PB-237 620

A TECHNICAL AND ECONOMIC STUDY OF WASTE OIL RECOVERY.

PART III: ECONOMIC, TECHNICAL AND INSTITUTIONAL BARRIERS TO WASTE OIL RECOVERY

TEKNEKRON, INCORPORATED

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY

INSTITUTE OF PUBLIC ADMINISTRATION

OCTOBER 1973

DISTRIBUTED BY:

NTIS

National Technical Information Service

U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA/530/SW-90c.3	2.

4. Title and Subtitle A TECHNICAL AND ECONOMIC STUDY OF WASTE OIL RECOVERY Part III: Economic, Technical and Institutional Barriers to Waste Oil Recovery	5. Report Date October, 1973
	6.
7. Author(s) Peter M. Cukor, Michael John Keaton, Gregory Wilcox	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Teknekron, Inc. and The Institute of Public Administration 2118 Milvia Street Berkeley, California 94704	10. Project/Task/Work Unit No.
	11. Contract/Grant No. EPA Contract No: 68-01-1806
12. Sponsoring Organization Name and Address Office of Solid Waste Management Programs U.S. Environmental Protection Agency Washington, D. C. 20460	13. Type of Report & Period Covered Final 1 year
	14.

15. Supplementary Notes

16. Abstracts

A study of the waste oil re-refining industry, emphasizing economic, technical and institutional barriers to waste oil recovery.

17. Key Words and Document Analysis. 17a. Descriptors

Secondary Oil Recovery, Economic Analysis

17b. Identifiers/Open-Ended Terms

Waste oil re-refining, recycling, re-refining industry analysis

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages
	20. Security Class (This Page) UNCLASSIFIED	

A TECHNICAL AND ECONOMIC STUDY

OF WASTE OIL RECOVERY

Part III: Economic, Technical and Institutional Barriers to Waste Oil Recovery

This report (SW-90c.3) was written by
PETER CUKOR, MICHAEL JOHN KEATON, and GREGORY WILCOX
Teknekron, Inc., and The Institute of Public Administration
under contract no. 68-01-1806

U.S. ENVIRONMENTAL PROTECTION AGENCY

1974

An environmental protection publication (SW-90c.3) in the solid waste management series.

Notice

The report A Technical and Economic Study of Waste Oil Recovery, prepared by Teknekron, Inc. and the Institute of Public Administration under EPA Contract 68-01-1806, has been published in three separate volumes under the following titles:

A Technical and Economic Study of Waste Oil Recovery - Part I: Federal Research on Waste Oil From Automobiles

A Technical and Economic Study of Waste Oil Recovery - Part II: An Investigation of Dispersed Sources of Used Crankcase Oils

A Technical and Economic Study of Waste Oil Recovery - Part III: Economic, Technical and Institutional Barriers to Waste Oil Recovery

Preceding page blank

TABLE OF CONTENTS

Preceding page blank

SUMMARY

Since 1960, the re-refining of used automotive engine oils, once a flourishing industry, has continuously contracted, both in number of firms in operation and annual volume of lube oil re-refined. A plentiful supply of virgin lube oils, adverse government rulings regarding lube oil taxation and labelling of recycled oils, and the failure of the re-refining industry to provide consumers with products of consistently high quality have been major factors in the decline of this business. For example, in 1960, about 150 firms produced 300 million gallons of re-refined oil. As of 1972, the 45 firms still operating produced only 100 million gallons of recycled lubricants. More recently, sharply reduced availability of waste oil supplies and environmental restrictions on the disposal of toxic wastes produced as by-products of re-refining have contributed to the contraction of the industry.

In order to understand the reasons for the decline of the re-refining industry, a study was made of the economics, structure and competitive aspects of the business. As a part of this analysis, interviews were conducted with thirteen re-refining companies throughout the United States. Economic and operating data for these firms were collected and analyzed in order to determine the key costs and criteria for success at each stage of the industry, the types of markets served, the profitability of these markets, and the ability of re-refiners to compete with producers of virgin lubricants. The analysis revealed the reasons why a few re-refiners have been able to prosper while the majority of firms still in existence are only marginally profitable.

Waste Oil Collection

The first stage of the re-refining industry is the collection of waste oil. Traditionally, used oils have been collected both by small, independent operators, who would sell the oil to re-refiners or anyone willing to pay the going price, and by re-refiners themselves. For many years most re-refiners were able to obtain adequate waste oil supplies at relatively low cost. However, since 1972 tight supplies of and rapidly rising prices for energy sources have served to divert substantial volumes of waste oil to the fuel market. Until recently, lube oil prices had not advanced sufficiently to permit re-refiners to compete successfully for waste oil supplies with persons buying waste oil for use as fuel. However, since late 1973, a growing shortage of virgin lubricants has resulted in substantial price increases for both new and re-refined oils. As a result, re-refiners are now able to pass along the increased costs of acquiring waste oil supplies. In the future, the degree to which these firms will be able to secure adequate volumes of feedstock will continue to depend on the relative market prices of virgin lube oil and fuels. Higher fuel prices in relation to

those for lube oil will direct waste oils to the fuel market. Conversely, higher lube oil prices in relation to fuel will enable re-refiners to compete successfully for scarce supplies of used lube oils.

Re-Refining of Waste Oil

Nearly all re-refining plants in the United States use the acid-clay process for treating waste oils. In this process water is removed by distillation. The water-free feed is extracted with sulfuric acid to remove spent additives and sludge. The raffinate (lube oil free of additives and sludge) is distilled to remove low boiling components and mixed with clay to remove colored bodies and colloidal carbon. The clay is separated from the distilled product by filtration. The viscosity of the re-refined product may be increased by blending with appropriate virgin lube oils or synthetic polymers. Chemical additives are then blended as required to meet specifications for various applications. The acid sludge is dumped whereever local regulations permit.

Based on interviews conducted with 13 re-refiners during the summer of 1973, average cost figures for each step in the re-refining of waste lube oils were obtained. The most important variable in the cost of re-refining is the annual production rate. Excluding the cost of feedstock, the combined expense of labor, overhead and depreciation accounts for sixty percent of total per gallon production costs for re-refined oil. Hence those firms with the largest throughput have the lowest production costs. Excluding feedstock, these costs ranged from 11¢ per gallon for a firm producing 7,200,000 gallons per year to 16¢ per gallon for a firm producing 540,000 gallons per year.

Excluding taxes and administrative costs, the average total production cost for the firms interviewed was 17.5¢ per gallon. This figure may be divided into the following component parts. *

The cost of feedstock (7¢ per gallon of product) represents the greatest cost in re-refining. As product yields are only about sixty percent of the waste oil feed, a one cent increase in the cost of feedstock increases production costs by 1.66 cents. Labor and materials (sulfuric acid and clay) costs are about equal in importance (3¢ per gallon for each), followed by the costs of overhead (2¢ per gallon), depreciation (1¢ per gallon) and utilities (1¢ per gallon). The cost of disposal of the acid sludge produced as a by-product of re-refining is only a small fraction (less than 0.5¢ per gallon) of total processing costs. However, inability to locate approved disposal sites has forced some firms to discontinue operations.

Depending on the product specifications, a variety of additives will be blended with the re-refined base stock. Blending costs for high performance,

* All costs are as of August, 1973.

top quality lube oils (17.5¢ per gallon of product) are as large as the total cost of re-refining.

Marketing

Marketing is the phase of re-refining in which the greatest differences between firms exist. Analysis of the types of markets served by re-refiners reveals the reasons why some firms have prospered while others have failed.

There are two main marketing paths accessible to re-refined lube oils. High quality oils which have been blended with additives are sold directly by re-refiners to final users such as industrial and commercial establishments (trucking firms, taxi fleets, railroads, etc.). Conversely, unblended, nondetergent re-refined oils are sold in bulk to independent jobbers who do their own packaging and distribution. Although direct sales of the high quality oils to final users are highly profitable, only a small fraction of the total production of re-refined oil is marketed in this fashion.

Most re-refined lube oil is sold in tank truck loads of several thousand gallons to independent jobbers. Margins on such sales are quite low, in some cases as little as a penny a gallon. The jobbers package the oil in 55 gallon drums or quart cans under one or several brand names and sell the packaged product to garages, independent service stations and discount stores. Re-refined oil sold in these markets competes with low quality virgin lubes and other unblended oils. The failure of the re-refining industry to monitor the quality of its products and a Federal Trade Commission ruling which requires that re-refined oils sold in interstate commerce be labelled to indicate that they were produced from previously used oils have definitely contributed to the public's lack of confidence in the quality of recycled lube oils. As a result, consumers who knowingly purchase such oils do so on the basis of the low price at which they are sold. With such a low margin per gallon of sales, the key to success in this market is volume. Yet the tight supply of waste oil has forced many firms to reduce production levels thereby increasing marginal costs. Re-refiners who serve primarily the bulk oil market have become only marginally profitable in recent years. However, all re-refiners interviewed experienced no difficulty in selling all the oil they could produce.

Due to lack of quality assurance and consumer confidence, it is quite difficult for a re-refiner to market his product in competition with high quality virgin lubricants produced by major oil companies. This is especially true in the retail market where consumer purchase habits have been shown to be strongly influenced by identification with nationally advertised brands. As a result, very little, if any, high quality re-refined oils are available in the retail market. If an attempt to market such oils were to be made, the oil would have to be sold at a much higher price than the nondetergent inexpensive (and frequently low quality) recycled lubes now available. Since the public does not have confidence in the quality of re-refined oil, few if any of these high quality products would be sold. Hence only unblended, low cost re-refined oil is available. This tends to reinforce the poor public image of recycled oils.

However, a few firms have been successful in selling high performance (blended with additives) re-refined oil to commercial and industrial accounts in competition with top quality oils produced by the large petroleum companies. Depending on the volumes involved, profit margins on such sales may run as high as forty cents per gallon. In some cases a large customer's waste oil is delivered to the re-refiner, re-refined separately from other oils, and returned to the customer. Such "closed-loop" or "custom" re-refining is not only financially attractive, but also provides the re-refiner with a secure supply of feedstock. Re-refiners who have penetrated the high quality market have been able to do so on the basis of long-term "toe to toe", "belly to belly" relationships with their customers. Such relationships involve a significant degree of trust on the part of the consumer. Hence a firm's success in this kind of market rests upon a very high degree of product quality control as well as a competitive price and prompt attention to the customer's needs. Typically such customers might include trucking companies, railroads and taxi fleets, and other companies which have very large investments in rolling stock and consume large volumes of lube oil. Without exception, re-refiners who have been able to establish such relationships with commercial and industrial clients have earned an attractive return on their invested capital.

A major conclusion of the analysis of the re-refining industry is that uncertainty as to the quality of re-refined lube oils is the principal barrier to increased recycling of used lubricants. In order to understand the nature of the quality issue, existing specifications for automotive lube oils and the testing procedures required by these specifications were examined.

Lube Oil Specifications

A variety of specifications for lube oils have been established. The most significant specifications are those set by the automobile manufacturers, the American Petroleum Institute/Society of Automotive Engineers (API/SAE), and the United States military. In the case of lube oils used in modern automobile engines, each set of specifications requires a number of laboratory tests of the physical and chemical properties of the candidate product. Such tests are neither prohibitively expensive nor excessively time consuming. In fact, a number of re-refiners operate their own quality control laboratories, a few of which are equipped to perform all specified tests.

In addition to bench scale laboratory tests, each set of specifications also requires that a series of engine sequence tests be performed. Unlike the bench scale tests described above, which examine the physical and chemical characteristics of the lube oil itself, a major purpose of engine sequence tests is to evaluate the "additive response" of the lube oil; that is, the performance properties of the lube oil-additive blend. These tests are performed in highly specialized laboratories and are designed to reproduce the actual conditions of temperature, vehicle load and weather conditions under which modern motor vehicles operate. The results of engine tests are evaluated subjectively by assessing the wear of key engine parts and amounts of varnish and other wastes deposited on these parts. Engine tests are quite costly. Expenditures per test typically amount to $10,000. Since a number of engine tests are required to qualify an oil for a given class of service, total costs can easily amount to $80,000 to qualify a single lube oil product.

Automobile manufacturer's specifications are particularly important in classifying lube oils, as new car warranties require that only lube oils meeting certain quality levels may be used. As a result, the lubricant manufacturers, notably the major oil companies, have established their own specifications based upon performance criteria set by the auto industry. These API/SAE specifications are, therefore, always consistent with lube oil specifications established by the individual automobile firms. It is the responsibility of the lube oil producer to establish that his product meets the specifications for the class of service for which the oil is recommended. An oil recommended for a given class of service must be capable of satisfying all the physical, chemical, and performance requirements (engine tests) for the specified class of service. However, the use of an API/SAE service label designating an oil as suitable for a given use is wholly the responsibility of the marketer of that particular brand of oil. If an oil is labelled as meeting the requirements of a given service classification, the oil may or may not have been subjected to all the tests required for that classification. The use of the label only means that the marketer is certain that the oil would pass all the tests specified *if these tests were actually performed.* There is no independent organization which monitors lube oil quality.

While neither API/SAE nor manufacturer's specifications exclude re-refined oils from consideration, the more stringent requirements for lube oil quality established by the Department of Defense do prohibit the use of re-refined materials in automobile engine oils. This is particularly important as all lube oil purchased by agencies of the federal government must meet military specifications. Further, the procurement practices of the U.S. government have established a standard which is followed by many other organizations, including state and local governments, which look to Washington for leadership in establishing quality control over automobile engine lubricants. According to the Defense Supply Agency, the government body which procures lube oil for all federal facilities, re-refined oil is excluded from consideration on the grounds that reliable information on the quality of such oils does not exist. In order to qualify an oil for government purchase, both laboratory bench scale tests and engine tests must be performed. Further, military specifications require that once an oil is qualified for procurement, no changes may be made in the feedstock from which the lube oil is manufactured without subsequent requalification of the product. Since the waste oil feed to a re-refining plant is derived from a variety of unknown sources, each batch of re-refined oil would have to be tested. Yet the cost of the tests required to qualify an oil is so high, that it has been economically impossible for any re-refiner to provide qualified oil for purchase by the federal government. This situation tends to reinforce the fear that re-refined oils may be inherently inferior to virgin lubricants and should, therefore, be labelled as made from previously used oil in order to protect the consumer.

Thus re-refined oils cannot be procured by the Defense Supply Agency because there is no evidence that such oils can meet quality standards. Yet the cost of providing such evidence is prohibitive, especially in view of the competitive bidding arrangements under which government facilities purchase lube oil.

Recommendation: A Closed-Cycle Experiment

If increased recovery of waste oils is to occur, then a different approach must be taken in order to establish the quality of these products. At the same time it is evident that regardless of the quality of re-refined oils, consumers will be reluctant to purchase these products as long as the government refuses to accept them for use in its own vehicles. Conversely, if government lube specifications were revised to permit the purchase of re-refined lube oils, then a more favorable climate for new private investment in waste oil recovery would result.

In order to resolve the question of the quality of re-refined oil, a simple experiment is proposed. An activity with a large demand for lube oil, such as a military base, would agree to supply used crankcase oils to a re-refiner. The oils would be segregated from other fluids and dirt to assure constancy of feedstock quality. The re-refiner would agree to process this oil separately from other feed streams so that the quality of the lube oil product would not be affected by feedstocks of unknown origin. The re-refined oil would then be returned to the activity which provided the waste lube stock. Under such a "closed-cycle" system it would be possible to prove or disprove the performance of re-refined oil on the basis of day to day usage under a variety of service conditions. A successful pilot program would lead to the second phase of the experiment in which the restriction against the use of outside sources of waste oil would be removed. Successful completion of this phase would lead to the establishment of new government specifications which would allow the procurement of recycled oil without the need for costly requalification. The establishment of lube oil quality through a closed-cycle/open-cycle experiment is the first step in acquiring the data necessary for a change in the federal labelling law. This law requires that all oils containing re-refined products bear a label stating that the oil was manufactured from previously used materials. Because the term "used" implies that a product may be of inferior quality, this law has frequently been cited as a deterrent to public acceptance of recycled oils. The labelling law has been justified on the basis of consumer protection. Yet if a re-refined oil can be shown to be of the same quality as equivalent virgin lubes, there is no reason to discourage its purchase by identifying the source of the materials from which it was manufactured.

With the government taking the lead in the use of re-refined oil, other large lube oil consumers would have an incentive to follow, as re-refiners can provide top quality lubes at prices competitive with those of virgin products.

The recommendations whose implementation can lead to increased waste oil recovery may be summarized as follows:

1. Establish the quality of re-refined lube oil in a controlled closed-cycle experiment.

2. Resolve the variable feedstock issue in an open-cycle experiment.

3. Revise federal procurement and labelling policies to reflect the quality of re-refined oil. Acceptable re-refined oils should be certified as being of the same quality as equivalent virgin lubes.

Successful completion of this program will aid in establishing public confidence in the quality of properly re-refined oils and will therefore remove the barriers which have prevented re-refined oils from penetrating the high quality, high profit retail and commerical markets.

CHAPTER 1

THE RE-REFINING INDUSTRY: AN ECONOMIC ANALYSIS

1.0 INTRODUCTION

Since the passage of the National Environmental Policy Act, a number of government agencies have sponsored or conducted their own research on the technical aspects and environmental impacts of various methods for the disposal of used lubricating oils. More recently, increasing concern for the recovery of scarce resources has prompted additional studies on ways of increasing the volume of waste oil which is recycled. These studies have shown that although re-refining of used lube oils is both a desirable method of reducing environmental damages due to waste oil disposal and a feasible way of conserving this valuable resource, the existing re-refining industry has been unable to expand its operations in order to recycle the steadily increasing volumes of waste oil generated each year. In fact, rather than expanding its operations, the re-refining industry has experienced an extended period of continuous contraction. Thus it is clear that any federal strategy aimed at reducing the environmental impact of waste oil disposal and stimulating efforts to recover the resource value of these materials must take account of the operations of the companies which re-refine used lube oils.

Although reclaiming of waste lube oils has been commercially practiced for nearly sixty years, re-refining companies now function in a business environment which has, since about 1960, been most unfavorable for new investment. Over the past 13 years, more than two-thirds of the 150 firms formerly engaged in re-refining have gone out of business. As a result very large volumes of waste oils which at one time were re-refined to produce lube stocks are now being disposed of in other ways, some of which are environmentally harmful. In addition, waste oil generation has increased roughly in proportion to the 33 percent increase in lube oil demand during this period. Thus while the volume of waste oil available for disposal has been rising, the capability to reprocess these wastes to useful products has been falling. Reasons for the decline of the re-refining industry have thus become a matter of considerable importance in forming government waste oil policy.

This chapter seeks to assist in policy formation by discussing the structure and economics of the re-refining industry as it presently exists and examining in detail the criteria for success and the reasons for failure in re-refining. For while in recent years a large number of firms have ceased operations, a few companies have managed to prosper. Business strategies for profitable operation are discussed with respect to the three phases of the industry: waste oil collection, re-refining, and marketing. Much of the data presented in this chapter were collected during interviews conducted with thirteen re-refiners located in or near major urban areas throughout the United States. Detailed cost breakdowns are provided for all important operations relevant to the recycling of automobile crankcase oils. Similar calculations are presented for new crankcase oils produced directly from crude oil. The results of this analysis provide insight into the business strategies of a profitable re-refinery and the changes in the business environment which are necessary to improve the climate for investment in this business. The effects of certain government policies on the re-refining environment are also discussed. The goal of this chapter is, therefore, to provide policy makers with an awareness of the effects of present and future strategies for recovery of waste oils on the industry whose viability is of central importance to this effort.

1.1 DESCRIPTION OF THE RE-REFINING INDUSTRY

1.1.1 Composition

The oil re-refining industry is composed of approximately forty-five companies located throughout the United States, principally in or near major population centers. The main activity of these companies is the recovery of marketable petroleum products from various types of previously used and/or contaminated lubricants and fuels. The largest re-refiner produced about 7,200,000 gallons of industrial and automotive lube oils and had total revenues of $3,000,000 in 1972. A typical small re-refiner produced about 500,000 gallons of lube oils and had total revenues of between $100,000 and $150,000 in 1972. Table 1 summarizes economic and operating data for thirteen re-refining companies interviewed in this study.

Due to the high cost of shipping lubricating oils and the relatively low market value of re-refined crankcase oils, re-refined oils are normally sold within a radius of not more than 300 miles from the point of manufacture. In most areas of the country the demand for re-refined oils is sufficiently large compared to the supply that re-refiners experience no difficulty in finding markets for all the oil they can produce. Hence there is little competition between re-refined lube oils. On the other hand, supplies of drain oil from which re-refined oils are produced are becoming increasingly scarce and re-refiners must now compete with each other and with other businesses to secure adequate volumes of feedstock.

1.1.2 Phases of the Industry

While there are vast differences in type, scale and diversity of operations between the oil re-refining industry and the petroleum industry, the former business may be divided into three phases similar to the production, refining, and marketing activities of large oil companies. These phases are: collection of waste oil, re-refining of waste oil, and marketing of re-refined products. The analysis, which begins on page 21 , is divided in this manner in order to understand the essentials of the oil re-refining business and to make comparisons between the firms which form this industry.

1.1.3 Description of Re-Refining

Previously used or contaminated oils may be treated by a number of methods. In some instances, especially in the case of fuel oils, the reclamation process may involve simply the removal of insoluble materials and limited treatment to reduce chemical contaminants such as water. If waste lubricating oils

Table 1

Economic & Operating Data for 13 Re-Refining Companies

For the Fiscal Year 1972 - 1973

Company	Waste Oil Collected and Re-refined gal/yr. Own Sources	Waste Oil Collected and Re-refined gal/yr. Purchased from Independent Collectors	Delivered Cost of Waste Oil ¢/gal	Fraction of Capacity Utilized (per cent)	Cost of Re-refining ¢/gal of Product (excluding taxes and administrative costs)	Products Sold gal/yr	Principal Markets Served	Total Revenues $/yr	Net After Tax Income $/yr (Loss)
1	3,500,000	3,500,000	4.25	86	17	5,000,000	60%: Bulk on sales of unblended auto lube to 6 local jobbers at 24¢/gal; 40%: Industrial sales of cutting oils	900,000	0
2	1,925,000	75,000	3	50	16	1,200,000	80%: Blended auto lube oil sold in drums to commercial accounts through distributors; 20%: Blended oil sold in quart cans to jobbers	760,000	16,000
3	1,300,000	---	2-3.5	82	19-20.5	760,000	100%: Bulk sales of unblended auto lube to jobbers at 25-26¢/gal	194,000	4,300
4	---	720,000	3	46	20	540,000	100%: Bulk sales of unblended auto lube to jobbers	NA	NA
5	---	10,300,000	5.5	73	17	6,000,000	10%: Railroad diesel lube; 50%: Railroad journal oil; 40%: Bulk sales of unblended auto lube to jobbers at 20¢/gal	1,300,000	0
6	2,100,000	2,100,000	3.6	100	17	2,475,000	100%: Bulk sales of blended and unblended auto lube to jobbers at 22¢/gal	1,250,000	13,500
7	6,000,000	5,000,000	3-3.6	71	16.5	7,200,000	95%: Industrial and railroad oils sold directly to final users; 5%: Bulk sales of unblended auto lube to jobbers at 23.5¢/gal	NA	NA
8	1,440,000	---	5	66	15.5	954,000	90%: Bulk sales of unblended auto lube to single jobber at 20¢/gal; 10%: Blended oils sold locally	307,000	4,000
9	660,000	300,000	2.8	57	15	980,000	100%: Bulk sales of unblended auto lube directly to garages and independent service stations at 26¢/gal	420,000	NA
10	---	3,000,000	3	72	20.5	2,100,000	100%: Bulk sales of unblended auto lube to jobbers at 23¢/gal	600,000	(46,000)
11	7,000,000	2,000,000	2.5-4.6	80	18	5,000,000	8%: Auto lube sold to commercial accounts; 15%: Auto lube sold packaged to wholly-owned distributor; 12%: Auto lube sold in bulk to jobbers at 22.5¢/gal; 36%: Fuel oil; 11%: Industrial oil sold directly to final users; 18%: Road oil	1,200,000	59,000
12	3,500,000	---	2-3	71	19	2,000,000	100%: Bulk sales of unblended auto lube to jobbers at 21¢/gal	NA	NA
13	1,370,000	---	Custom re-refining at a single tariff	50	20*	1,100,000	100%: Custom re-refined for industrial accounts	350,000	40,000

* Includes delivery of re-refined oil and all administrative costs.

Teknekron Inc

are to be re-refined to produce a quality lube oil, considerably more complex and thorough processing of the oil under controlled conditions is required. Frequently confusion arises as to the type of operation referred to in discussing the re-refining industry. This chapter focuses principally on the latter type of operation in which the objective is to remove all soluble and insoluble contaminants as well as any additive components from the waste oil feedstock. The product of such an operation is a clean mineral oil or "base stock" which is approximately equivalent in composiiton and performance characteristics to a quality, non-detergent virgin lubricating oil. From this mineral oil it is possible by blending with other oils and additives to produce a wide variety of automotive and industrial lubricants.

1.1.4 History of the Re-Refining Industry

Methods for the reclamation of waste lubricating oils were in use as early as 1915. At that time only simple processing was used in which the oil was first heated to remove volatile contaminants. The addition of a coagulant followed by settling or centrifuging completed the treatment. Following World War I such simple reclaiming procedures were established by the Army Air Corps at Air Depots in the United States. Although the reclaiming process would be considered rather primitive by today's standards, the recovered oil met essentially all the specifications for aircraft engine lubricating oil against which virgin lubricating oils were then procured. Prior to American entry into World War II, this program was operated on a small scale as the apparently inexhaustible petroleum reserves in the United States precluded the need for an expanded recycling program.

Commercial aviation provided a new market for re-refined lube oils. In 1932, American Airlines initiated a "closed-cycle" re-refining system in which used lubricating oils from company planes were treated to remove contaminants and then returned for use in company aircraft. This program resulted in a 20 percent net savings in lubrication costs and served to stimulate the use of re-refined oil in other industries. By 1939, the re-refining business had grown considerably and was processing more than 11 million gallons of waste oil per year. 1/

During World War II use of re-refined lubricating oils increased dramatically. In order to conserve limited supplies of petroleum, reduce costs, and simplify supply and distribution operations, in 1942 the Army Air Corps initiated a large scale "closed-cycle" system similar to the American Airlines program mentioned above. Previous Army Air Corps experience with reclaimed oil and the success of the product in commerical air fleets provided strong incentives for initiation of the program. During World War II, re-refined oil was used without restriction within the continental United States. Approximately 29 million hours of flight time was logged using re-refined oil without harmful effects on engine wear, life, or cleanliness. During this period average engine life increased by about 50 percent. 2/

Following World War II, the Air Force approved the use of re-refined lubricating oils without restriction. Table 2 shows how Air Force use of re-refined oil increased steadily in the late 1940's. Considerable savings were realized as re-refined lubricating oil could be purchased for about 40¢ per gallon less than a comparable virgin product. By 1949 about one-fourth of all Air Force aircraft oil was re-refined. However, the advent of jet aircraft requiring synthetic-based lubricating oils drastically reduced the volume of oil which was available for re-refining. As a result waste oil collection costs increased thereby reducing the economic incentive to use recycled oil. Eventually the program was discontinued.

