

601984

APL-TDR-64-74

1073

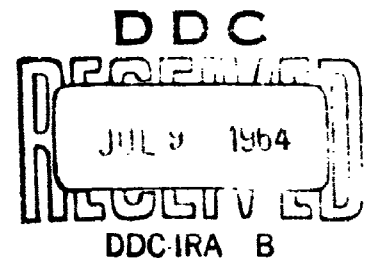
123 p - 2.75

Reclamation of JP-6 Type Jet Fuels Which Became Thermally Unstable During Storage

Technical Documentary Report No. APL-TDR-64-74
June 1964

AF Aero Propulsion Laboratory
Technical Support Division
Fuels and Lubricants Branch
Wright-Patterson Air Force Base, Ohio

Project No. 3048, Task No. 304801



(Prepared under Contract No. AF33(657)-11097
by Ashland Oil & Refining Company, Ashland, Kentucky,
Arnold M. Leas, author)

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Qualified requesters may obtain copies of this report from the Defense Documentation Center (DDC), (formerly ASTIA), Cameron Station, Bldg. 5, 5010 Duke Street, Alexandria 4, Virginia.

This report has been released to the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. for sale to the general public.

Copies of this report should not be returned to the Research and Technology Division unless return is required by security considerations, contractual obligations, or notice on a specific document.

FOREWORD

This report was prepared by Ashland Oil & Refining Company, Inc. under Contract AF33(657)-11097. The contract was initiated under Project No. 3048, Task No. 304801, and was administered by the Air Force Aero Propulsion Laboratory, Fuels and Lubricants Branch, Wright-Patterson Air Force Base, Ohio, with Mr. H. R. Lander as project engineer.

This report covers work performed from initiation of the contract effort on June 15, 1963, to May 15, 1964.

The work was directed for Ashland Oil & Refining Company by Mr. Arnold M. Leas.

ABSTRACT

∨
The thermal stability of nineteen degraded JP-6 type jet fuels was improved to a level in excess of the present MIL-J-25656B specification requirement by a filtration treatment. The improved thermal stability of these reclaimed fuels was retained for more than six months of ambient temperature storage.

The ASTM-CRC Coker was used to measure thermal stability. The coker ratings could not be correlated quantitatively with the chemical and physical analyses because of the minute quantity of the contaminants. However, with the use of filter media these contaminants were concentrated sufficiently to show some degree of correlation with the coker ratings.

Many of the additives present in these military fuels as well as those considered as possible future additives were removed in varying degrees by reclamation filtration. The generation of static electricity, filter media life, process economics, and design variables were other parameters which were investigated.

()
This technical documentary report has been reviewed and is approved.

Marc P. Dunnam
Marc P. Dunnam
Chief, Technical Support Division
AF Aero Propulsion Laboratory

TABLE OF CONTENTS

	<u>Page No.</u>
I. INTRODUCTION AND OBJECTIVES	1
II. METHOD FOR RECLAMATION FILTRATION	4
III. DISCUSSION	
A. Thermal Stability of the Test Fuels	5
B. Physical and Chemical Tests on Fuels	6
C. Removal of Biological Contaminants With Reclamation Filter	6
D. Removal of Other Contaminants With Reclamation Filter	7
E. Effect of Additives on Reclamation Filtering Process	10
F. Static Electricity Generated by Reclamation Filter	12
G. Life of Filter Media	13
H. Design Variables of Reclamation Filter	15
IV. SUMMARY	17
V. RECOMMENDATIONS	19
ILLUSTRATIONS	
<u>Figure</u>	
1. Process Flow of a Typical Reclamation Filter Unit	20
2. Thermal Stability Data - Reclaim Nos. 1 Through 5	21
3. Comparative Coker Preheater Tubes for Reclaim No. 1	22

TABLE OF CONTENTS (Continued)

Page No.

ILLUSTRATIONS (Continued)

Figure

4. Comparative Coker Preheater Tubes for Reclaim No. 2	23
5. Comparative Coker Preheater Tubes for Reclaim No. 3	24
6. Comparative Coker Preheater Tubes for Reclaim No. 4	25
7. Comparative Coker Preheater Tubes for Reclaim No. 5	26
8. Thermal Stability Data - Reclaim Nos. 6 Through 10	27
9. Comparative Coker Preheater Tubes for Reclaim No. 6	28
10. Comparative Coker Preheater Tubes for Reclaim No. 7	29
11. Comparative Coker Preheater Tubes for Reclaim No. 8	30
12. Comparative Coker Preheater Tubes for Reclaim No. 9	31
13. Comparative Coker Preheater Tubes for Reclaim No. 10	32
14. Thermal Stability Data - Reclaim Nos. 11 Through 15	33
15. Comparative Coker Preheater Tubes for Reclaim No. 11	34
16. Comparative Coker Preheater Tubes for Reclaim No. 12	35
17. Comparative Coker Preheater Tubes for Reclaim No. 13	36

TABLE OF CONTENTS (Continued)

Page No.

ILLUSTRATIONS (Continued)

Figure

18. Comparative Coker Preheater Tubes for Reclaim No. 14	37
19. Comparative Coker Preheater Tubes for Reclaim No. 15	38
20. Thermal Stability Data - Reclaim Nos. 16 Through 19	39
21. Comparative Coker Preheater Tubes for Reclaim No. 16	40
22. Comparative Coker Preheater Tubes for Reclaim No. 17	41
23. Comparative Coker Preheater Tubes for Reclaim No. 18	42
24. Comparative Coker Preheater Tubes for Reclaim No. 19	43
25. Tracing Fungi Through Filtering Process	44
26. Typical Bacteria (Optical Micrograph)	46
27. Typical Fungi (Optical Micrograph)	47
28. Bacteria-Inoculated JP-6 Fuel in Charge Drum (Optical Micrograph)	48
29. Chemical Dryer Effluent (Optical Micrograph)	49
30. Typical Bacteria (Electron Micrograph)	51
31. Typical Fungi (Electron Micrograph)	52
32. Uninoculated JP-6 Fuel in Charge Drum (Electron Micrograph)	53

TABLE OF CONTENTS (Continued)

Page No.

ILLUSTRATIONS (Continued)

Figure

33. Reclamation Filter Effluent (Electron Micrograph)	54
34. Fungi from Top Entrance Layer in Filter Media (Optical Micrograph)	55
35. Bottom Exit Layer in Filter Media - Fungi Specimen (Optical Micrograph)	56
36. Bacteria from Top Entrance Layer in Filter Media (Optical Micrograph)	57
37. Bottom Exit Layer in Filter Media - Bacteria Specimen (Optical Micrograph)	58
38. Inoculated Fuel Charge to Coker - Bacteria and Fungi (Optical Micrograph)	59
39. Coker Effluent from Inoculated Fuel - Bacteria and Fungi (Optical Micrograph)	60
40. Effect of Biological Contaminant on Coker Preheater Tube	61
41. Effect of Corrosion Inhibitors on Coker Ratings at 450/550/6	62
42. Removal of Lubricant Additive No. 1 from Fuel by Reclamation Filtering	63
43. Removal of Lubricant Additive No. 2 from Fuel by Reclamation Filtering	64
44. Filter Media Life Expressed as ¢/bbl Treating Cost	65
45. Filter Design Data With Varying Viscosities	66
46. Filter Design Data With Varying Filter Bed Depths	67

TABLE OF CONTENTS (Continued)

	<u>Page No.</u>
TABLES	
1. Test Data on Redistillation Fractions	68
2. Code Identification for Air Force Furnished Fuels	69
3. Code Identification for Contractor Blended Fuels	70
4. Thermal Stability Data for Doctor Treated Kerosene	71
5. Analysis of Doctor Treated Kerosene	72
6. Physical and Chemical Tests on Fuels	73
7. Growth Characteristics of Bacteria	92
8. Growth Characteristics of Fungi	93
9. Sample Schedule for Biological Research	94
10. Analysis of Extract Removed From Filter Media	95
11. Analysis of Grease Synthesized and Retained	96
12. Effect of Petroleum Sulfonates on Thermal Stability	97
13. Effect of Peroxides on Thermal Stability	98
14. Effect of Indenes on Thermal Stability	98
15. Effect of Naphthenic Acid on Thermal Stability	99
16. Removal of Elemental Sulfur by Reclamation Filtration	100
17. Phenol Content (ppm) Before and After Filtration	101

TABLE OF CONTENTS (Continued)

	<u>Page No.</u>
TABLES (Continued)	
18. Additive Content Before and After Reclamation Filter	102
19. Detailed Thermal Stability Data for Corrosion Inhibitor Treated Fuels	103
20. Lube Oil Additive Analysis by Infrared	104
21. Effect of Antistatic Additive on Thermal Stability	104
22. Recommended Fuel Flow Rates for Filtration Unit	104
APPENDIXES	
I. Detailed Thermal Stability Data for Reclaimed Fuels	105
II. Threshold Thermal Stability Data	106
III. Storage Stability Data of Unfiltered Fuels	107
IV. Laboratory Procedures Used for Physical and Chemical Testing	108
V. Bacteriological Procedures	110
VI. Life of Standard Filter Media	113

I. INTRODUCTION AND OBJECTIVES

There exists a gap in quality level of high-temperature jet fuel between the shipping point and the use point. One possible process method to close this gap in quality level is to pump the jet fuel through an in-field reclamation filter at the use point.

Prior to the date (June 14, 1963) of this contract award, the contractor had developed, independently and wholly upon his own initiative, a process for rehabilitating thermally degraded jet fuels upon which the contractor has filed a patent application on April 30, 1963, as Serial No. 276865 for United States Letter Patent. It has been demonstrated commercially within the last five years that this process has the ability to restore degraded jet fuels at the refinery or use point to a quality level as good or better than the original refined fuel at the production point. The Air Force, by acceptance of the contractor's proposal, desired the contractor to test the process with a wide range of degraded fuels to determine the full limitations and capabilities of such process for possible Air Force use. Details of this contractual agreement are available from the proper agency within the Air Force.

Business ethics made it difficult to document all of the case histories which resulted in considerable economic loss to the military, engine builders, and fuel suppliers as a result of degradation of delivered fuels which were rejected at the destination points because of loss in thermal stability. In some cases some of the degraded fuels in large storage tanks had to be downgraded into JP-4 type fuels by blending higher vapor pressure components to meet the quality standards even on the downgraded products. In other cases the fuel suppliers had to absorb the round-trip freight cost for returning the fuels to the production point and the additional rehabilitation expense at the refinery. In the interim period of such cases the consumer was either required to discontinue his operations or to procure alternate supplies. This new parameter of instability of such fuels during transit and storage is obviously untenable for both the supplier and the consumer. A few years ago a solution to this problem was found by the use of in-field reclamation filters. The success of these commercial reclamation units at the use points during the last few years attracted the attention of the military to evaluate this process for rehabilitating many different types of degraded fuels on a pilot plant basis. Hence, this research effort was initiated and completed to determine the full capabilities and limitations of this process.

Recently the contractor has installed five additional commercial filters at use point terminals for various processing rates ranging from 150 GPM to 1500 GPM. The purpose of these new filters is to insure the removal of all degrading contaminants that may accumulate during previous storage and transportation by barge, tanker, tank car, tank truck, and pipeline.

In addition to reclamation filtering, other methods of fuel rehabilitation were considered. The redistillation method can be used quite successfully to reclaim degraded jet fuels. Table 1 shows that most of the contaminants and additives can be concentrated in the 5% distillation residue as a reject by-product. The 95% distillation overhead is relatively free of contaminants and quite thermally stable. The test data on redistillation products listed in Table 1 show that the 5% residue concentrated such contaminants as copper, lead, indenenes, naphthalenes, and peroxides. The residual additives were also concentrated in the 5% distillation residue.

However, redistillation is not a very practical method to use in the field because of its prohibitive cost, i.e. the direct operating cost of redistillation reclamation ranges between 0.5 and 2.0¢/gallon. The total operating cost of such redistillation at the use point is prohibitive. The hydrotreating process can be used quite successfully to rehabilitate degraded fuels. Hydrotreating removes oxygenated, sulfonated, halogenated, and nitrogenated organic contaminants as acidic vent gases. Again, such hydrotreating operating costs are prohibitive (1 to 3¢/gallon) with some material loss as light catalytic cracked by-products. Another adverse economic consideration is that hydrotreating catalyst is poisoned by jet fuel contaminants and additives.

At the beginning of this research project, the contractor set aside about 30,000 gallons of degraded jet fuels in isolated, clean, carbon steel storage tanks or drums to be available as required. Tables 2 and 3 show the code identification system for all of these fuels. To differentiate these storage degraded fuels for this reclamation work, the first ten fuels received from the Aero Propulsion Laboratory were recoded Reclaim Nos. 1 through 10. These Air Force coded commercial JP-6 and thermally stable fuels were produced by several different suppliers. They were all specification products at the shipping point but had become thermally unstable in the customers' tankage. These fuels were drummed, retested in the Aero Propulsion Laboratory to confirm the bad coker ratings, and shipped to the contractor for processing through reclamation filters. Reclaim Nos. 11 and 12 fuels had previously been in terminal and customer's storage for about two years. These fuels were likewise shipped as specification fuels at the shipping point, but had become thermally unstable in the customer's tankage after about one year's storage. Two transport truck loads of each of these fuels were purchased by the contractor and stored in clean carbon steel tanks. Reclaim Nos. 13 through 19 were blends of Reclaim No. 12 and thermally stable fuels, thereby providing varying degrees of thermal instability.

To date about 5,000 gallons of these fuels have been processed through three coker machines and about 9,000 gallons have been processed through twelve reclamation filter pilot plants. Fifty-five gallons of each of the nineteen fuels have been filtered and placed in ambient storage without readdition of additives. An additional drum of each of Reclaim Nos. 11 through 19 has been filtered and stored with readdition of additives. All of these filtered fuels have been tested on the coker following the three and six month storage periods at ambient temperature. These fuels were stored under the same roof where the ambient temperatures during the course of this period varied from plus 10 to plus 100 F and the relative humidity varied from 20 to 100%. The storage containers were vented to the air for normal breathing. The residual filtered fuel samples have been forwarded to the Aero Propulsion Laboratory for long time storage evaluation.

This report shows performance data obtained from existing commercial and laboratory filter units as the result of processing many storage degraded fuels. The primary objectives of this research effort were to:

1. investigate treating methods to rehabilitate storage degraded fuels.
2. test the performance of a reclamation filter for processing many different jet fuels that had degraded during storage at air bases and terminals.
3. document all useful test data obtained from nineteen contract fuels before and after reclamation filtering to permit defining the detrimental contaminants that caused the degradation of the fuels.
4. recheck the coker ratings on these reclamation filtered fuels after additional storage at ambient temperature. These coker ratings were made after three months and six months to determine whether or not degradation would occur again on these reclaimed filtered fuels.
5. determine the effect of additives and designated contaminants on the reclamation filtering process.
6. determine whether the reclamation filter unit would remove detrimental contaminants, viz. biological, organic and inorganic (soluble and insoluble), and moisture.
7. determine the effect of design and operating variables of the reclamation filtering process.
8. recommend the optimum design of a field filtration unit that would be useful and practical to the military for rehabilitating storage degraded jet fuels.

II. METHOD FOR RECLAMATION FILTRATION

As shown in Figure 1, the reclamation filter unit consists of two zones. In the first zone the fuel flows upward through a chemical dryer which consists of a free water coalescing and settling area with bottom water drain facilities and a chemical drying area removing emulsified and soluble water. In the second zone the dried fuel flows downward through a filter which consists of a fine mesh activated media which removes particulate matter (including submicronic), soluble chemical and biological contaminants, etc.; a coarse mesh activated media which completely retains the above media; and three additional layers of coarser but completely inert graded metallurgical aggregate disengaging clean fuel and completely retaining the filter media.

Carbon steel vessels have been used successfully to minimize the cost and to provide flexibility in charging and dumping the filter media. To date the standard media continue to be most successful; however, the same hardware could readily adapt itself to possible improved filter media.

With the use of this filter the data presented later in this report demonstrate that this process can remove detrimental contaminants, viz. biological, organic and inorganic (soluble and insoluble), and moisture.

III. DISCUSSION

A. Thermal Stability of the Test Fuels

The Standard ASTM-CRC Coker and the Modified Coker were used to measure thermal stability of the test fuel samples. Figures 2, 8, 14, and 20 (bar graphs) show the maximum preheater coker ratings (450/550/6) for the test fuel samples: the degraded fuel as received, treated fuel immediately after reclamation filtration, treated fuel six months after reclamation filtration. Figures 3 through 7, 9 through 13, 15 through 19, and 21 through 24 (photographs of coker preheater tubes) show comparative thermal stability ratings for all fuels before and after filtration treatment. In the photographic work, it was necessary to fabricate a large tuberator housing in order to obtain authentic photographs of the maximum deposits on the cylindrical preheater tubes. By this means the photographs are comparable to visual inspection through the standard tuberator.

All of the filtered fuels were improved from failing (425/525/6) to passing on thermal stability as measured by the coker rig when operated at 450/550/6 severity. Likewise this improved thermal stability rating of the filtered fuels remained at the passing level after both the three months and six months storage periods at ambient conditions.

Appendix I shows the complete coker preheater ratings from which the graphical data were obtained. Appendix II shows the coker threshold stability data on the original fuels (Reclaim Nos. 1 through 10) as rated by the Aero Propulsion Laboratory. Nearly all of the unfiltered fuels tested continued to drop in thermal stability during the same storage time and under the same conditions. The data in Appendix III show the continued degradation of the unfiltered fuels during storage through the contract period.

The coker test data listed in Table 4 show that processing doctor treated kerosene through the reclamation filter increased the initial coker threshold temperature from 375/475/6 to 475/575/6. Table 5 shows the physical and chemical test data for the original doctor treated kerosene. Generally speaking, an aged doctor treated kerosene can be filtered to gain about 50°F coker threshold temperature whereas a desulfurized aged kerosene can be filtered to gain about 150°F coker threshold temperature.

B. Physical and Chemical Tests on Fuels

Table 6 shows comparative physical and chemical test data for all fuel samples included in this program: the degraded fuel as received, treated fuel immediately after reclamation filtration, treated fuel six months after reclamation filtration. Appendix IV lists the sources of the chemical and physical laboratory procedures.

These comparative physical and chemical test data failed to identify clearly the offensive contaminants. However, these test results did show in most cases that in the filtered fuel samples there was some reduction in olefins, peroxides, indenenes, pyrrole and basic nitrogen, surfactants including organic sulfonates, naphthalenes, naphthenic acids, sulfur, iron, lead, copper, phenols, spent additives, soluble water, gums, and particulate matter. Likewise, in the filtered fuel samples the water separating characteristics were improved as measured by the water tolerance, WSI, and WSIM tests. The regeneration of the filter media also confirmed that these same contaminants were removed from the treated fuels during the filter operation. These contaminants were concentrated in the extracting solvent during the regeneration cycle. This will be discussed in more detail later in this report under section "D".

C. Removal of Biological Contaminants With Reclamation Filter

Previous preliminary checks of fungal and bacterial removal from other petroleum products by application of the reclamation filter have indicated that microorganisms in the magnitude of even less than 0.1 micron are completely removed from hydrocarbon fuels by use of this process.

By arrangement with the Fuels and Lubricants Branch of Wright-Patterson Air Force Base, the University of Dayton Bacteriology Department supplied three different species of Pseudomonas bacteria in pure culture, one each on Bushnell-Haas mineral salts agar slants with JP-4 overlay and one each on trypticase soy agar. These were designated as B-40, B-44, and B-54. Two different species of fungi in pure culture were supplied, each on Sabouraud's agar slants. These were designated as B-29 and B-55.

In order to substantiate the preliminary work in this area, specific samples of JP-6 jet fuel were deliberately inoculated with fungi and bacteria, both separately and together, and filtered through the reclamation filter. The resultant effluent was filtered through a 0.45 micron Millipore filter to remove or to detect any remaining microorganisms. The filters were then incubated at 37 C in media suitable for the specific microorganisms for a one-week period. The cultures were inspected visually every day for potential growth and by use of both optical- and electron-microscopy every other day.

The fifteen-day cultures showed that the fuel which had passed through the chemical dryer section of the unit still contained a few of the injected microorganisms. The fuel which had filtered through both the chemical dryer and filter sections proved to be completely free of any bacteria or fungi, thus confirming the success of this process for removal of microscopic entrainments. In Figure 25 the fungi are traced through the filtration unit.

Other photomicrographs, Figures 26 through 39, illustrate the positive identification of bacteria and fungi prior to filtration and the negative identification following filtration. Figure 40 shows the effect of biological contaminants on coker preheater tubes. The coker rating confirms that fungi and bacteria leave a deposit on the preheater tube when operated at 450 F. The uninoculated fuel gave a maximum preheater code of 1 while the inoculated fuel gave a maximum preheater code of 2.

The procedures for propagating the cultures, inoculating the fuels, microscopically examining the fuel samples, and determining the results are presented in Appendix V and Tables 7, 8, and 9.

Three complete runs were made using different filter units (each conforming to the specifications of the contractor's reclamation filter). One test run was made using the bacteria alone, one using fungi only, and the final test run was made using both bacteria and fungi. It was found that in all three test runs no bacteria, no fungi, or spores were found to have passed through the active sections of the filter units. This is illustrated in photographs shown as Figures 25, 33, 35, and 37.

The depth of penetration by the microorganisms into the filter media indicated that all of these microorganisms were retained on the entrance layers of the filter media. This indicates that the filter media life for removing biological contaminants would be much greater than for other types of contaminants. Therefore biological contaminants are not the controlling contaminant for filter media.

From the results obtained, it can be concluded that the reclamation filter successfully and completely removed the injected microbiological contaminants from the JP-6 jet fuel utilized for the project.

D. Removal of Other Contaminants With Reclamation Filter

The other apparent detrimental contaminants to thermal stability which are removed by the reclamation filter media consist of naphthalenes, olefins, indenenes, phenols, pyrrole and basic nitrogen, sulfonates, peroxides, sulfur, naphthenic acids, surfactants including organic sulfonates, lead, iron, copper, gums, spent

additives, and particulate matter. The free and emulsified water containing soluble salts is also removed by the chemical dryer. Confirmation of the removal of these contaminants was evident upon analyzing the extract from the regeneration of the filter media.

A number of the pilot plant reclamation filtration units used for determining the life of the filter media were shut down, drained, and purged with nitrogen in preparation for regenerating the filter media. Trisolvent (benzene-acetone-isopropanol) was pumped into the reclamation filter and allowed to stand 16 hours, then the unit was flushed with additional trisolvent and drained. This extract was then tested to determine the contaminants removed from the filter media. The results from this determination follow.

1. Naphthalenes represented by far the greatest organic contaminant in the extract from the spent filter as measured by the ASTM D-1840-61T spectrophotometric method. A Model DU Beckman spectrophotometer was used for these analyses. Since the jet fuel processed had an Engler distillation end point of 416 F with a 0.5% residue; some of the expected interfering compounds such as phenanthrenes, dibenzothiophenes, biphenyls, benzothiophenes, and anthracenes, were minimized by the original fractionation of the jet fuel. This same processed jet fuel contained only 0.1% naphthalene both before and after the reclamation filter; therefore it appears that the 2.0 and 2.6% naphthalene found in the spent filter media from processing Reclaim Nos. 11 and 12 could have been synthesized from spent additives and contaminants and then retained. Such synthesized degradation products when extracted from the spent filter media gave a positive test for naphthalene by ultraviolet spectrophotometry. Even with such inconsistency, we can still conclude that the real or apparent naphthalene content, when determined by ultraviolet spectrophotometry (D-1840-61T), provides a contaminant identification method for projecting thermal stability. Pilot reclamation filters or their equivalent are required to concentrate such contaminants for extracting and testing.
2. Indenes, phenols, and pyrrole nitrogen were also found in much smaller concentrations in the extract from the spent filter media. These data are consistent with the data from the before and after reclamation filtered samples showing partial removal of such contaminants by the filter media.
3. Lead, iron, and copper were also found in the spent filter media. Nearly all of the pilot plant runs showed substantial removal of these inorganic contaminants by the filter media. The commercial reclamation filters showed removal of these inorganic contaminants.

The 24-foot pilot plant reclamation filter was shut down after an extended run for a similar regeneration with the exception that each 8-foot top, middle, and bottom section was analyzed separately. The data in Table 10 show the analyses of the contaminants removed from the filter media. The most detrimental contaminants and additives were completely removed in the top and middle filter sections.

When dismantling several of the reclamation pilot plant units, it was observed that a grease-like material accumulated in the void space between the chemical dryer and the filter. Most of this grease-like material had been retained on the entrance layer of the filter media and none of it had penetrated more than one inch into the filter media. Some of the other chemical reactions are not completely understood. However, the positive removal of contaminants from jet fuel is quite evident as shown in Table 11.

Some of these contaminants were deliberately injected into the jet fuel to determine their effect on thermal stability. These were petroleum sulfonates, peroxides, indenenes, and naphthenic acids.

Petroleum sulfonates were retained on the filter media yielding treated fuels free of these soluble organic contaminants as shown in Table 12. While petroleum sulfonate contaminant is very detrimental to the water separator test, such a contaminant is not detrimental to the coker test when operated at the 475/575/6 severity level on JP-6 jet fuel.

Benzoyl peroxides were retained on the filter media yielding treated fuels free of these soluble organic contaminants as shown in Table 13.

Indenenes were retained on the filter media yielding treated fuels free of these soluble organic contaminants as shown in Table 14.

Naphthenic acids were retained on the filter media yielding treated fuels free of these soluble organic contaminants as shown in Table 15.

Fuels that become off-test on the copper strip corrosion during storage due to generation of elemental sulfur by bacterial action become quite troublesome in the field. Confirming our original commercial reclamation filter data on both JP-6 and Mach 3 type fuels, our more recent laboratory data indicate that:

1. elemental sulfur can be generated in aged jet fuels, following improper fractionation or bacterial action, yielding a bad copper strip corrosion test during storage.

2. by adjusting the promoter agent to the filter media, the elemental sulfur can be removed from the reclamation filtered fuel without degrading other fuel qualities such as thermal stability.

The supporting data for these conclusions are shown in Table 16.

Test fuels, Reclaim Nos. 1 through 10, contained considerable phenols on the before treats (as received) while the after treated fuel samples contained only a small amount of phenols. This indicates that reclamation filtering removed phenols which in turn may have been partially responsible for the improved thermal stability rating of these types of fuels. Reclaim Nos. 11 through 19, manufactured by a different process, contained very little phenols on both the before and after treats which indicates that phenols were not responsible for the bad thermal stability ratings on these before treats. The data in Table 17 support these conclusions.

E. Effect of Additives on Reclamation Filtering Process

General observations to date from both the pilot plant filters and commercial filters indicate that:

1. some approved jet fuel additives, namely antioxidants and metal deactivators, that are normally included in jet fuel usually improve the performance of the reclamation filter media.
2. one approved jet fuel additive, namely icing inhibitor (ethylene glycol monomethyl ether with or without glycerol), usually reduces the effective life of the reclamation filter media.

