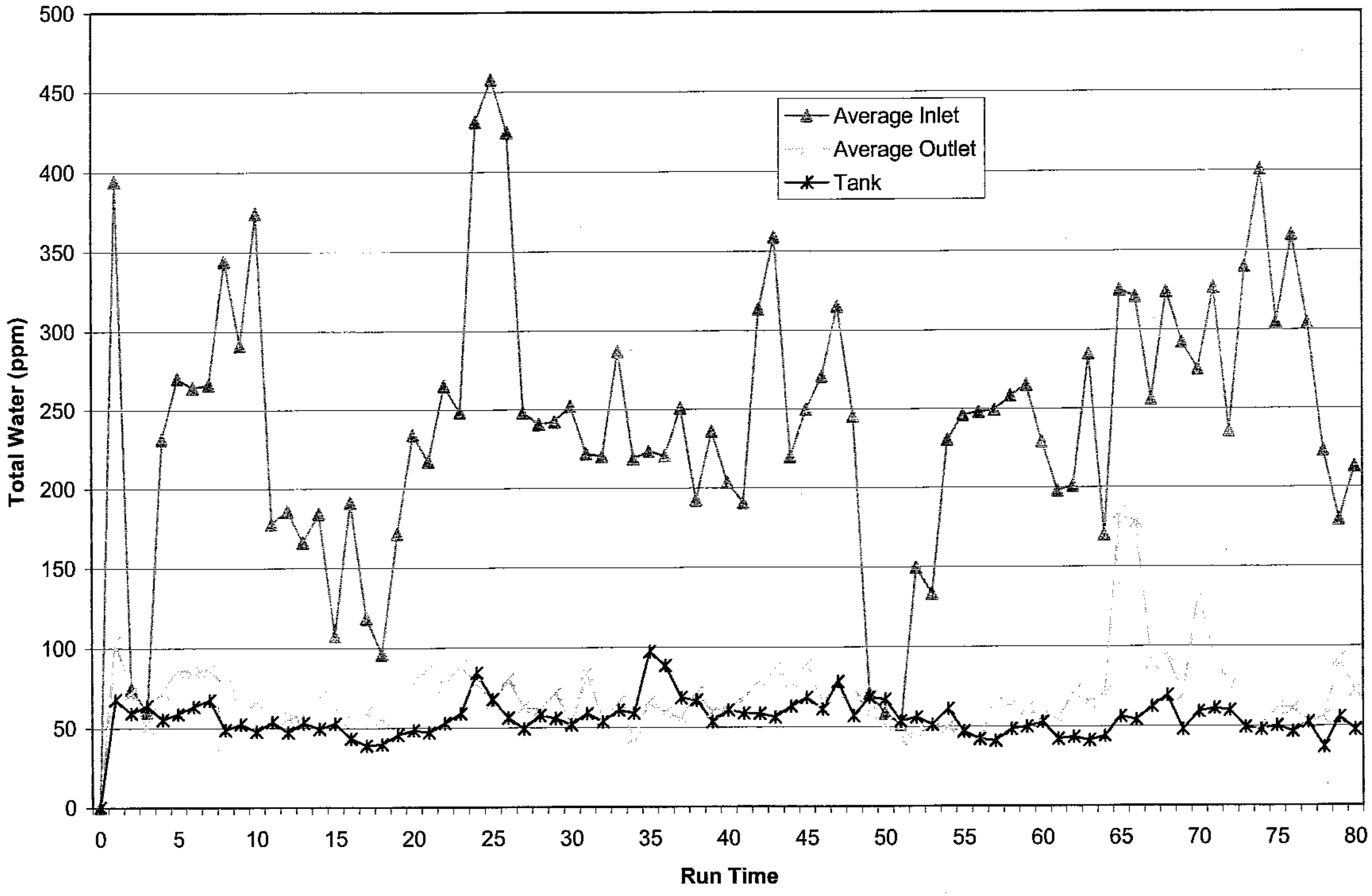
Average Water (Total ppm) For DESC NCT Run 6B