1.1.5 The Decline of the Re-Refining Industry

As shown in Table 3, following World War II the re-refining industry grew steadily. By 1960 about 300 million gallons per year of re-refined oils were produced. This represented about 18% of total domestic use of lube oils. Since then production of re-refined lubricants has fallen sharply. In 1971 it is estimated that only 120 million gallons of re-refined lubricating oils or 5.5 percent of domestic use were produced. This drastic decline in production has been accompanied by a parallel decrease in the number of companies engaged in re-refining. In 1960 there were between 125 and 150 re-refiners in operation. At present the number of firms producing re-refined lube oils is less than 50. The most recent compilation of commercial re-refiners listed 45 companies in operation as of mid-1972. A recent check indicated that at least three of these firms have discontinued operations. Further, as will be discussed below, most plants still in operation are working at less than full capacity.

As shown in Figure 1, a number of factors have contributed to the contraction of the re-refining industry. At the collection end of the business, the volume of waste oil available within a given geographical area has fallen sharply thereby necessitating an increase in the area covered to collect the required volume of feedstock. Longer periods between oil changes, a large increase in the number of backyard "do-it-yourself" oil changes, 3/ and the recent increase in the use of waste lube oil as fuel have been major contributors to the drop in waste oil supplies. This has resulted in higher costs of drain oil delivered to the re-refinery. Competition from cheap, low-quality virgin lube oils has, until very recently, not allowed re-refiners to recover these higher costs through price increases. This cost/price squeeze has been the major reason for the contraction of the re-refining industry.

TABLE 2

USAF Post-War Procurement of Re-refined Oil

Fiscal Year	Gallons of Re-refined Oil	Estimated Savings
1947	823,727	$338,000
1948	936,203	$384,000
1949	1,174,810	$482,000

TABLE 3

Estimated Industrial Production of

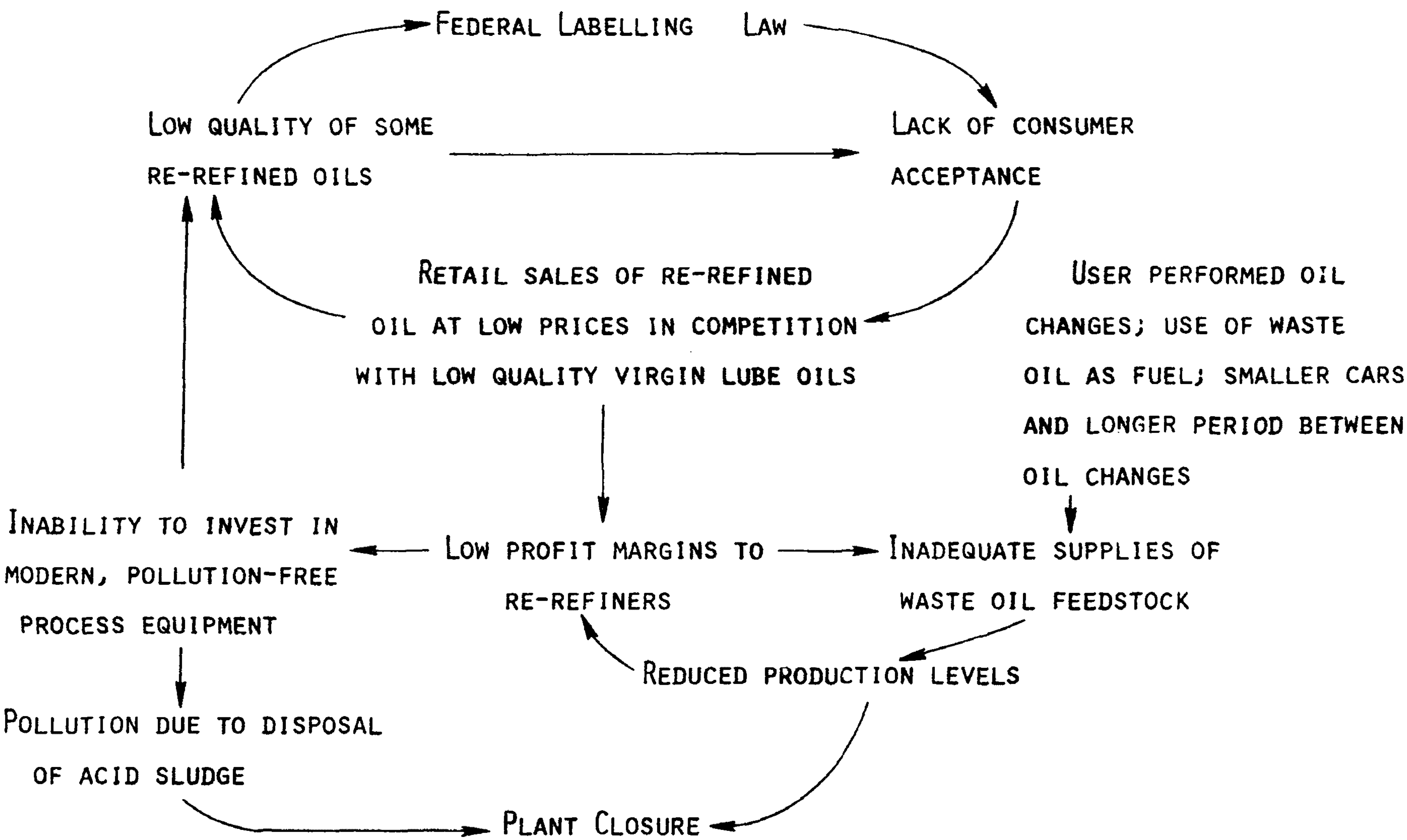
Re-refined Oil in the United States

Calendar Year	Volume of Gallons*
1939	11,250,000
1948	45,000,000
1950	50,000,000
1954	75,000,000
1960	300,000,000
1966	225,000,000
1971	120,000,000
1972	100,000,000

*Source: Estimates for 1939 and 1948 were included in a research paper prepared by Major Charles B. Cruikshank for the Air Command and Staff College of the Air University. Estimates for 1950 and 1954 were included in the April 26, 1954 issue of the Oil and Gas Journal. Figures for 1960-1971 were provided by the Association of Petroleum Re-Refiners, and the 1972 estimate was provided by EPA.

Figure 1

REASONS FOR CONTRACTION OF THE RE-REFINING INDUSTRY



At the re-refining end of the business, most plants now in operation are more than 30 years old, have very high maintenance costs, and cannot be modernized without large new investments. Laws concerning air and water pollution control have required considerable new investment in emissions control equipment which has, in some cases, been beyond the resources of some firms. These companies are no longer operating. Further, the re-refining process most commonly used produces large volumes of acid sludge which has traditionally been disposed of by dumping. In some states regulations controlling or prohibiting the disposal of such untreated hazardous materials have forced re-refiners out of business. In addition, the re-refining process has proved incapable of successfully removing chemical additives from modern automobile waste oils without the use of increased volumes of acid, thereby compounding the sludge disposal problem.

In marketing, the re-refining industry has never enjoyed a reputation for producing high quality products. The business has a history of opportunists and men of questionable integrity whose operations have served to discredit those firms which do produce high quality products. Partially as a result of this situation, in 1964 the Federal Trade Commission ruled that oils sold in interstate commerce which are composed in whole or part of previously used oils must be labelled as "manufactured from previously used oils." Hence, regardless of the quality of re-refined lubricants, the FTC ruling has cast a stigma on these oils since to the consumer the word "used" frequently implies a product of inferior quality. 3/ In 1965, the Excise Tax Reduction Act removed a 6¢ per gallon tax advantage which re-refiners had enjoyed on sales of lube oil for off-highway use. A subsequent ruling of the Internal Revenue Service concerning the payment of excise tax on virgin oil which is blended with re-refined products sold for off-highway use further weakened the competitive position of recycled oils by requiring re-refiners to pay a non-refundable tax of 6¢ per gallon on virgin oils which are blended with re-refined oils and subsequently sold for off-highway use. 4/

Considerations affecting the viability of the re-refining industry are further discussed below.

1.2 COLLECTION OF WASTE LUBRICATING OILS

Waste lube oils are collected from a variety of sources either by independent operators or directly by a re-refiner. The most important sources of used lube oils include service stations, garages, and industrial plants. Municipal vehicle fleets, private truck and taxi fleets and railroads also provide large volumes of drain oil. While only a small fraction of the waste oil is collected under contract, for some re-refiners contractual relationships account for the bulk of waste oil supplies. This is especially true of those firms engaged in "custom" or "closed-cycle" re-refining wherein the source of waste oil is also the customer for the re-refined product. In these arrangements a customer's waste oil is segregated from other oils throughout the entire re-refining process. A single tariff is normally charged for waste oil pickup, re-refining, and product delivery. An important advantage of custom re-refining is a firm's ability to control both the quantity and quality of its supplies of feedstock. This is especially important as competition for sources of drain oil is becoming increasingly strong principally due to the shortage and high cost of fuel oil (see below).

1.2.1 Independent Collectors

The bulk of all waste oil collected in the United States is handled by small, independent companies. The size of these firms ranges from a "father and son" operation involving a single 2000 gallon tank truck to a large scavenger company engaged in the collection of a variety of waste liquids including used lube oil and industrial solvents. In some instances large producers of waste oil such as cities and military facilities will solicit bids from local collectors for waste oil disposal. However, there are normally no contractual agreements between collectors and the companies whose oil they handle. Both personal relationships between collectors and those whose oil is being collected and the price charged or paid for oil removal determine who will get the waste oil. As recently as the mid 1960's collectors would pay as much as 3 to 5¢ per gallon for waste oil. By 1970 this situation had reversed itself; collectors were now charging up to 5¢ per gallon to remove waste oils. Today the trend is again towards payment by collectors for waste oil pickups.

1.2.2 Charges and Payments for Waste Oil Pickups

Changes in the price of waste oils can be readily understood by examining the supply of used oils and the markets available for this resource. In the early 1960's re-refining was a fairly attractive business. Most automobiles

 Preceding page blank

could operate satisfactorily using lube oils containing only a small percentage of additives which were easily removed in re-refining. The few existing laws controlling air and water pollution and the disposal of solid waste were relatively lax. Drain oil could be used for road maintenance and for dust control. Further, service stations, car dealers and garages accounted for more than eighty percent of automobile lube oil sales. Hence sources of drain oil were relatively concentrated and collection costs could be held to a minimum while demand for waste oil was quite strong. Under these conditions collectors could afford to pay for waste oil pickups and could be assured of a good price for their oil.

In the western part of the United States, two additional factors dominated the supply-demand picture for waste oils. In this region it was formerly common practice for independent producers of crude oil to blend several percent of crankcase drainings with their crude in order to raise the gravity of their production. Crude oil prices vary according to gravity with a price rise of about 8¢ per barrel per degree of gravity increase. The gravity of some western crudes may run between 13° and 18° API whereas the gravity of crankcase drainings averages 25° to 27° API. These blended oils were then sold to major oil companies for refining.

The second factor in the drain oil supply on the West Coast was the export market for used lube oils. For about nine years after World War II nearly 50 percent of the drain oil on the West Coast was treated to remove water and/or sludge and then shipped to Japan where it was re-refined to make a variety of lube oils and fuels. At this time Japan had little or no crude oil refinery capacity and had to import its petroleum requirements in the form of refined products. Further, there were strict controls on the volume of fuel oils which Japan was allowed to import. Importation of crankcase drainings provided a hidden supplement to the country's fuel supply.

During the mid-1960's the adoption of the federal labelling law and the repeal of the 6¢ per gallon tax on virgin lube oils sold for off-highway use drove some re-refiners out of business and forced others to seek ways to cut costs in order to survive. Of even greater significance was the buildup of large inventories of virgin lube oils by the petroleum industry. With increased lube supplies oil companies found it necessary to seek new markets for lubricants, thereby providing more intensive competition for re-refiners. At the same time, the flow of lube oils sales away from service stations and garages to mass merchandisers served to diminish the volume of drain oil available at any one source, thereby increasing collection costs. In addition, state and local governments were beginning to monitor waste disposal. In some instances collectors were required to obtain permits authorizing them as acceptable sources for the disposal of waste oils. By this time a number of crude oil refineries had installed catalytic cracking units whose catalysts would be rendered inactive by the lead contained in crankcase drainings. Hence the practice of blending used lube oils with crude oil came to an abrupt halt. Further, the Japanese, with the aid of some major oil companies, had built their own refineries and began to import crude oil from the Middle East. The export market for drain oil on the West Coast rapidly disappeared causing a drastic decline in the price paid by collectors for waste oils. Hence fewer markets existed for drain oil and those that did exist were under economic pressure to cut the cost of waste oil supply. As a result, service station and garage owners were forced to pay as much as 5¢ per gallon for waste oil collection. This served to decrease the delivered cost of feedstock for re-refiners. Further, since the value per gallon of drain oil free of water and other wastes is considerably higher than that of contaminated drainings, there was an economic incentive for service station and garage owners to reduce contamination of their waste oil, thereby minimizing disposal costs. At the same time, the number of independent collectors increased as one could be paid both to collect waste oil and to sell it for use as road oil, re-refinery feedstock or raw material for use in manufacture of products such as asphalt. Road oiling operations were especially attractive as collectors could charge between 10 and 15¢ per gallon for spraying oil on highways in addition to the 3-5¢ per gallon charge for waste oil collection.

This change in the waste oil market made it economically possible for certain irresponsible individuals to earn a profit by collecting waste oil for which they had no customer. With little or no monitoring of the disposition of drain oil, it was possible to dispose of it by dumping at some isolated location. Further, some service station managers, faced with having to pay to have their drain oil removed, decided to cut costs by disposing of their drainings in environmentally harmful ways such as dumping them into storm sewers. 5/

Recently there has been a marked shift in the waste oil market largely due to tight supplies and high costs of fuel oil. Untreated crankcase drainings can be blended with fuel oil and burned, although in some applications there is a risk of burner fouling and in all instances large amounts of oxides of lead and other heavy metals will be emitted. At current market conditions untreated drainings can sell for as much as 15¢ per gallon. A few large industries, especially electric utilities, are now using a blend containing between 1 and 10 percent waste lube oil. In some instances, crankcase drainings are treated to remove water and sludge before being sold for use as fuel. This dehydration process, which is the first step in re-refining to make lube oil, costs about 3¢ per gallon of de-watered product. In fact, some re-refiners have found it economically more attractive to process waste lubes for sale as fuel oil rather than as re-refined lube oil. Unless the price of lube oil rises relative to the price of fuel, it is likely that this trend will continue. At current price levels for re-refined products, some re-refiners cannot produce lube oil at a profit unless the delivered cost of drain oil feedstock is under 5¢ per gallon. With collection costs increasing as a result of the factors mentioned above, a decrease in the price paid to collectors for waste oil removal could increase the delivered cost of drain oil to over 5¢ per gallon.

In fact a trend towards lower prices for waste oil removal is now evident. Some re-refiners are now picking up crankcase drainings for free. Others are finding it increasingly difficult to secure supplies of drain oil sufficient to operate their plants at capacity. As shown in Table 1 only one of thirteen re-refiners visited is now operating at full capacity. All re-refiners interviewed (save this one) complained that the fuel oil market was making it impossible to obtain enough feedstock. Of course, this is equivalent to saying that the fuel shortage has served to raise the delivered cost of drain oil above what some re-refiners are willing to pay. If lube oil prices were to rise sufficiently, then an increase in the price of feedstock could be off-set by an increase in the price of re-refined products. In the absence of such a price increase, it is likely that a number of marginal re-refiners may be forced out of business in the near future.

1.2.3 Supply of Feedstock

Perhaps the most crucial difficulty facing re-refiners today is obtaining volumes of waste oil sufficient to maintain re-refining operations at or near capacity. As with petroleum refining, due to relatively high fixed costs, in re-refining incremental costs rise as throughput falls. Formerly, drain oil availability fell in summer as large volumes were consumed for road oiling operations. Re-refiners having adequate storage capacity would acquire large volumes of feedstock in winter to tide them over during the summer. This practice has been especially common in the Northeast and Midwest. However, since these are the areas of the country most seriously affected by the fuel oil shortage, it is highly likely that some re-refiners in these regions will find themselves unable to secure adequate supplies of drain oil either in summer or in winter. In the western and southern parts of the United States, where natural gas has been the principal industrial fuel, the current drain oil supply is not nearly so tight as in the Northwest and Midwest. However, as natural gas curtailments continue to spread, many industries in the South and West will be forced to convert heating and processing units to burn fuel oil. As fuel oil supplies are likely to remain tight for at least the next three years, large volumes of used crankcase oil will be diverted for use as fuel.

An interesting comparison regarding feedstock supply can be made between the re-refining industry and the petroleum industry. Throughout the history of the petroleum industry, a principal concern of refinery managers has been obtaining supplies of crude oil sufficient to operate at or near capacity and to meet the requirements of customers for refined products (gasoline, fuel oil, etc.). This concern caused many oil companies to integrate backwards - to become involved in crude oil exploration and production - in order to be assured that adequate refinery feedstock would always be available. The recent rash of closings of gasoline stations supplied by independent, non-integrated refiners is testimony to the need for refiners to have control over sources of crude oil.

The re-refining industry is faced with a similar problem. Shortages of feedstock are forcing re-refiners to reduce their production of lube oil and other products. However, a re-refiner cannot guarantee an adequate feedstock supply by backward integration into production of waste oil, for in a given geographical area the total supply of crankcase drainings is fixed. Ability to pay a higher price for used lube oil is the only way to guarantee an adequate supply of this material for re-refining.

1.2.4 Waste Oil Collection by Re-Refiners

Some re-refiners have, however, attempted to achieve security of feedstock supply by operating their own waste oil collection service. Table 1 summarizes the degree to which the re-refiners interviewed depend on outside sources for feedstock. A correlation between self-sufficiency in feedstock supply and percent utilization of re-refining capacity is, however, difficult to make as other considerations, namely frequent forced shutdowns for unscheduled maintenance, contribute significantly to reduced production levels. On the other hand, there can be little doubt that re-refiners who collect their own waste oil enjoy a more stable position regarding feedstock supply than those who depend entirely on independent collectors for waste oil deliveries.

Consider the position of the manager of a service station or garage. For him waste oil is a headache. Generally speaking, the cost of disposal is less of a problem than getting rid of the drainings in a reliable and legal manner. This is especially true for larger service stations and garages which have greater volumes of used crankcase oils to dispose of. Further, major oil companies, under increasing environmental pressures, have become quite responsive to the need to dispose of waste oils in environmentally sound ways and are encouraging service station managers to dispose of waste oil in a manner not harmful to the environment. The establishment of personal relationships between the waste oil collector and the people from whom he collects can contribute significantly to maintaining a secure supply of feedstock. While independent collectors come and go according to the market for drainings, a re-refiner provides a readily available, legitimate sink for waste oils.

However, there are disadvantages for re-refiners who collect their own oil. Most important is the higher delivered cost of feedstock. Many re-refiners must pay union wages to truck drivers. Maintenance of the vehicles, depreciation, and supervision of the drivers result in additional costs. On the other hand, an independent collector generally drives his own truck, fixes it himself and depends on scavenging for a livelihood. Hence an independent can deliver waste oil to a re-refiner at a lower cost than if the re-refiner collected his own oil. Further, independent collectors tend to be rugged individualists. More than one re-refiner interviewed expressed the opinion that infringement upon territories of independent collectors could result in a hostile reaction, especially in those areas where collectors have formed an association in order to stabilize prices and prevent territorial disputes amongst themselves.

1.2.5 Closed-Cycle or Custom Re-Refining

A more attractive route to follow to assure feedstock supply is to enter into "custom" or "closed-cycle" re-refining arrangements with industrial and/or commercial accounts which serve both as the source of waste oil and the customer for the re-refined product. "Closed-cycle" re-refining both guarantees a supply of feedstock and provides an incentive for the client to prevent the waste oil from becoming contaminated with other oils, greases, water, etc. Further, under closed-cycle arrangements sales of re-refined oil are made directly to the final user. "Middlemen," such as jobbers and distributors are eliminated thereby increasing profit margins to the re-refiner. Most importantly, a customer who has his lube oil custom re-refined is interested in securing a high quality product at a savings over the cost of equivalent virgin oils. This means that a re-refiner engaged in custom or closed-cycle work is competing against high quality, major brand virgin oils rather than against cheap virgin products and can, therefore, secure a much higher price (and margin of profit) for his production than he would otherwise be able to obtain (see Figure 3 and discussion in Section 4.4 Marketing). From the customer's point of view, closed-cycle re-refining both eliminates a waste disposal problem and decreases the cost of lubricating oil supply.

1.3 RE-REFINING OF WASTE CRANKCASE OILS

Re-refining of used automotive crankcase oils is a separation process in which water, sludge, spent additives and decomposition products are removed. The desired product is a mineral oil or neutral base stock roughly equivalent in lubricating properties to a virgin non-detergent oil. The physical properties and performance characteristics of properly re-refined base stocks can be altered to meet essentially any existing specification by the addition of specially formulated blends of chemical additives. General or "fat" additive "packages" are frequently designed for use with a range of base stocks in order to compensate for variations in the properties of re-refined oil. In recent years, due to the wide variety and severity of the conditions under which modern automobile engines operate, the volume of additives blended with lubricating oils has increased sharply. This has served to increase both the cost of additive packages used in blending and the cost and difficulty of removing spent additives during the re-refining process.

1.3.1 Process Description

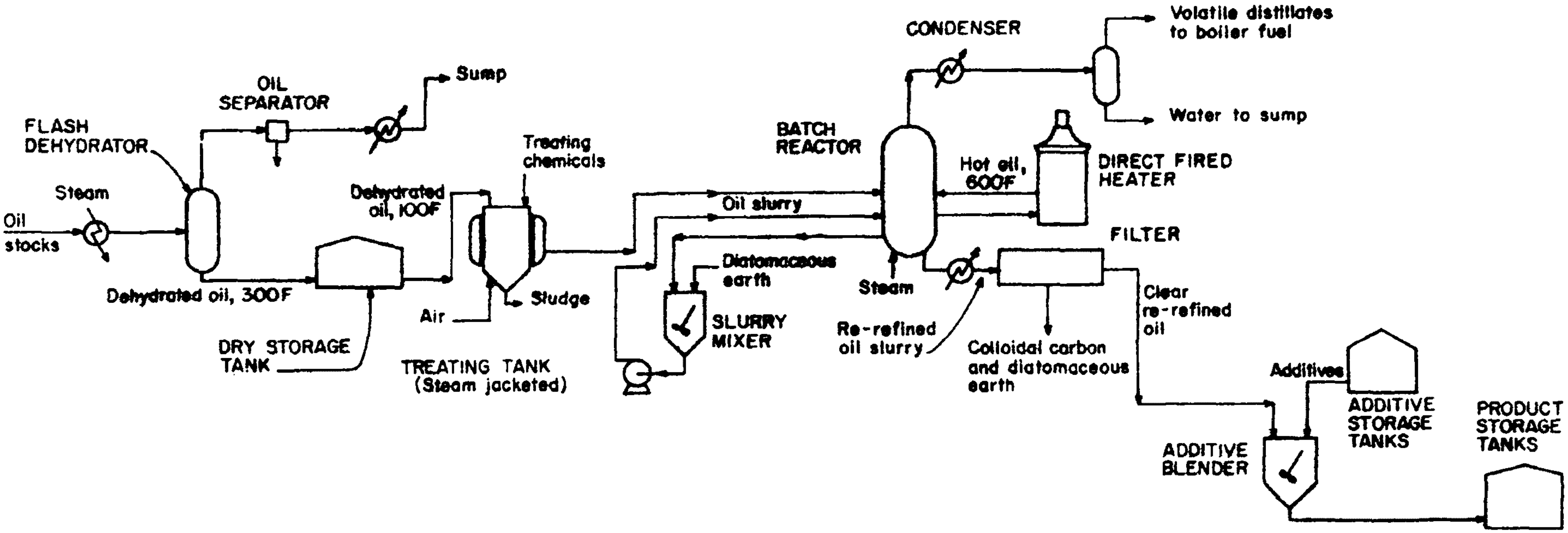
Nearly all of the approximately 45 U.S. re-refiners now in operation use the so-called "acid-clay" process for removing spent additives and other contaminants from used crankcase oils. Figure 2 shows a typical acid-clay processing plant.

Waste oil is stored in large tanks and allowed to settle thereby effecting gravity separation of some dirt, sludge, and water. After settling, waste oil is fed into an atmospheric dehydration unit. The temperature is raised to about 250°F using closed-cycle steam. Light hydrocarbons distilled from the waste oil are used as fuel to heat the steam which is used in dehydration. The dehydrated oil is cooled to 120°F and pumped to an acid treating tank. About 4% of concentrated sulfuric acid is added. Following acid treatment the oil is pumped to an atmospheric distillation unit; clay is added and the mixture is heated to about 600°F and agitated using open cycle steam. The distillate is condensed and used for fuel. The oil is then cooled and separated from the clay in a plate and frame press, blended with additives, packaged, and stored for shipment. All fuels consumed in re-refining are provided by separation of the waste oil into lube and fuel fractions.

1.3.2 Process Economics

Table 1 indicates an average re-refining cost of about 17.5 cents per gallon of finished product. This figure may be further divided into six components as shown in Figure 3. These components include cost of feedstock, labor, chemicals and other materials, utilities, waste disposal, depreciation, Fiqure 2

Flow Chart for Acid-Clay Re-refining Process



and overhead, but dc not include administrative costs such as officers' salaries and taxes. Because most re-refiners produce a variety of products in addition to unblended lube oil, it is not possible in general to determine separately the total cost of lube oil re-refining. Further, most re-refiners keep rather minimal records of financial and operating data and so it is difficult to perform an exact cost analysis for most firms. However, several companies interviewed produce only automotive lube oil which is sold unblended in bulk lots to independent jobbers. From financial and operating data supplied by these firms it is possible to estimate that administrative costs and taxes generally add about 3 to 4¢ per gallon to the stated cost of re-refining. This means that, on the average, the total cost of producing a gallon of re-refined but unblended oil is about 22¢. The average price realized on bulk sales of such oils for the companies interviewed was 23¢ per gallon. Hence the net margin for bulk sales of re-refined oil to jobbers is about 1¢ per gallon or 4% of the sales price. One of the largest (in terms of sales volume) re-refiners interviewed stated that his company's net margin on lube oil sales to jobbers had never exceeded 1¢ per gallon. Profit margins on such bulk sales have been small because of competition from cheap, low quality virgin lubes. As long as such oils are available at a low price, re-refiners will not be able to pass along increased production costs. On the other hand, if the price of fuel oil rises far enough, it will become more profitable for oil companies to sell the hydrocarbon stocks from which the cheap virgin lubes are made for use as fuel. This will permit re-refiners to increase the price for bulk sales of unblended lube oil. Under current conditions, with a small margin of profit per unit of sales, it is imperative for re-refiners to monitor operating costs closely in order to prevent operating losses. One re-refiner interviewed stated that several years ago his business had lost money because he had not realized that his operating costs per gallon had exceeded his sales price. Fortunately, he was able to raise prices and his company became profitable the following year.

