NBS SPECIAL PUBLICATION **488**

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Measurements and Standards for Recycled Oil

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Measurements and Standards for Recycled Oil

+ Special publication, no. 488

Proceedings of a workshop held at the
National Bureau of Standards
Gaithersburg, Maryland,
November 22 and 23, 1976

Donald A. Becker, Editor

Recycled Oil Program
Institute for Materials Research
National Bureau of Standards
Washington, D.C. 20234

Sponsored by
Recycled Oil Program
Institute for Materials Research
National Bureau of Standards
Washington, D.C. 20234

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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Acting Director

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Foreword

The Recycled Oil Program of the Institute for Materials Research, National Bureau of Standards (NBS) was formed in 1976 in direct response to the Energy Policy and Conservation Act of 1975. The goal of this program, as described in this legislation, is to develop test procedures for the determination of substantial equivalency of re-refined or otherwise processed used oil with new oil for all end uses. This program is particularly suitable for NBS because it involves both the development and evaluation of measurement methods and standards, and it requires the independent third-party role for acceptance by all concerned parties (virgin oil refining industry, oil re-refining industry, user industries, and government regulators).

An important reason why recycled lubricating oil products have not met with widespread consumer acceptance, both from the Federal Government as well as the public, is the lack of reliable test procedures and standards on which realistic performance criteria can be based. In the Energy Policy and Conservation Act (Public Law 94-163), NBS is directed to develop such test procedures and standards. The alternative to increased recycling of petroleum oils is the continued contamination of the environment and waste of our limited petroleum resources.

This volume contains the proceedings of a workshop on Measurements and Standards for Recycled Oil, held at NBS on November 22 and 23, 1976. An important objective of this meeting was to bring together interested persons from both the public and private sectors to obtain their input and expert opinion on the current status, needs, and problems relating to test methods and standards for the evaluation of recycled petroleum oil products. This publication should be of value to the many people who are interested in encouraging oil recycling.

John D. Hoffman
Director
Institute for Materials Research
National Bureau of Standards

Preface

On December 22, 1975, President Ford signed into law an act passed by the Congress of the United States entitled "The Energy Policy and Conservation Act of 1975" (Public Law 94-163). Section 383 of this act states that the National Bureau of Standards (NBS) shall develop test procedures "...for the determination of substantial equivalency of re-refined or otherwise processed used oil...with new oil for a particular end use." Further, NBS is to "...report such procedures to the [Federal Trade] Commission..." as soon as practicable. The NBS workshop held on November 22 and 23, 1976, is part of the NBS response to this legislation.

A major objective of the workshop was to obtain the input to NBS of those people knowledgeable about measurements and standards for petroleum oils on the current status, needs, and problems with existing test methods and standards for the evaluation of recycled petroleum oil products. Since the accurate evaluation of recycled oil quality is largely dependent upon the validity of virgin oil test methods when applied to recycled oils, it is essential that the expertise and experience of these experts be utilized wherever available. A second major objective of this meeting was to help foster closer personal contact and communication among all those working on the testing of virgin and recycled petroleum oil products.

There was a total of 69 attendees at the meeting, with a breakdown as follows: 28 government representatives (Federal Trade Commission, Environmental Protection Agency, Department of Defense, Energy Research and Development Administration, General Services Administration, two State governments, and NBS); 32 representatives from private industries (engine manufacturers--10, petroleum refiners and additive manufacturers--13, used oil re-refiners and processors--6, and other heavy industry--3); and 9 attendees who were consultants or who represented consulting firms, testing laboratories, or non-profit organizations.

It was felt that the workshop participants made a very important contribution to the knowledge and understanding of the current situation with regard to recycled oil. We plan to hold another such meeting on recycled oil on November 29 and 30, 1977.

Donald A. Becker
Manager, Recycled Oil Program

Abstract

This publication is the formal report of the workshop on Measurements and Standards for Recycled Oil, held at the National Bureau of Standards on November 22 and 23, 1976. There were seven sessions on specific subject areas at the meeting, with a total of 26 formal presentations, plus extensive discussion periods. The subject areas were as follows: (I) The NBS Responsibilities and Program, (II) Used Oil Reused as Fuel, (III) Recycled Industrial and Hydraulic Oils, (IV and V) Recycled Engine Oils, (VI) Barriers to the Utilization of Recycled Oils, and (VII) Problems and Needs in Establishing Quality for Recycled Oil Products. Included in this volume are the invited talks that were given and summaries of the extended discussions that were held on each of these subject areas.

Key Words: Engine oil; fuel oil; hydraulic oil; industrial oil; lubricating oil; oil specifications; petroleum standards; petroleum test methods; recycled oil; re-refined oil; used oil; waste oil.

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National Bureau of Standards Special Publication 488. Proceedings of
a Workshop on Measurements and Standards for Recycled Oil held at NBS,
Gaithersburg, Maryland, November 22 and 23, 1976. (Issued August 1977)

WELCOMING REMARKS

Ernest Ambler

Acting Director
National Bureau of Standards
Washington, D.C. 20234

Good morning and welcome to the National Bureau of Standards (NBS). It is a special pleasure for us to be sponsoring this workshop on Measurements and Standards for Recycled Oil.

The intent of this workshop is to bring together interest groups from both the public and private sectors to define the current status and needs and problems with existing test methods and standards for the evaluation of recycled petroleum oil products.

About a month ago, the NBS Executive Board held a Long-Range Planning Conference. Mr. Ted Gordon, the President of the Futures Group, spoke to us about "1985 and How We Get There." In discussing materials use, and particularly energy-producing materials, he said:

> "The emerging raw material situation will stimulate not only the development of marginal resources, but also the search for substitutes and acceptable recycling techniques and institutional arrangements. The use of recycling materials as a strategy to respond to increasing materials costs and uncertain availability is, of course, not new. What has changed are the equations by which the economics of such activities are evaluated."

I think Mr. Gordon's statement is a fair assessment of our presence at this workshop. We have only to look around us to see some of these recent equations demonstrating both the economic and environmental import of activities like this workshop.

The Federal Energy Administration (FEA) estimates that reuse of wasted oil could reduce oil imports by about 70,000 barrels per day, or about 7 percent of the Administration's energy conservation goal. Certainly, in these days of uncertain supply, potential embargoes, and increased flow of money out of the U.S., reuse of wasted oil is a much to be desired goal from both the economic standpoint and as a visible symbol of this Nation's energy conservation accomplishments.

But economics is not the whole story. Last year more than 2.4 billion gallons of lubricating oil were sold in the U.S. Nearly 20 percent of that total, or 500 million gallons of oil, was released into the environment. Thus, this oil was not only an economic waste, it is now a pollutant endangering the citizens of this Nation.

How hazardous a pollutant? The Environmental Protection Agency (EPA) reports that "...67 percent of all pollution in the waters of the world is caused by used motor and industrial oil." And the National Cancer Institute states that 60 to 90 percent of all cancer is caused by environmental factors.

The problem, however, has not gone unnoticed. Indeed, efforts have been made by many of you who are present today. In addition, several State and local groups have been working on the problem. The City of San Diego has, for the past three years, used re-refined oil in city vehicles. The States of Iowa and West Virginia have similar pilot projects for State vehicles. At the Federal level, the Environmental Protection Agency, the Energy Research and Development Administration (ERDA), and the Department of Defense (DOD) have programs to study these issues.

Among these Federal programs, I think this group might have particular interest in the ERDA work to examine variability of used engine oil composition and in the cooperative EPA/DOD project to evaluate re-refined oils for military use. In fact, there will be several speakers at this workshop detailing the activities of these programs.

But these efforts have also faced barriers. Perhaps the greatest of these barriers was defined by someone who will be speaking to you tomorrow. Mr. Peter Cukor of Teknekron was the project manager of a study on used oil done for EPA in 1973. That report to EPA stated, "Uncertainty as to the quality of re-refined lube oils is the principal barrier to increased recycling of used lubricants."

And that barrier has now been recognized and addressed by the U.S. Congress. Under the Energy Policy and Conservation Act of 1975, Congress has assigned to the National Bureau of Standards certain responsibilities for establishing the quality of recycled petroleum oil products. The purpose of Section 383 of this act is fourfold: (1) to encourage the recycling of used oil, (2) to promote the use of recycled oil, (3) to reduce the consumption of new oil, and (4) to reduce the environmental hazards associated with disposal of used oils.

As to why Congress assigned the responsibilities to the National Bureau of Standards, let me tell you briefly about our mission and activities. We were created by the Congress in 1901 as the central organization responsible for maintaining basic standards, developing measurement techniques, and establishing dissemination procedures. For three-quarters of a century, we have carried out a mission developed to support and encourage the growth of commerce, industry, science, and technology.

Over the years, NBS has provided the country with a scientific basis for accurate measurements and sources of information on basic properties of materials determined by such measurements. In addition, our responsibilities to determine physical constants and to solve almost any problem that arises in connection with standards have made the scope of our research in the physical sciences almost unlimited.

If there is any single hallmark of the National Bureau of Standards, it is the integrity and objectivity which are brought to bear on every project, thereby ensuring accuracy and precision. And, it is this quality of objectivity which we feel is crucial to our Recycled Oil Program. In response to Congressional mandate, we will be investigating and evaluating the test procedures which can be used for the determination of substantial equivalency for various petroleum oil products.

We have formally established the Recycled Oil Program within the NBS Institute for Materials Research. We have four line organizations, or institutes, at NBS engaged in different types of research and development. The Institute for Materials Research (IMR) conducts research to provide a better understanding of the basic properties of matter and materials and develops standards for measuring their properties to help ensure their proper use by scientific, industrial, and commercial communities.

One of the major IMR activities, and one which some of you may be familiar with, is the development, production, and distribution of Standard Reference Materials (SRM). These SRM's provide the basis for calibration of instruments and equipment, comparison of measurements on material, and aid in the control of production processes. As to the impact of these SRM's, let me tell you that in this past fiscal year, more than 32,000 SRM's were sold to more than 16,000 different organizations.

Thus, we feel that IMR is an appropriate "home" for the recycled oil work. The manager of this program is your workshop chairman, Mr. Donald Becker. Don and his staff are now actively reviewing and evaluating the test procedures and standards to establish priorities and goals.

There are several actions, outside of NBS, which have been of considerable help and interest to us, not the least of which is your very positive response to our announcement of and invitation to this workshop. The cooperation of the many interested groups in the public and private sectors has been quite helpful and encouraging to us. I would be remiss if I did not cite the assistance we have received from the American Society for Testing and Materials (ASTM) Task Force on Used Oil and the total membership of the ASTM Committee D-2 on Petroleum and Petroleum Products.

Finally, I would like to mention what we at NBS view as a very special action taken by the Association for Petroleum Re-refiners. This group has voted to support an industrial Research Associate to work in the NBS Recycled Oil Program during the coming year. I know that Mr. Duane Ekedahl, the Executive Director of that association, is with us this morning. Duane, I would like to say thank you for your vote of confidence in NBS. More importantly, I would like to commend your organization for taking a step which we believe will serve to strengthen your own technical competence, as well as to assist NBS and the Nation.

I would also like to invite any other organizations represented here today to seriously consider the Research Associate Program as a useful and effective method for further development of mutually beneficial interactions in a particular area. The Research Associate Program, which is an effort to increase understanding between business and government, enables scientists and engineers from the private sector--both domestic and foreign, as well as State and local governments--to work on a full-time basis for a specified period of time at NBS on projects of mutual interest.

Currently, we have 70 Research Associates at NBS representing 13 professional and trade associations, 7 private firms, and 1 Federal agency. The criteria for participation are simple. The project:

- must have non-proprietary objectives;
- must be within the scope of NBS activities; and
- must offer the prospect of publishable results of interest and significance to the industrial and technical communities represented and, thus, ultimately to the public.

For more information, may I refer you to this reprint from Commerce America (Appendix I) which details the NBS Research Associate Program--what it is and how it works. When you are ready to talk it over with us, please feel free to contact our Industrial Liaison Officer--Mr. Peter de Bruyn, Mr. Donald Becker, or myself.

In closing, let me say again how strongly I support the efforts and intentions of this workshop. And, I am very pleased that we are able to provide this important forum for discussion and exchange of ideas and information on recycled oil.

Dr. Ernest Ambler, Acting Director of the National Bureau of Standards, delivering the welcoming remarks.

Messrs. Peter de Bruyn, Industrial Liaison Officer of the National Bureau of Standards (NBS), and Duane Ekedahl, Executive Director of the Association of Petroleum Re-refiners (APR), discuss the APR/NBS Industrial Research Associate Program while Dr. Ambler and Mr. Michael Kerran, President of the APR, look on.

SESSION I

STATEMENT OF PURPOSE

National Bureau of Standards Special Publication 488. Proceedings of
a Workshop on Measurements and Standards for Recycled Oil held at NBS,
Gaithersburg, Maryland, November 22 and 23, 1976. (Issued August 1977)

THE NBS WORKSHOP OBJECTIVES AND THE NBS RECYCLED OIL PROGRAM

Donald A. Becker

Recycled Oil Program
Institute for Materials Research
National Bureau of Standards
Washington, D.C. 20234

I would first like to briefly discuss the overall objectives of the workshop. The first and major objective is to obtain input to the National Bureau of Standards (NBS) by the wide variety of experts present here in the areas of petroleum oils and test methods on petroleum oils, and on the current status, needs, and problems with existing specifications, with test procedures, and with standards for virgin petroleum oil products when these are applied to recycled oil products. Since the accurate evaluation of recycled oil quality is largely dependent upon the validity of these test methods, the information that you have used in the past in your company, in your organization, and in the American Society for Testing and Materials (ASTM) would be extremely useful to NBS in order to eliminate unnecessary duplication of efforts. This would greatly assist us to proceed as rapidly as possible in the responsibilities assigned to us by the Congress, and to avoid at least some of the many pitfalls which we realize stand ahead in this program.

The second important objective is to help foster personal contact and communication between all the people who are working on test methods, both on recycled oil tests and on virgin oil test methods. We think this communication will be very important in order to get test procedures which are valid, and useful, and which can be used to really determine the quality of the product.

The end uses which are considered here today, as shown in your program, are all types of end uses including reuse as fuel; as hydraulic oils; as industrial oils, including cutting oils, grinding oils, etc.; and as engine oils, both crankcase and transmission oils. Both gasoline engine and diesel engine oils are included. Now, I want to make a short overview of the NBS program as we see it; and, at the end of this I will have a number of questions which we have considered but, at present, for which we have no answers. These are the types of questions we are going to have to answer. And so, I will be throwing them out to you to to consider and giving you some of our thoughts on them. I think they are serious questions--questions which, to my knowledge, have not been previously addressed. They are the type of questions that are going to have to be resolved in the NBS program.

Now I will briefly discuss the NBS responsibilities. On December 22, 1975, President Ford signed an act passed by Congress entitled the "Energy Policy and Conservation Act of 1975," Public Law 94-163. In Section 383 of this act, it is stated that the National Bureau of Standards "... shall develop test procedures for the determination of substantial equivalency of re-refined or otherwise processed used oil...with new oil for a particular end use." Further, it states that NBS is to "...report such procedures to the [Federal Trade] Commission..." as soon as practicable.

As Dr. Ambler mentioned in his presentation, the purposes of Section 383 of this law are fourfold: to encourage the recycling of used oil, to promote the use of recycled oil, to reduce the consumption of new oil, and to reduce the environmental hazards associated with the disposal of used oils. These purposes can be more simply stated as energy conservation, resource conservation, and pollution control.

The NBS Recycled Oil Program therefore has as its primary objective to provide these test procedures to the Federal Trade Commission (FTC) so that they can be used to assure this substantial equivalence of recycled oil products with new oil products for particular end uses.

The initial NBS efforts were aimed toward gathering sufficient information about the various industries and existing problems in order to formulate an effective program. This was necessary because the last NBS project which was involved with lubricating oils or petroleum oils, investigating such things as lubricity and test methods, was terminated over 15 years ago. Therefore, when this law was passed, we had no program and we had to start from the ground up. The initial NBS efforts were concerned with contacting other organizations with interests in this area, i.e., the virgin oil refining industry, the used oil re-refining industry, the user industries, the automobile industries, various manufacturers, and the trade associations--the American Petroleum Institute, the National Petroleum Refiners Association, the Association of Petroleum Re-refiners, and the Society of Automotive Engineers. The standards organizations, especially ASTM, played an important part in our being able to get information on the responsibilities and the test methods that would be required for this type of work. Also, we interacted very strongly with the various government agencies which had programs in recycled oil or in oils at all: the Energy Research and Development Administration/Bartlesville was an important one, and you will hear more about their work later on in the program; the Environmental Protection Agency (EPA)/U.S. Army efforts for military specifications, like Dr. Ambler mentioned, and you will also hear more about that later on; the Federal Energy Administration, which is mainly responsible for used oil collection programs; the Federal Trade Commission (FTC), which will have the responsibility for the regulations as to labeling and enforcing these regulations; and EPA, from the environmental pollution point of view. The information gathered was reviewed and evaluated, and the NBS Recycled Oil Program was established.

Before I get into the specific NBS program, let me briefly discuss two other subjects. The first one involves the volumes of used lubricating oil generated in the States. Those of you who know much about used oils probably have seen these same figures over and over. Everyone, I think, uses the same numbers because they were generated for an EPA study, the 1974 Report to Congress. My information now is that new oil consumption is up to about 2.5 billion gallons per year; but the important thing that I want to point out is in the fate of used oil, the volume that is given for used oils which are reused as fuel--480 million gallons per year in 1972. This is the largest end use of used oil at that particular time. The question of where the unknown portion, which is the second largest, actually ends up is not known, but at least some of this could well be used as fuel also.

The second subject I want to mention is the applicability of Public Law 94-163. After our information gathering effort and a study of the specific terminology used, our interpretation is that the law includes all of the types of oils that were discussed earlier: engine oils, industrial lubricating oils, metal-working oils, hydraulic oils, and oil which is reused as fuel--any oil which can be recycled into an end product to which it can be substantially equivalent.

The NBS Recycled Oil Program is built around the knowledge that there presently is a large number of existing petroleum oil test methods. These include ASTM tests, Federal test methods and specifications, military test methods and specifications, and so on. In general, the specifications and test methods in current use appear to be effective. Therefore, the NBS efforts will be, first, to establish the properties which are both necessary and sufficient to establish substantial equivalency for any particular oil, and these are not necessarily the same properties that a virgin oil may have; and, second, to provide the FTC with a set of these test procedures which are capable of verifying this equivalency. As I said, wherever possible existing test procedures will be utilized.

The initial emphasis of the NBS program is on used oils which are recycled as fuel. This choice was made for a number of reasons. First, as I mentioned, the current fate of used oils is primarily as fuel. Therefore, we feel it should have the highest priority. Second, there are important environmental questions from uncontrolled burning of used oils. And, third, this is a use which apparently can be addressed rather quickly. As I mentioned when we started out, we had no program in lubricating oils or in oil testing. Therefore, we are taking an easier problem first, as long as it fits in with the other requirements; and we hope to gain the experience with this subject in order to go on to the more difficult ones, like the automobile engine oils. The other major uses will be addressed in turn. But, it is also interesting to note that most of the procedures which will be examined for use with recycled oil to be used as fuel are also the same test procedures which are used for many of the other oils.

As Dr. Ambler mentioned in his talk, the Recycled Oil Program is in the Institute for Materials Research, and I want to explain the internal structure a little bit to give you an idea how we will be working. In the Institute, which is composed of about 500 to 600 scientific and technical people, most of the technical people reside in the

6 technical divisions shown as squares on the bottom (figure 1): Analytical Chemistry, Polymers, Metallurgy, Inorganic Materials, Physical Chemistry, and Reactor Radiation. The programs are in circles in the middle, the Recycled Oil Program being on the right-hand side. The scientific expertise in the technical divisions, in all of the technical divisions, is available to us to be drawn upon to evaluate and to look at the test procedures required for this program. In addition, there are several other Institutes which will have information or basic expertise that will be available. For instance, in the Analytical Chemistry Division, we will have scientists looking at methods for sulfur analysis and for trace element analysis; in the Polymers Division, we have people who will examine test methods for viscosity; in Metallurgy, people from the Corrosion Section will be looking at the copper strip corrosion test method and will evaluate whether this method is a valid one when applied to recycled oil products; in Physical Chemistry, there are a number of test methods to be examined such as distillation temperature, flash point, etc. In addition, in the Institute for Basic Standards we have statistical support in the Applied Mathematics Division which will look at some of the sampling methods which are required for certain specifications.

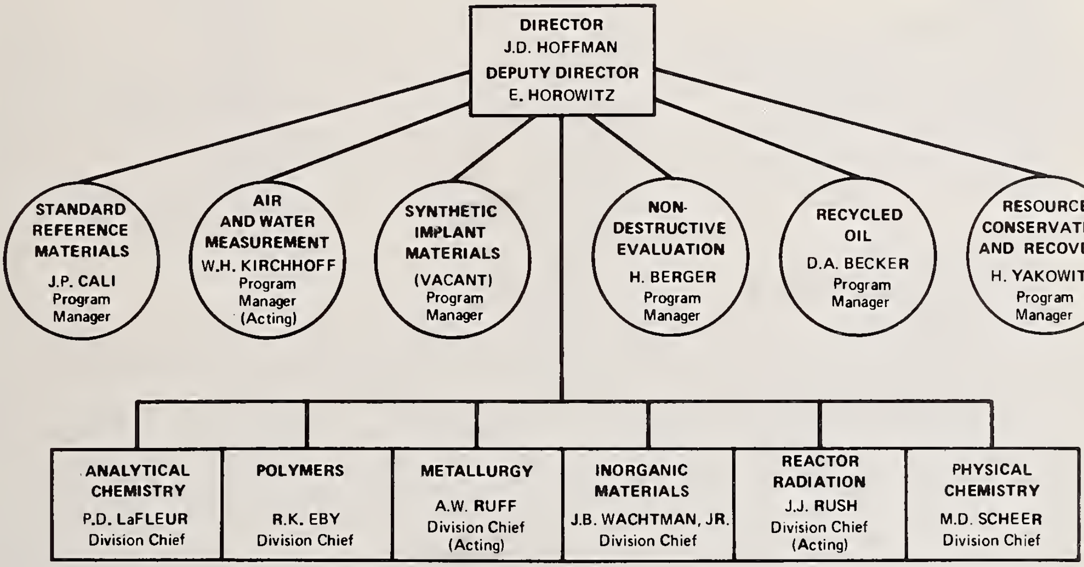

Figure 1. National Bureau of Standards' Institute for Materials Research.

The overall program plan, therefore, is to collect existing test procedures and to review them for applicability, whether they are necessary with a recycled oil product, and for validity, whether with some of the specific characteristics of a recycled oil product this test method is valid. Where required, laboratory programs will be established to evaluate the applicability of existing test procedures or to develop new test procedures. Then, these test procedures will be delivered to the Federal Trade Commission.

In our own evaluation of the testing situation, we separated the petroleum test procedures into three groups. The first group consists of existing test procedures which are used to specify or qualify virgin petroleum oils and upon examination are found to be suitably valid for recycled oil products. In the second group are existing test procedures (e.g., ASTM) which are perhaps not presently required for virgin petroleum oils but which may be required for recycled oil. For instance, an example might be the ASTM procedure for neutralization number; it is not currently specified for fuel oil, but for recycled oil it may be necessary. Group three consists of required test procedures which do not presently exist for petroleum oils; these will have to be developed.

Table 1 shows current fuel oil specifications. The middle column is the Federal specification for burner fuel oil, VV-F-815C; the right-hand column is the ASTM D-396 specification for fuel oil; and on the left are a list of test methods. All of these various test methods are currently specified for virgin fuel oil: flash point, pour point, water, sediment, carbon residue, ash, distillation, viscosity, etc. Most of these would fit into group one test procedures. The types of things we will be evaluating on each of these test methods include the effects of additives. This is necessary since much of the recycled oil that is presently used as fuel is obtained from what is called street drainings. This used oil has the additives from automobile motor oils and, thus, contains oil soluble organometallics. How do these affect other test methods? Viscosity improvers or pour-point depressants--how do these affect perhaps the pour point measurement itself and also other test methods? Is this additive going to make a particular test valid or invalid? The effect of contaminants on test procedures must also be evaluated. For instance, the particle size distribution of wear debris particulates--how does this affect the viscosity measurement? In many of the cases where street drainings contain also drainings from automobile radiators--ethylene glycol--how does this affect some of the test procedures? Will the test procedure still be a valid test if it has a contaminant in it, for example automobile hydraulic fluids? How is this going to affect each of these tests? What about synthetic motor oils? Obviously, if it is a polyester motor oil, it most likely will make the saponification number invalid; but how is it going to affect other tests? It is important to remember that, at least in some cases, these test methods that are going to be given to the Federal Trade Commission will be used on all quality oils. If someone represents a straight used oil as some type of product, the test has to be valid for a straight used oil, as well as a high-quality re-refined oil. At the least, there has to be some way to differentiate between these types of products in order to say it is or is not a valid test, or can or cannot be used on this type of product.

TABLE 1

FUEL OIL SPECIFICATIONS

	FED. SPEC. VV-F-815C FUEL OIL, BURNER	ASTM D-396 STANDARD SPECIFICATION FOR FUEL OIL
Flash Point	D-93 or D-56	D-93 or D-56
Pour Point	D-97	D-97
Water/Sediment	D-1796 (1,2,4)	D-1796 (1,2,4,5)
Water	D-95 (5,6)	D-95 (6)
Sediment	D-473 (5,6)	D-473 (6)
Carbon Residue	D-524	D-524
Ash	D-482	D-482
Distillation Temperature	D-86	D-86
Viscosity, kinematic	D-445	D-445 (1,2)
Viscosity, Saybolt	D-2161 or D-88	D-88 (4,5,6)
Gravity, API	D-287	D-287
Copper Strip Corrosion	D-130	D-130
Sulfur	D-1552, D-129 D-1551 or D-2622	D-129, D-1551 D-1552, D-2622
Aniline Point	D-611	--
Container Sampling	MIL-STD-105	--
Container Examination	MIL-STD-290	--
Test Sampling	D-270	--
Inspection	FED. TEST 791-9601	--

In the group two test procedures, the neutralization number is something that may be required for certain recycled oil products, or perhaps a precipitation number. There are existing tests for these, and they may very well be applicable directly to the recycled oil products. Trace element content is certain to be important for a number of end products. Elements such as lead, calcium, barium, zinc, etc., are of concern for environmental pollution as well as for effects on certain types of performance I have also recently found out that virgin fuel oil has some types of additives. For example, ferrocene is apparently added in low concentrations to improve burning and reduce smoke of virgin fuel oil. How does this affect the range of trace element concentrations for the existing virgin petroleum oils that are currently on the market?

Group three test procedures--fortunately, there are not too many of these, and perhaps they are not as much of a problem as they first appeared. Lead concentration is one possibility. We are going to have a speaker tomorrow who will talk about some of the problems EPA has with the lead pollution. Perhaps a test procedure for lead in recycled oil will be found necessary. There are two existing ones, or at least two: D-1262 for lead in greases, and D-2788 for lead in gas turbine fuel. We do not know at the present time whether one of these will be applicable to general recycled oil products.

The ash content is also very interesting. Current virgin fuel oil specifications include ash content. However, the ash method which is specified for use specifically states that it is not valid in the presence of lead or in the presence of organometallics. Recycled petroleum oil that is to be burned may very well have either or both of those. You can then use the sulfated ash procedure, which is valid for organometallics; but, here again, the procedure itself states that it is not valid in the presence of lead. The question of whether this could be adapted or modified with very little change is not really obvious at the present time. I think ash is an important characteristic of recycled fuel oil that needs to be defined, but how best should it be done in order to obtain an accurate value?

The last potential test I will discuss is the polynuclear aromatics. It was published in the open literature about a year ago that used oil has significantly higher polynuclear aromatic contents than virgin lubricating oil. For fuel use, that is not quite the question; but rather the question is whether used oil has a higher polynuclear aromatic content than virgin fuel oils. As far as we know at the present time, there is not enough information to determine whether that is true or not. So, in this case, we need more information. In industrial oils, it may be that the recent information which has come to light on nitrosamines might be significant for certain types of recycled industrial oils.

In summary, the detailed program plan is: (1) to identify the required test procedures for each particular end-use product; (2) to conduct a non-laboratory program to collect existing test procedures and establish a review protocol, including outside advice; (3) to review the test procedures for applicability and validity, all the while maintaining coordination with outside government and private-sector groups--where there are problems, we will have to go to the laboratory, verify the validity or applicability of existing test procedures, or develop new test procedures; and, finally, (4) to establish the adequacy of the total package to define substantial equivalency and then transmit these to the FTC. It is obvious that we will provide advice and consultation to the FTC on these tests wherever required.

As I am sure most of you already know, there will be problems in carrying out the requirements of this law. We are aware of some of these problems; others will certainly surface as we get further into the program itself. From what we know now, in principal, recycled lubricating oil products are potentially able to qualify for all end uses, i.e., the basic hydrocarbon structure is apparently not altered during use. However, at present we do not know whether existing qualifications or performance standards are capable of establishing the substantial equivalency of all recycled oil products for their end uses. In addition, the interlaboratory comparability of some of the existing tests, i.e., the accuracy and reproducibility, are not fully known. This is especially true for some of the non-ASTM tests for industrial oils and special-purpose oils where I have seen in the test procedure the statement, "Reproducibility is not established," or "Accuracy is not known."

Finally, we realize that the consequences of poor or inadequate standards could be large. One of the ways that NBS is attempting to obtain input from all interested parties is this workshop. We hope that you also will find the meeting both informative and stimulating; and we invite your continued cooperation and input into the NBS program in the future. I look forward to hearing the following speakers, and I especially look forward to the discussions to follow the speakers. I hope that all of you will want to participate in these discussions and will frankly and openly present your views and your experiences with these test methods and with recycled oil.

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DISCUSSION

SESSION I. STATEMENT OF PURPOSE

The discussion on this first session centered around a number of different areas. Initial interest was expressed in the time schedule for the National Bureau of Standards' (NBS) program. The estimate was given by NBS of approximately one year for the test procedures for recycled oil to be used as fuel. Completion of the other end uses that will be addressed cannot be reliably estimated at present due to the large number of unevaluated technical questions which still remain. It was pointed out, however, that many of the tests which are being evaluated for use with the first end use will also be the same tests as for other end-use products (e.g., viscosity, flash, sulfated ash, copper strip corrosion). It was also noted that this current schedule calls for the transmission of a set of tests for each end-use product as soon as completed, rather than waiting until all end uses have been completed.

The second area of discussion centered around NBS' cooperation with other groups interested in oil recycling, especially with the Environmental Protection Agency (EPA), concerning Public Law 94-163 as well as the more recent Public Law 94-580, the Resource Conservation and Recovery Act of 1976, which gives EPA broad responsibilities in resource conservation and hazardous waste management. In addition, NBS is interacting and cooperating with the Energy Research and Development Administration/ Bartlesville Energy Research Center in their program for the evaluation of new re-refining technology. It was also pointed out that the oil recycling system in Europe is far ahead of the U.S. and that perhaps it would be profitable for the U.S. to use available information from European governments and industries. The response indicated that interaction with the European governments is taking place and that this interaction will increase in the future. However, it was also pointed out that little or no information is currently available from Europe or elsewhere on the evaluation of virgin oil test procedures for recycled oil products or specifically addressing the basic question of determining quality in recycled oil products.

Another area of discussion was concern about the possibility of the government setting industrywide test methods and specifications. Specific questions which were brought up by industrial participants included what potential liability the government would accept when a consumer product meets a government specification or test but is later found not to be suitable for the end use described. In addition, concern was expressed about the ability of the appropriate government organization (i.e., NBS and/ or the Federal Trade Commission [FTC]) in keeping the promulgated test methods up to date in a rapidly changing field, as well as concern about the possibility of having different tests or specifications for virgin and recycled petroleum oil products. These concerns were thought to be serious ones by participants and were felt to require additional discussion at a later time.

One question concerned the meaning of the term "substantial equivalence," as used in Public Law 94-163, concerning the NBS responsibilities. In response, it was pointed out that the legislative requirement of Public Law 94-163 is that the NBS provide the FTC with test procedures which can be used to determine whether a recycled oil product is substantially equivalent to a virgin oil product. There is no requirement that the recycled oils have to be able to pass these tests, only that if it does it be substantially equivalent for that particular end use. It is also obvious that the law is strongly supportive of oil recycling, so the implication certainly is that these tests must be reasonable and usable for their intended purpose--and that purpose is to establish reliable quality control for recycled oil products.

Another area of concern expressed by participants was whether new American Petroleum Institute (API) engine oil classification(s) or equivalent would be developed in order to meet the requirements of recycled oils. In the ensuing discussion, it was stated that there was no intent nor should there be a need to develop new classifications for recycled lubricating oils. It was felt important that industry and government work together to develop adequate criteria for defining appropriate service levels for recycled oil products within the existing classification system. That could mean that engine sequence tests would be required in order to establish the additive response or various quality levels of a particular re-refined oil, for example, or that enough data be accumulated in order to assure that a particular additive package together with a certain base oil would provide an appropriate service level. Engine manufacturers then stated that engine sequence tests by themselves are not satisfactory to adequately define effective field performance, but that the correlation between satisfactory field use and engine sequence tests was required in order to originally establish the usefulness of sequence tests. It was further felt that field data for recycled oils should also be available in order to establish similar types of correlation with the tests to be used.

During the discussion, one suggestion was made that perhaps the possibility should be evaluated of using all of the recycled and/or re-refined oil either as industrial oils, or as fuel oil, in order to eliminate the difficult technical problems involved with motor oils. However, it was pointed out that, even other considerations aside, with the free enterprise system that exists in the U.S. it would be difficult or impossible to restrict the uses of a particular oil as long as it met the required quality criteria.

Finally, the session ended with a statement by the NBS moderator concerning the NBS program. It was stated initially that the NBS program does not wish to affect the established specifications and testing system any more than necessary in order to carry out the requirements of the various laws that have been enacted. It was also pointed out that NBS has these requirements to provide various test procedures to establish substantial equivalency, and these requirements will be carried out. It is not known at the present time exactly how these requirements are going to impinge on the existing system. However, it was emphasized that cooperation and collaborative work with both government and industry together, through the American Society for Testing and Materials and through other means, would be to everybody's advantage, especially the consumers and users in the U.S.

SESSION II

USED OIL REUSED AS FUEL

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BURNING USED OIL AT A MILITARY INSTALLATION

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What I would like to talk about today is a project that was initiated back in 1968 at the Aberdeen Proving Grounds. Much of the work took place while I was still head of the Fuel and Lubricants Division in the Coatings and Chemical Laboratory. The actual work was done by Messrs. Maurice E. LePera and Gerald DeBono of the Fuel and Lubricants Division. (This was before the subsequent reorganization and move to Fort Belvoir, where the report was compiled and completed.) The entire U.S. Army report (MERDC R-2127) is included as Appendix II, so my remarks today will be quite brief. However, I felt that the excellent and comprehensive work by Messrs. LePera and DeBono should be brought to your attention.

At that time (1968) Aberdeen was disposing of waste oil by blending it into No. 6 fuel oil, Federal Specification VV-F-815C. Approximately 40,000 gallons of waste oil were consumed each year in this manner at Aberdeen. Since No. 6 fuel oil is a relatively viscous product, no problems were encountered with the waste oil disposal system. But in August 1972 when, due to sulfur restrictions, Aberdeen changed from No. 6 fuel oil to No. 2 fuel oil, it was felt that a little more work should be done to evaluate the blending of used oil with this distillate fuel oil. Because of the obvious differences of properties between No. 2 and No. 6 fuel oil, Aberdeen became concerned over the continuance of the waste oil disposal program.

Some of the questions to be considered included: Could stratification and/or sedimentation problems due to the difference in gravity lead to a potential malfunctioning of the burner nozzles, since waste oil is considerably heavier than No. 2 fuel oil? Also, would burning used oil create excessive stack emissions exceeding the air pollution standards, due either to improper combustion or from the composition or concentration of the waste oil product itself?

In April 1973, Aberdeen conducted an initial waste oil incineration program at the main power house. Stack emissions were monitored by the U.S. Army Environmental Hygiene Agency, the emission specialists for the Army, and they took measurements while the No. 2 fuel oil, and the No. 2 fuel oil containing approximately one percent waste oil, were burned. As described in the report, it was obvious from the results that the one percent of waste oil burning in the No. 2 fuel oil did not cause any problems. This would be fine for us; but could other army installations that do not have a large power house blend larger amounts? We then selected a small boiler system at one of the Aberdeen Proving Ground (APG) messhalls for a second emission test program. This program was considered to be a simple and accurate method for investigating different waste oil/fuel oil blends.

The burning system consisted of three five-tube high-pressure boilers, and three oil-fired, low-pressure rotary cup KEWANEE burners. The system was originally designed to burn a No. 4 or No. 5 fuel oil and was rated at 86.3 hp, 30,808 pounds steam/hour, and 4,500,720 Btu.

In the initial program that was conducted in the power house, all the waste products that were generated at the Post were used. At that time, they were disposing of a lot of jet fuel from defueling aircraft, and so the fuel burned in the big power house was quite light.

For the second program, it was decided to get a typical crankcase draining, or waste oil, for evaluation. Therefore, all of the drainings from the Post Exchange Service Station were collected, and these were from commercial vehicles. No doubt, this waste material had trace amounts of antifreeze and hydraulic brake fluid and some transmission fluids. In addition, some water contamination occurred from the improper drum coverings and/or closure procedures since the drums were stored outside. This water, after settling, was pumped out prior to the combustion-emission tests to insure that water contamination did not influence the resultant stack emission studies. A 1,200 gallon tank truck containing 200 gallons of waste oil and 800 gallons of No. 2 fuel oil served as a temporary mixing reservoir. A final mixture of about 27 percent waste oil was used for the three two-hour test runs. The mixture was pumped directly from the fuel oil truck into our burners, so there was pretty good control over what was burning. The truck tank was also sampled at three levels--top, middle, and bottom--to see if stratification occurred. We therefore had a pretty good handle on the actual product that was being burned.

As I mentioned earlier, the complete results of these tests can be found in the U.S. Army Report 2127, Investigating Waste Oil Disposal By Direct Incineration, by Messrs. M. E. LePera and G. DeBono (Appendix II).

