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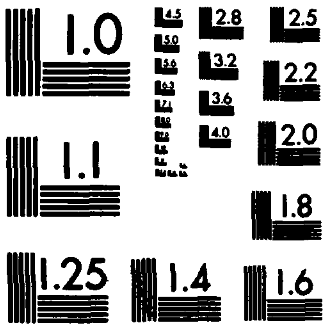

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US Army Corps
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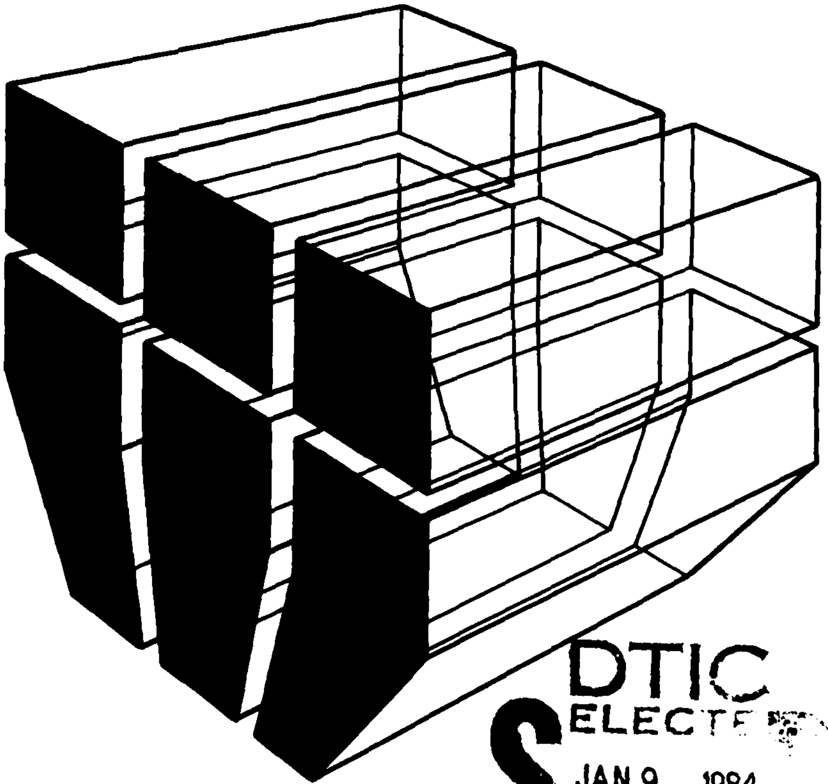
TECHNICAL REPORT N-171
December 1983

FEASIBILITY OF DEPARTMENT OF DEFENSE USED LUBRICATING OIL RE-REFINING



by
John Kubarewicz
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The Department of Defense (DOD) annually procures and uses a large amount of lubricating oil in its vehicle fleets. This results in a significant volume of used lubricating oil being generated at DOD installations. Characteristics of this used lubricating oil can lead to its consideration as a hazardous waste. While Federal regulations classifying used oil as a hazardous waste have not been promulgated, this is expected to change in late 1983 or early 1984. Several states have already classified used oil as a hazardous waste in advance of Federal action.

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One significant option for the disposal of used lubricating oil is recovery and re-refining to produce a product capable of meeting military specifications (mil specs) for lubricating oil. The objective of this study was to determine the feasibility of capture and re-refining of all DOD used lubricating oil. The quantities of virgin oil currently procured and the capture potential are examined as is the degree of technical sophistication available in the re-refining industry. A mathematical model involving the costs of transport and re-refining of used oil and backhauling the re-refined product was developed and exercised on the available data.

Results indicate that capture and re-refining of DOD's used lubricating oil is feasible under selected conditions with the cost of transportation being a major factor. The re-refining industry has both the capacity and the technical sophistication to produce a re-refined oil capable of meeting military specifications.

FOREWORD

This study was conducted as a reimbursable for the Defense Logistics Agency under Military Interagency Procurement Request SM 4900-9-0083-1. Work was performed primarily by Engineering-Science, Fairfax, VA, under contract DACA 88-83-M0267 to the U.S. Army Construction Engineering Research Laboratory (CERL). Assistance was provided by the Energy and Environmental Systems Division of Argonne National Laboratories. Mr. Jan Reitman, DLA-W, was technical monitor for the study.