With such small margins on lube oil sales it is not surprising that many re-refiners have ceased operations. While the costs of re-refining including labor, materials and plant maintenance have risen sharply in recent years, the price of unblended re-refined lube oil has been held down by competition from the lower grades of virgin oils. Although every re-refiner interviewed proudly stated that he can sell all the oil he can produce it is evident from Table 1 that only a few companies are making a reasonable profit as a percentage of total sales. A company operating with a small net margin per unit of sales must depend on large volume in order to show a reasonable profit. As mentioned earlier, economic operation of a re-refinery depends on maintaining production close to capacity. Due to high fixed costs if production drops, operating costs per gallon will rise, possibly resulting in net losses. The shortage of feedstock has already reduced the level of operations at a number of plants. If these shortages continue, as is likely to be the case due to the shortage of fuel oil, it is almost certain to reduce further the number of re-refiners in operation.

1.3.3 Breakdown of Production Costs

Feedstock

Figure 3 is an examination of the important cost factors in the production of re-refined lube oil. By far the most important cost component in re-refining is the delivered cost of the waste oil feedstock. According to Table 1, the average recovery of lube oil product is only about 57 percent by volume of the drain oil feed. With an average delivered cost of feedstock of four cents a gallon, this is equivalent to a cost of about seven cents per gallon of re-refined oil. It is certainly not surprising that re-refiners pay close attention to the volume of contaminants (especially water) in the waste oil which they collect and/or purchase from independent operators. In some cases the price charged for pickups or paid for deliveries of drain oil varies sharply with the level of contaminants in the oil. An unwary collector would at times be paying for a resource diluted with water which would have to be removed (at an additional cost penalty) in the re-refining process.

As mentioned earlier, access to feedstock is now a serious problem for re-refiners. Given a yield of 57 percent, a one cent per gallon rise in the delivered cost of drainings results in a cost increase of 1.75 cents per gallon of finished product. If these costs cannot be passed along to consumers, then partial processing of waste lube oils to fuel oil in which yields of more than 80 percent are common becomes particularly attractive (see below).

Labor

Labor costs have risen sharply in the past few years making it imperative for re-refiners to keep production at maximum levels in order to minimize unit costs. For companies with spare capacity, this has resulted in diversification of re-refining activities to produce a variety of products in addition to automotive lube oil, especially fuel oil and industrial oils, frequently under "closed-cycle" arrangements. Custom re-refining of industrial oils affords both greater profit margins per gallon of sales (see Marketing) and greater security of supply of feedstock. In some instances re-refiners have said that without increasing their industrial business they would not have been able to survive. In the case of smaller firms increased labor costs have invariably resulted in longer working hours for the companys' owners in order to cut expenses. Among the smaller firms interviewed, working days for management approximately 15 hours in length were not uncommon.

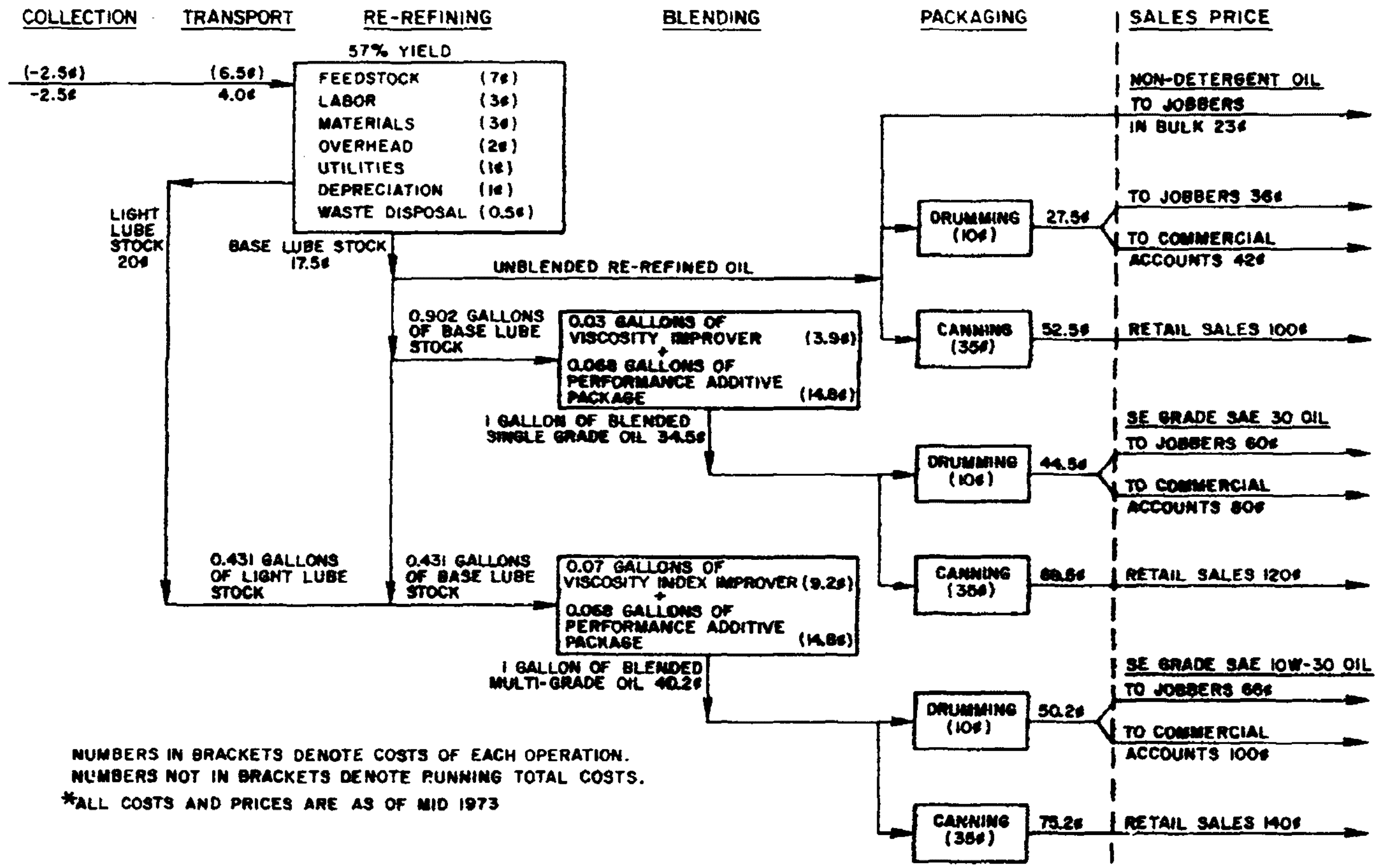
Materials

Materials costs have risen sharply in recent years as have the amounts of sulfuric acid and clay required per gallon of product produced. This increase in material use has been necessitated by the increased volume of additives blended with automotive lubricating oils. Typical quantities of sulfuric acid (66° Baume) and clay used per gallon of oil produced are 0.04 gallons of acid and 0.25 pounds of clay. At current prices for acid and clay this amounts to a total materials cost of about 3¢ per gallon of product.

FIGURE 3

SUMMARY OF RE-REFINING ECONOMICS*

(ALL COSTS EXPRESSED IN CENTS PER GALLON OF OIL)



A TECHNICAL AND ECONOMIC STUDY OF WASTE OIL RECOVERY

Principal Investigator: Dr. P. M. Cukor
Project Director: Dr. M. J. Keaton

EPA Contract No. 68-01-1806 Performed for:
Dr. John H. Skinner, Acting Deputy Director
Resource Recovery Division
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency

Waste Disposal

Although disposal of acid sludge is one of the most serious problems facing re-refiners today, the cost of sludge disposal is at present only a minor contribution to the total cost of re-refining. About 0.1 gallons of sludge are produced per gallon of re-refined oil. Most re-refiners pay less than 0.5¢ per gallon of finished product for sludge disposal. Clay disposal costs are much lower, less than 0.25¢ per gallon of product on the average. Generally, re-refiners depend on local refuse companies for removal of acid sludge and spent clay. In some areas of the country Class I dumps are available for sludge disposal. In other areas, local ordinances prohibiting the disposal of untreated hazardous wastes may force some re-refiners out of business. Acid sludge can be neutralized, but at greatly increased cost. One re-refiner quoted a cost of about 3.5 cents per gallon of product for treatment with calcium carbonate. Table 4 presents an analysis of acid sludge obtained from a typical re-refinery. The waste material contains about forty percent sulfuric acid as well as large quantities of heavy metals. All the metals except lead derive from additives blended with the oil. The lead results from contamination with gasoline combustion products.

1.3.4 Blending and Compounding

Viscosity Improvers

Re-refined oils vary somewhat in viscosity depending on feedstock properties and processing conditions. Generally the finished product has a viscosity of between 55 and 58 Saybolt Universal Seconds (SUS) at 210°F. This is equivalent to the viscosity of an SAE 20 weight oil. In order to raise the viscosity to that of a 30 weight or 40 weight oil, a small percentage of a heavy virgin oil or brightstock may be added. Brightstocks frequently used have viscosities of 150 and 165 SUS at 210°F. A rough rule of thumb is that the viscosity at 210°F of a 20 weight lubricating oil will increase by 1 SUS for every 3 percent of brightstock added. Brightstocks are purchased by re-refiners from major oil companies for about 37¢ per gallon. If it is desired to raise the viscosity of a re-refined oil from 55 SUS (SAE 20) to 61 SUS (SAE 30), then 18 percent brightstock must be added at a cost of 6.6¢ per gallon of oil produced. Since brightstocks are virgin oils, a tax of 6¢ per gallon must be paid on brightstocks used in blending. Alternatively, chemical additives such as polyisobutylene may be blended to increase viscosity. Polyisobutylene has the added advantage of raising the viscosity index as well as the viscosity of the oil with which it is blended. One supplier of such additives quotes a price for viscosity improver of $1.31 per gallon f.o.b. Los Angeles. For the same base stock mentioned above, only 3.0 percent of a polyisobutylene compound must be blended to raise the viscosity to 61 SUS at 210°F. This would cost 3.9¢ per gallon of product. No tax is levied on the blended material in this case.

Performance Package

Once the viscosity of a re-refined oil has been adjusted to the desired value, further blending with specialized additives is required to produce a high performance product which meets automobile manufacturer's specifications

TABLE 4

Analysis of Acid Sludge Produced in Re-Refining Automobile Crankcase Oils *

pH	0.1
Specific Gravity	1.2
Ash as $SO_4^{=}$	11.26%
Acid	40.8%
Sulfur	14.1%
Copper, Cu	40 ppm
Aluminum, Al	140 ppm
Iron, fe	1,100 ppm
Silicon, Si	1,400 ppm
Lead, Pb	20,000 ppm
Zinc, Zn	2,100 ppm
Barium, Ba	1,300 ppm
Chromium, Cr	50 ppm
Calcium, Ca	6,400 ppm
Sodium, Na	4,000 ppm
Phosphorus, P	4,300 ppm
Boron, B	50 ppm
Nickel, Ni	30 ppm
Tin, Sn	30 ppm
Magnesium, Mg	1,000 ppm

* Analysis dated January 12, 1971 based on sludge produced by one re-refining company.

for engine oils for use in new cars. 6/

One important supplier of engine oil additives manufactures a general purpose motor oil performance additive which when blended with a 30 weight non-detergent base oil produces an oil which meets all the specifications required for an API SE rating and meets automobile manufacturers warranty requirements for 1973 model vehicles. This performance additive sells for $2.18 per gallon f.o.b. Los Angeles, California. 6.8 percent by volume of this performance additive is required to produce an SE grade oil. The cost of this blending is about 14.8¢ per gallon of product. Hence the total cost to produce an SE grade oil from crankcase drainings is about 34.5¢ per gallon. Table 5 gives details of this calculation.

Multi-Grade Oils

Multi-grade oils are produced by combining a viscosity index improver with a blend of the lube oil base stock and the performance additive. As shown in Figure 3, 10W-30 oil (a popular multi-viscosity oil) can be made by mixing a viscosity index improver and a performance additive package with a blend of equal volumes of re-refined base lube stock (viscosity 56 SUS at 210°F) and re-refined light lube stock (viscosity 40 SUS at 210°F). (A re-refined light lube stock costs more to produce than a re-refined base stock because additional distillation and acid/clay treating steps are required.) The resulting mixture should have a viscosity at 0°F equal to that of a 10 weight oil (6,000-12,000 SUS) and a viscosity at 210°F equal to that of a 30 weight oil (58-70 SUS). Thus, multi-grade lube oils have the advantages of a light weight (SAE 10W) oil at low temperatures and a heavier weight (SAE 30) oil at high temperatures. Such oils are commonly recommended by automobile manufacturers for use in modern vehicle engines. While the cost of producing multi-grade oils is higher than that for single-grade and non-detergent oils, profit margins on such sales are very attractive (see Table 6).

TABLE 5

Blending Costs for Re-Refined Oils

(Single Viscosity)

Operation	Percent Additive Blended	Cost, ¢/Gal. of Blended Oil
Viscosity Improvement from 55 SUS to 61 SUS at 210°F	3.0	3.9
Performance package to meet SE specifications	6.8	14.8

Summary

Product	Gallons	Cost, ¢/Gal. of Blended Oil
Re-refined base stock	.902	15.8
Viscosity improver	.030	3.9
Performance package	.068	14.8
SE grade oil	1.00	34.5

1.4 MARKETING

1.4.1 Wholesale Markets

In most instances re-refined automobile crankcase oils are sold unblended in bulk lots (more than 2000 gallons) to independent jobbers who package the oil in 55 gallon drums or quart cans and sell it to commercial accounts, garages, independent (as opposed to major brand) gasoline stations, automotive supply stores and discount houses. As shown in Figure 3, bulk sales of unblended re-refined oil are made at rather low prices, generally about 23¢ per gallon. This leaves a re-refiner with about 6¢ per gallon gross margin. Administrative expenses and taxes will account for most of the 6¢, leaving the re-refiner with a net return of about 1¢ per gallon or 4¢ per dollar of sales.

In some instances a re-refiner will package his own production. He may then distribute products himself (usually through a wholly owned subsidiary company), through independent distributors who handle a variety of items but carry the re-refiner's oil exclusively, or sell the packaged products to a jobber who will sell the oil to the same outlets listed above. Jobbers are essentially independent brokers who handle a wide variety of petroleum and related products manufactured by a number of companies including re-refiners, independent and major oil companies. By packaging his own products, a re-refiner earns a return on the packaging operation and hence realizes a greater margin per gallon of sales. Typical packaging costs are about $2.10 for a case containing 24 one quart cans. This is equivalent to about 35¢ per gallon. The cost of filling a 55 gallon drum runs about 10¢ per gallon. This includes the cost of cleaning the drum after use which is about $2.50 per drum.

1.4.2 Retail Markets

Nearly all the re-refined oil which is available in retail markets is sold by re-refiners in bulk lots to independent jobbers. As shown in Figure 3, such exchanges are made at low margins, typically one cent per gallon. The jobber will package the oil in quart cans under one or several brand names and sell the packaged product to garages, service stations, discount stores and automotive supply stores. In these outlets re-refined oils compete with cheap, low quality virgin lubes as customers seeking a quality oil generally select their purchases on the basis of identification with nationally advertised major brands. 7/ Further, the public image of the quality of re-refined oils has been tarnished by the failure of the industry to regulate the quality of its products. This lack of quality control led to the enactment of the federal law which requires that re-refined oils sold in interstate commerce be labelled as "manufactured from previously used oils." Since the term "used" frequently implies that a product is inferior, this requirement has undoubtedly served to discourage further public acceptance of re-refined oil. As a result, individuals who knowingly buy re-refined lube oils in retail markets are concerned with obtaining the cheapest oil available. Hence high quality re-refined oils which have been blended with additives are rarely sold in retail outlets because the price of such oils is too high relative to that of the competing low quality virgin lubes.

These barriers to penetration of the high quality retail market by re-refined oils can best be illustrated by reference to Figure 4. This diagram shows how the considerations discussed above build upon one another and result in reinforcement of the public's negative attitude towards re-refined oil. The failure of the industry to regulate the quality of its products led to enactment of the federal labelling law. Both of these actions have served to foster a poor public image for recycled lube oil. Thus re-refined oil has become acceptable only to customers who are highly price conscious. High quality re-refined oils are not price competitive with low quality virgin lubes and thus are not available in most retail markets. As a result, only relatively low quality, low cost, non-detergent re-refined oil is marketed. Under these conditions public confidence in the quality of recycled oils can never be increased because high quality recycled oils are not readily available to the public. Because of these considerations, some re-refiners will not permit their unblended oil to be sold in the retail market as they fear that such a practice would tarnish their hard-won images as manufacturers of quality oils.

Paradoxically, some of the low quality virgin lubes with which re-refined oils compete are actually blends consisting of very low quality, very inexpensive virgin lubes and re-refined oil! The recycled oil is used to raise the viscosity and the viscosity index of the virgin products to minimal (but still unacceptably low) levels. Such oils are generally sold in retail markets as virgin oils (in violation of federal and state labelling laws), even though they may contain an appreciable fraction of re-refined oil. The performance characteristics of these low quality blends fall far short of specifications for lube oils intended for use in modern automobile engines.

Thus, in the retail trade it is the bulk packager who earns an attractive return on his investment by canning very large volumes of cheap oils (both re-refined and virgin). Large profits in the retail sale of re-refined oil can be made on a volume basis only. Hence it is not surprising that those re-refining firms whose principal customers are jobbers (who buy unblended oil in bulk) are among the least profitable (see Table 1).

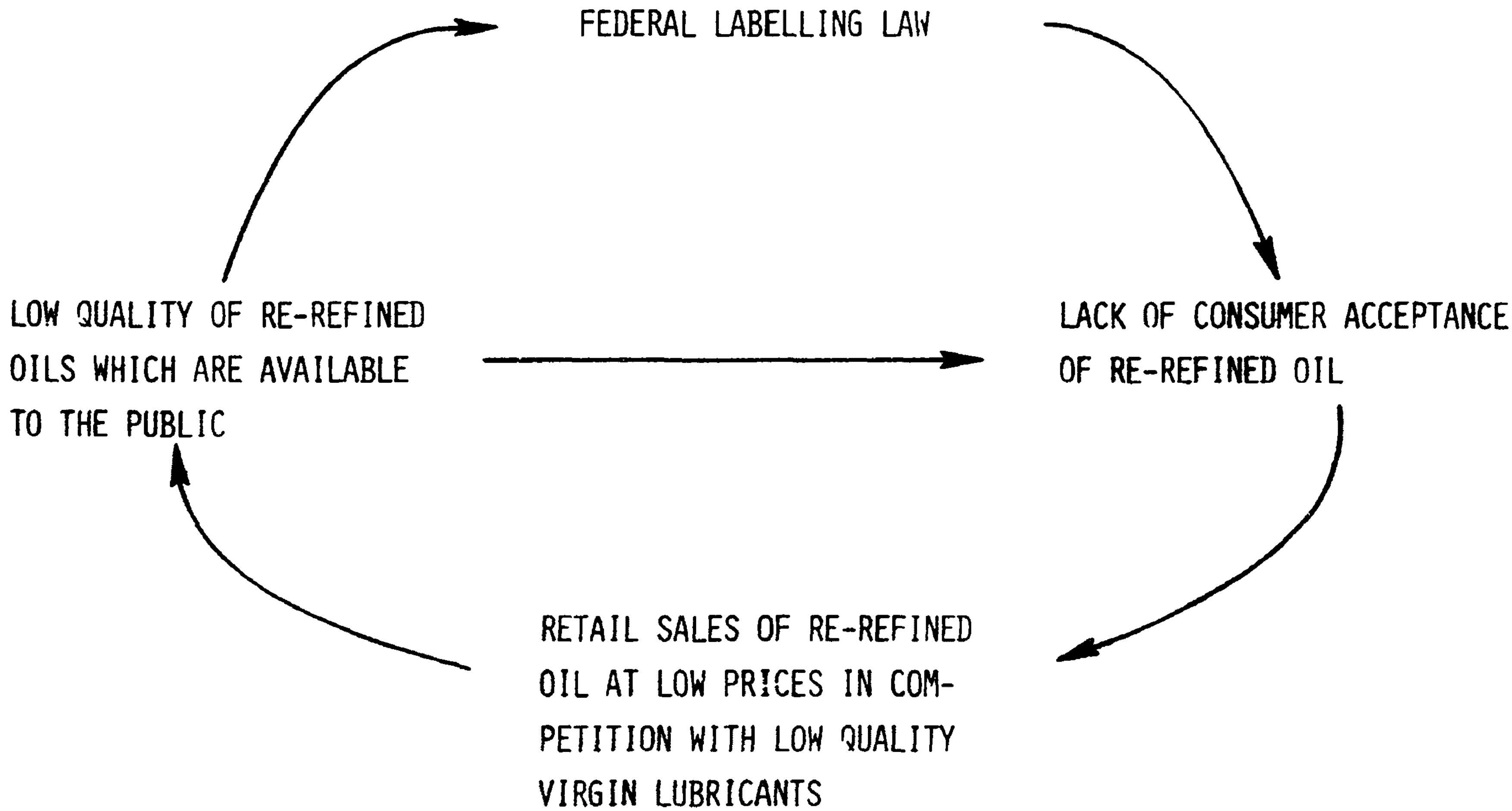
1.4.3 Commercial and Industrial Markets

The most lucrative markets for re-refiners involve sales to commercial accounts such as truck and taxi fleets, railroads and other industrial customers. The emphasis in these markets is on quality and hence the competition for re-refined oils is major brands of virgin lubes. The critical factors for success are thus a reputation for producing top quality oil and, of course, a price below that of the competiton.

A re-refiner expands his commercial and industrial business on the basis of "toe-to-toe" and "belly-to-belly" type relationships which have developed over extended periods of time. Satisfied customers generally provide the only demonstration as to the quality and performance record of oils produced by a re-refiner. While years of satisfactory engine performance and

Figure 4

Barriers to Public Acceptance of Re-Refined Oil



low maintenance costs are not adequate to qualify re-refined oils for procurement by federal agencies, such records should not be lightly dismissed as railroad, trucking and taxi companies have millions of dollars invested in rolling stock and certainly would not risk high maintenance costs and out of service time by using oils of questionable quality. At the same time, a re-refiner whose oil is used in such applications will monitor his product quality carefully. For if even one customer experienced maintenance problems due to poor oil performance, the re-refiner's ability to maintain or expand his sales to commercial and industrial accounts would be severely limited. A brief examination of Table 1 shows that, without exception, the most profitable re-refineries are those whose principal sales are to the commercial and industrial market.

Due to the high cost of shipping lubricating oils, a re-refiner's marketing area rarely extends beyond a 300 mile radius from the production location. A noticeable exception is the case of sales to railroads where tank car loads of re-refined oil are picked up by the customer at the re-refinery and distributed to points of locomotive service across the nation.

1.4.4 Comparison of Markets for Re-Refined Oil

Table 6 shows representative prices and production costs for several grades of re-refined oil sold in various markets. Considerable variation from these price levels occurs for large volume purchases as well as for negotiated "closed-cycle" custom re-refining arrangements. For example, consider the jobber price of 36¢ per gallon for non-detergent 30 weight oil delivered in lots of one to five 55 gallon drums. If bulk deliveries are made in tank car loads of approximately 2000 gallons, the price would be much lower, approximately 23¢ per gallon. Similarly, commercial accounts which buy oil in large volumes can expect to be granted discounts of between 5¢ and 15¢ per gallon.

The figures in Table 6 indicate that re-refining ought to be highly profitable. The profit margins on sales of all grades of re-refined oil in the retail market are considerable, especially in the case of the high quality SE grade oils. However, as has been previously discussed, most of the re-refined oil which reaches the retail market is not distributed by re-refiners but by independent jobbers who buy large volumes of non-detergent oil at low prices from re-refiners, package the products themselves, and sell these and other brands of oil at cut rate prices to discount stores, etc. The retail prices listed in Table 6 are representative of what a consumer would have to pay for the three grades of oil if he purchased the oil at a discount store or directly from a re-refiner. Prices for sales of lube oil by a jobber to a retail outlet are lower than those listed in the table.

If a re-refiner were to integrate forward by opening an automotive supply store or becoming a lube oil jobber, then he would be able to realize considerably larger profit margins on his re-refining operations. However, the poor market image of recycled oil would still severely limit the volume of heavy duty, high quality oil which could be sold.

Table 6

Representative Prices and Production Costs for Re-Refined Oils as of Mid-1973*

Grade of Oil	Sales by a Re-Refiner to: Jobber ¢/gal		Commercial Account ¢/gal		Retail Customer ¢/gal	
	Price	Cost[b]	Price	Cost[b]	Price	Cost[b]
Non-detergent SAE 30	36[a]	27.5	42	27.5	100	52.5
Heavy Duty SAE 30 (SE grade)	60	44.5	80	44.5	120	69.5
Heavy Duty Multi-Viscosity SAE 10W-30 (SE grade)	66	50.2	100	50.2	140	75.2

a For single purchases of tank car loads (approximately 2000 gallons) the price and cost are 23¢ and 17.5¢ per gallon.

* Prices and costs for sales to jobbers and commercial accounts are for purchases of between one and five drums each containing 55 gallons. For deliveries of more than five drums jobber and commercial prices are discounted further. Retail prices are for single purchases of cases containing 24 one quart cans. All prices listed are f.o.b.

b Cost figures exclude administrative costs and taxes.

Thus, under present conditions, the commercial market is the most profitable outlet for re-refined oils, because large volumes of high quality SE grade lubes can be sold here. As mentioned earlier, penetration of this market depends on the establishment of long-term working relationships with commercial and industrial clients. Word-of-mouth recommendations as to the quality of a company's lube oil have enabled several of the re-refiners interviewed to sell most of their production to commerical and industrial accounts. Gaining entry to this market would not be an easy task for a newcomer to the re-refining industry. However, since the major demand is for the high quality oils, a successful effort to gain access to this market would have a high payoff.

1.5 VIRGIN AUTOMOTIVE CRANKCASE OILS

Figure 5 presents economic data concerning the manufacture of virgin automobile engine oils and the subsequent blending and packaging operations. While the refinery gate price per gallon of unblended virgin lubes is higher than that for re-refined oils, the blending and packaging costs are somewhat lower. This is due to the much larger volumes of oil produced by a major oil company.

1.5.1 Production of Virgin Lube Oils

Virgin automobile lube oils are produced by blending light vacuum gas oils (approximately an SAE 10 oil) and heavy vacuum gas oils (approximately an SAE 50 oil). As shown in Table 7, crude oils produced in the United States yield, on average, about 1.7 percent lube oil per barrel. Pennsylvania crudes have the largest "lube cut," around 8 percent, while crudes produced in the interior of Texas yield only 0.1 percent lube oil per barrel. Further, lube oil made from paraffinic base crudes, such as those produced in Pennsylvania, has a much higher viscosity index than lube oil made from naphthenic base crudes, some of which are produced in California. However, with solvent refining to remove napthenic compounds and suitable blending with additives, naphthenic lubes can be "built up" to meet any specification, but at a higher cost.