In summary, it was determined that a 27 percent mixture of waste oil in No. 2 fuel oil was too high. From the results of these tests, a directive was issued to allow up to five percent of waste oil to be added to any No. 2 fuel oil in any other Army installation without actual tests of air emissions.

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FUEL OIL AND THE DEFENSE SUPPLY AGENCY

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In my talk this morning, I would like to tell you a little about Federal procurement of petroleum products. The Defense Fuel Supply Center procures most of the fuel, lubricants, hydraulic fluids, etc., for the Federal Government, including the civilian agencies. Primarily, we buy what the agencies ask for. They come to us and give us a set of requirements, along with specifications. Many civilian agencies, though, just say, "We want fuel oil." So, based on what the Environmental Protection Agency's restrictions are for the various locations that we buy for in the U.S., we procure an oil which will give them the acceptable atmospheric emissions; or, in some cases, the control is on the sulfur level in the fuel.

We are presently on the street trying to purchase two million gallons of a recycled oil for use as fuel. In this particular case, what we did is put in the regular VV-F-815C requirements, except the requirement that it not contain recycled materials was waived. We expect to have more of these types of purchases in the future. All of the existing specifications, including sulfur level, sediment, etc., still apply.

In the past, we have encountered some problems in procuring fuel oil in the midwest where we know that recycled oil is going into it. The primary problem we found with that oil was the sediment content. The supplier that is intending to bid on this two million gallons of recycled oil that we requested, as I understand it, simply settles the used oil and blends it in with virgin oil to make an acceptable blend.

The only way that we have determined in the past that our fuel oil was being blended with used oil was the higher metals content and other components that normally come only from used lubricating oil. It may be that one of the reasons that a lot of the Federal activities do not want to buy fuel oil that already has been blended with used lubricating or recycled oils is because they wish to add their own used oils that they have generated into the fuel oil burner instead. The U.S. Army has published a report on a program to determine to what extent and how much used lubricating oil you can put into fuel oil. In my opinion, one of the important limiting factors is the environmental considerations involved. You will hear more about this Army study by another speaker today.

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FUEL OIL SPECIFICATIONS

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Before I start discussing fuel oil specifications, let me tell you a little about why I am so interested in fuel oil. The National Oil Jobbers Council represents the 12,000 independent petroleum marketers who market heating oil, gasoline, diesel fuel, and related petroleum products, as well as the manufacturers of oil-burning equipment. In addition, I am chairman of the American Society for Testing and Materials (ASTM) Committee D-2's Panel on D-396, Standard Specification for Fuel Oils. The primary function of this panel is to consider recommended changes to this specification. This specification provides the minimum criteria for different grades of fuel oil intended for use in various types of fuel-burning equipment under a variety of climatic and operating conditions. It is used by purchasing agencies in formulating contracts for the purchase of fuel oil, and for the guidance of consumers and engineers in selecting the grades most suitable for their needs. Most fuel oils marketed are produced to meet this standard.

In this presentation I would first like to review the six grades of fuel oil. Secondly, I would like to provide an insight into some of the testing requirements that are outlined for these grades of fuel oil. There are ten testing criteria, along with a number of testing techniques. We will not cover all the testing techniques, but for a complete listing of them I would refer you to the specification itself (table 1). Finally, we will mention some of the new items that are currently being considered by the D-396 Panel.

As I previously mentioned, there are six grades of fuel oil at the present time. These may be broken into two categories: distillates are primarily used for residential heating, while residuals are mainly for commercial and industrial use.

- No. 1 - A distillate oil intended for vaporizing pot type burners and other burners requiring this grade of fuel.
- No. 2 - A distillate oil for general purpose heating for use in burners not requiring No. 1 fuel oil.
- No. 4 - Usually a residual oil and preheating is not required for handling or burning.
- No. 5 Light - A residual oil and preheating may be required, depending on climate and equipment.
- No. 5 Heavy - Also a residual oil, and preheating may be required for burning and, in cold climates, may be required for handling.
- No. 6 (Bunker C) - A heavy residual fuel oil for which preheating is required for burning and handling.

Turning now to the 10 testing requirements, these are each briefly discussed below.

Flash Point. - When fuel oils are heated, a vapor is produced. At a certain temperature, the vapor will ignite by an external flame. This temperature is called the flash point temperature.

ASTM D-396 provides for flash point testing by: (1) the Pensky-Martens Closed Tester, and (2) the Tag Closed Tester. The specific testing procedures D-56 and D-93 are available in the ASTM Handbook. In both cases, the sample is placed in the cup of the tester and, with the lid closed, heated at a specified constant rate. A small flame of a specified size is directed into the cup at regular intervals. The flash

TABLE 1

DETAILED REQUIREMENTS FOR FUEL OILS[a]
(ANSI/ASTM D-396-76)

Grade of fuel oil	Flash point °C (°F)	Pour point °C (°F)	Water and sedi-ment volume	Carbon residue on 10 % bottoms %	Ash wt. %	Distillation Temperatures °C(°F)			Saybolt Viscosity, s				Kinematic Viscosity, cSt				Specific gravity 60/60 °F (deg API)	Copper strip corro-sion	Sulfur %
						10 % point	90 % point		Universal at 30 °C (100 °F)		Furol at 50 °C (122 °F)		At 38 °C (100 °F)		At 50 °C (122 °F)				
	Min	Max	Max	Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Max	Max	Max
No. 1	38 or legal (100)	-18 (0)	0.05	0.15	---	215 (400)	---	228 (550)	---	---	---	---	1.4	2.2	---	---	0.8499 (35 min)	No. 3	0.5 or legal
No. 2	38 or legal (100)	- 6 (20)	0.05	0.35	---	---	282 (540)	338 (640)	(32.6)	(37.9)	---	---	2.0	3.6	---	---	0.8762 (30 min)	No. 3	0.5 or legal
No. 4	55 or legal (130)	- 6 (20)	0.50	----	0.10	---	---	---	(45)	(125)	---	---	5.8	26.4	---	---	---	---	legal
No. 5 light	55 or legal (130)	---	1.00	---	0.10	---	---	---	(125)	(300)	---	---	26.4	65	---	---	---	---	legal
No. 5 heavy	55 or legal (130)	---	1.00	---	0.10	---	---	---	(300)	(900)	(23)	(40)	65	194	(42)	(81)	---	---	legal
No. 6	60 (140)		2.00	---	---	---	---	---	(900)	(9000)	(45)	(300)	---	---	92	638	---	---	legal

[a] See 1976 Annual Book of ASTM Standards, Part 23, for additional detailed information on this specification.

point is taken as the lowest temperature at which application of the test flame causes the vapor above the sample to ignite.

NOTES: (1) If the oil contains water, it should be removed by heating the oil in a water bath. The test sample should then be taken from the top portion of the oil sample. (2) Sometimes erroneous results are obtained by heating the sample too fast. (3) Occasionally, one may contaminate the test sample with the cup-cleaning agent. (4) When specifying flash points, the type of instrument used should be named and, more specifically, the method of test should be specified. These and other precautions are taken in the testing procedures, as outlined in ASTM D-396 and the reference testing procedures.

Examples of typical flash points seen for the various fuel oil grades are found in table 2.

TABLE 2

COMPARISON OF FLASH POINTS

Fuel Oil Grade	Typical Flash Points[a]
No. 1	130, 134, 140
No. 2	160, 126, 176, 144, 204, 240
No. 4	170, 182
No. 5	245, 142, 100, 210
No. 6	190, 224, 250, 330

[a] in °F., Pensky-Martens closed cup

The type of equipment, location of storage tanks, the amount of preheating, and the condition of equipment all have an impact on the flash point requirements of an oil.

Pour Point. - Let us turn now to the second testing requirement, the pour point. If temperatures between 80°F to 90°F were experienced the year round, consumers, refiners, and suppliers in some instances would be happy. A feature of most oils is their ability to congeal into a semi-fluid or a solid as the temperature drops. When cold weather occurs, one can imagine what happens inside of tanks, lines, and pumps. To protect the user and refiner, the pour point test was developed. The temperature at which an oil will just flow under standardized conditions is known as the pour point. The standard method of test for pour point of petroleum products is outlined in ASTM standard D-97. After a preliminary heating, the sample is cooled at a specified rate and examined at intervals of 5°F for flow characteristics. The pour point is set at 5°F above the temperature at which the oil becomes solid.

Pour points are a fair indication of what happens under actual conditions. The type of oil and the condition to which the oil has been subjected immediately before the test have a direct bearing on the results of the test. Therefore, the standardized test procedure specifies the conditions and handling of the oil before the test.

Some of the troubles that are attributed to improper pour points in cold weather include clogged strainers, unpumpable oil, clogged lines, erratic combustion, spitting, and smoke and carbon from poor atomization due to the heaviness of the oil. Generally, the fuel oil supplier watches the pour point of his oil, especially those which are not heated in his storage tanks because he, as well as his customer, must be able to pump when cold weather sets in.

Water and Sediment. - The third testing requirement is for water and sediment. A great source of trouble in all grades of fuel oils is the water and sediment that are sometimes present in oil. Difficulties include: (1) complete stoppage of operation and combustion, (2) erratic and unsteady combustion, (3) sparking and spitting of the flame, (4) flashback of the flame, (5) blocking of passage ways, (6) loss of heat, and (7) erosion of mechanical parts. The water and sediment in grades Nos. 1, 2, 4, and 5 are tested in accordance with ASTM D-1796, and grade No. 6 is tested by ASTM D-95 test procedures. The first is the test by centrifuge. The test is conducted by mixing the oil with a solvent, in a glass tube, and then whirling it in a centrifuge. The centrifugal force throws any water and sediment to the bottom of the tube, which is calibrated, and a reading of the contaminants can then be taken. A second test method is the water distillation test. In this method, the oil is mixed with gasoline and distilled. The vapors are condensed and the liquids drop into a calibrated tube. The water, being heavier than the gasoline, is then measurable. The third method is sediment by extraction which will not be covered here.

There are a number of causes for bottom sediment and water. They include: (1) contamination by leaky tanks, (2) chemical reactions in the oil, (3) excessive tank heating, (4) condensation, and (5) improper mixing, which may cause separation.

Carbon Residue. - There are four different types of carbon that may be present in oil or may be produced by testing it. They are: (1) fixed carbon, which is the carbon of the chemical compounds in the oil; (2) free carbon, which is the carbon that has precipitated or has been loosened from the chemical hydrocarbon; (3) carbon formed on the burner tip due to incomplete combustion; and (4) carbon formed during the carbon residue test. The test procedure is outlined in D-524, Test for Ramsbottom Carbon Residue of Petroleum Products. The sample, after being weighed in a special glass bulb, is placed in a metal furnace maintained at approximately 1,000°F. The sample is quickly heated to the point at which all the volatile matter is evaporated out of the bulb. After a cooling period, the bulb is weighed and the residue is calculated as percentage of the original sample. The carbon residue serves as a rough approximation of the tendency of the fuel to form deposits. Some examples of the troubles encountered due to too high carbon residue are: (1) some burners will just not handle too high a carbon residue, and (2) small combustion chanbers can build up a carbon residue on their walls.

Ash. - There are certain impurities or foreign materials present in most fuel oil that are not apparent or noticible. These organic and inorganic substances are often non-combustible and, after the combustion of the fuel oil, they form a residue called ash. The laboratory procedure to determine the presence of ash is to heat the oil in the presence of air. The vapors are then ignited and burned; then the temperature is increased to burn the carbonaceous materials, leaving only the non-combustible ash, which is weighed.

There are a number of problems that can arise as a result of ash. They are: (1) manufactured objects in direct contact with combustion reactions may be affected by the ash; (2) in low pressure boilers, it may result in a heat-transfer problem due to the build-up of ash; and (3) in high-temperature steam boilers, it may cause the surface of the metal to rust or corrode.

Distillation Temperature. - An oil is made up of a series of petroleum fractions, each boiling at a higher temperature than the previous one. This is the basis of the distillation tests. It furnishes the distillation range of the oil under test. To run the distillation test, oils are heated and vaporized in a glass flask, and the vapors are then passed through a water-cooled condenser and into a graduated flask (ASTM D-86). The temperatures are rated in 10-percent increments. The initial boiling point (IBP) is the temperature at which the first drop of condensed vapor appears in a distillation test. The next temperature above the initial boiling point is the 10-percent point. This is the temperature at which 10 percent of the total volume of the sample of oil will distill off. The spread between the IBP and the 10-percent point should be small so once ignition takes place the oil will continue to burn. The distillation points of 20 through 80 are very seldom used, except to check the spread of fractions. The closer they are together, the better it is since it is better to have a greater percentage of the distillation range on the lighter or lower side of 50 percent to facilitate the burning of the heavier ends of the fuel oil. In specifying the 90-percent endpoint for a No. 2 oil with a minimum of 540°F to a maximum of 640°F, we have protected against a high endpoint. The maximum is specified as protection against contamination by heavy oils which may be difficult to burn.

Viscosity. - The viscosity of oil has been defined as its resistance to flow. In the U.S., the Saybolt viscometer is usually used, the two types of which are the Universal and the Furol. The difference between the two is the size of the opening at the bottom of the outlet tube through which the oil that is being measured flows. Another instrument used is the kinematic viscometer. The major difference between the kinematic and Saybolt test is in the testing technique. While running the test, the kinematic viscometer has a constant head which exerts a continuous downward pressure. The Saybolt viscometer has a fixed volume of liquid exerting the downward pressure Grades 1 and 2 fuel oil are run using the kinematic tester, and grades 4, 5, and 6 are run using the Saybolt viscometer. It is absolutely necessary when quoting a viscosity reading that the type of instrument, as well as the temperature, be given. To illustrate, a viscosity may be shown as 500 SUS at 100, meaning 500 Saybolt Universal Secon at 100°F.

Viscosity would have to be considered the one most important single specific characteristic of a fuel oil. This is especially true of grades 5 and 6 oils, where the viscosity has to be known in order to adjust the pumping temperatures, the atomizing temperatures, and the pump pressures. The difficulties which may occur when an oil has too high a viscosity are: (1) pumping problems, (2) insufficient oil at burner, (3) flashbacks, (4) trouble with initial starting, (5) poor combustion, and (6) a high carbon residue. An oil which is too light will: (1) cause too much oil to be pumped, and (2) result in loss of economy.

Gravity. - The oil industry employs the API gravity scale, devised jointly by the American Petroleum Institute and the National Bureau of Standards. The relationship between API gravity and the specific gravity is an arbitrary one: 1° API gravity equals 141.5 divided by the specific gravity at 60°F, minus 131.5. Where the term "gravity" is used by the oil industry, the term means API gravity. The test method is to float a hydrometer scaled to API units in the oil and take the API gravity readings along with the temperature of the oil. As the gravity varies with temperature, the reading taken is corrected to API gravity at 60°F.

The gravity will tell you: (1) the lower the API gravity, the heavier the oil in viscosity or consistency, the higher the carbon residue, and the heavier the weight; the opposite is true for the higher API gravity; (2) the higher the gravity, the greater the heat of combustion; (3) the higher the API gravity, the lower the unit weight of the oil; (4) the type of refining process; (5) the grade of the oil; and (6) as the API gravity decreases, the rate of combustion decreases.

Copper Strip Corrosion. - ASTM D-130, Standard Method for Detection of Copper Strip Corrosion, provides for the immersion of a polished copper strip in a sample of the fuel oil at a given temperature and for a given period of time. At the end of the test, the copper strip discoloration is compared with the ASTM copper corrosion standard. The purpose of the test is to detect the corrosiveness of the fuel oil to copper and is largely a measure of the active sulfur content of the oil.

Sulfur. - Sulfur is the third most important element present in oil. Compared with carbon and hydrogen, the percentage of sulfur is very small (up to 2 percent), but it consists of a large number of individual sulfur compounds. There are four methods of test for sulfur that can be used. They are: (1) D-129, Oxygen Bomb Combustion Method for Sulfur in Petroleum Products; (2) D-1551, Quartz Tube Method for Sulfur in Petroleum Oils; (3) D-1552, High Temperature Method for Sulfur in Petroleum Products, and (4) D-2622, X-Ray Spectrographic Method for Sulfur in Petroleum Products. In addition, No. 1 fuel oil may be checked by method D-1266, the Lamp Method. Because of the time element, I will not discuss the various testing techniques. Consistent results on sulfur testing by different operators in different laboratories is not always achieved. Naturally, this creates problems. Acceptable sulfur precision limits frequently range from 0.1 percent to 0.01 percent. There appears to be two principal reasons for this problem. The first reason is improper sampling. The supplier may have a large storage tank of oil that has been blended to provide the proper sulfur content. The sample is taken (correctly) from different levels in the tank, combining the samples to a composite on which the sulfur test is run. The consumer may take his sample from the truck which represents a certain strata of the supplier's tank. Consequently, the analyses have not necessarily been run on the same sample. The second reason is technique. At times, rather make-shift equipment has been used. This factor has been found in a number of laboratories which have tried to use the same apparatus for checking sulfur in both steel and petroleum oils. Some refined products, such as gasoline and kerosine, have been treated for the reduction of sulfur. With the advent of the H-Oil Desulfurization process, the refining industry can now make low sulfur residual fuel oils. The process can remove 60 percent of the sulfur, bringing the content of a residual oil from 2.5 percent down to about 1.0 percent.

There are a number of troubles that can be attributed to sulfur. They are: (1) corrosion by its combustion products (the most important problem), and (2) many manufactured articles are affected by the combustion products. In the glass industry, a low-sulfur fuel is required (~0.25 percent S). A high-sulfur material causes discoloration and pitting of the glass products. The largest users of fuel oil are the open hearth furnaces of steel mills. For this industry, the absorption of sulfur gases into the steel itself causes the metal to become brittle.

Finally, I have been asked to mention some changes that are currently being considered for inclusion into ASTM D-396. There are three potential changes that come to mind at this time. They are:

1. Specification for a light No. 4 oil: The committee has been requested to include a light No. 4 oil in the specification, with recommended limits of: Flash - 130°F, or legal; Pour Point - 20°F maximum; Water and Sediment - 50 percent maximum; Ash - 0.10 percent maximum; Viscosity - 5.8 kinematic centastokes maximum at 100°F or 45 Saybolt Universal Seconds maximum at 100°F; Gravity, API - 30° maximum; and, Sulfur - legal.

2. Lubricity: The committee is currently conducting tests on some samples of fuel oil to determine if there is a lubricity problem.

3. There is a feeling that the higher aromatic fuels that come from the catalytic cracking process may be causing a wear problem on the seals in a fuel oil system. The committee is also looking at this situation.

Obviously, with over 20 million burners and systems in the field, serious consideration must be given to any change in the specification prior to adoption by the panel.

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AUTOMOTIVE CRANKCASE DRAININGS USED FOR FUEL

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Automotive crankcase drainings have long been an important source of feedstock for re-refiners. The base oil derived from the used oil is used to compound motor oils, hydraulic oils, and various kinds of industrial lubricants.

For reasons peculiar to the industry, primarily economic in scope, over the years all of the available crankcase drainings have not been re-refined, and a significant volume was determined to be a pollutant of the environment. At the same time, some crankcase drainings were being put into industrial fuel streams with varying degrees of success. Because of the environmental impact and various economic considerations, much support has been given in recent years to burning the crankcase drainings with little recommended processing and with major emphasis on diluting with virgin fuel oil to meet ambient air quality standards and to minimize equipment fouling.

Much data are available to sustain the argument over whether to burn or not to burn and how to burn or how not to burn. I would like to present data which pose many of the considerations to be examined in the course of arriving at means of determining substantial equivalency of products made from these materials. It should be understood that the data do not draw any conclusions, they do not resolve the controversy, and are presented for the informational value. Similar testing of other samples may result in some variations, depending on technique of sample gathering and exposure to extraneous contaminants.

The data presented in table 1 were from samples of automotive crankcase drainings accumulated in our laboratory. The free water had already been drained from the material, and the combined samples retained 5 percent water in the emulsion.

TABLE 1

CRANKCASE DRAININGS USED FOR FUEL

	Raw drainings	Dehydrated drainings	Vacuum distilled	D-396 No. 5 light
Flash, °F.	275	385	380	130
Fire, °F.	390	425	415	
BS&W - vol.	12 %	5.2 %	0.01 %	1.0 %
Ash - wt.	1.95 %	1.87 %	0.002 %	0.1 %
SSU at 100 °F	372	340	211	150-300
V.I.	123	124	97	
Sulfur, %	0.5 %	0.5 %	0.22 %	Legal
Btu - per lb.	18,351	18,880	19,341	18,500-19,400

The data for the raw drainings, dehydrated drainings, and the vacuum distilled oil are presented to show the characteristics of crankcase drainings as they may be entered into an industrial fuel stream with varying degrees of processing (decanting to vacuum distillation), the latter removing substantially all of the contaminants. For comparative purposes, the D-396 specification for #5 light industrial fuel is presented.

In this case, the flash at any level of processing is above the D-396 minimum; however, the water and sediment, in both the raw and dehydrated drainings are substantially above the maximum specified in D-396

The ash shown for raw drainings is typical and is improved minimally by dehydrating, but does conform if processed by adequate means.

Our experience indicates that most crankcase drainings are presented as #5 fuel and, in this instance, come into spec only after having the extraneous materials removed.

The viscosity index is reasonably representative of both raw drainings and processed drainings, although the viscosity index is not a consideration in the D-396 specification. This, incidentally, is not a finished base lube oil, but little additional processing is required.

The sulfur, while generally legal and typical of crankcase drainings, is improved by vacuum distillation and does not conflict with most requirements established by regulation.

On the assumption that BTU content would be interesting, we arranged to have the analyses made on the drainings containing 5 percent water and those further processed. As you see, there is not a significant variation from the usually designated range for fuel oil (this is not an ASTM designation).

For the materials designated as raw drainings, dehydrated drainings, and vacuum distilled oil on the previous slide, we ran a spectrographic analysis on each and also an analysis of a typical water sample drained from a waste oil collection truck loaded with crankcase drainings. This latter material represents the free water which is pumped out of the service station drain tank. These data are shown in table 2.

TABLE 2

CRANKCASE DRAININGS USED FOR FUEL
SPECTROGRAPHIC ANALYSIS - PPM

	Raw drainings	Dehydrated drainings	Vacuum distilled	Typical water
Silver	0	0	0	0
Sodium	160	140	6	8,000
Zinc	1,100	1,000	2	1,300
Copper	50	40	6	18
Aluminum	33	28	2	74
Barium	200	160	4	230
Nickel	3	2	0	26
Chromium	27	23	0	10
Calcium	1,000	1,100	0	2,200
Iron	750	720	2	1,050
Silicon	47	40	4	100
Tin	20	17	0	340
Lead	7,800	6,900	13	550
Phosphorus	900	800	50	2,100
Boron	52	38	1	440
Magnesium	430	400	0	1,000
Vanadium	5	4	3	20
Molybdenum	7	6	0	28
Manganese	42	39	3	65
Cadmium	2	0	0	37
Titanium	5	1	0	45
Mercury, ppb				0.88

It is interesting to note on the oil samples that dehydration of the raw drainings appears to lower, although minutely, some of the metallics. The most significant numbers, of course, are lead, calcium, zinc, magnesium, and barium as they relate to accumulation and ashing. Vacuum distillation or other effective processing will remove a substantial amount of the material.

Another comment about the water analysis. This phase is generally overlooked when discussing the processing or non-processing of crankcase drainings for fuel; and, since the water represented here is not bound up in an emulsion, it is easily decanted either directly from the truck or from a settling tank.

Table 3 shows the materials in the water as illustrated in table 2 and compares that with maximum limitations acceptable to the greater Chicago Metropolitan Sanitary District (MSD) sewer system and also for discharge directly into streams under the jurisdiction of the MSD. The quantities are expressed in parts per million, except for mercury near the bottom of the list which has a maximum acceptability of one-half part per billion.

TABLE 3

MAXIMUM CONCENTRATIONS IN WATER ACCEPTABLE FOR DISCHARGE - PPM[a]

	Water from drain oil	Greater Chicago Metropolitan Sanitary District	
		Sewer	Streams
Barium	230	2	2
Silver	4	0.1	0.1
Boron	440	1	-
Copper	18	3	1
Cadmium	37	2	0.15
Chromium -Total	10	25	23
Iron	1,050	50	2
Nickel	26	10	1
Lead	550	0.5	0.1/0.5[b]
Mercury - (PPB)	0.88	0.5	0.5
Zinc	1,300	15	1
Manganese	65	--	1
Hexane Solubles	250	100	15

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[a] Except mercury, as noted

[b] State streams limits

The parts per million found in water from drain oil may or may not appear significant when looked at individually. They do become very significant when compared with the maximum levels of acceptability and must be taken into consideration in designing an oil/water separation and water-processing system for handling materials of this type.

Obviously, it is no longer acceptable to use a convenient ditch or empty lot to dispose of what I would term "process water."

Earlier tables showed crankcase oils processed through a vacuum still and the change in both properties and level of contamination. The data in table 4 show typical properties of the still bottoms consisting of some hydrocarbons, and the additive package remnants including V.I. improvers, pour-point depressants, and the like. The material poses some rather interesting considerations, although the ash level places it far outside the consideration of being used in a fuel product.

TABLE 4

VACUUM STILL BOTTOMS FROM CRANKCASE DRAININGS - TYPICAL PROPERTIES

Viscosity at 210 °F, SSU	5,000 ± 500
Viscosity at 210 °F, Brookfield No. 2 Spindle rpm	1,100 CPS ± 50
Pour point, °F.	+20
Flash COC, °F.	600+
Carbon residue, ASTM D-189	24%
Ash	14%
Odor	None
Sulfur	1.37
T.A.N.	4.0
T.B.N.	0.9
pH	5.8

A spectrographic analysis of the still bottoms (table 5) indicates the high concentration of the metallic components, particularly lead.

TABLE 5

VACUUM STILL BOTTOMS FROM CRANKCASE DRAININGS
SPECTROGRAPHIC ANALYSIS

Silver	0
Zinc	3,500
Copper	160
Aluminum	230
Barium	1,400
Nickel	10
Chromium	100
Calcium	7,000
Iron	2,000
Silicon	550
Tin	140
Lead	15,000
Phosphorus	2,000
Boron	10
Magnesium	1,300
Vanadium	0
Molybdenum	10
Manganese	70
Cadmium	0
Titanium	70

As a commentary, it is interesting to note that the lead level in crankcase drainings is beginning to decline, although not dramatically as some are inclined to believe. My information shows that about three years ago the lead level in crankcase drainings was about 1 percent by weight, and currently it has decreased to about 0.8 percent, a change of approximately 20 percent.

The data in table 6 are from a rather interesting situation where crankcase drainings were offered at the height of the energy crunch as recycled, reclaimed lube oil which correlated closely to a light #5 fuel. These data show the specifications quoted, an analysis of a sample taken from the material being offered, and a comparison with the ASTM D-396 specification.

TABLE 6

FUEL OIL FROM CRANKCASE DRAININGS
(LIGHT NO. 5)

	Quoted	Actual	ASTM D-396
API gravity at 60 °F	25.2	27.1	---
SSU viscosity at 100 °F	240	148	150-300
Pour point °F.	-5	-50	---
Flash, °F. (Pensky-Martins)	182	128	130
Sulfur, %	0.35	0.36	---
Ash, %	0.48	1.44	0.1
Water and sediment, %	---	7	1

A comparison of viscosities, pour points, and flash showed a high degree of dilution, which is not uncommon in either crankcase drainings or waste oils from industrial operations. This, of course, dictates that necessary precautions be observed to avoid endangering both employees and equipment.

The ash values are questionable, and the water and sediment level in the actual sample is about typical for decanted drainings.

Finally, table 7 shows spectroanalysis on samples taken from boilers which had been fired almost exclusively on waste oil fuel. The boilers were taken out of service for cleaning, due to the high concentration of deposits in the equipment. It is interesting to note the high level of metals in the deposits and the variations between types of waste oil used. As an example, in the second column, it is apparent that a significant volume of crankcase drainings were used as fuel because of the high lead concentration, lead being approximately 10 percent of the weight of the deposits.

TABLE 7

SPECTROANALYSIS ON SAMPLES OF BOILER DEPOSITS (PPM)
(WASTE OIL FUEL)

	1696	1872	1866	1868
Zinc	60,000	--	3,800	1,400
Copper	12,000	3,150	135	150
Nickel	2,500	2,000	105	90
Chromium	200	1,250	150	150
Calcium	84,000	--	8,850	114,000
Iron	12,000	10,500	18,000	2,850
Silicon	3,700	9,600	11,000	8,250
Lead	6,000	100,000	570	620
Phosphorus	160,000	--	33,000	18,800
Magnesium	--	15,000	530	950
Vanadium	--	3,700	--	--
Sodium	--	--	--	3,600

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DISCUSSION

SESSION II. USED OIL REUSED AS FUEL

The first area of discussion in this second session was why burning used oil should be considered as oil recycling. Most people agreed that burning was not the optimum end use for this material. However, any time a waste material is used more than once it is being recycled. The question of whether this type of recycling is the best use of existing resources is an entirely different question and depends on a number of factors, including whether existing resources of virgin lubricating oils are being used to the maximum or not. If current lubricating oil virgin stock is being reformed or cracked to form fuel oil or gasoline or something else, then the resource conservation aspect may not really be relevant here. Appropriate consideration must also be given to energy conservation and environmental pollution, however.

A second area of concern was expressed about the environmental aspects of emissions from burning used lubricating oils, especially the lead emissions (automotive used oils currently average 0.8 percent to 1.0 percent by weight of lead), along with other elements added as additives (zinc, phosphorus, calcium, magnesium, barium, etc.). A more recent concern may be the element manganese, which is now replacing lead in certain types of gasoline. Since there are no trace element test methods currently required in existing virgin fuel oil specifications, this is an area which requires consideration for recycled oils used as fuel. Part of the problem of lead and/or heavy-metal emissions is that the Environmental Protection Agency (EPA) currently does not have ambient air quality standards, as will be described in a paper in the conference. Therefore, even though some people were concerned about the emissions while burning used oil, they did not actively consider this a restriction since there were no existing regulations. It was pointed out by one speaker that the Federal Government is currently going out on bid for a large quantity of fuel oil in which the restrictive clause in the specification eliminating recycled oil has been removed. It was indicated that these bids will be evaluated on an "as is" basis, as long as the product meets all other existing specifications. These specifications would limit the amount of non-processed used oil which could be blended with a No. 2 fuel oil, for instance, and still meet the American Society for Testing and Materials (ASTM) specifications. However, apparently up to 30 percent or so of non-processed used oil could be blended with a No. 6 fuel oil and still meet these existing ASTM specifications. It was also mentioned that this type of procurement may result in problems if a No. 2 fuel oil were purchased which has a used oil component if that used oil were from a gasoline engine. This is so because in many cases at government installations the diesel fuel oil is stored together with No. 2 fuel oil, and it is known that lead from used gasoline crankcase oil is very damaging to diesel engines.

The discussion also centered around using a test method such as ash in order to evaluate the metals content of a fuel oil/used oil blend. There was a variety of opinions on this matter, some of the persons feeling that the ash specification should only cover those components of the fuel which actually create an ash in the end-use situation, thereby evaluating material buildup in the burner situation. The feeling was also expressed that the actual total ash content is of concern because of the potential effect on different types of combustion systems, such as erosion in the burner itself, or because of the effect on some types of furnace materials, such as refractory bricks.

In the ensuing discussion, the question was brought up as to whether the National Bureau of Standards (NBS) will actually be setting specifications for these materials. The opinion was expressed that the NBS responsibilities include developing test procedures and forwarding these test procedures to the Federal Trade Commission (FTC) for implementation by the FTC. However, it was also acknowledged that this implies providing technical expertise to the FTC in the evaluation of these test procedures as applied to oils. It was felt by several NBS representatives that the ideal situation would result from the cooperation of ASTM specifications committees and/or the Federal specifications people in providing the necessary specifications providing for effective utilization of recycled oil products. To this end, conversations have already been initiated between NBS personnel and ASTM and the appropriate Federal specifications personnel.

One point of discussion that was brought up was whether NBS had the right to consider limiting factors for used oil reused as fuel in light of EPA not having set such regulations. It was then pointed out that the enabling legislation under which the NBS Recycled Oil Program is functioning states "substantial equivalency" to the virgin end product, and, therefore, tests are required which will provide a recycled oil produce which is essentially the same as a virgin oil product. It was also discussed that there were available EPA studies which indicated that when straight crankcase drainings were used with appropriate environmental controls (e.g., venturi scrubbers, bag houses) the actual emissions were drastically reduced and apparently fell within the range expected from virgin oil use. It would thus seem that under certain conditions this type of burning would be acceptable. A comment was also made that a court decision exists which establishes that dilution of an environmental pollutant is not a valid way to circumvent EPA emission regulations.

There was also considerable discussion about the increased maintenance that apparently results from combustion of used oils when such used oils have not been processed to remove debris and inorganic contaminants. Since the only current EPA requirements are in the form of particulate emissions, the scrubbers mentioned previously apparently do an efficient job of removing these particulates and, thus, fall within the current environmental regulations. In addition, the use of used crankcase oil for wetting down powdered coal in coal-fired power plants has received some investigation. According to one report, this appears to be an acceptable way for disposal of used oil due to the effective particulate and other environemntal pollution controls on coal-fired power plants.

Finally, the discussion ended on the subject of whether the environmental considerations in disposal of the light ends and the heavy ends of the processed or re-refined oil (light ends including primarily the water removed from the used oil, heavy ends being the sludge remaining after processing) did not result in a greater problem than existed previous to the reprocessing of the used oil. Several participants spoke on the success that they have had in eliminating or cleaning up these supposedly environmentally very bad products. In particular, it was pointed out that since all of these by-products existed in the original material anyway, it was therefore difficult to see how separating and concentrating these away from a useful material resource would, in fact, be creating an additional problem that did not exist in the first place.

SESSION III

RECYCLED INDUSTRIAL AND HYDRAULIC OILS

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ASTM TEST METHODS FOR INDUSTRIAL OILS

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With all due apologies to Mr. Becker, I was not really certain what I was going to talk about this afternoon until this morning, so I wrote a speech. With your permission, I will try to wear two hats, too. I would like to tell you a little about Alcoa's program, but I will speak principally about the American Society for Testing and Materials (ASTM) and how it may interface with the Bureau's Recycled Oil Program.

Alcoa is very pleased to see the National Bureau of Standards' (NBS) program getting underway. We have been committed to conservation of petroleum energy sources for a long, long time. We think this is a necessity; we think we have to do it. We have spent a lot of money in the last few years developing techniques and methods so that we could recycle used materials. Admittedly, most of the volume of used oils is recovered in-house. Our industry, not just Alcoa, since its beginning has had a program of recycling rolling oil as an indication of our interest. These are all circulating systems; the materials are filtered, reclaimed, and reused continuously, we hope for a long period of time. When we have to dispose of materials because of some unforeseen circumstance, e.g., if we have something that has gotten out of hand, we try to rectify this in-house, also. As a last resort, we go outside for information. We are doing a great deal of this.

I might mention, because we were talking about burning fuels this morning, that we have adopted a policy at Alcoa that we will burn waste oil only as a last resort. We would much rather use it for something more valuable than fuel oil. Much of the oil that has to be reclaimed is intrinsically more valuable than fuel oil. We cannot see the point of burning this used oil unless there is absolutely nothing else we can do with it. So, we will be watching the NBS program as a corporate thing because we are very much in favor of it, and we will cooperate in any way we can.

I looked around this morning, and it looked to me almost like we were reconvening ASTM Committee D-2 because many in the audience are faithful D-2 workers.

For those of you not acquainted with D-2, I might explain our relationships. I was chairman of Committee D-2 for nine years until they got tired of me about a year ago. I have been on the Board of Directors of ASTM for the last two years, so I can speak from both standpoints. As was mentioned several times this morning, by Dr. Ambler and by others, there has been a very close relationship between NBS and ASTM--not just in Committee D-2, but ASTM in general. Mr. Becker's boss, Dr. John D. Hoffman, is on the Board of Directors of ASTM. I have sat with him on the board for the last year-and-a-half or two. I know he is very much interested in ASTM activities. We have had many NBS people in ASTM in the various committees, including D-2, and we hope that continues. We have an on-going program with the Federal agencies in all aspects of standardization. Some of you may know that a few years ago we had a president of ASTM who was a Federal employee, and he has been heading up an interagency committee to do more about standardization; and, of course, we have been getting a lot of input from him.

As many of you know, ASTM is committed to the development of test methods and specifications. This is our business; we are in the business of standardization. As you also know, many of the test methods used by yourselves and other people in this whole field are ASTM methods; and, if you remember the table Mr. Becker used, I believe the majority, if not almost all, of the methods listed were ASTM methods. We hope this will continue.

ASTM reacts from needs. We do not generate a need; hopefully, we react to needs expressed by somebody else. I would hope that if there is need in this area, ASTM will react to that need. This means that you have to participate. One of the things that disturbs some of us is that we will have somebody or a group of people coming to

ASTM saying, "We need test methods in this area," and they expect ASTM to do it. I am not sure what they think ASTM is. They will come in and say they need something, then walk out and we do not see them again. Apparently, they think there is a corporate body somewhere in the ASTM which works and does all this business for the government, and that is not so. It is you people and other people who have the need who are going to do the work. So, if you are not prepared to work toward the efforts, then do not come to ASTM because you are not going to find some anonymous group to do the work for you.

I was supposed to talk about industrial oils, but much of what I was going to say has already been mentioned by the others who have already spoken. Therefore, I would like to discuss some of the ways ASTM could interface with people involved with recycled oil.

We do not have a committee in D-2 specifically for recycled oil, and I do not know whether we will. That is yet to be determined. D-2 is made up of a number of committees and is generally broken into two general categories: the so-called product committees (committees on turbine oils, industrial oils, etc.), and the research and development committees which are structured differently and which do what is commonly called the scientific work in D-2. Several of these committees now have subgroups and subcommittees which are working on recycled oil and recycled products. This is still somewhat in its infancy, and I am sure it is going to grow. Just how it is going to be structured eventually has yet to be determined.

I am certain that you will find that many of the existing test methods are going to be able to be used, as they are, for recycled oil. I am sure we are going to find we are going to have to change some of the others. We would hope that this will be done within the confines of the ASTM.

