WASTE OIL MANAGEMENT - A STATUS REVIEW

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The U.S. Environmental Protection Agency (EPA) has been concerned with waste oil for 5 years. The Agency's program for the proper management of waste oils has been under the direction of the National Environmental Research Center-Cincinnati's Industrial Waste Treatment Research Laboratory and its predecessors. Recon Systems has been under contract to develop an input-output model for waste oil and evaluate waste oil processes with respect to their environmental impact. We would like to take this opportunity to review that program for you. Finally, we will indicate where we believe the Agency will continue to play a role in the management of waste oils.

Program Origin

EPA's concern with waste oil originated from reports that these oils found their way into watercourses. The Agency's initial concern was supported by the Congress in the Water Quality Improvement Act of 1970. This was followed by a mandate from Congress, in Public Law 92-500 (the 1972 Federal Water Pollution Control Act Amendments), that by April of 1974 a report be sent to the Congress indicating the state of waste oil management.

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Initially, the Agency's concern was with the water pollution aspects of waste oil management. Within the past 18 months, the conservation of natural resources has taken on as important a role in the management of waste oil as has its control from the water quality aspect. Thus, the current EPA program emphasizes resource recovery with environmental control.

<u>How Much Waste Oil?</u>

There are two primary sources of waste oil: the first is crankcase oil and the second, industrial oil. In addition to that, oil is recovered from spills, tank cleanings, ballast water, and a variety of miscellaneous activities indigenous to an industrial state. Data on the amount of waste oil are extremely difficult to accumulate.

Sales of new oils in the United States total about 2.5 billion gallons annually.(1) As seen in Figure 1 and Table 1, these are split between crankcase and industrial oils. The industrial oil is often recycled internally. The amount of industrial oil available in the open market for reuse is not well defined.* A recent survey in Pittsburgh suggests that perhaps 200 to 300 million gallons of crankcase and industrial oil are available in the open market for recycle.(3) Additionally, a considerable amound of waste oil from industrial sources is re-refined on a custom basis if it is not recycled within the plant itself.

Of the 1.2 billion gallons of crankcase oil sold in the United States, the API has estimated that about 68% leaves car engines as waste oil.(4)

*Reuse and/or recycling as used in this paper refer to use as a feed stock by re-refiners, a fuel, or other environmentally sound uses which replace virgin oil.

A more detailed breakdown of how oil sold is converted to waste oil, based on the recent Recon Systems study in Pittsburgh, is summarized in Table 2. Thus, about 800 million gallons annually should be available for recycle, as shown in Figure 2.[1] A number of surveys have been conducted to determine the availability of waste crankcase oils for recycle. Results of these surveys are summarized in Table 3. It is quite evident that there is a wide discrepancy between what should be available and what is thought to be available. The word "thought" is used because surveys of this kind are plagued by large confidence intervals. They depend on the memories of gas station owners who will often report the most recent data, if any at all. These data must be extrapolated to cover all stations.

Data for waste oil generation at automotive service centers, based on waste oil generation factors, are detailed in Table 4. Commercial fleets generate another 100 million gallons per year. Missing one major user (e.g. a city or state garage, or a major bus fleet) in the survey can result in a significant error. Nevertheless, it is quite evident that at best, if all the lube oil were sold for automotive use, 50% of the crankcase oil that should be available for recycle is available. If one is then to believe the accumulation versus pick-up results, as determined in the State of Maryland survey, only 50% of what is available is picked up and is actually recycled.

Thus, one can establish that 200 to 400 million gallons of crankcase oil are recycled annually. Yet only 100 million gallons are actually re-refined (operating throughput), as determined by personnel from the Industrial Waste Treatment Research Laboratory in a survey made in the spring of 1973 (Table 5).

The remaining oil that is unaccounted for ends up in a number of places. First, much is burned as a mixture with No. 4 or 6 oil in industrial furnaces. Although this practice is energy conserving, it does mean that more lead is emitted into the atmosphere. If all the waste crankcase oil were burned, and 50% of the lead ends up in the stack gas, somewhere between 7 and 15 thousand tons of lead would be emitted into the atmosphere annually. This is only a small fraction of the lead emitted from automobile exhausts (4 to 8%). It represents not only the addition of lead to the atmosphere, but also a loss of a natural resource. Lead is found in waste oils at up to one percent concentration as shown in typical analysis (Table 6[4]), and in waste oil distillation residue in concentrations up to 10%. Thus, the lead in the waste oil is as, or more, concentrated than that in many ores mined commercially. The Agency is working with industry to find a method to recover this lead.

Road oiling to keep down the dust, particularly in farming areas, uses significant quantities of waste oil in season. Waste oil has been cheaper than a specially compounded oil, and thus is favored from a short range economic point of view. However, the waste oil leaves the road quickly, potentially polluting watercourses and not having a lasting effect on preventing dust.[8] Thus, both from an environmental and a resource point of view, other methods of dust control will probably have to be found.

Some waste oil is utilized in hot road asphalt. This may be either in its raw waste form or as a distillate cut from the waste oil. Where specifications permit, this seems to be an acceptable utilization of waste crankcase oil. True, there are numerous other uses for crankcase oil, but these are the major ones. We have not mentioned the do-it-yourself changer who probably dumps his oil either into the sewer system or on a landfill. This oil is, of course, lost.

Under present economic conditions we believe that any oil collected is utilized. Contrary to one year ago: collectors cannot afford to dump oil.

<u>Waste Oil Processes</u>

The major re-refining process in use today, as seen from the IWTRL survey, is acid/clay treatment. Another process used in the United States is vacuum distillation followed by clay treating. This may be preceeded by a caustic treat. Detailed discussions of these, as well as a solvent extraction process are presented in the appendix.

Acid/clay treatment can produce a good lube stock. As practiced in this country, however, acid consumption and tar yields are high. The former results in poor economics; the latter produces a disposal problem. As discussed later, both these problems seem to be solved in German practice.

Although solvent extraction is old in the art of lube oil manufacture, it has not, in the past, found favor with waste oil reprocessors.

High solvent-to-oil ratios result in high operating costs. Continuous operation requires skilled operating personnel. Finally, acid and clay treatment are not fully eliminated. Several firms have developed solvent extraction processes at pilot plant scale. Only the Institut Francais du Petrole (IFP) has commercialized the process in Europe.

Agency's Program

EPA has had a multi-faceted program in waste oil management. To date, approximately $1.2 million have been spent on waste oil management studies. Table 7 indicates that most of this money has been spent to develop new process technology. Other significant expenditures have been made for development of institutional programs and evaluation of existing technology and methodology.

In process development, the Agency has funded a major program to develop a non-polluting process for re-refining and recovering waste oils for use as diesel fuel and/or lubricants. The major emphasis in this program has been the development of a distillation process preceded by a pre-treatment process or followed by hydrotreating to develop a stable lubricating oil. The first part of this study was completed in 1971 and the second part will be completed in 1974. We anticipate that, eventually, a hydrotreating process will be demonstrated for the production of lubricating oils. This particular program is being carried out by the National Oil Recovery Corporation (NORCO). A conceptual process using hydrotreating is discussed in the appendix.