1.5.2 Supply of Virgin Lube Oils

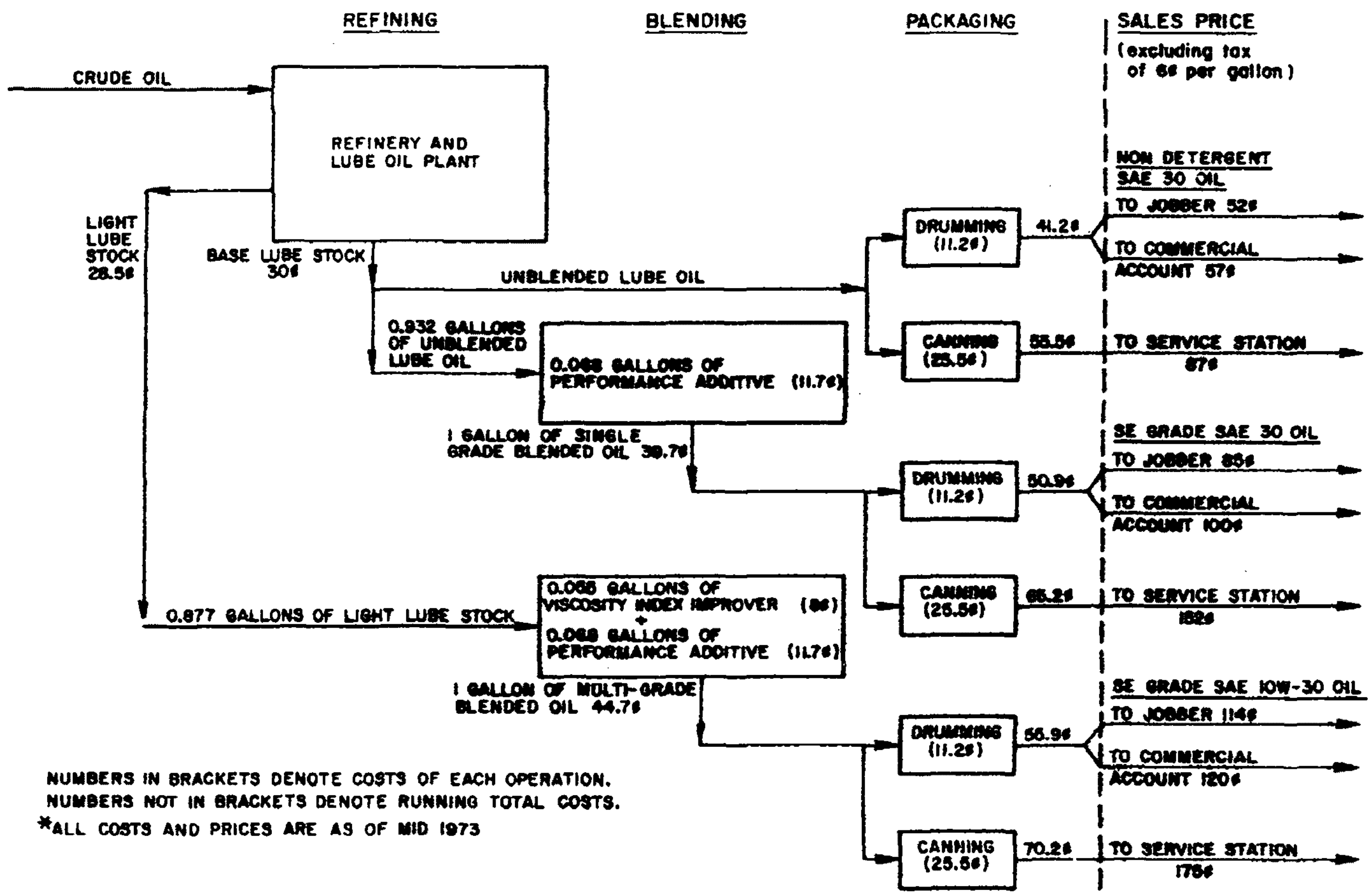
At present throughout the United States new lube oils are in short supply. One of the largest oil companies in the U.S. has halted expansion of lube oil sales, temporarily recalled its lube oil salesmen from the field, and placed all customers on allocation according to 1972 purchases. According to an official of one large oil company, the reason for the tight supply is a shortage of refinery capacity. The lube oil producing capacity of U.S. refineries depends on a number of factors including the composition of the crude oil processed and the economics of producing other products, such as fuel oil or gasoline, from those crude fractions from which lube oil can be made. As of August, 1973, refinery prices for new, unblended lube oil were about 25-26¢ per gallon. However, by the middle of October, 1973, prices had risen to about 30¢ per gallon. One oil company official has estimated that refinery prices for lube oils will rise to nearly 45¢ per gallon within a year.

Table 8 shows representative prices for sales of major brand lube oils to various marketing outlets. The differences in price between virgin and

FIGURE 5

ECONOMICS OF VIRGIN LUBE OIL PRODUCTION*

(ALL COSTS EXPRESSED IN CENTS PER GALLON OF OIL)



NUMBERS IN BRACKETS DENOTE COSTS OF EACH OPERATION.
NUMBERS NOT IN BRACKETS DENOTE RUNNING TOTAL COSTS.
*ALL COSTS AND PRICES ARE AS OF MID 1973

A TECHNICAL AND ECONOMIC STUDY OF WASTE OIL RECOVERY

Principal Investigator: Dr. P. M. Cuker
Project Director: Dr. M. J. Keaton
EPA Contract No. 68-01-1806 Performed for:
Dr. John H. Skinner, Acting Deputy Director
Resource Recovery Division
Office of Solid Waste Management Programs
U.S. Environmental Protection Agency

TABLE 7

Percentage Yield of Lubricating Oils per Barrel of Crude Oil by Refinery Districts for 1968

East Coast	1.4
Appalachian No. 1	8.1
Appalachian No. 2	1.1
Indiana, Illinois, Kentucky	0.9
Oklahoma, Kansas, Missouri	1.7
Texas Inland	0.1
Texas Gulf Coast	3.3
Louisiana Gulf Coast	1.7
Arkansas, Louisiana Inland	3.9
Rocky Mountain	0.3
West Coast	0.9
United States Average	1.7

 Preceding page blank

TABLE 8

Representative Costs and Prices for Major Brand Virgin Oils as of Mid-1973*
(not including federal tax of 6¢ per gallon)

	Sales by an Oil Company to:					
Grade of Oil	Jobber ¢/gal.		Commercial Account ¢/gal.		Service Station ¢/gal.	
	price	cost	price	cost	price	cost
Non-detergent SAE 30	52	41.2	57	41.2	87	55.5
Heavy Duty SAE 30 (SE grade)	85	50.9	100	50.9	152	65.2
Heavy Duty SAE 10W-30 (SE grade)	114	55.9	120	55.9	175	70.2

* Typical sales volumes required for each class of customer are: Jobber, 100,000 gallons per year; Commerical, 2000-4000 gallons per year; service station, single delivery of 50 gallons.

re-refined oils in all market sectors appear to give the re-refiner a significant competitive advantage, especially when the federal tax of 6¢ per gallon is added to prices of virgin oil sold for on-highway use. Re-refined oils are tax-exempt save for any virgin stocks blended with the recycled oil. However, in practice a large commercial customer, for example, will have need for petroleum products (principally fuel) other than lube oil. The dollar value of a fuel supply contract is certain to be many times larger than a lube oil supply agreement. Hence a large commerical customer will frequently be willing to pay a higher price per gallon for lube oil in order to obtain a discount on his fuel supply. The net savings to the customer can more than compensate for the higher price paid for lubricating oil.

1.5.3 Effect on the Re-Refining Industry

Shortages of and subsequent price rises for virgin oils will help re-refiners by enabling them to pass along increased costs of production. If the price of lubricating oils rises relative to the price of fuel oils, re-refiners will be able to compete successfully for needed supplies of waste oil feedstock. Further, if major oil companies are not able to fulfill the lube oil requirements of their existing customers, some of these clients will turn to re-refiners for their lube supply. This will both provide an opportunity for the re-refining industry to improve the image of its products and result in higher prices and higher profits for sales of re-refined oil.

1.6 CRITERIA FOR SUCCESS IN RE-REFINING

In view of the generally unfavorable marketing conditions for re-refined oils, the low margin which can be realized on bulk scales of unblended re-refined oil, and the tight supply of feedstock, it is apparent that the days of the single purpose (crankcase oil) re-refiner are numbered. From Table 1 we can see that re-refiners serve two basic markets - the "on-highway" market and the "off-highway" market. In both markets federal policy has contributed to making profitable operation very difficult. The federal labelling law discussed earlier has contributed to the difficulty of selling high quality blended re-refined oils in the retail "on-highway" market. The removal of the federal excise tax on virgin oils sold for "off-highway" use eliminated a built-in price advantage for re-refined oils of 6¢ per gallon. While other considerations, notably quality assurance in the case of the labelling statute, may have required the enactment of these laws, it must be made clear that these regulations have been major factors in the decline of the re-refining industry. Yet even with these handicaps, some re-refiners have been able to operate quite successfully.

1.6.1 The "On-Highway" Market

In the "on-highway" market re-refiners can make an attractive return through sales of blended oils to commerical accounts such as trucking companies, agricultural concerns, lumber firms, taxi fleets, etc. Such customers are very much concerned with the quality of the oils used in their expensive vehicles. Re-refiner number 2 in Table 1 serves this market and has built a widespread reputation as a producer of very high quality oils. This firm had the highest average revenue per gallon sold of the companies interviewed. Penetration of the high quality on-highway lube oil market is, however, not an easy task for a re-refiner. Many years of close working relationships with customers and close attention to their individual needs play an important part in building the very attractive business which this firm now enjoys.

1.6.2 The "Off-Highway" Market

Industrial Oils

Success in the "off-highway" market is based on the establishment of a number of agreements with industrial firms for purchases of a variety of lubricating, hydraulic, and other non-synthetic fluids used in manufacturing. Industrial oils include some which are quite expensive and some which present extremely difficult disposal problems. The ability to recycle these oils, frequently under "closed-cycle" arrangements, not only saves the company sizeable amounts of money when compared with the cost of virgin oils but also avoids those economic and environmental costs associated with disposal.

 Preceding page blank

For example, the Saginaw Steering Gear Division of General Motors Corporation in Michigan has implemented a "closed-cycle" system with a re-refiner for the recycle of more than 1,000,000 gallons of industrial oils annually. Rather than dispose of the used oils by burning, burial or other environmentally harmful methods, the oil is now recovered, cleaned, re-refined and fed back into the division's manufacturing plants for reuse. General Motors has found the re-refined oil to be equal to new oil for cutting, broaching and grinding operations. It must be emphasized, however, that re-refining of industrial cutting oils is a much simpler process than re-refining of crankcase oils. Generally, used cutting oils are processed to remove water and solids but are not treated with acid followed by clay addition and distillation. This is primarily because cutting oils do not contain additives.

Railroad Oils

The re-refining of railroad diesel engine oils is a completely different situation. Here, used oils are completely processed using acid treatment followed by clay addition and distillation. For many years a number of the nations largest railroads, including the Union Pacific and Southern Pacific, have engaged in "closed-cycle" re-refining agreements for the recycle of diesel engine oils. In fact, at one time the Union Pacific, in an attempt to cut costs, operated its own re-refinery in Ogden, Utah. However, this venture was not an economic success and eventually the railroad returned to its former policy of dealing with re-refiners. The Burlington Northern Railroad was somewhat more successful in re-refining its own oil and still operates a small plant in Livingston, Montana. However, most of Burlington Northern's engine oil volume is custom re-refined by an outside concern. One re-refiner interviewed processes a total of about 6,000,000 gallons annually of used diesel engine oil under closed-cycle arrangements with 15 different railroads. Waste oil is delivered to the plant site in tank car loads of approximately 20,000 gallons; re-refined oil is picked up by the railroads at the same time. This company is one of the largest re-refineries in the U.S. both in terms of volume of oil processed and in terms of total revenues.

Other re-refiners serving industrial accounts mentioned that without this business they would have ceased operations several years ago. In Table 1 re-refiners 1 and 11 emphasized the importance of industrial customers in their operations. Re-refiner 13, who serves only industrial clients under closed-cycle arrangements, has found this business strategy particularly successful.

1.6.3 Diversified Operations

Re-refiner 11 has managed to diversify his operations in order to serve a variety of markets. This strategy not only allows the company to change its product mix in order to serve the most profitable markets, but also permits the conversion to fuel of large volumes of lube oil. Further, diversification enables a re-refiner to serve a range of recycling requirements of industrial customers, a strong selling point in view of restrictions on disposal of industrial oily wastes. Re-refiner 11 stated that under current market conditions industrial oils are his most profitable product, followed by fuel oil and automobile lube oil.

FOOTNOTES CHAPTER 1

1. "Waste Oil Recycling Study". Department of Defense, Defense Supply Agency, September, 1972, p.20.

2. Ibid., p.21.

3. "A Technical and Economic Study of Waste Oil Recovery, Part II: An Investigation of Dispersed Sources of Used Crankcase Oils"; Teknekron, Inc.; EPA Contract No. 68-01-1806; October, 1973.

4. "A Technical and Economic Study of Waste Oil Recovery, Part I: Federal Research on Waste Oil from Automobiles"; Teknekron, Inc.; EPA Contract No. 68-01-1806; October, 1973.

5. Loetterle, Fred. "Use of Sewers for Oil Dumping Probed", New York Daily News, December 26, 1970.

6. Detailed explanations of the requirements of various lube oil specifications may be found in Chapter 2.

7. Op. cit., "A Technical and Economic Study of Waste Oil Recovery, Part II."

Preceding page blank

CHAPTER 2

EVALUATION OF LUBE OIL QUALITY

2.0 INTRODUCTION

The quality of re-refined lube oil is a major unresolved issue that has always stood in the way of federal efforts to encourage waste oil recovery. In 1970, for example, the Council on Environmental Quality abandoned its plans to support greater lube oil recycling largely because the quality of re-refined oil could not be adequately demonstrated. 1/ Product quality is also a major issue in the Federal Trade Commission's recent review of recycled lube oil labeling policies.

A number of issues bear upon the problem of quality. Particularly important is the distinction to be made between the quality of re-refined oils currently on the commercial market and the quality of re-refined oils which can be produced with the application of available technology. The quality of many re-refined oils produced for today's market does not represent the best that technology can produce--even economically produce. Rather, under current marketing conditions high quality re-refined oils are simply not being produced for the retail customer. Therefore, to judge re-refined oil in general by the quality of many re-refined oils now available to the public is an error. For, as has been shown in Chapter 1, market conditions have effectively discouraged the production of high quality re-refined oils for the retail consumer. Combined with the failure of the re-refinery industry to establish and enforce guidelines for maintaining acceptable levels of product quality, the market situation has resulted in public mistrust of re-refined products. This mistrust is reflected in the federal labelling law, in specifications for lube oil purchased by government agencies, and in the lube oil procurement practices of public and private organizations which have followed the government's lead in banning the use of re-refined oil. However, mistrust of the quality of re-refined lube oils is not, by any means, universal amongst consumers. As discussed in Section 1.4.3, a number of re-refiners currently produce high quality lube oils for industrial and commercial customers, frequently under closed cycle conditions. These re-refined oils have been used successfully for a number of years in such high cost, heavy duty equipment as railroad diesel engines and truck cabs for tandem trailers.

For example, in a recent publication, the Committee on Fuel and Lube Oil of the Locomotive Maintenance Officers Association reported that:

 Preceding page blank

> Re-refined crankcase drainings, fortified with an additive system, have been used successfully in all equipment for many years. Laboratory tests and road tests indicate that reclaimed oil is entirely equal to the best new oils, provided that the reclaimed oil has been properly handled by the re-refiner. 2/

Unfortunately, the only hard evidence as to the quality of these oils is the satisfaction of the clients who use them. Complete sets of test results required under existing lube oil specifications are not available for re-refined oils. As a result, under existing government procurement regulations, re-refined oils are excluded from consideration, largely because of the lack of evidence as to the absolute quality of and quality variations in recycled lubricants.

In order to provide an understanding of the details of the quality issue, this chapter focuses on the two aspects of lube oil quality evaluation: specifications and testing. Specifications establish the physical and chemical properties required of lube oil for various uses and also indicate performance criteria for those uses.

Testing involves both laboratory analyses of the physical and chemical properties listed in the specifications and engine sequence tests. Engine sequence tests are designed to evaluate the performance properties of the lube oil-additive blend under the operating conditions likely to be encountered in those applications for which the particular set of specifications has been established. A complete evaluation of lube oil quality requires that both types of tests be performed. The following discussion will deal with how specifications and testing apply both to virgin and to re-refined lube oils.

2.1 SPECIFICATIONS

Three major sets of specifications apply to motor vehicle lubricating oil. These are API/SAE specifications, auto manufacturers' specifications, and military specifications. The API/SAE and manufacturers' specifications are closely related, indeed interdependent. Military lube oil specifications are similar but establish some additional quality requirements for more demanding military uses.

2.1.1 API/SAE Specifications

The first attempts to classify or identify motor oils started with the first automobiles. Even then viscosity was known to be one of the most important qualities of an oil so far as lubrication is concerned. Oils were then classified as light, medium, heavy and extra heavy, in an attempt to identify their viscosity. After instruments were developed to measure viscosity accurately, the Society of Automotive Engineers developed a new classification based on viscosity, and the SAE numbering system of motor oils was born. This classification system is used today. Seven distinct viscosity classifications are defined by the Society of Automotive Engineers. SAE 5W, SAE 10W, SAE 20W, SAE 20, SAE 30, SAE 40 and SAE 50.

The "W" (for winter) after the SAE number indicates an oil suitable for use in colder temperatures and the viscosity of these "W" oils must have the proper value when measured at 0°F.

Those SAE classifications which do not include the "W" are suitable at higher temperatures such as are experienced in the summer months. The viscosity of these oils (SAE 20, 30, 40 and 50) must have the proper value when measured at 210°F.

It should be noted that SAE 20W and SAE 20 are identified as two separate classifications. However, with today's well-refined, high viscosity index oils, the SAE 20W oil will usually also meet the viscosity requirements of the SAE 20 oil and vice versa. Such oils are identified as SAE 20W-20 and actually are dual viscosity oils.

With the development of viscosity index improvers, the manufacture of multi-viscosity oils became possible. Multi-viscosity oils, SAE 5W-20, 5W-30, 10W-30, 10W-40, and 20W-40, are or have been marketed during post World War II years by oil companies in the USA. Actually, 5W-50 oils are possible through the use of VI (viscosity index) improvers. However, American car manufacturers design engines to operate normally on SAE 20 and SAE 30 oils at highest atmospheric temperatures. SAE 40 oil is used in heavy equipment and seldom used by passenger cars and as a result there is no technical demand or advantage in SAE 5W-50 oils.

Multi-viscosity oils are now generally marketed as SAE 5W-20 or 5W-30 for extreme cold, SAE 10W-30 or 10W-40 for normal operating temperatures and SAE 20W-40 for extremely hot conditions. In general and in all but extremely hot or cold climatic conditions, the SAE 10W-30 and SAE 10W-40 oils are the most popular and have the greatest versatility for the average motorist.

GUIDE TO SAE VISCOSITIES OF MOTOR OIL

Lowest Atmospheric Temperature Expected	Single Viscosity Oil	Multi-Viscosity Oils
32° F	20,20W	10W-30, 10W-40
0° F	10W	10W-30, 10W-40
Below 0° F	5W *	5W-20, 5W-30

* SAE 5W single viscosity oils should not be used for sustained high speed driving (above 50 mph).

The SAE classification system only identifies viscosity and does not indicate anything about the type of the oil, its quality or the service for which the oil is intended.

2.1.2 Engine Service Classification

Many years ago, the automotive and petroleum industries recognized the need for a system by which crankcase oils could be classified and described. A first step in this direction was the adoption in 1911 of the SAE Crankcase Oil Viscosity Classification system. However, this system classified crankcase oils in terms of viscosity only.

In response to inter-industry needs for a system which would include factors other than viscosity, the American Petroleum Institute in 1947 adopted a system which established three types of engine oils. In this system, crankcase oils were designated as: Regular Type, Premium Type, and Heavy Duty Type. Generally, the Regular Type oils were straight mineral oils; Premium Type oils contained oxidation inhibitors; and Heavy Duty Type oils contained oxidation inhibitors plus detergent-dispersant additives.

This oil-type classification system did not recognize that gasoline and diesel engines might have different crankcase oil requirements or that the engine requirements would be affected by engine operating conditions, composition of the fuel and other factors. In time, both the oil and engine manufacturers recognized that oil-type definitions were inadequate. As a result, the Lubrication Subcommittee of the American Petroleum Institute, cooperating with the American Society for Testing and Materials, developed a new system of Engine Service Classification in 1952 which was revised in 1955 and again in 1960.

This API Engine Service Classification System described and classified, in general terms, the service conditions under which engines were operated. It provided a basis for selecting and recommending engine crankcase oils. The system included three service classifications for gasoline engines (ML, MM and MS) and three for diesel engines (DG, DM, and DS).

While this system was a great improvement over the earlier system, it eventually became apparent that a more effective means of communicating the relationship of engine oil performance and engine service classification information between the engine manufacturers, the petroleum industry and the customer was required. There was need for a system that would provide more flexibility in order to satisfy the changing warranty maintenance service lubrication requirements of the automotive industry.

Accordingly, in 1969 and 1970 the American Petroleum Institute, the American Society for Testing and Materials, and the Society of Automotive Engineers cooperated in establishing an entirely new classification. SAE determined that there were eight separate categories of automotive type engine oils of current substantial commercial interest. ASTM established the test methods and performance characteristics and technically described each of the categories (ASTM Research Report D2:1002 January 1970). API prepared a "user" language, including new engine service letter designations, for each of the eight different operating conditions for which the eight different types of engine oil were suited. These eight engine service classifications were correlated to the ASTM technical descriptions and primary performance criteria. SAE then published the entire project result as SAE Recommended Practice J 183.

This entire classification system enables engine oils to be more precisely defined and selected according to their performance characteristics than heretofore, and to be more easily related to the type of service for which each is intended.

Late in 1970, a ninth class of service had been added to reflect the anticipated service requirements of new model automobiles. This addition is technically described in the January 1971 revision to ASTM Research Report RR D2:1002 and published in SAE Recommended Practice J 183a.

The SAE Crankcase Oil Viscosity Classification System is in no way affected by the new API Engine Service Classification System and therefore is used as before to indicate the SAE viscosities of oils.

The new API Engine Service Classification System continues to define and explain classes of service for both diesel and gasoline engine applications. It provides a means of identifying service requirements with oil performance from a lubrication standpoint. These requirements range from the mildest, requiring minimum protection against deposits, wear or rust, to the severe requirements imposed on automotive gasoline engines by:

- Short-trip, start-and-stop operations
- High-temperature trailer towing
- Sustained high-speed, high-temperature driving and on supercharged diesel engines operating on high sulfur fuel.

The new system continues the use of letter designations for each service classification. This provides a convenient means for the engine manufacturer to indicate the service characteristics of his various designs and hence their lubrication requirements. Similarly, petroleum companies use the letter designation to indicate for which class or classes of service each of their brands of lubricating oil is suitable.

2.1.3 Definitions and Explanations of API Engine Service Classifications

The new API Engine Service Classification System presently includes nine classes of service; five for service stations and four for commercial applications.

It is an "open-ended" system which permits the addition of new categories as required without changing or deleting existing categories. This means that any user, petroleum supplier or equipment manufacturer, may petition API, SAE or ASTM to establish a new classification, provided engine design, operating service conditions or a significant change in lubricant performance dictates a new category.

The API letter designations identifying the nine service classifications, with references to the previous API system, to related military and industry designations and to service descriptions, are summarized in Table 1. *

* "S"--SERVICE (Service Stations, Garages, New Car Dealers, etc.)
"C"--COMMERCIAL (Fleet, Contractors, Farmers, etc.)

TABLE 1

OIL SPECIFICATION REFERENCE CHART

API SERVICE CLASSIFICATIONS New	API SERVICE CLASSIFICATIONS Old	ENGINE SERVICE DESCRIPTION	RELATED DESIGNATIONS	AUTOMOBILE MANUFACTURERS SPECIFICATIONS
SA	ML	Utility Gasoline and Diesel Engine Service Service typical of engines operated under such mild conditions that the protection afforded by compounded oils is not required. This classification has no performance requirements.	Straight Mineral Oil	
SB	MM	Minimum Duty Gasoline Engine Service Service typical of engines operating under such mild conditions that only minimum protection afforded by compounding is desired. Oils designed for this service have been used since the 1930's and provide only antiscuff capability, and resistance to oil oxidation and bearing corrosion.	Inhibited Oil	
SC	MS	1964 Gasoline Engine Warranty Service Service typical of gasoline engines in 1964-1967 models of passenger cars and trucks operating under engine manufacturers' warranties in effect during those model years. Oils designed for this service provide control of high and low temperature deposits, wear, rust, and corrosion in gasoline engines.	1964 MS Warranty Approved	Ford ESE-M2C101-A (1964) "MIL-L-2104C"[2]

TABLE 1 Continued

SD	MS	1968 Gasoline Engine * Warranty Maintenance Service (revised) Service typical of gasoline engines in 1968 through 1970 models of passenger cars and some trucks operating under engine manufacturers' warranties in effect during those model years. Also may apply to certain 1971 and/or later models, as specified (or recommended) in the owners' manuals. Oils designed for this service provide more protection against high and low temperature engine deposits, wear, rust and corrosion in gasoline engines than oils which are satisfactory for API Engine Service Classification SC and may be used when this classification is recommended.	1968 MS Warranty Approved	Ford ESE-M2C101-B (1968) GM 6041-M (Prior to July, 1970)
SE	None	1972 Gasoline Engine Warranty Maintenance Service Service typical of gasoline engines in passenger cars and some trucks beginning with 1972 and certain 1971 models operating under engine manufacturers' warranties. Oils designed for this service provide more protection against oil oxidation, high temperature engine deposits, rust and corrosion in gasoline engines than oils which are satisfactory for API Gasoline Engine Warranty Maintenance, Classifications when either of these classifications are recommended.	1972 Gasoline Engine Warranty Maintenance Service	Ford M2C101-C (1972) GM 6136-M, previously GM6041-M Revised. American Motors AM 4042 "MIL-L-46152"[3]
SD or SE		Same as above.	Same as above.	Chrysler MS4071H Mack Truck EO-G Mack Truck EO-H Caterpillar Series 3

TABLE 1 Continued

API SERVICE CLASSIFICATIONS New	Old	ENGINE SERVICE DESCRIPTION	RELATED DESIGNATIONS	EQUIVALENT MILITARY SPECIFICATION
CA	DG	Light Duty Diesel Engine Service Service typical of diesel engines operated in mild to moderate duty with high quality fuels. Occasionally has included gasoline engines in mild service. Oils designed for this service were widely used in the late 1940's and 1950's. These oils provide protection from bearing corrosion and from high temperature deposits in normally aspirated diesel engines when using fuels of such quality that they impose no unusual requirements for wear and deposit protection.	MIL-L-2104A	MIL-L-2104A
CB	DM	Moderate Duty Diesel Engine Service Service typical of diesel engines operated in mild service. Oils designed for this service were introduced in 1949. Such oils provide necessary protection from bearing corrosion and from high temperature deposits in normally aspirated diesel engines with higher sulfur fuels.	Supplement 1	U.S. Army 2-104B, Suppl 1
CC	DM	Moderate Duty Diesel and Gasoline Engine Service Service typical of lightly supercharged diesel engines operated in moderate to severe duty and has included certain heavy duty, gasoline engines. Oils designed for this service were introduced in 1961 and used in many trucks and in industrial and construction equipment and farm tractors. These oils provide protection from high temperature deposits in lightly supercharged diesels and also from rust, corrosion, and low temperature deposits in gasoline engines.	MIL-L-2104B	MIL-L-2104B, MIL-L-46152[3]

TABLE 1 Continued

CD	DS	Severe Duty Diesel Engine Service Service typical of supercharged diesel engines in high speed, high output duty requiring highly effective control of wear and deposits. Oils designed for this service were introduced in 1955, and provide protection from bearing corrosion and from high temperature deposits in supercharged diesel engines when using fuels of a wide quality range.	MIL-L-45199B, Series 3	MIL-L-45199B, MIL-L-2104C[2]
--	--	Service typical of both spark-ignition and compressive-ignition (diesel) engines used in tactical service, i.e., all types of military ground equipment operating under the entire range of service conditions. Meets API engine service requirements CD and SC.	Tactical Service Vehicles	MIL-L-2104C
--	--	Service typical of commercial engines used in administrative (post, camp, and station) service Oils are to be appropriate for gasoline engines in passenger cars and light to medium duty trucks operating under manufacturers warranties and also for lightly supercharged diesel engines operated in moderate duty. Meets API engine service requirements SE and CC.	Passenger Cars Light Trucks	MIL-L-46152

2.1.4 Application of API/SAE Specifications

API/SAE ratings are used both by auto manufacturers and lube oil producers. Auto manufacturers take into account engine design and expected operating conditions. It is then their responsibility to indicate the API service class or classes, SA through SE, applicable to that design and use. Further discussion of manufacturers' use of specifications will be found in the section on manufacturers (see below).