One of the things going for the ASTM is the fact that we develop these standards by the so-called consensus method. Hopefully, the producers, users, and consumers get together in all these matters and the final result is that they agree on acceptable methods, tests, and specifications. We process the standardized tests to the American National Standards Institute, as you know, to become the national standards and to the International Standards Organization to become international standards. Consensus methods are going to have considerable weight in the legal aspects of standardization. I am quite sure that methods that are not developed by this method will not be looked upon legally, eventually. ASTM regards this as kind of a home for you.

I might mention that the next meeting of ASTM Committee D-2 (if you will allow me a bit of a plug) is going to be in New Orleans, so I hope it will be a little bit warmer than it is in Gaithersburg this morning. That will be the week in December starting December 5. I am sure that the problem of recycled oil tests is going to come up in those meetings, and I would like to see as many of you there as can possibly get there. It is a nice place to go, particularly in December.

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INDUSTRIAL OIL RECYCLING AT CHRYSLER

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I am very fortunate to have a lot of experts here today. I joined Chrysler about 10 years ago; and, long before I came aboard, Chrysler already was recycling oil. Mr. Swain, who was involved in it initially, and Mr. Mullinger, who had been involved in it long before I came aboard in the re-refining aspect, are both here. So, I am going to have a lot of people to help me today if I do not have the answers.

Basically, when the energy crunch hit in 1973, although Chrysler had been doing a lot of reclaiming, they decided to take another look at this program. In October 1974, a committee met to draw up new ways of improving our recycling; and, after many meetings, a new program emerged. In February 1975, the Chemical Division of Chrysler Corporation was given the job to manage tht total recycling program involving primarily waste oil sludges. Basically, the oil sludges were converted to oil by removing solids and water; and this cleaned-up oil was returned either as various reclaimed basestocks to meet original specifications, or else it was returned as a re-refined hydraulic fluid. As shown on figure 1, the manufacturing plants represent either our stamping plants or our general manufacturing plants. The waste influents are collected and go to our environmental treatment facilities which are waste treatment facilities. The material is treated sufficiently in order to generate a good water that can be disposed of directly into the sewer. That is the primary reason why we have these facilities--to generate a good water which meets required specifications. It just turns out that today this by-product that we get, which is an oil-containing sludge, has a value. The water goes to the sewer and the oil sludge is taken to a reclaimer who will then break the sludge, through various proprietary processes, remove the solids, remove the water, and will return the products to the Chrysler Corporation where they are formulated into industrial lubricants, cutting oils, hydraulic oils, etc. We now also utilize reclaimed oils for making water in oil emulsions and hydraulic fluids. These products are returned to our plants for reuse. Excess reclaimed oil is diverted to a re-refiner. He, in turn, will then make re-refined hydraulic fluid from it and return it to Chrysler.

One of the important things we talk about is segregation. In our stamping plants, for example, we generate a completely different type of fluid than we do in our general manufacturing plants. These press oils are very high in viscosity; and, since the stamping plants usually do not have any environmental treatment facilities, they basically have large tanks where the influent is collected. By heating and by letting the material stand, the water is separated and drained off. This water is now hauled to a waste treatment plant for processing. The oil is taken to a reclaimer who, in turn, will then break out the contaminants and blend it with other oils for reuse. What we are trying to do is keep it from being mixed in with other oils. At this time, it is a difficult problem and we are not having very much success.

Also shown in the figure is a return water from the reclaiming. The Chrysler Corporation feels that as long as the water that is generated in waste oil sludge goes to reclaimers, even though the reclaimer does not segregate from all the different feedstocks, that those volumes equal to what he gets are returned. He will therefore return water equal in volume to what he picks up.

A typical stamping plant reclaim oil that we get will run in the viscosity range of as high as 600 SSU to 800 SSU. When we pump it out of pits, where it is just purely from the presses, it is still a very good oil. We just received a sample in last week that was running close to the viscosity of the virgin oils (1450 SSU). If somehow we could segregate this, clean it up through a simple filtration method, it could be put right back into a plant and eliminate the 20-percent to 30-percent loss factor currently obtained through re-refining.

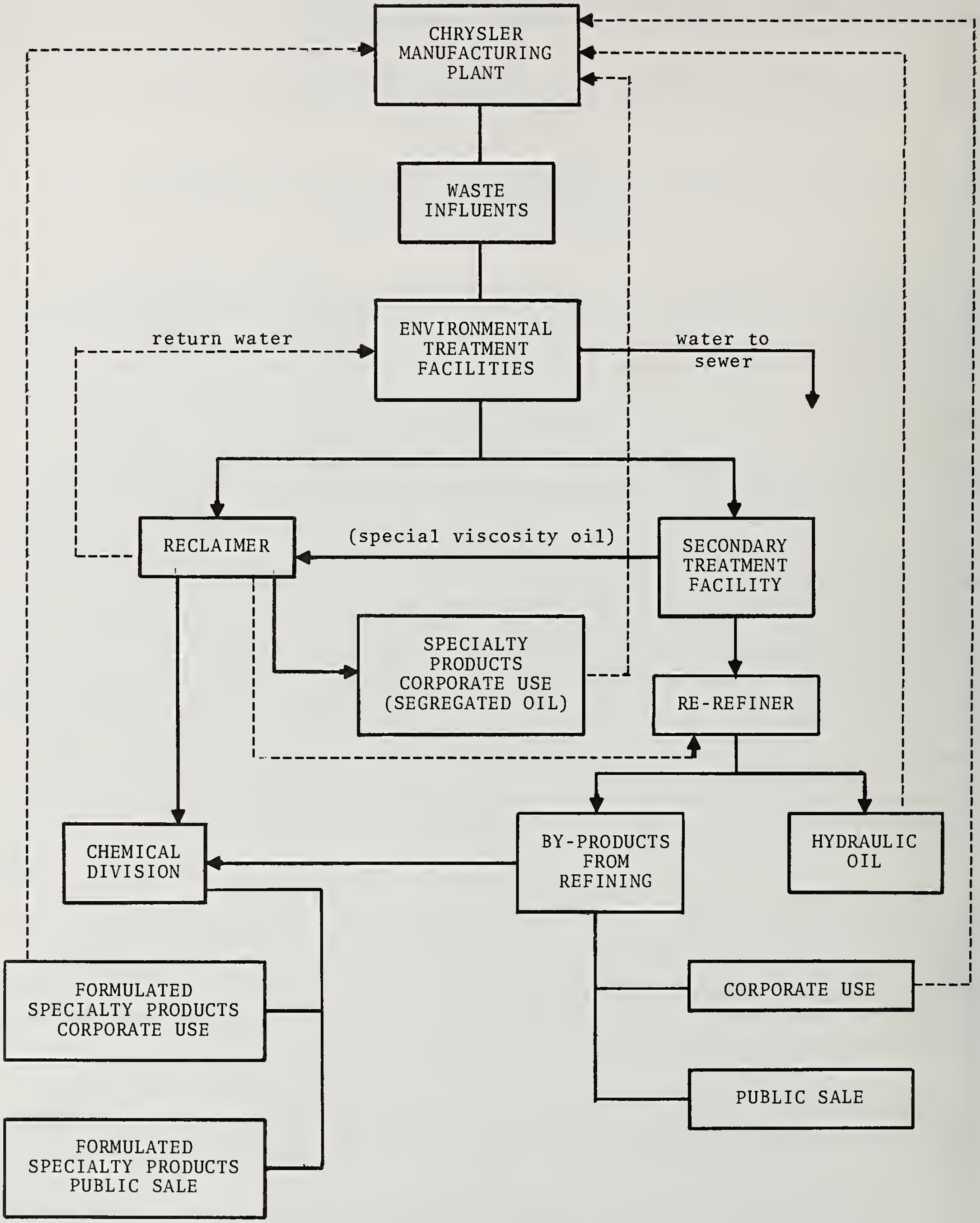

Figure 1. Industrial oil recycling process at Chrysler.

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INDUSTRIAL OILS: DESCRIPTIONS, ADDITIVES, AND TEST METHODS

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First, since this is a workshop on oil recycling, I believe we should define the processes used in oil recycling--reclaiming, reprocessing, and re-refining--which are used to recycled used engine oils and industrial oils.

Reclaiming is the process which removes large particles, sludge, and water using heat, gravity settling, or simple filtration.

Reprocessing goes one step farther and employs chemical treatment (usually acid or alkali), heating to 160°F to 200°F. This removes solids, water, and most of the original additives and compounds formed during use.

Re-refining has three steps: pretreatment to remove solids, water, most of the original additives and compounds formed during use by chemical and/or solvent action; distillation, usually with activated clay in-situ and steam, at temperatures ranging from 500°F to 650°F to remove light ends, color bodies, and other compounds not removed by pretreatment; and post treatment to remove the spent clay. This step may also include further steam stripping and neutralization. Currently, there is work being done using the hydrotreating process replacing clay.

Most of the emphasis on oil recycling has been directed to used engine oils, with little attention being paid to industrial oils. The fact is that use of industrial oils has been increasing at a higher rate than automotive and aviation oils. For example, the sales of these oils in 1967, 1973, and 1975 were:

	Million Gallons/Year		
	1967	1973	1975
Automotive and aviation oils	1,170	1,294	1,271
Industrial oils	1,450	1,883	1,586

The industrial oil sales for 1975 were down because of decreased industrial production.

The recoverability factor of industrial oils should be higher than automotive since there is a smaller volatility loss and no do-it-yourselfers.

Those not familiar with oils seem to think that there is a great difference between automotive lubricants and industrial oils. Actually, the major difference is in the additive package rather than the basestocks. For example, an oil with a viscosity of 170 at 100°F SSU can be used to produce engine oils, hydraulic oils, cutting oils, bearing oils, quench oils, gear oils, and many more.

There are several fluids used in industry which properly are not oils. These include the synthetic machining and process fluids, as well as non-flammable hydraulic fluids. However, the use of these is relatively small compared with use of other oils by industry.

It is generally thought that used industrial oils can be recycled more easily than used engine oils since the oils are less contaminated and the use of the oil is less critical. Neither of these propositions is necessarily true. Used industrial oils segregated at source can be reprocessed or re-refined more easily than used engine oils. However, the large volume sources of used industrial oils are the waste water treatment facilities of large manufacturing plants. These present problems which few re-refiners want to handle.

Re-refined oils are being used to produce hydraulic oils, cutting and grinding oils, drawing oils and compounds, and forging oils and compounds. Often, all of these, except hydraulic oils, can be made from effective reprocessing. I have set up seven categories of industrial oils and include some estimated sales for 1975.

Hydraulic and Circulating System Oils (314 million gallons) - Hydraulic oils have viscosities ranging from 150 to 900 at 100°F SSU. Today, most of the oils contain additives to prevent rust and oxidation, to decrease pump wear, to reduce leakage, to reduce foaming, and sometimes pour point depressants and viscosity index (V.I.) improvers.

Most of the tests specified for hydraulic oil are those using the American Society for Testing and Materials (ASTM) procedures. These will include gravity, viscosity and viscosity index, flash and fire points, pour point, total acid and base numbers, sulfated ash, copper corrosion, emulsion number, oxidation rate, and corrosion and foaming. While the ASTM D-943 is often used to test oxidation, many of the larger companies use other simpler bench tests such as controlled heating and air exposure of 300 ml to 600 ml of sample. The volatility loss, sludge generation, and acid number increase are measured, as well as observation of "gum" on the beaker wall. Many hydraulic oil specifications require pump-wear and seal-swell tests.

Circulating system oils are used to lubricate bearings and sometimes gears. Those lubricating bearings may contain rust and oxidation inhibitors, defoamers, V.I. improvers, and extreme pressure (EP) agents. Again, ASTM procedures are used for determining viscosity; V.I.; flash, fire, and pour points; total acid and base numbers; sulfated ash; saponification number; foaming characteristics; rust and corrosion; and copper corrosion, among others. Load and wear tests may also be specified. These may use equipment as the Falex, Timken, or Shell Four Ball test equipment or others devised by the user.

Metal Working Oils (145 million gallons) - Metal working oils include cutting and grinding oils, drawing oils and compounds, forging oil and compounds, and metal rolling and forming oil and compounds. Cutting, grinding, and drawing oils are divided into two categories: straight and emulsifiable.

The straight oils contain sulfur, chlorine, and phosphorus compounds, fatty oils and esters, and heavy metal soaps. The straight oils have a viscosity range of as low as 45 at 100°F SSU for honing and lapping oils to several thousand seconds at 100°F for drawing oils. Most of the tests use ASTM procedures for viscosity; flash, fire, and pour points; copper corrosion; sulfur; chlorine; phosphorus; and fatty oil, ester, and heavy metal soap content. In some cases, sulfated ash determination is required, as well as the saponification number. There may be user-modified tests of the above, as well as bench machinability and load tests. Shop trials of these oils are almost universally required.

Emulsifiable oils in use are mixed with water to provide a high rate of cooling. These contain soaps and emulsifiers and varying degrees of EP and rust-proofing additives and wetting agents to reduce surface and interfacial tension. Test requirements include viscosity; flash, fire, and pour points; sulfur; chlorine; phosphorus; fatty oil and soaps; and emulsifier content of the oil before mixing with water. Bench tests are also made for emulsion stability, foaming, rust-proofing, wetting, hard-water stability, particle suspension, and tramp oil emulsifying. While ASTM tests are widely used, there are more specific user laboratory tests than on hydraulic and circulating system oils. Occasionally, load tests are specified.

Drawing and Forging Compounds - These products range from compounded straight oils, often with high viscosity, to oils containing solid lubricants, for example, molybdenum disulfide, graphite and mica, to compounds containing soaps and oils and solid lubricants. Invert emulsions containing solid lubricants are also used. The trend, however, is away from the high soap, pigmented compounds, and invert emulsion products to highly compounded oils. The additives usually employed are sulfur and chlorine compounds, fatty oils and esters, and heavy metal soaps.

Testing of these products requires the determination of viscosity, flash and fire points, rust and corrosion, emulsion stability, water, solid lubricants, soap, emulsifier, sulfur, fatty oil, and ester content. Tests for welding and metal-coating compatibility, as well as load carrying ability, may also be required. While many of these tests follow ASTM procedures, the diversity of uses and individual operational requirements have established many specific in-house tests.

Rolling and Forming Oils and Compounds - Here again, there is a wide variety of lubricants used. Metal rolling uses fatty oils, straight compounded petroleum oils, and emulsifiable oils. Forming operations such as wire drawing require products ranging from emulsifiable oils to such materials as aluminum stearate and solid lubricants. ASTM procedures are used where applicable, but many user-developed tests are employed.

Process Oils (402 million gallons) - Process oils include quenching oils, test fluids, transformer oils, oils which become part of the product, rust-proofing oils, ink oils, and rubber and plastic oils.

These oils have special characteristics such as iodine number, KB value (Kauri Butanol), dialectic property, and tensile strength of rubber and plastic products. The usual tests such as gravity, viscosity, and flash, fire, and pour points are specified. Most of these are covered by ASTM procedures, although users usually have in-house analytical procedures.

Specialized Lubricants - In this category I have arbitrarily placed spindle oils, gear lubricants, and slide and way lubricants.

Spindle oils usually have a relatively low viscosity (70 to 150 at 100°F. SSU) and contain rust and oxidation inhibitors. Gear lubricants have a wider viscosity range and contain EP and anti-wear additives as well as rust- and oxidation-inhibitors, defoamers, and "tackiness" agents. Slide and way lubricants range in viscosity from 300 to 900 at 100°F. SSU. They contain EP and anti-wear additives as well as "tackiness" agents.

In addition to standard tests such as viscosity, flash and pour points, others such as panel retention and load and wear for slide and lubricants, wear tests for spindle oils and load and wear tests for gear lubricants are usually required. Again, many of these follow ASTM procedures but also employ in-house test procedures.

Test Oils - Many components of vehicles and other equipment are tested after final assembly. These include automatic transmissions and power-steering equipment. Usually these use the same oil as that specified for operation. These, then, are subjected to the same tests as the operating lubricant. Some, such as the oil used to test the valve body of automotic transmissions, are modified to simulate operational conditions, e.g., lower viscosity at operating temperatures.

These oils, with few exceptions, use standard ASTM test procedures. Exceptions would be specialized loading, wear tests, and oxidation tests.

Since this workshop on recycled oils was organized to aid the National Bureau of Standards in meeting the Congressional mandate to establish substantial equivalency, I would like to address this aspect.

ASTM and industry test procedures appear to be adequate for determining the substantial equivalency of recycled oils. The buyer-beware principle is not as important in the industrial area as in the consumer area since it can be argued that these users are, or should be, aware of their lubrication requirements.

However, I am afraid that manufacturers of hydraulic equipment, gears, machine tools, transformers, refrigeration units, compressors, and others will raise the same questions which have been raised by engine manufacturers. In some cases, such as hydraulic or compressor oils, the problem of establishing substantial equivalency may require study. In others, such as cutting and grinding oils, there should be fewer problems.

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THE USE OF RECYCLED INDUSTRIAL AND HYDRAULIC OILS AT FORD

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During the energy crisis of 1973, recyclers with fantastic claims pounded on our door, as I am sure they did everywhere. One major company even offered to set up a reclamation unit at one of our sites, to staff it, and to teach us how to operate it, saying it could save us money since we could cut down on the purchase of new oil.

We were interested enough to proceed with a shop trial, when the reclaimer backed off. We really do not know why; we believe they had second thoughts and they were not quite ready. I also believe we are not quite ready. We are in the business of making automobiles and do not really want to get into the oil reclamation business.

At Ford, our suppliers have been successful with recycling

- Turbine oil,
- Compressor oil,
- Cutting fluids,
- Hydraulic oil, and
- Synthetic fire-resistant hydraulic oil.

The most notable successes are in reclaiming cutting fluids and hydraulic oil. For one plant, 60 percent of all the cutting oil purchased is recycled; in another plant, 60 percent of all petroleum oil purchases end up being returned for recycling.

I think it is best to start out with how Ford does business. Ford has what is called the "M-Numbered" system for "Maintenance" materials. Any maintenance material that Ford buys in volume has a written specification furnished to Purchasing in order to obtain competitive prices.

Ford has three specifications for hydraulic oils:

- High viscosity index mineral oil with rust and oxidation inhibitors,
- Antiwear paraffinic oil, and
- Seal-swell oil with antiwear additive.

All approved sources have met the specifications; and, of course, recycled oil must meet those same specifications. The primary test is one of wear, and all who seek approval must pass a pump wear test conducted by our Manufacturing Process Laboratory.

The Ford Pump Test is run for 1,000 hours at 2,000 psi using a Vickers 104 pump, and the maximum ring and vane wear cannot exceed 125 mg. Of five reclamation candidates, three passed with 70 mg to 80 mg of wear, one exceeded virgin material with only 37 mg of wear, and the last failed with wear of 256 mg at 100 hours. This confirmed that the recycling is practical and the use of recycled oil will, when done properly, meet our needs.

The use or disposal of contaminated oil at Ford is accomplished by

- Recycling: preferred, based on favorable economics and the conservation of a natural resource;
- Burning as fuel: not preferred because of potential of contaminants affecting stack emission levels and reducing the boiler efficiency;
- Giving it away or paying to have it hauled away: not economically sound, least preferred method, and only done when other practical methods are not available.

The cost advantage lies in the recycling process which can produce an acceptable product at five-sixths the cost of virgin oil. We believe that as more oil is reclaimed the cost advantage will increase. Under today's economics, it may not be cost effective in some company's small plant, but in a larger Ford plant it usually is. Last year, Ford suppliers recycled over 7,100,000 gallons of oil. However, several open issues on recycled oil still exist.

- Is the Ford specification the same as all other companies'? Will Ford's oil be mixed with that of other companies and, if so, with what adverse effects to Ford?
- Do reclaimers have the capacity to handle segregated oil? What are the minimum quantities required?
- Is a national standard required? Or, does this drive out competitors?

We do not have all the answers, but we do know that

- Reclamation is feasible,
- Reclamation is cost effective, and
- Reclamation is necessary to conserve a natural resource.

The reclamation (recycling) companies have the expertise, we have the "raw material," and both of us can benefit through the recycling of waste oils. We do, however, urge caution on reclaimers making exaggerated claims. For example, based on one claim, we provided waste oil for reclamation and the returned product was so bad it almost shut down the plant. This experience is remembered and could hinder future applications of good systems and techniques.

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INDUSTRIAL LUBRICANTS, RECLAIMED OILS, AND TEST METHODS

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We have been asked to comment on test methods our company uses to evaluate hydraulic oils. First, I might say that we are not expert in the field; we have been working in this area for only a few years. We have developed a feel for performance tests and evaluation techniques.

We started with fire resistant hydraulic fluids, and the tests shown in table 1 are those that we believe the fluids must pass to meet our service requirements. For tight recirculating systems (low leakage), oxidation tests are of considerable importance. Studying the literature on oxidation tests, we came up with 20 different procedures in a very short time; obviously, there are more methods than agreement.

TABLE 1

PERFORMANCE TESTS USED TO EVALUATE HYDRAULIC FLUIDS[a]

- Viscosity - ASTM D-445
- Acid number - ASTM D-664 (Armco Modified Procedure)
- Low-temperature cycling (United States Steel Procedure)
- Oxidation resistance
    - Inhibited oil oxidation - ASTM D-943
    - Rotary bomb method - ASTM D-2273
    - Oxidation stability (Federal Test Method 5308.6)
    - Cigre method (IP 280)
- Pump test - ASTM D-2882
- Corrosion test
    - Rust test - ASTM-665
    - Copper strip corrosion - ASTM-130
- Thermal stability (United States Steel Procedure)

[a] Factory mutual approval required on fire resistant hydraulic oils.

When we finally got things sorted out, we decided that a combination of the American Society for Testing and Materials (ASTM) D-943, the Federal Test Method 5308.6, and the Cigre procedure appeared to provide the most valuable information. We believe our blend of the three tests works well, but we are collecting more data to evaluate this. We have little interest in the ASTM test by itself because it requires so much time to complete, 1,000 hours or more. This is too long.

We also have the rotary bomb oxidation equipment but find it effective only as long as you test fluids made from the same basestock and having the same additive package. This test does allow you to measure variability within that system. However, in our experience it is not effective for comparing two products from different suppliers. If you find that a hydraulic oil will pass this test, it is a good oil. However, if the limits set for this test are too strict, you may find good oils failing it. So we use it for comparing oils of similar types, but not for comparison between various kinds of oils.

In our estimation, the most important test for hydraulic fluids is the pump test. Although ASTM says the test should be conducted for 1,000 hours at 1,000 psi, most people are actually using 2,000 psi at 100 hours, or something similar. It is somewhat surprising to us that Ford is testing for 1,000 hours, as to my knowledge we have never had a test continue for anywhere near that length of time.

Other tests which we consider of value in qualifying hydraulics are the copper strip corrosion test (D-130) and the rust test (D-665). Generally, most fluids pass these tests, which do not appear to be overly severe. However, by the same token, if a failure should occur, it is likely that the use of this oil will lead to system corrosion problems.

A large quantity of gear oil is used in our plants, and its quality is of extreme importance because of the value of the equipment it protects. When we started testing gear oil, the Environmental Protection Agency was requiring a change-over from leaded products to sulfur-phosphorus compounds. A natural question was whether they would be as good as the lead compounds previously used. Some of the tests used are shown in table 2. We also used some of the tests shown in table 1 as well. Our testing program indicated the sulfur-phosphorus compounds to be better than the lead-base products because of much better demulsibility characteristics.

TABLE 2

OTHER PERFORMANCE TESTS USED ON LUBRICANTS

- Falex wear ASTM D-2670
- Timken extreme pressure test ASTM D-2782
- Demulsibility characteristics ASTM-2711
- Foaming characteristics ASTM D-892

In addition to the previously discussed testing of hydraulic fluids and gear oils, the steel industry is faced with evaluation of many other lubricants including cutting oil, rolling oils, grease, and the like. Further, major efforts have been made to collect and reclaim as much of our fluid losses as possible, and these pose a whole series of additional problems. I would now like to discuss these briefly.

We are interested in reclaiming and even re-refining of our waste fluids. Our terminology is a little different than usual, as we use the word "reclaiming" for what other speakers frequently call "reprocessing." Our plants are scattered around the country, and each of them has different needs. Our centralized research efforts are aimed at doing what we can to help each of them. For instance, one plant exchanges its oil waste for re-refined oil, so it requires only a very crude clean-up system. One of our southern plants is not interested in recycling oils as fuel; they sell all their oily wastes. Some other plants have small programs where they catch the leak coming out of the machine, filter it, and put it back into the same system. We hope to have more of this in the future. At this point, however, our major reuse of reclaimed fluids has been for fuel.

Our two biggest plants have cold mills, and cold rolling oils contain about 50 percent fats. These are recirculating systems that are not only periodically dumped, but also leak. These oils are collected, along with products from other sources, and result in about two million gallons per year. It has been a part of our work to up-grade these reclaimed oils to that we can reuse them as a more valuable product than fuel. We have, in a few cases, been successful in these efforts. Our oil reclamation plant using heat, polymer additions, and vertical column clarification produces a final product with very little water and sediment. Consequently, this reclaimed oil has, on occasion, been used for hydraulic oil. In one particular oil reclamation system which is not contaminated with rolling oil and therefore does not contain fats, the reclaimed product is a good oil. However, we sometimes get kerosene into this system and suddenly we have 100 second hydraulic fluid with a flash point of 120°F. That is not acceptable at all. We also use reclaimed fluid for oiling coal in the production of coke. However, our primary aim is to up-grade our reclaimed fluids for use as hydraulic oils or gear oils.

Another possible use is for cutting oil, as we wind up with something like 10 percent fats in our final stream. Unfortunately, we cannot use that much cutting oil.

It also appears to be potentially good stock for making greases. We have made a few experimental batches, and it seems to be practical. Once again, however, we have not got enough waste to provide grease for everybody, let alone ourselves.

There is one more thing I should mention. We did take a serious look at using re-refiners. Unfortunately, there are no re-refiners near many of our plants. By the time we consider the value of the reclaimed oil as fuel, transportation costs to and from the re-refiner and his fee, it is not economical at this point in time. It appears that such processing is possible, but costs are too high.

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DISCUSSION

SESSION III. RECYCLED INDUSTRIAL AND HYDRAULIC OILS

Session III had five presentations which covered descriptions and uses of test methods for industrial oils and hydraulic oils, a survey of different types of industrial oils and additives for industrial and hydraulic use, and descriptions of industrial and hydraulic oil recycling at the Chrysler Chemical Division and the Ford Motor Company. Discussion during this session produced estimates of the volumes of used oils generated from metal-working lubricants as approximately 500 million gallons per year (the largest industrial oil category) and of hydraulic fluids as approximately 240 million gallons per year.

A statement mentioned repeatedly in the discussion concerned the greatest problem in increasing the level of recycling for industrial and hydraulic oils, that of in-plant segregation of the various oils. This is most difficult in older plants which have not been designed to have separate internal waste screening and which use a variety of different types of oils (e.g., cutting oils and hydraulic oils) in high-leak systems. Because of the recent increases in virgin oil costs, most new plants are including in the design facilities to help in the segregation of these oils. Since recycling of used oils is much more economical and reliable if the re-refiner or processor is able to start from a single type of oil, these decisions as to used oil segregation are being justified on a cost-effectiveness basis.

Another area of discussion was in the final disposal of used oils which are not segregated and which often, therefore, end up as a conglomerate mixture. Most discussers acknowledged that when they had no other economic way to dispose of them these oils were burned for fuel to recover the energy content. Estimates as to the various percentages recovered for reuse as a lubricant ranged from approximately 20 percent to over 80 percent. A question was also asked as to whether there were particular difficulties with using waste industrial oils for fuel, since some of them contain fatty components, chlorinated compounds, or high-sulfur contents. The response indicated that for use in coal-burning power plants, either mixing with the coal or spraying on to the coal, this was no problem. Many types of oils can also be mixed directly into the virgin fuel oil and be burned in fuel oil burners. One person discussed a problem that arose when used cutting oils containing metal fines tended to erode the burner nozzles and cause extensive buildup of deposits in the combustion chambers.

Several people reported using several types of industrial oils interchangeably in order to eliminate contamination of one with the other. For example, in some construction equipment, an engine oil is used in the hydraulic system in order to have compatible oil systems. In another case, a recovered material which had only minor reprocessing was blended with a virgin hydraulic oil and reused in a high-leakage hydraulic system. Since the residence time in this particular hydraulic system was rather short, it was felt that these oils were more than sufficient for that particular service.

Several industrial companies which engaged the services of re-refiners to separate and re-refine their industrial oils essentially tell the re-refiner what type of industrial oil they wish to have back. Since the re-refiner produced, in effect, a basestock material, it is primarily the additive package and the eventual use which determine whether the product is satisfactory or not. Apparently, from the discussion, many plants are using internally reclaimed or externally reclaimed or re-refined industrial oils, either blending with virgin oils or in systems that have been evaluated with these types of oils.

There was a great deal of discussion on the oxidation stability tests used in evaluating both virgin and re-refined oils, and a great deal of antagonism surfaced towards the 1,000-hour American Society for Testing and Materials (ASTM) D-943, Test for Oxidation Stability of Steam Turbine Oils. Most large companies have apparently devised their own bench oxidation test and, thus, seldom use the D-943 method. It was stated that many of these bench tests apparently correlate well with plant operation, and obviously their actual operations requirements are the primary criteria which need to be met. Some of the conditions that were varied in order to increase the severity of oxidation tests include raising the temperature to 135°C (275°F) or 160°C (325°F), using oil soluble metal catalysts, or sometimes to bubble oxygen gas through the oil instead of air or no gas. Particular measurements which are taken during or at the end of the test include percent weight loss due to the volatility of light ends, viscosity increase, sludge formation, etc. Everyone seemed to be agreed that an effective replacement for D-943 would be very welcome for evaluating industrial oils.

Another area of discussion was on the suitability of re-refined crankcase oils for industrial uses. The consensus of the discussion seemed to be that a fully re-refined crankcase oil was essentially a high-quality base oil and could be formulated to meet any number of high-quality industrial oil specifications, including hydraulic oils, various lubricating oils, and cutting oils. It was also expressed that once the higher-quality lube oils were contaminated with the lower-quality oils such as press oils and rolling oils they could still be reclaimed for primarily lower-quality uses such as the metal-working oils.

The question was raised as to what effect the National Bureau of Standards' (NBS) Recycled Oil Program and the Federal Trade Commission (FTC) would have on the closed-loop recycling or re-refining. The reply was that the NBS program probably should not affect in-plant processing or re-refining at all. Since these products, in effect, do not reach the open market, it was felt that they would most likely not be considered by the FTC under any trade regulation requirement developed in response to the NBS test procedures.

In conclusion, comments by a speaker who was former chairman of the ASTM D-2 Committee on Petroleum Products and Lubricants (and is now a member of the ASTM Board of Directors), as well as by other participants in the meeting, strongly encouraged NBS to use ASTM to assist in helping develop needed test methods and specifications. It was noted that almost all of the methods listed by previous speakers were ASTM test methods, and it was hoped that this would continue in the area of recycled oils also.

The session discussion closed with a statement that the most important specification for industrial and hydraulic oils is that they must work well in the particular system in which they are to be used.

SESSIONS IV AND V

RECYCLED ENGINE OILS

National Bureau of Standards Special Publication 488. Proceedings of
a Workshop on Measurements and Standards for Recycled Oil held at NBS,
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DOD EXPERIENCES IN TESTING LUBE OILS

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Today I will review the Environmental Protection Agency (EPA)/Department of Defense (DOD) program on re-refined oils, make some general comments on military engine oil specifications, and discuss some limited experience the Army has had with re-refined oils. The major portion of the time I would like to spend on the EPA/DOD re-refined oil program.

Essentially, the program consists of looking at the quality of re-refined basestocks and their ability, once formulated, to meet specification requirements. This will involve the following steps. First, samples of re-refined basestocks will be collected. These are the basestocks themselves, not fully formulated oils. Second, laboratory analyses, i.e., standard American Society for Testing and Materials (ASTM) procedures, will be used to look at various aspects of the basestocks such as physical characteristics, re-refining levels, and composition. Hopefully, from this we will be able to categorize the stocks. Initially, it was envisioned that three or four different categories (good to poor) could be obtained. This may or may not be possible. You could also end up with two categories: one category where oils would not be considered for any further portion of the program, and another category where it would be considered feasible to treat the oils with additives to produce a fully formulated engine oil.

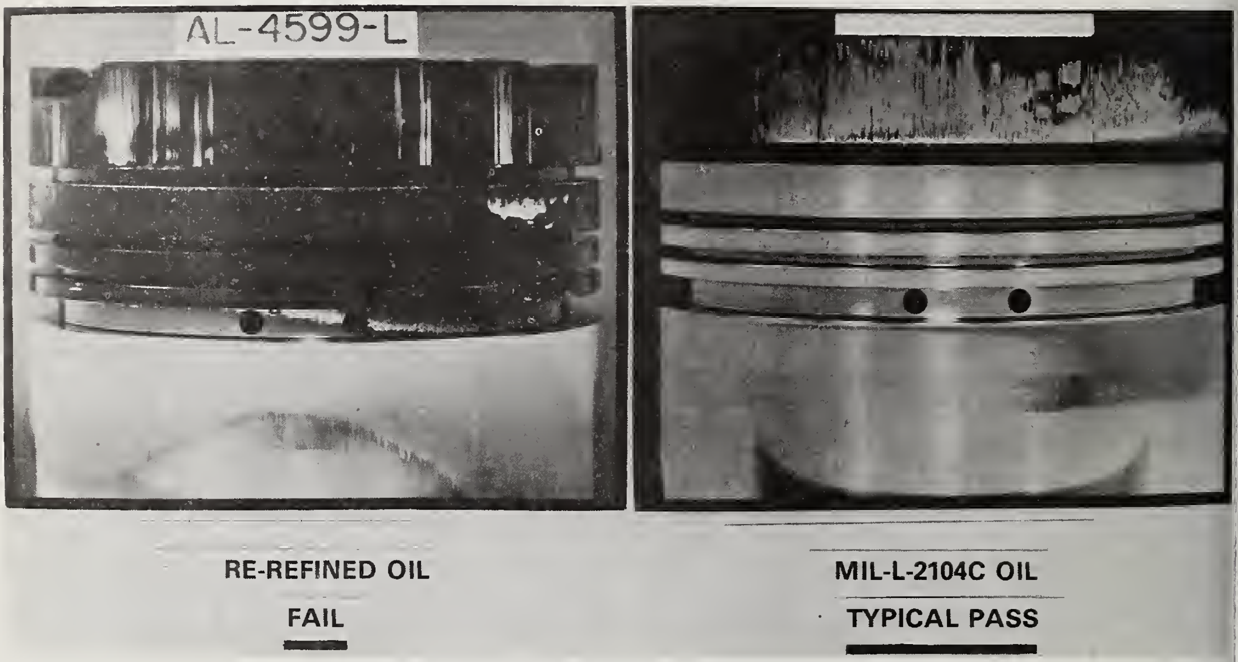
In the third portion, we will blend the basestocks with additives and conduct specification performance tests. These will be the laboratory engine tests, set forth by MIL-L-46152. Also, a portion of the program calls for evaluating the field use of re-refined products. However, this does not involve the oil previously discussed. We have contacted the City of San Diego and are trying to work out a program to examine vehicles they have operated for approximately two years on a re-refined engine oil. This is intended to generate some field-performance and tear-down inspection data on vehicles operated on re-refined oils.

At the present time, we have 15 samples of basestocks. These have been forwarded to the U.S. Army laboratory in San Antonio for chemical and physical analysis.

I now want to spend a little more time on the analyses. As I previously stated, we will be looking at the physical properties, the re-refining levels, and the composition of the oils. We will be using standard ASTM tests for this work. Tests will include physical properties, i.e., viscosity, API gravity, color, pour point, flash point, etc., of the oils. We are not going to address the validity of these tests for re-refined oil. We will also be examining the re-refining level using tests such as the neutralization number, carbon residue, total ash, and insolubles. The composition will be evaluated using tests for aniline point, characteristic groups by clay-gel absorption, boiling point distribution, and heavy metal content, both wear metals and additives.

From the Army's standpoint, we would like to demonstrate that you can re-refine an oil, treat it with additives, and produce a product of acceptable performance. Also, we would like to show that you can get some variation with re-refined products. In plain words, two different basestocks treated with the same additive may not necessarily give the same results. The Army believes strongly in the performance-type specification which uses the sequence tests. In addition to these sequence tests, we feel other items are required such as specifying a given viscosity class, compatibility with other oils, pour requirement of the oil, etc. At the present time, we undoubtedly are the "bad boys on the block" because our specifications state that re-refined oils are not allowed. It is not that we do not believe the technology and the capability are there to do the job. However, from past work we have seen less than satisfactory performance from marketed re-refined oils.

In 1972, the Army purchased two re-refined products on the retail market and subjected them to the 1-G diesel performance test. I feel this shows the concern that we had within the military towards re-refined oils. The photographs shown in figure 1 compare the typical pass results for our combat and tactical lubricating oil specification MIL-L-2104C with one of the re-refined oils that was tested. You can see the re-refined product allows excessive deposits. We feel an oil of this quality would create a serious problem if it were fielded in our equipment.



RE-REFINED OIL
FAIL

MIL-L-2104C OIL
TYPICAL PASS

Figure 1. 1-G diesel performance test results comparing a re-refined oil with a MIL-L-2104C oil.

The second re-refined oil tested was in essentially the same condition as the first, but was not labeled as such. One product failed all tests, and the other product passed only the bearing corrosion test. Since the first product was labeled MIL-L-2104C in large letters and in smaller letters "CC-CD" and "SD-SE," as a consumer I would gather this oil was fully compounded and satisfactory for use in high-performance diesel and gasoline engines. The test data do not substantiate this. It is not known if these oils were representative of re-refined products in general, and, therefore, one can only draw conclusions concerning the samples tested.

Where do we go after we finish the program? From our standpoint, we feel there is still more work to be done. Even though we may demonstrate that an oil can be formulated and will give you satisfactory performance in the tests, there has to be a method for controlling the product from batch to batch. At the present time, to meet military specifications the base oil must come from the same source and the same refining treatment must be used. For a re-refined product, this would require testing of every batch of oil produced, which from the re-refiners' standpoint is neither satisfactory nor economically feasible. Therefore, you would have to try and work data from this program and, hopefully, the data which the National Bureau of Standards will be generating in its program into some type of alternate method to accept and control re-refined oils.