Table 18 shows the antioxidant and metal deactivator content before and after reclamation filtering on all of the fuels. These data indicate that such additives may need to be readded to the filtrate after the initial filtration treatment. The data on the before treats indicate that thermal stability on these fuels deteriorated badly even though additives were still present in the aged fuels. Of the uncombined antioxidant and metal deactivator that were originally added to the freshly produced fuels, approximately 25% was still remaining in Reclaim No. 11 degraded fuel as received. During the course of these life tests on the filter media, nearly all of this uncombined and available antioxidant and metal deactivator was eluted in the treated fuel as effective additives. Tables 2 and 3 show that the coker break points of these aged fuels are below specification. These fuels contained nearly maximum concentrations of additives when freshly produced.

The ASTM-CRC coker ratings deteriorated with the addition of the military approved corrosion inhibitors. These data on JP-6 rehabilitated fuels confirm similar data on freshly produced commercial JP-6 type fuels which show:

1. that coker preheater ratings at temperatures above 425 F begin to deteriorate when the fuel is treated with minimum allowable concentrations of all current military approved corrosion inhibitors. Occasionally some of these corrosion inhibitor treated fuels have a higher threshold temperature, but additional testing shows inconsistency in the occasionally improved performance. These data indicate threshold break points of the corrosion inhibitor treated fuels below that of the virgin JP-6 jet fuel.
2. that reclamation filters can be used to remove some of the corrosion inhibitors from such inhibited fuels at the use point terminal thereby improving the coker rating of the filtered fuels. This approach has significant value when considering that jet fuel could be corrosion inhibited at production point, transported to destination, and reclamation filtered at the use point to minimize possible corrosion of storage and shipping containers. However, individual research would be required on a specific fuel to determine which contaminant (iron rust versus corrosion inhibitor) would be controlling in a specific fuel handling system.

Figure 41 shows that the military approved corrosion inhibitors when used in JP-6 jet fuel generally degrade a coker rating. It also shows that a portion of the corrosion inhibitor can be removed by a reclamation type filter which in turn improves the coker rating at 450/550/6. Table 19 shows the detailed coker preheater ratings supporting Figure 41.

The Aero Propulsion Laboratory used their reclamation filter to process two fuels containing lubricant additives. These two fuels were sent to Monsanto's Dayton laboratories for infrared identification of these lubricant additives in the samples before and after the reclamation filtration unit. The two runs that were made on the reclamation filtration unit showed that both lubricant additives were retained on the filter media and thereby removed from the treated fuels. These data are shown in Table 20 and indicate that such lubricant additives should be injected downstream from the reclamation filter. However, if a lubricant additive would become incompatible to the fuel, such fuel could then be pumped through the reclamation filter to remove the objectionable additive.

Figure 42 shows the infrared spectra for the base fuel, duplicate runs for the base fuel plus lubricant additive No. 1, and for the filtered fuel. Figure 43 shows similar spectra for lubricant

additive No. 2. The spectra representing the filtered fuels are identical to those of the base fuel with no additive.

A typical commercial antistatic additive (3 ppm) caused the deterioration of the thermal stability of JP-6 jet fuel with the coker operating at 450/550/6. These data are shown in Table 21.

F. Static Electricity Generated by Reclamation Filter

Most of the static electricity studies predate this contract work since safe laboratory procedures were required to conduct the original research work to develop a practical reclamation filter. In this original work, three phases of static electricity were evaluated.

1. Conductivity

Since reclamation filtering involves removing contaminants from the fuel processed, conductivity of the filtered fuel is decreased, as would be anticipated, with the use of a good jet fuel filter. Conductivity measurements varied considerably depending upon the quality of the fuel charge and its additive content, the contaminants removed, and upon the quality of the treated fuel required. If the reclamation filter accomplishes its primary objectives of removing contaminants, the conductivity parameters must become of secondary consideration.

2. Static charge build-up

The design of the reclamation filter has been made to reduce drastically the potential static charge build-up. These design features include relatively low fluid velocities (3 feet per minute), support media with neutralizing and/or relaxing components, grounding facilities, and media promoting agents that tend to lessen generation of static charge.

3. Fire hazard measurements at effluent product receiver

Drastic laboratory environment was arranged to initiate combustion at the product receiver. Ungrounded metal receivers were used to receive the fuel by top fill splash loading in an air atmosphere. The third component for ignition of the fuel became the controlling variable -- static electrical charge. The original laboratory work included varying the fuel flow rate from 1 to 300% of the recommended design flow rate, varying the fuel type to cultivate explosive ranges in the lean and rich zones and on both sides of these air-vapor ratios at the receiving tank, varying flow temperatures from minus 20 to plus 130 F (above and below flash points of

differer fuels), etc. To date, no actual fire flashes have been ignited by the static electricity generated by these reclamation filter runs.

While the number of laboratory runs prior to this effort were more numerous and more conducive to static electrical fires than the present laboratory runs, these runs also consisted of top splash filling in ambient air of about 1800 five-gallon metal cans (ungrounded) with treated product stream from the pilot plant reclamation filters. The potential hazards using any method of fuel handling should never be minimized. However, these laboratory runs as described above and actual commercial runs indicate that with well grounded reclamation filters -- the static electrical discharge from reclamation filters is considerably less than for many other existing high fluid velocity filter-separators. The normal laboratory configuration for reclamation filter units should incorporate grounding of product metal containers with submerged filling spouts.

When testing for static electricity build-up on both laboratory and commercial reclamation filters, it was found that:

1. negligible static electricity is generated in processing fuel as it flows through this unit.
2. the ability of both the unfiltered and filtered fuel to carry away artificially induced electricity would vary considerably with the type of fuel being processed (with or without additives).
3. proper grounding of metal filter units is required for general safety reasons regardless of whether or not a fuel is being processed.
4. when the product receiver in the reclamation filter was arranged in an environment which was very conducive to supporting combustion if static charge was generated, no ignition occurred indicating negligible static generated within the reclamation filter.

G. Life of Filter Media

Figure 44 shows the treating costs of the reclamation filter media when processing different degraded fuels. Appendix VI shows supporting data for Figure 44.

Life of the filter media is decreased with increasing soluble organic contaminants or increasing coker severity. Both pilot

units and commercial reclamation filter units have demonstrated that:

1. the greater the concentration of soluble organic contaminants, the lower the life of the filter media. However, this relationship is not directly proportional to the total amount of soluble organic contaminants since some organic contaminants elute sooner than others and some are more detrimental than others.
2. the greater the severity of the coker test conditions on the treated product, the lower the effective life of the filter media used for reclamation. This relationship approaches a logarithmic function.
3. the analytical complexity of reclamation filtering is such as to limit precise predictions of the life of filter media, however field experience and pilot runs give a reasonably good basis for design calculations on all grades of jet fuel processing. Obviously the degree of accidental contamination cannot always be predicted.

A specification JP-6 jet fuel containing antioxidant and metal deactivator in allowable concentrations when processed through a reclamation filter soon saturates the filter media with these additives without affecting the ability of the filter media to remove other contaminants. After filtering approximately 100 barrels of fuel per ton of filter media, these additives elute into the effluent in their original effective form. However, icing inhibitors do seriously decrease the life of the filter media. It was found that injecting the icing inhibitor following the reclamation filter provided a preferable operating procedure. While processing a very bad JP-6 jet fuel (Reclaim No. 11), the filter media life for complete reclamation for improving coker threshold temperature from 350 to 475 F exceeded 13,000 barrels of fuel per ton of filter media. The continued processing of this same fuel with a 16,000 barrels per ton rate showed a gradual increase in naphthalene, indenenes, pyrrole nitrogen, copper, lead, and iron bleeding into the fuel filtrate.

The foregoing data which show the life of the filter media when processing badly degraded fuels are somewhat distorted since two commercial units have considerably less operating cost when processing larger quantities of fuel. In practice, such filters could be used continuously to process both bad and good fuels in any sequence thereby insuring that all of the filtered fuels will be thermally stable. The continuous processing of all incoming fuels through reclamation filters would insure that all the fuel delivered to the aircraft would be thermally stable and on specification with considerable saving in testing time and cost of

testing the fuels. Additional additives that may be requested for flight benefits could be injected into the effluent stream from the reclamation filter unit with an automated proportional additive pump.

H. Design Variables of Reclamation Filter

Specifications for jet fuel filter-separators have been well documented for the removal of physical contaminants - namely solids and free water. With the continued more rigid requirement for the removal of physical contaminants, new requirements have been added to remove also chemical and biological contaminants from high-temperature jet fuels at the use point terminals. The usual design variables for filter-separators are viscosity, interfacial tension, temperature, differential density of fuel and water, and the type, quantity, and nature of contaminants to be removed. The new design criteria include the nature, type, and quantity of soluble chemical and biological contaminants and their ease of removal in the presence or absence of fuel additives. These design criteria may incorporate the supplemental flexibility of different filter media, different filter supports, different disengaging hardware along with the efficient disposal and replacement facilities for the active filter media. Optimum flow rates have been established for pilot and commercial filtration units with standard filter media for the different current types of military high-temperature jet fuels based on effective removal of typical contaminants, viz. physical, chemical, and biological.

Figure 45 shows the filter pressure drop versus the flow rate for fuels with varying viscosities. Figure 46 shows the filter pressure drop versus the flow rate for JP-6 fuel for varying filter bed depths.

Table 22 shows practical design data for maximum permissible flow rates on the reclamation filtration unit as taken from the curves in Figures 45 and 46. While other variables may be controlling, it is believed the maximum flow rates through the reclamation filtration unit listed in Table 22 provide a reasonably good design basis for insuring good performance and optimum economics. The cross sectional area of the chemical dryer can vary between 30 and 60% of the cross sectional area of the reclamation filter, depending on the anticipated drying duty. The depth of the filter bed and drier bed can vary with the permissible cost of the hardware but preferably with the anticipated effective-contaminant-load in the fuel to be processed. The effective-contaminant-load will vary with the coker severity level requirement on the treated fuel. For some operating requirements, considerably higher flow rates can be realized provided the charge pump and hardware are designed for the higher pressure drops.

In general, the performance of the commercial reclamation filter units is better than the simulated pilot units. Some of the contributing factors that favor the commercial unit are:

1. more consistent jet fuel charge quality
2. less contact of the fuel with the metal containers -- gallons fuel/ft² metal surface
3. less contact of the fuel with air
4. fewer experimental operating variables

Since the pilot filter units are less efficient, design data based upon pilot runs provide a greater contingency allowance in commercial installations for accidental mishandling of fuel. In any event, mishandling of fuel should be avoided whenever possible.

IV. SUMMARY

This research program included evaluating methods of reclamation for storage degraded jet fuel; viz. hydrotreating, redistillation, and reclamation filtering. The data indicate that hydrotreating and redistilling accomplish the reclamation, but these processes would not be practical in field applications where the problem exists. Reclamation filtration has been used commercially for several years in the field. Filter pilot plants were used in this research work to rehabilitate nineteen different degraded fuel samples. It can be concluded that reclamation filters are practical, economical, effective, simple, and safe. Commercial filters can be constructed and installed quickly within new or existing fuel facilities. Perhaps such a filter could be operated effectively with or without filter-separators.

The use of the filter unit could permit deleting some jet fuel additives during the production and transportation of these fuels. The filter could be used at the use point to rehabilitate the fuel and to allow also the injection of additives into the filtered fuel to meet the specific demands of the aircraft during flight. Hot residual fuel from returning aircraft could also be filtered at the air base and then returned to and commingled with fresh fuel.

Since the quality of the reclaimed filtered fuel is possibly better than the freshly refined fuel, laboratory testing could be minimized along with its corresponding time delays. The research data indicate that indenes and other contaminants are generated during ambient temperature storage. Since the greatest demand for stability of fuels is during flight, it is logical to provide for the greatest stability level just prior to fueling aircraft and then to fortify with additives for the specific flight. The use point filter could permit this optimum approach.

The filter also provides a means of concentrating and removing jet fuel constituents for supplemental measuring, identifying, and monitoring purposes. The coker test is much more sensitive than physical and chemical tests for determining thermal stability of high-temperature jet fuels. The filter removes and concentrates most of the contaminants regardless of what type or quantity causes the instability of jet fuels. The filter media are in sufficient quantity to enable several months or possibly several years operation prior to regeneration or recharging of the unit.

The rehabilitation of all of these fuels processed by the pilot filters helps to justify new installations of commercial reclamation filters for processing any storage degraded fuels at military tank farms. The processing of good fuels through filters produces even a higher quality fuel. The occasional or continuous processing and rehabilitating of bad fuels avoids downgrading of these bad fuels. Following their

reclamation filtration they can be commingled with the good fuels in any or all proportions since they have equivalent thermal stability ratings and compatibility characteristics. While most fuel suppliers expect the delivered fuel quality to be satisfactory, too many failures have already been documented at the threshold of the supersonic jet age. The installation of reclamation filters at the use point terminals could close the gap in quality levels and insure the delivery to the aircraft of as clean, dry, and thermally stable jet fuels as is possible with the present state of the art.

V. RECOMMENDATIONS

1. Install commercial reclamation filters at several fuel facilities to gain additional experience under full scale application and to provide field developmental data to determine feasibility of more extensive applications.
2. Conduct additional research work to develop an in-field thermal stability monitoring instrument to record automatically contaminant levels of jet fuels in storage tanks.
3. Conduct additional research work on correlating contaminants (extracted from filter media) with coker ratings on the before and after treat samples from reclamation filters.
4. Conduct additional research work on improving regenerative procedures for reclamation filters.

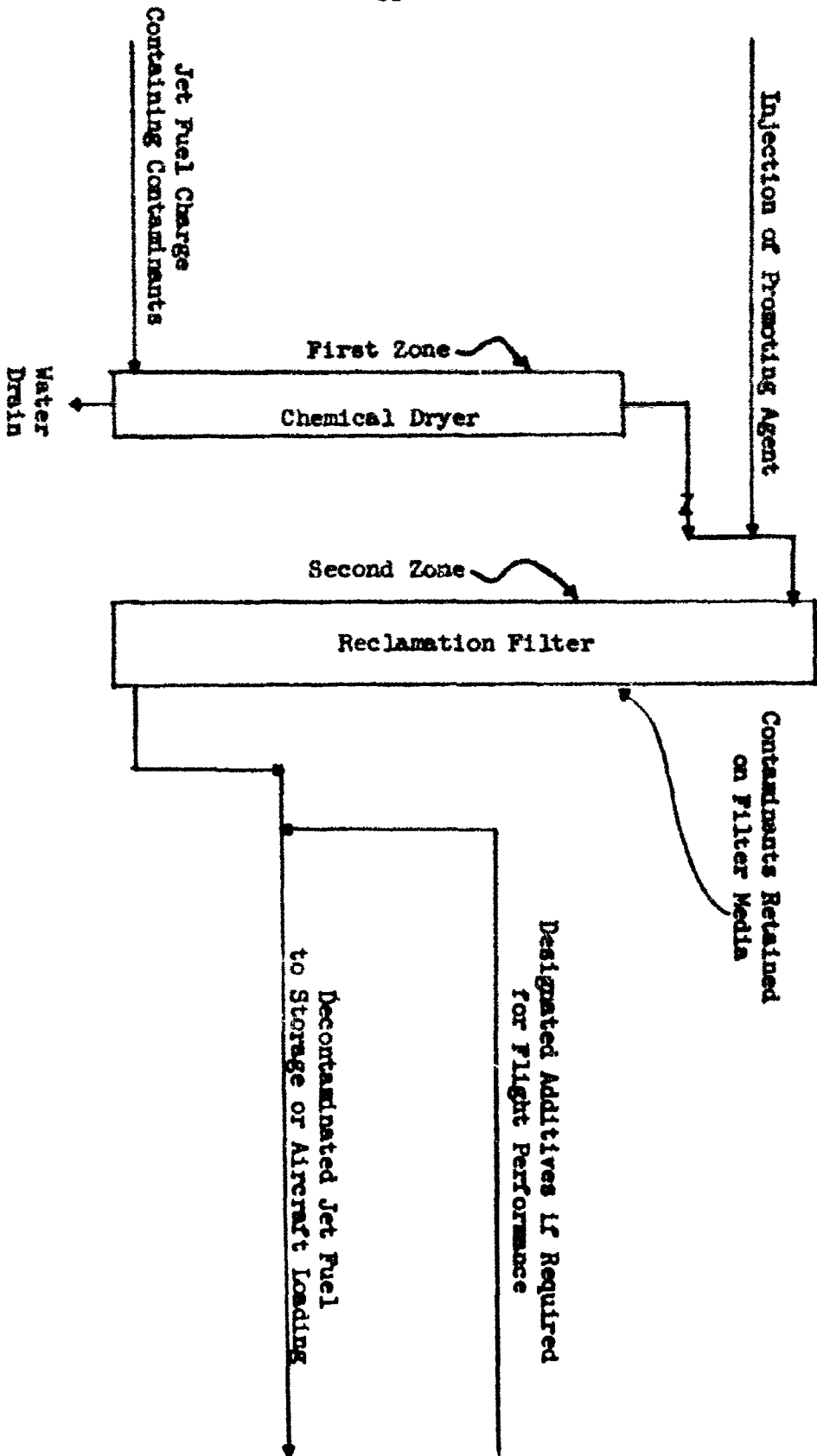
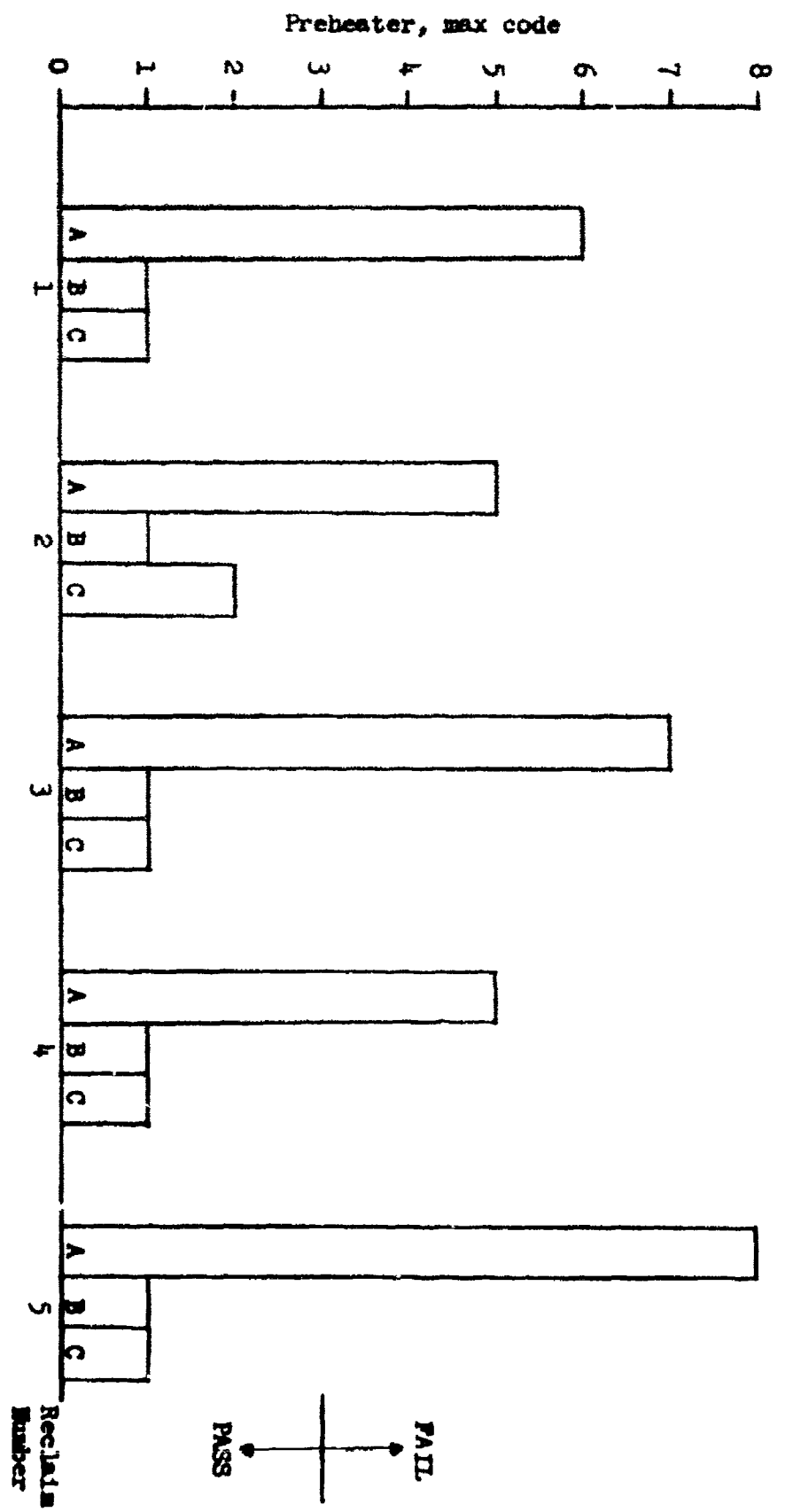


Figure 1. Process Flow of a Typical Reclamation Filter Unit



A - Degraded fuel as received
 B - Treated fuel immediately after reclamation filtration
 C - Treated fuel six months after reclamation filtration

Figure 2. Thermal Stability Data - Reclaim Nos. 1 Through 5

ASTM-CRC Comparative Coker Ratings (450/550/6)

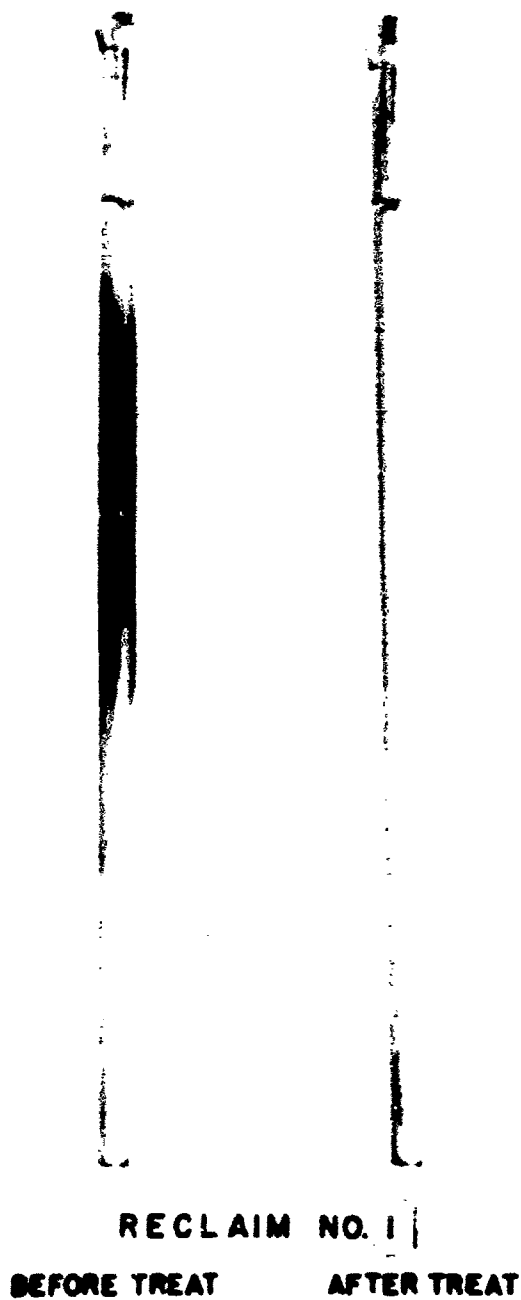


Figure 3. Comparative Coker Preheater Tubes for Reclaim No. 1

"Before Treat" (Code No. 6) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

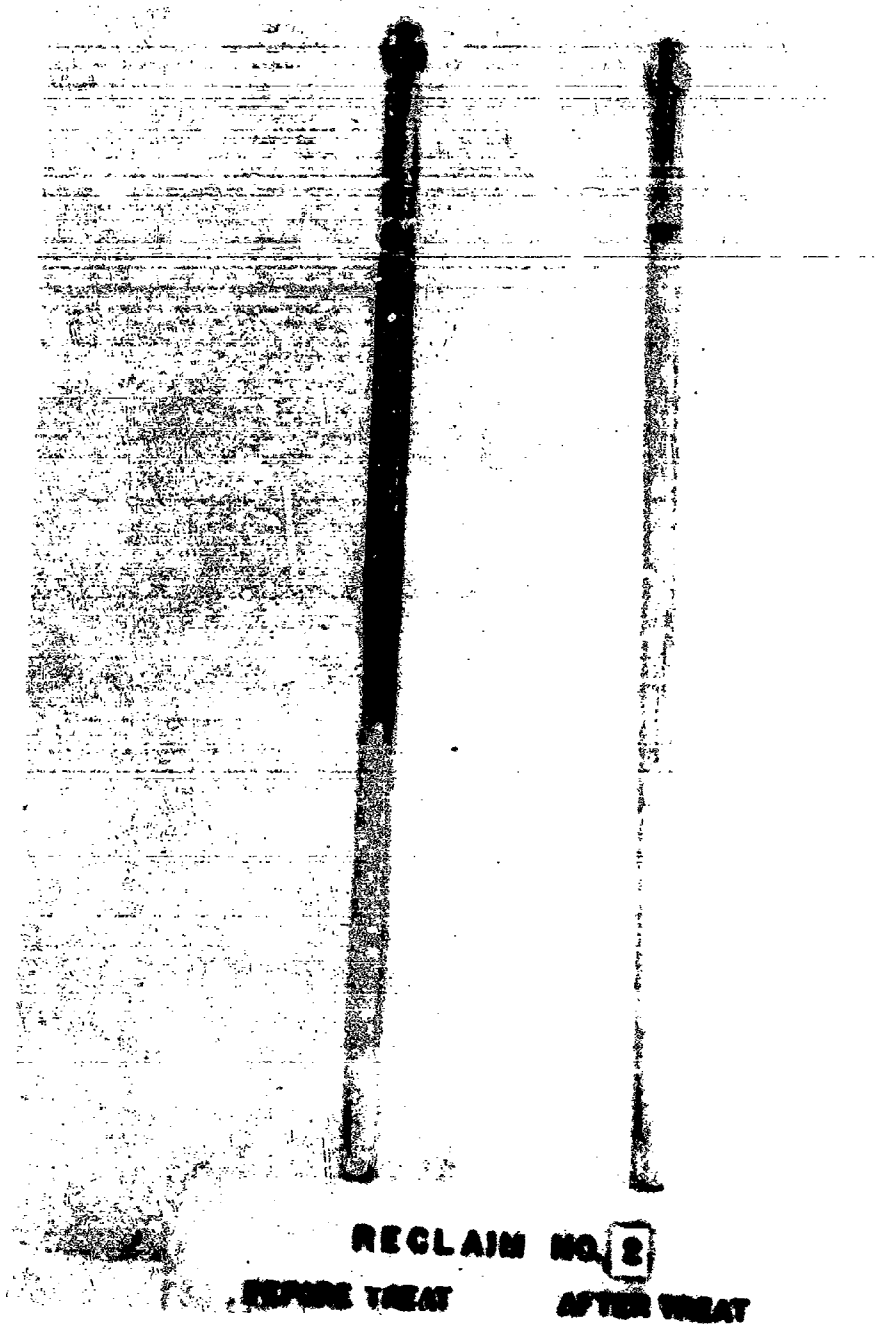
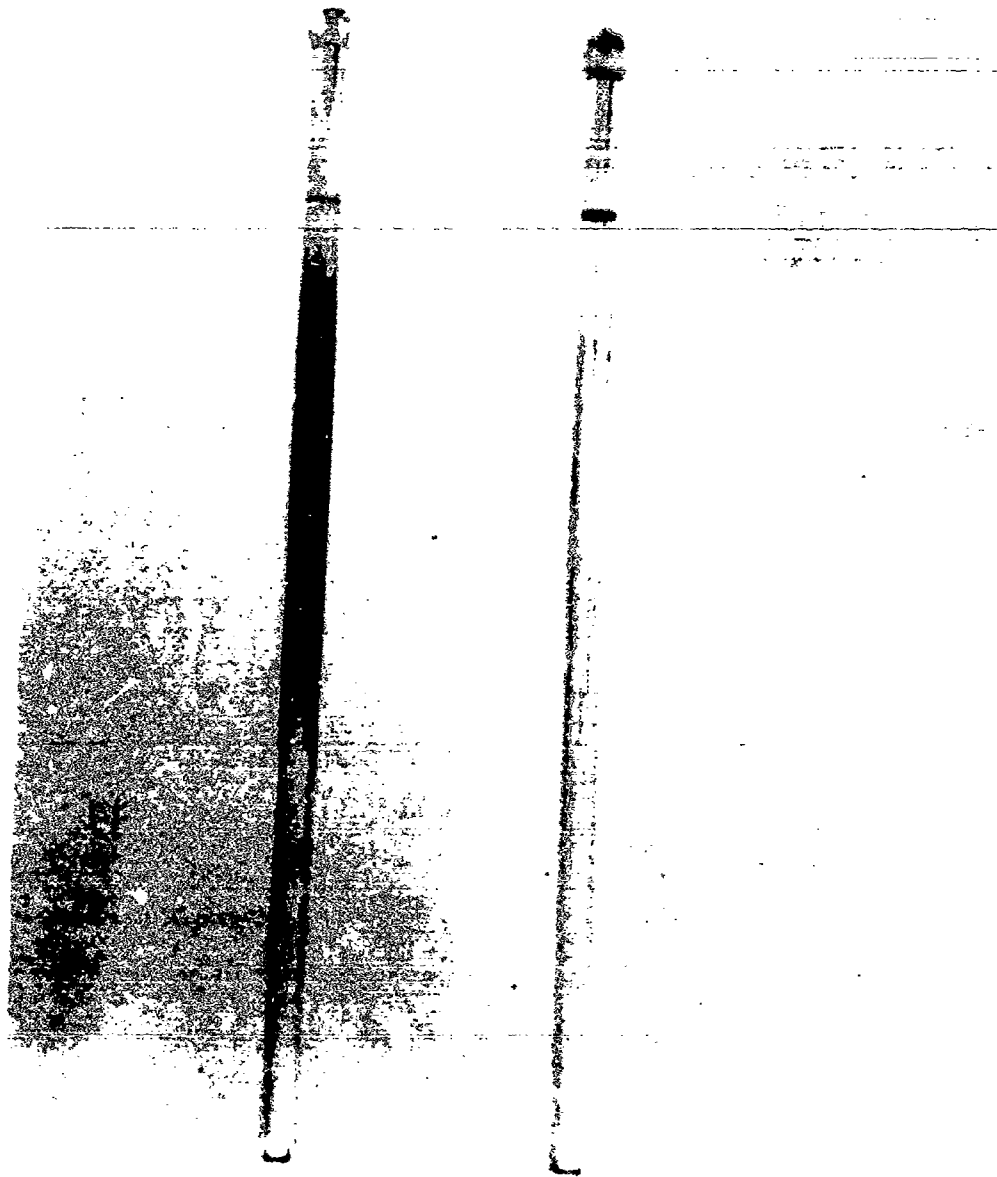


Figure 4. Comparative Coker Preheater Tubes for Reclaim No. 2
"Before Treat" (Code No. 5) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.