It is the responsibility of the lube oil producer to establish that his lube oil has the characteristics essential for the class of service for which the oil is recommended. An oil recommended for a given class of service should be able to satisfy all physical/chemical and performance requirements for the specified class of service.

The use of an API/SAE service label is totally up to the oil producer and is self-policed. There is no independent organization which monitors the quality of lube oils sold in the retail market. The API Motor Oil Guide states:

> The designation of an oil as suitable for a given API Service, such as "API Service SE", is wholly the responsibility of the marketer of that particular brand of oil. It is expected that his knowledge of the performance characteristics of his product provides the basis for proper service designation.

Although many consumers do, and should, rely on the API/SAE rating in purchasing lube oil, there is some evidence that the rating system has been abused. A 1962 study by a major additive manufacturer showed that second and third line oils frequently did not meet the API/SAE service quality level with which they were labeled.[3] However, lubrication engineers in major auto companies believe that API/SAE labels used by major oil producers are completely trustworthy. They feel that fraud would soon be discovered during engine tests made by additive producers, auto manufacturers, or professional trade organizations.

It is particularly important to note for the purpose of this study that neither the API/SAE service classifications nor the associated ASTM test methods and performance limits exclude re-refined lube oil. Re-refined oil may correctly use an API/SAE grade label if it is able to meet the performance tests applicable to oil of that grade.

2.1.5 Automobile Manufacturer's Specifications

Manufacturer's specifications for lube oil are used in three different ways. They are used by the manufacturer to buy factory fill lube oil and by automobile dealerships in purchasing lube oil with which to service cars. They are also used by the car purchaser in choosing lube oil appropriate for his car. This last use is particularly important because quality choice may affect customer's ability to get his new car warranty enforced.

Auto manufacturers are the prime movers behind the API/SAE specifications because it is their cars that have to use the oil. Automakers' interests are represented by the SAE in the joint SAE-ASTM-API decisions on lube specifications.

Ford and General Motors dominate the lube oil specification-setting process and new API/SAE specifications are written largely at their request. Chrysler and American Motors follow the lead of Ford and GM. API/SAE specifications are therefore always consistent with the lube oil specifications established by the individual auto firms. Ford's new car lube oil specification, ESE-M2C 101-C, and GM's new car lube oil specification, GM 6136-M, are virtually identical in tests and required performance to the API/SAE rating. *

Both new car owners' manuals and warranties indicate that vehicle failure due to use of non-specification lubricants are not covered by the warranty. Owners' manuals for new Ford and GM cars instruct the consumer to purchase only oils that meet SE service specifications. The Ford emmission control system warranty sets up particularly rigorous requirements for maintenance if its provisions are to be honored.

Most oil companies identify oils which have been tested and approved for warranty servicing with an identifying phrase on the oil container. These statements are frequently printed vertically on the side of the can:

"Meets Car Manufacturers' Test Requirements"

"Passes ASTM Sequence Tests"

"Sequence Tested"

"Exceeds (or Surpasses) Car Manufacturers' Service Requirements"

"Meets (or Exceeds) Car Manufacturers' Warranty Requirements", etc.

---

* These specifications are for "service fill", i.e., field servicing by dealers and consumers. Each automaker also has a "factory fill" specification for lube oil put in the crankcase at the plant. The factory fill specification is slightly more demanding than the companies' service-fill, i.e., API/SAE specification, because it has special additives for breaking in the engine.

Like API/SAE specifications, Ford and GM specifications nowhere exclude re-refined oils a priori. Ford's specifications, for example, only require that all suppliers provide a product which is "essentially identical in all characteristics and compensation to the material upon which qualification was originally based, and shall be suitable for the intended application." 4/

Although the specifications themselves do not bar manufacturer or consumer warranty purchases of re-refined oil, opinions among lubrication engineers employed by the major automakers differ on the quality of re-refined oil. Ford engineers state that they would not purchase re-refined oil for company use without complete engine testing of each batch. Their opinion is that without such testing feedstock variations make it impossible to be assured of lube oil quality or additive response. They do agree, however, that re-refined lube oil need not be inherently inferior.

GM lube engineers have a somewhat more charitable view of the quality consistency of re-refined oil. It is their belief that it is technically possible to get a consistent quality output from a widely varying input --if enough funds are available to apply the best re-refining technology and to withstand the increased costs which may result from lower product yields.

2.1.6 *Military Specifications*

Military specifications for lube oil are crucial in determining whether the military or other government agencies can purchase re-refined oil. However, unlike API/SAE or automaker specifications, military specifications specifically exclude re-refined lube oils from consideration.

This is particularly important because the military's oil specifications have a strong influence on all other federal agencies and on much of the private market. The General Services Administration (GSA), the federal unit that buys most government property, has delegated authority to the Defense Supply Agency (DSA) to procure fuels and lubricants for the entire federal government. Further, military lube oil specifications are followed by many state, local, and commercial fleet maintenance facilities.

The military lube oil specifications at issue are MIL-L-46152 and MIL-L-2104C. 5/ Both specifications require in their sections on materials that "no re-refined constituent material shall be used." 6/ MIL-L-46152 is the specification for "lubricating oil, internal combustion engine, administrative service." Lube oils covered by the specifications are "intended for the crankcase lubrication of commercial type vehicles used for administrative (post, station and camp) service typical of: (1) gasoline engines in passenger cars and light to medium duty trucks operating under manufacturers' warranties; and (2) lightly super-charged diesel engines operated in moderate duty." 7/

MIL-L-2104C is the specification for "lubricating oil, internal combustion engine, tactical service." Lube oils covered by the specification are "intended for the crankcase lubrication of reciprocating spark-ignition and compression-ignition engines used in all types of military tactical ground equipment and for the crankcase lubrication of high speed, high-output, supercharged compression-ignition engines used in all ground equipment." 8/

MIL-L-46152 oil is, in sum, chiefly for military automobiles and light trucks. It is an oil that will meet the performance requirements of API/SAE grade SE and as a moderate duty diesel oil it will meet the performance requirements of API/SAE grade CC.

MIL-L-2104C is chiefly a lube oil for heavy equipment such as trucks. As such it meets API/SAE grade CD for heavy duty diesel uses. However, it is only a single viscosity oil and therefore qualifies for only an SC gasoline engine rating. MIL-L-46152 oils can be single or multi-viscosity lubricants.

These two specifications exclude procurement of re-refined constituents on the grounds that there is no reliable information on the quality of such oils. According to the Defense Supply Agency, the government agency which procures lube oils for all federal facilities, the small, independent firms which typically engage in oil re-fining do not have the financial capability to support the level of laboratory and other testing needed to provide essential data on quality and consistency.

Aside from the explicit prohibition of re-refined constituents, the military specifications contain another provision which has been interpreted to exclude re-refined oil. This provision states:

> Whenever there is a change on the base stock, in the refining treatment or in the additives used in the formulation, requalification will be required. When proposed changes are minor and may not be expected to significantly affect performance, the qualifying activity may, at its discretion, waive complete requalification in order to determine the significance and acceptability of the proposed changes. 9/

The varying feedstocks that go into re-refining of waste lube oil are seen as a significant "change in the base stock." Each batch therefore is required to undergo prohibitively expensive requalifications.

2.2 TESTING

Lube oil must be tested in order to determine whether or not it meets the performance standards established by specifications. Indeed, the specifications themselves indicate which of a standardized set of tests must be performed in order to qualify lube oils for various classes of service.

Two kinds of tests are carried out -- laboratory bench scale tests and engine tests. The laboratory tests measure the physical and chemical properties of lube oil and the results of these tests must meet or exceed precise criteria established by the specifications. However, lubrication engineers have found that currently available laboratory tests cannot substitute for engine tests that approximate the operating conditions under which lube oil is required to perform. A sequence of expensive tests is therefore always required before a lube oil is found acceptable by major purchasers.

2.2.1 Laboratory Bench Scale Tests

a. Virgin Oils

An example of physical and chemical standards from the military specification, MIL-L-46152, appears in Table 2.

Several other characteristics in addition to these are also required, including high foaming, high stability, and compatibility with other oils made for similar uses.

As can be seen from these criteria, there are specific numerical standards for most, but not all, physical and chemical properties. This holds true also for API/SAE and manufacturer specifications. Those characteristics for which no precise standards exist must be measured and reported and the producer must establish tolerances for them. Evaluation by the analyst tends to be subjective in these areas. However, properties for which no minimum standard has been established are not generally considered to be critical determinants as to whether or not a candidate oil passes or fails the entire qualification test.

b. Re-Refined Oils

Re-refined oils now available can easily pass established laboratory tests such as those required under specification MIL-L-46152. Table 3

Table 2

Military Specification MIL-L-46152

Partial List of Physical and Chemical Requirements

Property	Grade 10	Grade 30	Grade 10W-30	Grade 20W-40
Viscosity at 210°F (99°C)				
kinematic, SUS				
min.	44.9	58.0	58.0	70.0
max.	< 50.8	< 70.0	< 70.0	< 85.0
Viscosity at 0°F (-18°C) 1/				
apparent, SUS				
min.	6000	--	6000	12000
max.	< 12000	--	< 12000	< 48000
Viscosity index, min	--	75	--	--
Pour point, °F (max.)	-25	0	-25	-10
°C (max.)	-32	-18	-32	-23
Stable pour point, °F (max.) 2/	-25	--	-25	-10
°C (max.)	-32	--	-32	-23
Flash point, °F (min.)	400	425	400	415
°C (min.)	204	218	204	213
Gravity, API 3/	X	X	X	X
Carbon residue 3/	X	X	X	X
Phosphorus 3/	X	X	X	X
Chlorine 3/	X	X	X	X
Sulfur 3/	X	X	X	X
Sulfated residue 3/	X	X	X	X
Organo-metallic components 3/	X	X	X	X

1/ Report measured, apparent viscosity at 0°F (-18°C) in centipoises for grades 10, 10W-30, and 20W-40 oils.
2/ After being cooled below its pour point, the oil shall regain its homogeneity on standing at a temperature not more than 10°F (6°C) above the pour point.
3/ Values shall be reported ("X" indicates report).

TABLE 3

Physical and Chemical Properties of Re-Refined Oil*

Property	Grade 10	Grade 30	Grade 10W-30	Grade 20W-40
Viscosity at 210°F kinematic, SUS	46.5	65.5	63.4	77.5
Viscosity at 100°F kinematic, SUS	190	540	310	480
Viscosity Index	110	96	144	134
Pour point, °F	-35	-10	-45	-35
Flash Point, °F	385	450	420	435
Fire Point, °F	440	480	455	465

* These data were supplied by one of the 13 re-refiners interviewed. Data supplied by two other re-refiners were essentially identical to the above figures.

presents data concerning the physical and chemical properties of some commercially available re-refined oils. The data indicate that these oils exceed the minimum requirements listed in Table 2 for lubricants qualified under specification MIL-L-46152. This does not, however, imply that these re-refined oils will necessarily pass the engine sequence tests required by specificaiton MIL-L-46152 (see below).

c. APR Emblem Licensing Agreement

In 1964, in response to the FTC's proposed rule requiring re-refined oils to be labelled as made from previously used oils, the Association of Petroleum Re-Refiners (APR) established an Emblem Licensing Agreement in order to set minimum quality standards for re-refined oils. Re-refiners subscribing to this agreement would certify that the physical and chemical properties of their oil would meet or exceed the list of specifications shown in Table 4. In return for this pledge, the APR would allow the re-refiner to print an emblem on all oil containers certifying that the re-refined oil had met the established quality criteria. The standards listed in Table 4 applied only to re-refined base stocks (non-detergent oils) before the addition of additives. Hence engine sequence tests were not a part of the Emblem Licensing Agreement.

Unfortunately, most re-refiners did not subscribe to this agreement, preferring to go their own ways in establishing and maintaining markets for their oil. To a degree, it is not surprising that few companies signed the emblem agreement. As discussed in Chapter 1, re-refined products have, in the main, been sold as non-detergent oils in competition with low quality virgin lubes. Since most re-refiners were not trying to compete with manufacturers of oils of established quality, there was little reason for them to take steps to have their products meet minimum quality standards. However, as was shown in the previous chapter, this was a bad strategy as it is precisely those firms (which have chosen to market unblended re-refined oils in bulk quantities) whose survival is now threatened. Of the 13 re-refiners interviewed, only one had signed the Emblem Licensing Agreement. His company, which sells blended re-refined oils to commercial and industrial accounts, is a profitable business and has a widespread reputation for producing quality products.

2.2.2 Engine Tests

Engine tests of lube oils have two major uses. Most obviously they are used to judge whether or not a specific compounded (blended with additives) lube oil will be adequate for expected field use. The engine

TABLE 4

CONTROL SPECIFICATIONS

ASSOCIATION OF PETROLEUM RE-REFINERS

EMBLEM OIL

S.A.E. 10 to S.A.E. 40 Incl.

Vis. @ 210	MIN. Flash	MAX. Color	Vis. @ 210	MIN. Flash	MAX. Color
40	365	3.0	60	435	5.0
41	365	3.0	61	435	5.0
42	370	3.0	62	435	5.0
43	375	3.5	63	440	5.5
44	380	3.5	64	440	5.5
45	385	3.5	65	440	5.5
46	390	3.5	66	445	5.5
47	395	3.5	67	445	5.5
48	400	4.0	68	445	6.0
49	405	4.0	69	450	6.0
50	405	4.0	70	450	6.0
51	410	4.0	71	450	6.0
52	415	4.0	72	455	6.0
53	420	4.5	73	455	6.5
54	425	4.5	74	455	6.5
55	425	4.5	75	460	6.5
56	425	4.5	76	460	6.5
57	430	4.5	77	460	6.5
58	430	5.0	78	465	6.5
59	430	5.0	79-84	465	6.5

In addition to the above, the oil must meet the specifications of the S.A.E. No. under which it is sold.

Following specifications apply to all A.P.R. Emblem oils:

Min. Viscosity Index of 90
Difference between Flash Point and Fire Point must be 40°F. Min.
Neutralization Number 0.075 Max.
Ash - 0.01% Max.
Moisture - Trace Max.
Precipitation No. to be 0.0 Max.

Above specifications apply to oil before addition of any additive.

These values shall be computed by the American Society of Testing Materials Standard Method of Test as follows:

	ASTM Test Designation		ASTM Test Designation
Flash Point	D-92	Viscosity Index	D-567
ASTM Color	D-1500	Neutralization No.	D-974 or D-664
Saybolt Viscosity*	D-88	Ash	D-482
		Precipitation No.	D-91

* It is preferable to determine Kinematic Viscosity by ASTM Method D-445 and convert Kinematic Viscosity to Saybolt Viscosity using ASTM Method D-446

Latest revisions of the above ASTM Test Procedures shall apply.

tests are set up to duplicate such field use and performance criteria must be passed if the oil is to qualify for purchase at its designated grade.

Engine tests are also performed to determine an appropriate additive package. Additive manufacturers will test formulations of the base stock blended with various combinations of additives until the least-cost package for the desired grade is determined. Both the kind and amount of additives are important. Oil producers, of course, want to buy from the additive company that can blend its oil up to specified performance criteria at least cost.

It is expected that if neither the crude source nor refining process change, then the additive package need never change since the "additive response" will be the same from batch to batch. If the crude, i.e. feedstock source, does change, as it must for re-refined oil, there is always a suspicion that a slightly different additive package may be needed. But without extensive and costly engine tests it is impossible to tell the precise additive amounts or changes required to just meet performance standards.

In order to alleviate such suspicions, it is common practice for additive manufacturers to perform engine tests on a number of basestock-additive blends in order to develop a general purpose additive package for use with a wide variety of lube oils. Such general additive formulations enable small firms, which cannot afford costly engine tests, to specify that their lube oils meet specifications required by their customers. Thus if a lube oil container bears the designation "For API Service SE," it does not necessarily mean that the engine sequence tests required for an SE rating were actually performed on the lube oil-additive blend which is in the container. Rather, such a designation may mean that an additive manufacturer, having performed engine tests on a number of base stocks blended with a certain concentration of a general purpose additive, has recommended to the lube oil producer that a certain blend of the producer's base stock and the additive would pass all engine tests specified for an SE rating *if such tests were to be carried out.*

In the case of re-refined oils, the general additive package is effective because there are only a few individual crude sources that are used to make lube oils for a specific geographic region, such as the West Coast. These same sources are used by both large and small lube oil producers. These oils eventually find their way into the re-refiner's waste oil feedstock so he, too, can be considered to be using the same crude from regional sources. As a result, the general additive package recommended to him is the same as that used by small virgin lube oil producers.

The practice of large virgin oil producers and re-refiners differs in the area of additives, but the difference is due not to their product but to their scale of operations. Virgin oil producers are frequently corporate giants while re-refiners, because of the high collection costs associated with distant waste oil pick-up, are generally small companies. To the extent that virgin oil producers are small firms, their behavior is like that of the re-refiners.

A large virgin lube oil producer will typically send its refined lube base stock from a new crude source to an additive firm and request that the additive producers run engine tests on compounded versions of the oil. The oil producer will be willing to pay the $10,000 to $80,000 cost of these tests because the tests will tell him how lean an additive package he can use and still meet the desired specification. Since the oil company requires large volumes of additives, a small savings in the volume of additives required per gallon of oil represents a major total savings in cost. The engine tests are, therefore, usually worth the expense.

Small virgin lube oil producers and re-refiners do not purchase such a large volume of additives. Consequently, engine tests to reduce the volume of additives per gallon are not economically practical. Instead, as discussed above, small lube oil producers avoid engine test expenses by purchasing a general additive package. By blending in more additives than may be required, the small producer can assure his potential customer that his oil <u>would</u> pass engine tests, if these tests were performed. This approach results in a greater additive cost to small lube oil producers, but the extra expense is frequently outweighed by the small firm's lower overhead costs.

This procedure of circumventing expensive engine tests was stimulated in 1967 by an agreement between the Ford Motor Company and the Independent Oil Compounders Association (IOCA). At this time Ford was attempting to establish its own oil quality certification business. Small, independent oil companies belonging to IOCA brought an antitrust suit against Ford, claiming that engine test requirements for oil certification by Ford were so expensive that the small oil companies would be squeezed out of the passenger car lube oil market. This was a particularly difficult problem for those IOCA companies who followed a practice of buying lube oil base stocks from a number of different sources depending on who offered the lowest price. Hence the lube oil blends produced by the independent oil compounders would not satisfy Ford's requirements regarding variation in base stock composition.

In order to resolve this problem, Ford engineers proposed a simple solution. Ford would approve (without having tests performed) oils blended from varying base stocks for use in new automobiles provided that the volume of additives blended with these base stocks was increased by ten percent above the level recommended for non-varying base stocks. A minimum value of 85 was established for the viscosity index of all base stocks which qualified under this arrangement.

a. Virgin Oils

There is a prescribed series of engine tests for each lube oil specification, whether it be API/SAE, manufacturer, or military (see Table 1). The API/SAE SE oil grade, for example, requires the following four engine tests:

Oldsmobile Sequence II B Test. This test procedure is used to evaluate the rusting characteristics of motor oils. Sequence II B is run under low speed, low load, and cold temperature conditions. It is designed to relate to short trip service under typical winter conditions encountered in the northern United States.

Oldsmobile Sequence III C Test. This test procedure is designed to evaluate the performance of engine oils operating under high temperatures. The main objective is to produce oil thickening resulting from oxidation. Sequence III C also evaluates sludge, varnish, and wear characteristics of motor oils. The test is meant to represent such high temperature usage conditions as trailer towing, power consuming accessories, emission control devices, and extended high speed driving on freeways.

Sequence V C Test. This test is used to evaluate sludge and varnish forming tendencies of motor oils under a variety of operating conditions. The engine is cycled through three different stages --- high-speed cold, high-speed hot, and idle operating conditions --- to accelerate deposit formation. The test was designed to represent a combination of low-speed, low temperature "stop and go" city driving and moderate turnpike operation.

CRC L-38 Test. The test is run on a special single cylinder engine and is used to evaluate the oxidation stability and copper-lead bearing corrosion characteristics of engine crankcase oils.

The following table gives the primary API/SAE performance criteria for these tests:

TABLE 5

<u>SE Primary Performance Criteria</u>

Sequence IIB	AVG. Rust rating, min.	8.9
Sequence IIIC	Visc. Incr. @ 100°F and 40 hrs., % max.	400
	Piston skirt varnish, min.	9.5
	Oil ring land varnish, min.	6.0
	Sludge rating, min.	9.0
	Ring sticking	None
	Lifter sticking	None
	Cam or lifter scuffing	None
	Cam + lifter wear, in. -Avg.	0.0010
	-Max.	0.0020
Sequence V-C	Avg. engine sludge, min.	8.5
	Avg. piston skirt varnish, min.	8.2
	Avg. engine varnish, min.	8.0
	Oil screen clogging, %, max.	5
	Oil ring clogging, %, max.	5
	Compression ring sticking	None
L-38	Bearing Wt. Loss, mg., max.	40

Some of the evaluation criteria listed in the right hand column in the table have no units. For these criteria a subjective evaluation is made of the results of the engine test by inspecting the particular engine part involved. A rating of 10 is perfect, a rating of zero is the worst failure. For example, under sequence V-C the average engine sludge must be rated at 8.5 or higher. In evaluating the results of an engine test, an experienced engineer will inspect the engine and pronounce his judgment. If any test is failed, the candidate oil must be resubmitted for an entire new series of tests.

In addition to these tests, the military requires one extra test sequence under its specification for automobile oil MIL-L-46152. This is because it requires this oil to be usable in moderate duty diesel engines:

<u>Caterpillar I-M Test</u>. The test is designed to measure diesel engine wear and accumulation of deposits under high temperature supercharged conditions. The I-M designation refers to small bore, highly supercharged diesel engines.

The MIL-L-2104C lube oil specification drops the IIIC test (high temperature) and replaces the I-M with I-D and I-G which are similar tests to I-M but are designed for larger and more highly supercharged engines.

b. Re-Refined Oils

Engine tests of re-refined oils have been totally inadequate. The military ran a series of tests on recycled lube oils in the mid-1950's and found that the oils were inferior to virgin oils. The test results have since been lost and some of those involved in the tests recollect that the samples used did not fairly represent the quality of recycled lube oil then available. Moreover, many changes have taken place in the additive packages used to upgrade the performance of both virgin and recycled oils since the mid-1950's.

Nevertheless, these unfavorable test results have often been cited by the military as proof of the inferior quality of re-refined oils. 10/ In the absence of contradictory data, they have also provided a rationale for excluding re-refined oil in military specifications. In addition, the tests were influential in the formation of the current Federal Trade Commission labeling policy which discriminates against re-refined oil. 11/

However, even if engine tests of re-refined oils indicated that these lubricants could meet the military performance requirements, under existing regulations re-refined oils could still not be purchased by any federal agency because of the requirement that once an oil is qualified, the source of the feedstock from which the oil is manufactured may not be changed.

2.3 CONCLUSIONS

Neither API/SAE specifications nor manufacturer specifications pose any obstacles to the use of re-refined oil. Neither set of specifications explicitly excludes re-refined oil from acceptability or establishes laboratory and performance criteria which are beyond the capability of such oil to meet. New car warranties from major automakers will remain legally binding with re-refined oil, providing the oil meets normal specification criteria.

The case is completely different with military specifications. The specifications for lube oils explicitly exclude re-refined oils from consideration even though the chemical/physical and engine test performance criteria are well within the capability of recycled lube oils. The exclusion is a formal obstacle to government procurement of re-refined lube oil.

Perhaps the most frequently cited problem for re-refined oils is the question of repeatability. Since the feedstock used in most re-refining operations is a mixture of a large number of crankcase oils produced from a variety of crude oil sources, it is argued that there can be no assurance that the re-refined product will be of consistent quality. While re-refiners have for years been using "fat" additive packages to account for any possible variations in product quality, no documentation in the form of engine sequence tests of re-refined oils is available to confirm the success of this strategy. Re-refiners claim that since their feedstock is composed of such a large number of lube oil products, the overall mixture will, in fact, be constant and will be composed of lube oils in proportion to the market shares of the major lube marketers in the geographical area concerned. Hence the effect on product quality of introducing some poor quality drain oil into a re-refiner's feedstock storage tanks will be negligible. The problem of proving the validity of either of these contentions is, of course, eliminated if the used oil is custom re-refined under closed-cycle conditions.

FOOTNOTES CHAPTER 2

1. A Technical and Economic Study of Waste Oil Recovery--Part I: Federal Research on Waste Oil From Automobiles, Teknekon, Inc., EPA Contract No. 68-01-1806, October 1973.

2. "Pre-Convention Presentations," in 1972 Annual Proceedings--1973 Pre-Convention Report, Locomotive Officers Maintenance Association, Chicago, Ill., September 10-12, 1973, p. 184.

3. Lubrication is a Responsible Job--But Do We Know It?, Frank Menton, April 21, 1965, ASLE Meeing, Buffalo, New York

4. Ford Specification ESE-M2C 101-C, revised August 1973.

5. See Table 1 and Appendix 3A.

6. MIL-L-2104C and MIL-L-46152, p.4 in each.

7. Language taken directly from specification, p. 11.

8. Language taken directly from specification, p. 10.

9. Page 3 in MIL-L-2104C and MIL-L-46152.

10. See copy of letter to RTC by R.G. Streets, Army Material Command, 1965, Appendix 3B.

11. A Technical and Economic Study of Waste Oil Recovery--Part I: Federal Research on Waste Oil from Automobiles, Teknekron, Inc., EPA Contract No. 68-01-1806, October 1973.

Preceding page blank

CHAPTER 3

FEDERAL PARTICIPATION IN WASTE OIL RECOVERY

3.0 INTRODUCTION

Present and future shortages of virgin lubricants and the need to prevent environmental damage due to uncontrolled disposal of crankcase drainings require that steps be taken that will stimulate the recovery of waste lube oils. Chapters 1 and 2 have shown that the removal of two barriers, one economic and one institutional, will greatly stimulate lube oil recycling.