In connection with that program, a bottoms product that is high in lead (10% lead and 25% solids) is produced. The Agency, working in concert with NORCO and NL Industries, is demonstrating that this product can be successfully recycled into a lead reclaiming operation for its lead and heating value.

In one of its earlier efforts, the Agency supported work at Villanova University to prove out caustic treatment of waste oils.[(9)] This process is being used at Blackwood Carbon Products, Inc. in

Blackwood, N.J., as well as by several commercial re-refiners.

The Agency also sponsored some work by the GCA Corporation on the enhancement of incinerator operation by adding waste crankcase oil.(10) This study was completed successfully, and a report on it is available. GCA recommended that a demonstration be initiated as a result of their findings that the addition of waste crankcase oil improved incineration operation and produced a better, more sterile, incinerator effluent.

One of the major problems that has been plaguing industry has been the disposal of the sludge remainders from re-refining. Landfilling of petroleum and acid sludges is coming more and more under fire. There are special situations where the sludges end up in road tars or roofing felts or other products, but these markets, too, are very limited. Therefore, in addition to its program at NL Industries, the Agency is sponsoring work to develop acceptable means of disposing of the re-refining sludges. This work is going on in the State of Maryland and at Rutgers University. Results from these studies should be available within the next year.

Probably as critical, if not more critical, than the re-refining of the waste oils is their collection. To determine the feasibility of setting up a statewide collection and re-refining system, the Agency in 1972, awarded a grant to the State of Maryland. Work under this grant has been completed, and part of the work will be reported very shortly.(7) Environmental Quality Systems, Inc. has developed for the State of Maryland, as a result of the grant, a waste oil collection model. They can, using collectors now available, collect all the waste oil in the State at an average cost of 3¢ per gallon. This compares to a sales value of 4¢ and more per gallon. The model can easily be adapted to other States or regions. The second phase of the report is a preliminary process design study for a plant to handle all waste oils generated within the State of Maryland.

A study to develop a recycling system for major Federal facilities, such as large military bases, has been completed by Teknekron Corporation. (11) They recommend that a collection system be established on a Federal facility and that re-refining to lube oil be done by an industrial re-refiner on a contract basis. This is, of course, similar to what is done for industry when their oils are custom re-refined.

GCA Corporation has been evaluating the burning of waste oil as a fuel. The study is still under way and is being complemented by work being done under the sponsorship of the API with Hawiian Electric Corporation.

In the evaluation area, the Agency has contracts with a number of groups to obtain data on waste oil generation, waste oil utilization, and the engineering evaluation of current waste oil re-refining processes. These studies will all be incorporated into the report, which is due to the Congress in April of this year.

What Are Others Doing?

Probably the most significant re-refining and recycling movement is that in Germany. The Germans, historically, have re-refined waste oil. Currently, of their million-ton-per-year lubricating oil requirements, 200 to 250 thousand tons are supplied by re-refined oil. This oil competes on the market with virgin oil. The collection of the oil is regulated by law and is supported by a tax on the sale of oil, which is then returned to the re-refiner (or burner of waste oil) who passes on most of the subvention to the collector. Under the law, all waste oil must be collected. However, do-it-yourselfers' crankcase wastes are probably not collected in Europe just as in the United States. The collectors are licensed--as are the reprocessers or burners. Oil is imported into Germany from other countries, re-refined, and sold back in those countries.

The German re-refining industry is basically an acid/clay industry. However, utilization of high-shear mixers and pre-treatment with a coagulant reduces the acid and clay treats to about five percent.

In Berlin acid sludges are landfilled, according to the Scientific Director of the Department of Health and the Environment; the acid sludges degrade rapidly on the fills.

The French (IFP) have, as has been well advertised, a propane extraction process. Unfortunately, this process still requires acid and clay treatment. It is currently being utilized to produce first-rate lubricating oils at the Viscolube plant in Milan, Italy. Two other plants, utilizing the propane extraction process followed by hydrofining, are being built in Yugoslavia and Sardinia by IFP. Both the Italians and the French encourage the recycling of oil, giving re-refiners tax advantages; these are not as favorable, however, as those found in Germany.

<u>Where to From Here?</u>

It is obvious to everyone that waste crankcase oil represents an opportunity for resource conservation as well as reduction of environmental pollution. Short run it would appear attractive to merely blend the collected waste oil with fuel and burn it. Someone has burned it straight when no ther fuel was available (with extreme burner plugging problems).[12] The policy of incinerating, with heat recovery, of waste oils does not take into account, however, the worth of the oils as lubricants. This factor must be considered.

Crudes to produce lubricants have always been more valuable than crudes used only for energy production. One could expect, although there are no hard figures, that lube crudes will be in even tighter supply than fuel crudes.[2] It probably behooves us to maximize the lubricating values of waste oils. It would appear that this would be economically attractive in the long range. In order to do this we must continue to develop non-polluting re-refining processes. It will also be necessary for the industry to develop a sound approach. This means that the industry must share in the development of these processes and develop plants of sufficient size to support newer re-refining processes. This support must be both in terms of economy of scale and in technological sophistication which comes with larger size plants.

In order for the industry to compete, it is necessary that it produce a first class product. It has done so in the past and continues to do so on a selective basis. The guiding light is there; in Germany re-refined lube oils compete with the quality lubricating market. Small quantities of re-refined oil compete in the United States. The United States industry can do the same on a large scale.

In the end there will be several ways of managing the waste lubricating oils industry: lube production, energy recovery, admixing into asphalts, and others. Local conditions will dictate the method of choice.

APPENDIX

Current Waste Oil

Re-refining Processes

ACID/CLAY TREATMENT

The process scheme for the typical acid/clay re-refining of waste automotive oils is shown in Figure 3. The process for diesel engine waste oils differs only in process condition details.

Incoming materials are unloaded into a partially submerged tank directly from the collection trucks. This receiving tank must be fitted with grids and screens to remove the debris which is normally found in the waste materials. The recommended tank would be large enough to accept the entire truck load and permit any free water to settle. The oil is then decanted and transferred to feed storate tanks, and the water layer to a skimmer and then to wastewater disposal. The proper handling of the raw material is extremely important to a smooth operating facility.

A typical analysis of oil in the storage tanks would be:

Water	3.5% by volume
Naphtha	7.0% by volume
Oil, etc.	89.5% by volume

More detailed analyses are presented in Tables 1 and 2. The feed is pumped through a steam heat exchanger to the flash dehydrator which operates at 300°F and atmospheric pressure. The steam/oil overhead is condensed and separated; the oil to light end storage to be used for fuel, and the water to the wastewater disposal system.

The dehydrated oil is sometimes stripped prior to acid treating, but more often it is pumped directly to dry oil tanks, where it is stored and cooled. It can be stored for 2 to 4 days before it picks up appreciable moisture which tends to increase acid requirements during the following step. After 48 hours storage the oil temperature has dropped to approximately 100°F.