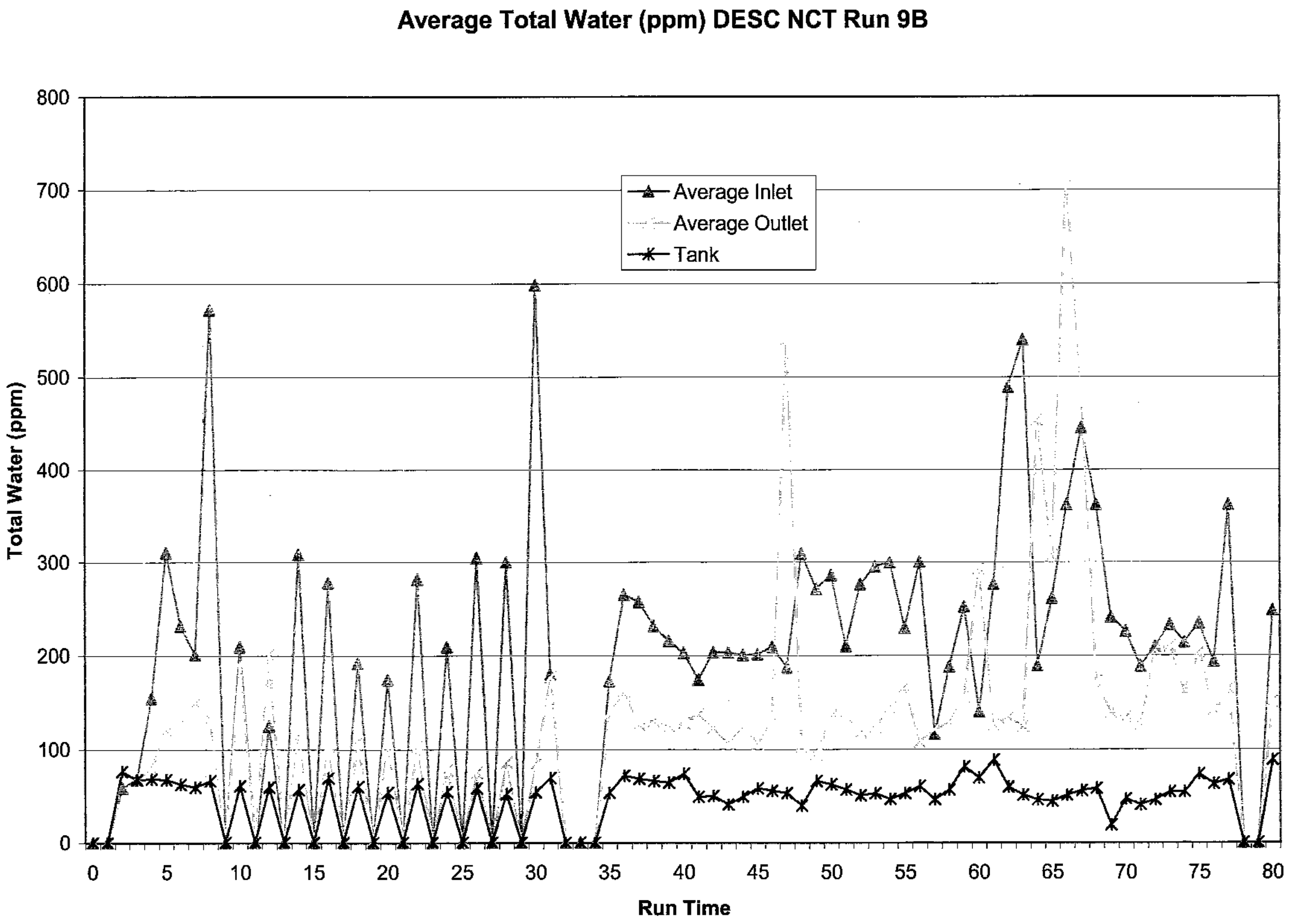




Average Total Water for DESC NCT 7B

Total Water (ppm) DESC NCT Run 8B




Average Total Water (ppm) DESC NCT Run 9B
Average Inlet
Average Outlet
Tank
Total Water (ppm)
800
700
600
500
400
300
200
100
0
Run Time
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