The first barrier stems directly from the lack of public acceptance of re-refined oil. As discussed in Chapter 1, the poor public image of recycled oil has been a major factor in discouraging re-refiners from producing high quality re-refined lubricants for the retail market. This is a particularly important problem as the retail market is by far the most profitable outlet for automotive lube oils. If high quality re-refined oils could compete in this market with equivalent virgin lubes, re-refining would become a highly profitable business thereby providing an attractive environment for new investment in modern, pollution-free facilities for waste oil recovery.

However, it is difficult to imagine that public confidence could be instilled in the quality of re-refined oil as long as the government refuses to use recycled oil in any of its own vehicles and requires that all re-refined lubes bear a label stating that they are made from "previously used" oils. This position is supported by a study of consumer attitudes toward the purchase of re-refined oil. This study showed that the public appears to be willing to buy recycled oils but only if such oils bear a government certification that they are equal in quality to virgin lubricants. 1/ Thus the second barrier to increased waste oil recovery is an institutional problem. Removal of this barrier will involve a reassessment by the appropriate federal agencies of both the specifications for lube oil procurement and the labelling law which now casts a stigma on all re-refined oils.

Hence the economic and institutional barriers to increased waste oil recovery are not independent of one another. On the contrary, the former barrier is due, in large part, to the existence of the latter. Therefore, it is clear that one possible strategy for removal of the economic barrier to increased waste oil recovery will require the participation of the government in a program to demonstrate whether or not properly re-refined oils can be used with confidence by the public.

 Preceding page blank

In order to understand ways in which government action might effect removal of the institutional barrier to waste oil recovery, it is necessary to be aware of the mechanism by which federal agencies purchase lubricants and dispose of their waste oils. Once these procedures are understood it will be possible to suggest plans which can lead to revision of those federal policies which now form an institutional barrier to increased use of re-refined oil.

3.1 PROCUREMENT OF LUBE OIL BY THE FEDERAL GOVERNMENT

Lubricating oils purchased for use in all government owned vehicles are procured by the Defense Fuel Supply Center (DFSC), Cameron Station, Alexandria, Virginia. DFSC is an arm of the Defense Supply Agency. A voluntary liaison between the General Services Administration (GSA), which has responsibility for supplying all materials to all civilian government agencies, and the Defense Supply Agency (DSA), which has responsibility for supplying all materials for military use, has been established wherein GSA has delegated authority to DSA for procurement of all petroleum products for use in civilian vehicles owned by the government. This relationship developed because DSA procures the largest volume of petroleum products of all government agencies. Hence an investigation of ways in which the government might take part in an effort to stimulate waste oil recovery must necessarily involve an analysis of the organization and procedures by which the military procures lubricating oils. This section provides such an analysis and includes data regarding both the volumes and qualities of lube oil purchased by various government agencies and the volumes and distribution of used lube oils which are now discarded.

3.1.1 Establishment of Lube Oil Specifications

All lube oil procured for government agencies by DFSC must be certified as having met one of a number of rather comprehensive specifications established by the Army Materiel Command's Coating and Chemical Laboratory (CCL) located at Aberdeen Proving Ground, Aberdeen, Maryland. Because the Army is the branch of the military which uses the largest volume of automotive lubricants, the other military branches have delegated authority for lube oil specifications setting to the Army Materiel Command. The Army Materiel Command, in turn, has delegated all authority for the management and direction of research and development programs dealing with fuels and lubricants to the CCL. The CCL also serves as consultant to Army Materiel Command Headquarters by providing the technical input as to the specifications and standards required of fuels and lubricants procured by DFSC. The CCL is responsible to the Research and Development Directorate at Army Materiel Command Headquarters.

3.1.2 The Coating and Chemical Laboratory

Figure 1 shows the organizational structure of the CCL. Mr. Harry L. Ammlung is the CCL Director and supervises the activities of the five different divisions. The Fuels and Lubricants Division, headed by Mr. Charles F. Schwartz, in consultation with engine manufacturers and the petroleum industry, sets specifications for lube oil. Further Mr. Schwartz sits on

Figure 1

Army Materiel Command

Coating and Chemical Laboratory - Organizational Structure

15 February 1973

COATING & CHEMICAL LABORATORY
- Tenho R. Hukkala, COL, CE, Commanding Officer
- Director: Harry L. Ammlung, GS-1320-15
- Deputy Director: Perry C. Reynolds, MAJ, OD

SECRETARY: Marie R. Breitbart, GS-318-7

CHEMIST: Charles W. Preston, GS-1320-11

SMEFB-CLO — ADMINISTRATIVE OFFICE — X2226
- Chief: Ward F. Bakken, GS-341-11
- Budget Officer: F. Auvan Smith, GS-560-11
- Clerk: Delores R. LePera, GS-301-6
- General Supply Specialist: Nelson Noble, GS-2001-7
- Clerk Stenographer: Jeanne S. Rohr, GS-301-4
- Editorial Clerk: Vinetta Upchurch, GS-1087-4
- Supply Clerk: Elwood F. Watkins, GS-2005-4
- Laboratory Worker: Annie Addison, WG-3566-2

SMEFB-CLA — AUTOMOTIVE CHEMICAL DIVISION — X4284
- Chief: Charles B. Jordan, GS-1320-14
- Chemist: Jules B. Counts, GS-1320-12
- Chemist: James H. Conley, GS-1320-11
- Physical Science Technician: Horace R. Sheets, GS-1311-9
- Physical Science Technician: Robert G. Jamison, GS-1311-10
- Chemical Test Unit Operator: Brady B. Caudill, WG-5429-10
- Military (Enlisted): Jesse J. Davis, E4, 01F20

SMEFB-CLP — PAINT, VARNISH & LACQUER DIVISION — X3875
- Chief: Melvin H. Sandler, GS-1320-14
- Chemist: Dr. James I. McLeskey, GS-1320-13
- Chemist: William H. Deaver, GS-1320-12
- Chemist: Stanley F. Koutek, GS-1320-12
- Chemist: Joseph H. Thompson, GS-1320-12
- Chemist: Andrew A. O'Bruchta, GS-1320-11
- Physical Science Technician: Merrill Cohen, GS-1311-11
- Physical Science Technician: Kenneth E. Smith, GS-1311-9
- Physical Science Technician: John H. Pong, GS-1311-7
- Chemical Test Unit Operator: Joshua J. Buchanan, WG-5429-6
- Military (Officer): James F. Southern, 1LT, 7319

SMEFB-CLC — CHEM. CLEANING & CORROSION DIVISION — X4083
- Acting Chief: Melvin H. Swann, GS-1320-14
- Chemist: George G. Esposito, GS-1320-14
- Chemist: Martha L. Adams, GS-1320-13
- Chemist: George Svarnas, GS-1320-12
- Chemist: Robert F. Wagner, GS-1320-12
- Chemist: Mary J. Carroll, GS-1320-11
- Chemist: Troy R. Nichols, GS-1320-11
- Physical Science Technician: C. Cole Jackson, GS-1311-7
- Military (Officer): Kenton C. Travis, LT, 7319

SMEFB-CLF — FUELS & LUBRICANTS DIVISION — X3367
- Chief: Charles F. Schwarz, GS-0830-14
- Research Chemist: Maurice E. LePera, GS-1320-13
- Research Chemist: Dr. Marjan Kolobielski, GS-1320-13
- Physical Scientist: Forrest W. Schaekel, GS-1301-13
- Chemist: Thomas C. Bowen, Jr, GS-1320-11
- Chemist: James V. Shimek, GS-1320-9
- Physical Science Technician: John G. Sonnenburg, GS-1311-9
- Chemist: John P. Doner, GS-1320-9
- Mechanical Engineer: Gerald J. DeBono, GS-0830-7
- Military (Enlisted): Michael S. Gutierrez, E4, 01G20
- Military (Enlisted): George Oswald, E4, 01G20

the Military Automotive Review Committee which evaluates laboratory and engine tests performed on lube oils submitted for qualification for government procurement. There are seven other members on the committee in addition to Mr. Schwartz, one representative from each of the following vehicle manufacturers and testing laboratories: Caterpillar Tractor Company, Ford Motor Company, General Motors Company, International Harvester Company, AutoResearch Laboratories (Chicago), Southwest Research Institute, and AutoResearch Associates (San Antonio). This committee meets five times a year and is the decision-making body concerning the qualification of lube oils for government purchase. DFSC will not procure any lube oils which have not been approved by this committee. The two specifications under which most automotive lube oils are procured, MIL-L-46152 and MIL-L-2104C have already been discussed. Copies of these specifications are contained in Appendix A.

As has been previously discussed, re-refined oils are excluded under specifications MIL-L-46152 and MIL-L-2104C. The principal reason cited by CCL for this policy is that lack of assurance that re-refined oils produced from waste oil feedstocks of varying composition will be of uniform quality. Even if one batch of re-refined oil was tested and found to meet a given specification, CCL feels that there is no assurance that succeeding batches will also qualify. Since military specifications require that once a lube oil has been approved, the manufacturer must agree not to change the crude oil feedstock, the refining process, or the additive package blended with the lube oil, re-refined oils produced from a varying feedstock source are automatically excluded from consideration.

CCL is willing to reconsider approval of re-refined oils if laboratory reports can be provided which show that the oil meets military specifications. As discussed in Chapter 2, no such data are known to exist.

The Coating and Chemical Laboratory has already been involved in at least one study of the possible use of re-refined oils by federal agencies. In September, 1972, DSA published a report entitled "Waste Oil Recycling Study" which examined the possible development of military specifications under which re-refined lube oils might be procured. In consultation with CCL the authors of the report proposed that:

1. Samples of re-refined oil be collected from a number of re-refiners over an 18 month period. This would allow variations due to weather conditions and feedstock variations to be accounted for.

2. Laboratory tests be performed on these samples. CCL recommended that the tests shown in Table 1 be performed as the minimum analysis necessary to insure adequate product quality control.

3. Multi-cylinder engine tests be performed on a variety of brands of re-refined oil and different blends of re-refined and virgin stocks each blended with a selection of additive components.

4. Based on the results of the engine tests CCL develop specifications for automotive oil using re-refined components. These specifications will contain limits on the physical and chemical properties of re-refined oils established under (2) above.

5. A demonstration project be performed at a military installation over a period of one year to evaluate thoroughly the performance characteristics of re-refined oils.

A proposal was made to the Department of Defense to carry out these recommendations. At present a decision to fund this proposal has not been made.

Table 1

Minimum Analysis Required to Insure Lube Oil Quality Control

Test Method	ASTM Method Number
Kinematic Viscosity @ 210°F and 100°F	D 445
Ramsbottom Carbon Residue	D 524
Total Ash	D 482
Flash Point	D 92
API Gravity	D 287
Aniline Point	D 611
Neutralization No., TAN & TBN	D 664
Emission Spectograph for Sulfur, Phosphorus, Lead, Calcium, Barium, Zinc	

3.1.3 Procurement Procedures

As discussed above, all lube oils required by agencies of the federal government are procured by DFSC. Nearly all lube oil is procured in five gallon pails, 55 gallon drums or in bulk tank car loads. An exception is lube oil ordered by the Defense General Supply Center in Richmond, Virginia, some of which is procured in containers smaller than five gallons.

Each year DFSC prepares a list of the previous year's lube oil purchases for each government agency. Such a list is sent to all ordering activities who then respond with an estimate of the coming year's requirements. The various military and executive branch agencies then submit to DFSC their total lube oil requirements. DFSC then distributes invitations to submit bids for lube oil supply to all firms listed on a bidder's mailing list. Any company may submit a bid provided the firm can prove that:

1. It is a qualified supplier (i.e. its lube oil meets the military specification under which the oil is being procured); or

2. It is supplying the product of a qualified supplier.

Bids received are evaluated solely on the basis of price, provided, of course, that the lowest bidder is a qualified supplier. Contracts are then prepared and a bulletin of successful bidders is printed and mailed to the ordering activities for all government facilities. The ordering activities place their order directly with the contractors listed in the bulletin. DFSC does not maintain an inventory of lube oil products. All the contracts are for indefinite quantities of oil and are unfunded with no prepayment clauses. Payment is made after delivery by the facility making the order. However, DFSC administers any problems which may arise between the ordering activity and the lube oil supplier.

Lube oil ordered by the Defense General Supply Center in packages smaller than five gallons is procured by DFSC on firm quantity, firm funded contracts. The Defense General Supply Center maintains inventories of these packaged lube oils at locations throughout the United States.

3.1.4 Organizational Structure

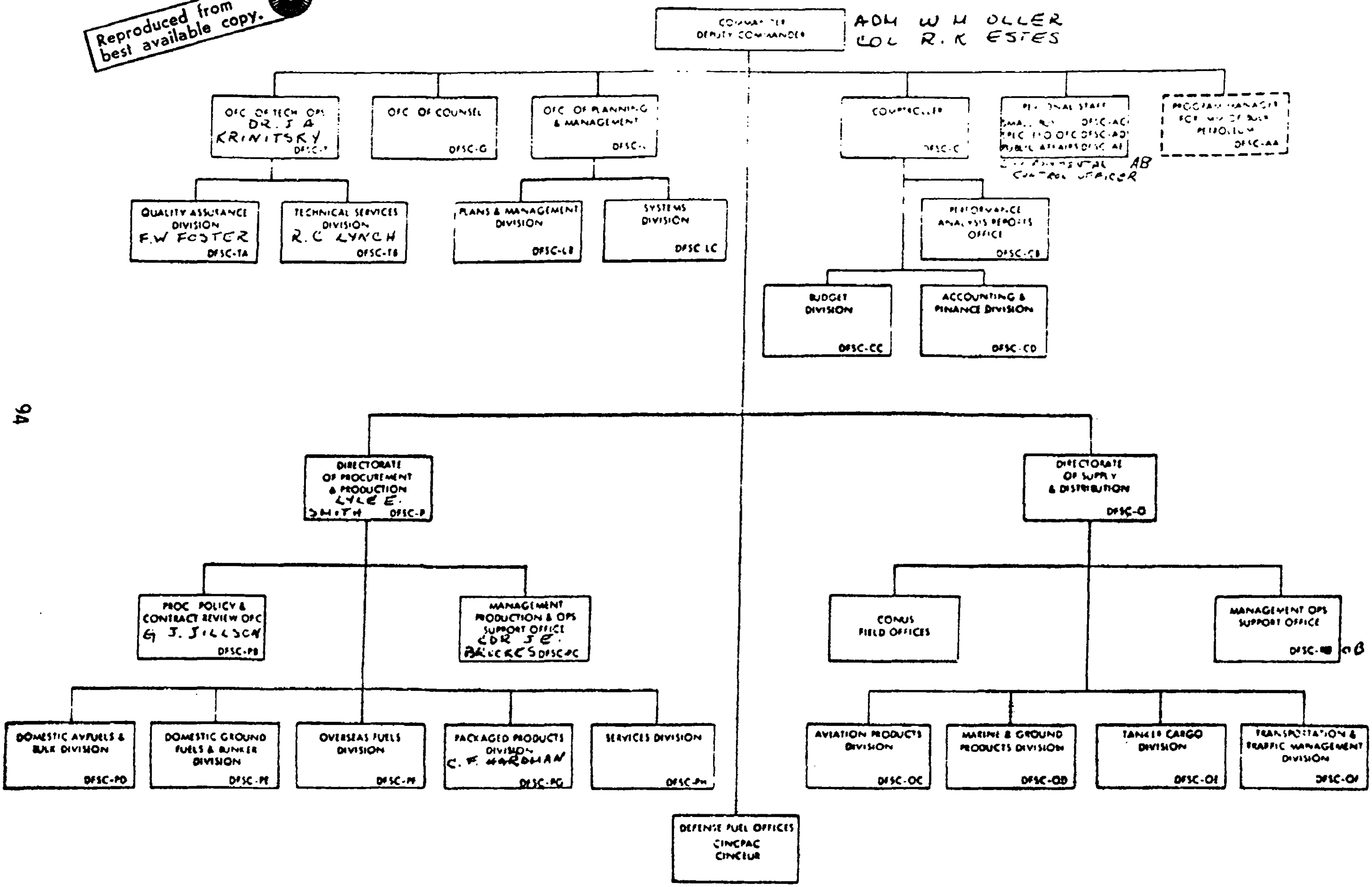
Figure 2 shows the organizational structure of the Defense Fuel Supply Center. The Commander, Rear Admiral William M. Oller, was himself in the 1950's in charge of a naval facility which successfully used re-refined cutting oils and is, therefore, well aware of the beneficial aspects of re-refining.

The Office of Technical Operations, headed by Dr. John A. Krynitsky, has two divisions. The Technical Services Division monitors all purchase requests to insure that the buyers of petroleum products are buying the right product for the intended use. This division also specifies packaging, packing and marking of containers and has the power in the case of negotiated procurements to waive certain specification requirements in return for lower prices. However, this is not done for items procured on open bids.

The Quality Assurance Division acts to insure that once a procurement contract is signed, the items procured meet all the pertinent specifications. In the case of lube oil, inspectors are sent to refineries and blending plants to monitor the production operations.

Figure 2

Defense Fuel Supply Center - Organizational Structure



3.2 WASTE LUBE OIL DISPOSAL BY MILITARY FACILITIES

3.2.1 Organization

The Executive Directorate, Technical and Logistical Services, is the branch of the Defense Supply Agency responsible for property disposal. As shown in Figure 3, property disposal is the responsibility of a number of local Defense Property Disposal Offices (DPDOs) which report to regional offices or second level field activities. Mr. Richard G. Bruner is the Executive Director of Technical and Logistical Services. The Property Disposal Division, headed by Mr. Frank Alesi, is directly responsible to Mr. Bruner's office. These organizations are located at the Defense Supply Agency, Cameron Station, Alexandria, Virginia. Lieutenant General Wallace H. Robinson is the Director of DSA. He reports directly to the Secretary of Defense.

3.2.2 Procedures

In theory all military activities are supposed to dispose of surplus and waste materials through one of the 190 DPDO's located throughout the country. The DPDO's in turn dispose of the surplus materials and wastes in the most economical way available. However, current practice at nearly all military facilities is for the base commander to assume responsibility for the disposal of waste lube oils. In most cases bids are solicited from local scavengers for removing the waste oils. Once they are removed from the installation, no record of the ultimate fate of these materials is kept. Since many military facilities dump all waste oils into a single storage tank, under current disposal practices much of the used lube oil is probably too contaminated to be economically re-refined. For example, Table 2 lists the volume of all waste oils accumulated annually at the Army facilities in the U.S. having the largest volume of waste oil generation. Data concerning the volume of used lube oils generated at Army installations are, unfortunately, not available. It is estimated that in 1972 approximately 3,600,000 gallons of waste oils were generated and disposed of at Army facilities in the continental United States.

Figure 3

DISPOSAL PROGRAM ORGANIZATION

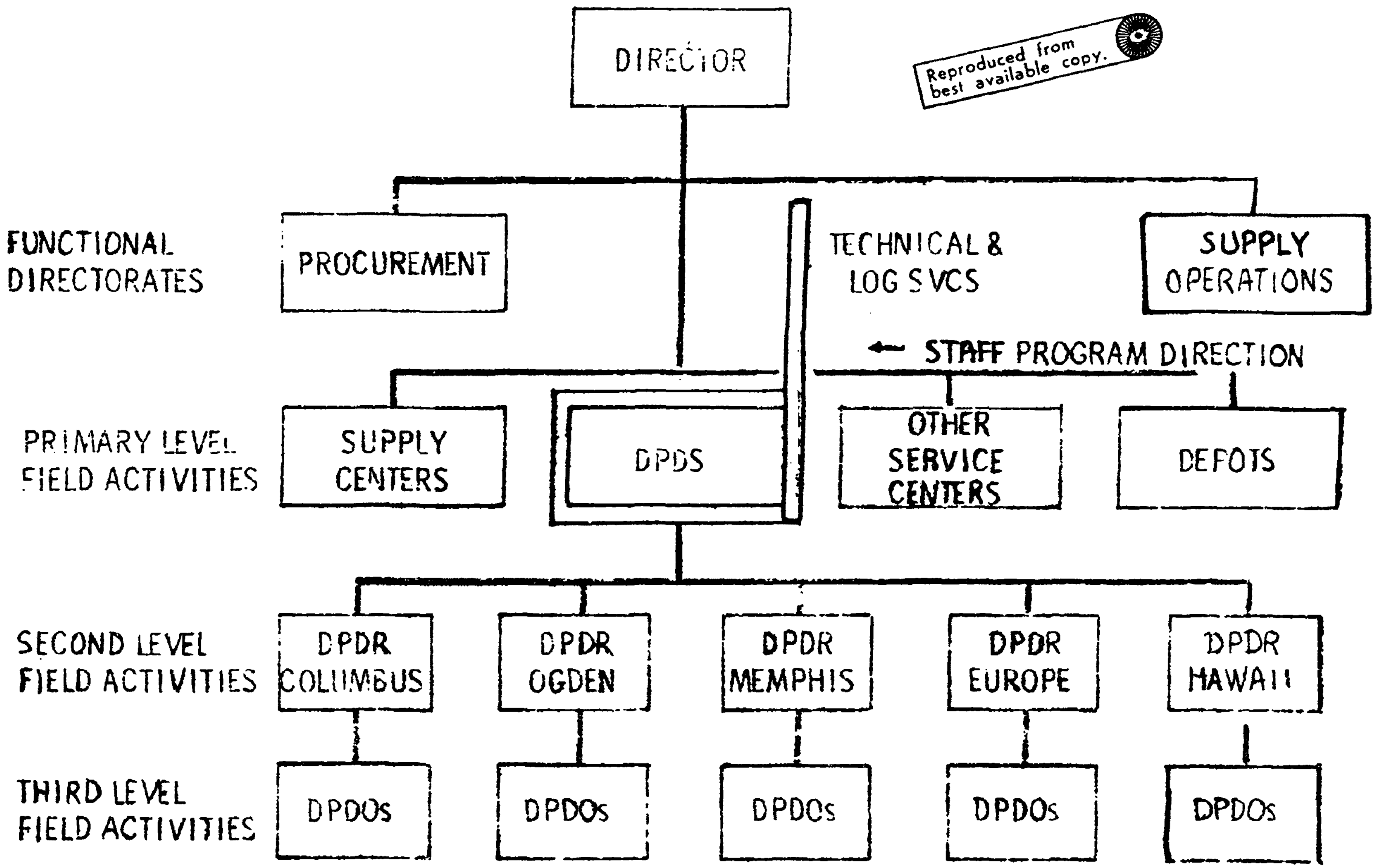


TABLE 2

Waste Oil Generation at Army Facilities

Having the Largest Volumes of Used Oils

Facility	Waste Oil Generated (Gallons per year)
Red River Army Depot, Texas	271,200
Fort Carson, Colorado	216,000
Fort Hood, Texas	204,000
Fort Meade, Maryland	198,000
Rock Island Arsenal, Illinois	168,000
Anniston Army Depot, Alabama	117,000
Fort Bragg, North Carolina	108,000
Letterkenny Army Depot, Pennsylvania	104,400
Sharpe Army Depot, California	84,000
Toelle Army Depot, Utah	57,600

3.3 REMOVAL OF FEDERAL BARRIERS TO WASTE OIL RECOVERY

3.3.1 A Restatement of the Problem

The primary barrier to federal procurement of re-refined oils is the lack of documentation that such lubricants can consistently meet all performance requirements established in military specifications. The principal reason for the failure of re-refiners to provide such evidence is the military's requirement that once an oil has been qualified for purchase, no changes may be made in the feedstock from which the oil is produced. Thus under existing regulations each batch of re-refined oil would have to be qualified separately in order for government agencies to use recycled engine oils in their vehicles. Since the cost of qualifying a lube oil is high, typically $50,000 to $80,000, it has been economically impossible for refiners to provide lube oil to the government, especially in view of the fact that federal agencies purchase lubricants under competitive bid arrangements. Thus it is clear that if the federal ban on use of re-refined lube oil is to be removed, at least one of the following steps must be taken:

1. A new specification must be established which permits changes in the feedstock from which lube oils are manufactured, or

2. Re-refined oil that has been produced from a constant source of waste oil must be provided.

3.3.2 Establishment of a New Specification

As discussed in detail in Chapter 2, under military specifications MIL-L-2104C and MIL-L-46152 re-refined oils are specifically excluded from consideration. Hence a new specification must be written if federal agencies are to use re-refined oil. Both these specifications require a series of engine sequence tests. The requirements set forth in MIL-L-46152 are quite similar to those established for an API/SAE SE rating. Oils procured under this specification are generally used in passenger cars and light gasoline powered trucks. The requirements set forth in MIL-L-2104C are more stringent, as oils procured under this specification are for use in tactical military vehicles.

The new specification must not exclude oils which are made from a varying feedstock. The discussion in Chapter 2 presents ample evidence that use of general or "fat" additive packages can compensate for any changes in additive response due to variations in base stock properties.

Preceding page blank

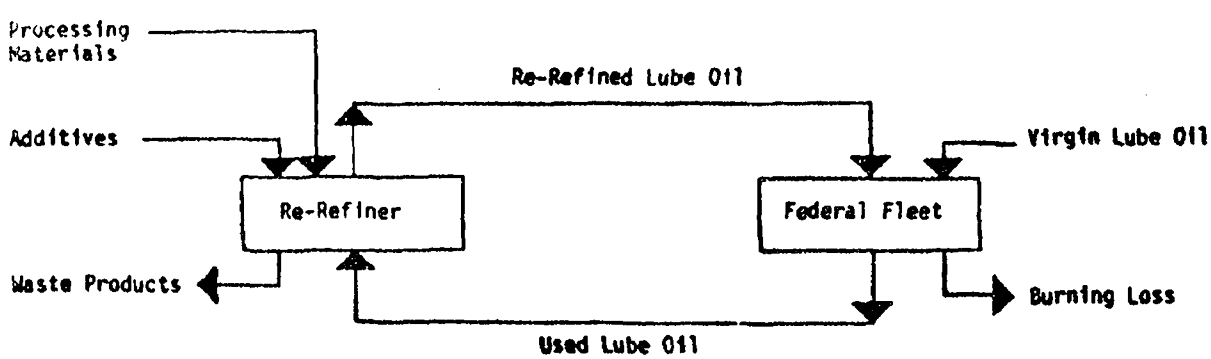
The fact that additive manufacturers have spent considerable sums of money in the development of such compounds specifically for use with a variety of base stocks lends further support to this premise. The success of the Independent Oil Compounders Association in their dispute with the Ford Motor Company over the question of lube oil quality assurance provides additional evidence that variation in the base stock need not result in concern over the performance characteristics of a lube oil-additive blend. However, if such a specification is to be established, evidence of the quality of re-refined base stocks and blends of re-refined base stocks with general additive packages will have to be provided.

3.3.3 Re-Refining From a Constant Source of Waste Oil

The current military specifications for lube oil were established in order to protect government vehicles, especially tactical vehicles, from excessive engine wear which might result from the use of lube oils not suitable for the variety of services required of these engines. Since evidence that properly re-refined oils are appropriate for such service conditions has not been forthcoming, the military, specifically the Army Materiel Command's Coating and Chemical Laboratory, has prohibited the procurement of recycled lubricants by government agencies. Thus if this federal barrier to the use of re-refined oil is to be removed, evidence that such oils are suitable for use in government vehicles must be provided. Implementation of a closed-cycle re-refining system is one way of providing such evidence.