The report was written by John Kubarewicz and Timothy Shea of Engineering-Science and Walter Mikucki of the CERL Environmental Division. Special recognition is given for the assistance of Mr. Morris Gilbert and Ms. Paula McLain of DLA headquarters and their staffs.

Dr. R. K. Jain is Chief of the CERL Environmental Division, Dr. L. R. Shaffer is Technical Director of CERL, and COL Paul J. Theuer is Commander and Director.

EXECUTIVE SUMMARY

The study was initiated by Defense Logistics Agency as a result of a tasking by the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs & Logistics). Impetus for the study was a General Accounting Office report recommending re-refining as well as concern over pending Federal regulations designating used lubricating oil as a hazardous waste.

It was determined that the critical elements of the study were:

1. To determine quantities and locations of used lubricating oil in DoD.

2. To establish the state of technology of the re-refining industry with emphasis on yield, flexibility to handle contaminants, and the potential for generation of pollutant/hazardous waste streams.

3. To establish any institutional impediments to re-refining in DoD.

4. To determine the economics of collection, re-refining and reintroduction of the oil.

Actual shipment records were obtained from Defense General Supply Center (DGSC) in Richmond, VA. The DGSC breakdown allowed the establishment of geographic as well as quantitative information for use in the economic analysis.

An analysis of the re-refining industry showed that it is relatively small now compared to the 1950s. A prime reason was the enactment of stringent environmental regulations which virtually excluded the acid-clay re-refining technology prevalent at that time. Today's re-refinery is based on relatively high technology; such processes as chelation/extraction for removal of heavy metals and wiped-film evaporators are in general use, and some membrane separation processes are in limited use. Despite the smaller size of the industry, however, a survey revealed that all major re-refineries have excess capacity and most have enough capacity to handle all of the used oil available from DoD. This fact essentially negates the concept of establishing a Government Owned/Government Operated (GOGO) or Government Owned/Contractor Operated (GOCO) re-refinery to handle used DoD lubricating oil.

Further, it was established that one currently operating re-refinery had proven that its product met military specifications (Mil Specs) and therefore was as capable as virgin oil of meeting military requirements. It is reasonable to assume that the other re-refineries could also meet military specifications.

The oil supply process was examined to discover any institutional impediments to the capture, re-refining and reintroduction of the oil into the system. Since military specifications for lubricating oil have been revised to permit re-refined oil, no impediments were found. However, several issues were surfaced. The question of who in DLA is responsible for the administration of a re-refining program must be resolved. Both the Property Disposal and Supply groups have a role. The Disposal group now has responsibility for disposing of most DoD hazardous wastes, and thus has the network and facilities to administer a used oil re-refining program. The Supply group is involved in the distribution of virgin oil and would thus have the mechanism for introducing the re-refined oil into the distribution system.

Another concern, which seems to have been resolved, is the question of custody of the used oil during the re-refining process. Early in the study, it appeared desirable to institute a closed-loop operation in which DoD used oil would be maintained in separate storage tanks and processed separately to keep the integrity of the base stock. Data collected by the National Bureau of Standards indicated, however, that concerns about base stock integrity were unfounded and that a quasi-closed loop process was feasible. In such an arrangement, a re-refiner would accept a batch of used DoD oil with stipulated quantity and characteristics. He then would deliver a quantity of mil spec lubricating oil based on the yield factor of his process. This product would result from the re-refining of used lubricating oil in his inventory, and not necessarily from the DoD used oil.

The final concern that requires resolution is the question of incentives. The proceeds of sales of recyclable material at a military installation are currently returned directly to the installation for use in support of environmental programs. Thus the capture and sale of used oil, even at such minimal rates as $0.15 per gallon, can result in substantial return to an individual installation. A re-refining program would eliminate this incentive unless some method of "drawing rights" against the stock of re-refined oil were established, and the savings in Operation and Maintenance Funds thus resulting were somehow made available to the installation.

The element of ecomonics is a strong influence on the success of any program such as the re-refining of DoD used oil. A combination of cost factors come into play: the costs of capture, storage to accumulate economic quantities, transportation to a re-refinery, and backhaul of the finished product to users. In this study, costs were determined or estimated for all of these factors and incorporated into a cost model. The quantities of oil available and the geographic distribution of the generating installations and re-refineries were examined. Competitive modes of transport of the used lubricating oil were considered, including an examination of the complicated railroad tariff schedules. Several strategies were examined involving, respectively, seven, three, and one re-refinery. The degree of participation of oil-generating installations was examined.

The study drew the following conclusions:

--Re-refined lubricating oil has been proven to meet military specifications.