APPENDIX G

FUEL INSPECTIONS

1/9/2002

ANALYSIS by CHEMISTRY LABORATORY

Base Fuel A

Technical Contact: Jack Buffin
Job Order Number: A000114369 (NCT/MSEP Program)
Sample Information

Sample ID	Submitter ID	Sample Type
FUEL.TEST.00917		JET-A D1655 Commercial Jet A/A-1 F

Results

Result	Rep #	Value	Units
API gravity 15C	1	41.91	
Aromatics FIA	1	22.91	vol %
Color, Saybolt	1	29.	
Copper strip cor100C	1	1A	
Density 15C	1	0.815600	kg/l
Distill (F) Init BP	1	317.0	deg F
Distill (F) 10% rec	1	372.0	deg F
Distill (F) 20% rec	1	386.0	deg F
Distill (F) 50% rec	1	427.0	deg F
Distill (F) 90% rec	1	464.0	deg F
Distill (F) End Pt	1	522.0	deg F
Distillation Loss	1	0.6	vol %
Distillation Residue	1	1.2	vol %
Doctor test	1	NEG	
Existent Gum	1	0.5	mg/100ml
Flash Pt PM (C)	1	50.1	deg.C
Freezing Point C	1	-46.5	deg C
Fuel Sys Icing Inhib	1	0.00	vol %
Heating Value	1	18523	BTU/lb
% Hydrogen by NMR	1	13.71	wt %
Particulate Matter	1	0.0	mg/l
Mercaptan Sulfur	1	0.000000	wt %
Smoke Point	1	23.0	mm
Total Sulfur	1	0.0134	wt %
Tot Acid No Fuels	1	0.006	mg/g
Viscosity @ -20C	1	5.598	cSt
Water Reaction	1	0.0, 1, (1), Curved	Rating
Water Sep Index Mod	1	94.	

* Indicates value is out of specification

Results

Base Fuel B

Result	Rep #	Value	Units
API gravity 15C	1	45.05	
Aromatics FIA	1	20.70	vol %
Color, Saybolt	1	27.	
Copper strip cor100C	1	1A	
Copper strip cor100C	2	1A	
Density 15C	1	0.8011	kg/l
Distill (F) Init BP	1	296.0	deg F
Distill (F) 10% rec	1	338.0	deg F
Distill (F) 20% rec	1	347.0	deg F
Distill (F) 50% rec	1	386.0	deg F
Distill (F) 90% rec	1	459.0	deg F
Distill (F) End Pt	1	530.0	deg F
Distillation Loss	1	0.4	vol %
Distillation Residue	1	1.0	vol %
Doctor test	1	NEG	
Existent Gum	1	0.3	mg/100ml
Filtration Time	1	4.4	min/gal
Flash Pt PM (C)	1	45.2	deg.C
Freezing Point C	1	-52.0	deg C
Fuel Sys Icing Inhib	1	0.00	vol %
Heating Value	1	18406	BTU/lb
% Hydrogen by NMR	1	13.69	wt %
Interfacial Tension	1	36.09	dyne/cm
NAPHTHALENES	1	2.2	% wt
Particulate Matter	1	2.4	mg/l
Mercaptan Sulfur	1	0.000000	wt %
Smoke Point	1	23.0	mm
Total Sulfur	1	0.0502	wt %
Total Sulfur	2	0.0512	wt %
Tot Acid No Fuels	1	0.002	mg/g
Viscosity (cs) -20C	1	3.79	cs
Water Reaction	1	-.05 / 1 / (1)	Rating
Water Sep Index Mod	1	98.	