Dry oil is pumped to one of several acid treating units. These units are steam jacketed and are agitated with plant air. Four to six volume percent of 93% sulfuric acid is added to the reactor where the temperature is maintained at about 100°F. The oxidized products contained in the oil are usually coagulated within 24 hours; but up to 48 hours may be be required depending on the raw material. The acid sludge, containing oil contaminants and ash, separates from the oil and is drawn off from the reactor bottom. Acid sludge disposal, which usually is done in landfills or lagoons, is one of the most critical problems in this process.

The acid treated dehydrated oil is then transferred to the steam stripping-clay treating operation. The clay treater is equipped with overhead condensing equipment and direct fired heater through which the oil is circulated. The capacity of the clay treater is usually on the order to 5,000 to 10,000 gallons. It is equipped with a sparger for direct introduction of steam.

The temperature of the batch is brought up to 550-600°F by circulating through the heater after the batch has been transferred. Simultaneously, live steam is introduced into the batch. The purpose of this stripping operation is to remove the remaining light fuel fractions and any mercaptans which may be present. This operation normally takes 12-15 hours to complete. The steam-stripped materials are condensed, and the oil separated from the water. The water fraction is treated through the wastewater disposal system and the oil fraction used as plant fuel.

The heat is discontinued and part of the fuel oil is diverted to the clay slurry tank. The oil temperature is permitted to drop to approximately 400°F. The clay, often a 50% mixture of activated clay and diatomaceous earth (200-250 mesh), is mixed into the circulating oil. The clay dose is approximately 0.4 pounds per gallon of oil. The clay removes color bodies as well as colloidal carbon by adsorption.

The hot air (250-350°F) containing the clay is filtered through a plate and frame filter press, sometimes followed by a second filter in series. The clarified oil is then stored either prior to or after having the necessary additives blended into the stock.

The filter cake, a mixture of clay, impurities, and oil, is uneconomical to separate and recover after filtration in small plants. It must therefore be discarded, usually by landfill. This is becoming increasingly difficult to do, as discussed in a later section of this report. Paper, which is often used as a filter medium in the plate and flame press, is discarded with the cake.

Odors can be a problem with acid/clay re-refining. These may emanate from storage tanks, processing vessels, wastewater treatment facilities, acid sludge, and oil spills. In some re-refining operations, odors can be controlled adequately by sealing open vessels and tanks, good housekeeping, and by venting process vessels to furnaces where vapors are burned with the normal fuel. Other plants have resorted to control methods such as caustic scrubbers.

The wastewater system varies from plant to plant, depending on cooling water and vacuum facilities, water runoff problems, land availability, water contamination of feedstocks, governmental regulations, and availability of a local sewage plant. A typical installation includes an API separator with oil skimming, pH control, some water recycle, and discharge to a sewage plant. Sewage plants will normally accept water with oil contents up to about 100 ppm, a quality level relatively easy to meet. Little data is available on other wastewater characteristics.

Overall lube stock yields for acid/clay treatment have been reported from 45 to 75%. These obviously depend upon operating conditions and feed composition, with water, sludge, ash, and gasoline contents being most critical. For the type of feed reported herein (3.5% H_2O, 7.0% maphtha), greater than 70% yield is possible with good operation.

The oil produced by the acid/clay process can be considered a solvent neutral blending stock, with properties approximating an SAE 20 lubricating oil. SUS (Saybolt Universal Second) viscosity is generally between 55 and 58 at 210°F. The oil can be blended to a finished lube by the re-refiner or sold directly to a jobber with blending facilities. Viscosity is increased by the addition of virgin bright stocks, or by the addition of polyisobutylene. Conventional additive packages are used when necessary to meet high performance specifications.

DISTILLATION/CLAY TREATMENT

The distillation/clay process (Figure 4) overcomes the serious acid sludge waste disposal problem connected with acid/clay treatment. At least two re-refiners now use such a process. The following description is based on work supported by EPA(13) and partly on patent literature (14)(15).

The crude collected waste oils are received in the usual manner, insuring that extraneous matter does not enter the process stream. The wet oil is heated to 300°F in a direct heater, using as fuel light hydrocarbon streams generated during processing. The flash tower operates at atmospheric pressure and 300°F. The oil/water overhead is condensed and sent on to an oil decanter. The water phase is separated and removed to the wastewater disposal system. The oil layer is used as fuel in the plant.

The flash tower bottoms are passed through a head exchanger to reduce the temperature to approximately 100°F. Light oil, having a boiling range of 150-250°F is introduced into the dehydrated oil stream. The quantity used is approximately 20% based on oil volume. A small amount of caustic 0.2-2.0%, dependent on feedstock, is also introduced. The addition of the light oil and caustic tends to break the oil-water emulsion and precipitate solids. These materials are removed by centrifugation. The sludge from the centrifuge can be disposed of separately, e.g., by landfill, or it can be mixed with the distillate bottoms to be described.

The maphtha/caustic/centrifuge pretreatment step may not be a necessary adjunct to distillation, but it does tend to eliminate some of the materials which can cause fouling and erosion in the vacuum distillation furnace, column, and associated heat exchangers.

The centrifuged oil is then pumped to the vacuum distillation tower through a direct fired heater. The furnace heats the oil to about 700°F. The columns operate at a vacuum of 27 inches of mercury. The overhead maphtha is condensed, cooled, and used as fuel in the plant.

The bottoms, which contain almost the entire ash content of the feed, are cooled and used as fuel, for blending into asphaltic products, or stored in a lagoon. The middle cut is sent on to clay treatment for finishing as a lube blending stock.

The clay treatment is similar to that described for the acid/clay process except that prior stripping is unnecessary and may be reduced to as little as 0.125 lbs. per gallon of oil. The filter cake is disposed of in the usual manner.

The yields for this type operation, based on input oil, are approximately 70%, comparable to the best acid/clay treating operations.

The product quality produced by the distillation/clay process as described is also comparable to that produced by acid/clay treating. However, by taking more than one sidestream from the vacuum distillation column, it may be possible to obtain a part of the yield as higher viscosity lube stocks. The properties of some distilled motor oils are shown in Tables 5 and 6. It is believed that clay treatment leaves most of these properties relatively unchanged, except for improvements in color, neutralization number, and reductions in oxygen and nitrogen content.

Odor and wastewater problems are not believed to be any more serious with this process than with acid/clay treatment.

SOLVENT EXTRACTION/ACID/CLAY TREATMENT

The solvent extraction/acid/clay process (Figure 5) is a relatively new development in the re-refining of waste lubricating oils.[16, 17] It has been tried experimentally in the United States but no plants are now in operation. A 9-million-gallon-per-year plant is operating in Italy based on a process developed by Institut Francais du Petrole (IFP).[16] Similar processes have been developed and patented, but not commercialized by U.S. firms.[17, 18]

The basis for the process is the use of propane to selectively extract the base lube stock from the additives and impurities. The propane, containing dissolved oil, is removed from the extractor, while the high boiling, dark colored asphaltic and oxidized hydrocarbons and suspended solids are removed from the unit bottom as a residue. The bottoms are mixed with a fuel oil and used as plant fuel, or otherwise disposed of; whereas the propane is flashed from the oil and recycled.