RECLAIM NO. 3
BEFORE TREAT AFTER TREAT

Figure 5. Comparative Coker Preheater Tubes for Reclaim No. 3

"Before Treat" (Code No. 7) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

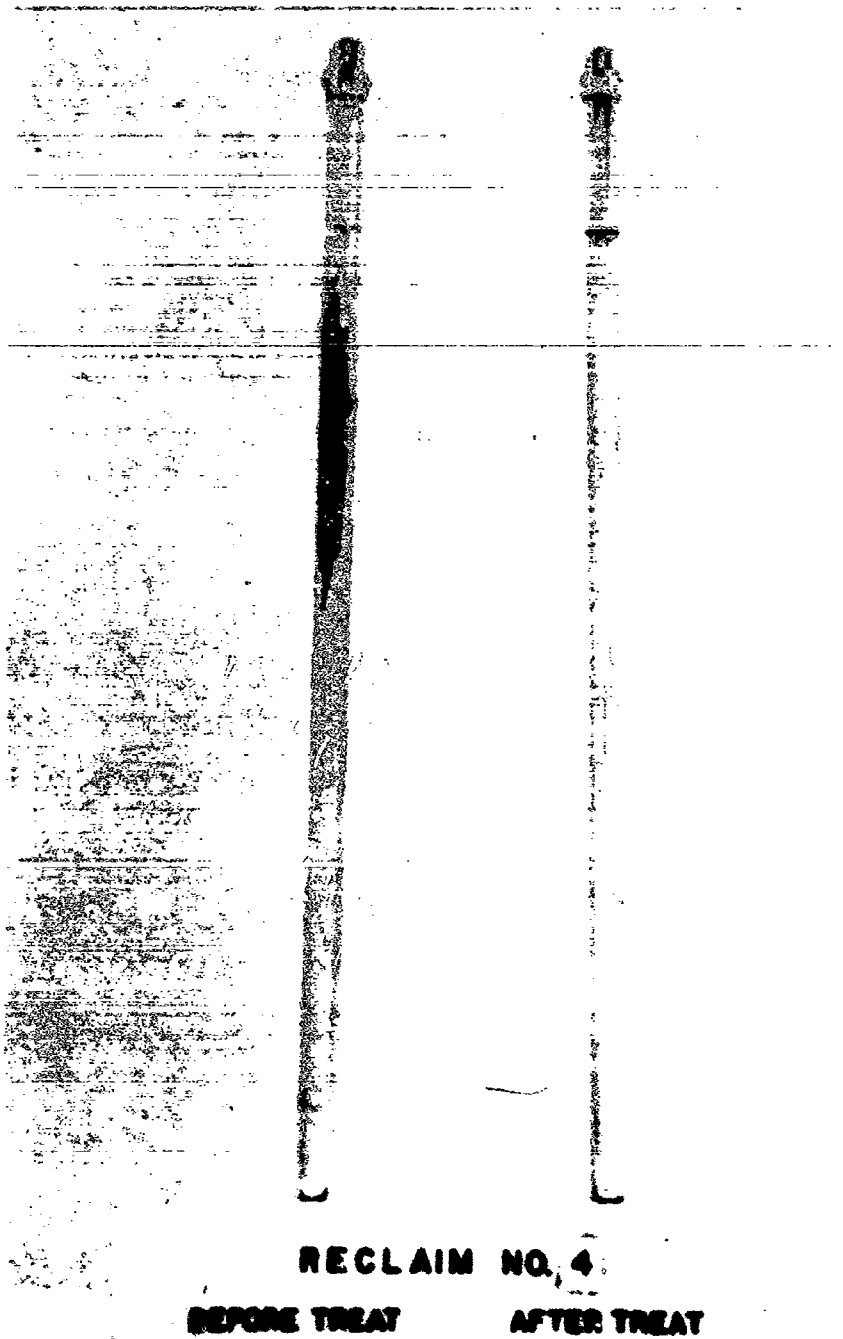


Figure 6. Comparative Coker Preheater Tubes for Reclaim No. 4

"Before Treat" (Code No. 5) represents charge to filter and "After Treat" (Code No. 1) represents effluent product from reclamation filter.

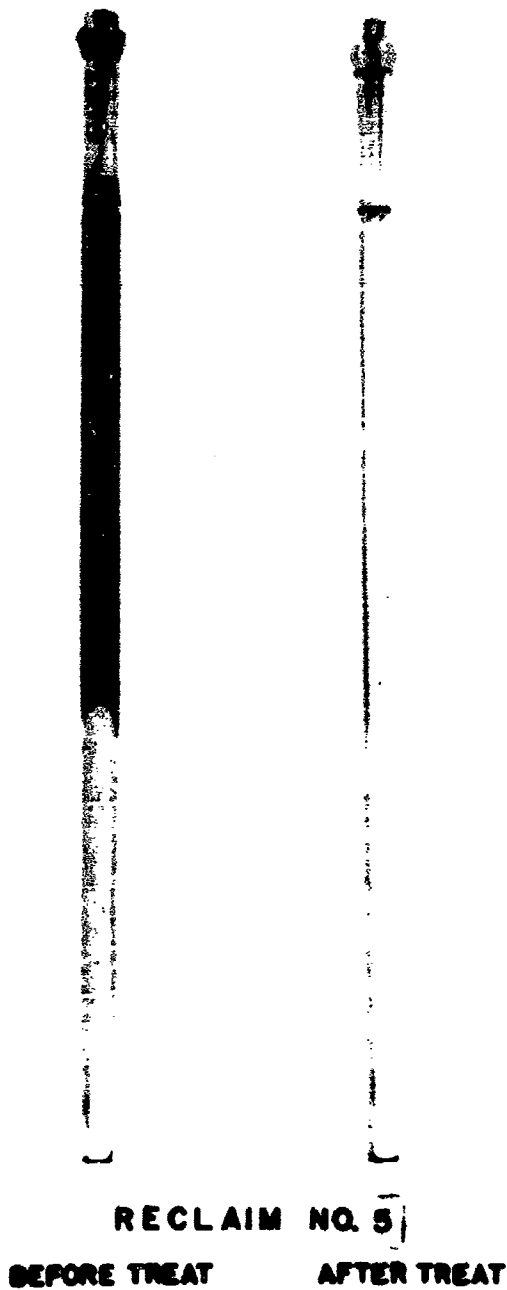
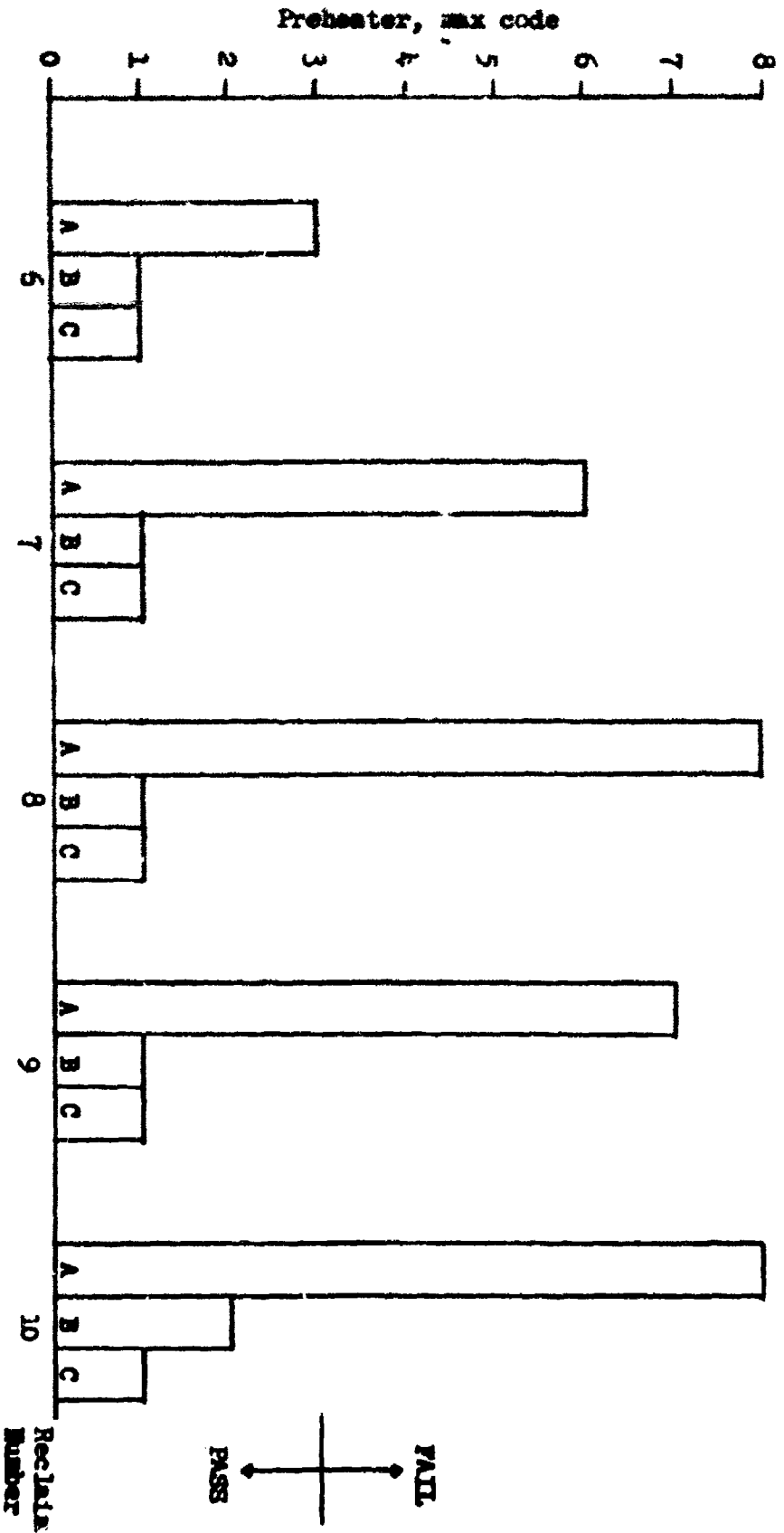


Figure 7. Comparative Coker Preheater Tubes for Reclaim No. 5

"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.



- A - Degraded fuel as received
- B - Treated fuel immediately after reclamation filtration
- C - Treated fuel six months after reclamation filtration

Figure 8. Thermal Stability Data - RecJala Nos. 6 Through 10

ASTM-CRC Comparative Coker Ratings (450/550/6)



Figure 9. Comparative Coker Preheater Tubes for Reclaim No. 6

"Before Treat" (Code No. 3) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

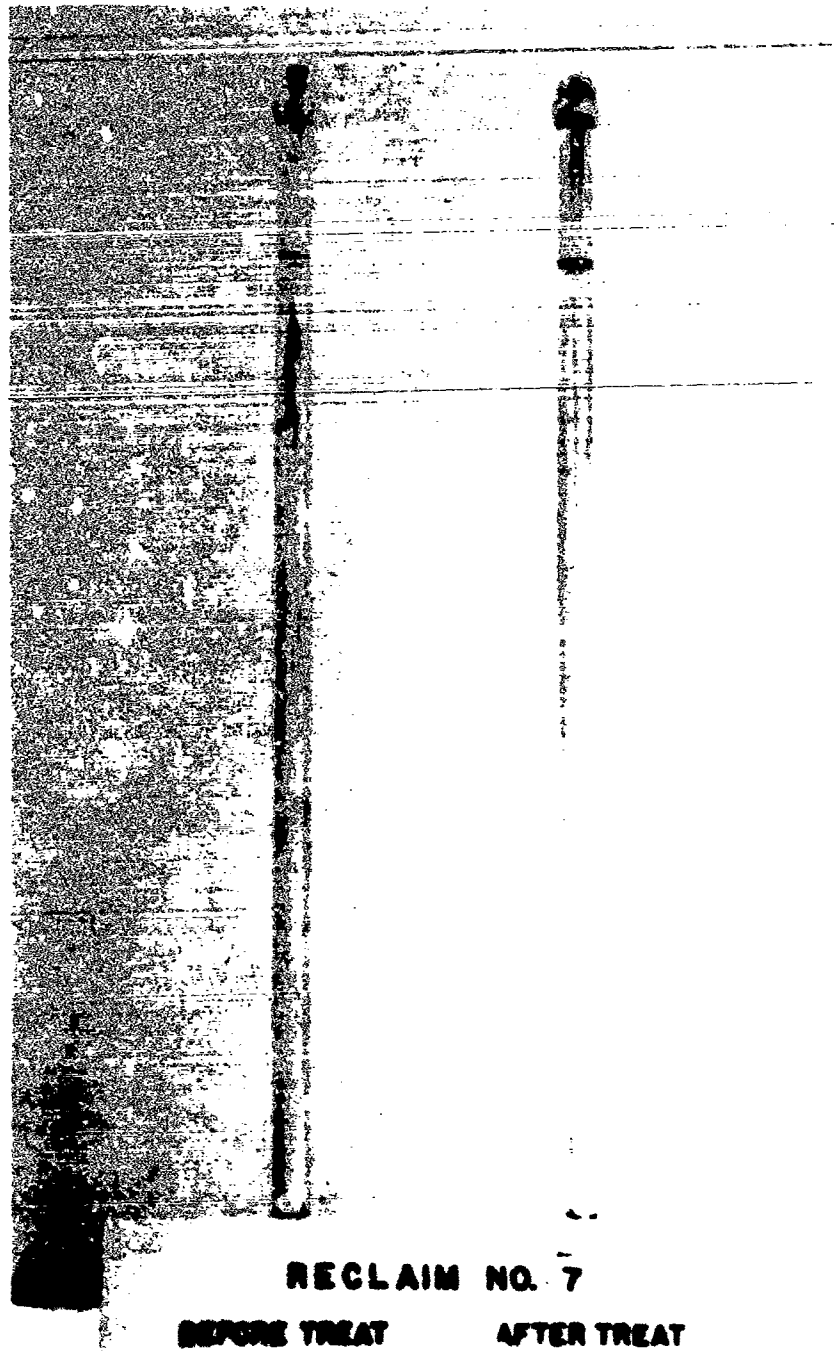


Figure 10. Comparative Coker Preheater Tubes for Reclaim No. 7

"Before Treat" (Code No. 6) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

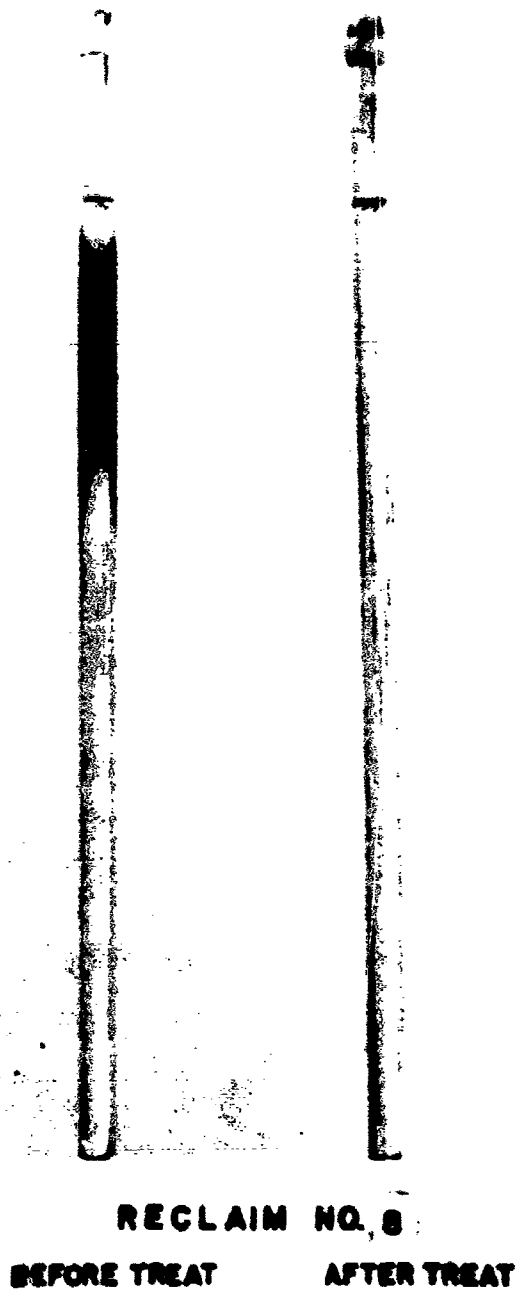


Figure 11. Comparative Coker Preheater Tubes for Reclaim No. 8

"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

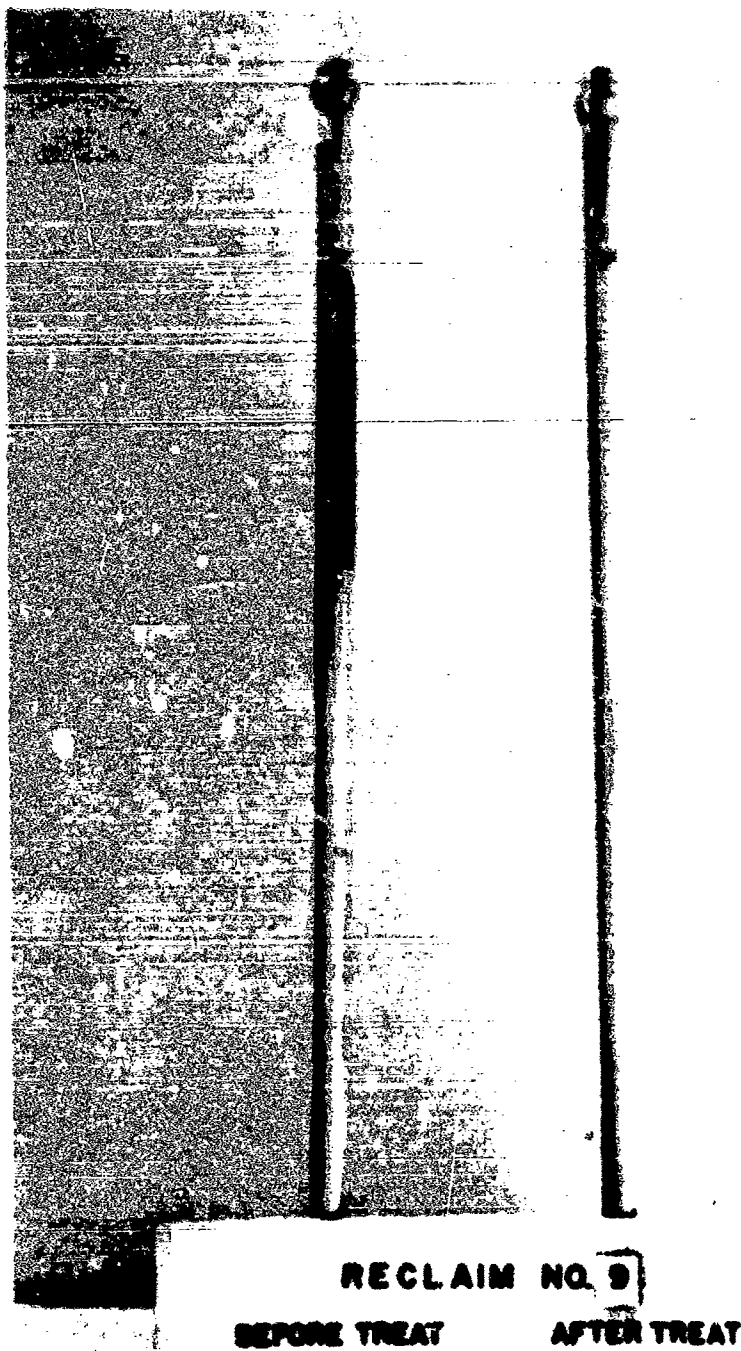


Figure 12. Comparative Coker Preheater Tubes for Reclaim No. 9

"Before Treat" (Code No. 7) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

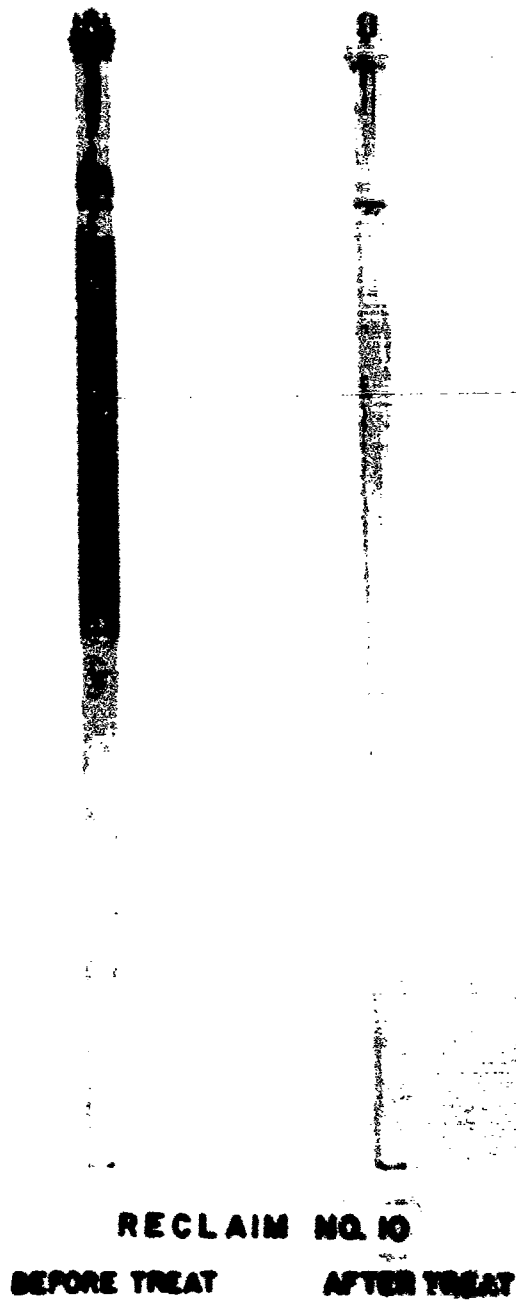
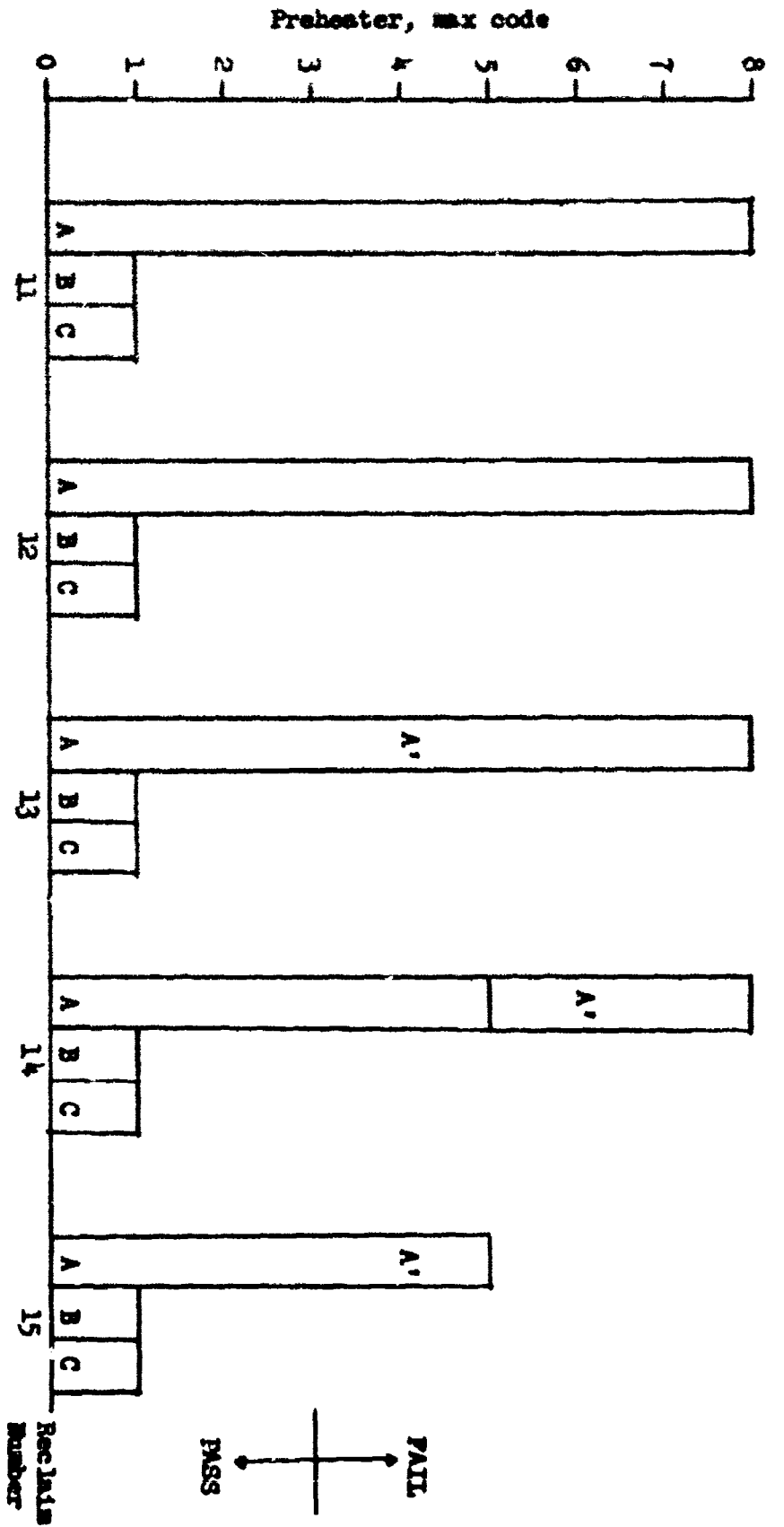


Figure 13. Comparative Coker Preheater Tubes for Reclaim No. 10

"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 9) represents effluent product from
reclamation filter.