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WASTE OIL RECYCLING--AN IDEA WHOSE TIME HAS COME

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A research project to investigate re-refining of used crankcase oil conducted for the U.S. Energy Research and Development Administration at the Bartlesville Energy Research Center (BERC) is described with past accomplishments and planned goals. Technology developed at BERC during the course of this investigation restores used oil to original quality through a vacuum-distillation procedure that depends upon a solvent pretreatment to reduce thermally activated coking and fouling precursors. The process produces high yields of high-quality oil with essentially neutral by-products that should be easy to dispose of in an environmentally acceptable manner. Engine-performance data have been obtained on two oils reclaimed with BERC-developed technology and a commercially re-refined oil with largely successful results. Studies are described that define the hydrocarbon composition of typical re-refinery feedstocks for evaluation of geographical and seasonal differences. The major hydrocarbon composition of each of 30 feedstocks strongly suggests that the feed to a re-refinery is sufficiently uniform to produce consistent products with reasonable quality-control measures.

Plans are presented for future composition studies, increased in-house processing capability, and the production of 1,000 gallons of reclaimed oil from the BERC process. Fleet tests, currently in progress in the State of Iowa, to evaluate the quality of the oil and the potential savings represented by the use of re-refined lubricating oil in State-operated motor vehicles are outlined.

Introduction

For years, most commercial, industrial, and governmental agencies considered the dirty, black oil drained from automobile engines as a waste product and a nuisance, to be disposed of. Now, however, with the increasing realization that the Nation's supplies of petroleum are limited and dwindling, used oil is being looked upon not as a waste product, but as a valuable resource which can and should be recycled and reused.

In order to determine the significance of this resource, an estimate of the volume and type of used lube oil that is potentially available is needed. Since there is no systematic inventory of used lubricating oil in this country, the volume of available used oil must be estimated from the quantity of new oil that is sold.

More than two billion gallons of new lubricating oils of all types are sold annually in the U.S. According to recent U.S. Bureau of Mines data, the total lubricating oil demand in 1974 was 2.4 billion gallons. Of that total amount, 49 percent is sold for automotive use, 1.7 percent is purchased by the government, and the remaining approximately 49 percent is divided among industrial, electrical, railroad, aviation, and like oils.

Scarcely any quantitative information is available as to the ultimate fate of this lubricating oil. However, reasonable estimates suggest that about 1.2 billion gallons of used oil are generated annually in the U.S. About half of the lube oil sold is lost or consumed during use, and 1.2 billion gallons salvaged, 60 percent from auto waste and 40 percent from industrial waste.

How significant is 1.2 billion gallons per year of used oil? It might be easier to make comparisons if we convert gallons to barrels, the unit commonly used in the petroleum industry. This quantity, 1.2 billion gallons, equals 28.5 million barrels. This is enough oil to heat and cool 675,000 homes or operate 1,350,000 cars for a year. Further, each barrel of used oil recycled saves a barrel of imported oil.

An often-stated, near-term conservation goal is to reduce oil consumption by one million barrels per day within the next five years. If all used lube oils were recycled and reused, that one effort would exceed five percent of the stated goal.

Perhaps of equal significance to the conservation aspects is the pollution potential of the large quantity of used lube oil generated annually. Uncontrolled disposal of used oil causes severe environmental damage. Used oil poses the greatest potential damage to the environment through ground-water and stream contamination, but its heavy-metals content makes uncontrolled burning equally undesirable.

The fate of the 1.2 billion gallons of used oil can only be estimated. Approximately 43 percent is burned; 18 percent is used for road oil; 31 percent is unknown; and, unfortunately, less than 10 percent is being re-refined.

The idea of re-refining used oil is certainly not new, and the re-refining industry was quite active in the years following World War II. By 1960, there were about 160 re-refining companies in the U.S., with a combined annual capacity of about 300 million gallons.

Since that time, the re-refining industry has declined to fewer than 30 companies today. There are many reasons for this decline--economic, technological, environmental and political.

Prior to 1965, re-refiners enjoyed an excise tax rebate on sales of lubricating oil for off-highway use, which is a major market for re-refined oil. The tax rebate was removed in 1965, and subsequent rulings by the Internal Revenue Service have changed what was formerly a tax advantage into what the re-refiners now consider a tax disadvantage.

Re-refiners claim that they have been placed at a further competitive disadvantage by the 1964 Federal Trade Commission ruling that oils sold in interstate commerce which are compounded in whole or in part of re-refined oil must be labeled as "Manufactured from Previously Used Oils." Re-refiners say that this label unfairly brands all re-refined oils as inferior products.

Most re-refiners have limited resources to develop improved process technology or to construct new facilities. Also, because of increased environmental awareness, the disposal of re-refining wastes has become more difficult and more costly.

Several approaches toward revitalizing the re-refining industry are now being pursued. Legislation has been introduced at both the national and State levels which is intended to encourage the re-refining of used oil. On the national level, Representative Vanik of Ohio and Senator Domenici of New Mexico have introduced oil-recycling bills into their respective branches of Congress. Neither of these bills progressed very far through the Federal law-making process. However, the Energy Policy and Conservation Act, which was signed into law last December, contains a section on recycled oil which incorporates some of the provisions of the Vanik and Domenici bills and does encourage the use of recycled oils.

On the State level, oil-recycling bills have been introduced into several State legislatures, including New York, California, Wisconsin, and Illinois, to name but a few.

Now, let us turn our attention from the legislative area to the research and technology areas.

Experimental

The Bartlesville Energy Research Center has been involved in a research project on re-refining of used crankcase oil for several years. One phase of this research has been the development of improved re-refining technology. A basic philosophy of this research has been that the best method of reclaiming used oil is one that effectively removes impurities but does not substantially change the hydrocarbon composition of the oil. The method which has been developed, and for which a patent is pending, includes dehydration to remove water and gasoline and solvent treatment with a mixture of alcohols and ketones to precipitate coking precursors followed by vacuum distillation. Color and odor are improved by clay or hydrogen treatment. This process produces equal or greater recovery of re-refined oil and a smaller quantity of by-products than the commonly used sulfuric acid-clay process. The by-products that are produced are less hazardous and should be easier to find alternate uses for or to dispose of than sulfuric acid sludge. Re-refined oil produced by the solvent treatment-vacuum distillation method is equal if not superior in quality to that produced by the acid-clay process, and oils produced by this technology have shown some success in passing engine-performance tests (1).[1] Although initial economic studies look promising, they have not yet been fully investigated.

Another phase of the research has been to determine if there is a significant and serious variation in the used oil feedstocks to re-refineries.

A question that has concerned re-refiners for many years is whether or not there is so much variation in the feedstock to a re-refinery that a consistent and quality product cannot be produced. Some authorities claim that each truckload of used oil delivered to a re-refinery presents a different feedstock, and, therefore, a potential difference in the quality of the re-refined product. Others have suggested the possibility of geographical and seasonal differences in used-oil feedstocks which would affect the quality of the products. In order to investigate these questions, 30 samples of used automobile crankcase oil typical of re-refinery feedstocks were obtained from 25 different locations in the U.S. Duplicate samples were obtained from five of the locations at different times of the year to check for seasonal variations.

The major hydrocarbon composition of each of the 30 used oils was determined by separating each of the oils into four fractions by adsorption chromatography and analyzing the fractions by mass spectrometry. Comparison of the composition data from the 30 used oils indicated great similarity in the hydrocarbon composition regardless of the regional or seasonal origin of the oil (2). This study strongly suggests that the feed to a re-refinery is sufficiently uniform that consistent products can be produced by re-refineries with reasonable quality-control measures in the plant.

A third phase of this research project compared commercially re-refined oils with new oils in a number of laboratory bench tests, most of which were standard American Society for Testing and Materials test methods. Some of the re-refined lubricating oils purchased on the open market contained no additives and therefore could not pass such tests as foam, corrosion, wear, and oxidation (3). Other re-refined lubricating oils provided by the re-refiners and formulated to meet American Petroleum Institute service classification SE could not be distinguished from new oils by these bench tests; however, several failed one or more of the tests, indicating the need for better quality control in the re-refinery (4). Since the results of bench tests do not always correlate with the results of engine-performance tests, bench tests are not completely definitive in measuring the quality of an automotive lubricant; therefore, conclusions for equivalency based on bench tests await additional research.

Engine-performance data have recently been obtained on three reclaimed lubricating oils. Two oils reclaimed from used automotive crankcase drainings by BERC-developed technology and one commercially re-refined oil were subjected to standard bench tests and engine-test sequences to measure the quality of these oils (1). A commercially re-refined SAE 20 automotive lubricating oil successfully passed the IIC, IIIC, and VC engine-test evaluations that are required by automobile manufacturers to meet the standards established for service SE and also the L-38 test required by the military to meet the major requirements set forth in MIL-L-46152 specifications. One BERC-produced sample passed both IIIC and VC sequence tests and failed the IIC marginally. Another BERC-produced oil successfully passed the IIC and IIIC test and failed the VC marginally. Both oils passed the bench-scale L-38 test, which we understand correlates quite well with the large scale L-38 test.

This study is believed to be the first documentation in the U.S. of successful passing of engine-sequence tests by re-refined lubricating oils to meet standards established for service SE and/or military specifications. Success in these tests does not constitute qualification in these categories as this status is granted by an evaluation board and such qualification was not the purpose of this study. Rather, these tests were run to establish the capability of producing quality products from used lubricating oil feedstocks, and such capability now has been established.

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[1] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

In addition to these engine tests, fleet testing of recycled oil produced by BERC technology is being conducted in the State of Iowa. Vehicles operating with virgin lube oil, commercially re-refined, and BERC-processed oil are in their 4th month of a 24-month test program. Dip-stick samples are being taken and detailed analyses completed on the used oil drained at selected intervals. At the end of this 2-year, carefully monitored program, 10 engines will be disassembled to evaluate their condition and to determine any significant differences attributable to the oils used.

Proposed goals at BERC for fiscal year 1977 include a scaled-up pilot-plant operation to produce about 1,000 gallons of reclaimed oil using BERC-developed technology. This product will be used in the evaluation of modified processing and polishing procedures and to obtain further engine-test data. In this regard, some measure of in-house capability for processing is being achieved with the installation of a full vacuum fractionation tower with a throughput capacity of about five gallons per hour. This equipment plus reactors, appropriate tankage, and a solvent stripping distillation unit should provide the in-house capability required to evaluate parameters associated with converting the BERC technology from a batch process to a continuous process.

Another study being initiated is an extension of the composition studies which have been performed and reported. This investigation is basically a composition study on used automobile crankcase drainings generated in a closed-loop experiment. Specifically, virgin stocks will be blended into a finished 10W30 lube oil and the composition of the basestock determined. A fleet of automobiles will then be employed to accumulate about 4,000 miles using the blended oil. The drainings from this fleet will be reclaimed using BERC technology and the composition study repeated on the reclaimed products. This cycle will be repeated once more to compare compositional changes occurring in the oil resulting from both use in the automobile fleet, and also in processing after one and two complete cycles of use and reclamation. The benefits to be derived from this study are the assessment of compositional changes and the correlation of these changes with any marked improvement or detriment to oil quality that occur.

Conclusions

It appears that the turn in the road has been reached for the reclamation of used lubricating oil. In spite of the decline over the past decade of the re-refining industry, waste oil recycling is an idea whose time has come. Conservation of our petroleum resources is likely the strongest driving force in the turnabout for recycling. The development of improved technology through both government and private research should have the end effect of stimulating a depressed industry. Higher prices of virgin crude oil make the economics of recycling more attractive, and with higher profits will come increased activity in re-refining operation. And, too, recent legislation which emphasizes increased use of recycled oil must be an important factor. Finally, environmental concern should soon reverse the trend toward burning and dumping used lubricating oils and channel more feedstock to the re-refiner. The day might well come in the foreseeable future when much of the used lubricating oil presently discarded, burned, poured upon rural roads, or otherwise wastefully disposed of will be reprocessed for continued use as a lubricating oil--not once or twice--but many times.

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COMMENTS ON ADDITIVE RESPONSE TO DIFFERENT BASE OILS

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The point that I would like to make in this short presentation is that I do not believe that anybody knowledgeable in the industry doubts the fact that an oil can be re-refined and formulated to pass the engine sequence tests. I do not know of anybody who doubts this. The data I want to present are not on re-refined oils; they are on virgin base oils. The four oils shown in table 1 are all from major oil companies; they are all solvent refined oils. From our capability after long years of experience, we could not tell that any of those four oils were not the same as the others as far as performance is concerned. But, you will notice the first three are passing and the fourth one is a bad fail. We are not talking about test precision here; oil D is a bad fail. They all have the same dispersant-inhibitor in them.

TABLE 1

BASESTOCK RESPONSE

Oil company	Sequence VC piston varnish
A	7.9
B	8.0, 8.0
C	7.9
D	6.7, 7.2

All major oil companies
All run with same dispersant-inhibitor
All virgin solvent refined basestocks

Here is another case. In this case, there are only two oils (table 2). We do have more data on them than the VC; however, notice the very drastic differences--differences in all three tests. (I believe Mr. Kabel will agree that an 8.8 to a 6.0 is a very great difference.) The difference between a solid oil at 64 hours and a 90-percent viscosity increase is significant. I just wanted to make the point here, again, that passing the sequence test with 1, 2, 3, or 10 oils and a given additive treatment does not prove that you are not going to get an outlier sometime; and I seriously doubt that there is any physical or chemical bench test that is able to pick out the differences between these kinds of oils with acceptable precision.

TABLE 2

BASESTOCK RESPONSE

Oil company	Sequence VC	Sequence IIC	Sequence IIIC	
E	7.7	8.8	40 h	33 %
			64 h	91 %
F	6.0	6.0	40 h	124 %
			64 h	solid

Both major oil company virgin solvent refined oils
Both run with same dispersant-inhibitor additive

My only additional comment is that after 10 years experience at Gulf Oil Corporation, from the oil company standpoint, and after 30 years experience in additives, we have not found any way of characterizing a basestock to know what it will do from a performance standpoint. There have been a lot of people who have tried; you get a lot of young engineers who believe that they can set up a bench test that would screen them. We give them the opportunity to find out, and I do not know of any who have been successful. We end up by putting them in an engine and running them. If they do not work, we reformulate, we increase the additive, we change the blend, we do something. Believe me, speaking for this additive company--and I was talking to Dr. Peter Asseff of Lubrizol at lunch and he agreed--we would all like very much to have some way of doing this to save the tremendously time-consuming and costly evaluations that we have to go through. If I had been collecting information on this subject over thes 40 years, I probably could have had several hundred examples like this. These that I gave today just happened to be two that we found within the last three months in our work.

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ACTIVITIES OF THE ASTM USED OIL TASK FORCE

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Today I plan to give a brief discussion that will cover (1) where the Task Force fits in to the American Society for Testing and Materials (ASTM) organization, (2) what is the objective of the Task Force, (3) what we have done to date, and (4) the expertise we have currently on the Task Force to give you a feel of what we can do and probably cannot do.

To start with, the title "ASTM Used Oil Task Force" is probably very misleading because it implies a much broader scope for our work than I feel we actually have. The location of the Used Oil Task Force is in the ASTM organization within Committee D-2 on Petroleum Products and Lubricants and, under that, in the Product Committee, Technical Division B on Automotive Lubricants, and then further into Section 1 of the Technical Committee B which is concerned only with gasoline engine oil. Therefore, our scope is essentially limited to the engine oil area.

The objective of the Task Force is to provide technical expertise and assistance in the engine oil area to the Environmental Protection Agency (EPA) and to the National Bureau of Standards (NBS) to aid them in carrying out their respective charges. The reason the Task Force was created was from a request from the EPA, which at the time came from Mr. Larry McEwen.

To date, we have had two meetings. The first was with the EPA and the Department of Defense to discuss their proposed program to characterize re-refined oils and evaluate them as fully formulated engine oils. This is the program that Mr. Thomas Bowen just discussed. The second meeting was held with EPA and NBS to review these programs that are currently being started. In the interim, the EPA program was transferred to Hazardous Waste Management under Mr. Hugh B. Kaufman as Project Manager.

Finally, the membership of the Task Force contains the following representation. We have additive suppliers represented, car makers, re-refiners, engine builders, petroleum refiners (including the American Petroleum Institute), military approval agencies, the Energy Research and Development Administration, the National Research Council of Canada, consultants, the Defense Fuel Supply Center, and, of course, NBS and EPA.

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ACTIVITIES OF THE API USED OIL TASK FORCE

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I appreciate the invitation to participate in this program. I think it is a good one. Any time a complicated subject like this can be discussed among various interests with interchange of ideas, I think it is a step in the right direction.

My interest this afternoon can be stated very simply. I wish to relate to you what the American Petroleum Institute (API) has been doing in the area of waste oil for the past 10 years, or so; also, what it is doing now and what its general viewpoint is on the overall subject of used oil.

Let me move back in time about 10 years, to the late 1960's, and discuss a problem which we think is virtually non-existent today, i.e., that our member companies were experiencing serious problems with their service stations in having drainings picked up. I think if we look at the economics existing 10 years ago, we can see why this was a problem. It is hard to realize now, but heavy fuel oil was selling for $0.06 per gallon and commodity lubes were selling for less than $0.20 a gallon. As a result, very few people, with the exception of the re-refiners, had very much interest in used oil, and it was simply treated like garbage, at best. A lot of it was getting into the waterways, which was an outrageous situation. It became so serious that the API took it upon itself to try to find a solution to the problem and spent quite a bit of time doing so. One of the first things that the Institute did was to determine how great the problem was and to find out where the oil was really going--what disposal methods were being used. I do not have the time to go into all the work that was done during these studies, but I think a few highlights are in order.

First of all, in looking at the extent of the problem, we did find that, in fact, it was a big problem. Based on our own surveys and those of others, particularly the Arthur D. Little study of 1969, we estimated about 40 percent of automotive used oil was being disposed of in a questionable manner or in a downright harmful manner with regard to the environment. Of course, this figure of 40 percent translated into several hundred millions of gallons a year, which was an outrageous situation.

Secondly, the investigation showed that the other 60 percent of the oil was being disposed of by burning, by being re-refined, or used as various forms of dust control. For a number of reasons, some of which are still valid today, the re-refining industry was judged to be unable to consume all of this used oil, even that from service stations alone. So, the API took upon itself to find alternative means of disposal. Burning looked like a reasonable alternative simply because you could extract the very high heating value that we talked about today. In an attempt to further clarify the question of whether a used oil could be burned as a viable method of reuse, the API, in 1974, planned and undertook a study at the Hawaiian Electric Company. Since this represented one of the largest efforts of API in the area, I think it merits a few minutes discussion.

By way of a little background, the Hawaiian Electric plant was an ideal test vehicle because it had burned used oil for a number of years with no mechanical problems. They were used to handling it and had the proper facilities for handling it. The unit itself, of course, was a boiler, normally firing No. 6 fuel oil, and it generated 20 to 50 megawatts of power; so, it was a moderate-sized plant. No special pollution control equipment was installed. The testing that the API undertook was over a five-day period in January. The first day and the last day, No. 6 fuel oil alone was burned to obtain baseline values; and, during the intervening three days, various percentages of waste oil (primarily crankcase oil) were burned in the range of 6 percent to 15 percent. Some of the major findings were: (1) about half of the lead was determined to remain inside the boiler, and this has been, I think, the same figure that other people have found, with only half of it being emitted into the atmosphere; and (2) the estimates of atmospheric dispersion of the lead that was emitted were calculated based on equations published by the Environmental Protection Agency (EPA), taking wind direction and normal averaging times into account. The ground level lead concentrations were estimated to be below two micrograms per cubic meter, which, at that time and I think probably still, is below the proposed ambient air standard for lead. This was true even under soot-blowing conditions, when the emissions were higher. I think it is important to note, again, that used oil was burned at the rate of 6 percent to 15 percent of the fuel. The reason I say that is important is if you take all of the waste oil in the U.S. containing lead and blend it with all of the No. 5 and No. 6 fuel oil consumed in the U.S., the ratio would be only about 1-percent used oil. So, we feel that, although you cannot distribute all the lead-containing used oil evenly, you probably can work on a practical basis of perhaps 2 percent to 3 percent. We think, however, burning should take place only where economics dictate that re-refining or some other alternative is just not the better way to go.

All this preceding discussion dealt with what API has done in the past to look for ways of keeping used oil, primarily crankcase oil, out of our waterways. The other half of the problem is the industrial oil, which we have talked about considerably today. Metal-working fluids, hydraulic oil, and other lubricants--these, of course, eventually become used oil also. We think the answer to this situation is fairly simple, and that is that economics are forcing a fair amount of these products to be recycled now. One of our member companies did a study to dictate why this was happening. Although some of these economics I am going to discuss (table 1) will not agree with some of the ones you have heard today, I think in the cases where the used industrial oils are of low additive formulations, these are the economics at which we are looking. We have looked at this over a period of years, going back in time to 1972, which, of course, was a pre-Arab embargo year (pre-escalating of the crude oil price by the Oil Producing and Exporting Countries [OPEC]. You see that probably on an average lubes were costing about $0.39 a gallon, while low-sulfur fuel oil was costing about $0.11 per gallon. The user who consumed both lubes and fuel, of course, had a choice of what to do with the material: reclaim it or consume it himself. We feel that for some of the low-additive materials, with proper equipment, he could reclaim it for $0.20 to $0.30 per gallon, which gave an incentive for reclaiming, for lube use, of about $0.09 to $0.19 in 1972.

TABLE 1

INDUSTRIAL CUSTOMER'S INCENTIVES FOR RECLAIMING WASTE OIL

	cents/gallon					
	1972	1973	1974	1975	1976	1980
Industrial lube, average FOB cost	39	41	70	75	79	94
Cost of reclaiming from survey	(20-30)	(20-30)	(20-30)	(20-30)	(20-30)	(20-30)
Incentive for reclaiming[a]	9-19	11-21	40-50	45-55	49-59	64-74
Low S HFO, average FOB cost	11	15	30	30	30	40
Cost of cleanup or maintenance	(1-5)	(1-5)	(1-5)	(1-5)	(1-5)	(1-5)
Net value of waste oil as fuel	6-10	10-14	25-29	25-29	25-29	35-39
Delta savings in reclaiming over burning	(1)-13	(3)-11	11-25	16-30	20-34	25-39

*First year incentive. Sun, Keene, and others indicate waste oils can be reclaimed up to 10 times, depending on the type of waste oil.

The other alternative was to burn it as fuel. Although in the case of Hawaiian Electric and many other reported instances there were no problems with maintenance, a reasonable debit for burning might have been $0.01 to $0.05 per gallon, mostly to get rid of the water. So, the value of the waste oil for fuel is the difference between the cost of virgin fuel and the debit or $0.06 to $0.10.

Faced with these two alternatives, the choice of which way to go is based on the difference between total costs and total sales price. In 1972, this was anywhere from -$0.01 to, perhaps, as high as +$0.13 per gallon. I do not know what the average was.

But look at 1976, this year. We are looking at a $0.79 average price for virgin lube because of OPEC's escalation in crude price; we are looking at a much higher fuel cost, perhaps $0.30 per gallon for a low-sulfur fuel oil. Following the same line of economic argument, we see that the incentive for reclaiming industrial oil is now up to about $0.49 to $0.59 a gallon versus a net fuel value of only $0.25 to $0.29. We think this is the reason why many companies are reclaiming, particularly those that are using low-additive lube oils. They are not burning them. We have heard some of this spoken about today.

I do not think anybody is smart enough to know what 1980 is really going to look like, but one scenario has it looking like this: again, an escalation on lube prices, perhaps as high as $0.94 a gallon, fuel up perhaps as high as $0.40 a gallon. Here we see an even higher incentive for reclaiming industrial lubes. So, we feel that reclaiming is going to grow even faster, even with some probable increases in costs for reclaiming.

This reclaiming is taking place both within the users' plants, as well as by outside reclaimers. Many of these outside reclaimers are re-refiners or ex-re-refiners. There is one story about one such reclaimer, a very successful one, who is helping to recycle about 12 million gallons per year of industrial lubes. Even though it is in a house organ, you might be interested in reading about his story. (Editor's note: "The Second Time Around," Wallover Oil Company, Exxon Oilways, No. 4, 1976.)

I think without too much of an over-simplification you can put used oil into three distinct categories in discussing them in terms of today's environment. These three are: (1) used industrial oils, (2) used commercial crankcase oils and service station drainings, and, finally, (3) used oil removed from engines by do-it-yourselfers. We think that in the majority of industrial lube applications economics are going to force reclaiming to a maximum extent in the future--not burning, but reclaiming for lube use.

Some problems still remain with heavily compounded oil such as gear oils and semiliquid greases, but we think most industrial lubricants can be reclaimed and money can be made doing it. We also believe that, with a very few exceptions, used commercial crankcase oil and service station oil are being "recycled," either for lubes or fuel. The value is simply too great these days to throw it away by dumping it in the environment.

The third category, do-it-yourself drainers, remains a very serious problem. Many attempts are being carried out right now; and I think there are just too many people trying to work on the problem for it not to improve, including Federal agencies, State governments, re-refiners, major oil companies, and civic groups. As chairman of the API group most heavily involved in the used oil area, I hope to be able to propose in the near future a program for API and its various member companies to undertake that would help in overcoming this important problem.

This latter point brings me to the last part of my story -- what API is doing now and what its overall position is in regard to used oil. First of all, in addition to trying to work this problem of the do-it-yourself drainer, we feel that the API can be of the most use in the overall area by contributing its expertise and counsel to those who are charged with finding solutions to the problem. This means, of course, primarily working with government agencies which by mandate under the law have to find some type of solution. We have been doing this to a certain extent in the past few months. We hope to accelerate this and continue it in the future.

Our final statement is this. API has not yet taken a public, formal position on many aspects of used oil management. But, I think I can state without fear of contradiction that its members subscribe to two basic concepts. One is that used oil represents a resource that should be conserved and should be recycled; but, we also feel that any economic recycling method should be allowable as long as it is not dangerous to the environment. We do not feel at the present time that burning is dangerous to the environment.

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CHEVRON RESEARCH'S EXPERIENCES WITH RE-REFINED OILS

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Today I want to show you data generated about a year ago on a program that we at Chevron Research carried out.

About a year-and-a-half ago, we became very interested in the possibilities of marketing a re-refined motor oil, initially at the service station level, which would be an SE or SE/CC type oil. So, we began looking at different samples of lube oil that came out of a re-refining company (Company A) with which we were working. These results are found in table 1, and I think this will add a little more data to the Energy Research and Development Administration/Bartlesville information. You see over approximately one year, perhaps somewhat over a year, some physical analyses of nine samples of basestock from the re-refiner. If you look at the values, there are not many changes. It looks surprisingly uniform and consistent. You can see that the viscosity at 210°F is about a 63 or 64; so, it is a reasonable starting material for an SAE 30 motor oil.

TABLE 1

TEST RESULTS ON RE-REFINED BASESTOCKS FROM COMPANY A

	Sample number								
	1	2	3	4	5	6	7	8	9
Gravity, °API	28.5	--	--	--	--	--	--	--	--
Flash, COC, °F	450	450	415	440	460	460	400	465	465
Viscosity at 100 °F, SUS	480	488	498	499	496	499	506	508	468
Viscosity at 210 °F, SUS	62.6	63.2	63.8	63.8	63.8	63.8	64.2	64.2	61.8
Viscosity index	98	98	99	99	99	99	99	98	97
Color, ASTM D 1500	5.0	6.5	7.0	L 7.5	L 7.5	7.0	L 6.5	6.0	L 7.0
Aniline point, °F	228.5	--	--	--	--	--	--	--	--
Sulfated ash, wt %	0.07	0.13	0.16	0.16	0.16	0.16	0.15	0.15	0.17
Metals, ppm									
Total	223	414	477	458	462	491	437	428	527
Calcium	175	366	440	430	432	445	410	404	459

A little more detailed analysis of these basestocks is shown in table 2. What I have done is added some of the metallics in detail. A couple of points I think you should keep an eye on are the oxygen content of one--1,200 ppm-- and the chlorine, which ranges from about 190 down to about 83. We will discuss this in more detail a little later.

The data given in table 3 are for comparison purposes. These results are from another re-refined oil source we looked at (Company B). You will notice its metallics level is very low. Again, though, the chlorine concentrations are pretty high--390 ppm--and the oxygen level is at 570 ppm.

We pointed out the oxygen and chlorine levels to Company A and worked with it on the source of those particular elements in the finished base oil. Using its product, we started out on a first-step basis to formulate an SE/CC oil. I think, as Mr. Sands pointed out to you, we are all capable of making a satisfactory oil from almost anything that looks like a reasonable basestock. It is just a matter of money and time. Some of the work we did is shown in table 4. We took an additive package that we have been using with an SE/CC approval. The results shown for the virgin base oil are

TABLE 2

ADDITIONAL RESULTS FOR SELECTED SAMPLES FROM COMPANY A

	Sample number		
	LCM 1782	LCM 1788	F-29729
Gravity, °API	--	--	28.1
Flash, COC, °F	450	465	445
Viscosity @ 100 °F, SUS	488.5	468.1	482.0
Viscosity @ 210 °F, SUS	63.2	61.8	62.7
Viscosity index	98.3	97.0	98.2
Color, ASTM D 1500	6.5	L 7.0	7.5
Oxygen, ppm	--	--	1200
Calcium, ppm	366	466	376
Chlorine, ppm	140	190	83
Magnesium, ppm	6	11	17
Silica, ppm	5	9	--
Aluminum, ppm	7	7	14
Nickel, ppm	5	5	5
Sodium, ppm	3	4	--
Iron, ppm	--	--	19
Zinc, ppm	--	--	15

TABLE 4

RE-REFINED BASE OIL - SE PROGRAM FOR RE-REFINED OIL FROM COMPANY A

Test	SE limits	Wt % additive package		
		8.4[a] X[b]	8.4 Y[c]	11.0 Z[d]
Sequence IIC				
AER	8.4	8.5	8.1 7.9 8.1	8.4
Sequence IIIC, % ΔV_{100} at 40 h	400	31	923	81
Sequence VC				
PV	7.9	-	7.6	8.3
AV	8.0	-	8.0	8.5
AS	8.5	-	9.4	9.3
L-38, BWL at 40 h, mg	40	-	18	26

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[a] Has full SE/CC approvals in virgin base oil.
[b] X is a virgin base oil.
[c] Y is a re-refined base oil.
[d] Z is a re-refined base oil.

TABLE 3

PHYSICAL, CHEMICAL, AND BENCH TESTS ON RE-REFINED OIL FROM COMPANY B

	Results	
	Company B	Chevron Research Company
Gravity, °API	28.8	--
Flash, COC, °F	460	440
Viscosity @ 100 °F, cSt	--	82.27
Viscosity @ 100 °F, SUS	373	376.7
Viscosity @ 210 °F, cSt	--	9.402
Viscosity @ 210 °F, SUS	57.13	57.1
Viscosity index	102	99
Pour, °F	+5	+10
Color, ASTM D 1500	4	4.5
Aniline point, °F	--	224.6
Acid No., mg KOH/g, D-3242	--	0.04
Sulfur, wt %		0.19
Ash, sulfated, wt %	Nil	<0.005
Nitrogen, ppm		42
Chlorine, total, ppm		390
Chloride, ion, ppm		23
Oxygen, ppm		570
Spectrographic & Atomic Absorption Analysis for Metals		
Spectrographic		
aluminum, boron, barium, calcium, chromium, copper, magnesium, silica, tin		Below limit of detection
lead, zinc, iron, nickel, phosphorus		Threshold of detection
Atomic absorption:		
lead, zinc, iron, nickel, ppm		>1
Distillation, ASTM D 1160 (atmospheric pressure), °F		
St		681
5		756
10		771
20		801
30		832
40		840
50		862
60		887
70		912
80		941
90		995
End point		1024
Recovered, %		93
In flask (by difference)		7

actual data obtained at the time we were doing the re-refined oil formulation work, so those results are back-to-back with the re-refined base oil. You see that when we tested the same weight percent additive treatment, we had quite a bit of problem with the sequence IIC test average engine rust. The Bartlesville people pointed out that they, too, had some problems with the sequence IIC test. The IIIC was a failure, and VC piston varnish was 7.6. The L-38 was fine.

We next tested an intermediate formula with about 10.0 weight percent additive and had more IIC problems. Then we went to an 11.0 weight percent additive treatment, which is about 30 percent overtreat, and about 1.2 percent to 1.3 percent sulfated ash. At the normal treatment level, the package itself is close to 1 percent ash. You can see that we did finally meet all the SE specification targets. However, we did not obtain a 1-H pass on that oil needed for CC performance.

We did some further diesel testing with a different additive package to investigate the possibility of making a CD oil from this basestock. We again ran into problems.

I would like to show you the last step we took. We further processed the base oil using a proprietary extraction procedure and additional clay treating. This reduced the metals to virtually nothing, chlorine down to less than 20 ppm (that is the detection limit), and the oxygen down to about 730 ppm in this particular case (table 5). Based on some additional in-house diesel engine screening work we did with a commercial CD package, we concluded that the base oil was satisfactory. We felt confident that we could, for example, pass a 1-G with it.

TABLE 5

TESTS ON RE-REFINED OIL AND
RE-REFINED, EXTRACTED, CLAY-TREATED OIL
FROM COMPANY A

Tests	Sample number	
	F-29729	Extracted F-29729 (F-30183)
Gravity, °API	28.1	28.4
Flash, COC, °F	445	450
Viscosity at 100 °F, SUS	482.0	465.3
Viscosity at 210 °F, SUS	62.7	62.0
Viscosity index	98.2	99
Color, ASTM D-1500	7.5	4.5
Pour, °F	+10	--
Sulfur, wt %	0.18	0.15
Nitrogen, ppm	50	--
Chlorine, ppm	83	<20[a]
Oxygen, ppm	1200	730
Calcium, ppm	376	nil
Magnesium, ppm	17	nil
Zinc, ppm	15	<10[a]
Iron, ppm	19	nil
Aluminum	14	nil

[a] Below detection level indicated.

We are not doing any more work on re-refined oils at the present time, but I did want to bring everyone up to date. I know some of you have been aware of this work, and I thought it would be helpful to openly discuss it today.

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ENGINE SEQUENCE TESTS FOR DETERMINATION OF LUBE OIL QUALITY

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For my presentation this morning I was asked to talk a little bit about sequence tests and the history of the sequence tests. Back in 1952, the American Petroleum Institute (API) service classification system had three different service categories: ML, MM, and MS. The more common one was used as the MS, or the "most severe," as it became known. However, one of the problems was that these service classifications were not defined by performance tests. So, as one of my predecessors has said, it allowed an oil company to make an oil as well as they knew how--which many did, or as poorly as the public would let them--which in some cases did happen. This service classification did result in field problems.

In about 1954 and 1955, the automotive industry encountered many problems with some MS oils; and the MS definition included oils that were very good to oils that cause excessive problems in the field. So, they started collectively and individually to develop sequence tests, and the American Society for Testing and Materials (ASTM) got involved in 1956--Section G-IV, Technical Division B of Committee D-2. They formed a Section I at that point and gave it the responsibility to look at performance tests which were being developed by the engine manufacturers. This was the formation of Section I, Technical Division B, Committee D-2.

The engine sequence tests were introduced in about 1958, and they became widely used in about 1960, as shown in table 1. The first publication of ASTM to include them in the STP form was STP 315, first published in 1962 and later periodically revised. It included the first five sequence tests. Sequences I, II, and III were developed by General Motors, IV by Chrysler, and V by Ford. As shown, the sequence I evaluated low-temperature and medium-speed scuffing; sequence II was rusting or low-temperature deposits; sequence III was high-temperature oxidation; sequence IV evaluated high-temperature, high-speed scuffing and wear; and sequence V evaluated insolubles, sludging, and screen clogging, or sludge from taxicab-type operations.

TABLE 1

ENGINE SEQUENCE TESTS

1958	Introduced
1962	ASTM STP 315
Sequence I	Low-temperature, medium-speed scuffing and wear
Sequence II	Low-temperature deposits and rusting
Sequence III	High-temperature oxidation
Sequence IV	High-temperature, high-speed scuffing and wear
Sequence V	Insolubles, sludging, screen clogging

These sequence tests were introduced to evaluate specific parameters. They were not intended to be all-proof type tests. Their intention was to distinguish between acceptable and unacceptable performance in specific areas. They were not intended to replace field testing. They evaluated only these certain specific parameters, and oil companies continued to field test their products before they were marketed.

Periodically, these sequence tests were revised, as shown in table 2. The MS definition carried through to about 1971 and was followed by the SE classification

TABLE 2

ASTM STP 315 PUBLICATIONS

MS - 1962 - STP 315	SEQ. I, II, III, IV, V
MS - 1963 - STP 315A	SEQ. I, II, III, IV, V
MS - 1966 - STP 315B	SEQ. IIA, IIIA, IV, V
MS - 1967 - STP 315C	SEQ. IIA, IIIA, IV, VB
MS - 1968 - STP 315D	SEQ. IIB, IIIB, IV, VB
SE - 1973 - STP 315F	SEQ. IIC, IIIC, VC

system. The first publication of STP 315 included the sequences I, II, III, IV, and V. In 1963, STP 315A was published and contained updated or revised versions of several of the procedures that improved the precision--the same basic five procedures. In 1966, STP 315B was published; sequence I was dropped and was combined with the results obtained from sequences IIA and IIIA. In 1967, STP 315C was published and sequence VB was introduced, replacing sequence V. In 1968, STP 315D was published, and sequences IIA and IIIA were replaced by sequences IIB and IIIB. In 1973, STP 315F was published, and this was when we went to the SE classification system (actually, we went to it in 1971). Sequence IIC replaced sequence IIB; sequence IIIC replaced IIIB; sequence IV was dropped, since oils that passed the sequence IIIC tests also passed the sequence IV tests; and sequence VC replaced sequence VB.

The SE performance classification system came into being about 1971 and is shown in table 3. Category SA is still defined as motor light, or the most optimum type of service. There are no performance tests involved in defining SA other than some pour and foam inhibition tendencies, as well as the viscosity. This may be one that we may wish to consider for some re-refined oils if the equivalency can be established with respect to foam and pour.