The process scheme consists of the following:

a. Thermal dehydration

b. Precipitation and solvent extraction

c. Vacuum distillation

d. Acid treatment

e. Clay treatment and filtration

The incoming waste oil is unloaded into a receiving tank as described before. The feed for the process is pumped through the steam heat exchanger to the flash dehydrator, operated at about 300°F and atmospheric pressure. The overhead is condensed and drained into an oil separator. The water layer is disposed of through the waste water disposal system; the oil layer is either stored or processed immediately in the solvent extractor.

The oil is pumped to the precipitation tower (solvent extractor) via a head exchanger. The propane is also heated and introduced into the tower approximately 1/3 up from the bottom. The oil is introduced 1/3 down from the top. The solvent extractor operates at about 500 psig and elevated temperatures. The propane-oil solution (the oil having dissolved in the solvent) goes overhead due to specific gravity differences, whereas the precipitate flows to the extractor bottom.

For very high quality lube oil, the solvent-to-feed ratio would be approximately 20:1. This will vary dependent upon feed stock and must be determined for each one. The lowest solvent-to-feed would be 1:1, yielding poor quality oil in the raffinate. Current operations are believed to be in the vicinity of 15:1.

A small amount of fuel oil is added to the pipeline to assist in the flow of residue from the unit. The residue is released from the extractor by a liquid level controller. The fuel oil-residue mixture is stored for use as fuel for the direct fired heaters, or for other means of disposal.

The propane-oil solution is flashed through a pressure reducing valve into a solvent flash drum. It is usual to use a two-stage flash to separate the propane and oil. The first stage operates at 250°F and 250 psig. The propane gas is liquified and recycled.

The lube oil is sent on to acid/clay treatment as described in the acid/clay process. The acid and clay dose is approximately one-half of the amount used without solvent extraction. That is, this process requires only about 2% of 93% sulfuric acid by volume based on oil, compared with 4-6% for the acid/clay process. After treatment with about 0.15 lbs. of clay per gallon at 300°F and filtration, the lube oil quality is reported to be superior to the acid/clay product, at least in terms of color and color stability, and perhaps viscosity. These properties are shown in Table 7 and Figure 4.

Although the quantities of acid and clay required in the IFP process are greatly reduced, a disposal problem still exists. No acid sludge analysis is available, but the metals content, e.g., lead, is undoubtedly lower than for the acid/clay process. Most of the metals and other impurities appear in the fuel oil-residue mixture, making the use of this material as a fuel environmentally questionable, unless accompanied by a considerable investment in air pollution control equipment, and a problem also as to furnace or boiler tube fouling.

DISTILLATION/HYDROGEN TREATING

The distillation/hydrogen treating process is similar to distillation/clay treating, except for the finishing step, shown in Figure 6.[19] Although this scheme is widely used in petroleum refineries, no plants are now operating on waste oils. However, two European installations to be started up in the period 1974-76 are apparently planning to combine hydrogen treating with the IFP propane extraction process previously described.

As described before, a pretreat section can be used ahead of vacuum distillation to reduce fouling and erosion problems. The distillate (sidestream) from the vacuum distillation column is heated using hydrotreating product and an oil fired heater before being mixed with recycle and makeup hydrogen. The hydrogen-oil mixture is contacted with a standard commercial hydrotreating catalyst in a fixed bed. The hydrogen reacts with oxygen and nitrogen containing impurities and unsaturates.

The pressure is reduced in two flash drums in series and the recovered gaseous hydrogen is recycled. The purified oil is used to preheat the incoming feed and then injected into a stripping column where the small amount of volatile materials which may have formed are removed. The purified product leaving the stripper can be used to preheat vacuum distillation feed before final cooling and storage.

Recent work has shown that the hydrogen treated distillate can match typical properties of 150 vis neutral lube blending stock.[20] Hydrotreating conditions used in this work were 650 psig, 650^{o}F, 800 standard cubic feet of hydrogen recycled per barrel of feed, and a space velocity of 1.0 v/v/hr.

The distillation bottoms which contain almost all of the objectionable impurities can be disposed of as discussed before. However, in conjunction with the distillation/hydrogen treating process development now under way, plans are being made for introduction of this high lead material into a secondary lead smelting operation. If this is successful as expected, the distillation/hydrogen treating scheme holds promise as being the first re-refining process available without a solid waste disposal problem.

As for other environmental problems, the wastewater problem is similar to other re-refining processes and can be overcome by conventional design. A scrubber may be required to remove impurities from the hydrogen purge stream and other minor gaseous discharges.

Additional work on catalyst life and hydrogen consumption would be desirable before commercialization of this process.

Table 1.

ESTIMATED LUBRICATING AND INDUSTRIAL OIL SALES IN THE U. S. - 1970-71[19]

		Millions of Gallons/Yr.
Automotive Lubricating Oils		1086
Commercial engine oils - fleet sales	200	
Commercial engine oils - retail sales	90	
Factory fills, automotive and farm	60	
Private automobiles*, automobile fleets, other	736	
Aviation Lubricating Oils		8
Industrial Lubricating Oils		726
Hydraulic & circulating system oils	325	
Metalworking oils	150	
Railroad engine oils	60	
Gas engine oils	62	
Other	129	
Other Industrial Oils		377
Process Oils	310	
Electrical Oils	57	
Refrigeration Oils	10	
Federal Government		37
Exports		487
TOTAL		2721

*Approximately 600 million gallons/year. (45% = service stations; 17% = car dealers; 10% = garages, auto supply stores; 28% = mass marketers)

Table 2.

FACTORS FOR ESTIMATING THE CONVERSION OF AUTOMOTIVE SALES TO WASTE OIL QUANTITIES

Service Stations

70% of oil sold is used for changes
Oil drained is 90% of filled capacity
70% x 90% = 63% of oil sold = waste oil generated

Garages and Auto Supply Stores

Assume average is same as service stations (63%)

New Car Dealers

100% of oil sold is used for changes
Oil drained is 90% of filled capacity
100% x 90% of oil sold = waste oil generated

Retail Sales for Commercial Engines

Assume same as service stations (63%)

Automotive Fleet and Other Lube Oil Uses

Assume 50%, allowing for two-cycle engines and internal use, e.g., fuel, by commercial and governmental fleets.

Factory Fills, Automotive and Farm

Assume 90% recovery in automotive service centers

Oil Bought at Discount Stores

Assume same as service stations (63%)
Assume 35% of waste oil generated finds its way to service stations
63% x 35% = 22% of oil sold = waste oil generated at service stations

Table 3.