* Indicates value is out of specification

Results

PROBLEM FUEL A

Result	Rep #	Value	Units
API gravity 15C	1	37.09	
Aromatics FIA	1	18.28	vol %
Color, Saybolt	1	-4,	
Copper strip cor100C	1	1b	
Density 15C	1	0.8389	kg/l
Distill (F) Init BP	1	364.0	deg F
Distill (F) 10% rec	1	391.0	deg F
Distill (F) 20% rec	1	397.0	deg F
Distill (F) 50% rec	1	417.0	deg F
Distill (F) 90% rec	1	455.0	deg F
Distill (F) End Pt	1	491.0	deg F
Distillation Loss	1	0.4	vol %
Distillation Residue	1	1.0	vol %
Doctor test	1	NEG	
Existent Gum	1	<1.0	mg/100ml
Filtration Time	1	6.4	min/gal
Flash Pt PM (C)	1	72.2	deg.C
Freezing Point C	1	-71.0	deg C
Fuel Sys Icing Inhib	1	0.00	vol %
Heating Value	1	18419	BTU/lb
% Hydrogen by NMR	1	13.37	wt %
NOTES, CAROLE	1	ash=.0004%	
NOTES, CAROLE	2	tan=.00029mg/g	
Particulate Matter	1	0.2	mg/l
Mercaptan Sulfur	1	0.000000	wt %
Smoke Point	1	23.0	mm
Total Sulfur	1	0.0299	wt %
Total Sulfur	2	0.0274	wt %
Tot Acid No Fuels	1	0.000	mg/g
Viscosity (cs) -20C	1	6.35	cs
Water Reaction	1	0.0,1,(2),curved	Rating
Water Sep Index Mod	1	88.	

* Indicates value is out of specification

APPENDIX H

ANALYSIS OF PARTICULATES IN BASE FUEL B

Memorandum **February 7, 2001**

From : **A. Huang**
To : **J. Buffin**
CC : **R. Kamin, M. Sundberg, and T. Jalinski**

Subj : **<u>Analysis of Particulate Matter in Fuel Sample for Elements by ICP</u>**

The particulate matter in fuel sample was acid digested, filtered, and the filtrate was diluted with distilled water prior to the ICP analysis. The ICP result of the filtrate is listed below:

Element	Element Symbol	Relative Element Content (%)
Iron	Fe	75.21
Sodium	Na	6.91
Chromium	Cr	4.41
Calcium	Ca	3.87
Sulfur	S	3.75
Nickel	Ni	2.49
Zinc	Zn	1.11
Manganese	Mn	0.76
Antimony	Sb	0.38
Tin	Sn	0.34
Magnesium	Mg	0.32
Copper	Cu	0.23
Aluminum	Al	0.22

Note : The % for each element in the above table is the relative abundance of each element to the listed elements, not to the original particulate matter.

APPENDIX I

CORRESPONDENCE FROM ASSOCIATION FRANCAISE DE NORMALIZATION

STEVE CASPER
NOV 30 1999
SFOFU

AFNOR
Association Française de Normalisation

BT/99-221

Paris, November 22, 1999

Mr. Steve CASPER
United Airlines, Inc.
Maintenance Oper. CTR-SF0FU
San Francisco International Airport
San Francisco, CA 94128-3800
USA

Par mandatement
(by delegation)

B.N.PE.

**Bureau
de Normalisation
du Pétrole**

Adresse postale
(Mail address)
92038 Paris La Défense cedex
FRANCE

Accès
(Office address)
45 rue Louis Blanc
92400 Courbevoie

Tél : +33 (0)1 47 17 68 75
Fax :+33 (0)1 47 17 67 89
bernard.thiault@wanadoo.fr

Re; : ASTM D 1094 *STM for Water Reaction of Aviation Fuels*

Dear Mr. Casper,

I am writing you as the chairman of ASTM-D02 sub-committee J, about the standard D 1094. I know that this standard is assigned to section J.10. However as I do not know who are the chairman and secretary of this section, I am unable to send them a copy of this letter. Please be kind enough to pass them a copy.

A group of French Companies have found some problems in applying D 1094 to new types of products. Encountered phenomena are described hereafter, in appended sheet, in order they are transmitted to SC J/J.10 during next ASTM meeting, in Reno, and discussed.

In our opinion the wording of D 1094 should be revised in order to avoid any ambiguity.