TABLE 3

ENGINE OIL PERFORMANCE CLASSIFICATION (1971)

SA	ML
SB	L-4, L-38, SEQ. IV
SC	IIA, IIIA, IV, V, L-38, L-1
SD	IIB, IIIB, IV, VB, L-38, L-1
SE	IIB OR IIC, IIIC, VC, L-38
CA	L-4, L-38, L-1
CB	L-4, L-38
CC	L-38, LTD, IIA or IIB, 1-H
CD	1-D, 1-G, L-38

The SB classification was defined by the L-4 test, the L-38 test, and the sequence IV test. As you can see, there are the various S categories down to the SE which currently requires the IIC, IIIC, VC, and L-38 engine sequence tests. Originally, the SE had a IIB test requirement in it. The C category of oils for diesel engines involves the L-4, L-38, and L-1 for the CA classification, CB requires the L-4 and L-38; CC the L-38, LTD, IIA or IIB, and 1-H; and the CD takes the 1-D, 1-G, and L-38 tests. The CC and CD categories are still being used by engine manufacturers.

After discussing the history of the sequence tests overall, I would now like to take a moment to tell you a little bit about some of the problems that General Motors has had in developing some of these sequence tests.

We have been working on sequence tests since about 1955, as shown in table 4. In our development of several of these, we have found it does take a considerable amount of time and effort to establish correlation with field service. In table 5, you can get an idea of the number of tests involved and of the length of time required to develop test procedures that correlate with the field. We are talking about over 810 tests for development and about 10-1/2 years of time. This does not include ironing out problems such as hardware and fuel and things of that nature or the monitoring

TABLE 4

HISTORY OF GENERAL MOTORS-DEVELOPED SEQUENCE TESTS

1955 - 1960	Development stages
1960 - 1964	Sequences I, II, and III
1964 - 1967	Sequences IIA - IIIA
1967 - 1970	Sequences IIB - IIIB
1970 - 1972	Sequences IIB and IIIC
1972	Sequences IIC and IIIC

TABLE 5

TIME REQUIREMENTS FOR SEQUENCE TEST DEVELOPMENTS

Sequence	No. of tests	Time
I, II, and III	400	5 years
IIA - IIIA	165	2-1/2 years
IIB - IIIB	100	14 months
IIIC	85	1 year
IIC	60	10 months
TOTAL	810	10-1/2 years

effort for reference oils. This only includes development time to correlate with field service. Many types of field service have to be considered and have to be correlated in order to have a test that is meaningful. Because of the various types of service, you cannot develop everything into a sequence test. Thus, they are not all-proof type tests. They only evaluate certain specific parameters. I guess we could probably add a couple more years on here because we have been working on the wear tests.

The philosophy that we have used in developing tests is to control all parameters which influence the test result except the quality of the lubricant. We try to make that the only variable involved. Then we control the parameters at the levels which result in good field correlation in the shortest possible time. All this means is field tests plus the lab tests mean a lot of work and expense. We think it is necessary to define the performance requirements of engine oils.

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SCREENING TESTS ON LUBE OILS

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Perhaps the title should be lack of screening tests rather than screening tests. There is a great incentive to develop laboratory bench-test procedures to correlate with full-scale engine specification test requirements. Among the most obvious incentives, of course, is the economic consideration and the time-saving potential of such procedures. During my association with the additive industry, which spans an interval of over 40 years, my company has continually investigated various methods for accomplishing this objective. To date, we have not discovered satisfactory methods to replace the engine tests; we wish we could. We have been able to use certain bench tests to measure single properties of a lubricant such as oxidation stability, thermal stability, rust protection, bearing corrosion protection, dispersivity characteristics, high-temperature detergency, and others. One might then ask the question as to why these tests cannot be combined to accurately predict the performance characteristics of the lubricant in the various engine specification tests which were designed to measure pretty much the same parameters. We believe that the principal reason for our difficulties is the inability to duplicate the engine environment. One essential part of this aspect is the effect of the fuel and the fuel-combustion product on the performance of the lubricant. Many attempts have been made to introduce this fuel effect into laboratory bench scale tests. But, to date, these efforts have not met with any appreciable degree of success.

The lubricant screening tests which are employed in the investigation of additive performance, at their best, merely improve one's chances of meeting the engine test requirements. Among some of those which we have employed and which others have employed over the years are oxidation tests such as the Continental Oxidation Test, which is a well-known aeration type test in the presence of a catalyst such as iron at temperatures in the range of 341°F. Others have used, and we have also, oxygen absorption tests such as the Rotating Bomb Tests, which are currently in the American Society for Testing and Materials procedure, running under pressure in a bomb or a circulation of oxygen in a closed system at low pressures, measuring the amount of oxygen absorbed in a unit time at elevated temperatures. Other types of tests are bearing corrosion tests which measure the tendency of the lubricant to corrode bearings, principally copper-lead bearings, under the conditions conducive to oxidation, and generally at temperatures around 300°F to 325°F. Among these are the Indiana Stir Oxidation Tests which involve aeration by high-speed agitation in the presence of a copper-lead bearing; the temperature in this case is 300°F. An old test from way back is the Underwood Oxidation Test, developed by Mr. Arthur Underwood, I believe of General Motors Research, which involved circulation of an oil over an in-line electric heater, followed by spraying the lubricant against bearing materials in a chamber in which air is simultaneously mixed with the lubricant. Bearing corrosion and oil deterioration are determined at various intervals during the test. The temperature in this case is 325°F. There are tests which attempt to measure the combination bearing-corrosion and lacquer-deposits tendencies of the lubricant, and these are oxidation tests run in the presence of a metal catalyst such as copper-lead bearing and steel surfaces which serve as a surface for plating out varnish-forming materials which are the result of the oxidation of lubricants. One of these is the SOHIO Oxidation Test, which is run at 325°F. A section of a copper-lead bearing is subjected to a high rate of shear in oil surrounding the specimen in the presence of an excess of air. Catalysts are employed to accelerate the rate of oil oxidation. Lacquer ratings are also determined on the outer surface of the corrosion test unit.

Other tests have been designed to evaluate low-temperature sludge dispersency characteristics. One laboratory-type test, which is used to evaluate this property, is one which rates materials on the basis of their ability to suspend insolubles derived from drain oils which have already been used in the engine. The suspended material is that which remains after a high-speed centrifugation of a mixture of the sludge and oil, this said mixture having been prepared by either a sonic or a vigorous mechanical agitation.

Other type tests have been used to measure the high-temperature deposition or the detergency characteristics at high temperatures of the additive oil system. The Panel-Coker Test, which many of you are familiar with, has been found to be a useful screening device to evaluate the thermal stability and the detergency ability of the lubricant oil additive system. In this test, the oil is flashed against a heated steel panel, and the panel is then evaluated for deposits. Varying temperatures ranging up to about 600°F are employed, depending on the objectives of the test. The deposit level can also be varied by a variation in the time allowed for the oil to cook on the surface of the test specimen in the absence of splashing or renewing the oil. Tests such as this may simulate the deposits produced in diesel-engine operation.

One last comment I would like to make is about something called the "fuel factor." In general, as you know, the fuel does not burn completely. Various oxidation products--acids, aldehydes, ketones, cracked hydrocarbons, unsaturates, oxides of nitrogen, etc.--will get into the lubricant as blow-by. These materials then form a part of the lubricant. They are all mixed together in there, and you no longer can consider the pure clean lubricant. You must consider the effect of these materials which are also a part of the lubricant. As these materials accumulate, they become a greater part of the lubricant. The oxidation stability of these materials cannot be satisfactorily determined, for example, by running a bench test on just the lubricant by itself. If you attempted to combine all of these things together, you might just as well put it in the engine, because that is where they exist in the first place.

In conclusion, I did not attempt to cover all of the various tests which have been used as screening tests or tests to predict the possible performance in the various engine tests; however, these types I think are representative in general of what has been employed. Again, let me emphasize that the only way to determine engine performance is to run the oil in an engine.

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LABORATORY TESTING ON RE-REFINED MOTOR OIL

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When the subject of used oil arises, it is usually discussed in terms of crankcase drainings from automobiles. Similarly, when re-refined oil becomes the subject of discussion, it most frequently is thought of in terms of the same crankcase drainings processed for reuse as motor oils. To broach either subject accordingly is normal. Most of the attention given the subject of used oil and its recovery for reuse is expressed in terms of whether or not it can adequately lubricate an internal combustion engine.

It, of course, has been noted that the subject neither begins nor ends with this rather limited scope. The parameters of consideration are far broader, touching upon many kinds of petroleum lubricants used in a multitude of applications and being recovered for a variety of reuses. It does follow, however, that the recovery and re-refining of automotive crankcase drainings for reuse in motor oils has a tremendous importance to the acceptability of re-refining as a viable secondary industry. In a nut shell, it is because of the questionable quality connotation historically attributed to this concept of reuse.

In all candor, neither the proponents nor the opponents of motor oils made from re-refined crankcase drainings have unequivocably proved their position. This is mainly because one will not concede the validity of the other's arguments, and there is insufficient data to prove one or the other totally wrong.

Neither my remarks nor the data I will present are intended to settle the controversy once and for all, but hopefully will demonstrate that an advocacy position is acceptable within the frame of reason and practicality.

As discussed yesterday, the matter of feedstock variability has historically been a primary point of contention. It has been charged that the re-refiner deals with a new feedstock every day; and, thus, his end product must also be variable. The re-refiners have attempted to address this situation over the years.

In 1960, the Armour Research Foundation of Illinois Institute of Technology did a study of re-refining for the Association of Petroleum Re-refiners and stated:

> "There is an amazing uniformity in the chemical composition of the oil drainings from the various parts of the country. It is more uniform than the composition of the crude oils from different sections. This uniformity was established by infrared analysis and determinations of the physical and chemical properties of the distillate and residual material."

Yesterday, Mr. Charles J. Thompson related the work of the Bartlesville Energy Research Center and their conclusions that feedstock to re-refiners is similar in petroleum base composition regardless of seasonal or geographical location within the U.S. Obviously, neither of these findings is absolute assurance that the feedstock will not be contaminated with oils of lesser quality, nor that it will be processed to meet the quality requirements of a base oil suitable for compounding high-quality motor oils. It does, however, help to establish a credible base for re-refiners to build upon in controlling their applied technology to produce products of acceptable quality.

As is the case in any processing activity where the optimization of yields and product quality is paramount, a re-refiner must utilize appropriate technology and employ control systems throughout the process to achieve a consistently desirable result. In short, control is mandatory.

Figure 1 is typical of the type of equipment used in collecting drain oil from service stations. Upon arrival at the re-refinery, the free water is drained from the truck into a primary water recovery system; and after being sampled and approved for unloading, the truck is hooked up into an unloading manifold and the oil is metered into the proper storage tanks.

Figure 1. Drain oil collection truck.

Control for the re-refiner begins with the receipt and segregation of feedstocks from which the base oils are to be extracted (figure 2). Obviously, the re-refiner depends on the waste oil collector to segregate or at least identify the types of oil being delivered. It also behooves the re-refiner to establish safeguards to protect the integrity of his feedstock.

Actually, crankcase drainings have peculiar characteristics readily identifiable by experienced personnel who examine the material at the time the sample is drawn for BS&W (bottom settling and water) analysis. Verification of quality can be rather quickly accomplished by determining the viscosity, viscosity index, and flash, when the oil appears to contain a diluent such as gasoline or solvent. If there is doubt beyond this point, and in the absence of other means of determining the characteristics of the material, the re-refiner can exercise the option of segregating the material for processing into material for less critical use. A part of the control process definitely includes careful segregation and storage of oils according to their properties.

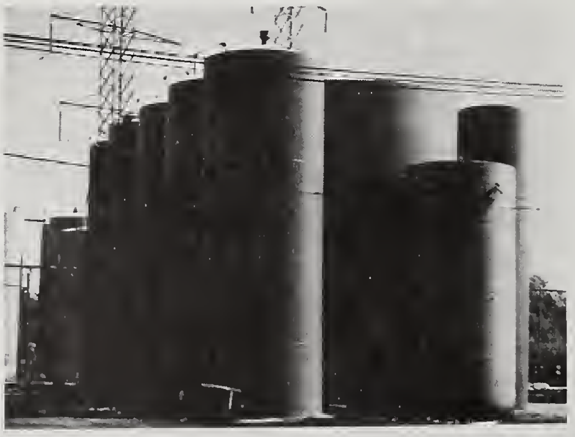

Figure 2. Tankage for feedstock segregation.

Various methods of re-refining are employed and include various combinations and permutations of chemical treating, vacuum distillation, and atmospheric distillation (figure 3). This is usually followed by clay contacting and filtration. Throughout the process, it is absolutely essential that the re-refiner control temperatures, steam pressure, pump pressure, and other factors which bear upon the quality of the end product.

The plate and frame filter press, as shown in figure 4, is commonly used in re-refining. While not altogether necessary, it is considered a good idea to pass the oil through a second filtration, or polish press, to be certain the finished oil contains no ash materials which could have escaped the first filtration because of broken filter pads. At this point in the process, a base mineral oil has been produced which is suitable for blending and compounding into motor oils or other products for which they are appropriate.

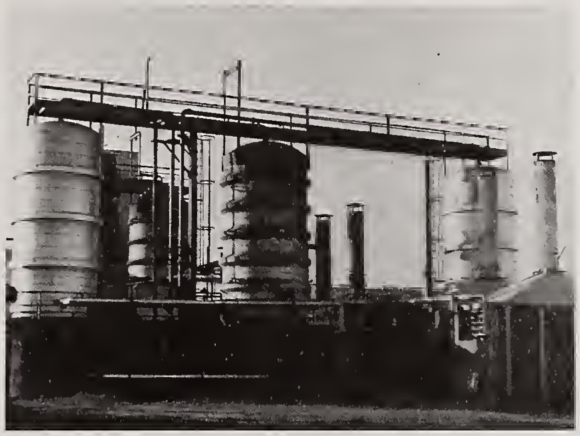

Figure 3. Distillation units.

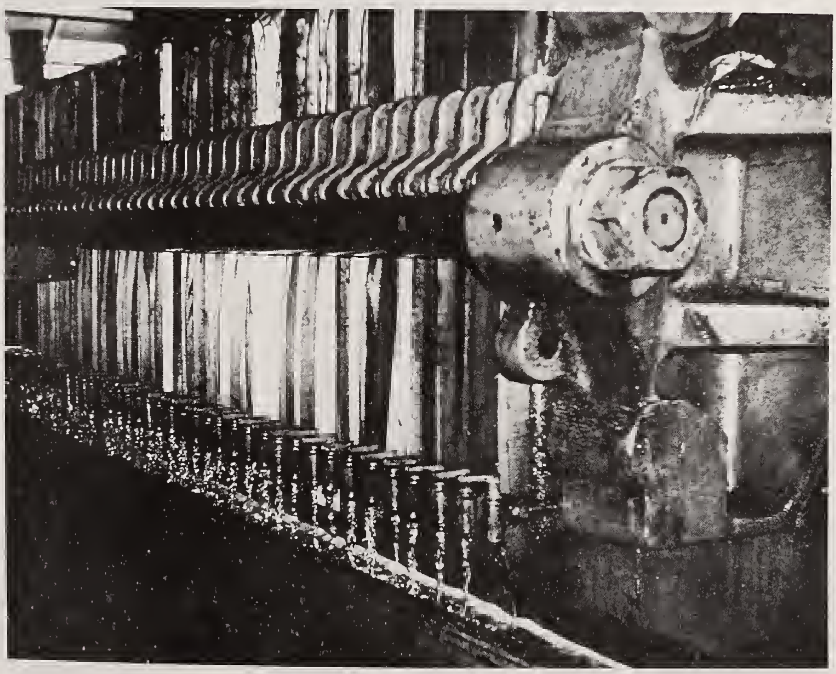

Figure 4. Plate and frame press.

As mentioned earlier, control is extremely important, and the re-refiner must either have in-house facilities or utilize the services of a commercial laboratory to the extent necessary to insure quality (figure 5).

Figure 5. Quality control laboratory.

The laboratory depicted here is used for checking all incoming materials, such as drain oil, blending oils, and additives. It is used for monitoring the re-refining process for blending and for finished-product quality assurance. Samples are taken from various stages of the process and are brought to the laboratory control booth where they are checked for viscosity, filterability, flash, etc., for process control.

All incoming blending materials, products in process, and finished products are checked at this point for viscosity at 100°F and 210°F. The Cleveland open cup method is used for flash and fire tests. We also run sulfated ash tests on our motor oils.

Figure 6 shows the oxidation tester we use. This is an adaptation of the General Motors E.M.D. silver corrosion tester and is used for making comparative oxidation tests on base oils and finished products. Typical test results on motor oils will be discussed later in this paper.

A Baird atomic emission spectrometer is used for determining the kinds and quantities of metals in various oils being tested. It is very useful in identifying characteristics of drain oil and additive level in finished products, as well as for analysis of wear conditions in operating engines.

A sulfur tester, analytical balance, pH meter, and bench vacuum distillation equipment are used in the laboratory for performing various tests and analyses.

In summary, the tests performed in our laboratory on motor oils include gravity, flash and fire, viscosity at 100°F and 210°F, viscosity index, pentane insolubles, total base number, total acid number, sulfated ash, spectrographic analysis of additive, pour point, and others as deemed appropriate.

We continually test the virgin neutrals and bright stocks, as well as additives, to determine their miscibility with re-refined base oils. This is accomplished by making up blends and letting them stand for long periods of time to observe whether there is any separation or stratification.

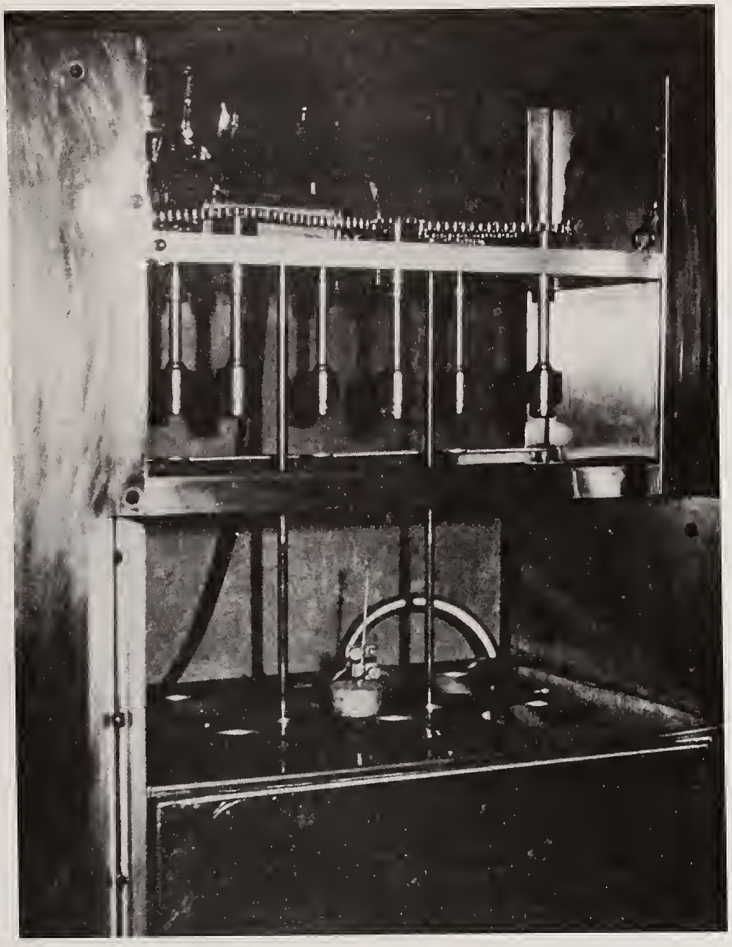

Figure 6. Oxidation test equipment.

Results and Discussion

The data shown in table 1 represent approximately one million gallons of drain oil and the finished base oil derived from it. You will note from the viscosity that the oil is an SAE 20 and the changes in viscosity, viscosity index, and pour point indicate the removal of diluents and polymers. From a re-refining standpoint, the critical comparison is the ash, which is typical for automotive drain oil, and the absence of ash in the finished oil, which is indicative of a proper re-refining job.

TABLE 1

TYPICAL PROPERTIES
BASE OIL RE-REFINED FROM AUTOMOTIVE DRAIN OIL

	Drain oil	Finished oil
Viscosity at 100 °F, SSU	357	366
Viscosity at 210 °F, SSU	61.45	57.27
Viscosity index	125	104
Ash, %	2.1	0.0
Pour point, °F	-35	-20

Table 2 shows typical properties of a partial listing of motor oils utilizing re-refined base oil, virgin blending oils, and appropriate additive packages. The American Petroleum Institute service classifications indicate that the oils are compounded to the equivalent of SE grade or series 3.

TABLE 2

TYPICAL PROPERTIES
MOTOR OILS MADE FROM RE-REFINED OILS

		Viscosity at		
	Flash	100 °F	210 °F	Viscosity index
SAE 20 - SA Grade	420	320	54.4	104
SAE 20W - SE Grade	420	320	55.0	104
SAE 30 - SE Grade	450	540	65.5	96
SAE 10W40 - SE Grade	395	322	74.0	153
SAE 30 - Series 3	450	540	65.5	96

The oxidation tester shown earlier is used for running comparative oxidation tests. The test consists of heating 300 ml of oil to a selected temperature and holding it consistently for 72 hours while stirring at 300 rpm with stainless-steel stirrers. Both copper strips and steel strips are immersed in the oil during the test.

In the results shown in table 3, samples 5 and 6 are re-refined oils which have been compounded to the equivalent of the SD and SE American Petroleum Institute service classifications and are compared with four major brands, all of which are SE oils:

- The percent weight loss of the four major brands ranged from 0.88 percent to 1.32 percent, while the re-refined oils were at about the median of the range.
- The viscosity increase at 100°F ranged from 2.5 to 7.3 for the first four and were 3.6 to 4.0 for the re-refined oils.
- At 210°F, the percent viscosity change for the re-refined oils was less than the major brands.
- The re-refined oil had less weight change on the steel strips than the four major brands, while weight loss for the re-refined oils on copper strips was about the median of the first four.
- The results of the pentane insolubles test show that all six oils were good material and the variations in the final percentage are infinitesimally small.

Another test was recently run to test re-refined diesel lube oil. This is an E.M.D. two-cylinder silver bearing smear test. This test utilizes an E.M.D. 67 two-cylinder engine and runs for 25 hours. The test results are based on a demerit rating of the four central grooves in the silver bearing and the rating scale for excellent, good, fair, bad, and very bad. The test conditions, the product being tested, and the results are shown in table 4.

TABLE 3

OXIDATION TEST NO. 181

(72 Hours at 275°F., Stirred at 300 RPM)

Type	SAE viscosity	API service	Weight loss (%)	Viscosity increase (%)		Weight change (mg)		Pentane insolubles	
				SSU at 100 °F	SSU at 210 °F	Steel strips	Copper strips	Original %	Final %
1. Major brand	30	SB/SE - CA/CC (MS - DM)	1.12	3.4	2.1	-0.7	-0.9	nil	0,001
2. Major brand	30	SE - CC	1.32	4.7	2.3	-1.0	-0.7	nil	0,002
3. Major brand	30	SE - CC (MS - DM)	0.88	2.5	1.5	-0.6	-0.9	nil	0,001
4. Major brand	30	SD/SE/CC (MS - DM)	1.28	7.3	2.9	-0.8	-1.2	nil	0,001
5. Re-refined	30	SD - CC	1.00	3.6	1.2	-0.3	-1.0	nil	0,001
6. Re-refined	30	SE - CC	0.96	4.0	1.7	-0.5	-1.0	nil	0,001

TABLE 4

E.M.D. TWO-CYLINDER SILVER BEARING SMEAR TEST

1. 25-hour, two-cylinder engine test - EMD 567 engine	1. Re-refined oil, compounded with high dispersant additive	1. Test oil: Re-refined diesel lube oil
2. Test results - EMD demerit rating of four central grooves	2. Test oil properties	2. Bearing demerits: 7.3
3. Rating based on silver smear and groove deposits	<u>Tests</u> — <u>Results</u> Viscosity at 100 °F — 982 Viscosity at 210 °F — 79.2 Viscosity index — 74 TBN (D-2896) — 9.32 Calcium (M-950) — 0.32 Infrared trace — Matches	3. Bearing appearance: Bright
4. Rating scale (demerits): 0 to 10 Excellent 10 to 20 Good 20 to 50 Fair 50 to 100 Bad 100 to 200 Very bad		4. Overall rating: Excellent

The material used was re-refined oil compounded with high dispersant additive taken from a normal production run. The test oil properties are typical of that produced for railway diesel engine service. At the conclusion of the test, the re-refin diesel lube oil had bearing demerits of 7.3. The bearing appearance was bright, and the overall rating was excellent. A photograph of the silver bearing at the conclusi of the test shows an absence of groove deposits and silver smear (figure 7).

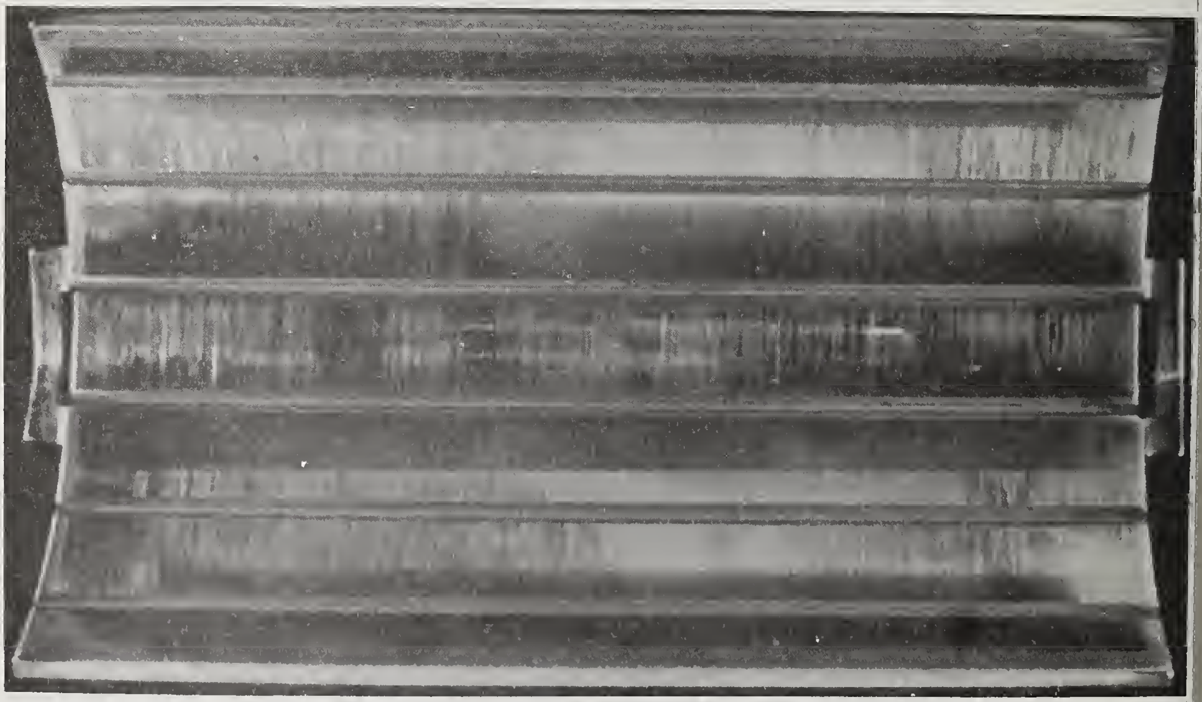

Figure 7. Silver bearing after the E.M.D. two-cylinder silver bearing smear test.

Much has been said about engine tests, and we have our own proprietary engine test (figure 8). All joking aside, this figure shows a piston removed from an engine with over 105,000 miles, which was lubricated only with re-refined oil. Although possibly of interest and comfort only to ourselves, it does indicate that re-refined oil can be a quality product.

Figure 8. Piston after 105,000 miles and lubricated only with re-refined oil.

There are many considerations involved in doing an acceptable job of re-refining. Much, of course, depends on the adequacy of the technology; but the burden is ever upon the re-refiner to control his process and product quality through the medium of the same standards which are applied to the primary industry.

There is no substitute for performance, and there is no substitute for control to maintain a standard of performance.

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DIESEL LUBE OIL TEST METHODS

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Caterpillar Tractor Company first experienced difficulty with lubricating oil performance when we tried to put a diesel engine into a tractor back in the middle 1930's. The trouble was the accumulation of residue from fuel and degraded oil which forms deposits in the ring grooves of the pistons and on the lands and firmly locks the rings in place so they cannot perform their normal function of sealing against combustion pressure. As can be seen in figure 1, the face of the compression rings is stained with lacquer, indicating the rings are stuck in the groove and, thus, are not sealing. As this continues and gets worse, the second ring, which is now not protected by the first compression ring, will begin to break up into small pieces. This has already started in this figure. These pieces of piston ring will eventually wallow away in the groove and seize against the liner; or, there might be scuffing due to the increased temperature from improper heat flow out through the ring belt, which will continue to the point that the engine will fail.

Figure 1. Diesel piston which has received inadequate lubrication.

There was a question at that time whether we could continue to offer a diesel engine tractor because of this problem, but our friends in the oil industry worked with us to develop oil additives which could reduce piston deposits and thus control this problem. In figure 2 you can see the effect of oil additives on deposit control. These are pictures of the top part of the piston from a late model, 3406 Caterpillar diesel engine. From three different runs, one with a CC-class oil, which is not the recommended oil for this model engine, the second with a moderate performing CD-class oil (you can see the difference here in deposits on the piston lands), and then the third with a superior CD oil. It is obvious that there is a significant amount of difference in performance within the CD classification itself. This very clearly demonstrates what oil additives are capable of contributing to the control of piston deposits.

Figure 2. The effect of oil additives on deposit control.

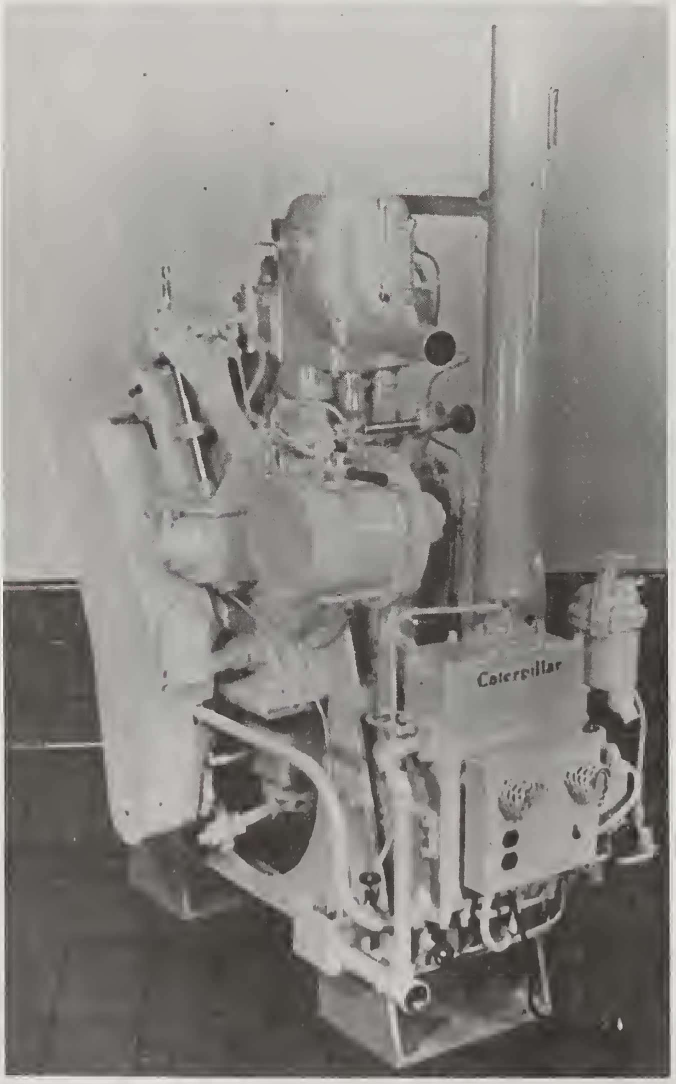

Figure 3. A Caterpillar single-cylinder test engine.

In these early days, we carried out oil tests in multicylinder engines. At first we could not interest very many people in the oil industry in marketing the kind of oil we needed, so we went into business for ourselves for a little while. As the interest grew in the new oil formulations and oil companies became interested in marketing these products, we developed a qualification system for oil and published a list of brand names of oil which we considered acceptable in Caterpillar engines. As this oil qualification became a way of life, we developed the single-cylinder oil test engine. This engine has had some significant modifications with time, but it is essentially the same today (figure 3) as it was when originally designed.

TABLE 1

SUPERIOR LUBRICANTS (SERIES 3)
FOR CATERPILLAR DIESEL ENGINES

Caterpillar test no.	1-D	1-G
Duration, hours	480	480
Speed, rpm	1,200	1,800
Heat input (load), Btu/min	5,600	5,850
Brake horsepower (approx.)	42	42
BMEP (approx.)	134	141
Temperatures, °F		
Water from cylinder head	200	190
Oil to bearings	175	205
Air to engine	200	255
Pressures		
Oil to bearing, psi	30	30
Air to engine, in.Hg.abs.	44-45	53
Fuel to injection pump, psi	15-25	15-25
Fuel sulfur, % wt	1.0	0.4

The engine test conditions that are currently used are shown in table 1, and are used for two reasons, one to assess the effects of high sulfur in fuel. This is called the 1-D test. The sulfur in the fuel for the test must be 1 percent. In this country, it is becoming a little unusual to find a fuel with 1-percent sulfur; however, we market worldwide and in many areas of the world it is quite common to find fuels with 1-percent sulfur or higher. That is why we continue to keep this test in our system. The 1-G test is somewhat more severe in the sense that it is more highly super-charged. Note that the BMEP level for the 1-G test is at 141, as compared to the 134 for the 1-D. If you are not familiar with the term BMEP, this is a way of comparing the specific output of engines; 141 BMEP is a very typical output for heavy-duty, turbocharged diesel engines. I think this would also be typical of our competitors--Cummins, Mack, and so forth.

Caterpillar happened to be the first engine manufacturer to get into this oil qualification business, probably because we were the first ones to put a diesel engine in a tractor. Since we had started this, it became an industry-accepted specification. It remains so today, even though in 1972 we abandoned our certification procedure and now use other methods for describing our requirements to the field. One of these is the military specification. It has become very common for diesel-engine builders to use the military specifications as a way of telling people in the field what kind of oil is recommended for a particular model of machine. You will notice that the tests 1-G and 1-D for the MIL-L-2104C are identical to those used in the Series 3 certification program (table 2). The military qualification today is the only way that a company can get an outside organization to become involved with the approval of their product. Many oil companies are interested in getting their product qualified by the military so they can demonstrate to their customers that they have had an evaluation by an independent body. But, if you qualify against the military specification, you not only have to satisfy the diesel engine test requirement, you also have to satisfy the gasoline engine tests also called for in that specification. This stimulated some interest in multipurpose oils, oils which were good performers in both gasoline- and diesel-engine service. Many oil companies are interested in marketing an oil which will satisfy the needs of both kinds of engines, gasoline and diesel.

The other common military specification used is MIL-L-46152, which includes one more gasoline engine test and a milder diesel engine test (table 3). This one is used by the military primarily for Federal gasoline-engine powered vehicles and for light diesel trucks. However, many county, municipal, and other organizations establish their specifications based on the military. So, again, there is a reason for people who are supplying oil to want to go through the procedure of obtaining an approval of their product by an independent body.

TABLE 2

MIL-L-2104C REQUIREMENTS

Tests and Performance Criteria Evaluated

Diesel engine performance tests:

Test No. 1-G: Ring sticking performance - high-speed 141 BMEP

Test No. 1-D: Ring sticking performance - 1-percent sulfur fuel 135 BMEP

Gasoline engine AMA test sequences:

IIC	Rust, scuffing, wear performance - low temperature
VC	Low-temperature deposition performance
L-38	Oxidation and bearing corrosion

TABLE 3

MIL-L-46152 REQUIREMENTS

Tests and Performance Criteria Evaluated

Diesel engine performance tests:

Test No. 1-H: Ring sticking performance - high-speed 110 BMEP

Gasoline engine AMA test sequences:

IIC	Rust, scuffing, wear performance - low temperature
VC	Low-temperature deposition performance
L-38	Oxidation and bearing corrosion
IIIC	Rust, scuffing, wear performance - high temperature

You have heard the American Petroleum Institute (API) classes mentioned, and table 4 shows how the API service classes are related to the military specifications. The ones for diesel engines of most interest today are the CD and the CC because most diesel engines today use either one or the other of these specifications. Mack would be the only exception, and they have their own qualification procedures and their own engine tests.

Down through the years, from the middle 1930's, there have been a number of specification changes. As the Army upgraded their specifications, the API upgraded theirs; and, Caterpillar upgraded theirs as the severity of the engine output was increased. The chronological sequence is shown in table 5. The point I want to make here is that this is an ongoing program. It is not going to stay at the current level; there are other specification changes which will come along and require additional modifications.

Caterpillar and some other engine manufacturers do not just use engine oil in engines. They try to use engine oil in as many of the oil compartments of a vehicle as possible. A few years ago we began to find that while some CD oils performed satisfactorily in power-shift transmissions, others allowed slipping of the transmission clutch. Once the clutch slips enough, it will actually destroy itself. Figure 4 shows segments of a failed clutch. The material in sintered bronze, and some of the bronze material has been pulled out of position. The opposing plate is steel, and the copper from the friction plate has smeared across the steel plate. This is a sign of incipient failure. We find that certain CD oils will produce this kind of failure and other CD oils will not. So, in our recommendations for transmissions these days, we have a requirement using an SAE-#2 Friction Test Machine to test the friction qualities of oils. This is called the TO-2 test. We call for a CD/TO-2 transmission oil. Becuase oil needs this extra quality for transmission service, many oil companies will market only a CD/TO-2 oil in the construction-industry area. So, in effect, we have added a requirement on to CD oil, the TO-2, not for engine performance, but for transmission performance.