ESTIMATES
WASTE CRANKCASE OIL GENERATED
UNITED STATES

Source	Million Gallons
National Estimates - Generated	
American Petroleum Institute	700[4]
M.E.S. State-of-the-Art	730[5]
Per Capita Projections - Generated	
Massachusetts Survey	440[6]
Per Capita Projection-Available for Recycle	
Maryland Survey	360[7]
Pittsburgh Survey	400[3]

Table 4.

ESTIMATED LUBE OIL SALES AND
WASTE OILS GENERATED AT AUTOMOTIVE SERVICE CENTERS*
1970-71

	Sales 10^6 gal/yr	Waste Oil Factor+	Waste Oil 10^6 gal/yr
Automobiles in service stations	270	0.63	170
Automobiles in garages and auto supply stores	60	0.63	38
Automobiles at new car dealers	102	0.9	92
Retail sales for commercial engines	90	0.63	57
Automotive fleet and other lube oil uses‡	136	0.5	68
Factory fills, automotive and farm	60	0.9	54
Oil bought at discount stores	168	0.22	37

*Includes motor oils, transmission oils, hydraulic oils, etc.
+See Table 3 for estimates of waste oil factors
‡Marine, agricultural, etc.

Table 5.

SURVEY OF SELECTED OIL RE-REFINERS: PROCESSES AND CAPACITY

Company	Processes			Capacity (gpd)		Waste Crankcase Oil*
	Dehydration	Acid-Clay	Other	Design	Operating	Feed gpd
No. 1	X	X	-	-	5,000	4,000
No. 2	X	X	-	2,200	2,100	2,000
No. 3	X	X	-	23,000	12,000	12,000
No. 4	X	X	Batch Basis	-	9,000	-
No. 5	-	-	-	-	-	-
No. 6	X	X	3/4 Capacity	20,000	20,000	16,700
	X	-	1/4 Capacity			
No. 7	-	-	HiPres.Dist.	130,000	65,000	-
No. 8	X	X	-	62,500	50,000	-
No. 9	X	X	W/Steam Strip	4,300	3,200	2,750
No. 10	X	X	-	6,500	3,250	3,000
No. 11	-	-	Dry,HiSpdCent	12,500	12,500	11,200
No. 12	X	X	-	5,250	5,250	4,700
No. 13	-	-	Caustic Clay	17,000	17,000	-
No. 14	X	X	-	20,000	10,000	-
No. 15	X	X	Steam Strip	-	8,300	4,100
No. 16	X	X	-	12,500	10,500	5,000
No. 17	X	X	-	-	20,000	12,000
No. 18	X	X	Steam Strip	12,500	12,500	-
No. 19	X	X	-	7,500	7,500	-
No. 20	X	X	-	8,300	8,300	6,250
No. 21	-	-	Caustic Clay	40,000	30,000	-
No. 22	X	X	-	33,000	20,000	-
No. 23	X	X	-	17,000	10,000	7,000
No. 24	-	-	Caustic Clay	25,000	5,000	4,500
			HCl Act.Clay			
No. 25	-	X	-	6,700	2,000	2,000
No. 26	X	X	-	-	1,000	1,000
No. 27	X	X	-	3,600	2,000	2,000
No. 28	X	-	-	40,000	20,000	-
No. 29	-	-	-	33,000	-	-
TOTAL				636,850	372,400	100,200
AVERAGE				28,000	14,000	

*Other sources not listed

Table 6.

TYPICAL WASTE AUTOMOTIVE OIL COMPOSITION

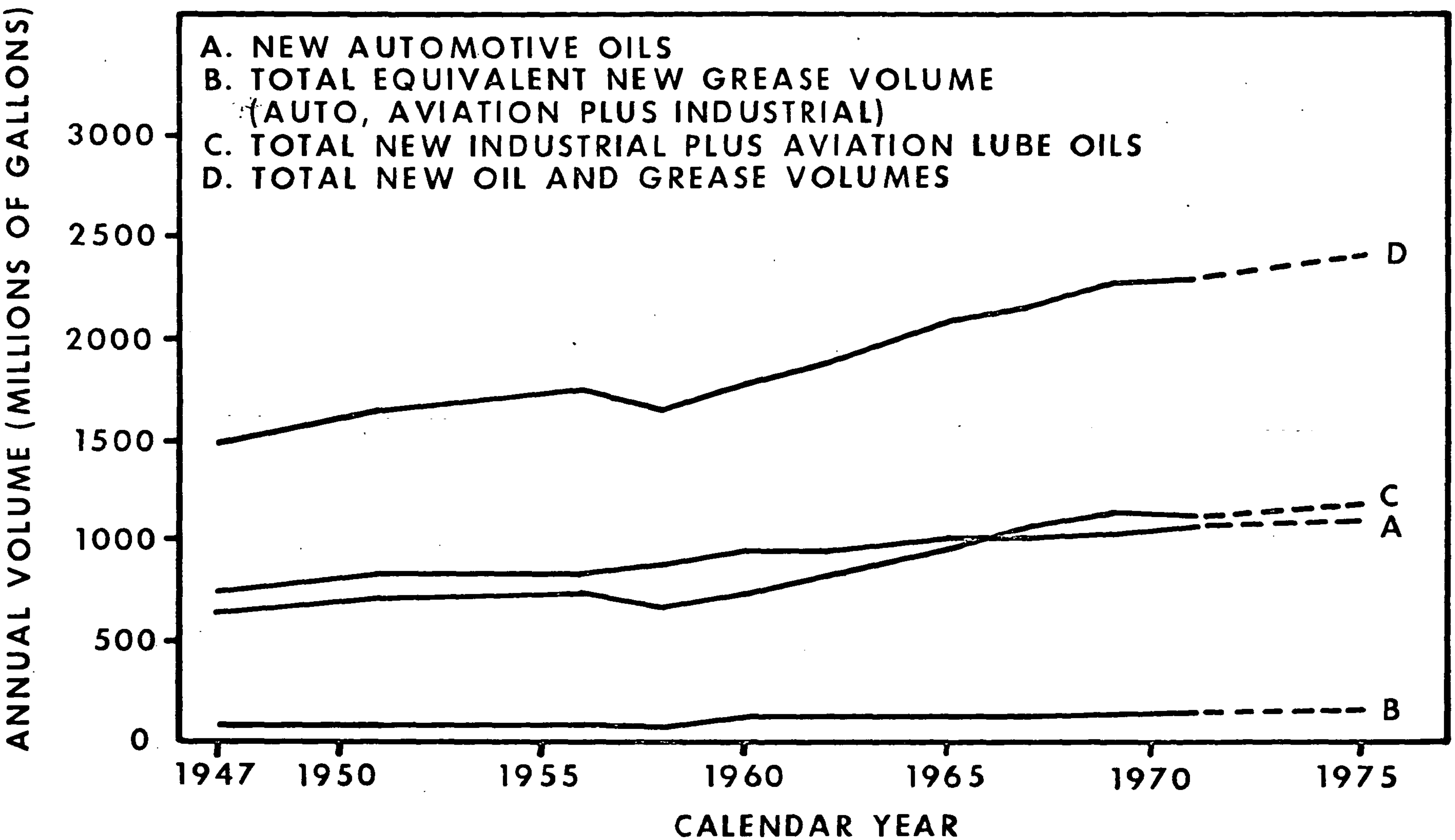
Variable	Value
Gravity, °API	24.6
Viscosity @ 100°F	53.3 Centistokes
Viscosity @ 410°F	9.18 Centistokes
Flash Point	215°F (C.O.C. Flash)
Water (by distillation)	4.4 Volume %
BS&W	0.6 Volume %
Sulfur	0.34 Weight %
Ash, sulfated	1.81 Weight %
Lead	1.11 Weight %
Calcium	0.17 Weight %
Zinc	0.08 Weight %
Phosphorous	0.09 Weight %
Barium	568 ppm*
Iron	356 ppm*
Vanadium	5 ppm*