A - Degraded fuel as received. A' - second run at close of contract.
 B - Treated fuel immediately after reclamation filtration
 C - Treated fuel six months after reclamation filtration

Figure 1b. Thermal Stability Data - Reclaim Nos. 11 Through 15

ASTM-C92 Comparative Coker Ratings (450/550/6)

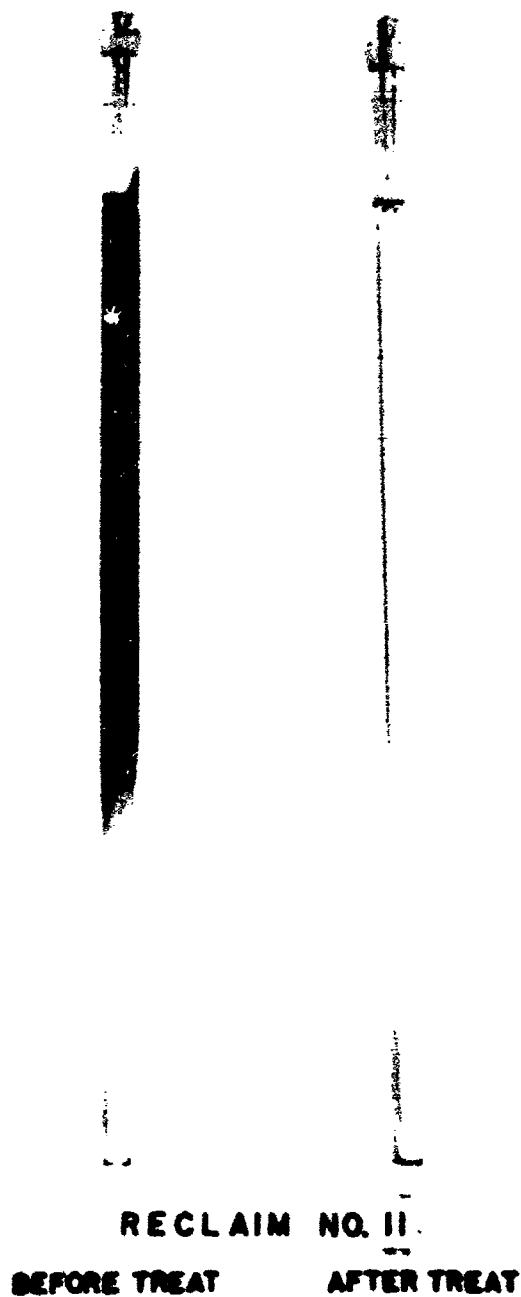


Figure 15. Comparative Coker Preheater Tubes for Reclaim No. 11

"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

Reclaim No. 12

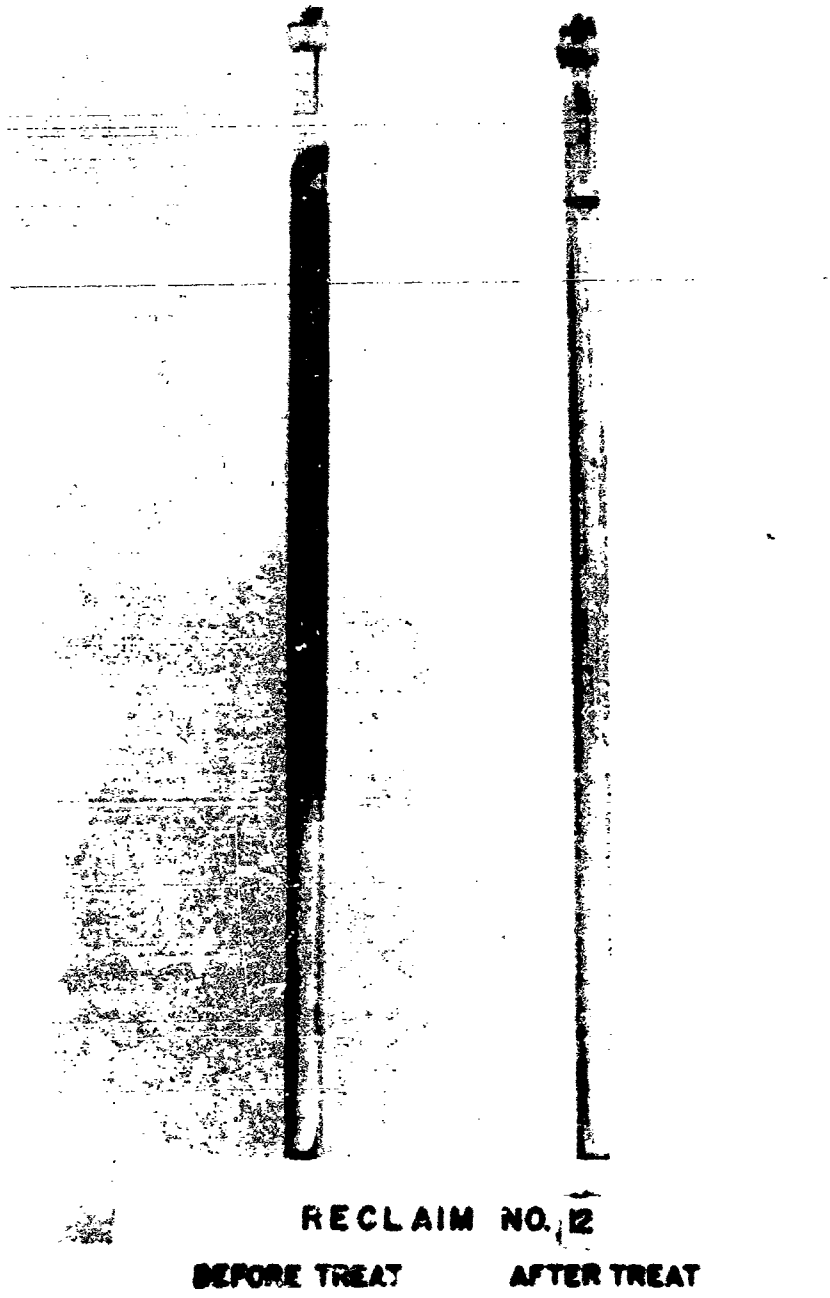


Figure 16. Comparative Coker Preheater Tubes for Reclaim No. 12

"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

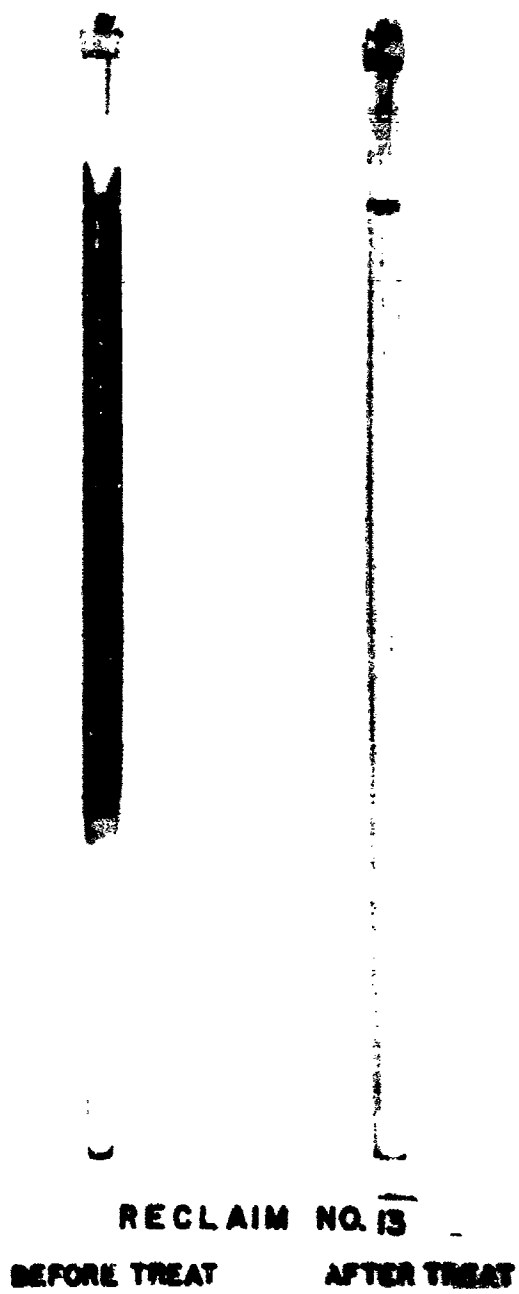


Figure 17. Comparative Coker Preheater Tubes for Reclaim No. 13

"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

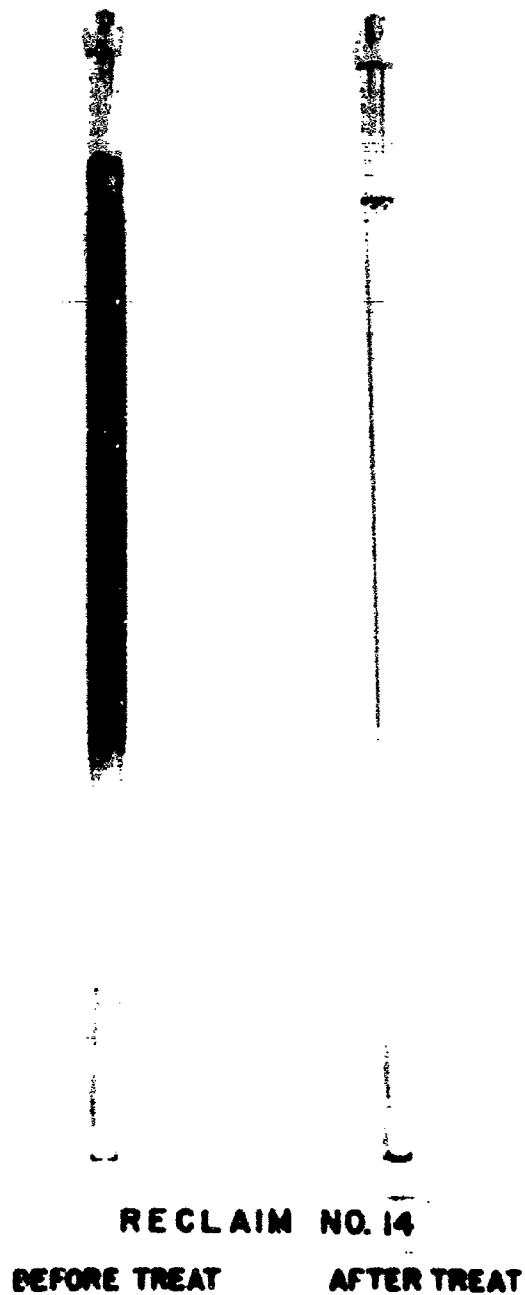


Figure 18. Comparative Coker Preheater Tubes for Reclaim No. 14

"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

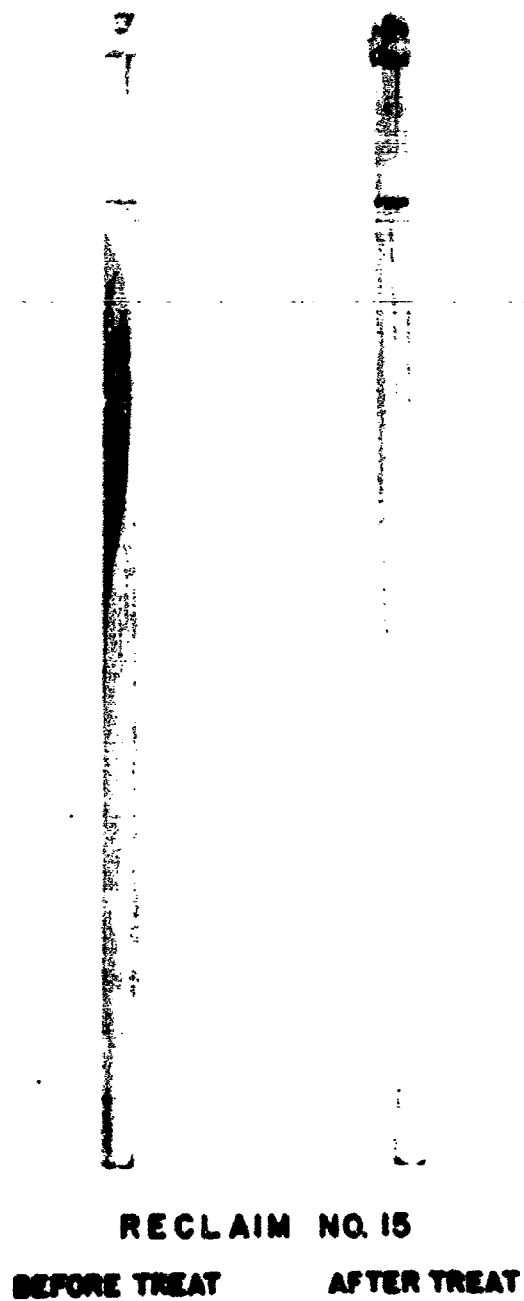


Figure 19. Comparative Coker Preheater Tubes for Reclaim No. 15

"Before Treat" (Code No. 5) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

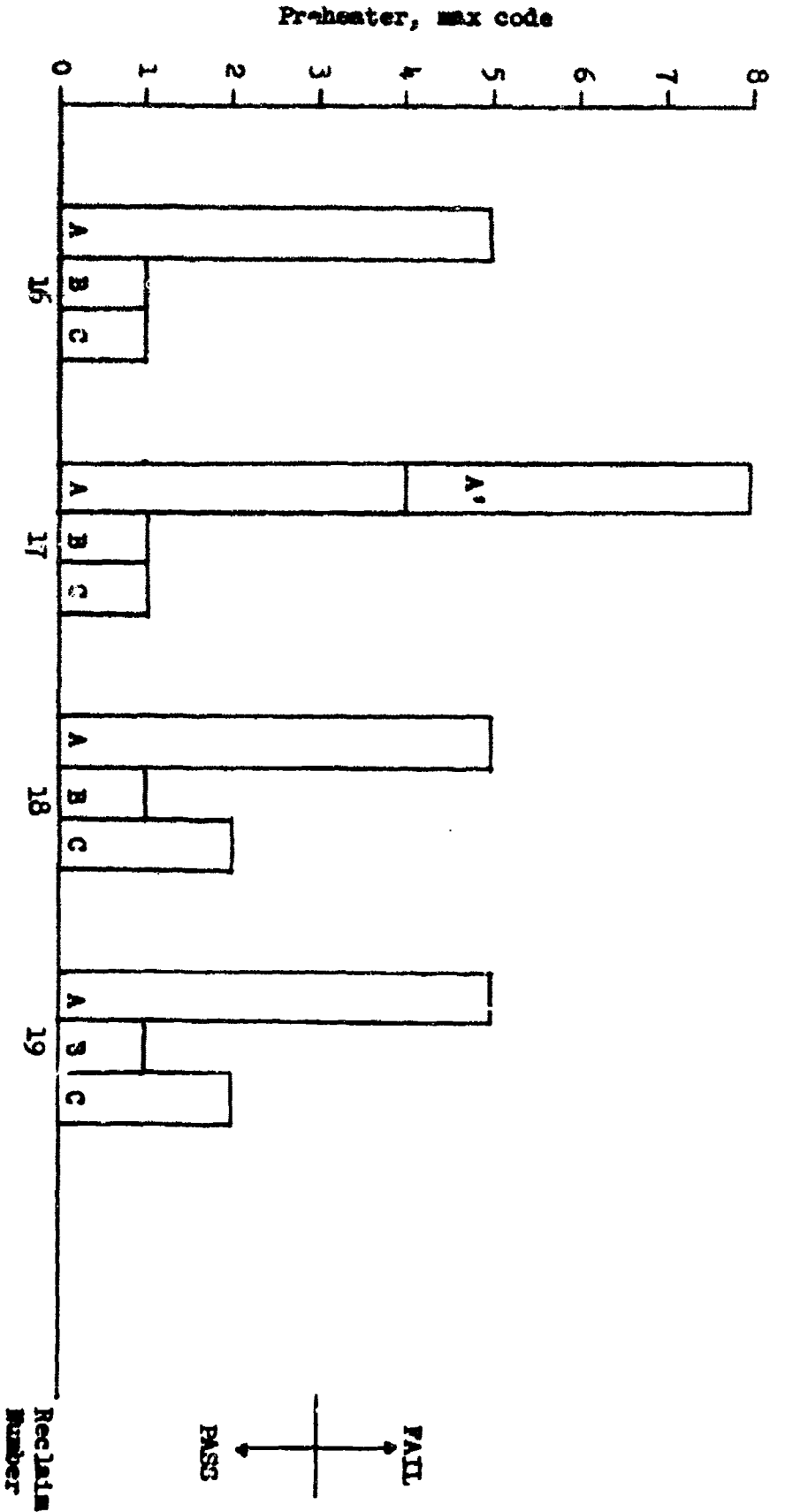


Figure 20. Thermal Stability Data - Reclaim Nos. 16 Through 19
ASTM-CRC Comparative Coker Ratings (450/550/6)



RECLAIM NO. 16
BEFORE TREAT **AFTER TREAT**

Figure 21. Comparative Coker Preheater Tubes for Reclaim No. 16

"Before Treat" (Code No. 5) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

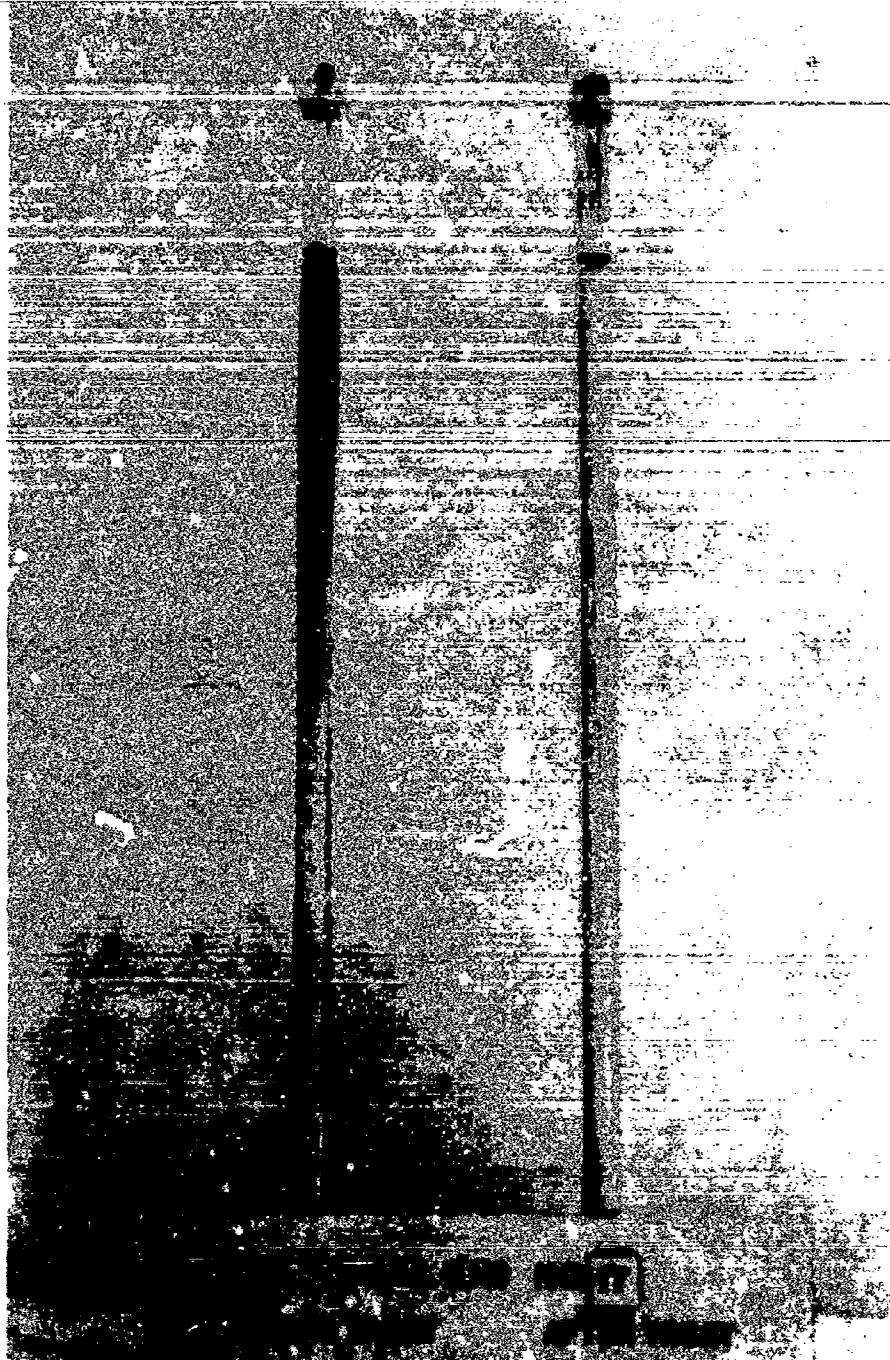


Figure 22. Comparative Coker Preheater Tubes for Reclaim No. 17

**"Before Treat" (Code No. 8) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.**

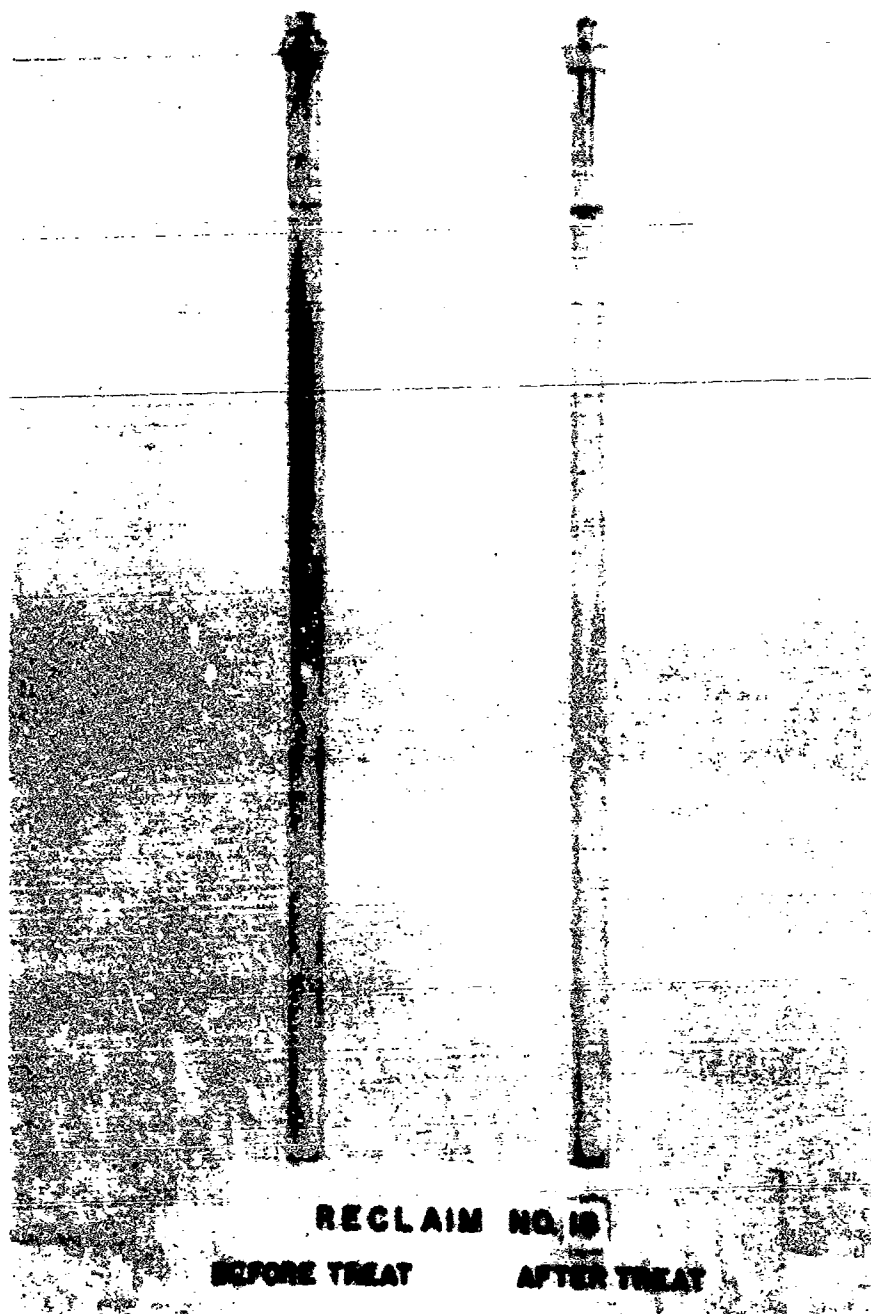
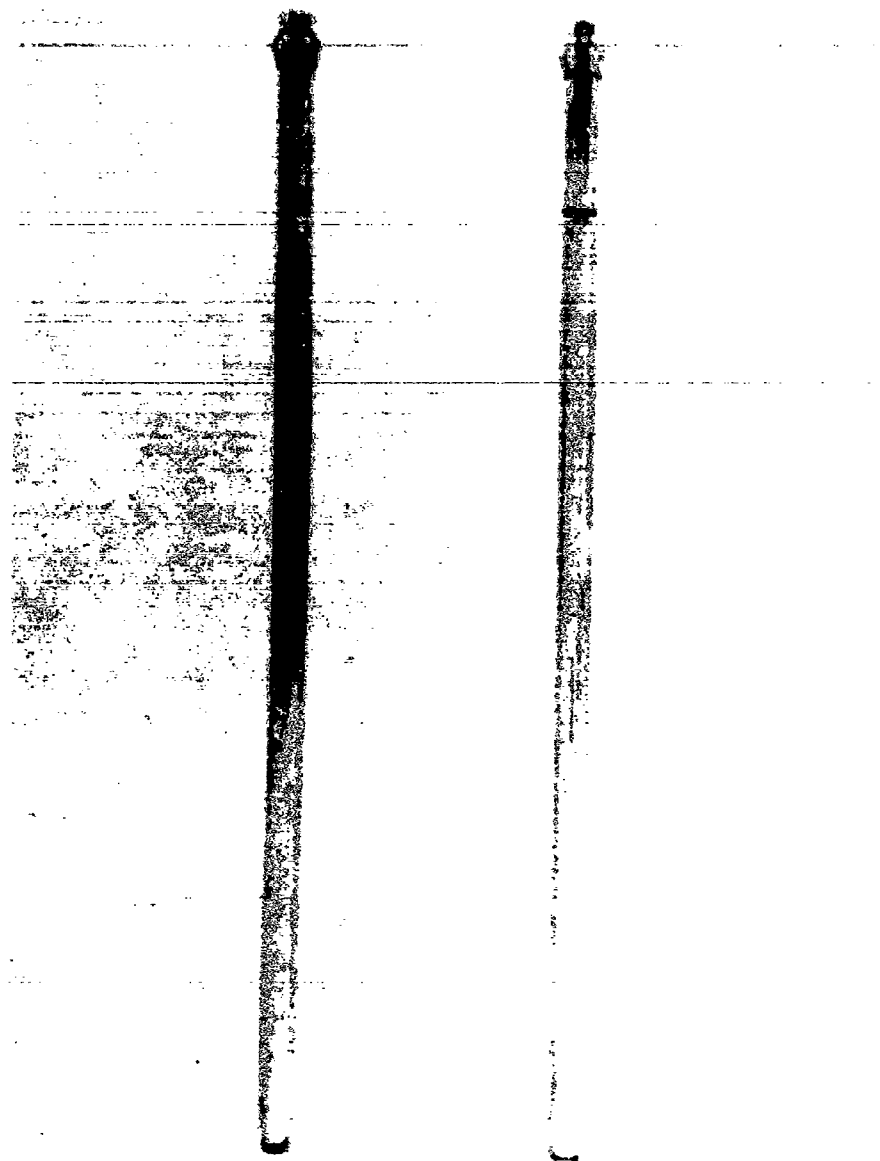


Figure 23. Comparative Coker Preheater Tubes for Reclaim No. 18

"Before Treat" (Code No. 5) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.