TABLE 4

RELATIONSHIP BETWEEN API CLASSIFICATIONS AND MILITARY SPECIFICATIONS

API service class	Military specification	Old designations	
		Commercial	API
CA	MIL-L-2104A		DG
CB	MIL-L-2104A, Supp. 1	Supp. 1	DM
CC	MIL-L-46152 MIL-L-2104B	MIL-B	DM
CD	MIL-L-2104C MIL-L-45199	Series 3, S-3	DS
		Mack EO-H	

TABLE 5

CHRONOLOGICAL SEQUENCE OF SPECIFICATION CHANGES

1935 - Caterpillar Superior Lubricants
1938 - Detroit Diesel List
1941 - U.S. Army 2-104
1947 - API Engine Oil Classification (D Series)
1948 - Caterpillar Superior Lubricants (Series 2)
1950 - U.S. Army 2-104B Supp. 1
1950 - U.S. Army 2-104B Supp. 2
1952 - API Engine Oil Classification (D Series)
1954 - MIL-L-2104A
1956 - Caterpillar Superior Lubricants (Series 3)
1958 - MIL-L-45199
1961 - MIL-L-2104B
1970 - MIL-L-2104C
1970 - Mack EO-H
1970 - API Engine Oil Classification (C Series)
1971 - MIL-L-46152

Figure 4. Results of inadequate lubrication on a power-shift transmission clutch.

With all of this testing required, it can be very expensive to qualify an oil. Table 6 lists typical costs for tests run by Southwest Reseatch Institute, one of the independent laboratories doing this type of testing. Notice that in order to qualify an oil for MIL-L-2104C the cost will run close to $15,000. If you add the TO-2 test, where we require two runs minimum, it increases to $17,500. If a new additive system is used, it is required that additional testing above and beyond just the single-cylinder test be done. We also require some kind of multicylinder engine test, so I have included the cost of an OL-1 test. So, for a new additive system for one grade only, for both military specifications and the TO-2 and the Mack (this is the minimum testing for a universal oil), total cost approaches $45,000. This assumes a passing result for each test run. If any test fails, rerunning of one or more of the specified tests and possible reformulation of the oil will be necessary. We are talking about a considerable sum of money to qualify an oil with these engine tests. Everybody involved would welcome any kind of test, bench or otherwise, which would allow us to do the job cheaper and still in a satisfactory fashion; but since 1935 we have not found a way to do it, not for oils with virgin basestocks -- not for oils with recycled basestocks.

TABLE 6

TYPICAL DIESEL VEHICLE OIL QUALIFICATION COSTS

MIL-L-2104C		MIL-L-46152	
Test	Cost	Test	Cost
1-G	$ 3,290	1-H	$ 3,160
1-D	3,380	IIC	2,570
IIC	2,570	IIIC	3,995
VC	4,300	VC	4,300
L-38	1,330	L-38	1,330
	$14,870		$15,355
TO-2	$ 2,600 (2 Tests Minimum)		
TOTAL	$17,470		

	CD/TO-2		ADDITIONAL
1-G	$ 3,290	OL-1	$ 7,150
1-D	3,380	T-1	6,560
L-38	1.330	T-5	13,830
TO-2	2,600		
	$10,600		

New additive system, one grade only, both military specifications plus TO-2 and Mack, October 1, 1976 - $45,000 minimum, assumes no reruns.

National Bureau of Standards Special Publication 488. Proceedings of
a Workshop on Measurements and Standards for Recycled Oil held at NBS,
Gaithersburg, Maryland, November 22 and 23, 1976. (Issued August 1977)

DISCUSSION

SESSIONS IV AND V. RECYCLED ENGINE OILS

There were two sessions on the subject of recycled oils, reflecting the current interest and concern with the re-refining of used engine oils back into high-quality engine lubricants. These presentations can be separated into two groups: one on organizations with programs which are concerned with re-refined oils, and the other on the test methods currently used on both virgin and re-refined engine oils. In the first group, presentations were made on the Environmental Protection Agency/U.S. Army used oil program for evaluation of re-refined oils for use in military specifications; the Energy Research and Development Administration recycled oil program, which includes establishing the variability of used oil composition throughout the country, developing improved re-refining technology, and some testing of re-refined oils with engine sequence tests; activities of the American Society for Testing and Materials (ASTM) Used Oil Task Force; activities of the American Petroleum Institute Used Oil Management Task Force; and investigations of re-refined oils by a major oil company. The second group of presentations was made on the subjects of engine sequence tests for the determination of lubricating oil quality, screening tests used on lube oils, diesel lube oil test methods, and laboratory tests currently used on re-refined motor oils.

The discussions resulting from these sessions were long and varied, but centered on a number of important points. There seemed to be no fundamental disagreement on whether a used crankcase oil could be re-refined into a high-quality product capable of passing the very expensive and quality-defining engine sequence tests. The basic problem, apparently, is that there are not enough test data on re-refined oils to enable these tests to be applied at a level which can produce sufficient economic return. A particular concern of re-refiners is that current military specifications specifically exclude re-refined oils, an exemption based on limited previous testing experience with several oils. These oils apparently were not high-quality formulated motor oils, and there was concern by a number of participants that these tests have unjustifiably given re-refined oils a bad name. This is particularly important since military specifications for administrative vehicle use (MIL-L-46152) are specifications that are widely used in Federal, State, and local government procurement, as well as in many industrial and company procurements for both gasoline and diesel engine lubricating oils. Therefore, the exclusion of a particular type of oil from these marketplaces could well have serious adverse effects, especially on consumer acceptance. Several participants brought up the question of how these particular re-refined oils were selected for testing by the military, and it was acknowledged that no special selection process was used to choose these re-refined oils, and it was also acknowledged that the re-refined oils tested were probably not representative of the general quality of re-refined oils. However, one of these oils was submitted to the military for their consideration in purchase, and apparently both of the oils were labeled as meeting certain high-quality criteria.

In several presentations, the engine sequence tests were described in some detail. In these tests, the gasoline or diesel engine is on a test stand and is run for a prescribed period of time under very tightly controlled conditions. As many variables as possible are specified during the run, including the use of a standard fuel. For example, one particular engine test runs for 196 hours. Then, the engine is dismantled and inspected by certified "raters," who rate the engine as to the particular component that is being tested: the Sequence IIC evaluates engine rusting and corrosion, the Sequence IIIC primarily evaluates oil thickening and oxidation, the Sequence VC evaluates sludge and varnish deposits, and L-38 evaluates bearing weight losses, and the 1-H is a single-cylinder test to evaluate diesel performance. The important point was made that these engine sequence tests only evaluate selected parameters, problems that were found to be important for virgin lubricating oils. It was suggested that these same tests would not necessarily be able to judge whether a particular re-refined oil would be effective in actual usage or not, since the re-refined oils may produce some problems which virgin oils do not have. For virgin oils, it was felt extremely important that extensive correlation of these sequence tests have been made with field data in order to establish whether or not there were problems not evaluated by these existing tests. Apparently, such a problem had been recently discovered with regard to a particular new additive component. This additive formulation in oil apparently passed the sequence tests easily but caused excessive wear in field use. This problem was discovered in actual use, and that additive was quickly removed from the marketplace for those uses in which there was a problem. Efforts are currently being made, particularly in the ASTM, to develop an additional engine sequence test to help evaluate this type of wear problem.

In the current lubricating oil testing situation, the engine sequence tests are a fairly recent development. They were first developed in the mid-1950's and introduced in 1958. The current SA-SE classification system for motor oils was adopted in 1971. There was a great deal of discussion about the various tests for these categories and about a perceived problem in that the SA category has no specified performance tests and the SB category has only limited available performance requirements. Another problem is that the actual purchaser (consumer), e.g., the do-it-yourselfer, seems to have very little understanding of what the entire classification system really means. The automobile manufacturers state in the instruction manual that their warranties require an SE oil, and the manufacturer, by and large, seems to assume that the customer reads and remembers the instruction manual and always uses an SE oil. It was pointed out to the assembled group that there presently exist many non-additive oils for which rather excessive claims are made, often sounding like high-quality oils. These oils apparently sell in relatively large quantities at inexpensive prices in retail outlets. It was also stated by several people that approximately 50 percent of all engine lubricating oil is now sold over the counter to the do-it-yourselfers. Therefore, when individuals who do not completely understand the service classification system purchase and change their own engine lubricating oils, in some cases mistakes will be made and inappropriate oils used.

There was also a great deal of discussion on the question of the SE classification and under what conditions that classification is assigned to a particular oil. During the discussion, a number of pertinent facts were brought out, including the information that there is no formal SE qualification system. The oil is "required" to pass engine sequence tests, but this can be the opinion of the additive company or the oil company; there is no formal approval system for SE service classification. In addition, it was brought out that in these engine sequence tests if an oil does not pass the first time, it may be submitted for testing a second time or a third time without prejudice. However, if a certain base oil and additive system does pass one or more of the sequence tests, these tests do not have to be repeated in future submissions in order to fulfill all requirements for the SE classification. It is apparently then up to the individual company to decide whether the SE quality is obtained by that oil; each company has the responsibility to decide if that is true or not.

These test results can become important, particularly in situations where a customer may make a claim against either the oil company or the automobile manufacturer, e.g., during the warranty period of an automobile. If an oil that has an SE service classification is used and a problem develops which entails litigation, the company involved can substantiate that it did meet the SE performance criteria by showing the test reports, etc., that absolve it from responsibility. It was also stated that it would be very difficult to prove, in court or otherwise, that the oil was the primary cause of a failure.

It was acknowledged in the discussion that it is certainly possible to put the SE classification on a can of motor oil without running any engine sequence tests. It was felt that people in the oil companies or additive companies could put together an SE additive package for a particular base oil and be confident that it will perform adequately in the field without ever running sequence tests on that particular combination. Therefore, the discussion seemed to indicate that the SE service classification system is really a form of self approval; it is a way of providing a guarantee to yourself and to other companies and of providing legal support needed in case of claims made against you by any of your customers. The point was also brought up, however, that the major refiners certainly have an extensive program of evaluating their oils and additive packages, as do the additive companies; and, of course, the engine manufacturers are also very interested in the quality of the product that will be used in their vehicles. All of these organizations work together to try to better define performance criteria for evaluating these oils, and, without question, many of these companies are evaluating each other's products in order to determine whether problems do exist. The statement was made that these sequence tests are methods whereby the engine builders can convey to the oil industry the quality and performance required in lubricants for these modern engines.

There was also some discussion on the engine sequence tests and the precision and reliability of these tests. Each of these tests was designed to evaluate specific problems experienced in virgin oils and additive packages, and so there was some question about whether these tests would be adequate to evaluate recycled oil products without extensive field experience with recycled products. The actual standard deviation of the engine sequence is discussed in detail in the ASTM publication STP 315; however, the statement was also made that these deviations are not really that great. And, without a particular piece of information which would indicate that something has been changed or a very near miss in passing a sequence test, it would be a waste of money to just go back and try again, hoping that the sequence test would be passed.

There was some discussion on the variability of test results for the single-cylinder diesel tests. It was acknowledged that the single-cylinder diesel tests have greater variability than the multicylinder tests for a number of reasons, including having only one piston to evaluate, rather than multiple pistons. For this and other reasons, the diesel tests are usually considered to be on the severe side, and sometimes a good oil will fail if the test happens to be a little more severe than normal. In this case, people in their best judgment may want to re-run this test. It was pointed out that not only the test variability is included, but also the rating variability. The various rating seminars have indicated, for example, that in the area of rust over half of the variability is attributable just to the rating technique itself. Therefore, both of these factors need to be involved in the overall decision on whether to re-run or not. However, there was general agreement that the proof of the pudding is still performance in the field. If a lubricating oil is produced and passes all the tests and if there are problems which start to come up in the field, these tests certainly become questionable, not necessarily from the standpoint of the test itself, but perhaps from the viewpoint of that particular product.

The final discussion in this session concerned expectations of the NBS efforts with regard to test procedure development and evaluation for lubricating oils. Persons very experienced and close to the engine lubricating oil field felt very strongly that no bench test known can possibly replace the engine sequence tests. This was stated to be due in part to what is called the "fuel effect," which is the effect due to contamination from the fuel particles, from gasoline dilution, and from the other effects which actually occur in an engine and are virtually impossible to duplicate in any other environment besides an engine. It was also stated that no bench tests or series of bench tests can reliably predict how a lubricating oil basestock (before formulation with additives) will perform after formulation, or whether the formulated product will be able to pass an engine sequence test. Finally, it was stated that, since the proof of this system is in performance in the field and, at the present time, there is very little data available which indicate that re-refined oils (even when formulated to pass the engine sequence tests) can effectively function over long periods of time in a variety of field service conditions, obtaining this type of field data was felt to be crucial to any increased utilization of re-refined oils for motor use.

SESSION VI

BARRIERS TO UTILIZATION OF RECYCLED OILS

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RECENT USED OIL LEGISLATION

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Before I begin my short talk. I would like to give credit to a man named Mr. Larry McEwen, who works at the Environmental Protection Agency (EPA) in the Solid Waste Management Program. He really started a lot of our efforts, beginning about three or four years ago. He is doing other things now, but he did a good job and started the ball rolling. I only hope that we can continue on as well as Mr. McEwen did.

Let me start by discussing a book I read about 10 or 15 years ago. It was written by a man named Mr. Robert Townsend; it was called Up the Organization. He said that when you are in a management position or are looking at specific issues sometimes it is good to be like a man from Mars--pretend you are just walking in cold and try to figure out exactly what is going on. I did not know much about waste oil when I started, but I am trying to look at the subject right now as a man from Mars, as Mr. Townsend recommended. I would like to share with you some of the things that I see.

The first thing I see is that many of you feel the best way to solve the problem is to form another American Society for Testing and Materials (ASTM) committee. I am not sure that is going to solve anything. Another thing I see is there is a tremendous preponderance of a "can't do" mentality. Let me illustrate what I mean. When we started a noise pollution program at EPA, we were talking about what we can do about cutting down airport noise. The airport operators said, "We can't do anything; it's the airlines." The airlines said, "We can't do anything; it's the airplanes we buy." The engine manufacturers said, "We can't do anything; it's the guy who keeps running his airport all day and all night." I noticed some of that going on here, too.

I have also copied down some "quotable quotes" that I have heard these past two days. One of the things I heard was that the re-refining industry will not be able to make it; the transportation costs are going to be excessive. Mr. Belton Williams has to go to New York and pick up some used oil and then cart it all the way back to Chicago. I also heard some comments that we can only do this in a real small urban area because of the transportation issue. I understand that at the present time Mr. Williams is going all the way from Chicago to West Virginia, picking up the used oil, and then re-refining it and selling it back to the State at less total cost than virgin oil. I also heard a statement that the engine sequence test is probably the best way for us to know whether a lubricating oil is going to work or not. Yet, for about three years the City of San Diego has been using recycled oil in their municipal vehicles, and they have a lot of mileage on them by now. I do not know of any engine sequence tests run on this re-refined oil, and I am not sure that the oil they are using could pass them if they were run.

I am saying these things not to say that what you are doing is, from my viewpoint, wrong, or to try to cast aspersions. What I am saying is I do not think anybody here but a few people really want the country to recycle their oil continuously. I could be wrong, and I hope I am. In fact, it was interesting driving in today. I heard on the radio that OPEC (Oil Producing and Exporting Countries) is going to meet again on December 15. They are not arguing about whether they are going to raise the price or not; they are arguing about how much they are going to raise it. I suspect the new President is going to be faced with, probably in the spring or summer, his first test on the energy area; and they will probably have another kind of soiree and raise the price again.

At the present time, a number of other countries in the world are recycling their oil and making high-quality lubricating oil out of it, West Germany and South Africa, for example. I would like to see us do that, too. Some people in the Congress would like to see it also; and, I hope that Mr. Donald Becker's work and some of the technical people here helping Mr. Becker can help us get into that mode.

Before I start discussing the two pieces of legislation that are going to impact on some of the issues we are discussing at this meeting, let me say that I would like to see industry get their act together so the government does not always have to walk in to help solve problems.

The first law passed involving oil recycling was the Energy Policy and Conservation Act that gave the National Bureau of Standards responsibility for developing test procedures. The EPA has some authority in that law, too, with regard to labeling containers of all new and used oil--more specifically, where to dispose of it and how and to eliminate wasteful practices. "Wasteful practices" is a very interesting phrase which we are having fun with at EPA.

The second act is the brand new Resource Conservation and Recovery Act of 1976, which will lay down national standards for how to treat, dispose, or store hazardous wastes. We are right now defining what a hazardous waste is, and one of the things which might be a hazardous waste is used oil. We also have a section of that new act which requires us to do certain things that would require the Department of Defense to spend a premium for a recycled product, compared with the price they spend for a virgin product. There is another section which states that within two years we can take certain actions to require all Federal facilities to procure recycled commodities, like re-refined oil.

I guess most of you here have read those two acts. Some of you may not be as familiar with the second as the first. If you need further information, write me a note and I will be happy to send you copies of it, and we can also discuss them if you are interested in doing so, especially since one of the main purposes of this meeting was stated to be to get people talking to each other. Or, perhaps one of the problems has been that some people have been talking to each other too long.

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THE LEAD PROBLEM ASSOCIATED WITH RECYCLED OIL

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The Environmental Protection Agency's (EPA) current activities on lead as an air pollutant are the result of recent litigation with the Natural Resources Defense Council (NRDC). On March 1, 1976, Judge Steward, Southern District of New York, ruled in NRDC vs. Train that EPA must list lead under Section 108 of the Clean Air Act as a pollutant for which air quality criteria must be issued. Simultaneous with issuance of air quality criteria, national ambient air quality standards will be proposed for lead. Once an air quality standard is established, States must submit implementation plans to EPA describing steps for achieving and maintaining such standards. Our current schedule states that EPA will propose ambient standards for lead on August 10, 1977.

Because lead is used as a gasoline addition, it poses a problem as a contaminant in used crankcase oil. In some cases, the used crankcase oil is burned as a supplemental fuel. The lead contained in the used oil is emitted when the oil is burned. One of EPA's concerns regarding used crankcase oil stems from these potential emissions of lead.

There are already two EPA regulations established to control the lead content of gasoline. First, there is a regulation which requires the availability of an unleaded grade of gasoline; unleaded gasoline is necessary for use in automobiles equipped with catalytic converters. The second regulation requires the phase-down of lead content in the total gasoline pool to 0.5 grams of lead per gallon of gasoline by October 1, 1979. Both regulations will significantly reduce lead emissions from mobile sources, as well as the lead concentration in used crankcase oil.

Since 1971, ambient air quality levels of lead around the country have shown a decreasing trend, with most levels well below 5 $\mu g/m^3$ for 90-day and 30-day averaging periods. The decreases can be attributed primarily to the (1) introduction of automobiles with lower compression engines which require gasoline with lower octane and, thus, lower lead content, and (2) the introduction of unleaded gasoline for use in catalyst-equipped automobiles.

The EPA's activities relating to the establishment of an ambient air quality standard are well underway. The draft air quality criteria have just been made available by EPA's Office of Research and Development for external review by the public. This document addresses the scientific and technical information on lead and provides a recommendation that an ambient level of 5.0 $\mu g/m^3$ be considered as the point below which adverse effects have not been observed. From this point, the Office of Air Quality Planning and Standards will assess the data, determine an appropriate margin of safety for the standard, and develop the recommendation for a proposed air quality standard for lead. At present, our range of standard alternatives for assessment range from 0.5 $\mu g/m^3$ to 5.0 $\mu g/m^3$ for a 90-day averaging period.

The burning of used crankcase oil could result in significant emissions of lead. The majority of the studies currently available indicates that the burning of used crankcase oil in power plants and other facilities results in ambient concentrations below 5.0 $\mu g/m^3$ for 24-hour periods. In most of these studies, the used oil is used as a supplemental fuel and is mixed in small proportions with other fuel oils. It does not appear that burning of used crankcase oil would result in significantly high air quality concentrations (greater than 5.0 $\mu m/g^3$) unless the oil is used alone as a fuel oil.

In support of the air quality standard, we are completing an analysis of the total emissions of lead from the burning of used crankcase oil. Our emission calculations indicate that approximately 4,300 tons of lead per year come from the burning of used crankcase oil. These calculations assume that 50 percent of the lead in the crankcase oil is lost as an emission and that 300 million gallons of used oil are burned each year. The 4,300 tons of lead emissions per year from burning used oil can be compared to the more than 200,000 tons of lead from automobiles each year. The number of facilities which could burn waste oil is large, and the emission problem could be widespread, although emissions at any one facility are probably small. At present, we feel that the emissions of lead around major stationary sources such as primary nonferrous smelters will be our greatest problem with regard to lead, aside from automotive emissions of lead.

The available studies regarding the burning of used crankcase oil and the analysis which we completed indicate that on the average lead emissions from sources burning used oil do not result in significantly high ambient concentrations of lead. As phase-down of lead content in gasoline occurs and unleaded gasoline continues in use, the lead content of used crankcase oil will decrease and the ambient lead concentrations associated with burning of used crankcase oil will also decrease.

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FACTORS AFFECTING USED OIL RECOVERY/UTILIZATION AND EFFECTS OF PROPOSED POLICY ALTERNATIVES

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In assessing the determinants of used oil allocation and recycling, we have examined various facts pertaining to virgin and waste oil markets. Our analysis has shown that there are several factors that influence the recovery of used oil and its methods of utilization. Conveniently, we can group these factors into three classes:

1. Technical factors
2. Economic factors
3. Institutional factors

By technical factors we mean chemical and other contaminants in used oils that prevent re-refiners from producing a final product with consistent characteristics. Technical barriers result in higher production costs for re-refiners and affect the overall marketability of re-refined products.

By economic factors we mean the supply-and-demand conditions in the virgin oil markets and their influence on the supply-and-demand conditions in the used/re-refined products markets. For example, when the price of virgin oils decreases, there is less demand for used virgin oil, either as a fuel supplement or as a re-refining feedstock. This means less recovery in general and probably more dumping. Beginning in 1973 with the Oil Producing and Exporting Countries' embargo and the resulting increases in the price of virgin oils, used oil has become widely demanded and recovery has increased substantially. However, strong profit incentives dictate that the bulk of used oil supplies be used as fuel supplement rather than re-refined. Environmentalists view this trend with alarm because burning used oil as a fuel supplement without control of emissions--by far the most prevalent use recently--results in serious air pollution, and it creates potential fire hazards.

By institutional factors we mean government actions that directly and/or indirectly have influenced recovery, reuse, and re-refining of used oil. As we noted, the 1965 Reduction Excise Tax, by lowering the price of virgin lubricants to consumers, resulted in approximately a 66-percent reduction in re-refiners' output. The Federal Trade Commission (FTC) labeling requirement (also instituted in 1965), by emphasizing rather the origin of the re-refined oil ("used oil") and not the characteristics and quality properties acquired through re-refining, displaced re-refined products from the retail market. Current regulation of the market price of virgin products also militates against used oil recovery and re-refining.

With present policies failing to regulate the flow of used oil and, indeed, unwittingly discouraging re-refining, many feel that there is need for some change in current social policy toward used oil disposal and reuse methods. The general goal of policy changes would be to encourage greater recovery of used oil (i.e., collection of spent virgin oils) and to encourage more re-refining and less uncontrolled burning of recovered used oil supplies.

To this effect, we have examined several proposed policy alternatives. These alternatives fall into one of four groups:

1. Policies that aim to improve the quality of re-refined products:
    - Good-housekeeping regulations for generating sources and collectors

- Subsidies to re-refiners for technology improvements
- Quality tests for re-refined products

2. Policies that aim to change the economic incentives that burners and collectors face, including:
    - Taxes on burners
    - Taxes on collectors for sales to burners
    - Subsidies to collectors for deliveries to re-refiners above normal levels of deliveries
    - Licensing of collectors
3. Policies that aim to lower institutional barriers to re-refined products, including:
    - Taxes on virgin lubricants
    - Quotas for virgin oils
    - Tax rebates for users of virgin and re-refined oils
    - Regulating government procurement to include re-refined oils
    - Revising labeling requirements of the FTC
4. Policies that aim to change disposal habits and reuse methods through educational and information programs addressed to:
    - Used oil generating sources
    - Used oil direct users
    - Buyers of virgin and re-refined oils

The key to analyzing the effects of these policies for changing the current pattern of disposal and reuse to better reflect social costs and benefits is an understanding of the determinants of prices and quantities in used oil markets. One can, of course, always appeal somewhat vaguely to the laws of supply and demand, but more is required to develop an understanding that is useful for policy analysis.

The evidence we have examined leads us to the conclusion that the used oil collector--the middleman between the generating sources and the intermediate or ultimate users of used oil--operates as a discriminating monopolist serving two main sets of buyers: fuel dealers and re-refiners. These two markets have very different demand elasticities, with fuel oil dealers' demand being far more inelastic than that of re-refiners'. From the resulting price discrimination model and our evidence on demand elasticities, it followed that the supply to re-refiners is a residual and is therefore very vulnerable to changes in conditions in virgin oil markets.

Using the discriminating monopolist model to explain price and quantity determination in used oil markets, we performed a qualitative analysis of the policy measures listed above. In addition, whenever data were available we made quantitative estimates of the effects of the proposed policies. From these analyses, the following conclusions were obtained.

1(a) Measures that improve the quality of used oil will result in an increase in both re-refiners' demand for feedstock and in burners' demand for fuel supplement. They may also cause the collectors' costs to change. The net effect of such measures on quantities of used oil recovered and re-refined is, thus, ambiguous.

1(b) Measures that improve the real and perceived qualities of re-refined products will result, unambiguously, in an increase in re-refiners' demand for feedstock and, hence, in an increase in recovery and re-refining. Unfortunately, it is difficult to implement policies that improve output quality without instituting those that improve input quality.

2(a) Measures that provide direct incentives for sales of used oil to re-refiners (e.g., subsidies for sales to re-refiners) and/or disincentives for sales to burners (e.g., taxes on such sales) will be effective in promoting re-refining and discouraging burning. However, only those incentive measures which have the effect of raising the marginal revenue from sales to re-refiners (e.g., subsidies for such sales) will result in more recovery. If disincentive measures such as a tax on sales to burners are applied, care must be taken that the tax is not so large as to cause collectors to exit the industry and thereby reduce ultimately the quantity of waste oil recovered.

2(b) Measures that require licensing of collectors and constrain collectors to sell specified quantities to re-refiners will, if enforced, result in increased re-refining. Whether or not these measures will result in increased recovery and/or decreased sales to uncontrolled burning will depend upon the incremental cost of additional recovery relative to the incremental loss of revenues of diverting sales from burners to re-refiners. Constraint levels must be structured carefully to avoid driving collectors out of the market altogether.

3(a) Measures that provide for taxes or returnable deposits on virgin lubricants will promote additional recovery and re-refining. However, the imposition of a tax introduces a distortion in the market for virgin lubricants if current price and marginal social cost are approximately equal.

3(b) Measures that remove institutional barriers to the marketing of re-refined products (e.g., government purchase specifications, labeling requirements), assuming that there are no valid reasons for such barriers, will increase the demand for re-refined products and, hence, result in more re-refining, more recovery, and less burning.

4 Measures that aim to educate the public on used oil handling and reuse methods, as well as on the properties of re-refined products, may contribute to higher recovery, less uncontrolled burning, and higher demand for re-refined products.

Unfortunately, in this study as in so many other studies of environmental resource policy, we have had to leave many questions unanswered. The most important of these is: "Just how far should we go in encouraging recovery and re-refining and in discouraging burning of used oils?" To provide a fully satisfactory answer to this question, we would need a great deal of quantitative information of the social costs of the various methods of used oil reuse and disposal and information on the social costs of implementing the various different policy measures that we have discussed. The problem of information unavailability clearly points to the need for future work on the benefits of environmental protection. However, while the evidence on benefits is being gathered, practical decisions will be made concerning target levels for recovery, re-refining, and burning of used oils. Whatever target levels are selected, we have shown that there are both effective and ineffective measures for implementing these targets. Indeed, we have demonstrated that many of the commonly proposed measures which we have examined will actually work in a direction opposite to that intended. We concluded that used oil policy makers must conduct economic analyses of the policy options under final consideration if serious mistakes are to be avoided.

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ENERGY CONSERVATION ASPECTS OF RE-REFINED OIL

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I am going to discuss a study we have in progress related to the energy conservation aspects of re-refined oil. The scheduling of this meeting relative to the scheduling of our study is such that we are not far enough into the study to be able to present answers, but we can tell you something of what we are trying to do in this study.

Most of the information is found in the tables, and I will just cover these rather briefly; I hope they are somewhat self explanatory. The title of our study is "The Energy Conservation Aspects of Re-refined Oil." I am in the Environment and Energy Conservation Division of The Aerospace Corporation. This study is being sponsored by the Alternative Fuels Branch of the Division of Transportation Energy Conservation of the Energy Research and Development Administration (ERDA). Mr. Eugene Eckland is the Branch Chief.

A summary of the items covered in the briefing is found in table 1. As I said, this is a presentation of what we are planning to do in the study, how we are planning to do it, where we are, the factors we are going to consider, and some initial observations we have made from looking into used lube oil re-refining and from talking to people in the industry.

TABLE 1

BRIEFING OUTLINE

- Background and objectives
- Study approach
- Task description
- Study status and initial observations
- Re-refining energy and process considerations
- Virgin lube oil energy requirements
- Factors impacting production and usage of re-refined oil

TABLE 2

BACKGROUND AND OBJECTIVES

- Study initiated in September 1976
    - Projected completion date March 1977
- Assessment of energy conservation potential of re-refining lubricating oil
    - Re-refining of used oil to lube oil
    - Utilization of used oil as a fuel
        - Required lube oil produced from crude
- Study tasks
    - Survey and evaluation of re-refining process
    - Economic and institutional aspects of re-refining
    - Cost/benefit analyses
    - Recommendations for future ERDA action

The background of our study, which was initiated in September 1976, is shown in table 2. The study is concerned with the assessment of re-refining issues and does not involve the development of new technology. The basic scenario that we will address is designed to provide a more clear-cut answer to the question: "Is the use of used oil re-refined back to lube oil the best use?" A second scenario assumes burning of used lube oil in furnaces.

The study basically has four tasks, which are: survey of re-refining processes; economic and institutional aspects of re-refining; cost/benefit analysis; and, finally, recommendations to ERDA regarding future re-refining issues.

Our basic study approach (table 3) is to acquire and assess data. As I said before, we are not attempting to develop technology; this is an assessment study. The items we will be covering in the assessment range from process technology to the ability of the re-refining industry to remain healthy and viable and to re-refine used oil successfully. The so-called "bottom line" is the impact of our two scenarios of disposing of used oil, either by burning or re-refining, and the impact on crude oil usage.

TABLE 3

STUDY APPROACH

- ● Data acquisition procedure
  - - Review of literature related to re-refining of used oil
    - • Lube oils
    - • Hydrocarbon oils (not synthetic)
  - - Liaison with industry
    - • Re-refiners and refiners
    - • Government agencies and laboratories
    - • Universities and research organizations
    - • Additive manufacturers
- ● Data review and assessment summary
  - - Process technology
  - - Process economics
  - - Energy requirements
  - - Product utilization (marketing)
  - - Impact on crude oil usage

Detailed objectives in the study plan are given in table 4. These correspond to the four original ones that I showed rather briefly before.

Task A, as we call it, is basically the compilation of data on re-refining. Task B is an assessment of the data that we have acquired and assembled in a logical order. This type of task is directed to the economic viability of the industry to re-refine oil. Task C is termed the cost/benefit analysis; this contains two scenarios that we propose where the used oil is either re-refined back to lube oil or mixed with fuel oil for subsequent combustion in a furnace or boiler.

In the scenario that looks at the burning of used oil, we would like to address two aspects, one where used oil is just burned straight, and the other where it is processed back to the equivalency of a fuel oil, which increases costs and its desirability as a fuel oil. The task output of this item is the assessment of energy aspects of used oil utilization.

The final task is based on the previous work--to provide ERDA with recommendations for their action. Potential items are shown in the table. ERDA, of course, will not be providing legislative assistance, but perhaps they will be in a position to recommend certain legislative action.

The current status of the study is shown in Table 5. We are essentially completing the acquisition of data at this time. Some of the typical sources of information are shown. We did a patent search to see what kind of new processes or technologies were potentially available and talked to people in the business.

Some observations that we are finding as we go through data and talk to people are that the re-refineries that we have seen typically lack sophisticated instrumentation to keep track of process energy requirements. Some data we would like to have for this study are not available; they are generally proprietary, and we cannot use them. On the operation of refineries, we would like to address actual energy savings.

TABLE 4

TASK DESCRIPTION

Task A: Survey and Evaluation of Re-Refining Processes

- Lube oil re-refining processes
  - Existing and new processes
  - Process description
  - Process equipment requirements
  - Process energy requirements
  - Product type and yield
  - Environmental impact
- Task output
  - Collation of data on process design, plant operation, economics, etc.

Task B: Economic and Institutional Aspects of Re-refining

- Process economics and energy evaluation
  - Plant capacity
  - Plant investment, operating costs, return on investment
  - Feedstock collection and transportation
  - Plant environmental considerations
  - Expansion of capacity and conversion to new processes
  - Assessment of process energy requirements
- Institutional impacts
  - Specifications on lube oil quality
  - Usage by governmental agencies
  - Financial/tax assistance to re-refiners
- Task output
  - Assessment of technical and economic aspects of existing and new processes

Task C: Cost/Benefit Analysis

- All used oil re-refined back to lube oil
  - Petroleum savings due to less virgin lube oil production
  - Replacement of used oil currently used for road oil and furnace fuel by fuel oil or residual oil
- All used oil used as furnace fuel
  - Increase in petroleum consumption to satisfy lube oil demand
  - Assessment of potential problems related to combustion of waste oil (burner corrosion, burner operation, emission of trace elements)
  - Burning of untreated used oil versus processing of used oil to comply with fuel oil standards
    - Environmental considerations
    - Economic impact
- Task output
  - Assessment of the energy aspects of used oil utilization

Task D: Recommendations for Future ERDA Action

- Preparation of plan for future government-supported activities in the area of used oil re-refining
  - Technology research and development
  - Demonstration of new processes
  - Legislative assistance
  - Environmental considerations

TABLE 5

STUDY STATUS AND INITIAL OBSERVATIONS

- Data acquisition phase nearly complete
  - Government publications
  - SAE publications
  - Industry reports
  - Journal articles
- Patent search completed
  - Approximately 50 patents located
  - Covers 1950 to 1975 time period
  - U.S. and foreign patents
- Liaison with industry and other organizations in progress
  - Re-refiners, refiners, and additive manufacturers
  - Government agencies, universities, and research organizations
- Literature and data review and assessment in progress
  - Acid clay process widely used (sludge disposal; new processes)
  - Many existing plants are small, individually owned, and old
  - Re-refinery plants run on self-generated fuels
  - Heat recovery equipment not widely used
  - Sophisticated process instrumentation lacking
  - Computer modeling required to assess refinery operations
  - Some data considered proprietary
  - Energy conservation may be secondary to environmental and natural resource issues

If a mixed refinery product were produced at a different ratio of lube oil to fuel oil, would there be savings in process energy? These data typically require a sophisticated computer model of the refinery. We do not have practical information from industry on this subject. It appears that perhaps the energy conservation potential may not be the big driving force, but rather lube oil availability and/or conservation and the environmental issues will be of primary concern.

Table 6 shows what we are attempting to do in regard to re-refining, energy conservation, and energy usage. We would like to consider the overall energy required in the re-refining process, which includes the energy required to collect the oil, the energy required to dispose of waste products, process energy, and the energy required to make chemicals or other treating agents used in the re-refining process.

TABLE 6

RE-REFINING ENERGY AND PROCESS CONSIDERATIONS

- Process energy
- Process applicability to available feedstock
  - Industrial oil
  - Crankcase drainings
- Process suitability to scale of operation
- Process yield and characteristics of end product
- Credit for usable by-products
- Manufacture and transport of process chemicals
- Collection and transportation of used oil
- Waste product disposal

TABLE 7

VIRGIN LUBE OIL ENERGY REQUIREMENTS

- Current refinery practices and yield of lube oil
- Change in refinery efficiency due to lube oil/fuel oil product shift
    - Reduced virgin lube oil production due to demand filled by re-refining used oil
    - Increased virgin lube oil production due to expansion of market and no recycling of lube oil
- New lube oil production technology
    - Hydrotreating in place of solvent extraction
- Availability and difficulty of extraction of lube oil from new sources of crude

TABLE 8

FACTORS IMPACTING PRODUCTION AND USAGE OF RE-REFINED OIL

- Industry capacity
    - Approximately 10 to 20 percent of available used oil
    - Number of re-refiners declining
    - Existing capacity not fully utilized
- Capability for expansion
    - Availability of feedstock
    - Availability of capital
- Product acceptance
    - Question of quality
    - Cost relative to virgin lube
    - Widespread availability
    - Label recognition
- Legislative impacts
    - Product standards and specification
    - Controls on used oil disposal
    - Environmental controls on re-refinery operations
    - Favorable tax legislation
    - Mandatory utilization of re-refined lube oil by governmental agencies

Table 7 is essentially a corollary to the preceding table. Here we are looking at the total energy requirement to produce virgin lube oil using current refinery practices. We would like to address the potential energy changes for varying product mix, and maybe address new lube oil production techniques, such as hydrotreating, that may make a lube oil from virgin crude less energy intensive. The final item shown is to try to predict future production of virgin lube oil from crude. It may not be as suitable or as easy to obtain as it is from current crude stocks.

Finally, in table 8 we delineate some of the factors we see that are impeding the production and use of re-refined oils. Industry capacity has been declining in recent years, and the typical re-refiner is a small businessman who generally lacks capital to expand and who is also having difficulty increasing the availability of feedstock. Of course, they will be in competition with the fuel oil people. The other serious problem is related to product acceptance, quality, and costs relative to virgin lube oil. Another somewhat institutional concern is the ability of a customer to recognize the label. If he were buying a major brand, like Shell X-100, the label is recognized from the east coast to the west coast; re-refiners tend to be small with brands which are only distributed locally. Consumers are often reluctant to buy brands with which they are not familiar. There are legislative impacts, which were previously discussed, which can drastically influence the fate of re-refined oil. These include the development of product standards and specifications for re-refined oil, the amount of controls that are applied on used oil disposal, passage of favorable tax legislation, and the use of re-refined oil by government agencies to provide an example for the marketplace.

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a Workshop on Measurements and Standards for Recycled Oil held at NBS,
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MARKETING BARRIERS FOR RECYCLED OIL

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I would like to discuss briefly some of the important conclusions of three of the six parts of the recent studies we performed for the Environmental Protection Agency (EPA) and how these relate to the problems of encouraging new investment in waste oil recovery by re-refining [1, 2, 3].[1] This is important because the "bottom line," from all the discussion we have had with re-refiners, oil companies, and private investors, is: "Will anybody invest money in this business?" Money will be invested in re-refining only if an adequate return can be realized.