--The re-refining of DoD's used lubricating oil may be economically feasible under selected conditions.

--The re-refinery capacity exists today on a decentralized, regionalized, or centralized basis for handling the quantities expected from a DoD oil recovery program.

--The cost of transportation to a centralized re-refinery serving the continental United States would raise the total cost of a gallon of re-refined oil to uneconomical levels.

--The added cost of true closed-loop re-refining (as compared with quasi-closed loop) is unjustifiable from a quality assurance standpoint.

--The target economic volume of oil required for re-refining and the optimum geographic radius for used oil collection are based upon local factors and cannot be generalized.

--Total participation of all installations in a re-refining program is not cost effective since low volume oil users increase the unit cost of re-refined oil.

--Increasing the efficiency of oil collection (volume and quality) will reduce the unit cost of re-refined oil.

--Although current DoD policy encourages re-refining practices, additional policy development and implementation as well as improved facilities are needed in the areas of collection and segregation of used oil.

--The energy cost to produce a gallon of re-refined oil meeting military specifications is approximately one-fourth that required to refine virgin crude to produce a gallon of military specification oil.

--At the installation level, increased command emphasis, education and an incentive program based upon quantity and quality of oil collected will increase capture and minimize contamination.

The following recommendations are based upon the findings of this investigation:

--DoD used oil policy should be uniformly enforced.

--DoD collection practices should be improved by policy modifications which provide installation incentive and education programs.

--An additional study should be undertaken to collect the detailed local data needed to determine the target economic volume and optimal geographic oil collection radius for re-refining.

--The recyling and re-refining of used oil should be demonstrated on a pilot basis at a large user installation, or several installations based upon the above-mentioned study, to collect the detailed operating experience necessary for a full-DoD operation.

--The long-term contracting provisions of the Military Construction Codification Act (PL 97-214) should be exploited to permit 4 to 8 year re-refining contracts to amortize the cost of qualification of process and product.

--A spot quality test should be developed for used oil at the point of collection.

--An installation cash-incentive program based on the cost differential between re-refined and virgin oil should be developed.

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CHAPTER 1

INTRODUCTION

The United States Congress has recognized the importance of conserving used oil and reducing oil pollution. Since 1972, when the Federal Water Pollution Control Act was passed, the Congress has directed government agencies such as the U.S. Environmental Protection Agency to investigate used oil conservation. These efforts resulted in the Energy Policy and Conservation Act of 1975, which was specifically directed at promoting oil conservation by Federal agencies. In 1976, the Resource Conservation and Recovery Act (RCRA) brought hazardous waste management under Federal-State regulatory control. To date used oil has not been classified as a hazardous waste by the Federal EPA; however, the EPA is expected to promulgate used oil regulations under this law in 1983. Several states have already made this classification in advance of Federal action.

Other recent legislation has provided a stimulus for the re-refining of used oils. The 1978 Energy Tax Act exempted re-refined oils from the 6 cent per gallon Federal Excise Tax. The Used Oil Recycling Act of 1980 eliminated the Federal Trade Commission labeling requirements for re-refined oils; the re-refining industry had claimed that labeling restrictions limited marketability of their product.

The United States Department of Defense (DoD) has had the lead role in the government procurement, collection and disposal of lubricating oils. The United States Army Mobility Equipment Research and Development Command (MERADCOM) is responsible for the military procurement specifications pertaining to lube oils, and has developed standard specifications (MIL-L-46152B and MIL-L-2104D) which are applicable to administrative and tactical vehicles respectively and which have found widespread use throughout other Federal, state and local agencies and within industry. Until recently the use of re-refined oil was prohibited by the military specifications. In 1980 the Army, working in conjunction with the National Bureau of Standards, revised the specification for administrative vehicles (MIL-L-46152B) to include re-refined oils. The tactical vehicle specification (MIL-L-2104D) is expected to be revised shortly.

In 1979 the DoD established an oil recycling and reuse policy in which "the military departments and defense agencies were directed to: (1) maximize the recovery and collection of used lubricating oil; (2) maximize the sale of used lubricating oil for the purpose of re-refining; (3) burn the used lubricating oil as a fuel or fuel supplement if no reasonable arrangements can be made for recovery by re-refining; and (4) discontinue any disposal practices that are not environmentally acceptable" (Reference 1). A follow-up review of DoD activities performed by the United States General Accounting Office (GAO) found that many DoD installations were not following the directive and that collection and selling practices tended to discourage the re-refining of used oil. The GAO recommended that the use of used oil be economically improved through the development of closed-loop re-refining (collection, processing and reuse of used oil) within the DoD. While the DoD agreed that improvements could be made in the areas of collection and segregation of used oils, they did not feel that the economics of the existing capacity for re-refining had been adequately developed (Reference 1). Hence, the present and several other investigations were authorized.