RECLAIM NO. 19
BEFORE TREAT AFTER TREAT

Figure 24. Comparative Coker Preheater Tubes for Reclaim No. 19

"Before Treat" (Code No. 5) represents charge to filter and
"After Treat" (Code No. 1) represents effluent product from
reclamation filter.

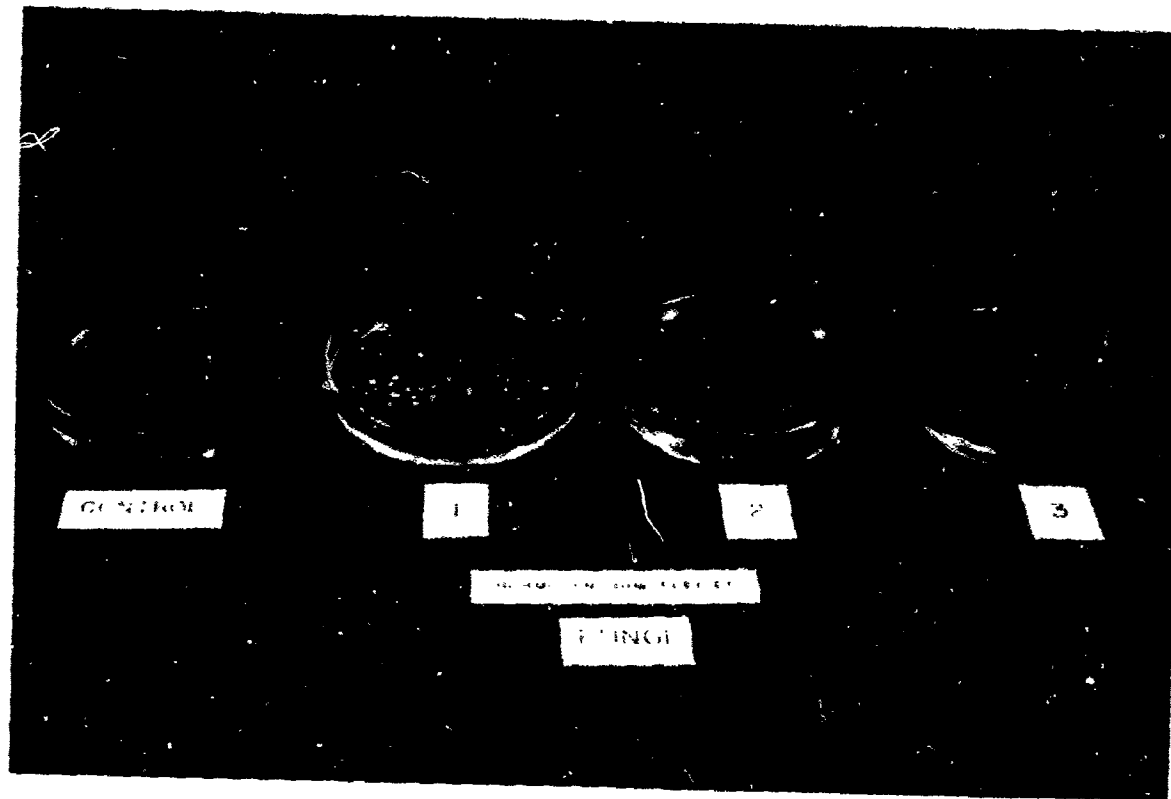


Figure 25. Tracing Fungi Through Filtering Process

Hormodendrum Species
(Following 72-hours incubation)

- KEY: Control: Petri dish containing sterile Sabouraud's medium
Petri 1: Inoculated drum, JP-6 fuel (~250 colonies)
Petri 2: JP-6 fuel following chemical dryer section (~12 colonies)
Petri 3: JP-6 fuel following the reclamation filter section

OPTICAL MICROSCOPY SECTION

Photomicrographs, Figures 26 Through 29

Microscope: Leitz Triocular Ortholux Microscope
Oil immersion achromatic objective
with focal length of 1.9 mm

Camera: Leica M-1 Body Camera
with microattachment



Figure 26.

Typical Bacteria
Pseudomonas Species

Total magnification: 2450 X

5 μ



Figure 27.

Typical Fungi
Hormodendrum Species

Total magnification: 1300 X

.1011.

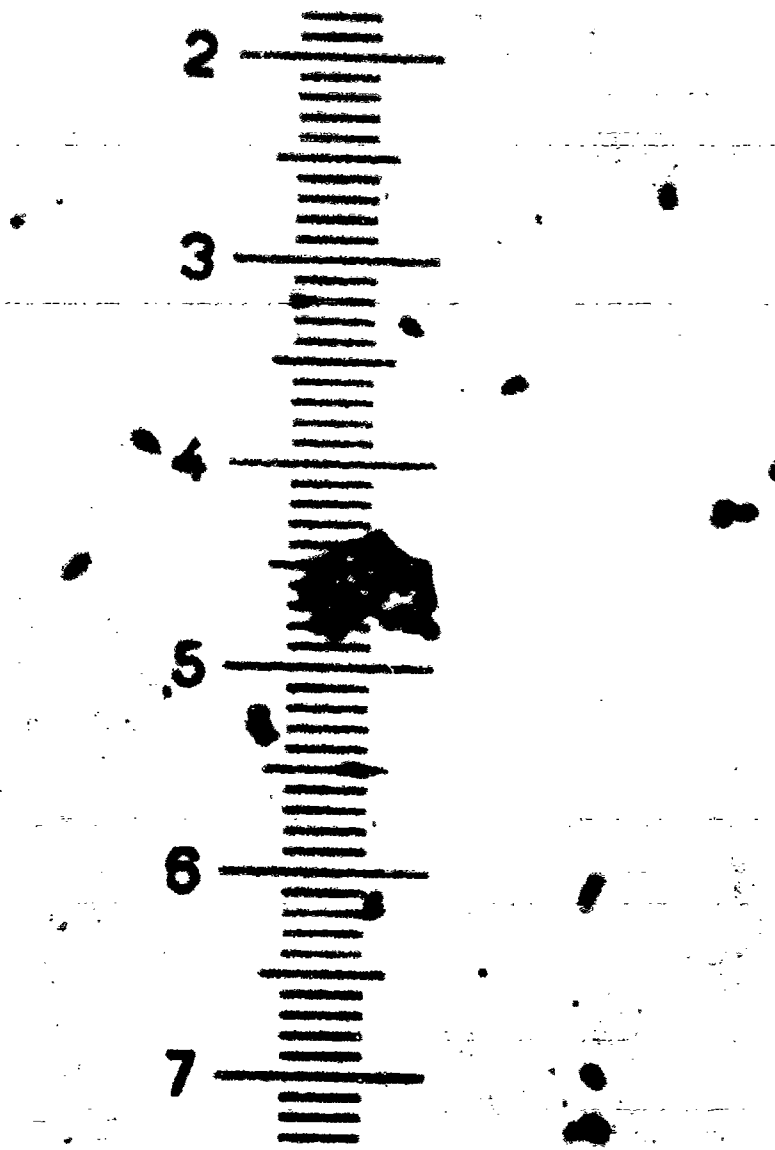


Figure 28. Bacteria-Inoculated JP-6 Fuel in Charge Drum

Total magnification: 2450 X

5 μ

Note intimate dispersion of bacteria throughout fuel sample.

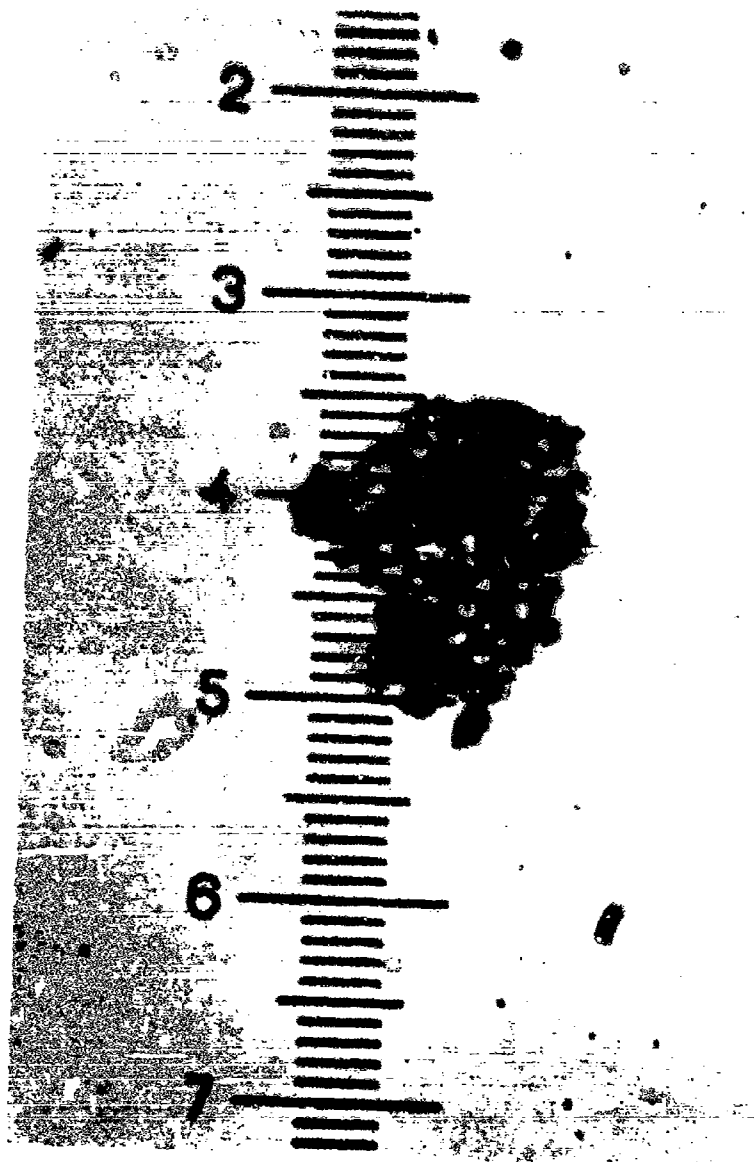


Figure 29.

Chemical Dryer Effluent

Total magnification: 2450 X

5 μ

Note bacterial clump in center of photograph.

ELECTRON MICROSCOPY SECTION

Electronphotomicrographs, Figures 30 Through 33

Microscope: Phillips Model EM-75

Continually variable magnification of
1500 - 15,000 diameters. Resolving
power, 75 angstroms.

Camera: Phillips, 35-mm

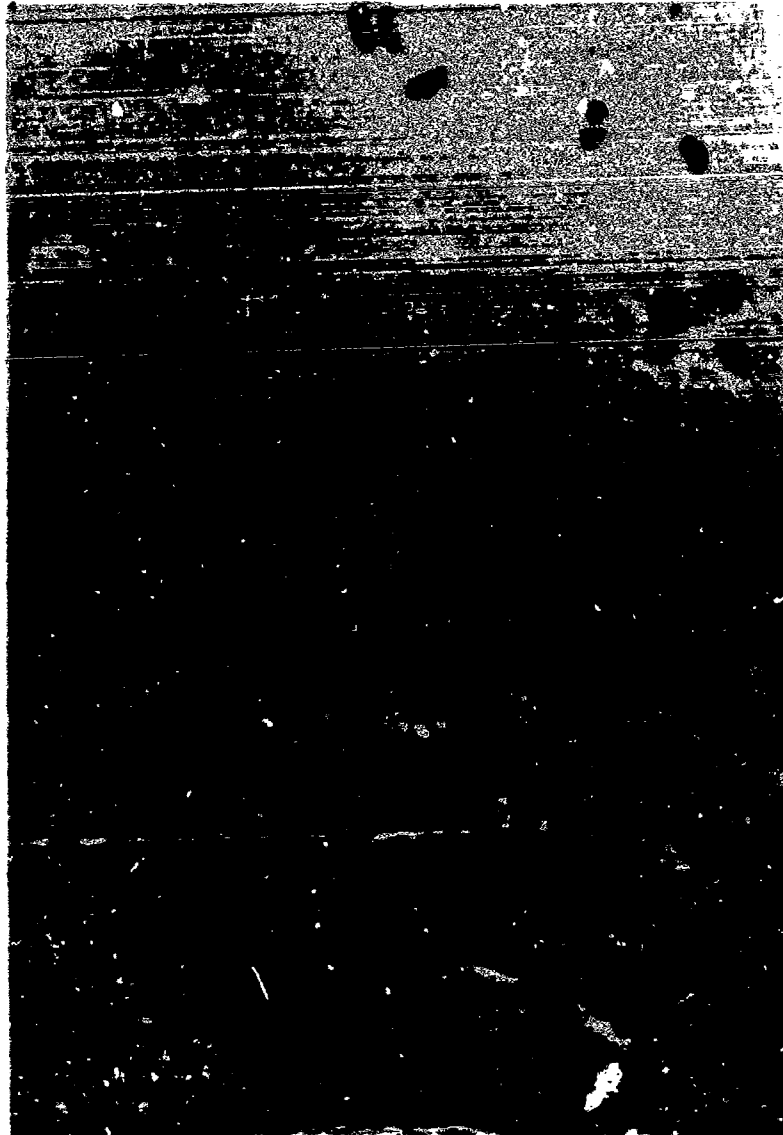


Figure 30.

Typical Bacteria
Pseudomonas Species

Total magnification: 7500 diameters





Figure 31.

Typical Fungi
Hormodendrum Species

Total magnification: 7500 diameters

U .

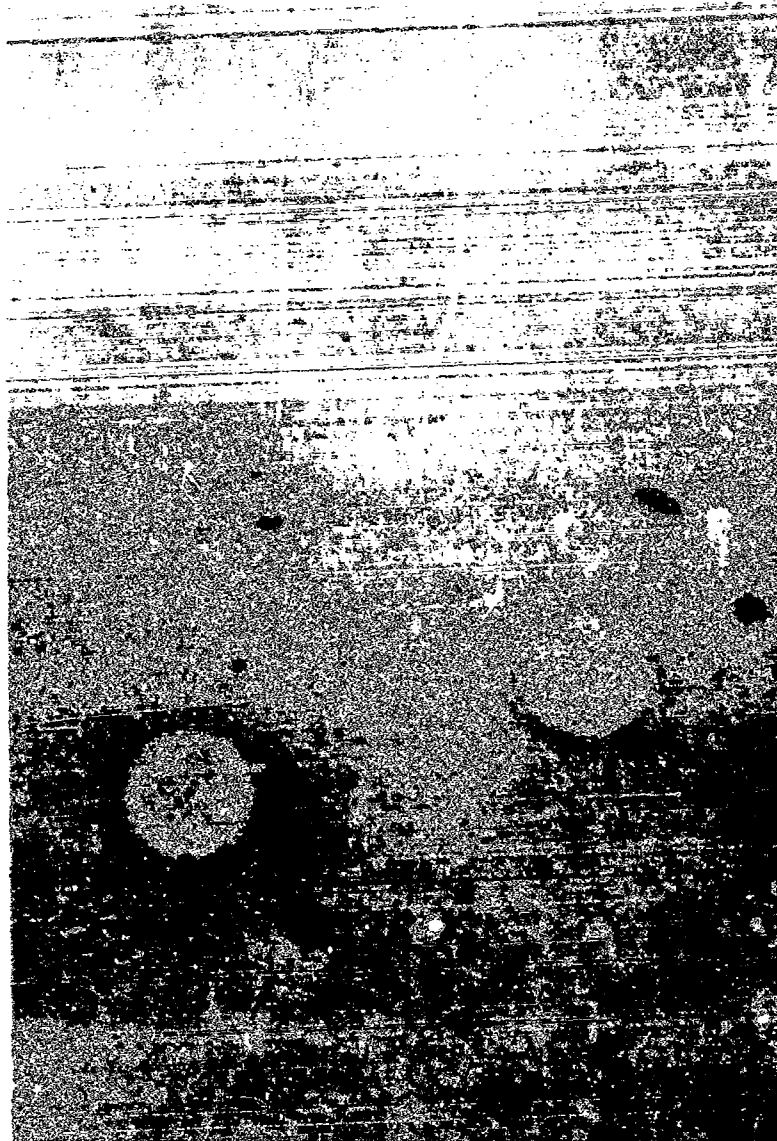


Figure 32.

Uninoculated JP-6 Fuel in Charge Drum

Total magnification: 7500 diameters



- Note: 1. Large spheres present due to collodion film.
2. Darkened areas due to inorganic and not biological particles.

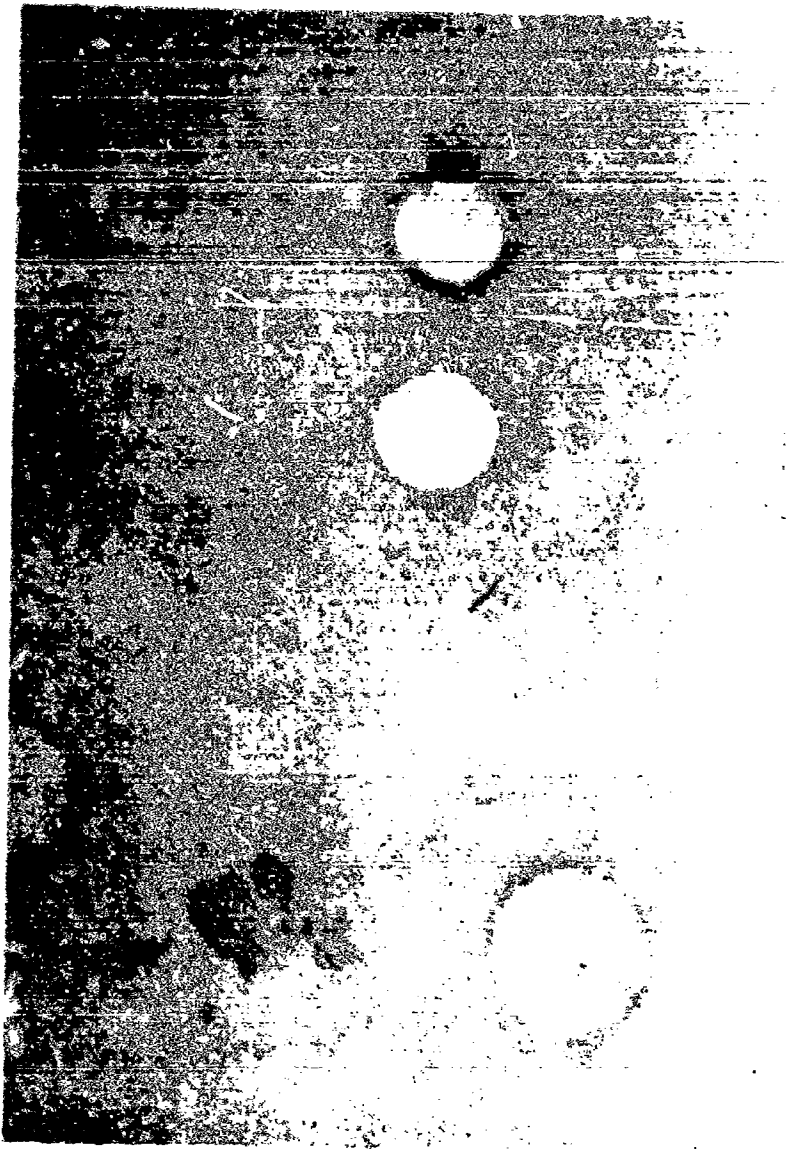


Figure 33.

Reclamation Filter Effluent

Total magnification: 7500 diameters

111

- Note: 1. Dark particle present due to aerial contamination of grid.
2. Cleanliness of fuel at this point.



Figure 34. Fungi from Top Entrance Layer in Filter Media

(Optical Micrograph) Total magnification: 2450 X

511

Note fungi present at top of filter media.

Figure 35. Bottom Exit Layer in Filter Media - Fungi Specimen

(Optical Micrograph) Total magnification: 1250 X

10μ

Note absence of fungi at bottom of filter media.



Figure 36. Bacteria from Top Entrance Layer in Filter Media

(Optical Micrograph) Total magnification: 1250 X

10 μ

Note presence of bacteria at top of filter media.

Figure 37. Bottom Exit Layer in Filter Media - Bacteria Specimen

(Optical Micrograph) Total magnification: 1250 X

10 μ

Note absence of bacteria in bottom of filter media.



Figure 38. Inoculated Fuel Charge to Coker - Bacteria and Fungi
(Optical Micrograph) Total magnification: 1250 X

10 μ

Note presence of bacteria and fungi in fuel charge to coker.



Figure 39. Coker Effluent from Inoculated Fuel - Bacteria and Fungi

(Optical Micrograph) Total magnification: 1250 X

10μ

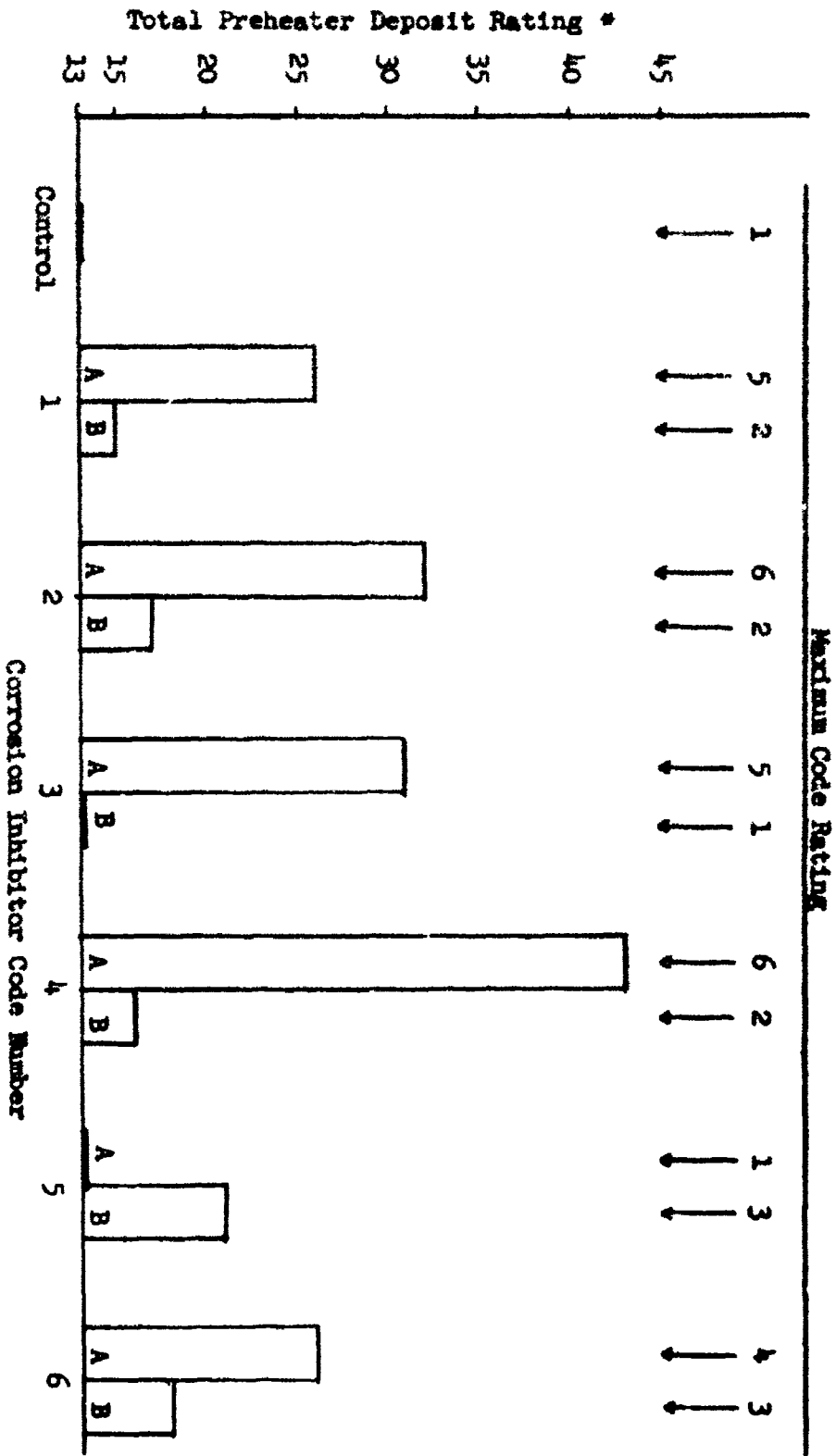
Note presence of bacteria and fungi in fuel effluent from coker.