*ppm = parts per million

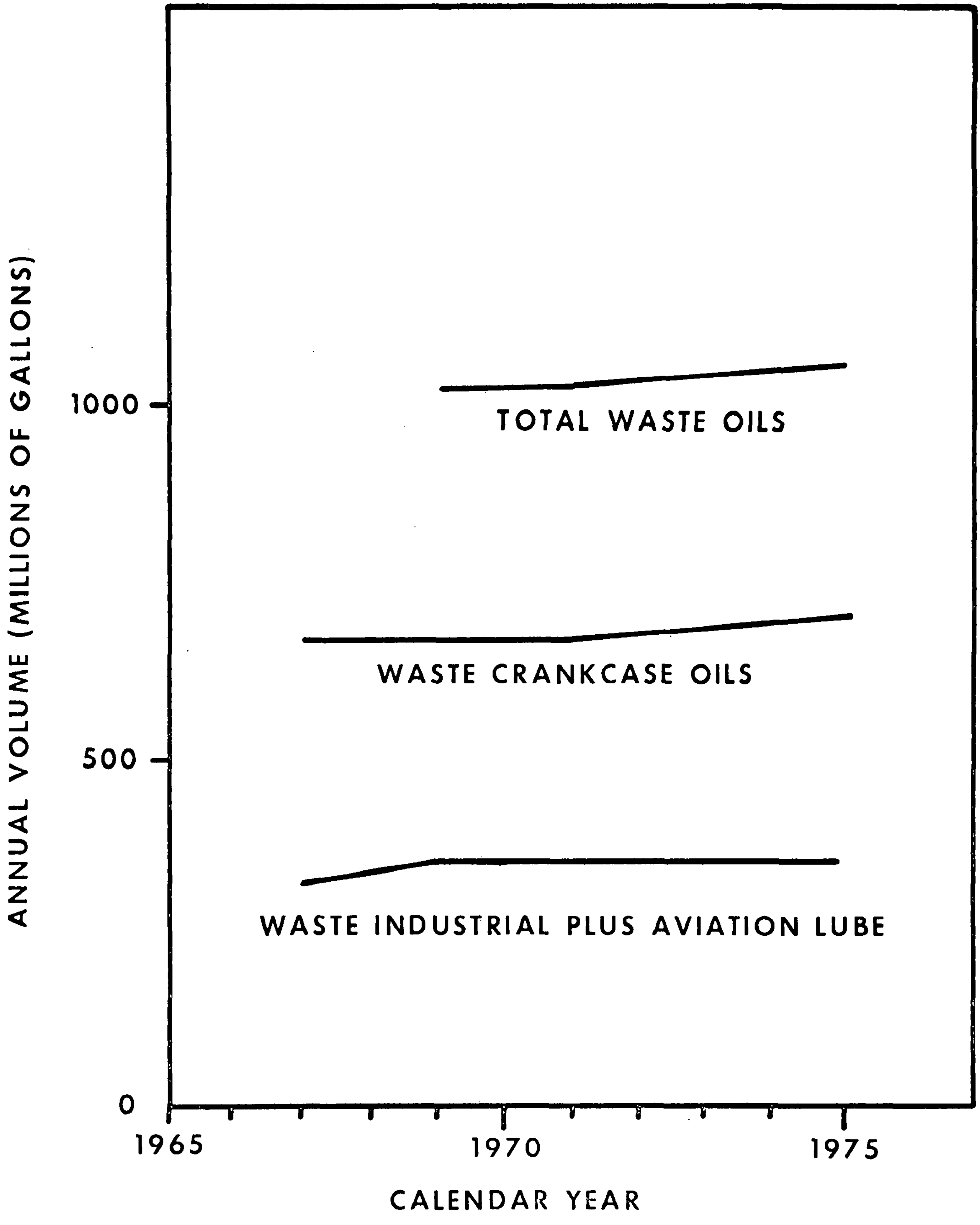
Table 7.

EPA WASTE OIL PROGRAM EXPENDITURES

	EPA FUNDING ($1,000)
Total Process Development	827
Institutional Development	221
National Evaluation	141
TOTAL	$1,189