As discussed in Chapter 1, a closed-cycle re-refining system is an arrangement in which lube oil consumers agree to purchase re-refined oil which has been produced from waste oils drained from their own vehicles. The following materials flow diagram illustrates the operation of such a system:

"CLOSED-CYCLE" RE-REFINING SYSTEM



The most important advantage of the closed-cycle system is that it avoids the dilemma of choosing between prohibitively expensive testing expenditures and the possibility of a fluctuating "additive response." It does so by shifting attention from the waste oil feedstock to the quality of the re-refined product. If the quality of the re-refiners' feedstock can be held constant, batch-to-batch product variations will disappear as an issue. Ordinarily this is not possible because re-refiners collect waste oil from diverse and varying sources: service stations, auto dealerships, and so forth. However, the closed-cycle system would guarantee the re-refiners a continuing supply of waste oil of known quality. If the recycling process is closely controlled, the user of recycled oil under this system is himself responsible for any batch-to-batch variations since he is also the waste oil supplier.

3.3.4 Rationale for Federal Participation

Although a closed-cycle project could be implemented with no government involvement, federal participation is a desirable way to initiate such a system. While a number of re-refiners already engage in "custom" re-refining of lube oil under closed-cycle conditions, all such operations are presently restricted to industrial lube oils or diesel engine oil used by railroads.

Federal participation would first take the form of a demonstration involving a federal installation or set of installations and a re-refining facility. Once the system's feasibility is demonstrated, the system can be expanded to a larger number of federal installations. What is required in each case is that the federal installations operate a relatively large number of vehicles and are geographically near re-refining facilities. A number of military, Postal Service, and General Services Administration motor pools would meet these criteria.

The federal government has three major reasons to involve itself directly in this way. First, the approach is effective. Procurement has been demonstrated to be one of the federal government's most useful tools for support of innovation in the private sector. It makes immediate and significant use of the market system while avoiding the problem of enforcing new regulations on private industry. It has the capability of demonstrating new technology on an operational scale without burdening the federal government with actual production management. Congress recently recognized these advantages in giving GSA authority to make extra payments for equipment it purchases that meet EPA noise abatement standards. In the case of the closed-cycle waste oil recovery plan, successful use of the recovered lube oils and subsequent revision of government policies which discriminate against re-refined oil would give assurance to consumers that properly re-refined lube oils perform as well as high quality virgin lubricants. This would enable re-refiners to increase sales of high quality oils. Profit margins on such sales are much greater than on sales of the non-detergent oils which presently account for most of the volume of re-refined oil sold in the United States. Closed-cycle operations can thus lend needed support to a troubled industry but only if those re-refiners participating in the program maintain the highest standards of quality control in their production processes. In this sense a federal effort to recycle lube oil must be regarded as an opportunity (as opposed to a subsidy) for re-refiners to remove the stigma of questionable quality which has prevented wide public acceptance of their products.

Secondly, government use of recycled oils will reduce the environmental costs associated with waste oil disposal by federal facilities. More than 24 million gallons of automotive lube oil are purchased annually by agencies of the federal government. Perhaps two-thirds of this oil is not consumed. Given present practices, it is highly likely that a significant fraction of the waste oil is disposed of in ways harmful to the environment. While the disposal of acid sludge from conventional re-refining plants is itself a serious environmental problem, the initiation of lube oil recycling projects which result in the establishment of consumer confidence in the quality of re-refined oil would create attractive opportunities for capital investment in new, more efficient re-refining technologies which do not produce environmentally hazardous waste products.

Thirdly, participation in an effort to demonstrate the quality of re-refined oil is consistent with national policies for resource recovery and environmental improvement. If dislocations resulting from shortages of basic materials are to be minimized, it is only logical that the government, which consumes about two percent of all automotive and industrial lubricants, assume a position of leadership in the use of recycled materials. Moreover, since federal agencies generate very large volumes of waste oil, it is imperative that the government set an example by disposing of its own waste oil in a way which is ecologically sound.

3.3.5 Implementation Plan--Exceptions to Procurement Procedures

As discussed in Section 3.1, lube oil purchases by federal facilities are made by consulting a bulletin prepared by the Defense Fuel Supply Center, which contains a list of all successful bidders whose products have been found to meet pertinent specifications. Thus if a federal activity is to participate in a closed-cycle waste oil recovery project, the participating group will not be able to order its lube oil from the firms listed in the bulletin. Under existing regulations this bulletin must be used for lube oil purchases by all activities of the military departments and by all other activities in the executive branch of the government unless:

1. The maximum single order is less than the minimum quantity obtainable under the contracts listed in the bulletin; or

2. Container sizes required are smaller than those available from contracts listed in the bulletin; or

3. Purchase without regard to existing Defense Fuel Supply Center contracts is otherwise authorized.

Thus, under present circumstances, in order for a "closed-cycle" pilot project involving re-refined oil to be established at a federal facility, one of these three conditions must be met. Given EPA's authority to issue guidelines for disposal of solid wastes at federal installations, condition 3 might well provide the most direct method for circumventing military procurement policies which now exclude re-refined oil. Authorization for a military facility to purchase re-refined oil might have to come directly from the Office of the Secretary of Defense. However, chemists at CCL have stated that if regulations or legislation, such as that proposed by Representative Vanik 2/ were adopted which required the use of re-refined oil, they would urge the military not to use re-refined oil in those vehicles (largely tactical vehicles) which normally use virgin lube oil meeting specification MIL-L-2104C. On the other hand, the chemists stated that use of re-refined oil in vehicles which normally use virgin lube oils procured under specification MIL-L-46152 (mainly passenger cars and light trucks) would not be so strongly discouraged.

Table 3 shows the very significant volumes of lube oil procured for fiscal year 1974 by ten important military bases throughout the United States. Any of these facilities could provide the waste oil and purchase the re-refined oil in a closed-cycle pilot program.

3.3.6 Further Examples of Lube Oil Procurement

Some examples of lube oil procurement by federal facilities located in California can serve to illustrate how conditions 2 and 3 might be used to circumvent the normal procurement procedures. Table 4 lists estimated lube oil requirements for 16 California postal facilities for the fiscal year 1974. The oil required is a multi-grade lubricant meeting specification MIL-L-46152. All deliveries are to be made by tank wagon. The largest minimum delivery is 800 gallons for the postal service in San Diego. Note that the delivered price per gallon is much lower than those listed in Table 8 of Chapter 1. The government's competitive bidding program does, indeed, result in considerable savings for oil purchases when compared with prices paid by large commercial accounts to major oil companies. For this reason most of the oil bought by government agencies is not supplied by major oil companies but by independent oil firms and

TABLE 3

Internal Combustion Engine Lube Oil Procurement for
Some Military Bases for Fiscal Year 1974

	Base and Location	Lube Oil Procured (Gallons)
1.	Fort Hood, Texas	267,060
2.	Fort Riley, Kansas	260,000
3.	Camp Lejeune, North Carolina	173,450
4.	Fort Bragg, North Carolina	118,500
5.	Fort Lewis, Washington	104,280
6.	Camp Pendleton, California	95,890
7.	U.S. Marine Corps, Tampa, Florida	71,500
8.	Fort Sill, Oklahoma	64,670
9.	Fort Benning, Georgia	48,700
10.	Camp Shelby, Mississippi	40,000

TABLE 4

Lube Oil Requirements of Some Postal Facilities in California

for Fiscal Year 1974

Location	Minimum Delivery (Gallons)	Total Estimated Requirements (Gallons)	Price ¢/Gallon
Walnut Creek	400	1,700	NA
Hayward	400	1,000	NA
Van Nuys	600	1,500	66
San Diego	800	4,400	73
Oxnard	400	1,500	75
Los Angeles 1	600	4,800	66
Los Angeles 2	300	1,200	66
Los Angeles 3	300	600	66
Los Angeles 4	300	900	66
Torrance	400	4,000	66
Santa Ana	500	1,500	68
Huntington Beach	500	2,000	68
La Puente	500	1,000	68
San Jose	500	3,000	NA
San Rafael	400	1,800	NA
San Bernardino	500	2,000	71

smaller blending and compounding companies. These firms frequently buy base stocks from the major oil companies in large quantities and perform the blending operations themselves. Lower overhead costs allow smaller firms to outbid the Majors for lube oil supply to the government. In fact, due to the present shortage of lube oils, some large companies are avoiding sales of lube oil to the government as more profitable markets are now available.

If it were decided that one or more of these postal service facilities should be chosen to implement a closed-loop oil recycling project, conditions 2 or 3 might suffice without the need for "special authorization" options. For example, the postal facilities might wish to have the re-refined oil provided in 55 gallon drums or 5 gallon pails or even quart cans rather than in tank wagon loads. In the case of the San Diego facility a delivery of less than 800 gallons would qualify as an exception to DFSC purchase regulations. In all cases, however, approval from local Post Office authorities would have to be obtained. In the absence of "special authorization" from higher level authorities in Washington, D.C., this approval would probably be very difficult to obtain. Note also that purchases of re-refined oil in smaller volumes or in smaller containers would probably be more costly than existing contracts for virgin lube oils.

3.4 A PROPOSAL

A closed-cycle pilot project at federal facilities for the use of re-refined automotive lube oils should be initiated. A federal facility should be selected which is both willing to participate and can provide adequate volumes of used lube oil to be "custom" re-refined. In most cases the minimum batch of feedstock which can be economically custom re-refined is about 2000 gallons. In order to assure constance of feedstock quality, the federal facility must agree to purchase all its virgin lube oil from the same supplier and to store crankcase drainings separately from other waste materials.

The selection of a re-refiner to participate in this project should be based on geographical proximity to the federal facility, recommendations of long-term customers who have used the firm's products, the willingness of the company to participate, and the opinions of additive suppliers and analytical laboratories as to the consistency of the quality and performance of the products which the firm produces.

The purpose of the pilot project is to establish that properly re-refined oil can be used in place of high quality virgin lubricants by providing a performance record for these oils under controlled conditions. A successful closed-cycle project will provide an important stimulus to the review and possible removal of restrictions on the procurement of re-refined oils by the Defense Fuel Supply Center. An extensive program of analysis of re-refined oils and drain oil feedstocks available throughout the country, such as that proposed in the DSA Waste Oil Recycling Study, will need to be performed before CCL will write a specification under which re-refined lube oils can be procured. However, the studies proposed by DSA, once they are funded, will require three years for completion and offer no guarantee that even one pilot recycling project will ever be implemented. If no action is taken soon to provide documentation as to the quality of re-refined oils and thus lend needed support to an industry facing an uncertain future, it is highly probable that greater and greater volumes of waste lube oil will be absorbed in markets which neither provide for the recovery of this now scarce resource nor offer any assurance of reducing the environmental impact of its disposal.

This proposal should, however, not be interpreted as an unrestricted endorsement of the re-refining industry as it now exists nor of lube oil recycling as the universal solution to the waste oil problem. A number of re-refiners have gone out of business for valid reasons. Some have followed poor business practices. Others have failed to provide adequate quality control on their operations. Still others have not been willing or able to comply with regulations regarding air and water pollution control. Further, present re-refining technology must be improved to eliminate the problem of acid sludge disposal. In many instances it may be grossly uneconomic to transport used lube oils to a re-refinery and return the recycled product to the facility which supplied the used oil. In these instances at least a part of the resource value of the oil might be recovered through use of the oil as fuel. While, in the final analysis, market forces should dictate the most beneficial means of waste oil disposition, the establishment of a closed-cycle re-refining project should be viewed primarily as an opportunity to remove the institutional barriers which have prevented the free market from operating.

Arguments can be raised which challenge the proposition that federal policy should encourage the recycling of used lube oils. "Let the market decide the ultimate disposition of crankcase drainings" is a proposition frequently put forth. This would be an admirable policy provided a free market atmosphere in which re-refined lube oils can compete with virgin products in fact existed. However, past federal policies have distorted the "free market" by discriminating against re-refined products, regardless of their quality. The results of a recent consumer survey verify the low regard held for re-refined lube oils by those individuals who know of the existence of these products. 3/ If the federal government were to reverse its policies and provide a more supportive atmosphere for recycled lube oils, then the re-refining industry would have an opportunity to establish its products as viable competitors in the marketplace. In fact, as discussed in Chapter 1, some re-refiners have been able to compete successfully with producers of virgin oils despite the effects of government policy and the poor reputation of the industry in general.

FOOTNOTES

1. A Technical and Economic Study of Waste Oil Recovery--Part II: An Investigation of Dispersed Sources of Used Crankcase Oils, Teknekron, Inc., EPA Contract No. 68-01-1806, October 1973. Hereafter referred to as Waste Oil Recovery--II.

2. A Technical and Economic Study of Waste Oil Recovery--Part I: Federal Research on Waste Oil From Automobiles, Teknekron, Inc., EPA Contract No. 68-01-1806, October 1973.

3. Waste Oil Recovery--II.

ACKNOWLEDGMENT

Teknekron, Inc. and The Institute of Public Administration wishes to acknowledge the Resource Recovery Division, Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, for support of this study. In particular we are grateful to Dr. John H. Skinner, Acting Deputy Director, Resource Recovery Division and to the Project Officers, Messrs. Thomas D. Clark and Laurence B. McEwen for their guidance and assistance in the performance of this research.

We would also like to express of sincere appreciation to the following individuals and organizations whose assistance was vital in completing this project:

The thirteen re-refiners interviewed

Mr. Belton R. Williams, President, Association of Petroleum Re-refiners

Mr. Curtis Gordon, The Lubrizol Corporation

Mr. Rick Richardson, The Lubrizol Corporation

Mr. Joseph Byrne, Vice President, Union Oil Company of California

Colonel Ralph J. Walsh, Office of the Assistant Secretary of Defense for Health and Environment

Preceding page blank

APPENDIX A

MILITARY SPECIFICATIONS MIL-L-46152 AND MIL-L-2104C FOR ENGINE CRANKCASE OILS

MILITARY SPECIFICATION

LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, ADMINISTRATIVE SERVICE

This specification is mandatory for use by all Departments and Agencies of thd Department of Defense.

1. SCOPE

1.1 Scope. This specification covers engine oils suitable for lubrication of commercial-type vehicle reciprocating internal combustion engines of both spark-ignition and compression-ignition types used in administrative service (see 6.1).

1.2 Classification. The engine lubricants shall be of the following viscosity grades (see 6.2):

Viscosity grade

Grade 10W
Grade 30
Grade 10W-30
Grade 20W-40

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

MILITARY
- MIL-L-2104 - Lubricating Oil, Internal Combustion Engine, Tactical Service
- MIL-L-21260 - Lubricating Oil, Internal Combustion Engine, Preservative and Break-In

FSC 9150

STANDARDS

FEDERAL

Fed. Test Method Std. No. 791 - Lubricants, Liquid Fuels and Related Products; Methods of Testing

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-290 - Packaging, Packing and Marking of Petroleum and Related Products

(Copies of specifications, standards, drawings and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated the issue in effect on date of invitation for bids or request for proposal shall apply:

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) TEST METHODS

D 92 - Flash and Fire Points by Cleveland Open Cup
D 97 - Pour Point
D 129 - Sulfur in Petroleum Products by the Bomb Method
D 270 - Sampling Petroleum and Petroleum Products
D 287 - API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
D 445 - Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)
D 524 - Ramsbottom Carbon Residue of Petroleum Products
D 808 - Chlorine in New and Used Petroleum Products (Bomb Method)
D 811 - Chemical Analysis for Metals in New and Used Lubricating Oils
D 874 - Sulfated Ash from Lubricating Oils and Additives
D 892 - Foaming Characteristics of Lubricating Oils
D 1091 - Phosphorus in Lubricating Oils and Additives
D 1317 - Chlorine in New and Used Lubricants (Sodium Alcoholate Method)
D 1552 - Sulfur in Petroleum Products (High Temperature Method)
D 2270 - Calculating Viscosity Index from Kinematic Viscosity
D 2602 - Apparent Viscosity of Motor Oils at Low Temperature Using the Cold Cranking Simulator

Engine Test Sequence IIB
Engine Test Sequence IIIC
Engine Test Sequence VC

(The ASTM test methods listed above are included in Part 17 or Part 18 of the Annual Book of ASTM Standards and are also available separately, except for Engine Test Sequences IIB, IIIC, and VC. Engine Test Sequence IIB is a part of ASTM Special Technical Publication STP 315-D. Engine Test Sequences IIIC and VC will be included in ASTM Special Technical Publication STP 315-E, scheduled for publication after May 1971, and are currently available only as preprints.)

(Application for copies of all ASTM test methods except Engine Test Sequences IIIC and VC should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

(Until publication of Special Technical Publication STP 315-E by ASTM, information concerning Engine Test Sequences IIIC and VC may be obtained from U. S. Army Aberdeen Research and Development Center, Coating and Chemical Laboratory, AMXRD-CF, Aberdeen Proving Ground, Maryland 21005.)

Specifications and standards of technical societies are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

3. REQUIREMENTS

3.1 Qualification. Engine lubricating oils furnished under this specification shall be products which are qualified for listing on the applicable qualified products list at the time set for opening of bids (see 4.5.1 and 6.4).

3.1.1 Each viscosity grade of oil which satisfies all the requirements of this specification shall be qualified for a period not to exceed four years from the date of its original qualification. When the qualification period has expired, each product must be requalified if the supplier wishes to maintain the formulation as a qualified product and be eligible to bid on prospective procurements.

3.1.2 Whenever there is a change in the base stock, in the refining treatment or in the additives used in the formulation, requalification will be required. When proposed changes are minor and may not be expected to significantly affect performance, the qualifying activity may, at its discretion, waive complete requalification or may require only partial requalification in order to determine the significance and acceptability of the proposed changes.

3.1.3 The engine lubricating oil supplied under contract shall be identical, within permissible tolerances assigned by the qualifying activity for the properties listed in 3.4, to the product receiving qualification. The values resulting after the application of tolerances shall not exceed the maximum nor fall below the minimum limits specified herein (see table I and 3.3.1 through 3.3.7).

3.1.4 Pour-point depressant: All grade oils. No changes shall be made in either the type or concentration of the pour-point depressant after qualification testing and approval unless:

a. The oil is retested for conformity to the stable pour point requirement (see table I).

b. The qualifying activity (see 6.4) is informed of the proposed change(s) and of the retesting of the stable pour point.

c. The qualifying activity approves the proposed change(s) in writing.

3.2 Materials. The engine lubricating oils shall be petroleum products, synthetically prepared products, or a combination of the two types of product compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, etc.) as are necessary to meet the specified requirements. No re-refined constituent materials shall be used.

3.3 Physical and chemical requirements. The oils shall conform to the respective requirements specified in table I and in 3.3.1 through 3.3.7.

Table I. Requirements

Property	Grade 10	Grade 30	Grade 10W-30	Grade 20W-40
Viscosity at 210°F (99°C)				
kinematic, centistokes				
min.	5.7	9.6	9.6	12.9
max.	< 7.5	< 12.9	< 12.9	< 16.8
Viscosity at 0°F (-18°C) 1/				
apparent, centipoises				
min.	1200	--	1200	2400
max.	< 2400	--	< 2400	< 9600
Viscosity index, min	--	75	--	--
Pour point, °F (max.)	-25	0	-25	-10
°C (max.)	-32	-18	-32	-23
Stable pour point, °F (max.) 2/	-25	--	-25	-10
°C (max.)	-32	--	-32	-23
Flash point, °F (min.)	400	425	400	415
°C (min.)	204	218	204	213
Gravity, API 3/	X	X	X	X
Carbon residue 3/	X	X	X	X
Phosphorus 3/	X	X	X	X
Chlorine 3/	X	X	X	X
Sulfur 3/	X	X	X	X
Sulfated residue 3/	X	X	X	X
Organo-metallic components 3/	X	X	X	X

1/ Report measured, apparent viscosity at 0°F (-18°C) in centipoises for grades 10, 10W-30, and 20W-40 oils.

2/ After being cooled below its pour point, the oil shall regain its homogenity on standing at a temperature not more than 10°F (6°C) above the pour point.

3/ Values shall be reported ("X" indicates report).

3.3.1 Foaming. All grades of oil shall demonstrate the following foaming characteristics when they are tested in accordance with 4.6, table II (ASTM D 892).

a. Initial test at 75° ± 1°F (24° ± 0.5°C). Not more than 25 ml of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

b. Intermediate test at 200° ± 1°F (93.5° ± 0.5°C). Not more than 150 ml of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

c. Final test at 75° ± 1°F (24° ± 0.5°C). Not more than 25 ml of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

3.3.2 Stability and compatibility.

3.3.2.1 Stability. The oils shall show no evidence of separation or color change when they are tested in accordance with 4.6, table II (Method 3470 of Fed. Test Method Std. No. 791).

3.3.2.2 Compatibility. The oils shall be compatible with oils previously qualified under MIL-L-2104, MIL-L-46152 and MIL-L-21260. The oils shall show no evidence of separation when they are tested against selected reference oils in accordance with 4.6, table II (Method 3470 of Fed. Test Method Std. No. 791).

3.3.3 Moisture-corrosion characteristics. The oils shall prevent or minimize corrosion of ferrous-metal engine components in the presence of moisture induced by low-temperature operating conditions. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.6, table II (Engine Test Sequence IIB).

3.3.4 Low-temperature deposits. The oils shall minimize the formation of undesirable deposits associated with intermittent, light-duty, low-temperature operating conditions. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.6, table II (Engine Test Sequence VC).

3.3.5 Oxidation characteristics. The oils shall resist thermal and chemical oxidation and prevent or minimize thickening and deposits associated with high-temperature operating conditions. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.6, table II (Engine Test Sequence IIIC).

3.3.6 Ring-sticking, wear, and accumulation of deposits. The oils shall prevent the sticking of piston rings and the clogging of oil channels, and shall minimize the wear of cylinders, rings and loaded engine components such as cam shaft lobes, cam followers, valve rocker arms, rocker arm shafts, and the oil pump and fuel injection pump drive gears. Satisfactory performance shall be demonstrated when the oils are tested in accordance with 4.6, table II (Method 346 of Fed. Test Method Std. No. 791).

3.3.7 Bearing corrosion and shear stability.

3.3.7.1 Bearing corrosion. The oils shall be non-corrosive to alloy bearings. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.6, table II (Method 3405 of Fed. Test Method Std. No. 791).

3.3.7.2 Shear stability. Grade 10W-30 and 20W-40 oils shall demonstrate shear stability by remaining within the respective viscosity ranges at 210°F (99°C), when tested in accordance with 4.6.3.

3.4 Other requirements and tolerances for quality conformance testing. The following physical and chemical properties shall be tested in accordance with the appropriate methods listed in 4.6 to insure that purchased products are of the same compositions as the respective qualification samples and to identify the products. No specific values or limits are assigned in qualification testing, except as otherwise specified in table 1 and in 3.3.1 through 3.3.7, but test results shall be reported for all properties listed. The qualifying activity (see 6.4) shall establish specific values and tolerances for subsequent quality conformance testing for these properties (see 6.3 and 6.4):

Viscosity
Viscosity index
Pour point
Flash point
Gravity, API
Carbon residue
Foaming
Phosphorus
Chlorine
Sulfur
Sulfated ash
Organo-metallic components

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Lot.

4.2.1 Bulk lot. An indefinite quantity of a homogeneous mixture of one grade of oil offered for acceptance in a single, isolated container; or manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

4.2.2 Packaged lot. An indefinite number of 55 gallon drums or smaller unit containers of identical size and type, offered for acceptance, and filled with a homogeneous mixture of one grade of oil from a single, isolated container; or filled with a homogeneous mixture of one grade of oil, manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

4.3 Sampling.

4.3.1 Sampling for the examination of filled containers. Take a random sample of filled containers from each lot in accordance with MIL-STD-105, at inspection level II and acceptable quality level (AQL) = 2.5 percent defective.

4.3.2 Sampling for tests. Take samples from bulk or packaged lots for tests in accordance with ASTM Method D 270.

4.4 Inspection. Perform inspection in accordance with Method 9601 of Fed. Test Method Std. No. 791.

4.4.1 Examination of filled containers. Examine samples taken in accordance with 4.3.1 for compliance with MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and marking requirements. Reject any container having one or more defects or under the required fill. If the number of defective or underfilled containers exceeds the acceptance number for the appropriate sampling plan of MIL-STD-105, reject the lot represented by the sample.

4.5 Classification of tests.

a. Qualification tests
b. Quality conformance tests

4.5.1 Qualification tests. Qualification tests consist of tests for all of the requirements specified in section 3 and may be conducted in any plant or laboratory approved by the qualifying activity (see 6.4) unless otherwise specified in 4.6.1 through 4.6.3. Qualification tests shall be performed on each viscosity grade except as specified in 4.5.1.1 and 4.5.1.2.

4.5.1.1 The stable pour-point test (Method 203 of Fed. Test Method Std. No. 791) shall be required only on grade 10W, 10W-30 and 20W-40 oils.

4.5.1.2 Shear stability shall be required for only grade 10W-30 and 20W-40 oils.

4.5.2 Quality conformance tests. Tests for quality conformance of individual lots shall consist of tests for all of the requirements in section 3, except for the following (see table II):

Stable pour point
Stability and compatibility
Ring-sticking, wear, and accumulation of deposits
Low-temperature deposits
Oxidation characteristics
Moisture-corrosion characteristics
Bearing corrosion and shear stability

4.6 Test methods. Perform tests in accordance with table II and with 4.6.1 through 4.6.3 as applicable.

4.6.1 Stability and compatibility. Determine the stability and compatibility of the oils by the procedures for "Homogeneity" and "Miscibility" given in Method 3470 of Fed. Test Method Std. No. 791, as explained in 4.6.1.1 and 4.6.1.2. The procedures in 4.6.1.1 and 4.6.1.2 should be performed at the same time. This test shall be conducted only in a laboratory designated by the qualifying activity (see 6.4).

4.6.1.1 Stability. Determine the stability by subjecting an unmixed sample of oil to the prescribed cycle of temperature changes, then examine the sample for conformance to the requirements of 3.3.2.1. Record the test results on a copy of the "Homogeneity and Miscibility Test" form in the column marked "None".

4.6.1.2 Compatibility. Determine the compatibility of the oil with other oils previously qualified under MIL-L-2104, MIL-L-21260, and MIL-L-46152 by subjecting separate mixtures of the oil with selected reference oils designated by the qualifying activity (see 6.4) to the prescribed cycle of temperature changes, then examine the mixtures for conformance to the requirements of 3.3.2.2. Record the test results on the same copy of the "Homogeneity and Miscibility Test" form (see 4.6.1.1) in the appropriate colums marked "1-30", "2-30", etc.

4.6.2 Stable pour point. The stable pour-point test shall be conducted only in a laboratory designated by the qualifying activity (see 6.4).

4.6.3 Shear stability. Determine the shear stability of grade 10W-30 and 20W-40 oils by the following method:

a. Weigh 25 grams of used oil, obtained at 10 hours of testing in accordance with Method 3405 of Fed. Test Method Std. No. 791, into a 50-ml three-necked round bottom flask equipped with a thermometer, gas inlet tube, stirrer, and distillation side arm.

b. Heat the sample at 248° ± 9° F (120° ± 5°C) in a vacuum of 100 mm of mercury with a nitrogen sparge for one hour.

c. Filter the stripped sample through a 0.1 micron Seitz filter pad.

d. Determine the kinematic viscosity at 210°F (99°C) of the filtered sample using ASTM Method D 445 for conformance to the requirements of 3.3.7.2.