Figure 40. Effect of Biological Contaminant on Coker Preheater Tube

Note slight deposit at top of tube after inoculation.

After inoculation, preheater code No. 2
Before inoculation, preheater code No. 1



A - Control Fuel with addition of corrosion inhibitor
 B - Control Fuel with addition of corrosion inhibitor, followed by reclamation filtration

* The "Total Preheater Deposit Rating" is defined as the sum of the code rating numbers on the thirteen individual sections of the coker preheater tube as rated by the tuberator.

Figure 41. Effect of Corrosion Inhibitors on Coker Ratings at 450/550/6

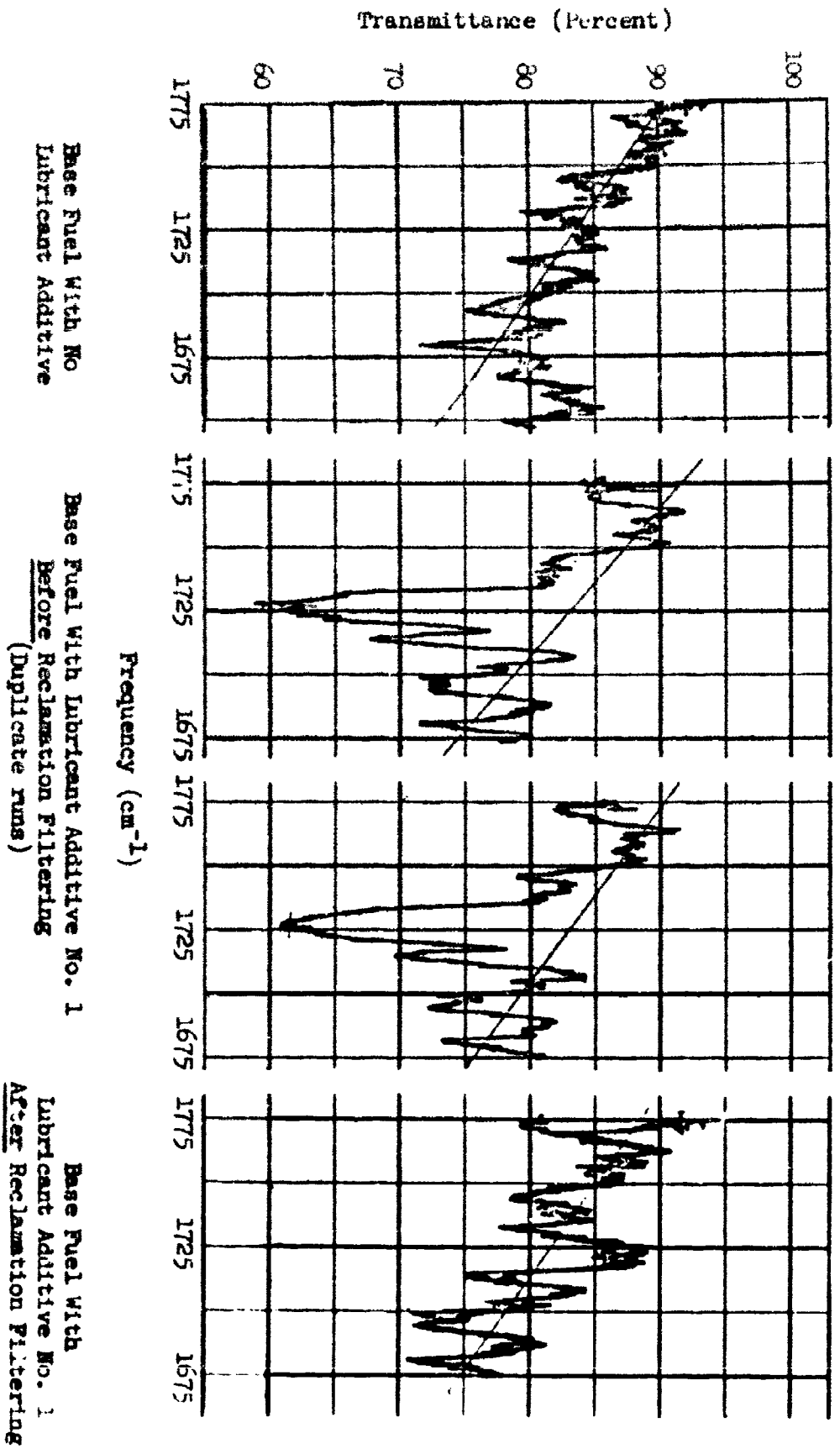
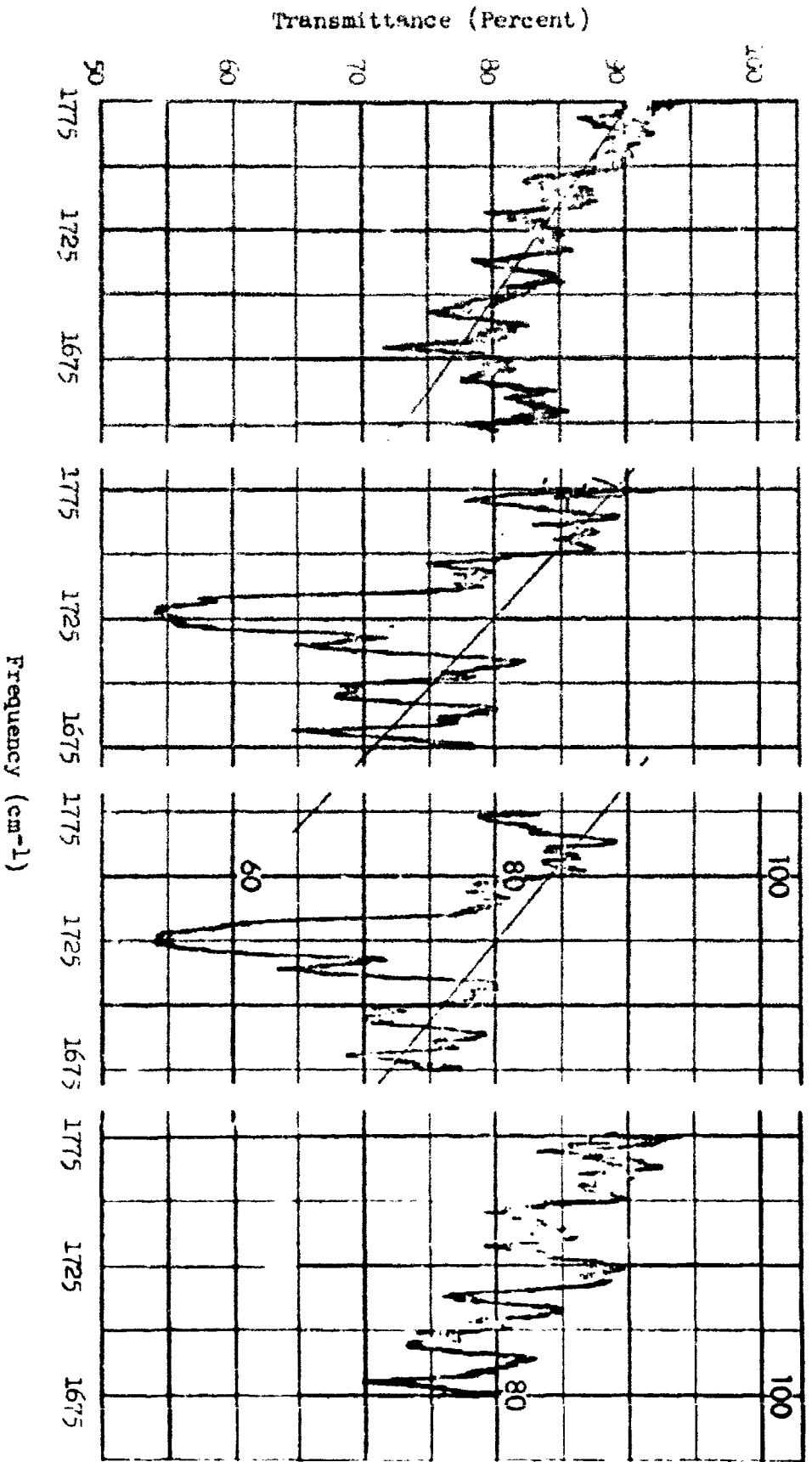


Figure 42. Removal of Lubricant Additive No. 1 from Fuel by Reclamation Filtering
Infrared Spectra by Monsanto's Dayton Laboratories

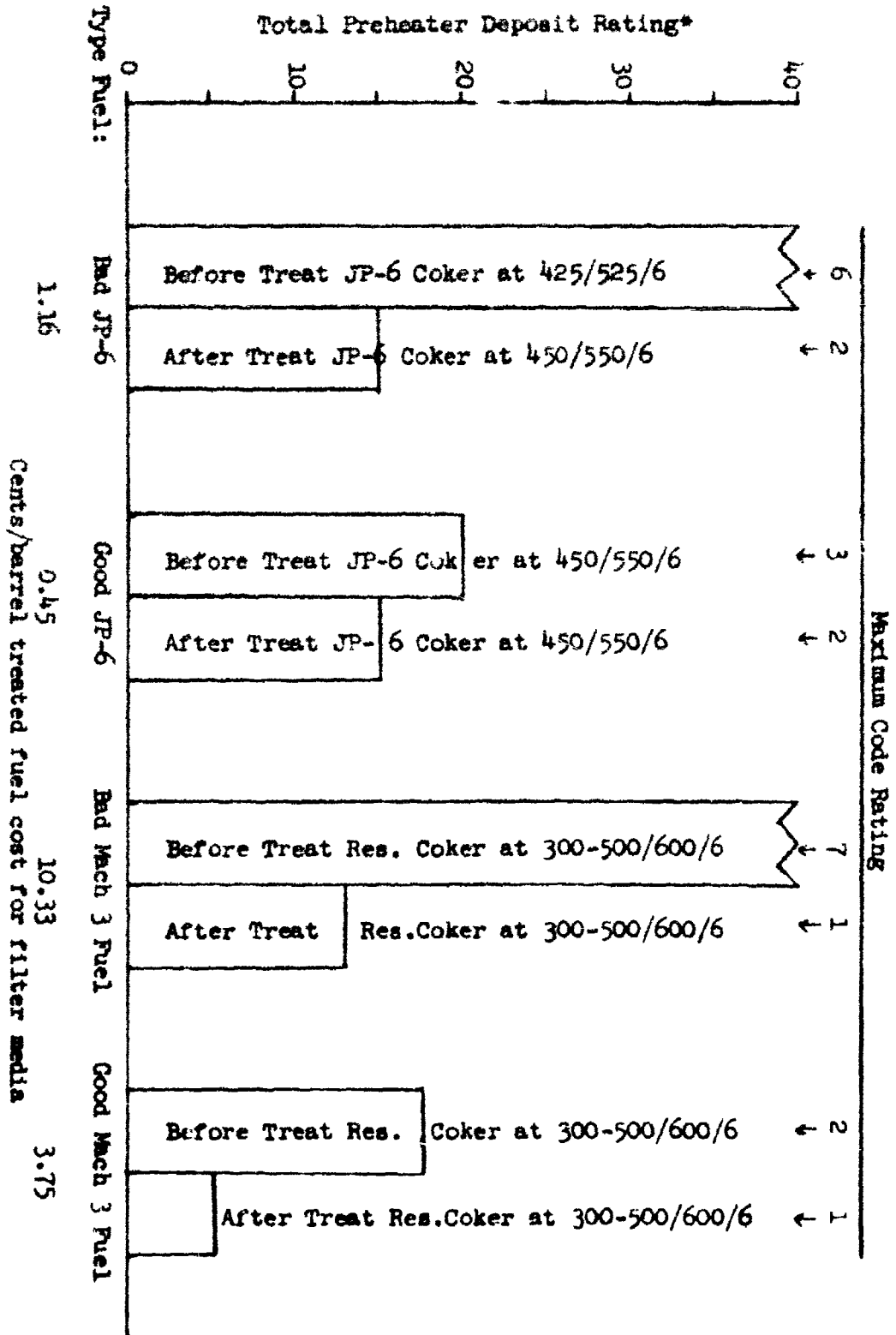


Base Fuel With No Lubricant Additive

Base Fuel With Lubricant Additive No. 2 Before Reclamation Filtering (Duplicate runs)

Base Fuel With Lubricant Additive No. 2 After Reclamation Filtering

Figure 43. Removal of Lubricant Additive No. 2 from Fuel by Reclamation Filtering
Infrared Spectra by Monsanto's Dayton Laboratories



* The "Total Preheater Deposit Rating" is defined as the sum of the code rating numbers on the thirteen individual squares of the coker preheater tube as rated by the tubercator.

Figure 44. Filter Media Life Expressed as ϕ /bbl Treating Cost

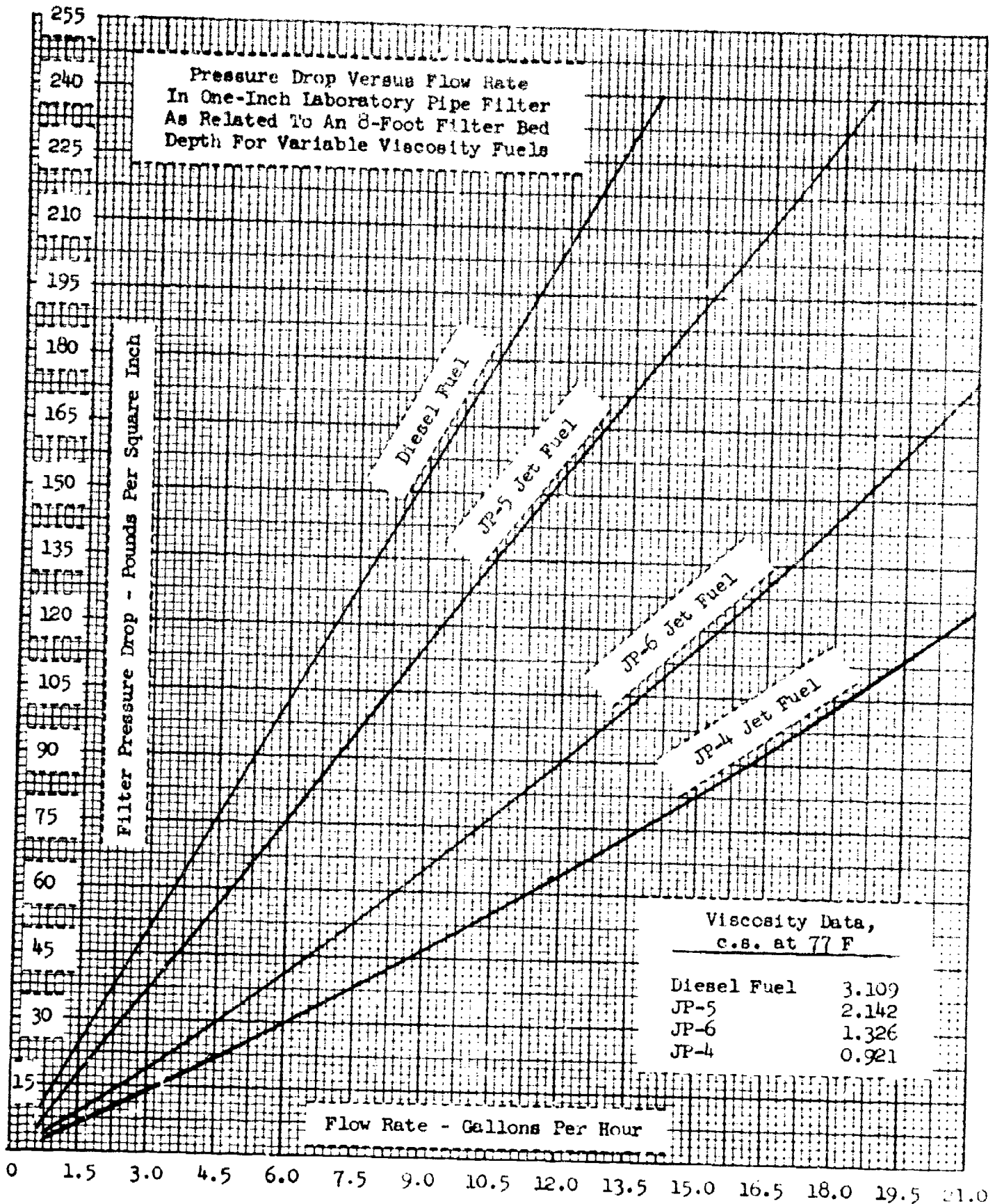


Figure 45. Filter Design Data With Varying Viscosities

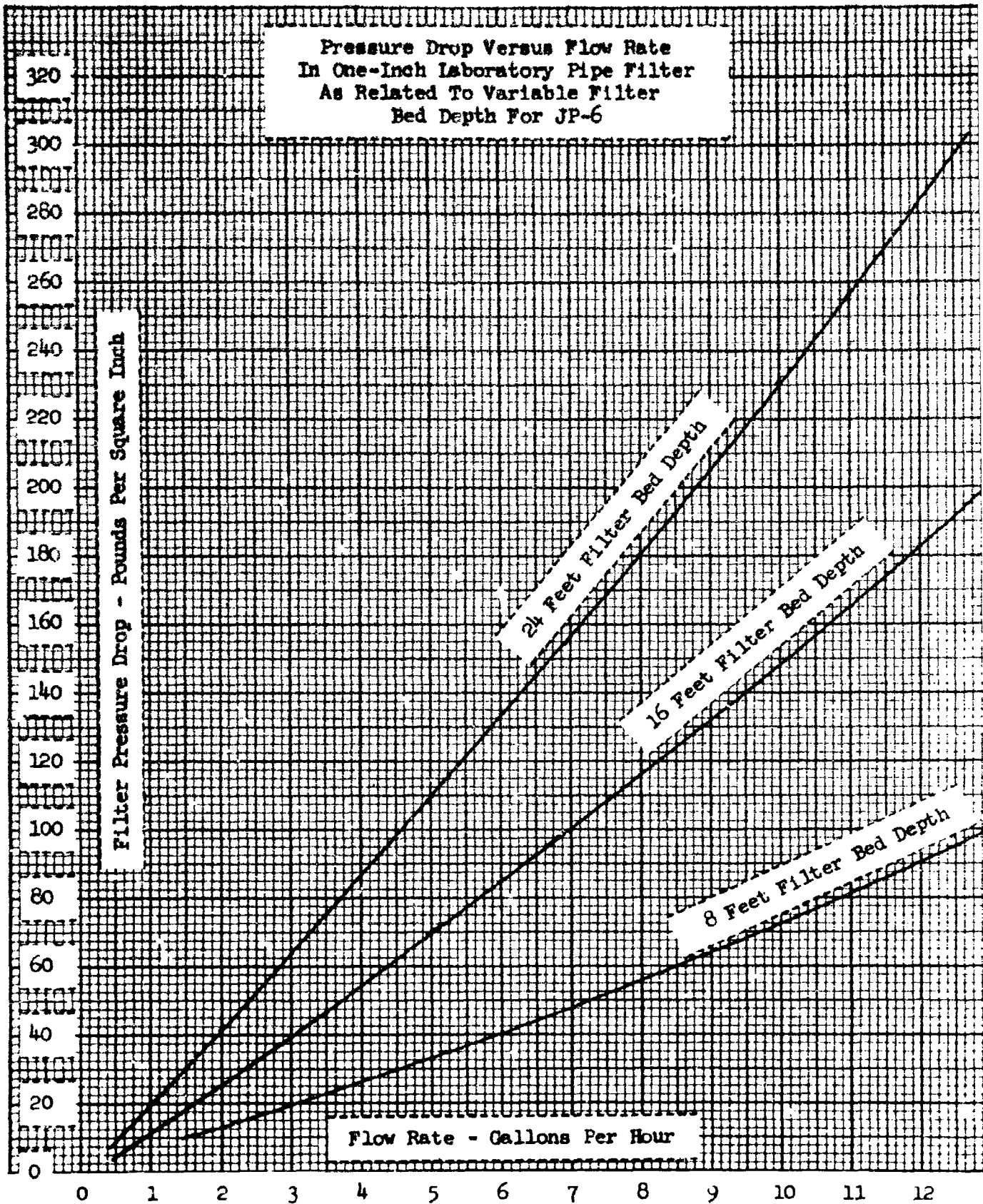


Figure 46. Filter Design Data With Varying Filter Bed Depths

Table 1

Test Data on Redistillation Fractions

	Reclaim No. 11		Reclaim No. 12	
	<u>95% Overhead</u>	<u>5% Residue</u>	<u>95% Overhead</u>	<u>5% Residue</u>
<u>Coker (450/550/6)</u>				
Preheater, max code	3	8	2	8
Diff. Pressure, in. Hg	0.3	>25	0.3	>25
<u>Coker (450/550/6) Plus Reclamation Filter</u>				
Preheater, max code	1	--	1	--
Diff. Pressure, in. Hg	0.3	--	0.0	--
Metal Deactivator, lbs/1000 bbls	0.95	16.7	0.83	14.9
Paraphenylenediamine*, lbs/1000 bbls	Nil	1.05	Nil	0.70
Corrosion, copper strip at 212 F	3A	1B	3A	1B
Copper, ppb	Nil	40	Nil	80
Indene, ppm	46	900	44	865
Lead, ppb	40	5110	51	4333
Naphthalene, weight %	0.07	0.61	0.07	0.56
Nitrogen: Basic, ppm	1.9	11.5	2.1	6.5
Pyrrole, ppm	0.2	0.4	0.3	0.3
Peroxide, ppm	1.68	16.64	1.44	11.60
Sodium, ppm	2.00	5.55	1.75	14.73
Sulfonate, ppm	0.08	1.13	0.12	1.20

* Analyzed before readdition of antioxidant

Table 2
Code Identification for Air Force Furnished Fuels

<u>Contractor Fuel Code No.</u>	<u>Air Force Code</u>	<u>Type</u>	<u>ASTM-CRC Coker Break Point Temperature</u>	
			<u>Preheater, °F</u>	<u>Filter, °F</u>
Reclaim No. 1	SF6-6201	JP-6	425	525
Reclaim No. 2	SF6-6202	JP-6	425	500
Reclaim No. 3	SF6-6203	JP-6	425	500
Reclaim No. 4	TSF-6206	*TSJF	425	500
Reclaim No. 5	SF6-6207	JP-6	425+	525
Reclaim No. 6	SF6-6208	JP-6	425+	500
Reclaim No. 7	SF6-6209	JP-6	400	500
Reclaim No. 8	SF6-6213	JP-6	425+	525
Reclaim No. 9	SF6-6214	JP-6	425+	525+
Reclaim No. 10	TSF-6312	*TSJF	400	475

* Thermally Stable Jet Fuel, MIL-F-25524A (USAF)

Table 3

Code Identification for Contractor Blended Fuels

Contractor Fuel Code No.	Source	Type	ASTM-CRC Coker Break Point Temperature	
			Preheater, °F	Filter, °F
Reclaim No. 11	Ashland Tk 76	JP-6	375	525
Reclaim No. 12	Ashland Tk 78	JP-6	375	550
Reclaim No. 13	50% Ash. Tk 78 50% Fresh JP-6 No additives	JP-6	425	575
Reclaim No. 14	50% Ash. Tk 78 50% Fresh JP-6 With additives	JP-6	450	575
Reclaim No. 15	50% Ash. Tk 78 50% Fresh TSJF With additives	*TSJF	425	550
Reclaim No. 16	50% Ash. Tk 78 50% Fresh JP-6 With anti-icing	JP-6	375	500
Reclaim No. 17	10% Ash. Tk 78 90% Fresh JP-6 No additives	JP-6	400	525
Reclaim No. 18	10% Ash. Tk 78 90% Fresh JP-6 With additives	JP-6	450	575
Reclaim No. 19	10% Ash. Tk 78 90% Fresh JP-6 With additives	JP-6	450	575

* Thermally Stable Jet Fuel, MIL-F-25524A (USAF)

Table 4

Thermal Stability Data for Doctor Treated Kerosene

As Received (No Treatment)

<u>Coker Conditions</u>	<u>Preheater</u>	<u>ΔP-Minutes</u>
325/425/6	11111111111111	3.0-300
350/450/6	11111111111111	25.0-175
375/475/6	1111111112321	25.0-263

Following Processing by Reclamation Filter

<u>Coker Conditions</u>	<u>Preheater</u>	<u>ΔP-Minutes</u>
400/500/6	11111111111111	0.3-300
450/550/6	11111111111111	0.0-300
475/575/6	1111111233331	0.2-300

Note: The analysis of the original doctor treated kerosene (Table 5) is representative of all the fuels used for the research work shown above.