Rather than take a theoretical approach in trying to describe the economics of re-refining, we conducted extensive interviews with industry representatives. Most of the conclusions of our work are based on interviews with about 24 re-refiners which were carried out in 1973, 1974, and 1975. It is interesting to find, however, that firms in existence today differ from one another quite a bit; and those that went out of business in the 1960's differ quite a bit from today's firms, as well.

Although some firms are larger than others, the major difference between firms is the markets served. We found three different kinds of re-refiners. There is the re-refiner who, in the main, produces base oil for sale to jobbers or wholesalers. This is an SA oil, perhaps an SAE-20, sold in the wholesale market. Such re-refiners compete with other lubricating oil wholesalers; they do not sell oil to final users. The second kind of re-refiner sells to the final-user market, typically to commercial customers such as operators of vehicle fleets, industrial firms, etc. In this case, re-refined oil competes with established major brands of oil; the re-refiner sells directly to the final user and at a price substantially greater than that charged the wholesaler. The third kind is the custom "closed cycle" re-refiner who deals with railroad or industrial oils. He is really providing a service, rather than a product. This is an important distinction because the question then is not, "Is the quality of re-refined oil as good as the quality of virgin oil," but rather, "How well have I segregated my product and how well is the re-refiner doing his cleaning." It is quite a different situation.

Our conclusions from the survey were as follows. Firms which sell mostly in the wholesale market had the worst economic performance, and I will describe the reasons for that shortly. Most firms which sell in the commercial/industrial market were able to survive through the difficult times of the 1960's and early 1970's and are, by and large, the most profitable. Therefore, one of the major recommendations of our study was to examine marketing barriers to the sale of re-refined oil in the commercial/industrial sector.

Before discussing the different market sectors, let us take a look at figure 1, which shows the refinery gate price of a 300 neutral lube oil, f.o.b Houston, as a function of time.

Many of you have heard the frequently cited statistics that there were about 150 re-refiners in business in 1960 processing about 300 million gallons per year and that currently there are somewhere around 26 re-refiners processing under 100 million gallons per year. Now, consider the refinery gate price for 300 neutral lube oil. From 1960 to 1974, it remained essentially constant. Of course, the cost of re-refining did not remain constant during that period. As a consequence, you can see very clearly that if you had to sell re-refined oil in the wholesale market (at a price discount because in this market re-refined oil competes with the lower grades of virgin oil, not this 300 neutral) you could probably sell it for about $0.23 or $0.22 per gallon over this period of time. So, re-refiners during that time were caught in a

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[1] Figures in brackets indicate literature references at the end of this paper

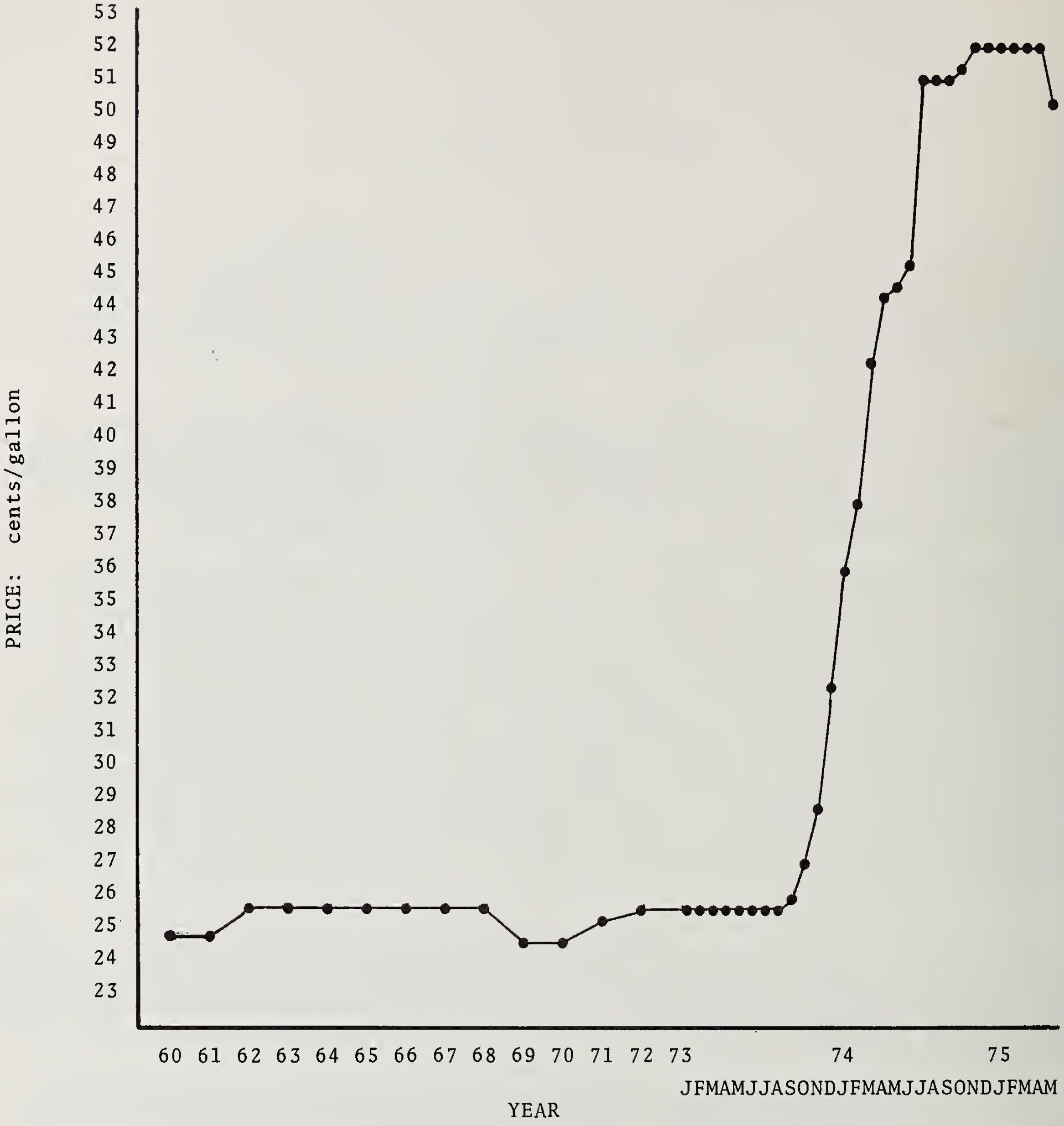

Figure 1. Refinery gate price for 300 neutral lube oil 1960-1975 [4,5].

classic cost/price squeeze, and a lot of them went out of business. The cost of re-refining went up due to the higher cost of collection, increased use of acid to remove greater concentrations of additives, increased labor and material costs, etc. After the Arab oil embargo, prices rose very sharply. Part of that very sharp rise was a consequence of price controls. Following the embargo, price controls on fuel oils were removed; however, controls on lube oil prices remained, creating a shortage of these products. This enabled some re-refiners to penetrate markets they had never served previously. It also tended to push up the price at which lube oil was sold after price controls were relaxed. Since that time, prices have softened somewhat, and I believe they have now risen to where they were somewhere in early 1975.

The point of this discussion is that re-refiners serving the wholesale market could not increase prices for about 15 years; now prices are higher, but so are costs. If we again see a period of continued moderation in the price of oil at the same time that other costs are escalating, we are likely to see a recurrence of this cost/price squeeze. Therefore, the re-refiner who sells in the wholesale market, where profit margins tend to be smaller than in the final-user market, is vulnerable to considerable fluctuations in profitability.

The conclusion is as follows: How does a re-refiner penetrate the final-user market? Again, we use some examples of what existing re-refiners have done. I would like to talk about two final-user markets now and restrict my discussion to crankcase oils.

First, let us discuss the retail market. As part of the program for EPA, Teknekron conducted a survey of lube oil consumers in Oakland, California [2]. We interviewed about 600 people who were buying lubricating oils at automotive supply stores and discount houses. We had a number of objectives of this study. One was to investigate the possibility that purchasers of "over-the-counter" oil would return their used oil for recycling. We also investigated some of the purchase habits of retail consumers--why they bought what they bought. Table 1 shows the API/SAE (American Petroleum Institute/Society of Automotive Engineers) specifications of oils bought by the interviewees. You can see that, in the main, top quality SD and SE oils were bought. Very few customers bought non-detergent oils. This may lead someone who is not familiar with oil marketing into thinking that the individual consumer is quite sophisticated. However, we found that most purchasers did not know what those letters mean and probably could not care. Table 2 shows the factors that led to the oil purchase. We asked the people, "Why did you buy what you bought?" We recorded the number of times each factor was mentioned. As you can see, brand name was mentioned approximately twice as often as lowest price. It is interesting that viscosity received a higher frequency of response than the API classification. It shows that the consumers may not be conscious of the difference between viscosity and performance level. The conclusion here is, of course, that brand name is the major factor. It is a surrogate for quality. Most consumers never want to see lubricating oil; they certainly do not want to get it on their hands. There is no way they can tell how good it is by looking at it. So, they buy on the basis of brand name.

TABLE 1

GRADE OF OIL PURCHASED [2]

	Number of respondents	Percent
SC and SE	245	41.7
SD and SE	96	16.3
SC and SD-SE	69	11.7
SE	68	11.6
SA or ML	40	6.8
SC or MS	21	3.6
SB and SC	20	3.4
Others, rated	20	3.4
Others, not rated	9	1.5
	588	100.0

TABLE 2

MOST IMPORTANT FACTOR
IN PURCHASE DECISION [2]

Factor	No. of times mentioned	Relative frequency, %
Brand name	349	65
Lowest price	114	21
Viscosity	34	6
API classification	8	2
Others	31	6
	536	100

TABLE 3

FACTORS IN OIL PURCHASE DECISIONS [2]

	No. of times mentioned	Relative frequency, %
Brand name	461	56.3
Lowest price	199	24.3
Viscosity	69	8.4
API classification	12	1.5
Recommendations of mechanic, dealer, or manufacturer	13	1.6
Medium price	6	0.7
Recommendations of friends or relatives	5	0.6
High price	5	0.6
Labeling[a]	3	0.4
Other reasons	46	5.6
	819	100.0

Respondents were then asked to rank these factors in their order of importance in deciding which oil to buy. Whereas brand name was mentioned 2.3 times as often as lowest price, brand name was selected as the most important factor in the purchase decision 3.1 times as often as lowest price.

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[a] refers to phrases like "meets or exceeds all car manufacturers' warranty requirements."

Table 3 indicates the frequency with which each of the factors listed in table 2 was mentioned as the most important factor. The previous table showed that brand name was mentioned twice as often as price. Here we see that in considering the most important factor in the purchase decision, brand name was mentioned three times as often as price. A logical question is: "Is there any difference in consumer purchase habits between those who buy only small amounts of oil and those who buy a lot of oil? The answer is shown in the next table (table 4) where we did a cross tabulation.

Table 4 relates the most important factor in oil purchases to annual oil consumption. Again, we see that those who consume the most lube oil tend to make purchase decisions on the basis of brand name rather than price or other factors.

What can we conclude from this information? It is clear that in the retail market brand name is really the prime indicator of quality. We interpret this to mean that customers view the brand name as a surrogate for quality. This implies that re-refined oils sold in the retail market under the label of an independent re-refining company probably cannot compete with quality virgin oils produced by the major oil companies. For this reason, some re-refiners who do produce quality oils tend to discourage or even prohibit their sale in discount houses or service stations.

TABLE 4

MOST IMPORTANT FACTOR IN PURCHASE DECISION AND ANNUAL OIL CONSUMPTION[a]

	Very low		Low		Moderate		High	
	Number of respondents	%	Number of respondents	%	Number of respondents	%	Number of respondents	%
Lowest price	25	22.9	27	21.6	27	19.7	10	15.4
Brand name	71	65.1	84	67.2	83	60.6	45	69.2
Viscosity	9	8.3	2	1.6	7	5.1	3	4.6
API classification	0	0	2	1.6	5	3.6	0	0
Labeling	0	0	0	0	0	0	1	1.5
Performance	0	0	3	2.4	5	3.6	2	3.1
Other	4	3.7	7	5.6	10	7.3	4	6.2

Very low: less than or equal to 12 quarts per year
Low: over 12, but less than or equal to 20 quarts per year
Moderate: over 20, but less than or equal to 50 quarts per year
High: over 50 quarts per year

Number of respondents: 436

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[a] The observed relationship is statistically significant at the 0.136 level.

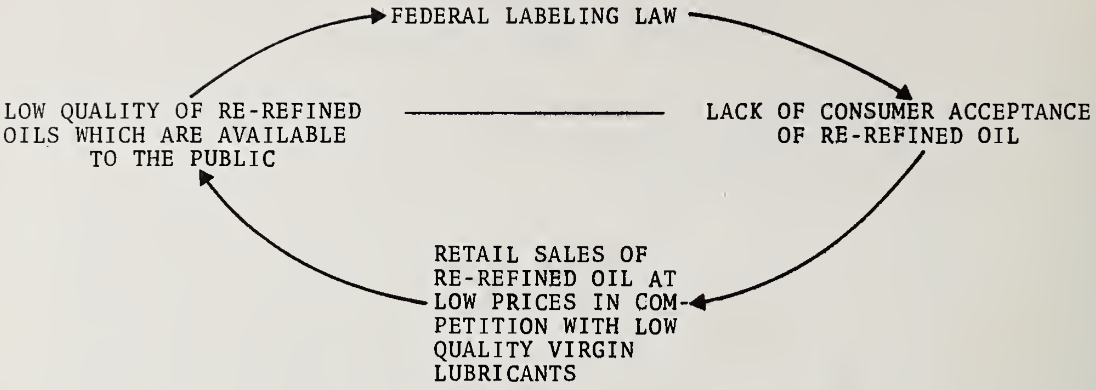

Figure 2. Barriers to public acceptance of re-refined oil [3]

In figure 2, we see an interesting phenomenon with regard to barriers to public acceptance of re-refined oil. Keep in mind the situation in the retail market, and let us consider some of the historical problems faced by the re-refining industry. On the right side we have this lack of consumer acceptance. Re-refined oils never really have enjoyed a quality image. Although some re-refiners produce quality products, the re-refining industry has a history of opportunists and men of questionable integrity whose actions have discredited the products of the quality-conscious firms. Partially as a result of this situation, the Federal Trade Commission established labeling regulations to protect the consumer from these shady operators. Because of these regulations and because of the lack of consumer acceptance, we find that high-quality re-refined oils are not sold in the retail market because retail customers buy on the basis of brand name. This tends to reinforce the public's negative image of re-refined oil. And what does re-refined oil compete with in the retail market? They compete with the cheapest oils available, some of which have a negative viscosity index (VI) or a very low VI. Some of the jobbers I have interviewed actually admitted to buying negative VI base oil from virgin oil producers and blending it with re-refined oil to raise the VI. These products sell for $0.30 to $0.40 a quart or less. There is no incentive for re-refiners to produce quality oils for the retail market because retail consumers do not believe that they are of high quality and will not pay the required price to make that sale attractive. So, we have this "vicious circle."

The real question one wants to ask is: "How do you break that vicious circle?" The only way I can think of is if the major oil companies were to sell re-refined oil--not necessarily produce it, but sell it. Then re-refined oil might be accepted in the retail market as a quality product. There is some evidence that over the past couple of years at least one, and perhaps two or three, major oil companies have actively investigated the feasibility of doing this. I think that the recession of 1974-1975 tended to dampen this activity quite a bit because lube oil supply became relatively abundant. As far as the retail market is concerned, acceptance of re-refined oil will require the participation of those firms which have earned the confidence of quality-conscious consumers.

Let us talk briefly now about the commercial market. There are a couple of key differences between the commercial and the retail market. Of course, the commercial customer buys a lot more oil than an individual. The contact between the seller and the consumer is direct, not through a middleman or a marketing outlet. The consumer also tends to be able to evaluate the quality of the oil more objectively than the individual purchaser in the retail market. He can look at the oil pressure guage on his vehicle; he frequently monitors the oil consumption. If he drives a diesel-engine truck several hundred thousand miles, he is certainly very concerned about frequency of maintenance. He is also very concerned about customer service. I understand that some of the major oil companies have been rationalizing their marketi operations so that they pay less attention to some of the more specialized, lower volume accounts. This is an opportunity for re-refiners.

So, the factors for success in this commercial market are, of course, quality assurance, a competitive price, and service.

How do we get this quality assurance? This is certainly a concern for the National Bureau of Standards. As the gentleman from Cummins said earlier, it is very expensive to provide quality assurance. How have re-refiners been able to compete successfully in the commercial market? They have not succeeded because their products have been qualified under specification MIL-L-2104C. Rather, re-refiners have been able, over a number of years, to establish "toe to toe, belly-to-belly" relationships with quality-conscious commercial customers based on product quality and reliable service.

One question that I think the government has to address now is how do you enable a producer of re-refined oil to penetrate the commercial market without having to spend, say, 25 years in the business; you will not be able to attract new investment in waste oil recovery unless investors can earn a reasonable return in a relatively short period of time. Let me cite an interesting example. One of the firms we interviewed had historically sold almost all of its oil in the wholesale market, earning about $0.01 per gallon on such sales. In the winter of 1974, when the Federal Energy Administration had released price controls on fuels but not on lubes, the City of San Diego received only one bid for its lube oil supply for the following year. The only bidder was the local re-refiner, who was awarded the contract. As a result of this contract, he has been able to expand his commercial business on the basis of customer satisfaction. The City of San Diego is, of course, a large quality-conscious customer and a very visible one. Because of the favorable image of selling oil to the City, this re-refiner has been able to compete in the commercial market. Now, more than half of this re-refiner's sales are in the commercial sector, and he is making enough money to expand his plant and facilities. So, I submit that if re-refiners want to expand sales to commercial consumers, they must get a foot in the door somehow. And, if the government is interested in stimulating investments in re-refining, then perhaps some demonstration projects involving municipalities, State governments, or larger industrial or commercial firms which are willing to participate would go a long way towards showing that re-refined oils can be acceptable to the consumer. Once this happens, the barriers in the commercial market will be much reduced, thereby increasing incentives for investment in waste oil recycling.

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[4] Platts Oil Price Handbook and Oilmanac, 1960-1974.

[5] Platts Oilgram, January-May 1975.

National Bureau of Standards Special Publication 488. Proceedings of
a Workshop on Measurements and Standards for Recycled Oil held at NBS,
Gaithersburg, Maryland, November 22 and 23, 1976. (Issued August 1977)

DISCUSSION

SESSION VI. BARRIERS TO UTILIZATION OF RECYCLED OILS

There were five speakers in this session, and their presentations were on the topics of the recent used oil legislation, the lead problem in recycled oils, economic aspects of used oils, energy conservation aspects of oil recycling, and marketing barriers for recycled oil. Besides the legislation under which the National Bureau of Standards (NBS) is working, additional recent legislation affecting used oil includes the Resource Conservation and Recovery Act of 1976 (Public Law 94-580) and, perhaps, the Toxic Substances Control Act (Public Law 94-469). This legislation affects both the conservation of resources and the environmental and the toxicological problems with disposing of certain types of waste products. The lead content of used oil has been considered a serious environmental problem for many years, especially for uncontrolled burning or disposal. Recent court decisions have required the Environmental Protection Agency (EPA) to set ambient air quality standards for lead, and the level currently being discussed was reported to be about 5.0 $\mu g/m^3$. These recommendations were apparently based on data reported in the literature; and, according to the discussion, EPA has not made burning tests to evaluate this problem first hand. Also, it was reported that, to date, lead is the only trace element being evaluated for an ambient air standard.

Discussion on this question suggested that perhaps the total mass of lead from used oil was rather small when compared to total lead emissions due to gasoline. The rough estimate of contribution to lead emissions due to the burning of used oil was about 2 percent, although the uncontrolled burning of used oil was indicated to be the largest stationary source of ambient air lead at the present time. Also, during the discussion, the information was mentioned that some of the calculations involved in the test of burning waste oil at the Hawaiian electric plant apparently were in error. New data sheets have been released with these corrections, and the new figures indicate that a maximum of 2.7 $\mu g/m^3$ was found 1,800 meters downwind for normal burning operations, with figures considerably higher than these for soot-blowing periods.

Another important question which was addressed was the total energy conservation aspect of recycling used oils. The Energy Research and Development Administration has contracted for a study of this question, and preliminary indications are that, indeed, recycling of used oil back to a high-quality lubricant requires less energy than refining a high-quality lubricant from crude petroleum. However, this total energy conservation aspect apparently depends a great deal on the refining methodology used, since the energy requirements per barrel of crude were stated to differ significantly among refineries. Some of these calculations went into detailed energy balances, including solvent extraction refinery processes using furfural extraction, followed by additional solvent extraction, with hydrotreating and dewaxing, etc., with the result that substantial amounts of energy are expected to be saved by re-refining, rather than burning and replacing the lube oil by the virgin product. This calculation included losses in the acid-clay process (which are higher than any other re-refining process) and assumed a water content of the used oil of about 7 percent and a light petroleum fraction of about 3 percent. Also during the discussion some differing calculations were discussed that had been made by the virgin refining industry, and these calculations indicated that, while re-refining still appears to conserve energy, the amount of saving is down to about 4 percent or 5 percent. There was some question as to whether these particular calculations were on a very efficient refining operation versus many other companies which have less efficient virgin lubricating oil refineries. A sensitivity analysis on the different variables considered in the first set of energy calculations indicated that the quoted savings of 4 percent or 5 percent were for the lowest case; and, for the average or the best situation, the savings could be considerably higher. Another aspect that was brought up on the question of energy savings was whether the energy cost of a failed piece of equipment was considered in these calculations. It was acknowledged that such energy costs were not considered, but that effective quality control on a re-refined oil product should be able to bring these costs in line with similar costs for virgin lubricating oils.

Some of the economic questions which were discussed included the ability of retail customers to recognize a quality oil. It was reported in one paper that a study of over 600 people who were queried as to why they bought a particular lubricating oil for their automobile indicated that brand name was the preferred determinant, with price a distant second. It was suggested that re-refiners could break into the quality oil market most easily by having their product marketed under a national brand, e.g., marketed by a major refiner.

It was also mentioned that currently the strongest area for re-refining is custom re-refining or re-refining for industrial, commercial, or fleet-type operators. In this commercial area, the re-refiner can offer personalized service and long-time effective relationships in order to obtain and retain these markets. A case in point used to illustrate this is the use of re-refined oil by the City of San Diego. During the energy crisis, this city had difficulty obtaining bids for their lubricating oil products. A local re-refiner bid and, after some investigation, this supplier was accepted and even now retains the market for the entire fleet of city vehicles. This is, in effect, not a closed-loop system in that the re-refiner bid on an equal basis with all other lube sources, and no requirement to pick up and/or reprocess the existing city waste oil product was involved in the contract. However, once the quality of the re-refiner's product was established through testing and use, the purchaser was happy to consider the re-refined oil on an equal basis with all other lubricating oil sources. The widely disseminated and favorable publicity for the re-refiner has also apparently resulted in improved marketability of their products throughout the area.

Finally, it was pointed out in some detail that there is a large number of economic and political factors which interplay in the area of re-refining, including legislation, economic questions, disposal of hazardous waste materials, marketability, and consumer acceptance. There was extensive discussion on the question of whether it was economic or practical to try to market a recycled oil at the highest quality levels. This discussion acknowledged the possibility of doing almost anything if economics, cost, practicability, etc., were not taken into consideration. The example was quoted that even though a man can be put on the moon, moon travel was not an established transportation means. As a result of this comment, there was a general question brought up as to whether everybody agreed that re-refined oil was really capable of being formulated into a high-quality engine oil. In the ensuing discussion, it was asked if there were anyone in the room who did not agree that this could be done, i.e., did everyone agree that a used crankcase lubricating oil could be re-refined into a high-quality motor oil. The response indicated that all agreed that this, indeed, was the case. However, several statements were made that the economics indicated to them that the most reasonable position to take was that used oil should be recycled into fuel or industrial oils, depending upon which was most reasonable for a particular situation. It was felt that the economic cost of testing would be a deterrent to assuring suitable quality control in the re-refined motor oil field. Indeed, several statements were made that a re-refined automobile crankcase oil made an excellent base oil for many different types of industrial and hydraulic oils. Another aspect of the economic factors influencing re-refining and recycling discussed was the government "interference" in the mid-1960's which eliminated favorable tax treatment and effectively taxed re-refiners more than virgin oil refiners and the Federal Trade Commission trade regulation which prescribed unfavorable labeling of all recycled lubricating oil products.

It was readily apparent during all these discussions that there were many areas which affected the oil recycling industry, and the difficulty of working with all of these factors simultaneously has created problems in many areas for the re-refining industry.

SESSION VII

PROBLEMS AND NEEDS IN ESTABLISHING QUALITY FOR RECYCLED OIL PRODUCTS

National Bureau of Standards Special Publication 488. Proceedings of a Workshop on Measurements and Standards for Recycled Oil held at NBS, Gaithersburg, Maryland, November 22 and 23, 1976. (Issued August 1977)

DISCUSSION

SESSION VII. PROBLEMS AND NEEDS IN ESTABLISHING QUALITY FOR RECYCLED OIL PRODUCTS

This session was a free and open discussion, with no formal presentations. All of the previous subjects were discussed, to a greater or lesser extent, with an emphasis on motor oils as the subject of primary interest. Summaries of these discussions are included below.

The session started with a brief description by the moderator on his perceptions of some of the basic assumptions that could be described at the present time. These assumptions are: (1) the legislation under which the National Bureau of Standards (NBS) is working is clearly supportive of the concept of recycling used petroleum oils; (2) used oil collection and waste management methods are going to improve with time, producing a larger feedstock volume for the various end uses considered; (3) the major foreign system that effectively recycles used lubricating oils (West Germany) seems to work very well in practice, and this system is partly supported by a tax on virgin lubricating oil which helps to pay for recycling or disposal of the used oil; and (4) the Congress of the U.S. has mandated that the Federal Government will become involved in this subject area. These assumptions will have to be realized and accepted by everyone in order to work together to try to obtain the best possible solution to the existing problems. Where oil recycling goes from here depends a great deal on the manufacturers, the refiners, the re-refiners, the consumers, and everybody else working together to try to get the most beneficial use out of this natural resource, consistent with reason and common sense. With those comments, the floor was opened to discussion.

The first area of discussion was on the subject of labeling requirements and their effect on consumers. A major oil company representative discussed some of their considerations as to whether to get into marketing a re-refined lubricating oil and product and stated that one of the important reasons why they did not try to market that product was because an independent survey of consumers had indicated that the labeling requirements were such that it was virtually impossible to eliminate a very negative consumer bias against the oil. Consumers in general felt that it would be a "rip off" if a re-refined oil were sold to them for the same price as a virgin oil, despite any quality claims. In addition, that same representative briefly described the field tests his company had made with the re-refined oil on which it had acquired the SE qualifications. It was put into 51 pursuit vehicles for the California Highway Patrol, for about 25,000 miles each. The condition of the used oils were monitored, but there were no engine inspections at the end of the test. As far as could be determined, this re-refined oil had completely satisfactory performance in this field test.

There was also some discussion about the future availability of used oil feedstock. Due to improved lubricating characteristics of the existing lubricating oils, the drain intervals have been extended significantly and will continue to be extended in the future. In addition, in some industrial applications tighter lubricating systems are being acquired and, for example, chemical process pumps were described which now use lube-for-life bearings instead of recirculating oils. Therefore, it was suggested that these forces would tend to offset the increased number of vehicles and equipment and reduce or hold constant the total volume of used oil expected to be available. However, it was also acknowledged that relatively small portions of the existing used oils are actually collected and recycled; and, therefore, the total potentially available feedstock for recycling is still rather large compared to existing volumes.

Another important area of discussion centered upon the question of whether current requirements for oil quality would be relaxed in order to encourage the effective reuse of recycled oils. Significant concern was expressed by a number of engine manufacturers that this, in effect, would be the case and that reduction of lube oil quality would essentially negate many years of difficult and expensive work trying to extend drain intervals, maintenance intervals, and the general quality of lubrication for their equipment. The response to this concern by the NBS personnel indicated that the term "substantial equivalence" means just that, that the recycled oil will be required to perform on a equal basis with the virgin oil product. A re-refiner commented that the re-refining industry as a whole is not looking to lower the standards or products, but, in fact, is looking at this program to enable the quality of performance in the re-refining industry to be raised. If the high-quality lube oil markets are essentially closed to re-refiners, there is little incentive to work at improving their product. It was also mentioned that it was important to consider requiring only meaningful tests, tests which can effectively measure the useful quality of a lubricating oil for a particular end use.

There was also discussion on the subject of what would happen in the future if, for example, the virgin oil industry or equipment manufacturers developed new tests to measure overall performance or, conversely, if individual tests were upgraded to new and different conditions. The concern was that the NBS program would provide a set of tests, go out of business, and leave the industry hanging, dependent upon those particular tests without the mechanism for updating them. This was acknowledged as an area of concern, but this also supported the concept that the various industries involved should become more involved with effective utilization of used oils and provide, with the Federal Government, a mechanism through the American Society for Testing and Materials (ASTM) or through the Federal test and specification system to tie new test procedures into existing on-going programs.

The question of applicability of the existing ASTM or Federal tests to recycled oils was also discussed. There was some concern shown by NBS that some of the existing virgin oil test methods may not be valid for used oils or recycled oils. A case in point is the ash method which is currently specified for virgin fuel oil. With the trace metals present in used oil, the standard ash method may not be applicable, but would require the sulfated ash method, if found valid, or some other new test. Another example would be the copper strip corrosion method and whether a recycled oil product would react in a similar way to the virgin oil product and, if not, whether the resulting corrosion test value would be acceptable for a specification which was developed for a virgin oil product. Several people spoke to this concern, most of whom stated that they had been using existing ASTM methods for used oil or recycled oil products quite successfully, and that most of these tests seem to be applicable and valid for recycled oils. The comment was also offered that, in general, recycled oils may very well require one or more additional tests besides all the tests required for virgin oils. These additional tests may be needed to monitor some characteristic of the recycled product that is normally always at an acceptable level for a virgin product. These individuals could not think of a test which was applied to a virgin oil but which would not be required for a similar recycled oil product.

Another subject which received considerable discussion was the monitoring of basestock for motor oils. This basestock will be considered by the NBS program because for an SA oil, a straight mineral oil, the basestock is the end product. It had been pointed out by a number of people that the monitoring of basestock between primary quality-defining tests could be an effective way to evaluate the variability of the re-refined product. There was concern voiced from the military as to methods for monitoring basestock for virgin oils also; some means to identify and demonstrate consistency of virgin oil basestock would be extremely useful with regard to the military specification. Presumably, similar types of methods could be used on re-refined oils also.

There was a great deal of discussion on the American Petroleum Institute (API) service classification system, especially as it applies to the SE classification. Much of this discussion was in trying to understand the various workings of this classification system. It finally was clarified to where it was understood that there is no formal SE spproval system which looks at oils and provides a stamp of approval, except as you apply for the Qualified Products Listing for military approval. That was stated as the only way that an outside body can be used to render a judgment for all to see and indicate that this is, in fact, an SE/CC oil (e.g., for MIL-L-46152). In these discussions, it came out that any individual or company who is willing to legally stand behind his oil can put the SE classification on the can. He thus assumes the warranty for his product and, obviously, is liable to litigation if the product causes problems which are traceable to a quality lower than was stated. At this point, a re-refiner spoke up and commented that he had been told unequivocably many times that in order to put an SE on the container, you would absolutely have to pass the engine sequence tests. The comments in response to this were that it may not be "correct" to do so, but there is no legal requirement that these tests be passed. In effect, this is because there is nobody monitoring the marketplace to determine the quality of the lubricating oils on the marketplace. It was then stated that in the area of military specifications, in order to qualify for a particular military specification and be put on to the Qualified Products List, the test data must be supplied to the qualification committee and the results passed on by that committee. However, there is nothing that requires the manufacturer to pass these tests and bring the oil before the military board in order to put on the can that this meets or exceeds a particular military specification, and it is perfectly legitimate if he feels like doing it. The military apparently does not have any way to stop him as long as he is willing to stand behind it. This is essentially the same as was stated for the SE and the SE/CC classifications. In fact, of course, a can containing a statement that it meets a certain specification is certainly not a qualified product, and this product has not demonstrated the performance that would be required for these tests.

There was another extensive discussion on the subject of warranties and the effect of a non-SE oil affecting the warranty for an automobile or other vehicle. This disucssion can be summarized by stating that apparently the warranty generally guaranties only workmanship and materials; and, if there is a substantial flaw in a particular engine which would cause it to fail, the manufacturer really does not care whether a virgin oil or a re-refined oil was used or what quality level was used. They should repair or replace that particular problem. However, if the workmanship and materials of the engine were of an acceptable level and the customer, through abuse or through use of the wrong lubricating oil--virgin or re-refined--causes failure in an engine, the manufacturer is not going to accept the warranty for that failure. If a particular lubricating oil product actually caused a failure in an engine still under warranty, the manufacturer would tell the consumer to go see the oil company, it is their fault. It was suggested that this holds true for both virgin oils and re-refined oils.

One additional participant spoke up at that point and commented on how difficult is it to try to pin down a particular failure to a specific cause. The illustration was made that even though a mechanic had told him about what was suspected to be the cause, in general the relatively unsophisticated consumer is not willing to pursue the question of trying to obtain redress from the engine manufacturer or lubricant manufacturer unless that failure were absolutely unequivocable. The cost of expert testimony would be greater than the repair, not even considering loss of vehicle time.

There was discussion on the subject of what the re-refiner could do in order to become more involved with the "system," the working relationship between oil companies, additive manufacturers, and engine companies. The response was that the ASTM meetings are open to everyone and that re-refiners or anyone else are strongly encouraged to attend, to participate, and to work together for the good of the industry in general. It was also pointed out that the ASTM is an excellent way for smaller organizations with limited technical facilities to pick up large amounts of technical data and sophistication from the larger companies which are supporting much of this testing research which is discussed in the ASTM, the Society of Automotive Engineers, the American Society of Lubrication Engineers, and other such organizations.

There was substantial discussion on the question of the exclusionary clause against re-refined oil in military specifications for engine oils. The statement was made that the problem is not so much that the re-refining industry is concerned about attempting to sell lubricating oil to the government; in general, they are too small for that type of operation. However, it was pointed out very dramatically that the very fact that the prohibition exists in the military specifications is a strong deterrent to the public and private sectors against utilizing re-refined oils. It was described that there are many times when, for example, a fleet could use re-refined oil but when this re-refining arrangement is discussed with the fleet operator one of the first comments made is, "Does it meet the military specification?"

Finally, there was discussion on the experiences and data which have been generated over many years on the application and usefulness of virgin lubricating oils. One participant described when the military required virgin oil producers to obtain base oil samples from various refineries all over the world and then a large series of tests was run with many of these (refined by a solvent extraction technique). These oils were then tested with a certain additive package. All of this background information exists on virgin oils; these experience and data just do not exist for re-refined oils at the present time. It was obvious that the military is very concerned about potential applications of re-refined oils wihout enough background information to be able to effectively evaluate their operability in use. One of the most important considerations in this background data is the consistency that can be expected from re-refiners on a long-term basis.

The workshop ended on the afternoon of November 23, 1976, with participants agreeing in general that useful and informative discussions had taken place. A number of comments were also received which indicated that additional such meetings in the future would be helpful, and this possibility is being explored.

Mr. Robert Teasley of Cummins Engine Company makes a point during the workshop discussion.

Messrs. Peter Asseff of The Lubrizol Corporation and William Katzenstein of Chrysler Corporation listen during a presentation.

APPENDIX I

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The Research Associate: Catalyst For INDUSTRY/ GOVERNMENT COOPERATION

The Research Associate: Where Familiarity Breeds Respect

Alma Coats is a chemist with Hooker Chemical currently working as a Research Associate for the Society of the Plastics Industry.

Just as exchanges of people can improve relations between countries, assignments of employees are leading to increased understanding between business and government in this country.

The Research Associate Program at Commerce's National Bureau of Standards is helping to build this understanding by allowing U.S. firms and business associations to send technical employees to use the elaborate facilities at NBS laboratories in Boulder, Colorado, and Gaithersburg, Maryland.

The program enables scientists and engineers from the private sector, both domestic and foreign, as well as state and local governments and occasionally the academic community, to work on a full-time basis for specified periods at NBS on projects of mutual interest to NBS and the sponsor.

The base criteria for a program are simple: it must have nonproprietary objectives; it must be within the scope of NBS activities and interests; and it must offer the prospect of publishable results of interest and significance to the industrial and technical communities represented, and thus ultimately to the public.

The programs start when convenient to both parties and may last from a few months to several years. They may be staffed by one or many Associates. The American Dental Association research unit, something of an unusual case, currently has 22, including physical chemists, ceramists, metallurgists, dentists, crystallographers, a mathematician, and supporting personnel.

A Research Associate must have appropriate academic background and sufficient experience to perform independent research in the field covered by the program. The sponsor and NBS must agree on the associate's qualifications and acceptability for the assignment.

"My experience here is going to prove very valuable to my company when I return," says Alma Coats of Hooker Chemical. "This definitely needs to be an ongoing program, because of the improved technology that's developing all the time. I'm going to make a firm recommendation to my company that they continue to make use of this program by sending someone else here after I finish."

"The facilities here are so much better," says Randall Lawson, a Research Associate from the Gypsum Association who is trying to devise a test measuring the fire-resistive properties of gypsum board products. "Also, the quality of the staff is excellent. There's a much broader range of technical knowledge available here than you would find in any industrial research situation."

"The equipment and people that are available here can't be duplicated anywhere else," says Alan Meierhofer of the Manmade Fiber Producers Association, who is trying to establish the fire hazard potential of the different apparel fibers. "It was somewhat of a transition at first, learning the government's way of doing things, but it's worked out quite nicely."

"The task of developing standards for consumer products is very difficult, and both industry and government are faced with serious problems in this area," says Joe Dort of Sears, Roebuck. He is trying to develop tests to accurately predict the service life of small appliances. "Lab tests are difficult to relate to actual use by consumers, since the amount of time an appliance is operated and the treatment it receives varies from user to user. We're trying to devise tests that come as close as possible to the reality of actual use and abuse by a consumer."