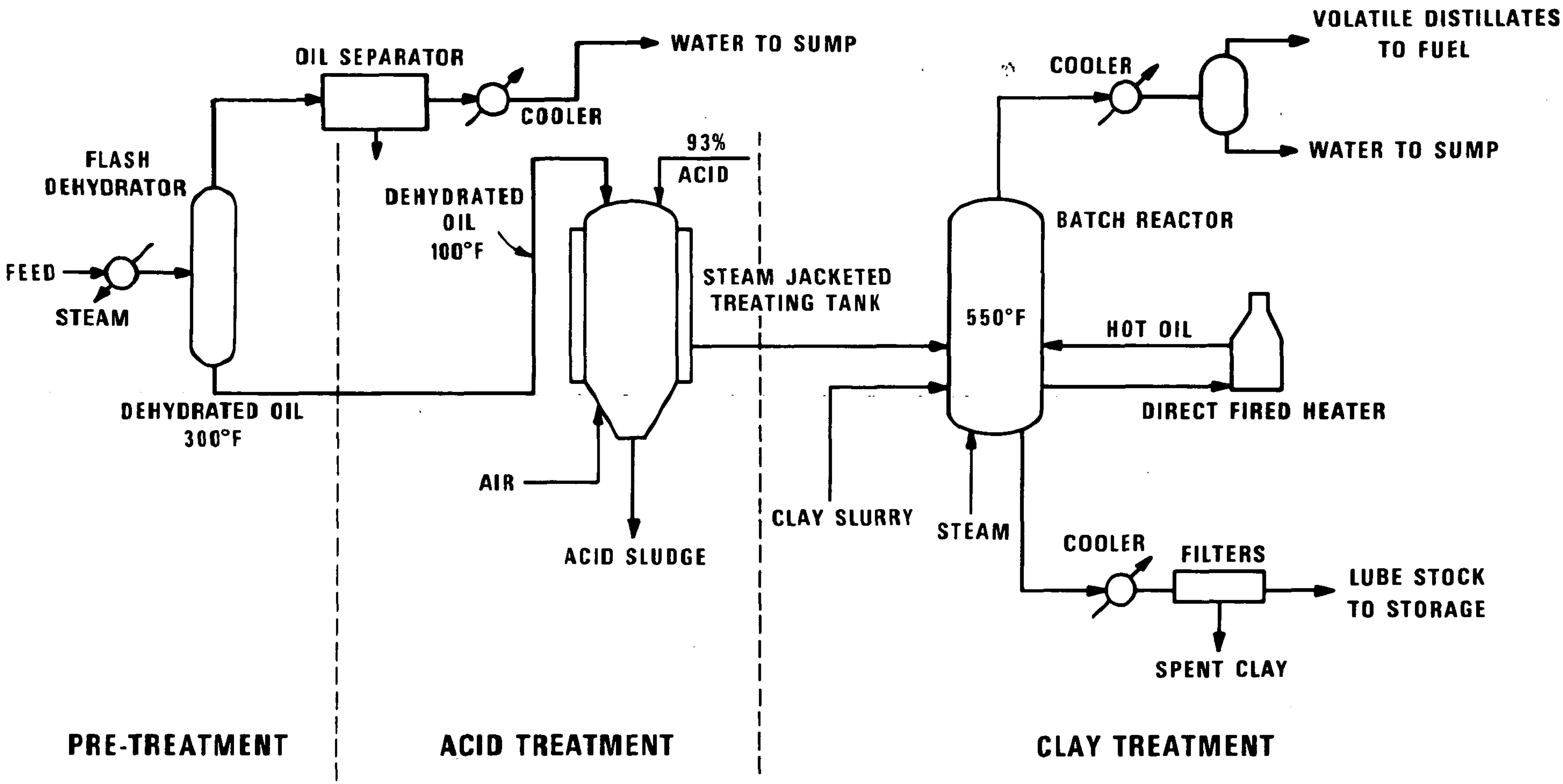


VIRGIN OIL SALES IN THE UNITED STATES
Figure 1



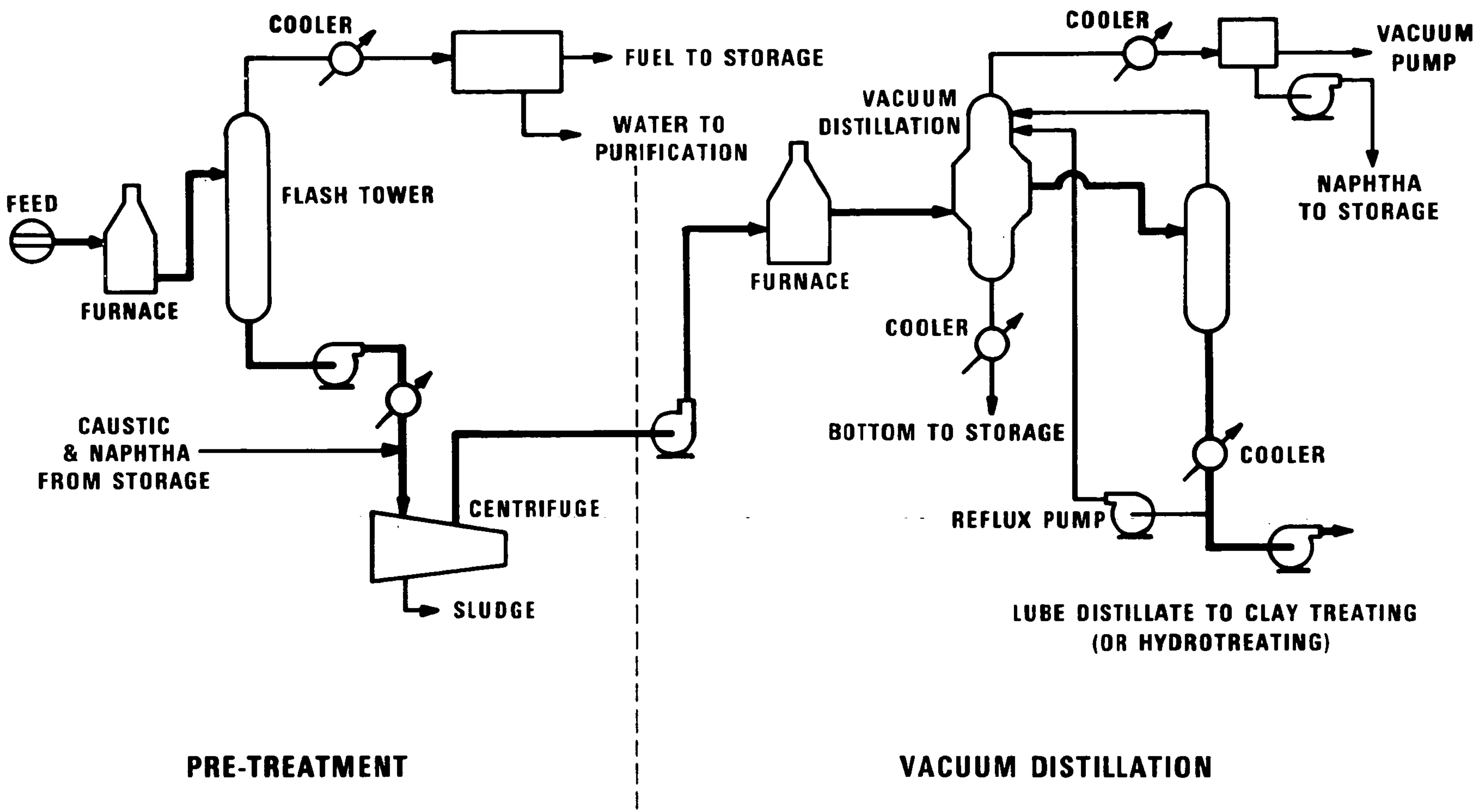
WASTE OILS GENERATED IN THE UNITED STATES