Table 5

Analysis of Doctor Treated Kerosene

Gravity, °API	43.7
Distillation: IBP, °F	342
10% Evap., °F	354
50% Evap., °F	406
90% Evap., °F	460
EP, °F	482
Residue, volume %	1
Loss, volume %	0
Saybolt Color	25
Freezing Point, °F	-56
Viscosity, cs at -30 F	8.26
Flash Point, °F	132
Gum: Existent, mg/100 ml	2.0
Potential, mg/100 ml	3.6
Water Tolerance: Interface	1
Vol. change	0
Water Separometer: WSIM	89
Moisture, ppm	58
Net Heat of Combustion, Btu/lb	18602
Aniline-Gravity Product	6297
Corrosion	1A
Sulfur: Mercaptan, weight %	0.001
Total, weight %	0.063
Doctor Test	Sweet
Aromatics, volume %	12.3
Olefins, volume %	3.0
Smoke Point, mm	26
Naphthalene, weight %	2.02
Copper, ppb	8.8
Indene, ppm	38
Iron, ppm	0.05
Lead, ppb	34.7
Nitrogen: Basic, ppm	1.8
Pyrrole, ppm	0.93
Peroxide, ppm	0.89
Phenol, ppm	70
Saponification Number	0.20
Sodium, ppm	4.64
Sulfonate, ppm	Nil

Table 6

Physical and Chemical Tests on Fuels

Reclaim No. 1

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		50.0	
Distillation: IBP, °F		290	
10% Evap., °F		305	
50% Evap., °F		326	
90% Evap., °F		360	
EP, °F		404	
Residue, volume %		1.0	
Loss, volume %		1.0	
Saybolt Color		Yellow	
Freezing Point, °F		-70-	
Viscosity, cs at -40 F		3.70	
Particulate Matter, mg/gal, 0.45 μ Filter		1.1	
Gum: Existent, mg/100 ml		0.4	0.8
Potential, mg/100 ml		2.1	5.4
Water Reaction Index		1	
Water Separometer: WSI		82.3	
WSIM		56.0	
Moisture, ppm		48.0	
Specific Heat at 300 F		0.612	
Net Heat of Combustion, Btu/lb		18,725	
Aniline-Gravity Product		7475	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.044	
Doctor Test		Sweet	
Aromatics, volume %		9.5	
Olefins, volume %	1.0	0.9	
Smoke Point, mm		25.0	
Naphthalene, weight %	0.25	0.10	0.06
Copper, ppb	35.0	50.0	4.0
Indene, ppm	61	9	34
Iron, ppm	28	0.68	
Lead, ppb		22.8	27.2
Nitrogen: Basic, ppm	2.1	1.9	0.6
Pyrrrole, ppm	0.3	0.1	N11
Oxygen, Dissolved, ppm		35.0	
Peroxide, ppm		1.50	0.44
Sodium, ppm		2.39	4.85
Sulfonate, ppm		0.055	N11

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 2

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		49.8	
Distillation: IBP, °F		290	
10% Evap., °F		300	
50% Evap., °F		316	
90% Evap., °F		344	
EP, °F		384	
Residue, volume %		0.5	
Loss, volume %		0.5	
Saybolt Color		+30	
Freezing Point, °F		-70-	
Viscosity, cs at -40 F		3.52	
Particulate Matter, mg/gal, 0.45µ Filter		1.1	
Gum: Existent, mg/100 ml		0.2	0.2
Potential, mg/100 ml		2.1	2.8
Water Reaction Index		1	
Water Separometer: WSI		85.6	
WSIM		57.0	
Moisture, ppm		45.0	51.9
Specific Heat at 300 F		0.612	
Net Heat of Combustion, Btu/lb		18,625	
Aniline-Gravity Product		6524	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.052	
Doctor Test		Sweet	
Aromatics, volume %		8.2	
Olefins, volume %	3.1	3.1	
Smoke Point, mm		23.0	
Naphthalene, weight %	0.07	0.02	0.10
Copper, ppb	33.0	38.0	15.0
Indene, ppm	6	0	3
Iron, ppm	17	0.42	
Lead, ppb		14.2	25.3
Nitrogen: Basic, ppm	0.7	<1.0	7.3
Pyrrole, ppm	0.2	0.1	Nil
Oxygen, Dissolved, ppm		32.5	
Peroxide, ppm		0.50	0.44
Sodium, ppm		0.00	3.00
Sulfonate, ppm		0.029	Nil

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 3

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		49.8	
Distillation: IBP, °F		290	
10% Evap., °F		304	
50% Evap., °F		318	
90% Evap., °F		344	
EP, °F		379	
Residue, volume %		1.0	
Loss, volume %		0.5	
Saybolt Color		+30	
Freezing Point, °F		-70-	
Viscosity, cs at -40 F		3.28	
Particulate Matter, mg/gal, 0.45µ Filter		1.3	
Gum: Existent, mg/100 ml		0.2	0.4
Potential, mg/100 ml		0.6	0.6
Water Reaction Index		1	
Water Separator: WSI		89.7	
WSIM		58.0	
Moisture, ppm		34.3	45.6
Specific Heat at 300 F		0.612	
Net Heat of Combustion, Btu/lb		18,623	
Aniline-Gravity Product		6499	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.053	
Doctor Test		Sweet	
Aromatics, volume %		10.5	
Olefins, volume %	2.8	1.2	
Smoke Point, mm		28.0	
Naphthalene, weight %	0.14	0.04	0.04
Copper, ppb	26.0	11.0	10.0
Indene, ppm	6	1	17
Iron, ppm	18.0	0.62	
Lead, ppb		16.0	
Nitrogen: Basic, ppm	1.3	2.0	24.7
Pyrrole, ppm	0.2	0.2	7.3
Oxygen, Dissolved, ppm		0.2	Nil
Peroxide, ppm		31.7	
Sodium, ppm		0.80	0.20
Sulfonate, ppm		1.00	5.01
		0.110	Nil

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 4

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		47.9	
Distillation: IBP, °F		326	
10% Evap., °F		340	
50% Evap., °F		358	
90% Evap., °F		400	
EP, °F		440	
Residue, volume %		1.0	
Loss, volume %		1.5	
Saybolt Color		+23	
Freezing Point, °F		-80	
Viscosity, cs at -40 F		5.13	
Particulate Matter, mg/gal, 0.45 μ Filter		1.9	
Gum: Existing, mg/100 ml		0.2	0.2
Potential, mg/100 ml		1.2	1.7
Water Reaction Index		1	
Water Separometer: WSI		98.7	
WSIM		36.0	
Moisture, ppm		38.2	
Specific Heat at 300 F		0.608	
Net Heat of Combustion, Btu/lb		18,639	
Aniline-Gravity Product		6658	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.032	
Doctor Test		Sweet	
Aromatics, volume %		11.7	
Olefins, volume %		0.6	
Smoke Point, mm		27.0	
Naphthalene, weight %		0.29	0.04
Copper, ppb		24.0	12.5
Indene, ppm		5	33
Iron, ppm		0.61	
Lead, ppb		4.0	
Nitrogen: Basic, ppm		3.8	4.4
Pyrrole, ppm	0.5	0.1	Nil
Oxygen, Dissolved, ppm		31.4	
Peroxide, ppm		1.70	1.50
Sodium, ppm		1.90	
Sulfonate, ppm		0.110	Nil

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 5

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		50.2	
Distillation: IBP, °F		290	
10% Evap., °F		305	
50% Evap., °F		320	
90% Evap., °F		366	
EP, °F		414	
Residue, volume %		0.4	
Loss, volume %		0.6	
Saybolt Color		+16	
Freezing Point, °F		-70-	
Viscosity, cs at -40 F		3.59	
Particulate Matter, mg/gal, 0.45µ Filter		1.7	
Gum: Existent, mg/100 ml		0.0	0.4
Potential, mg/100 ml		2.0	1.6
Water Reaction Index		1	
Water Separator: WSI		83.9	
WSIM		47.0	
Moisture, ppm		40.2	
Specific Heat at 300 F		0.612	
Net Heat of Combustion, Btu/lb		18,646	
Aniline-Gravity Product		6727	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.021	
Doctor Test		Sweet	
Aromatics, volume %		9.4	
Olefins, volume %	0.7	0.8	
Smoke Point, mm		30.0	
Naphthalene, weight %	0.19	0.11	0.10
Copper, ppb	137.0	18.0	5.0
Indene, ppm	96	14	37
Iron, ppm		0.28	
Lead, ppb		10.8	
Nitrogen: Basic, ppm	1.6	4.0	4.4
Pyrrole, ppm	0.3	0.1	Nil
Oxygen, Dissolved, ppm		41.4	
Peroxide, ppm		0.70	0.44
Sodium, ppm		2.85	
Sulfonate, ppm		0.005	Nil

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 6

	<u>Before Treat.</u>	<u>After Treat.</u>	<u>Aged After Treat.</u>
Gravity, °API		49.7	
Distillation: IBP, °F		290	
10% Evap., °F		302	
50% Evap., °F		312	
90% Evap., °F		337	
EP, °F		390	
Residue, volume %		0.7	
Loss, volume %		1.3	
Saybolt Color		+30	
Freezing Point, °F		-70	
Viscosity, cs at -40 F		3.31	
Particulate Matter, mg/gal, 0.45µ Filter		1.5	
Gum: Existent, mg/100 ml		0.0	0.4
Potential, mg/100 ml		2.6	5.2
Water Reaction Index		1	
Water Separometer: WSI		93.0	
WSIM		41.0	
Moisture, ppm		53.1	
Specific Heat at 300 F		0.611	
Net Heat of Combustion, Btu/lb		18,606	
Aniline-Gravity Product		6337	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.023	
Doctor Test		Sweet	
Aromatics, volume %		12.1	
Olefins, volume %	1.2	0.5	
Smoke Point, mm		28.0	
Naphthalene, weight %	0.12	0.02	0.21
Copper, ppb	15.0	25.0	9.0
Indene, ppm	8	0	
Iron, ppm		0.38	
Lead, ppb		9.4	
Nitrogen: Basic, ppm	1.1	2.0	4.4
Pyrrole, ppm	0.2	0.1	Nil
Oxygen, Dissolved, ppm		38.6	
Peroxide, ppm		0.60	0.36
Sodium, ppm		0.76	
Sulfonate, ppm		0.014	Nil

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 7

	<u>Before</u> <u>Treat</u>	<u>After</u> <u>Treat</u>	<u>Aged</u> <u>After</u> <u>Treat</u>
Gravity, °API		49.0	
Distillation: IBP, °F		300	
10% Evap., °F		311	
50% Evap., °F		334	
90% Evap., °F		372	
EP, °F		412	
Residue, volume %		0.5	
Loss, volume %		0.5	
Saybolt Color		+16	
Freezing Point, °F		-70-	
Viscosity, cs at 40 F		4.27	
Particulate Matter, mg/gal, 0.45 μ Filter		2.2	
Gum: Existent, mg/100 ml		1.0	0.8
Potential, mg/100 ml		1.0	1.4
Water Reaction Index		1	
Water Separometer: WSI		99.7	
WSIM		58.0	
Moisture, ppm		39.2	
Specific Heat at 300 F		0.610	
Net Heat of Combustion, Btu/lb		18,632	
Aniline-Gravity Product		6591	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.018	
Doctor Test		Sweet	
Aromatics, volume %		11.6	
Olefins, volume %	0.7	0.6	
Smoke Point, mm		30.0	
Naphthalene, weight %	0.39	0.17	0.17
Copper, ppb	146.0	<10.0	7.0
Indene, ppm	145	0	
Iron, ppm	128	0.72	
Lead, ppb		19.9	
Nitrogen: Basic, ppm	1.7	<1.0	4.4
Pyrrole, ppm	0.2	0.1	N11
Oxygen, Dissolved, ppm		31.6	
Peroxide, ppm		0.90	0.53
Sodium, ppm		2.11	
Sulfonate, ppm		0.160	N11

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 8

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		48.8	
Distillation: IBP, °F		304	
10% Evap., °F		320	
50% Evap., °F		340	
90% Evap., °F		377	
EP, °F		414	
Residue, volume %		0.2	
Loss, volume %		0.8	
Saybolt Color		+16	
Freezing Point, °F		-70-	
Viscosity, cs at -40 F		4.37	
Particulate Matter, mg/gal, 0.45 μ Filter		1.0	
Gum: Existent, mg/100 ml		1.8	0.2
Potential, mg/100 ml		3.0	3.5
Water Reaction Index		1	
Water Separator: WSI		86.0	
WSIM		39.0	
Moisture, ppm		32.3	
Specific Heat at 300 F		0.610	
Net Heat of Combustion, Btu/lb		18,635	
Aniline-Gravity Product		6612	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.022	
Doctor Test		Sweet	
Aromatics, volume %		11.1	
Olefins, volume %	0.8	0.7	
Smoke Point, mm		29.5	
Naphthalene, weight %	0.42	0.21	0.15
Copper, ppb	49.0	<10.0	20.0
Indene, ppm	94	14	
Iron, ppm	262	0.63	
Lead, ppb		19.1	27.8
Nitrogen: Basic, ppm	1.9	1.0	4.4
Pyrrole, ppm	0.3	0.1	
Oxygen, Dissolved, ppm		38.2	
Peroxide, ppm		0.60	0.44
Sodium, ppm		0.00	
Sulfonate, ppm		0.180	0.002

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 9

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		49.4	
Distillation: IBP, °F		300	
10% Evap., °F		314	
50% Evap., °F		332	
90% Evap., °F		370	
EP, °F		400	
Residue, volume %		0.4	
Loss, volume %		0.6	
Saybolt Color		+16	
Freezing Point, °F		-70-	
Viscosity, cs at -40 F		5.09	
Particulate Matter, mg/gal, 0.45 μ Filter		3.2	
Gum: Existent, mg/100 ml		1.2	0.2
Potential, mg/100 ml		1.0	1.9
Water Reaction Index		1	
Water Separometer: WSI		86.3	
WSIM		37.0	
Moisture, ppm		38.2	
Specific Heat at 300 F		0.611	
Net Heat of Combustion, Btu/lb		18,638	
Aniline-Gravity Product		6644	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0006	
Total, weight %		0.019	
Doctor Test		Sweet	
Aromatics, volume %		11.4	
Olefins, volume %	1.1	0.9	
Smoke Point, mm		30.0	
Naphthalene, weight %	0.29	0.18	0.09
Copper, ppb	48.0	10.0	11.3
Indene, ppm	95	8	
Iron, ppm	90	0.72	
Lead, ppb		16.3	25.3
Nitrogen: Basic, ppm	2.1	1.0	3.5
Pyrrole, ppm	0.3	0.1	
Oxygen, Dissolved, ppm		40.3	
Peroxide, ppm		1.42	0.36
Sodium, ppm		2.05	
Sulfonate, ppm		0.000	N11

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 10

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API		47.6	
Distillation: IBP, °F		316	
10% Evap., °F		332	
50% Evap., °F		358	
90% Evap., °F		390	
EP, °F		420	
Residue, volume %		0.3	
Loss, volume %		0.7	
Saybolt Color		+28	
Freezing Point, °F		-80-	
Viscosity, cs at -40 F		5.53	
Particulate Matter, mg/gal, 0.45 μ Filter		2.1	
Gum: Existent, mg/100 ml		0.8	0.4
Potential, mg/100 ml		1.4	5.8
Water Reaction Index		1	
Water Separometer: WSI		74.3	
WSIM		28.0	
Moisture, ppm		53.9	
Specific Heat at 300 F		0.607	
Net Heat of Combustion, Btu/lb		18,628	
Aniline-Gravity Product		6545	
Corrosion, copper strip at 212 F		1A	
Sulfur: Mercaptan, weight %		0.0030	
Total, weight %		0.025	
Doctor Test		Sour	
Aromatics, volume %		12.8	
Olefins, volume %	0.7	0.8	
Smoke Point, mm		28.0	
Naphthalene, weight %	0.81	0.13	0.27
Copper, ppb	13.0	13.0	10.0
Indene, ppm	38	16	
Iron, ppm	59	1.11	
Lead, ppb		22.0	25.3
Nitrogen: Basic, ppm	1.7	1.0	5.3
Pyrrole, ppm	0.2	0.1	
Oxygen, Dissolved, ppm		37.7	
Peroxide, ppm		1.36	0.44
Sodium, ppm		0.65	
Sulfonate, ppm		0.054	0.062

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 11

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API	46.5	46.5	
Distillation: IBP, °F	330	325	
10% Evap., °F	340	334	
50% Evap., °F	355	356	
90% Evap., °F	376	378	
EP, °F	416	412	
Residue, volume %	0.5	1.2	
Loss, volume %	1.0	1.3	
Saybolt Color	+15	+30	
Freezing Point, °F	-70-	-80-	
Viscosity, cs at -40 F	5.52	4.99	
Particulate Matter, mg/gal, 0.8 μ Filter	2.3	--	
0.45 μ Filter	7.6	1.5	
Gum: Existent, mg/100 ml	0.4	0.6	0.2
Potential, mg/100 ml	4.3	2.8	1.2
Water Reaction Index	4	1	
Water Separator: WSI	8.3	89.3	
WSIM	27.0	55.0	
Moisture, ppm	36.0	28.8	16.3
Specific Heat at 300 F	0.607	0.605	
Net Heat of Combustion, Btu/lb	18,615	18,604	
Aniline-Gravity Product	6426	6314	
Corrosion, copper strip at 212 F	3B	1B	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.016	0.020	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	11.7	12.6	
Olefins, volume %	3.0	1.5	
Smoke Point, mm	23.0	24.0	
Naphthalene, weight %	0.11	0.11	0.19
Copper, ppb	30.0	49.0	12.5
Indene, ppm	89	51	62
Iron, ppm	0.32	0.002	
Lead, ppb	55.6	2.5	51.4*
Nitrogen: Basic, ppm	3.0	5.0	5.9
Pyrrole, ppm	0.30	0.00	0.21
Oxygen, Dissolved, ppm	32.6	46.0	
Peroxide, ppm	3.40	3.60	0.98
Sodium, ppm	1.86	2.08	1.49
Sulfonate, ppm	0.507	0.100	0.000

* Lead content is abnormally high because of using tin coated storage cans.

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 12

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API	46.5	46.5	
Distillation: IBP, °F	322	324	
10% Evap., °F	340	340	
50% Evap., °F	354	356	
90% Evap., °F	376	378	
EP, °F	412	401	
Residue, volume %	0.7	1.2	
Loss, volume %	1.3	0.8	
Saybolt Color	+15	+30	
Freezing Point, °F	-70-	-80-	
Viscosity, cs at -40 F	5.30	4.84	
Particulate Matter, mg/gal, 0.8 μ Filter	13.2	--	
0.45 μ Filter	15.1	1.9	
Gum: Existent, mg/100 ml	0.2	0.6	0.2
Potential, mg/100 ml	1.2	2.9	1.6
Water Reaction Index	4	1	
Water Separator: WSI	15.6	70.3	
WSIM	44.0	50.0	
Moisture, ppm	62.6	40.8	25.5
Specific Heat at 300 F	0.607	0.605	
Net Heat of Combustion, Btu/lb	18,615	18,604	
Aniline-Gravity Product	6426	6314	
Corrosion, copper strip at 212 F	3B	1A	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.018	0.023	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	11.5	13.1	
Olefins, volume %	2.8	1.6	
Smoke Point, mm	23.0	24.0	
Naphthalene, weight %	0.11	0.10	0.17
Copper, ppb	25.0	49.0	7.0
Indene, ppm	85	56	56
Iron, ppm	0.40	0.01	
Lead, ppb	468	7.5	50.6*
Nitrogen: Basic, ppm	3.0	2.0	5.9
Pyrrole, ppm	0.50	0.20	0.00
Oxygen, Dissolved, ppm	48.5	38.9	
Peroxide, ppm	3.40	2.90	0.71
Sodium, ppm	1.69	1.88	1.51
Sulfonate, ppm	0.356	0.110	0.030

* Lead content is abnormally high because of using tin coated storage cans.

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 13

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API	46.9	46.9	
Distillation: IBP, °F	312	334	
10% Evap., °F	336	340	
50% Evap., °F	351	352	
90% Evap., °F	374	374	
EP, °F	396	416	
Residue, volume %	1.0	1.0	
Loss, volume %	1.0	1.0	
Saybolt Color	+22	+30	
Freezing Point, °F	-70-	-80-	
Viscosity, cs at -40 F	5.19	5.37	
Particulate Matter, mg/gal, 0.45 μ Filter	6.8	3.0	
Gum: Existent, mg/100 ml	0.4	0.2	0.2
Potential, mg/100 ml	3.9	1.9	1.0
Water Reaction Index	1	1	
Water Separator: WSI	62.6	97.6	
WSIM	23.0	43.0	
Moisture, ppm	38.7	28.8	27.5
Specific Heat at 300 F	0.606	0.606	
Net Heat of Combustion, Btu/lb	18,613	18,604	
Aniline-Gravity Product	6402	6322	
Corrosion, copper strip at 212 F	1A	1B	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.039	0.014	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	10.7	13.0	
Olefins, volume %	2.5	1.8	
Smoke Point, mm	26.0	26.0	
Naphthalene, weight %	0.08	0.08	0.12
Copper, ppb	26.0	7.0	10.0
Indene, ppm	44	25	30
Iron, ppm	0.28	0.04	
Lead, ppb	109	5.0	55.1*
Nitrogen: Basic, ppm	<1.0	<1.0	
Pyrrole, ppm	0.50	0.30	0.02
Oxygen, Dissolved, ppm	34.5	50.3	
Peroxide, ppm	1.22	0.89	0.62
Sodium, ppm	3.59	1.12	5.31
Sulfonate, ppm	0.132	0.000	0.005

* Lead content is abnormally high because of using tin coated storage cans.

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 14

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API	46.9	47.1	
Distillation: IBP, °F	318	323	
10% Evap., °F	336	336	
50% Evap., °F	351	350	
90% Evap., °F	374	373	
EP, °F	401	394	
Residue, volume %	0.5	1.0	
Loss, volume %	1.5	1.0	
Saybolt Color	+22	+25	
Freezing Point, °F	-70-	-80-	
Viscosity, cs at -40 F	5.13	5.39	
Particulate Matter, mg/gal, 0.45 μ Filter	1.5	3.0	
Gum: Existent, mg/100 ml	0.6	0.2	0.4
Potential, mg/100 ml	2.7	1.0	1.0
Water Reaction Index	1	1	
Water Separometer: WSI	55.7	97.3	
WSIM	28.0	64.0	
Moisture, ppm	44.7	12.0	23.5
Specific Heat at 300 F	0.606	0.606	
Net Heat of Combustion, Btu/lb	18,613	18,607	
Aniline-Gravity Product	6402	6349	
Corrosion, copper strip at 212 F	1A	1B	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.035	0.009	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	13.1	12.0	
Olefins, volume %	1.6	1.9	
Smoke Point, mm	27.0	25.0	
Naphthalene, weight %	0.08	0.08	0.09
Copper, ppb	27.0	3.0	5.0
Indene, ppm	48	20	22
Iron, ppm	0.41	0.40	
Lead, ppb	40.3	20.0	51.9*
Nitrogen: Basic, ppm	<1.0	1.0	
Pyrrole, ppm	0.40	0.10	0.00
Oxygen, Dissolved, ppm	34.5	48.6	
Peroxide, ppm	1.22	0.71	0.62
Sodium, ppm	0.72	0.66	4.36
Sulfonate, ppm	0.129	0.000	0.000

* Lead content is abnormally high because of using tin coated storage cans.

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 15

	Before Treat	After Treat	Aged After Treat
Gravity, °API	46.9	47.0	
Distillation: IBP, °F	322	329	
10% Evap., °F	336	336	
50% Evap., °F	352	350	
90% Evap., °F	376	374	
EP, °F	404	408	
Residue, volume %	1.0	1.0	
Loss, volume %	1.0	1.0	
Saybolt Color	+22	+30	
Freezing Point, °F	-80-	-80-	
Viscosity, cs at -40 F	4.87	5.30	
Particulate Matter, mg/gal, 0.45 μ Filter	4.9	2.0	
Gum: Existent, mg/100 ml	2.4	0.4	0.4
Potential, mg/100 ml	3.7	1.3	1.3
Water Reaction Index	1	1	
Water Separator: WSI	50.9	93.9	
WSIM	22.0	48.0	
Moisture, ppm	42.1	18.6	18.4
Specific Heat at 300 F	0.606	0.606	
Net Heat of Combustion, Btu/lb	18,615	18,607	
Aniline-Gravity Product	6425	6345	
Corrosion, copper strip at 212 F	1A	1B	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.034	0.020	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	10.8	13.6	
Olafins, volume %	2.6	1.6	
Smoke Point, mm	27.0	27.0	
Naphthalene, weight %	0.08	0.08	0.08
Copper, ppb	33.0	<10.0	15.0
Indene, ppm	33	16	33
Iron, ppm	0.92	0.77	
Lead, ppb	37.8	8.5	22.2*
Nitrogen: Basic, ppm	2.0	3.0	3.0
Pyrolic, ppm	0.10	0.10	0.00
Oxygen, Dissolved, ppm	27.6	40.1	
Peroxide, ppm	1.06	0.71	0.58
Sodium, ppm	2.05	2.64	7.59
Sulfonate, ppm	0.177	0.000	0.000

*Lead content is abnormally high because of using tin coated storage cans.

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 16

	Before <u>Treat</u>	After <u>Treat</u>	Aged After <u>Treat</u>
Gravity, °API	46.9	47.1	
Distillation: IBP, °F	322	332	
10% Evap., °F	338	338	
50% Evap., °F	352	352	
90% Evap., °F	370	374	
EP, °F	408	394	
Residue, volume %	0.5	1.0	
Loss, volume %	0.5	1.0	
Saybolt Color	+27	+30	
Freezing Point, °F	-70-	-80-	
Viscosity, cs at -40 F	5.23	5.32	
Particulate Matter, mg/gal, 0.45 μ Filter	2.3	1.2	
Gum: Existent, mg/100 ml	0.6	0.8	0.6
Potential, mg/100 ml	1.8	3.7	1.4
Water Reaction Index	1	1	
Water Separator: WSI	55.6	92.9	
WSIM	26.0	46.0	
Moisture, ppm	34.4	36.9	23.5
Specific Heat at 300 F	0.606	0.606	
Net Heat of Combustion, Btu/lb	18,610	18,612	
Aniline-Gravity Product	6378	6391	
Corrosion, copper strip at 212 F	1A	2A	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.024	0.020	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	11.7	12.7	
Olefins, volume %	1.7	1.4	
Smoke Point, mm	28.0	25.0	
Naphthalene, weight %	0.07	0.08	0.12
Copper, ppb	30.0	<10.0	30.0
Indene, ppm	44	23	28
Iron, ppm	0.40	0.83	
Lead, ppb	92.0	5.1	24.7*
Nitrogen: Basic, ppm	<1.0	6.5	
Pyrrrole, ppm	0.00	0.00	0.00
Oxygen, Dissolved, ppm	25.8	39.4	
Peroxide, ppm	1.22	0.89	0.67
Sodium, ppm	3.08	1.67	6.99
Sulfonate, ppm	0.183	0.000	0.009

*Lead content is abnormally high because of using tin coated storage cans.

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 17

	<u>Before Treat</u>	<u>After Treat</u>	<u>Aged After Treat</u>
Gravity, °API	48.1	48.0	
Distillation: IBP, °F	324	326	
10% Evap., °F	332	332	
50% Evap., °F	342	343	
90% Evap., °F	366	366	
EP, °F	406	388	
Residue, volume %	1.0	1.0	
Loss, volume %	0.0	1.0	
Saybolt Color	+30	+30	
Freezing Point, °F	-80-	-80-	
Viscosity, cs at -40 F	5.21	4.96	
Particulate Matter, mg/gal, 0.45 μ Filter	3.4	2.7	
Gum: Existent, mg/100 ml	0.4	0.4	0.4
Potential, mg/100 ml	1.6	0.6	1.1
Water Reaction Index	1	1	
Water Separator: WSI	71.9	99.7	
WSIM	35.0	50.0	
Moisture, ppm	36.4	38.2	21.4
Specific Heat at 300 F	0.608	0.608	
Net Heat of Combustion, Btu/lb	18,633	18,626	
Aniline-Gravity Product	6595	6528	
Corrosion, copper strip at 212 F	1A	1B	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.023	0.015	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	9.5	10.7	
Olefins, volume %	1.7	1.5	
Smoke Point, mm	25.0	27.0	
Naphthalene, weight %	0.15	0.06	0.10
Copper, ppb	33.0	<10.0	22.5
Indene, ppm	16	7	13
Iron, ppm	0.06	0.22	
Lead, ppb	49.7	27.9	22.2
Nitrogen: Basic, ppm	<1.0	2.8	3.0
Pyrrrole, ppm	0.30	0.30	0.00
Oxygen, Dissolved, ppm	39.6	47.1	
Peroxide, ppm	2.84	0.71	0.62
Sodium, ppm	1.79	0.97	5.06
Sulfonate, ppm	0.039	0.000	0.000

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 18

	<u>Before</u> <u>Treat</u>	<u>After</u> <u>Treat</u>	<u>Aged</u> <u>After</u> <u>Treat</u>
Gravity, °API	47.4	47.2	
Distillation: IBP, °F	328	330	
10% Evap., °F	336	336	
50% Evap., °F	346	348	
90% Evap., °F	368	370	
EP, °F	404	410	
Residue, volume %	1.0	1.0	
Loss, volume %	0.0	1.0	
Saybolt Color	+29	+25	
Freezing Point, °F	-80-	-80-	
Viscosity, cs at -40 F	5.23	5.11	
Particulate Matter, mg/gal, 0.45 μ Filter	4.9	1.9	
Gum: Existent, mg/100 ml	0.4	0.4	0.2
Potential, mg/100 ml	2.0	1.0	1.1
Water Reaction Index	1	1	
Water Separator: WSI	95.0	98.3	
WSIM	27.0	30.0	
Moisture, ppm	42.0	43.7	22.4
Specific Heat at 300 F	0.606	0.606	
Net Heat of Combustion, Btu/lb	18,621	18,615	
Aniline-Gravity Product	6484	6419	
Corrosion, copper strip at 212 F	1A	1A	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.021	0.018	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	11.9	11.6	
Olefins, volume %	1.5	1.5	
Smoke Point, mm	25.0	26.0	
Naphthalene, weight %	0.10	0.06	0.06
Copper, ppb	19.0	<10.0	20.0
Indene, ppm	23	12	12
Iron, ppm	0.34	0.22	
Lead, ppb	52.7	4.6	21.5*
Nitrogen: Basic, ppm	2.5	3.0	3.0
Pyrrole, ppm	0.30	0.30	0.00
Oxygen, Dissolved, ppm	47.9	36.3	
Peroxide, ppm	0.89	0.71	0.62
Sodium, ppm	0.68	0.72	5.06
Sulfonate, ppm	0.035	0.005	0.000

* Lead content is abnormally high because of using tin coated storage cans.