OBJECTIVES

The major objectives of the study were to:

(1) Assess the feasibility of establishing regional used vehicular crankcase oil re-refining capabilities for the DoD; and

(2) Determine the DoD-controllable conditions under which it will be economically feasible.

The specific study objectives were to:

(1) Assess DoD waste oil generation.

(2) Determine the target economic volume of oil required to justify re-refining.

(3) Determine the capacity and willingness of the re-refining industry to perform contract closed-loop re-refining.

(4) Evaluate the characteristics and sensitivities of current re-refining technology.

(5) Determine causes of contamination during collection, and recommend control procedures.

(6) Determine quality assurance methods.

(7) Define the logistic flowpath for closed-loop re-refining.

(8) Summarize essential closed-loop contract elements.

(9) Determine the overall feasibility of re-refining for DoD.

APPROACH

The initial steps in the study approach were to identify the total volume of lubricating oil used within the DoD, and to apply collection factors to determine the theoretical volume of used lubricating oil available for re-refining. Simultaneously, the actual quantities of used oil available from major sources within DoD were identified, and the availability of this oil for re-refining was determined. A comparison of the theoretical and actual quantities of oil available for re-refining enabled an estimation of the demand for re-refining capacity that would be required. The re-refining companies were contacted to determine the basic characteristics of their operations, including re-refining technology, excess capacity and willingness to participate in a closed-loop contract. Basic economic information on re-refining technologies and the minimum volumes required for a closed-loop contract were also solicited.

Cost functions were then developed for all aspects of used oil collection, storage, transportation, and processing, and were combined into an economic model. The model was used to determine the cost sensitivity of closed-loop re-refining to the degree of regionalization, the total volume of oil recycled, and the inclusion of low-volume sources of used oil within the DoD installations.

The results of this work were then used to assess the feasibility of establishing regional used oil re-refining capabilities for DoD.

CHAPTER 2

GENERATION AND DISPOSAL OF USED OIL

Vehicular lubricating oil consumption by DoD activities is estimated to be approximately 10 mgy (million gallons per year) in the continental United States. Because oil is obtained and consumed in varying patterns, oil usage and disposal data are not readily available; however, general estimates can be made from DoD procurement information.

Figure 1 presents a simplified logistic flowpath of lubricating oil supply and disposal. Individual installation estimates of oil type and volume are compiled by Major Command (MACOM) and by Service and assembled into a bid package for procurement by the Defense Fuel Supply Center (DFSC). The DFSC negotiates contracts with the industry; oil for small-volume users is purchased by the Defense Stock Fund and shipped to four major Defense Logistic Agency (DLA) depots for further distribution within Continental United States (CONUS). Activities submit their requisitions to the Defense General Supply Center (DGSC), the item manager, and the product is shipped from the depot closest to the requiring activity. Large-volume users may purchase oil at the DFSC contract price directly from the manufacturer using their own funds. Additional oil may be purchased from each contract by exercising the 30 percent overrun clause of the contract. No statistics are available to indicate the extent the overrun clause is exercised.

A copy of the Oil Contract Bulletin for Fiscal Year (FY) 1982-1983 was obtained from the DFSC. Data on the volume and destination of vehicular lubricating oils were extracted and used to develop a computerized data base. A breakdown of the purchase of vehicular lubricating oil from depots for the past year was obtained from the DGSC, and also placed in the computer file. The oil use data were then compiled by user, and a listing of each installation was developed and ranked by descending rate of consumption (Table 1). Installations purchasing less than 1000 gallons of oil a year were excluded from the listing.

A total of 299 sources were identified, with a total purchase volume of about 4.02 mgy. As shown in Figure 2, 100 sources (a third of the total) accounted for 80 percent of the total purchase. Approximately 40 percent of the bases purchased less than 4000 gallons per year, while over 60 percent purchased less than 10,000 gallons per year. Although incomplete, the data represent the best available basis for estimating lubricating oil consumption that could be obtained within the framework of this study.