Figure 2



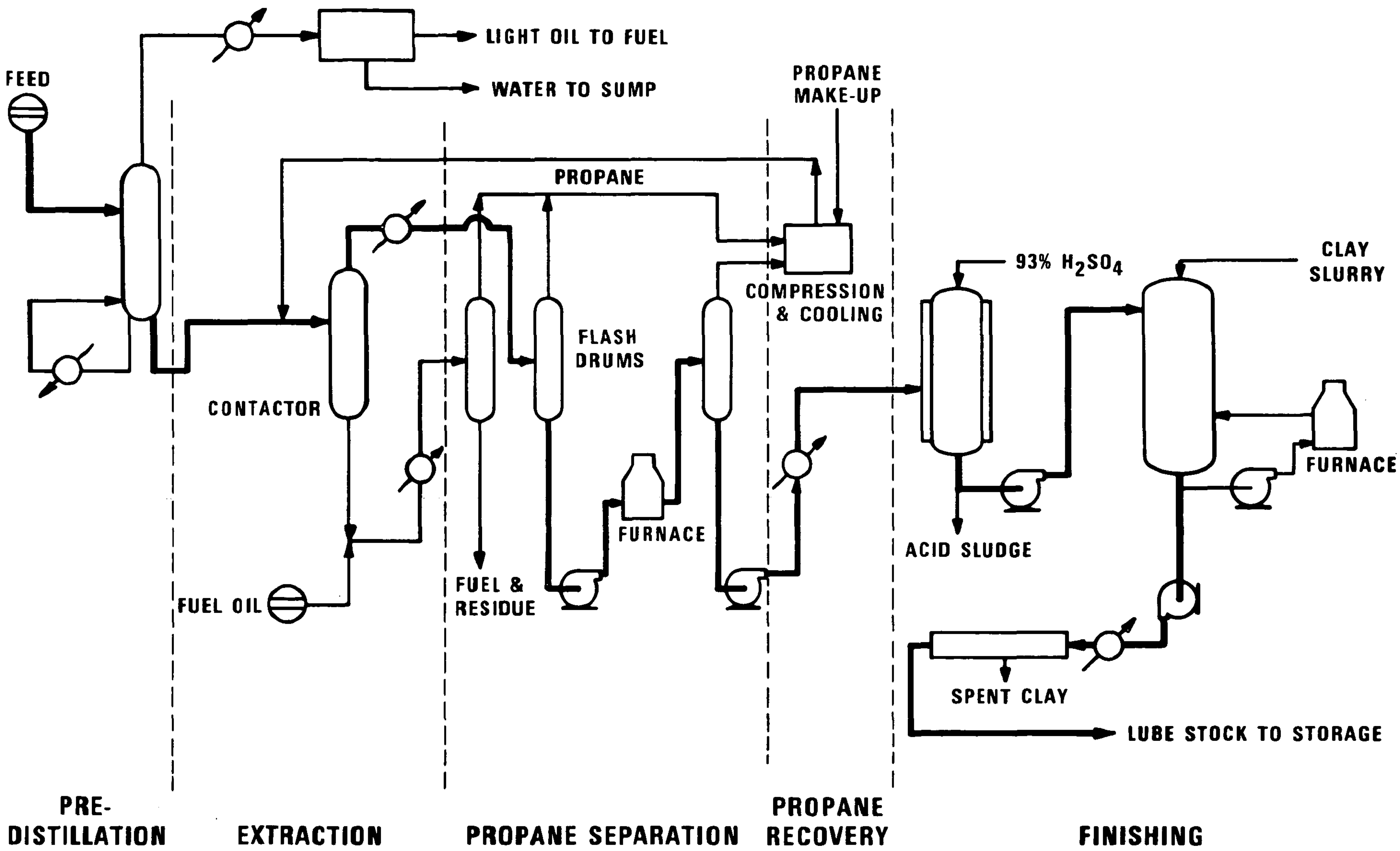
RE-REFINING BY AN ACID CLAY PROCESS

Figure 3



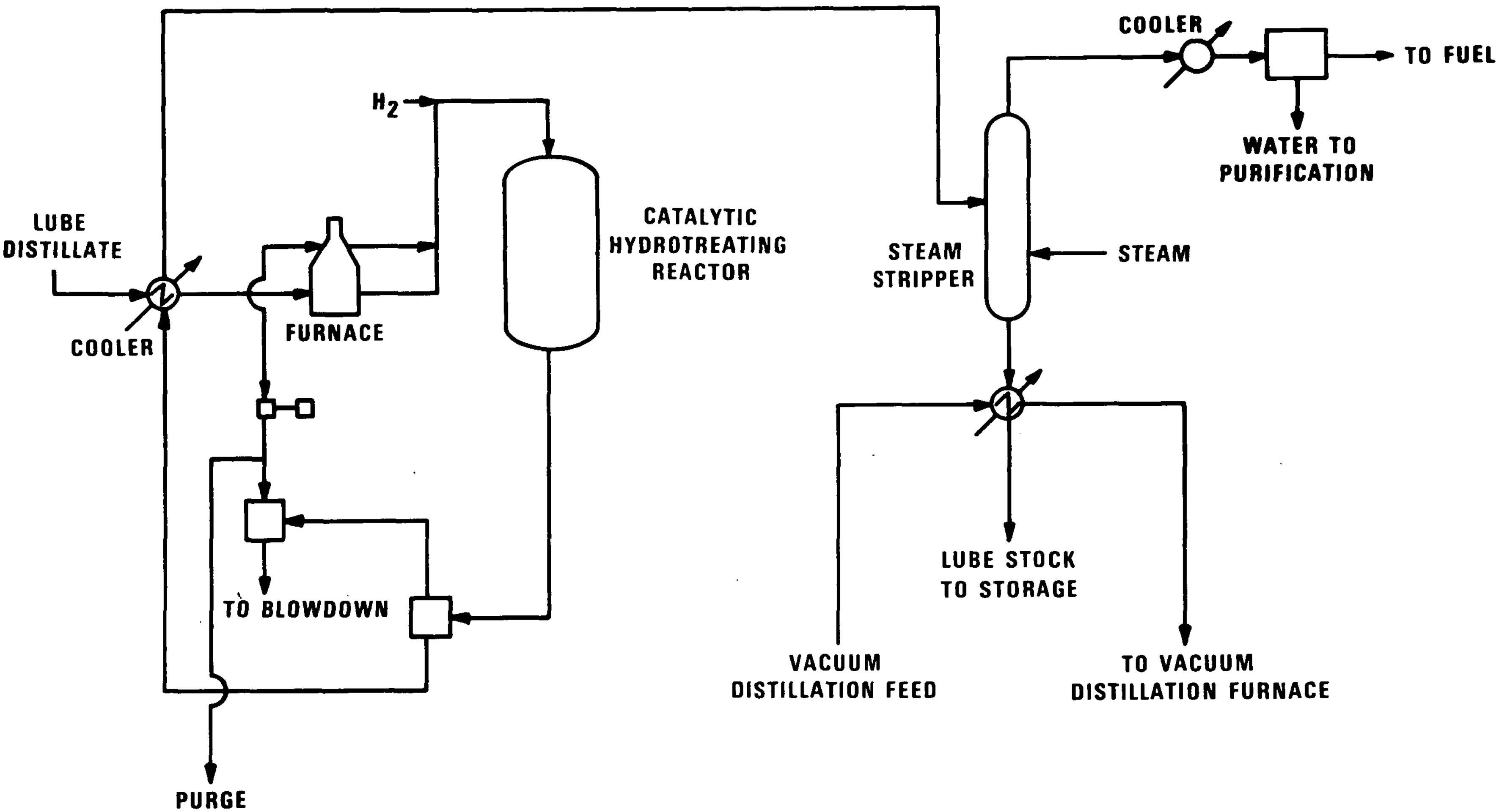
VACUUM DISTILLATION OF CRANKCASE WASTE OIL

Figure 4



RE-REFINING BY A PROPANE EXTRACTION PROCESS

Figure 5



HYDROTREATING

Figure 6

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