Table 6 (Continued)

Physical and Chemical Tests on Fuels

Reclaim No. 19

	Before Treat	After Treat	Aged After Treat
Gravity, °API	47.3	47.2	
Distillation: IBP, °F	326	328	
10% Evap., °F	334	336	
50% Evap., °F	344	347	
90% Evap., °F	368	370	
EP, °F	403	414	
Residue, volume %	1.0	1.0	
Loss, volume %	1.0	1.0	
Saybolt Color	+27	+25	
Freezing Point, °F	-80-	-80-	
Viscosity, cs at -40 F	5.31	5.12	
Particulate Matter, mg/gal, 0.45 μ Filter	4.5	2.9	
Gum: Existent, mg/100 ml	0.2	0.2	0.4
Potential, mg/100 ml	1.7	3.8	1.0
Water Reaction Index	1	1	
Water Separator: WSI	79.1	99.9	
WSIM	22.0	50.0	
Moisture, ppm	36.4	29.1	53.0
Specific Heat at 300 F	0.606	0.606	
Net Heat of Combustion, Btu/lb	18,620	18,616	
Aniline-Gravity Product	6471	6429	
Corrosion, copper strip at 212 F	1A	1A	
Sulfur: Mercaptan, weight %	0.0006	0.0006	
Total, weight %	0.017	0.027	
Doctor Test	Sweet	Sweet	
Aromatics, volume %	11.0	11.9	
Olefins, volume %	1.7	2.2	
Smoke Point, mm	25.0	26.0	
Naphthalene, weight %	0.11	0.07	0.04
Copper, ppb	43.0	<10.0	5.0
Indene, ppm	18	4	14
Iron, ppm	0.62	0.02	
Lead, ppb	48.3	5.2	24.7*
Nitrogen: Basic, ppm	1.5	2.5	1.5
Pyrrole, ppm	0.30	0.30	N11
Oxygen, Dissolved, ppm	51.1	33.4	
Peroxide, ppm	0.71	0.89	0.31
Sodium, ppm	0.92	0.88	3.00
Sulfonate, ppm	0.000	0.010	0.005

* Lead content is abnormally high because of using tin coated storage cans.

Table 7
 Growth Characteristics of Bacteria
 Pseudomonas Species

<u>Bacterial Designation, University of Dayton</u>	<u>Culture Media, University of Dayton</u>	<u>Culture Media, Contractor</u>	<u>Growth Rate</u>
B-40	B. Haas slant; JP-4	B. Haas liquid; JP-6	Prolific
B-40	TSA slant	B. Haas liquid; JP-6	Moderate
B-40	TSA slant	Nutrient broth	Slight
B-44	B. Haas slant; JP-4	B. Haas liquid; JP-6	Prolific
B-44	TSA slant	B. Haas liquid; JP-6	Slight
B-44	TSA slant	Nutrient broth	Slight
B-54	B. Haas slant; JP-4	B. Haas liquid; JP-6	Prolific
B-54	TSA slant	B. Haas liquid; JP-6	Prolific
B-54	TSA slant	Nutrient broth	Prolific

Table 8
Growth Characteristics of Fungi

<u>Fungal Designation, University of Dayton</u>	<u>Culture Media, University of Dayton</u>	<u>Culture Media, Contractor</u>	<u>Growth Rate</u>
B-29	Sab. agar slant	B. Haas; JP-6	Slight
B-29	Sab. agar slant	Sab. liquid	Prolific
B-55	Sab. agar slant	B. Haas; JP-6	Moderate
B-55	Sab. agar slant	Sab. liquid	Moderate

Notes: B-29 is *Cladosporium resinae* f. *avellaneum*.

B-55 is *Homodendrum hordei*.

Table 9
 Sample Schedule for Biological Research
 Standard Reclamation Filter

<u>Control</u>	<u>Inoculated Drum</u>	<u>Following Chemical Dryer</u>	<u>Following Reclamation Filter</u>
X	X	1 gallon through	1 gallon through
		5 gallons through	5 gallons through
		15 gallons through	15 gallons through

Notes: Column size of chemical dryer: 0.5 inch x 60 inches

Column size of reclamation filter: 1.0 inch x 96 inches

Table 10

Analysis of Extract Removed from Filter Media

<u>Constituents Removed</u>	<u>Weight, %</u>		
	<u>Top</u>	<u>Middle</u>	<u>Bottom</u>
Metal Deactivator	1.38	0.30	0.25
Naphthalene	0.53	0.47	0.26
Sodium	0.099	0.014	0.011
Lead	0.086	0.084	0.056
Indene	0.051	0.025	0.017
Paraphenylenediamine	0.042	0.0008	Nil
Sulfonate	0.0047	0.0011	Nil
Basic Nitrogen	0.0018	0.0002	Nil
Iron	0.0015	0.0015	0.0019
Pyrrole Nitrogen	0.0002	Nil	Nil
Copper	0.00012	Nil	Nil

Table 11
 Analysis of Grease Synthesized and Retained

<u>Constituents</u>	<u>Weight %</u>	<u>PPM</u>
Apparent Naphthalene	8.00	
Sulfur	2.87	
Indene	1.34	13400
Sulfonate	0.078	777
Paraphenylenediamine	0,063	629
Metal Deactivator	0.027	272
Peroxide	0.027	266
Iron	0.020	200
Lead	0.017	172
Copper	0.0017	17.5
Saponification Number	0.0 (Neutral)	
Ash Content	23.68	
Total Analyzed Contaminants	12.44	

Table 12

Effect of Petroleum Sulfonates on Thermal Stability

Reclaim No. 12 (Plus Filtration)

<u>Coker Conditions</u>	<u>Preheater</u>	<u>Diff. Pressure, in. Hg</u>
425/525/6	1111111111111111	
450/550/6	1111111111111111	0.0
475/575/6	11111111111221	0.0
Modified Water Separometer (WSIM):		98.0

Reclaim No. 12 (Plus 2 ppm Petroleum Sulfonate then Plus Filtration)

<u>Coker Conditions</u>	<u>Preheater</u>	<u>Diff. Pressure, in. Hg</u>
475/575/6	1111111111221	0.0
Modified Water Separometer (WSIM):		99.0

Reclaim No. 12 (Plus Filtration then Plus 2 ppm Petroleum Sulfonate)

<u>Coker Conditions</u>	<u>Preheater</u>	<u>Diff. Pressure, in. Hg</u>
475/575/6	111111111121	0.0
Modified Water Separometer (WSIM):		23.0

Reclaim No. 12 (Plus 0.5 ppm Petroleum Sulfonate then Plus Filtration)

Modified Water Separometer (WSIM): 98.0

Reclaim No. 12 (Plus Filtration then Plus 0.5 ppm Petroleum Sulfonate)

Modified Water Separometer (WSIM): 53.0

Table 13

Effect of Peroxides on Thermal Stability

<u>Fuel</u>	Preheater, max code <u>450/550/6</u>
1 JP-6 with no treatment	1
2 JP-6 plus 10 ppm benzoyl peroxides	3
3 Fuel 2 inoculated and filtered	1

Table 14

Effect of Indenes on Thermal Stability

<u>Fuel</u>	Preheater, max code <u>450/550/6</u>
1 JP-6 with no treatment	1
2 JP-6 plus 25 ppm indenes	4
3 Fuel 2 inoculated and filtered	1

Table 15

Effect of Naphthenic Acid on Thermal Stability

<u>Treatment</u>	<u>Operating Conditions</u>	<u>Preheater</u>	<u>Diff. Pressure, in. Hg</u>
Control, JP-6 with no treatment	450/550/6	11111111111111	0.0
Control, JP-6 with no treatment	475/575/6	1111111123331	0.1
JP-6 plus 1 ppm naphthenic acid	450/550/6	1111111112221	0.3
JP-6 plus 3 ppm naphthenic acid	450/550/6	11111111433331	0.0
JP-6 plus 5 ppm naphthenic acid	450/550/6	1111223366443	0.0
JP-6 plus 5 ppm naphthenic acid then reclamation filtration	450/550/6	11111111111111	0.0
Second run for confirmation	450/550/6	11111111111111	0.0

Notes: The last run was a duplicate of the preceding run to confirm that filtration removes naphthenic acid and therefore rehabilitates the fuel.

All treatments were made with the same JP-6 jet fuel.

Table 16

Removal of Elemental Sulfur by Reclamation Filtration

<u>Fuel</u>	<u>Type of Reclamation</u>	<u>Corrosion, copper strip at 212 F</u>	<u>ASTM-CRC Coker Conditions</u>	<u>Preheater</u>
A	Control, no treatment	3B	400/500/6	1111111134554
A	Filtration through 0.01 μ Millipore filter	3B	400/500/6	1111111178876
A	Filtration through 30/60 clay	3B	400/500/6	1111111133543
A	Standard reclamation filtration	1A	400/500/6	1111111111111
B	Control, no treatment	3B	575/650/2.5	11111111234554
B	Standard reclamation filtration	1A	575/650/2.5	1111111112221

Notes: The control samples with no treatment gave positive identification of the presence of elemental sulfur by the mercury test.

The standard reclamation filtered samples gave negative results for elemental sulfur by the mercury test.

Table 17

Phenol Content (ppm) Before and After Filtration

<u>Reclaim No.</u>	<u>Before Treat</u>	<u>After Treat</u>
1	250	10.0
2	40	0.0
3	35	0.0
4	--	0.0
5	290	0.0
6	63	0.0
7	320	0.0
8	315	12.5
9	285	10.0
10	250	15.5
11	5.0	10.0
12	5.0	8.0
13	4.0	4.0
14	6.0	2.0
15	6.0	0.5
16	2.0	0.0
17	0.0	0.0
18	0.0	0.0
19	0.0	8.0

Note: The before treat results represent phenol content on fuel samples prior to filtration. The after treat results represent phenol content on the fuel samples after filtration.

Table 18

Additive Content Before and After Reclamation Filter

<u>Reclaim No.</u>	<u>Paraphenylenediamine Antioxidant, lbs/1000 bbl</u>		<u>Metal Deactivator, lbs/1000 bbl</u>	
	<u>Before</u>	<u>After</u>	<u>Before</u>	<u>After</u>
1	Nil	0.00	2.69	0.00
2	0.35	0.00	Nil	0.00
3	6.98	0.00	0.88	0.00
4	7.36	0.35	1.40	0.00
5	0.87	0.00	1.54	0.00
6	2.44	0.00	Nil	0.00
7	Nil	0.00	2.27	0.00
8	0.17	0.00	2.36	0.00
9	1.05	0.00	1.82	0.00
10	Nil	0.00	1.01	0.00
11	2.27	0.00	0.33	0.00
12	7.33	0.00	1.42	0.07
13	1.57	0.00	0.93	0.00
14	7.86	0.00	1.83	0.07
15	4.19	0.00	1.46	0.16
16	1.80	0.35	0.94	0.30
17	1.40	0.00	0.40	0.02
18	2.79	0.00	2.50	0.00
19	2.27	0.00	1.10	0.00

Table 19

Detailed Thermal Stability Data for Corrosion Inhibitor Treated Fuels

<u>Treating Sequence</u>	<u>Corrosion Inhibitor Code No.</u>	<u>Preheater</u>	<u>Diff. Pressure, In. Hg</u>
1. Filtered only	Control	11111111111111	0.0
1. Filtered, 2. Corrosion inhibited	1	1111111123454	0.2
1. Filtered, 2. Corrosion inhibited	2	1111111136555	0.0
1. Filtered, 2. Corrosion inhibited	3	1111112234554	0.4
1. Filtered, 2. Corrosion inhibited	4	1111115666663	0.0
1. Filtered, 2. Corrosion inhibited	5	1111111111111	0.0
1. Filtered, 2. Corrosion inhibited	5	111111111223	0.5
1. Filtered, 2. Corrosion inhibited	6	111112344421	18.2
1. Corrosion inhibited, 2. Filtered	1	111111111221	0.0
1. Corrosion inhibited, 2. Filtered	2	111111112221	0.0
1. Corrosion inhibited, 2. Filtered	3	1111111111111	0.0
1. Corrosion inhibited, 2. Filtered	4	1111111111222	1.1
1. Corrosion inhibited, 2. Filtered	5	1111111123332	0.0
1. Corrosion inhibited, 2. Filtered	6	1111111111332	0.1

103

Notes: Fuel used throughout: Reclaim No. 11

ASTM-CRC coker conditions used throughout: 450/550/5

Military approved corrosion inhibitors: minimum allowable concentration

Table 20

Lube Oil Additive Analysis by Infrared

Run	% Lube Additive	
	Before Treat	After Treat
1	0.024	0.0
2	0.022	0.0

Table 21

Effect of Antistatic Additive on Thermal Stability

<u>Fuel</u>		<u>Preheater, max code</u>	<u>Diff. Pressure, in. Hg</u>
1	JP-6 with no additives	1	0
2	Fuel No. 1 with antistatic additive	3	1.2
3	Fuel No. 2 after reclamation filter	1	0

Table 22

Recommended Fuel Flow Rates for Filtration Unit

<u>Fuel Type</u>	<u>Viscosity at 77 F, cs</u>	<u>Max Flow Rate, gals/hour/ft²</u>	<u>Pressure Drop, lbs/in² Filter Bed Depth</u>		
			<u>8 ft.</u>	<u>16 ft.</u>	<u>24 ft.</u>
JP-4	0.921	400	8	19	28
JP-6	1.326	375	12	28	42
JP-5	2.142	350	21	49	74
Diesel	3.109	315	28	65	97

Appendix I

Detailed Thermal Stability Data for Reclaimed Fuels

ASTM-CRC Comparative Coker Ratings (450/550/6)

Reclaim No.	Preheater		
	A	B	C
1	1111235666664	1111111111111	1111111111111
2	1111111113335	1111111111111	1111111112221
3	1112223677765	1111111111111	1111111111111
4	1111114555543	1111111111111	1111111111111
5	1111111188888	1111111111111	1111111111111
6	1111111133332	1111111111111	1111111111111
7	1111111111665	1111111111111	1111111111111
8	1111111688886	1111111111111	1111111111111
9	1111111137754	1111111111111	1111111111111
10	1112368888888	1111111111222	1111111111111
11	1111111156666	1111111111111	1111111111111
12	1111235778887	1111111111111	1111111111111
13	1111688888888	1111111111111	1111111111111
14	1111168888888	1111111111111	1111111111111
15	1111111245332	1111111111111	1111111111111
16	111111112454	1111111111111	1111111111111
17	1111111666885	1111111111111	1111111111111
18	1111111155532	1111111111111	1111111112221
19	111111111555	1111111111111	1111111112221

A - Degraded fuel as received
 B - Treated fuel immediately after reclamation filtration
 C - Treated fuel six months after reclamation filtration

Appendix II

Threshold Thermal Stability Data

ASTM-CRC Coker Ratings by the Aero Propulsion Laboratory
on Reclaim Nos. 1 Through 10

Reclaim No.	Date	Test Conditions, °F	ΔP-Minutes	Preheater
1	7/1 /63	400/500/6	0.2-300	111111111111
1	7/25/63	400/500/6	0.7-300	111111111111
1	7/1 /63	425/525/6	17.5-300	111111111143
2	7/22/63	375/475/6	8.8-300	111111111111
2	7/2 /63	400/500/6	25.0-280	222222222333
2	7/2 /63	425/525/6	25.0-188	111111112433
3	7/23/63	375/475/6	3.4-300	111112211111
3	7/3 /63	400/500/6	25.0-249	3333333311333
3	7/3 /63	425/525/6	25.0-234	1123331111343
4	7/24/63	375/475/6	25.0-300	111111111111
4	7/15/63	400/500/6	25.0-128	0600001134441
4	7/15/63	425/525/6	25.0-191	111111114443
5	7/23/63	375/475/6	1.7-300	111111122222
5	7/8 /63	400/500/6	1.7-300	111111111322
5	7/8 /63	425/525/6	25.0-300	111111111111
6	7/23/63	375/475/6	9.1-300	111111222221
6	7/9 /63	400/500/6	14.8-300	222222222332
6	7/9 /63	425/525/6	25.0-178	111113321111
7	7/24/63	375/475/6	6.2-300	111111111112
7	7/10/63	400/500/6	25.0-198	111111224332
7	7/10/63	425/525/6	25.0- 68	111111111221
8	7/11/63	400/500/6	6.7-300	111111111111
8	7/24/63	400/500/6	1.1-300	111111111111
8	7/11/63	425/525/6	14.2-300	111111111122
9	7/12/63	400/500/6	0.5-300	111111111111
9	7/12/63	425/525/6	0.4-300	111111111111
10	7/18/63	400/500/6	25.0-260	111111112441
10	7/18/63	400/500/6	25.0-235	111111124442
10	7/22/63	375/475/6	23.6-300	111111111111
10	7/25/63	375/475/6	11.6-300	111111111111

Appendix III

Storage Stability Data of Unfiltered Fuels

<u>Reclaim No.</u>	<u>Date Tested</u>	<u>ASTM-CRC Coker Operating Conditions at Threshold Temp.</u>	<u>Preheater</u>
11	8/14/63	375/475/6	
11	8/15/63	350/450/6	1111111116655
11	2/11/64	325/425/6	1111111111111
11	2/12/64	300/400/6	1111111136541 1111111111111
12	8/14/63	375/475/6	
12	8/15/63	350/450/6	1111111115555
12	4/3 /64	350/450/6	1111111111111
12	4/3 /64	325/425/6	1111111113453 1111111111111
14	8/27/63	450/550/6	
14	8/24/63	425/525/6	1111111124532
14	4/7 /64	450/550/6	1111111111121
14	4/7 /64	425/525/6	1111111478542
14	4/7 /64	400/500/6	111111111243 1111111111111
17	8/29/63	450/550/6	
17	8/29/63	400/500/6	1111111244432
17	8/30/63	375/475/6	1111111114432
17	4/10/64	450/550/6	1111111112221
17	4/11/64	375/475/6	1111112468887
17	4/13/64	350/450/6	111111135432 111111122211

Appendix IV

Laboratory Procedures Used for Physical and Chemical Testing

<u>Test</u>	<u>Federal Std. No. 791</u>	<u>ASTM Standard</u>	<u>Others</u>
Gravity, API		D 287	
Distillation		D 86	
Saybolt Color		D 156	
Freezing Point		D 1477	
Viscosity		D 445	
Particulate Matter		Proposed	
Existent Gum		D 381	
Potential Gum		D 873	
Water Reaction Index	3251		
Water Separometer Index	3255		
Water Separometer Index Modified	3256		
Moisture		D 1364-62 Vol. II	
Specific Heat			Calculated
Net Heat of Combustion			National Bureau of Standards
Aniline-Gravity Product		D 287 and D 611	
Corrosion		D 130	
Sulfur, Mercaptan		D 1323	
Sulfur, Total		D 1266	
Doctor Test			UCP 41-59

<u>Test</u>	<u>Federal Std. No. 791</u>	<u>ASTM Standard</u>	<u>Others</u>
Aromatics		D 1319	
Olefins		D 1319	
Smoke Point		D 1322	
Naphthalene		D 1840	
Copper			AORCO (Photometric)
Indene			Monsanto 2521-2
Iron			AORCO (Photometric)
Lead			AORCO (Photometric)
Nitrogen, Basic			Sinclair
Nitrogen, Pyrrole			UOP 276-59
Oxygen, Dissolved			Phillips GC
Peroxide			Louisville Neoprene Lab #S-17.08
Sodium			AORCO (Emission)
Sulfonate			California Research Corporation
Phenol			Shell
Saponification Number		D 939	
Thermal Stability		D 1660	

Appendix V

Bacteriological Procedures

A. Culture Propagation

In order to propagate the quantity of both bacteria and fungi necessary to inoculate adequately 15-gallon drum samples, subcultures were prepared using for the bacteria Bushnell-Haas liquid medium with JP-6 (sterile) overlay and nutrient broth (see Table 7). For the fungi, both Bushnell-Haas mineral salts liquid medium with JP-6 overlay and Sabouraud's liquid medium were used (see Table 8). These subcultures were allowed to incubate at 37 C for several days prior to their inoculation into the fuel.

As the growth rates shown in the tables indicate, the bacteria proliferate more readily in a mineral salts-jet fuel environment than the two fungal species.

B. Fuel Inoculation, Sampling, and Culturing Procedures

1. Isolation of microorganisms

Each subculture was isolated from the liquid culture medium by means of decantation and filtration.¹ The suction of the filtration assembly was released when approximately 30 milliliters of organism-containing medium remained. To preclude aerosol contamination, the apparatus was covered with foil and moved to the reclamation filter pilot plant units.

2. Actual drum inoculation procedure

Prior to inoculation of the JP-6 with the microorganisms, a stream of cylinder-nitrogen was delivered through a fritted agitator into the fuel with such velocity that the fuel was mixing violently at the time of inoculation. At this point, the microorganisms were emptied into the fuel and allowed to circulate for five minutes prior to sampling of the inoculated 15-gallon drum of JP-6. Figure 28 shows the intimate dispersion of the bacteria in the fuel.

¹ Millipore pyrex filter assembly; 0.45 micron pore diameter, type HA filter.

3. Sampling procedure for inoculated drum

A one-quart sample was siphoned from the inoculated drum through sterilized tygon tubing into a sterilized quart bottle. This was returned to the bacteriological laboratory for culturing.

4. Isolating and culturing procedure for samples

Aseptic conditions were maintained in the laboratory at all times and elsewhere during the course of this project as required. The quart fuel samples taken at various points (see Sample Schedule, Table 9) were filtered through a 0.45 micron Millipore filter. Each empty sample bottle was rinsed with four 25-milliliter increments of sterile water. These incremental washes were added to the respective Millipore filtration assembly and suction applied to aid in drawing the wash-material through the cellulose filter. Finally, the Millipore cellulose filter was carefully placed in previously sterilized petri culture dishes containing the appropriate medium to optimize growth of the organisms sought. (Sabouraud's liquid medium in the case of the fungi and Bushnell-Haas mineral salts in the case of the bacteria.) These were incubated at 37 C for fourteen days.

C. Culture Examinations and Determinations of Results

1. Visual examination

Visual examinations were made daily and a log kept of the presence or absence of biological growth. These inspections revealed that fungal growth could be detected within 24 hours. Following a 72-hour incubation period of a Hormodendrum-species (fungi)-inoculated-drum sample, approximately two hundred and fifty colonies were counted. Figure 25 shows the culture of these fungi through the test sequence. The control sample and the sample following the reclamation filter (designated as number 3), show a complete absence of fungal growth; whereas number 1, which is the inoculated drum sample, and number 2, the fuel following the chemical dryer section of the unit, show 250- and 12-colonies, respectively. (The fungi grew at the fuel-culture medium interface while the bacteria dispersed throughout the culture medium phase only.) Visual inspection for bacteria was less successful since approximately forty-eight hours were necessary to produce turbidity within the Bushnell-Haas medium, great enough to assure positive or negative identification. It was therefore decided that microscopic checks were more reliable in this area.

2. Optical microscopic² checking procedure

One-inch by three-inch slides were prepared using various stains to accentuate contrast between the cell walls of the microorganisms and their background which in turn produced better photomicrographs. Loeffler's staining procedure proved to be adequate for this application.

Optical microscopy was found to be adequate for determination of the presence of both bacteria and fungi. Electron microscopy was also utilized both because it is more definitive and because it provides a means of double checking.

3. Electron microscopic³ checking procedure

Nickel grids were covered with the culture in question by means of a looped inoculating needle. These grids were then scanned in order to detect micronic and submicronic particles in addition to microbiological contaminants. This served a very useful purpose of not only revealing the fuel to be completely free of bacteria and fungi following the reclamation filtration, but also to be virtually free of extraneous matter of all types. The electron photomicrograph 7500 X magnification enhances the cell wall differentiation and enables the viewer to obtain a better concept as to its cellular structure.

2 Leitz Ortholux microscope, maximum magnification (oil) 1225 X.

3 Phillips Electron Microscope, Model 75.

Appendix VI

Life of Standard Filter Media

Reclaim No. 11	Coker Run No.	Filter Media's Life Barrels of Fuel Per Ton Filter Media	Preheater	Diff. Pressure, In. Hg.
Control, no treatment				
Filtered through pilot unit No. 1	1	381	1111112678888	< 25
Filtered through pilot unit No. 1	13	6096	11111111111111111111	1.5
Filtered through pilot unit No. 1	17	12192	11111111111111111111	6.0
Filtered through pilot unit No. 1	18	14859	11111111111111111111	0.0
Filtered through pilot unit No. 1	20	16774	11111111111111111111	0.1
Filtered through pilot unit No. 1	21	18288	11111156666665	0.0
Filtered through pilot unit No. 1	22	19431	11111157666666	0.3

Reclaim No. 12

Control, no treatment	Reclaim No. 12	Coker Run No.	Filter Media's Life Barrels of Fuel Per Ton Filter Media	Preheater	Diff. Pressure, In. Hg.
Filtered through pilot unit No. 2		1	381	1111235778887	0.1
Filtered through pilot unit No. 2		12	8763	11111111111111111111	2.0
Filtered through pilot unit No. 2		21	16353	11111111111111111111	0.0
Filtered through pilot unit No. 2		26	19812	11111111111111111111	0.0
Filtered through pilot unit No. 2		27	20193	11111111111111111111	0.0
Filtered through pilot unit No. 2		28	20574	11111111112333	0.0
Filtered through pilot unit No. 2		29	20955	11111111113321	0.0
Filtered through pilot unit No. 2		33	22479	11111111113333	0.0
Filtered through pilot unit No. 2		34	22860	1111112334442	0.0
Filtered through pilot unit No. 2		35	23241	1111112334444	0.0