Thanking you in advance for consideration of this problem.

Yours sincerely.

Bernard THIAULT

NB . I intend to attend next meeting in Reno. However it is not sure, so that I cannot promise to present myself the problem explained in this letter.

BNPE (France) November 22, 1999 ASTM D 1094

1 – Conditions of test

It was decided to test possible influence of lubricity additives on properties of Aviation Fuels passing through a multi-products pipe line after a load of diesel fuel added for lubricity.

The procedure was the following :

- In a first step, 2 000 to 3 000 m^3 of diesel fuel with 5 to 10 mg/kg of lubricity additive were pushed through the pipe line ;
- In a second step, 1 000 m^3 of aviation fuel were pushed through the pipe line.

Samples were regularly taken at delivery point, all along the run, for analyze in a laboratory.

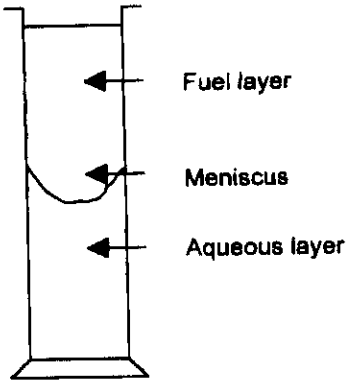
2 – Analysis

The water reaction was determined by D 1094 on all the samples taken at delivery point.

When doing these determinations, the three laboratories in charge of this work noticed some unusual phenomena, as explained hereafter.

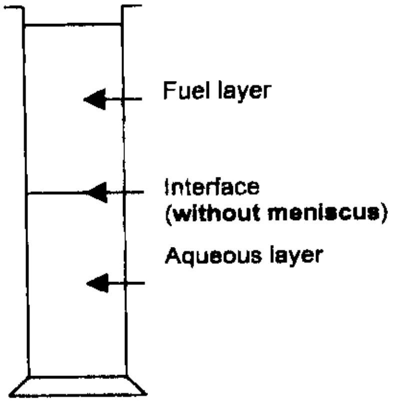
2.1 - Reminding General Case

In general cases, when water reaction is determined on samples of aviation fuels taken from a pipe line, after having shaken the cylinder as required in the standard, an interface appears **with a meniscus** (see figure beside this text).



2.2 – Case of this test

In the particular case of this pipe line test run, and after having shaken the cylinder as required in the standard, the interface appears as different : it is a straight line, **without any meniscus** (see figure beside this text).



3 – Conclusion

The appearance of interface **is not** described in the text of D 1094.

Therefore the case presented here above was very controversial : can a product be considered as good when the interface appears without any meniscus ?

In the case of the described test run, the problem resulted in a dispute between involved companies and no referee was able to decide whether or not the product can be considered as good.

It is suggested therefore that when D 1094 is revised, the form of interface is described.

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Staff Manager: DAVID R. BRADLEY, (610) 832-9681, EMail: dbradley@astm.org

August 17, 2000

Mr. Bernard Thiault
Association Francaise de Normalisation
Bureau de Normalisation du Petrole
92038 Paris La Defense cedex
FRANCE

Dear Mr. Thiault:

Your letter relative to the ASTM D 1094 Standard Test Method for Water Reaction of Aviation Fuels has been forwarded to me. I regret the delay in our response. In ASTM Subcommittee J Section 10 we have an active Task Force which has been working for a number of years to improve various aspects of the D 1094 method. However, to date we have not looked at the effect of diesel fuel lubricity additive contamination on the appearance of the interface in the D 1094 test. In a related area in Section 10 we are planning an extensive experimental program this Fall which will include measuring the effect of a diesel fuel lubricity additive on a number of tests including D 1094.

It would be very helpful if you or one of your colleagues could present your observations to Section J at a future ASTM meeting, and if possible, join our D 1094 Task Force.

Sincerely yours,

William F. Taylor

William F. Taylor
Chairman, S/C J Section 10

In response reply to:
Taylor Associates, LLC
1598 Brookside Road
Mountainside, NJ 07092, USA