OIL HANDLING/USAGE

The U.S. Army Mobility Equipment Research and Development Command (MERADCOM) is responsible for military vehicular oil procurement specifications. Lubricating oil service is generally classified into two service groups by MERADCOM: administrative and tactical. The major specifications for each group are MIL-L-46152B and MIL-L-2104D, respectively. Although

FIGURE 1. LUBRICATING OIL LOGISTIC FLOWPATH

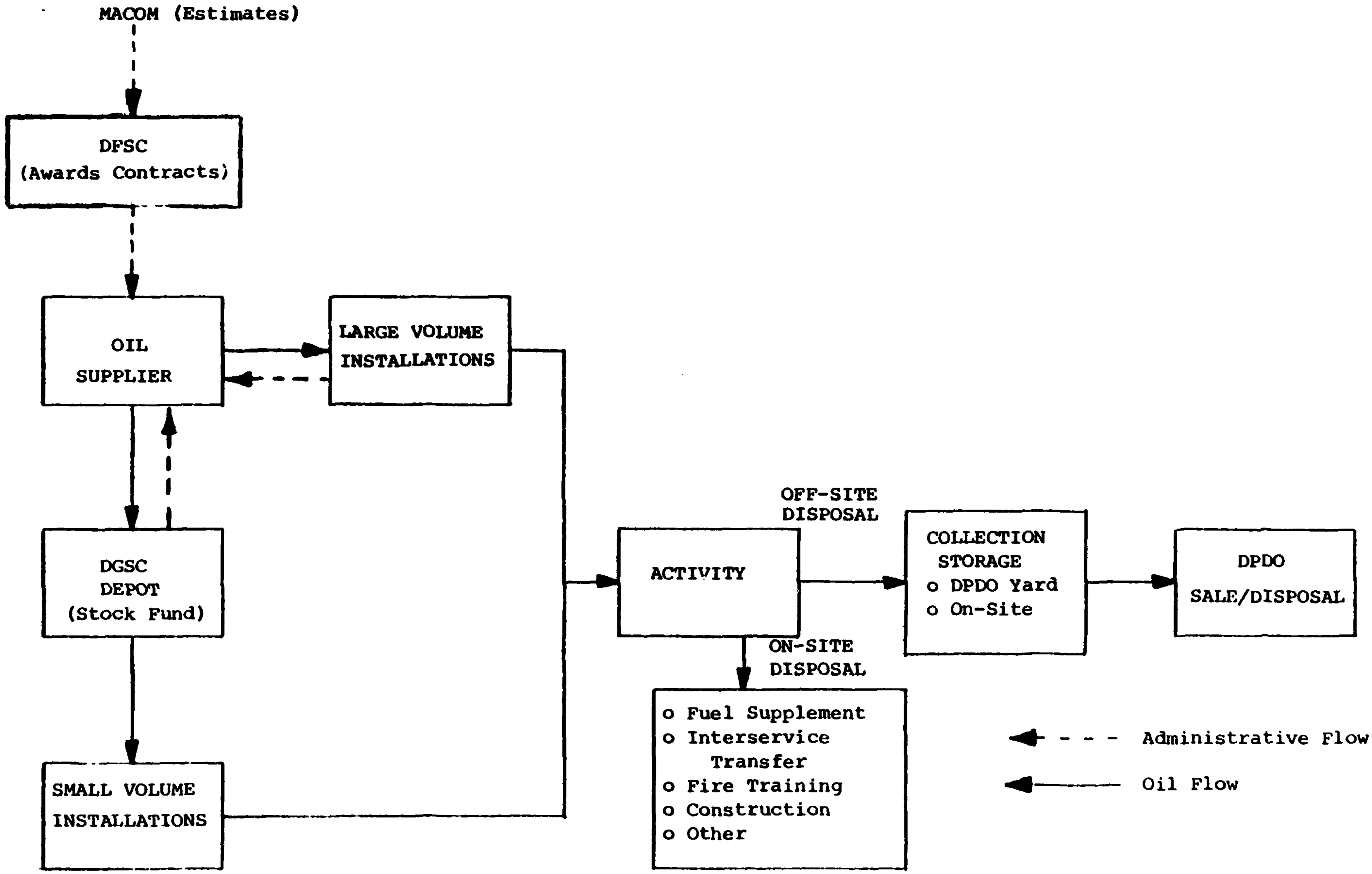


TABLE 1

PURCHASES OF LUBRICATING OIL (1982-1983 FY)
TOTAL PURCHASE: 4.02 MGY

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
4427	Fort Hood	TX	187658	4.7	4.7
1918	Fort Polk	LA	140323	3.5	8.2
613	Fort Carson	CO	125662	3.1	11.3
5065	Fort Stewart	GA	116817	2.9	14.2
1717	Fort Riley	KS	98841	2.5	16.7
5027	Camp Pendleton	CA	91830	2.3	18.9
3415	Fort Bragg	NC	86326	2.1	21.1
4820	Fort Lewis	WA	79737	2.0	23.1
4438	Fort Bliss	TX	79660	2.0	25.1
1812	Fort Knox	KY	76868	1.9	27.0
5016	Fort Irwin	CA	66593	1.7	28.6
5039	Colorado Springs	CO	65277	1.6	30.3
1117	Fort Benning	GA	63812	1.6	31.8
4716	Fort Eustis	VA	60127	1.5	33.3
109	Montgomery	AL	52170	1.3	34.6
4702	Norfolk	VA	49384	1.2	35.9
548	Fort Ord	CA	46974	1.2	37.0
4119	Charleston Air Force Base	SC	40819	1.0	38.0
524	Twentynine Palms	CA	38618	1.0	39.0
3714	Fort Sill	OK	38006	0.9	40.0
4516	Tooele	UT	37659	0.9	40.9
2216	Fort Devens	MA	37486	0.9	41.8
4501	Hill Air Force Base	UT	37095	0.9	42.7
2613	Fort Leonard Wood	MO	36894	0.9	43.7
5050	Patrick Air Force Base	FL	34600	0.9	44.5
4419	Kelly Air Force Base	TX	34478	0.9	45.4
5090	Fort Campbell	KY	34012	0.8	46.2
4715	Fort Belvoir	VA	33198	0.8	47.1

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