Table II. Test methods

Test	Test Method No. Fed. Std. 791	Test Method No. ASTM
Viscosity, kinematic		D 445
Viscosity, apparent		D 2602 1/
Viscosity index		D 2270
Pour point		D 97
Stable pour point	203 2/	
Flash point		D 92
Gravity, API		D 287
Carbon residue		D 524
Phosphorus		D 1091
Chlorine		D 808 or D 1317 3/
Sulfur		D 1552 or D 129 4/
Sulfated residue		D 874
Organo-metallic components		D 811 5/
Foaming		D 892
Stability and compatibility	3470 6/	
Moisture-corrosion characteristics		Sequence IIB 7/
Low temperature deposits		Sequence VC 8/
Oxidation characteristics		Sequence IIIC 8/
Ring-sticking, wear, and accumulation of deposits	346	
Bearing corrosion and shear stability	3405 9/	

1/ Obtain the viscosity at 0°F (-18°C) by D 2602 for grade 10W, 10W-30 and 20W-40 oils.
2/ See 4.6.2
3/ D 808 is the preferred method but D 1317 may be used as an alternate.
4/ D 1552 is the preferred method but D 129 may be used as an alternate.
5/ X-ray fluorescence or atomic absorption spectrochemical analysis methods that have been previously approved by the qualifying activity (see 6.4) may be used as alternates to D 811.
6/ Homogeneity and miscibility test (see 4.6.1 for clarifying instructions.
7/ Included in ASTM STP 315-D.
8/ Not yet published by ASTM. To be included in ASTM STP 315-E, when published (see 2.2).
9/ See 4.6.3

5. PREPARATION FOR DELIVERY

5.1 Packaging, packing, and marking. Unless otherwise specified in the contract or purchase order (see 6.2), packaging, packing, and marking shall be in accordance with MIL-STD-290.

6. NOTES

6.1 Intended use. The lubricating oils covered by this specification are intended for the crankcase lubrication of commercial-type vehicles used for administrative (post, station, and camp) service typical of: (1) gasoline engines in passenger cars and light to medium duty trucks operating under manufacturer' warranties; and (2) lightly supercharged diesel engines operated in moderate duty. The lubricating oils covered by this specification are intended for use, as defined by vehicle manufacturer, when ambient temperatures are above -20°F (-29°C).

6.2 Ordering data. Procurement documents should specify the following information:

a. Title, number, and date of this specification.
b. Grade of oil required (see 1.2).
c. Quantity of oil required.
d. Type and size of containers required (see 5.1).
e. Level of packaging and level of packing required (see 5.1).

6.3 Other requirements and tolerances for quality conformance testing. Definite numerical values are not specified for certain of the physical and chemical properties listed in 3.4, and for which corresponding test methods are given in Section 4. Values of some properties vary from one commercial brand of oil to another for the same grade. These values are influenced by the source of the base stock, the identities and quantities of additives, etc. Definite numerical values are not always functionally important except, for some properties, within specified maximum and/or minimum limits. It is not possible (or necessary) to assign restrictive values in the specification before the testing of qualification samples. During qualification, test values will be determined which are characteristic of a particular product and which can serve thereafter to identify the product. Using the results of qualification testing, the qualifying activity (see 6.4) can set values, including permissible tolerances, for future quality conformance testing.

6.4 Qualification. With respect to products requiring qualification, awards will be made only for products which are at the time set for opening of bids, qualified for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the U.S. Army Aberdeen Research and Development Center, Coating and Chemical Laboratory, Aberdeen Proving Ground, Maryland 21005 and information pertaining to qualification of products may be obtained from that activity.

Custodians:
Army - MR
Navy - SH
Air Force - 68

Preparing activity:
Army - MR

(Project No. 9150-0316)

Review activities:
Army - MI, WC, AT
Navy - SH, SA, AS, YD, MC
Air Force - 11, 68
DSA - PS

User activities:
Army - ME
Navy - OS

☆ U. S. GOVERNMENT PRINTING OFFICE: 1970 .433-693/3080

MIL-L-2104C
20 November 1970
SUPERSEDING
MIL-L-2104B
1 December 1964
MIL-L-45199B
28 June 1968

MILITARY SPECIFICATION

LUBRICATING OIL, INTERNAL COMBUSTION ENGINE, TACTICAL SERVICE

This specification is mandatory for use by all Departments and Agencies of the Department of Defense

1. SCOPE

1.1 Scope. This specification covers engine oils suitable for lubrication of reciprocating internal combustion engines of both spark-ignition and compression-ignition types used in tactical service (see 6.1).

1.2 Classification. The lubricating oils shall be of the following viscosity grades (see 6.2):

Viscosity Grade	Military Symbol
Grade 10	OE/HDO-10
Grade 30	OE/HDO-30
Grade 40	OE/HDO-40
Grade 50	OE/HDO-50

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-L-21260 - Lubricating Oil, Internal Combustion Engine, Preservative and Break-In.
MIL-L-46152 - Lubricating Oil, Internal Combustion Engine, Administrative Service.

STANDARDS

FEDERAL

/FSC 9150/

Fed. Test Method Std. 791 - Lubricants, Liquid Fuels and Related Products; Methods of Testing.

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-290 - Packaging, Packing and Marking of Petroleum and Related Products.

(Copies of specifications, standards, drawings and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) TEST METHODS

D 92	Flash and Fire Points by Cleveland Open Cup
D 97	Pour Point
D 129	Sulfur in Petroleum Products by the Bomb Method
D 270	Sampling petroleum and Petroleum Products
D 287	API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
D 445	Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)
D 524	Ramsbottom Carbon Residue of Petroleum Products
D 808	Chlorine in New and Used Petroleum Products (Bomb Method)
D 811	Chemical Analysis for Metals in New and Used Lubricating Oils
D 874	Sulfated Ash from Lubricating Oils and Additives
D 892	Foaming Characteristics of Lubricating Oils
D 1091	Phosphorus in Lubricating Oils and Additives
D 1317	Chlorine in New and Used Lubricants (Sodium Alcoholate Method)
D 1552	Sulfur in Petroleum Products (High Temperature Method)
D 2270	Calculating Viscosity Index from Kinematic Viscosity
D 2602	Apparent Viscosity of Motor Oils at Low Temperature Using the Cold Cranking Simulator

Engine Test Sequence IIB
Engine Test Sequence VC

(The ASTM test methods listed above are included in Part 17 or Part 18 of the Annual Book of ASTM Standards and are also available separately, except for Engine Test Sequences IIB and VC. Engine Test Sequence IIB is a part of ASTM Special Technical Publication STP 315-D. Engine Test Sequence VC will be included in ASTM Special Technical Publication STP 315-E, scheduled for publication after May 1971, and is currently available only as a preprint.

(Application for copies of all ASTM test methods except Engine Test Sequence VC should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

(Until publication of Special Technical Publication STP 315-E by ASTM, information concerning Engine Test Sequence VC may be obtained from U.S. Army Research and Development Center, Coating and Chemical Laboratory, AMXRD-CF, Aberdeen Proving Ground, Maryland 21005.)

Specifications and standards of technical societies are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

3.1 Qualification. Engine lubricating oils furnished under this specification shall be products which are qualified for listing on the applicable Qualified Products List at the time set for opening of bids (see 4.5.1 and 6.4).

3.1.1 The qualifying activity (see 6.4) may waive complete qualification testing or may require only partial qualification testing of grade 40 oil if the supplier states in a written affidavit that the product has been formulated with base stocks, refining treatment, and additives the same as those used in the formulation of grade 30 and grade 50 oils qualified under this specification.

3.1.2 Each viscosity grade of oil which satisfies all the requirements of this specification shall be qualified for a period not exceeding four years from the date of its original qualification. The qualification period for each grade 40 oil qualified in accordance with 3.1.1 shall not exceed that of the grade 30 and grade 50 oils used in the qualification procedure. When the qualification period has expired, each product must be requalified if the supplier wishes to maintain the formulation as a qualified product and be eligible to bid on prospective products.

3.1.3 Whenever there is a change in the base stock, in the refining treatment or in the additives used in the formulation, requalification will be required. When proposed changes are minor and may not be expected to significantly affect performance, the qualifying activity may, at its discretion, waive complete requalification or may require only partial requalification in order to determine the significance and acceptability of the proposed changes.

3.1.4 The engine lubricating oil supplied under contract shall be identical, within permissible tolerances assigned by the qualifying activity for the properties listed in 3.4, to the product receiving qualification. The values resulting after the application of tolerances shall not exceed the maximum nor fall below the minimum limits specified herein (see table I and 3.3.1 through 3.3.6).

3.1.5 Pour-point depressant. No changes shall be made in either the type or concentration of the pour-point depressant after qualification testing and approval unless:

(a) The oil is retested for conformity to the stable pour point requirement (see table I).

(b) The qualifying activity (see 6.4) is informed of the proposed change(s) and of the retesting of the stable pour point.

(c) The qualifying activity approves the proposed change(s) in writing.

3.2 Materials. The engine lubricating oils shall be petroleum products, synthetically prepared products or a combination of the two types of product compounded with such functional additives (detergents, dispersants, oxidation inhibitors, corrosion inhibitors, etc.) as are necessary to meet specified requirements. No re-refined constituent materials shall be used.

3.3 Physical and chemical requirements. The oils shall conform to the respective requirements specified in table I and 3.3.1 through 3.3.6.

Table I. Requirements

Property	Grade 10	Grade 30	Grade 40	Grade 50
Viscosity at 210°F. (99°C.), kinematic, centistokes				
min.	5.7	9.6	12.9	16.8
max.	<7.5	<12.9	<16.8	<22.7
Viscosity at 0°F. (-18°C.) 3/, apparent, centipoises				
min.	1200	--	--	--
max.	< 2400	--	--	--
Viscosity index (min.)	--	75	80	85
Pour point, °F. (max.)	-25	0	5	15
°C. (max.)	-32	-18	-15	- 9
Stable pour-point, °F. (max.) 2/	-25	--	--	--
°C. (max.)	-32	--	--	--
Flash point, °F. (min.)	400	425	435	450
°C. (min.)	204	218	224	232
Gravity, API 3/	X	X	X	X
Carbon residue 3/	X	X	X	X
Phosphorus 3/	X	X	X	X
Chlorine 3/	X	X	X	X
Sulfur 3/	X	X	X	X
Sulfated residue 3/	X	X	X	X
Organo-metallic components 3/	X	X	X	X

1/ Report measured, apparent viscosity at 0°F (-18°C) in centipoises for grade 10 oil.

2/ After being cooled below its pour point, the oil shall regain its homogeneity on standing at a temperature not more than 10° F (6° C) above the pour point.

3/ Values shall be reported ("x" indictes report).

3.3.1 Foaming. All grades of oil shall demonstrate the following foaming characteristics when they are tested in accordance with 4.6, table II.(ASTM D 892).

(a) Initial test at 75° ± 1° F (24° ± 0.5° C). Not more than 25 ml of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

(b) Intermediate test at 200° ± 1° F (93.5 ± 0.5° C). Not more than 150 ml of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

(c) Final test at 75° ± 1° F (24° ± 0.5° C). Not more than 25 ml of foam shall remain immediately following the end of the 5-minute blowing period. No foam shall remain at the end of the 10-minute settling period.

3.3.2 Stability and compatibility.

3.3.2.1 Stability. The oils shall show no evidence of separation or color change when they are tested in accordance with 4.6, table II (method 3470, Fed. Test Method Std. No. 791).

3.3.2.2 Compatibility. The oils shall be compatible with oils previously qualified under MIL-L-2104, MIL-L-46152, and MIL-L-21260. The oils shall show no evidence of separation when they are tested against selected reference oils in accordance with 4.6, table II (method 3470, Fed. Test Method Std. No. 791).

3.3.3 Moisture-corrosion characteristics. The oils shall prevent or minimize corrosion of ferrous-metal engine components in the presence of moisture induced by low-temperature operating conditions. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.6, table II. (Engine Test Sequence IIB).

3.3.4 Low-temperature deposits. The oils shall minimize the formation of undesirable deposits associated with intermittent, light-duty, low-temperature operating conditions. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.6, table II (Engine Test Sequence VC).

3.3.5 Bearing corrosion. The oils shall be noncorrosive to alloy bearings. Satisfactory performance in this respect shall be demonstrated when the oils are tested in accordance with 4.6, table II (method 3405, Fed. Test Method Std. No. 791).

3.3.6 Ring-sticking, wear, and accumulation of deposits. The oils shall prevent the sticking of piston rings and the clogging of oil channels, and shall minimize the wear of cylinders, rings and loaded engine components such as cam shaft lobes, cam followers, valve rocker arms, rocker arm shafts, and the oil pump and fuel injection pump drive gears. Satisfactory performance shall be demonstrated when the oils are tested in accordance with the appropriate methods listed in 4.6, table II (methods 340 and 341, Fed. Test Method Std. No. 791).

3.4 Other requirements and tolerances for quality conformance testing. The following physical and chemical properties shall be tested in accordance with the appropriate methods listed in 4.6 to insure that purchased products are of the same compositions as the respective qualification samples and to identify the products. No specific values or limits are assigned in qualification testing, except as otherwise specified in table I and in 3.3.1 through 3.3.6, but test results shall be reported for all properties listed. The qualifying activity (see 6.4) shall establish specific values and tolerances for subsequent quality conformance testing for these properties (see 6.3 and 6.4):

Viscosity
Viscosity index
Pour point
Flash point
Gravity, API
Carbon residue
Foaming
Phosphorus
Chlorine
Sulfur
Sulfated ash
Organo-metallic components

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Lot.

4.2.1 Bulk lot. An indefinite quantity of a homogeneous mixture of one grade of oil offered for acceptance in a single, isolated container; or manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

4.2.2 Packaged lot. An indefinite number of 55 gallon drums or smaller unit containers of identical size and type, offered for acceptance, and filled with a homogeneous mixture of one grade of oil from a single, isolated container; or filled with a homogeneous mixture of one grade of oil manufactured in a single plant run (not exceeding 24 hours), through the same processing equipment, with no change in the ingredient materials.

4.3 Sampling.

4.3.1 Sampling of filled containers. Take a random sample of filled containers from each lot in accordance with MIL-STD-105 at inspection level II and acceptable quality level (AQL) = 2.5 percent defective.

4.3.2 Sampling for tests. Take samples from bulk or packaged lots for tests in accordance with ASTM Method D 270.

4.4 Inspection. Perform inspection in accordance with method 9601 of Fed. Test Method Std. No. 791.

4.4.1 Examination of filled containers. Examine samples taken in accordance with 4.3.1 for compliance with MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and marking requirements. Reject any container having one or more defects or under the required fill. If the number of defective or underfilled containers exceeds the acceptance number for the appropriate sampling plan of MIL-STD-105, reject the lot represented by the sample.

4.5 Classification of tests.

(a) Qualification tests.
(b) Quality conformance tests.

4.5.1 Qualification tests. Qualification tests consist of test for all of the requirements specified in section 3 and may be conducted in any plant or laboratory approved by the qualifying activity (see 6.4), unless otherwise specified in 4.6.1 through 4.6.2. Qualification tests shall be performed on each viscosity grade except as specified in 4.5.1.1 and 4.5.1.2.

4.5.1.1 The stable pour-point test (method 203, Fed. Test Method Std. 791) shall be required only on grade 10 oil.

4.5.1.2 Grade 40 oils may be qualified in accordance with 3.1.1.

4.5.2 Quality conformance tests. Tests for quality conformance of individual lots shall consist of tests for all of the requirements in section 3, except for the following (see table II):

Stable pour point
Stability and compatibility
Ring-sticking, wear, and accumulation of deposits
Low temperature deposits
Bearing corrosion
Moisture-corrosion characterisitcs

4.6 Test methods. Perform tests in accordance with table II and with 4.6.1 through 4.6.2 as applicable.

4.6.1 Stability and compatibility. Determine the stability and compatibility of the oils by the procedures for "Homogeneity" and "Miscibility" given in method 3470, Fed. Test Method Std. No. 791, as explained in 4.6.1.1 and 4.6.1.2. The procedures in 4.6.1.1 and 4.6.1.2 should be performed at the same time. This test shall be conducted only in a laboratory designated by the qualifying activity (see 6.4).

4.6.1.1 Stability. Determine the stability by subjecting an unmixed sample of oil to the prescribed cycle of temperature changes and examining the sample for conformance to the requirements of 3.3.2.1. Record the test results on a copy of the "Homogeneity and Miscibility Test" form in the column marked "None."

4.6.1.2 Compatibility. Determine the compatibility of the oil with other oils previously qualified under MIL-L-2104, MIL-L-21260 and MIL-L-46152, by subjecting separate mixtures of the oil with selected reference oils designated by the qualifying activity (see 6.4) to the prescribed cycle of temperature changes, then examining the mixtures for conformance to the requirements of 3.3.2.2. Record the test results on the same copy of the "Homogeneity and Miscibility Test" form (see 4.6.1.1) in the appropriate columns marked "1-30", "2-30", etc.

4.6.2 Stable pour point. The stable pour point test (method 203, Fed. Test Method Std. No. 791) shall be performed only in a laboratory designated by the qualifying activity (see 6.4).

Table II. Test Methods

Test	Test Method No. Fed. Std. 791	Test Method No. ASTM
Viscosity, kinematic		D 445
Viscosity, apparent		D 2602 1/
Viscosity index		D 2270
Pour point		D 97
Stable pour point	203 2/	
Flash point		D 92
Gravity, API		D 287
Carbon residue		D 524
Phosphorus		D 1091
Chlorine		D 808 or D 1317 3/
Sulfur		D 1552 or D 129 4/
Sulfated residue		D 874
Organo-metallic components		D 811 5/
Foaming		D 892
Stability and compatibility	3470 6/	
Moisture-corrosion characteristics		Sequence IIB 7/
Low temperature deposits		Sequence VC 8/
Bearing corrosion	3405	
Ring-sticking, wear, and accumulation of deposits:		
Medium-speed, supercharged, high-sulfur fuel	340	
High-speed, supercharged	341	

1/ Obtain the viscosity at 0°F. (-18°C.) by D 2602 for grade 10 oil.
2/ See 4.6.2.
3/ D 808 is the preferred method but D 1317 may be used as an alternate.
4/ D 1552 is the preferred method but D 129 may be used as an alternate.
5/ X-ray fluorescence or atomic absorption spectrochemical analysis methods that have been previously approved by the qualifying activity (see 6.4) may be used as alternates to D 811.
6/ Homogeneity and Miscibility Test. See 4.6.1 for clarifying instructions.
7/ Included in ASTM.
8/ Not yet published by ASTM. To be included in ASTM STP 315-E, when published (see 2.2).

5. PREPARATION FOR DELIVERY

5.1 Packaging, packing, and marking. Unless otherwise specified in the contract or purchase order (see 6.2), packaging, packing, and marking shall be in accordance with MIL-STD-290.

6. NOTES

6.1 Intended use. The lubricating oils covered by this specification are intended for the crankcase lubrication of reciprocating spark-ignition and compression-ignition engines used in all types of military tactical ground equipment and for the crankcase lubrication of high-speed, high-output, supercharged compression-ignition engines used in all ground equipment. The lubricants covered by this specification are intended for all conditions of service, as defined by appropriate Lubrication Orders, when ambient temperatures are above -20°F. (-29°C.).

6.2 Ordering data. Procurement documents should specify the following information:

(a) Title, number, and date of this specification.
(b) Grade of oil required (see 1.2).
(c) Quantity of oil required.
(d) Type and size of containers required (see 5.1).
(e) Level of packaging and level of packing required (see 5.1).

6.3 Other requirements and tolerances for quality conformance testing. Definite numerical values are not specified for certain of the physical and chemical properties listed in 3.4, and for which corresponding test methods are given in section 4. Values of some properties vary from one commercial brand of oil to another for the same grade These values are influenced by the source of the base stock, the identities and quantities of additives, etc. Definite numerical values are not always functionally important except, for some properties, within specified maximum and/or minimum limits. It is not possible (or necessary) to assign restrictive values in the specification before the testing of qualification samples. During qualification, test values will be determined which are characteristic of a particular product and which can serve thereafter to identify the product. Using the results of qualification testing, the qualifying activity (see 6.4) can set values, including permissible tolerances, for future quality conformance testing.

6.4 Qualification. With respect to products requiring qualification, awards will be made only for products which are at the time set for opening of bids, qualified for inclusion in the applicable qualified products list whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the qualified products list is the U.S. Army Aberdeen Research and Developement Center, Coating and Chemical Laboratory, Aberdeen Proving Ground, Maryland 21005, and information pertaining to qualification of products may be obtained from that activity.

6.5 Certain provisions of this specification are the subject of international standardization agreement (NATO STANAG 1135). When amendment, revision or cancellation of this specification is proposed which would affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels, including departmental standardization offices, if required.

Custodians:
Army - MR
Navy - SH
Air Force - 68

Review activities:
Army - ME, WC, AT
Navy - SA, SH, AS, YD
Air Force - 11, 68
DSA - PS

User activities:
Navy - MC

Preparing activity:
Army - MR

(Project No. 9150-0167)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1971-433-497 6503

APPENDIX B

LETTER TO FTC BY R.G. STREETS, ARMY MATERIEL COMMAND

June 5, 1964

Mr. H. Paul Butz, Chief
Division of Trade Regulation Rules
Bureau of Industry Guidance
Federal Trade Commission
Washington 25, D. C.

Reference: File 959

Dear Mr. Butz:

Reference is made to your proposed rule relating to the advertising and labelling of previously used lubricating oil and to the revised text of proposed trade regulation rule as submitted by the Association of Petroleum Re-refiners.

In my opinion, the proposed rule is very desirable from the stand point of consumer protection. With the increasingly severe performance requirements being placed on engine crankcase lubricants, automatic transmission fluids and conventional transmission and axle lubricants by today's automobiles and trucks, the use of an inadequate or improperly labelled product can lead to costly damage varying from slow degradation to catastrophic failure.

I feel that the requirement for a clearly visible and conspicuous marking to indicate the presence of previously used lubricating oil is of primary importance since it at least serves to make the customer aware of what he is buying.

The provision in Part 3 of the proposed rule for the use of the term "re-refined" is more difficult to define since it involves the question of degree.

In general, the term "re-refined" is understood to mean that the previously used oil has been subjected to a complete refining process equal to or exceeding that used to prepare high quality virgin base oils. In the case of used oil this might include settling, filtration, vacuum distillation, sulfuric acid treatment, and clay treatment. In some cases selected solvent refining may be necessary to remove asphaltic and resinous materials.

The selection of the processing details normally depends on the knowledge of the characteristics of the charge stock. In the case of used oil collected at random from a variety of sources, these characteristics are essentially unknown since the original base oil types can cover a wide range and contaminants may include grease drippings, antifreeze, and extreme pressure gear lubricants as well as all the physical and chemical contaminants produced by previous use of the products.

Simple "reclaiming" or "reprocessing" which involves only the removal of insoluble physical contaminants or at best a mild treatment to reduce chemical contaminants such as fuel fractions, water, combustion products, and perhaps resinous oxidation products is completely inadequate to assure that the base oil, even when re-treated with functional additives, will be satisfactory for use with modern engines and transmissions.

After extensive tests some years ago with re-refined oils which had been given very thorough re-refining as discussed above followed by re-treating with balanced blends of recognized engine oil additives, the U.S. Army found that the performance of these oils in actual engine tests was very inferior to the minimum standards required for qualification under the then current specification for engine oil.

Subsequent to this, and realizing that base stock characteristics would be constantly changing with used oil drainings, the Army prohibited any consideration of the use of re-refined components in engine oils and gear lubricants qualified under specifications MIL-L-2104A (Lubricating Oil, Internal Combustion Engine, Heavy-Duty), MIL-L-45199A (Lubricating Oil, Internal Combustion Engine, High Output Diesel), and MIL-L-2105B (Lubricating Oil, Gear, Multi-purpose).

The reasons for this basically relate to the fact that these are all performance specifications requiring qualification prior to any procurement. The qualification requirements involve a number of expensive and, in some cases, lengthy performance tests in actual test engines or gear sets. Although the composition of the oil submitted for qualification is not otherwise restricted, once the performance tests have been passed no significant change is allowed in either the base stock or additive components without requalification.

From our years of experience with products of this type, it became apparent that changes in base stock source or treatment even with virgin base oils could greatly alter the performance of a product. Since re-refined oils were of unknown origin, could contain organic contaminants which would degrade performance and might have lost all natural inhibition due to excessive acid treatment (the result of original refining plus acid treatment during re-refining) it was obvious that the use of re-refined oils in products having severe performance requirements was out of the question.

In reviewing the proposed control specifications submitted by the Association of Petroleum Re-refiners, it is my opinion that these standards represent essentially no quality control from the stand point of assuring satisfactory performance in use.

For example, the list of color and flash standards against viscosities would do nothing except to assure the removal of volatile fuel fractions. This is desirable, of course, but does not assure satisfactory lubricant performance. Color, per se, is no assurance of quality since good virgin base stocks may range from very light to very dark, depending on crude source and refining treatment. In the case of re-refined oils, the color standards listed may allow masking of some contaminants, but on the other hand, severe treatment to produce very light colored oils may increase the degree of over-refinement and thus impair performance even further. An example of this is water-white medicinal mineral oil which has lost all the natural oxidation inhibitors and is a very unsatisfactory lubricant base stock.

The standard for viscosity index is an acceptable number although low viscosity index virgin base stocks have and are being used to formulate some very high-grade heavy-duty oils.

The neutralization number has some merit when applied to the base stock alone since it may control the amount of undesirable acids present (both organic and inorganic). The number suggested by APR is too high however, and I would suggest a maximum of 0.02.

The ash value (sulfated residue) will control the presence of inorganic or metal-organic compounds resulting from previous use or the existence of metal-containing additives originally placed in the oil. In order to establish that the re-refining process has been effective in removing such contaminants, the ash determination must be made on the base oil before any subsequent additions of oxidation inhibitors, detergents, dispersants, or other metal-containing chemicals. This value should be no higher than 0.005 percent by weight.

In addition, some control should be placed on the maximum content of any single metallic element since the presence of even a few parts per million of some metals such as copper may produce undesirable catalytic effects in the finished oil. A maximum of 5 parts per million (by spectrographic analysis) of any metallic element, phosphorus, chlorine, or silicon is recommended.

All of the above controls would apply to the re-refined base stock simply as a means of assuring that a thorough job of re-refining had been done with the intent of removing essentially all of the contaminants associated with previous use.

This, however, provides no assurance that this re-refined base stock will provide satisfactory performance when subsequently used to blend engine oils, gear lubricants, or automatic transmission fluids.

In the case of both military and industry standards for such materials, it is recognized that the only accepted method for determining whether performance will be satisfactory is through the use of full-scale performance tests involving equipment of the type in which the fluid will be used.

To my knowledge, no re-refined products are being subjected to such performance tests on a routine basis in order to verify the maintenance of a performance standard. In the absence of such control, the purchaser of such a product has no real guarantee of satisfactory performance regardless of claims or API service classifications which may be printed on the container.

For these reasons, the requirement for a clearly visible and conspicuous marking on the front panel of the container to indicate the presence of previously used lubricating oil seems to be a minimum requirement to protect the consumer.

Sincerely yours,

/s/ R.E. Streets
R. E. STREETS
Chief, Power Sources Section
Chemistry and Materials Branch
Research Division
R&D Directorate
U. S. Army Materiel Command