The advantages of having a company scientist or engineer working on non-proprietary matters (research that will not be held secret) at NBS have attracted more than 400 companies and trade organizations and some 1500 individuals to the Bureau since the program began in 1920.

Some of the advantages are obvious. There is the use of the NBS computer and libraries, the laboratories and special research facilities that are difficult to match anywhere else. There is the advantage of working with the NBS staff, which includes many scientists of recognized importance in their fields.

A Research Associate remains the employee of the sponsoring organization. His employer pays his salary, fringe benefits and travel, and makes arrangements as necessary for temporary relocation of the Research Associate for the period of his assignment to the program.

"As to salary level there are no requirements," says Peter R. de Bruyn, the NBS liaison officer who coordinates the program. "But we do suggest that they be comparable to the levels of the people they'll be working with. That way nobody feels any resentment about different compensation for doing essentially the same job."

The sponsors also pay for any special supplies or services required by their associates, such as computer time, unusual or expensive materials, or the use of technician assistance, just like any NBS unit would.

NBS provides, at no cost to the sponsor, technical supervision, office and laboratory space, routine supplies and services, and the use of available research equipment not normally subject to time or usage charges.

"Everybody carries his share of the load and everybody benefits," says de Bruyn.

Each memo of agreement setting up a research associate program assigns a specific NBS supervisor to each associate, assuring the sponsoring organization that their employee will not fall between the cracks, and will know where to turn with problems.

"Many of these associates are people on whom the company has had an eye for some time as potential comers, and quite a few of them come home to promotions. Consequently, especially in firms that have continuing programs or have run programs in the past, these assignments tend to be looked on as a plus and the competition for them can get pretty intense," says de Bruyn.

"They also value the acquaintances they make among their contemporaries—both the other associates and the government specialists they work with —which will prove useful later."

A recent listing contained 21 projects currently in progress, with 5 of them, involving Research Associates, dealing with problems associated with fire. Why the emphasis on fire? There are probably many reasons, but almost certainly one of them is the fact that it is possible at NBS to conduct full scale "burns" of rooms and vehicles inside a 6,500 cubic meter test chamber—a facility that most companies do not have.

Other associates are studying the impact resistance of eyeglass lenses, the criteria for performance of automatic data processing systems, the measurement of paper characteristics, energy conservation in mobile homes, and dental materials.

Found a home

Many firms run a succession of programs, usually of about two years duration. Armstrong Cork has had at least one associate here for the past 40 years.

The longest-running association on a continuing basis is with the American Dental Association, which dates back to 1929. This association has

. . . the advantages are obvious. There is the use of the NBS computer and libraries, the laboratories and special research facilities . . .

Dentist Dr. George Paffenbarger is a Senior Research Associate representing the American Dental Association.

Work on consumer product technology is just beginning . . .

produced more than 600 publications, including books, reports and articles in various professional journals.

There are other places, of course, where this work could be done, but, notes Dr. George Paffenbarger, senior research associate of the ADA unit, "In no instance would the ADA have the facilities, or expertise, or large laboratories such as are available here at the National Bureau of Standards."

"Thus far there's been a very minimum of trouble," reports de Bruyn. "The thing's been running for more than 55 years without becoming ossified, which is more than you can say about many programs, in or out of government. This program has been climbing steadily since 1970. We're pleased, and a little bit puzzled, because it's all happened during a period when everyone was crying that they were 'research poor' and firms were generally lowering their research goals."

"Actually, I've got one of the easiest sales jobs in the world. I'm trying to sell people something they've paid for already—with their taxes. These facilities are available and waiting for them.

"This program is open to all; our problem is getting the word around.

"It takes a while to convince scientists that you're going to represent them and their capabilities correctly. The steady increase in the number of calls I receive from technical people around the Bureau, suggesting areas that might prove promising for a research associate project, is the best evidence to me that the program has really caught on.

"We're not in competition with private labs. What we offer is an unbiased source that everyone's willing to accept. All of the results of the program are published, and industrial labs can then pick up the technology that has been developed and profit from it.

"In some cases, it could even ultimately provide the basis for an entirely new industry.

"New measurement technology is the end product. What has evolved from the program to date? Among other things, a new Standard Reference Material for steels based on work done by a U.S. Steel Research Associate. And, through the contribution of a Research Associate sponsored by IBM, a secondary standard computer amplitude tape is now available to industry as a regular Standard Reference Material.

"What each associate is seeking is a new measurement procedure in a highly specialized area, that will be acceptable to everyone in the field. They're looking for a test that you can plug every piece of a particular material into. Since both industry and government have had a hand in it, these associations usually result in very rational standards that protect the public interest without hindering industry.

"The results are available to all. We want everyone to use our stuff. For example," de Bruyn goes on, "John Robertson was a research associate from Dow Chemical. He brought ten years of experience in the energy conservation field to NBS. He'd been dreaming up ways to conserve energy years before any of the rest of us even dreamed about an energy crisis. Well, John put his decade of experience into our *Energy Conservation Program Guide for Industry and Commerce,* a guidebook especially designed to help smaller and medium-sized firms get a handle on their energy problem. That was an extremely generous contribution by one firm to all of industry."

The Atomic Industrial Forum's agreement calls for research into measuring techniques for radioactive pharmaceuticals, an area which is "pretty crucial to the public that the situation is properly handled," de Bruyn points out.

The National Microfilm Association sent a Research Associate to NBS with a major problem: the microfilm on which the Library of Congress was preserving the nation's priceless documents had, unaccountably, started to deteriorate. The problem was traced to a gas evolving from the cardboard storage containers. Substituting stainless steel containers solved the problem.

However, not all Research Associates produce such dramatic fruit. Nor are the solutions often that simple. "It's usually a matter of the data that's developed here ultimately filtering down to the public in the form of products incorporating it. Much of this material is significant scientifically, but very little of it has any dramatic one-shot impact," says de Bruyn.

A number of governmental agencies have used the program: In 1930 the Port of New York Authority sent specialists down to do some research relating to bridge towers, and in 1940 the Florida Citrus Commission did an analysis of citrus juices. Universities, too, occasionally make use of the program, such as the time Yale sent a technical team down to do optics research.

Work on consumer product technology is just beginning, and an associate from Sears, Roebuck has been assigned to NBS Gaithersburg headquarters since last November. Sometimes these agreements turn into two-way streets, with the government sending a specialist out to work in private laboratories. This has happened in the Sears case, with an NBS scientist being assigned to Sears under the provisions of the Federal Training Act. "He's learning how they do it in industry, which we need to know if we're going to deal with the consumer product problem realistically," says de Bruyn.

Research Associate Programs still have rather informal beginnings. The initiative may come from either industry or the Bureau, depending upon who first conceives a project that might be of interest to the other.

Representatives of a prospective sponsor get together with the appropriate members of the NBS staff at the invitation of either party to discuss the details of a potential program. De Bruyn works with them to establish a mutually acceptable project definition, statement of objectives, and work plan. Following this, with the assistance of members of the NBS legal, patent, budget and accounting staffs, he negotiates with the sponsor's management personnel a Memorandum of Agreement describing the program and setting forth the terms and conditions governing the relationship between the sponsoring organization and NBS.

To sum it up, "The Research Associate Program helps give each of us a mutual perspective as to what the others' problems are, says Sear's Joe Dort.

"If government and industry understand each other, they should be able to work out solutions that are beneficial to both, and eventually the public, because that's what it's all about." ☆

APPENDIX II

Report 2127

INVESTIGATING WASTE OIL DISPOSAL BY DIRECT INCINERATION

Maurice E. LePera and Gerald DeBono

February 1975

Approved for public release; distribution unlimited.

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

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INVESTIGATING WASTE OIL DISPOSAL BY DIRECT INCINERATION

I. INTRODUCTION

1. Background. The Facilities Engineering Directorate at Aberdeen Proving Ground (APG), Maryland, initiated a program in 1968 to dispose of generated waste oil by blending with a No. 6 Fuel Oil (Federal Specification VV-F-815C). Approximately 40,000 gallons of waste oil have been consumed each year in this manner at the main APG powerhouse facility. Since No. 6 Fuel Oil is a relatively viscous product, no problems were encountered with the waste oil disposal system. In August 1972, it was reported that APG would be changing from No. 6 to No. 2 Fuel Oil (Federal Specification VV-F-815C) as a result of air pollution abatement legislation restricting the level of sulfur in the fuel. Because of the obvious difference in properties (other than sulfur content) between No. 2 and No. 6 Fuel Oil, this office became concerned that continuance of the waste oil disposal system could:

- cause stratification and/or sedimentation problems due to the difference in gravity (waste oil is generally higher than No. 2 Fuel Oil) leading to potential malfunctioning of the burner nozzles.
- create excessive stack emissions exceeding the air pollution standards either due to improper combustion (i.e., nozzle deposits) or from the composition/concentration of the waste product itself.

In April 1973, this office conducted an initial waste oil incineration program at the main powerhouse facility (Bldg. 345) at APG. The stack emissions, monitored by US Army Environmental Hygiene Agency (AEHA) emissions specialists, were measured while No. 2 Fuel Oil and No. 2 Fuel Oil containing approximately 1% waste oil were burned.[1] In summary, there was no significant difference in the emissions levels between the neat fuel and the fuel adulterated with waste oil. Furthermore, the APG facility engineer reported that incineration of this mixture did not create any burner nozzle maintenance problems. There were, however, several shortcomings in this initial program. Since the mixing of the waste oil with the base fuel oil was extremely difficult to control, only an estimate of the percent of waste oil reaching the burner during the steady-state emissions test could be obtained. Also, the low concentration of waste oil may not have been a significant contaminant when compared to the tank-bottom residue of the No. 6 Fuel Oil remaining in the main storage tank from previous years. Finally, the introduced waste oil generated at APG was not considered to be representative of typical waste oils due to its unusual lightness (i.e., low viscosity, high API gravity, low ash, etc.). An analysis of this waste oil compared with other waste oils reported in the literature brings attention to this point (Table 1). A review of the results of this initial emissions test, the physical arrangement of the burner-boiler system, and the atypical properties of the waste oil indicated the need for a second combustion-emissions program to establish baseline parameters for this waste oil disposal system. This report describes the results of the second combustion-emissions test conducted at APG.

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[1] G. E. DeBono, "Investigating Waste Oil by Combustion," CCL Interim Report No. 3008, AD No. 772911, January 1974

Table 1. Comparison of APG Waste Oil with Other Sources

Waste Oil Source/Reference	Kin. Vis. @100°F, D 445	°API Gravity D 287	Water & Sediment, D 1796	Sulfur, % Wt, D 129	Total Ash, % Wt, D 482	Sulfated Ash, % Wt, D 874
APG[1]	7.34	32.0	1.4	0.21	0.50	--
(2)	53.3	24.6	0.6	0.34	--	1.81
	57.7	26.0	--	--	--	1.80
	55.1	25.0	--	0.21	1.61	--
(3)	--	26.7	4.8	0.26	0.40	--
(4)	248	24.6	0.6	--	--	--
	256	25.0	--	--	1.62	--
	161	27.9	2.4	--	1.10	--
	--	24.8	18.0	--	2.16	--
(5)	--	--	--	0.44	1.43	1.69
Patuxent N.A.S.	60.3	28.1	Trace	0.35	0.95	--

[1] G. E. DeBono, "Investigating Waste Oil By Combustion," CCL Interim Report No. 3008, AD No. 772911, January 1974.

[2] Anonymous, "Final Report of the API Task Force on Used Oil Disposal," American Petroleum Institute, New York, N.Y., May 1970.

[3] M. Liberman, "Combustion and Heat Recovery of Air Force Waste Petroleum Oils and Lubricants," Air Force Weapons Laboratory Report No. AFWL-TR-73-244, February 1974.

[4] S. Chansky, W. McCoy, and N. Surprenant, "Waste Automotive Lubricating Oil as a Municipal Incinerator Fuel," Environmental Protection Technology Series Report No. EPA-R2-73-293, September 1973.

[5] G. A. Chappell, "Waste Oil Processing," Commonwealth of Massachusetts, Division of Water Pollution Control Publication No. 6722-41-100-4-73-CR, January 1973.

II. INVESTIGATION

2. Details of Test. The details of the test are as follows.

a. Plant Facilities/Operation. The powerplant system at the APG Messhall (Bldg. 4219) was selected for this second combustion-emissions test because the fuel-system design offered a simple and accurate method for controlling the waste oil/fuel oil ratio. The burner system consisted of three five-tube, high-pressure boilers and three oil-fired, low-pressure, rotary-cup KEWANEE burners. This system, originally designed to burn a No. 4 or a No. 5 Fuel Oil, was rated at 86.3 hp, 30,808.5 pounds of steam/hour, and 4,500,720 Btu. For this test, the fuel was to be metered directly to the burners from a 1200-gallon tank truck not only permitting accurate mixing of the desired fuel oil/waste oil ratio, but also controlling delivery to the burners during the steady-state emissions test.

b. Waste Oil Collection. The waste oil used in this test was considerably heavier than that used in the previous test at the APG powerhouse.[2] To insure that a sufficiently "heavy product" was tested, the waste oil was collected in 55-gallon drums located at the main APG Post Exchange Service Station. It consisted almost entirely of drained crankcase oil from commercial-design vehicles with trace amounts of antifreeze and hydraulic brake fluid and some transmission fluid. In addition, some water contamination occurred from improper drum covering and/or closure procedures since the drums were positioned outside. This water, after settling, was pumped out prior to the combustion-emissions test to insure that the water contaminant did not

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[2] G. E. DeBono, "Investigating Waste Oil by Combustion," CCL Interim Report No. 3008, AD No. 772911, January 1974.

influence the resultant stack emissions. A comparison of the characteristics of this collected "referee-type" waste oil versus the waste oil used in the initial program is shown in Table 2.

Table 2. Comparison of APG Waste Oils

	Kin. Vis. @100°F, D 445	Gravity, °API D 287	Water & Sediment D 1796	Sulfur % Wt, D 129	Total Ash % Wt, D 482	Ramsbottom Carbon Residue D 524
Initial Combustion Test	7.34	32.0	1.4	0.21	0.50	0.89
Second Combustion Test	86.7	24.9	0.1	0.39	1.60	4.36

c. Fuel and Stack-Emission Sampling. To assess the effect of this referee waste oil on combustion of No. 2 Fuel Oil, the AEHA again participated in monitoring stack emissions. As before, two series of emissions tests were required. The first series of tests was made while No. 2 Fuel Oil obtained from the 10,000-gallon underground storage tank located at the messhall facility was burned. Samples of this base fuel were obtained from the sampling valve adjacent to the burner system and from the underground storage tank prior to the baseline combustion-emissions test. Using this base fuel, AEHA personnel monitored the stack emissions during three 2-hour runs. The details of the emissions stack sampling/analysis procedures performed by AEHA are presented in the Appendix.

The second series of combustion-emissions tests was made while the referee waste oil/fuel oil blend was burned. A 1200-gallon tank truck containing 200 gallons of waste oil and 800 gallons of No. 2 Fuel Oil served as the temporary mixing reservoir. The resultant blend was pumped to the burner system from the bottom of the tanker via tubing. The 200 gallons of referee waste oil, collected in four 55-gallon drums, was sampled prior to mixing to assess the variation in composition and the occurrence of stratification. To possibly avoid any stratification occurring within the tanker, the waste oil from the four drums was pumped into the tanker at different time intervals. Although this precaution was taken, it was anticipated that stratification could occur due to the wide differences in API gravity between the waste product and the No. 2 Fuel Oil. In view of this, the waste oil/No. 2 Fuel Oil mixture was sampled at three levels in the tank truck top, middle, and bottom prior to initiation of the steady-state emissions tests. With this 20% volume "nominal blend" of waste oil in No. 2 Fuel Oil being used, the second series of combustion-emissions tests was monitored by AEHA personnel during the three 2-hour runs. Details on the fuel oil samples, waste oil, and waste oil/fuel oil sample blends obtained during this second combustion-emissions test are provided in Table 3 with the analyses of the samples presented in Table 4. Accordingly, the emissions measured during this second combustion-emissions test by AEHA at the messhall facility are tabulated in Tables 5 and 6.

3. Results of Test. The analysis data on the "collected" waste oil samples indicated that stratification was occurring within the four drums. For that reason, the composite sample was taken (Sample No. 5, Table 5) to characterize the collected waste product. As noted, this composite waste consisted primarily of crankcase drains as evidenced by its high viscosity and low API gravity. After the 200 gallons of waste oil were introduced into the tank truck containing the 800 gallons of No. 2 Fuel Oil, the sample analysis indicated that satisfactory mixing had not occurred since the top, middle, and bottom samples (Samples 7, 8, and 9) revealed the waste product to be stratifying. Although the nominal concentration of waste oil was 20%, the fuel oil/waste oil blend was being fed to the burner system via a connection located at the bottom of the tanker. Because of this apparent stratification, the burner system was in fact combusting a fuel oil/waste oil blend of something in excess of the selected 20% volume ratio. Since the burner system was being fed primarily a "bottom sample" of fuel oil/waste oil during the three 2-hour runs of stack emissions measurements, the amount of waste oil in the No. 2 Fuel Oil for this "bottom sample" was determined by preparing known blends of waste oil in No. 2 Fuel Oil. The kinematic viscosity for each of these blends was determined and plotted on a graph (see Figure). From this

graph, the concentration which corresponded to the viscosity of the bottom sample (Sample No. 9) was interpolated and found to be 27%.

Table 3. Identification of Fuel Oil/Waste Oil Samples

Sample No.	Date Sampled	Sample Type	Origin or Location	Sampling Depth	Sample Description
1	8/20/73	Waste Oil	Drum No. 1	Bottom	One of four drums of collected waste oil for combustion-emissions test.
2	8/20/73	Waste Oil	Drum No. 1	Top	Same as above.
3	8/20/73	Waste Oil	Drum No. 4	Bottom	One of four drums of collected waste oil for combustion-emissions test.
4	8/20/73	Waste Oil	Drum No. 4	Top	Same as above.
5	8/20/73	Waste Oil	Drums No. 1,2,3, & 4	Middle	This was a composite sample from all four drums of the collected waste oil.
6	9/24/73	No. 2 Fuel Oil	Fuel Line @ Messhall	---	Fuel sample obtained prior to initial baseline emissions test at messhall.
7	9/27/73	No. 2 Fuel Oil	Tank Truck	Top of Fuel Tanker	Sample taken from tanker containing 200 gallons waste oil and 800 gallons fuel oil.
8	9/27/73	No. 2 Fuel Oil	Tank Truck	Middle of Fuel Tanker	Same as above.
9	9/27/73	No. 2 Fuel Oil	Tank Truck	Bottom of Fuel Tanker	Same as above.
10	7/20/73	No. 2 Fuel Oil	Contractor's Delivery Truck	---	Sample taken of No. 2 Fuel Oil delivered to messhall and other APG facilities.

Table 4. Inspection Properties of Fuel Oil and Waste Oil Samples

Sample Number	Kin. Vis. @100°F, D 445	°API Gravity, D 287	Water & Sediment, D 1796	Sulfur, % Wt, D 129	Total Ash, % Wt, D 482	Carbon Residue,[1] D 524	Distillation, °F, D 86			Aromatics, % Vol., D 1319
							10% Evap.	50% Evap.	90% Evap.	
1	83.3	23.9	1.9	---	1.55	3.74	---	---	---	---
2	72.2	25.6	Trace	---	1.90	4.04	---	---	---	---
3	86.8	25.1	0.05	---	2.15	4.16	---	---	---	---
4	84.1	25.8	0.02	---	1.95	3.97	---	---	---	---
5	86.7	24.9	0.10	0.39	1.60	4.36	---	---	---	---
6	3.15	33.8	Trace	0.20	Nil	0.38	450	518	610	32.1
7	3.58	35.7	0.90	---	0.20	0.88	---	---	---	---
8	3.65	32.4	1.40	---	0.30	0.95	---	---	---	---
9	6.16	30.6	0.50	0.35	0.65	1.49	---	---	---	---
10	2.80	34.6	Trace	0.23	Nil	0.35	426	502	596	29.3

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[1] Although a 4.0-gram sample is specified for D 524 (Ramsbotton Carbon Residue), the presence of H_2O in some of the samples causes excessive scattering. As a result, the sample size for *all* samples was reduced to 1.0 gram.

Table 5. Combustion-Emissions Results from APG Messhall (Bldg. 4219)

Test Parameter	Allowable or Legal Limit	Results Obtained: No. 2 Fuel Oil (No Waste Product)	Results Obtained: No. 2 Fuel Oil + ~ 20% Waste Oil
Emissions Rate:			
GR/SCF[1]	[2]0.03	0.047	0.262
lb/MBtu[3]	0.6	0.031	0.158
lb/hour	---	0.184	0.938
Visible Emissions	No. 2 Max[4]	0	0
Sulfur Content, % Wt	0.30	0.20	0.35
Trace Metal Emissions, GM/Day:			
Lead	---	3.86	172
Calcium	---	Nil	97
Zinc	---	1	410
Magnesium	---	Nil	37

[1] Corrected to 50% excess air, dry basis, 25°C., and 1 atmosphere.
[2] This limit, imposed by the State of Maryland, applies only to *residual oil burning* equipment.
[3] As specified in AR 11-21, Environmental Pollution Abatement.
[4] A maximum No. 2 rating on the Shell Bacharach Scale.

The net effect of this 27% waste oil on air pollution regulations was explained by AEHA in their emissions survey report.[3] This was explained in the following manner:

- AR 11-21 Environmental Pollution Abatement limits emissions from boilers in Bldg. 4219 to 0.6 lb/MBtu.
- The State of Maryland Bureau of Air Quality Control limits smoke emissions from distillate-fired boilers to a No. 2 rating on the Shell Bacharach Smoke Scale. No visible emissions are allowed except during start-up, and the sulfur content of the fuel oil is limited to a maximum of 0.30% wt. *Residual oil burning* equipment is limited to 0.03 GR/SCF.

In applying these limits to the initial combustion-emissions program wherein 1% waste oil was used at the main powerhouse facility (Bldg. 345), no violation of any emission standards occurred. However, in reviewing the results from this latter program in which 27% waste oil was consumed, there were indications that some emission standards were violated. More specifically, the sulfur content of the waste oil/fuel oil mixture was 0.35% (Note: a 0.30% maximum is permitted) and, more important, the particulate emissions rate was 0.262 GR/SCF. (Note: a 0.03 maximum rate is permitted.) This value is 773% greater than the maximum allowable rate and represents a fivefold increase over the baseline level. However, AEHA concluded that no emission levels were exceeded in this instance since there are no emission standards for No. 2 Fuel Oil. (Note: the 0.03 GR/SCF maximum applies to residual fuels only.) AEHA personnel maintained the position that a fuel oil/waste oil blend must be considered a distillate product if it meets the specification requirements given under Federal Specification VV-F-815C, Fuel Oil, Burner. A tabulation of the inspection properties of this 27% waste oil/ fuel oil blend versus the specification limits in VV-F-815C is

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[3] A. R. Paine and J. T. Higgins, "Air Pollution Engineering Special Study No. 21-015-73/74, Waste Oil Utilization Program, Aberdeen Proving Ground," April and September 1973.

Table 6. Stack Emissions Data from APG Messhall (Bldg. 4219)

Test Details	Results Obtained					
	No. 2 Fuel Oil (No Waste Oil)			No. 2 Fuel Oil + ~ 20% Waste Oil		
Date:	24 Sep 73	24 Sep 73	24 Sep 73	27 Sep 73	27 Sep 73	27 Sep 73
Run Number:	1	2	3	4	5	6
Stack Gas Composition, %[1]						
CO_2	4.8	4.9	4.8	4.9	4.7	4.1
O_2	15.3	15.5	15.3	15.1	15.6	16.2
N_2	79.9	79.6	79.9	80.0	79.7	79.7
Moisture	8	8	8	8	8	8
Excess Air	257	273	257	245	282	325
Stack Temperature, °F	443	444	448	444	435	426
Stack Velocity, m/sec	9.31	9.22	9.14	8.90	8.99	8.43
Flow, SCM[2] sec	1.25	1.23	1.22	1.20	1.22	1.16
Sample Volume, SCM[2]	2.75	2.75	2.78	2.55	2.63	2.49
Filter Catch, GM	0.0283	0.0101	0.0135	0.2485	0.2118	0.1617
Probe Catch, GM	0.0292	0.0327	0.0423	0.0522	0.0412	0.0448
Total Catch, GM	0.0575	0.0428	0.0558	0.3010	0.2530	0.2060
Concentration from filter, GM/SCM[2]	0.0103	0.0037	0.0048	0.0974	0.0805	0.0649
Concentration from probe, GM/SCM[2]	0.0106	0.0119	0.0152	0.0205	0.0157	0.0180
Total concentration, GM/SCM[2]	0.0209	0.0156	0.0201	0.1180	0.0961	0.0829
Mass Rate from filter catch, lb/hour	0.1020	0.0361	0.0465	0.9270	0.7790	0.5980
Mass Rate from probe catch, lb/hour	0.1050	0.1160	0.1470	0.1950	0.1520	0.1660
Total Mass Rate, lb/hour	0.2070	0.1520	0.1940	1.1200	0.9310	0.7630

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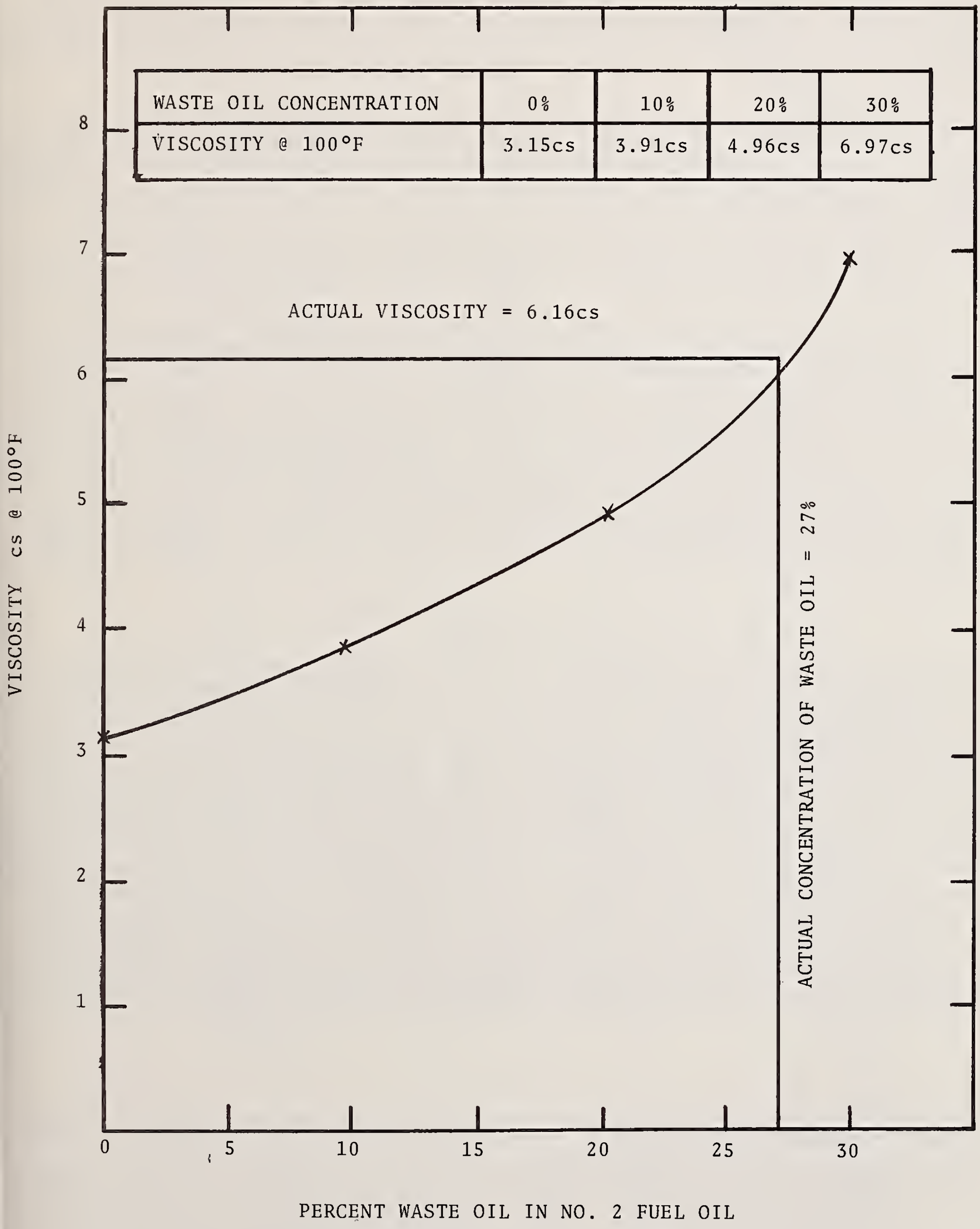
[1] Determined on a dry basis.

[2] Standard conditions; 25°C and 1 ATM.

DETERMINING THE CONCENTRATION OF WASTE OIL IN THE FUEL



WASTE OIL CONCENTRATION	0%	10%	20%	30%
VISCOSITY @ 100°F	3.15cs	3.91cs	4.96cs	6.97cs

Determining the concentration of waste oil in the fuel.

shown in Table 7. The Maryland Bureau of Air Quality (MBAQ) initially informed this office that a fuel could not be considered a distillate if it contains a non-distillate product such as waste oil. In view of this, their initial position was that the particulate emissions rate for the 27% waste oil blend was in violation of the MBAQ standards. However, in subsequent discussions between AEHA personnel and the MBAQ, tentative agreement was reached in favor of AEHA's conclusions. (Note: the problem of defining a distillate versus a residual fuel in terms of applying emission standards has been presented to ASTM D-2 Technical Committee E on Burner and Diesel Fuel Oils for an official ruling.)

The emission rates of the four trace metals analyzed showed a significant increase when the 27% waste oil was introduced. These increases were anticipated due to the nature of the "collected" waste product which had high concentrations of engine oil drains. To provide additional information on this point, samples of the products used in this combustion-emissions test and the previous program were analyzed for the four suspect metals: lead, zinc, calcium, and magnesium.[4] The results of these analyses are shown in Table 8. Since neither AR 21-11 nor MBAQ provides emission standards for these or any trace metals, the obtained emission rates for all metals were not considered to be in violation although the rate for zinc was relatively high.

As mentioned in the AEHA report,[5] the combustion-emissions test program was conducted on a short-term basis to observe whether significant increases in particulate emissions would be evidenced with the addition of the waste oil component. No attempt was made to assess the potential deleterious effects of waste oil combustion on burner nozzles or heat-transfer surfaces of the boiler system. A previous study conducted for the State of Massachusetts revealed that attempts to combust 100% waste oil resulted in severe operating problems in a 50-hp Cleaver-Brooks boiler system.[6] The results of the Massachusetts study emphasized the need to remove or separate the inorganic ash materials from the waste product prior to combustion. More recently, under a USAF program addressing the feasibility of this approach, experimental combustion tests were performed using up to 10% waste oil in both No. 2 and No. 6 Fuel Oil.[7] The results of the USAF program revealed no short-term air pollution effects or operational problems.

III. CONCLUSIONS

4. Conclusions. The two combustion-emissions programs conducted at APG demonstrated that waste oil can be incinerated as fuel-oil-blending components without attendant stack emissions problems. However, the use of the 27% waste oil/fuel oil blend in the KEWANEE burner system produced emission rates which could be in violation depending on whether the particular waste oil/fuel oil blend is defined as a residual or a distillate product. The high particulate emissions evidenced were in part attributable to the rather inefficient operation of the rotary-cup atomizers employed in the burner system. This important variable involving burner-boiler configurations can significantly affect and/or alter the emissions produced from the same waste oil/fuel oil mixture. It should be noted, however, that this combination of "heavy waste oil" and the burner system employing rotary-cup atomizers essentially represented a referee, or "worst case," situation, Other burner systems employing the steam-assisted atomizers could be expected to produce substantially lower particulate emissions. These limited data acquired from these two combustion-emissions tests further support the need for additional test programs to quantify the relationships between particulate emission rates, boiler-burner configuration and endurance, and long-term operation on waste oil/fuel oil blends to identify any potential burner nozzle and heat-transfer-surface problem areas.

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[4] G. E. DeBono, "Investigating Waste Oil by Combustion," CCL Interim Report No. 3008, AD No. 772911, January 1974.

[5] A. R. Paine and J. T. Higgins, "Air Pollution Engineering Special Study No. 21-015-73/74, Waste Oil Utilization Program, Aberdeen Proving Ground," April and September 1973.

[6] G. A. Chappell, "Waste Oil Processing," Commonwealth of Massachusetts, Division of Water Pollution Control Publication No. 6722-41-100-4-73-CR, January 1973.

[7] M. Liberman, "Combustion and Heat Recovery of Air Force Waste Petroleum Oils and Lubricants," Air Force Weapons Laboratory Report No. AFWL-TR-73-244, February 1974.

Table 7. Properties of 27% Waste Oil Blend vs VV-F-815C Limits

Characteristics	Sample #9 (27% Waste Oil in Fuel Oil)	Inspection Limits in VV-F-815C					
		No. 1 Fuel Oil	No. 2 Fuel Oil	No. 4 Fuel Oil	No. 5 Fuel Oil (Light)	No. 5 Fuel Oil (Heavy)	No. 6 Fuel Oil
Flash Point, °F	215	100 min.	100 min.	130 min.	130 min.	130 min.	150 min.
Pour Point, °F	---	0 max.	20 max.	20 max.	---	---	---
Water & Sediment	0.5	trace, max.	0.05 max.	0.50 max.	1.00 max.	1.00 max.	2.00 max.
Carbon Residue, 10% BTMS, %	[1]1.49	0.15 max.	0.35 max.	---	---	---	---
Ash, %	0.65	---	---	0.10 max.	0.10 max.	0.10 max.	---
Distillation, °F:							
10% Evap.	399	420 max.	---	---	---	---	---
90% Evap.	---	550 max.	540-640	---	---	---	---
Kin. Viscosity, cSt, @ 100°F	6.16	1.4-2.2	2.0-3.6	5.8-26.4	32-65	75-162	---
Gravity, °API	30.6	35 min.	30 min.	---	---	---	---
Sulfur, % Wt	0.35	[2]0.5	[2]0.5	(3)	(3)	(3)	(3)

[1] Carbon residue on 10% BTMS was obtained using a 1.0-gram sample instead of the required 4.0-gram sample.

[2] Legal requirements may lower this value.

[3] Legal requirements must be met.

Table 8. Metal Analysis of "Products" Used in Combustion-Emissions Test

		Sample Obtained		Metals Present (ppm)			
Sample Number	Type of Sample	Initial Test @ Bldg. 345	Second Test @ Bldg. 4219	Lead	Zinc	Calcium	Magnesium
--	Base No. 2 Fuel Oil	Yes	---	16.8	2.4	7.2	103
--	Waste Oil	Yes	---	1121	355	317	42
--	1% Waste Oil in No. 2 Fuel Oil	Yes	---	21.2	2.4	8.2	123
6	Base No. 2 Fuel Oil	---	Yes	50	30	50	5
10	No. 2 Fuel Oil	---	Yes	54	11	54	5
5	Waste Oil	---	Yes	6655	1331	1109	1008
9	27% Waste Oil in No. 2 Fuel Oil	---	Yes	4934	518	399	379

APPENDIX

SAMPLING AND ANALYTICAL METHODS

1. Sampling Methods

a. Particulates

(1) The particulate train used consisted of a probe tip, heated stainless steel probe, glass cyclone, and glass fiber filter in a heated chamber; four Greenburg Smith impingers in an ice bath; vacuum pump; gas meter; and calibrated orifice.

(2) Isokinetic sampling conditions were maintained as close as possible by controlling pump vacuums in relation to pertinent system parameters so that the velocity of the gas entering the probe tip was equal to the velocity of the surrounding gas stream. The gas velocity was determined by use of an S-type pitot tube. Temperature was measured with a chromel-alumel thermocouple.

(3) The particulate was collected at several points across the stack diameter. Two diameters 90° apart were traversed. The number of sampling points was determined by the stack diameter and distance above and below flow disturbances. In this case, 10 points on each of two diameters were sampled for boilers in Bldgs. 345 and 4219.

B. Moisture. Moisture determination was made from the change in weight of the impinger containing silica gel and the change in liquid volume of the other three. Impingers 1 and 2 contained 100 ml of H_2O, impinger 3 was empty, and impinger 4 contained silica gel.

c. Gaseous Sampling. A Mylar bag sample was collected concurrently with each particulate sample. The sampling velocity was maintained proportional to stack gas velocity for the entire test.

2. Analytical Methods

a. Particulates. Particulate determination was accomplished by measuring the weight change of the particulate traps in the system. The glass cyclone and the probe were washed with acetone. The washings were combined and dried to constant weight and a final weight was taken. An acetone blank was also included. The glass fiber filter was dried to constant weight in a desiccator and weighed. In accordance with ASME Power Test Code 27,* condensible particulates collected in the impingers were not included as particulate matter.

b. Moisture. Moisture content was determined by weighing four impingers before and after sampling.

c. Gases. A Fisher-Hamilton Gas Partitioner was used to determine CO_2, O_2, N_2, and CO in the Mylar bag samples.

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*Power Test Code No. 27, "Determining Dust Concentration in a Gas Stream," adopted 29 April 1957, the American Society of Mechanical Engineers.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This publication is the formal report of the workshop on Measurements and Standards for Recycled Oil, held at the National Bureau of Standards on November 22 and 23, 1976. There were seven sessions on specific subject areas at the meeting, with a total of 26 formal presentations, plus extensive discussion periods. The subject areas were as follows: (I) The NBS Responsibilities and Program, (II) Used Oil Reused as Fuel, (III) Recycled Industrial and Hydraulic Oils, (IV and V) Recycled Engine Oils, (VI) Barriers to the Utilization of Recycled Oils, and (VII) Problems and Needs in Establishing Quality for Recycled Oil Products. Included in this volume are the invited talks that were given and summaries of the extended discussions that were held on each of these subject areas.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Recycled oil; petroleum test methods; re-refined oil; petroleum standards; oil specifications; industrial oils; fuel oil; engine oil; hydraulic oil; lubricating oil; used oil; waste oil.

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