3308	Watertown	NY	31246	0.8	47.8
5038	San Luis Obispo	CA	30775	0.8	48.6
1025	Pensacola	FL	30274	0.8	49.4
5106	Aberdeen Proving Ground	MD	29976	0.7	50.1
4415	Dyess Air Force Base	TX	27341	0.7	50.8
410	Little Rock Air Force Base	AR	26985	0.7	51.5
5127	Raleigh	NC	26478	0.7	52.1
545	Port Hueneme	CA	25442	0.6	52.7
1033	Homestead Air Force Base	FL	24783	0.6	53.4
5200	Austin	TX	24553	0.6	54.0
566	Oakland	CA	24314	0.6	54.6
5221	Fort McCoy	WI	24255	0.6	55.2
2609	Camp Shelby	MS	23754	0.6	55.8
5062	Atlanta	GA	21762	0.5	56.3
5144	Nellis Air Force Base	NV	21187	0.5	56.8
5071	Boise	ID	20820	0.5	57.4
557	San Diego	CA	20418	0.5	57.9
5168	Annville	PA	19983	0.5	58.4
2011	Loring Air Force Base	ME	19885	0.5	58.9
1010	Eglin Air Force Base	FL	19681	0.5	59.4
5028	Santa Ana	CA	19438	0.5	59.8
3712	Tinker Air Force Base	OK	19342	0.5	60.3
2308	Lansing	MI	19339	0.5	60.8
5151	Peekskill	NY	19276	0.5	61.3
5183	Nashville	TN	19199	0.5	61.8
5210	Fort Lee	VA	19134	0.5	62.2
2314	K I Sawyer Air Force Base	MI	19107	0.5	62.7
1113	Robins Air Force Base	GA	18925	0.5	63.2

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
3924	Philadelphia	PA	18800	0.5	63.6
313	Davis Monthan Air Force Base	AZ	18769	0.5	64.1
4815	McChord Air Force Base	WA	18751	0.5	64.6
3413	Cherry Point	NC	18573	0.5	65.0
5121	Gulfport	MS	17826	0.4	65.5
5094	Pineville	LA	17431	0.4	65.9
5061	Albany	GA	17250	0.4	66.3
3214	White Sands Missile Range	NM	17086	0.4	66.8
5124	Pope Air Force Base	NC	17004	0.4	67.2
2710	Malmstrom Air Force Base	MT	16834	0.4	67.6
5004	Fort Rucker	AL	16831	0.4	68.0
119	Anniston	AL	16809	0.4	68.5
522	Travis Air Force Base	CA	16738	0.4	68.9
5020	Norton Air Force Base	CA	16508	0.4	69.3
3110	McGuire Air Force Base	NJ	16469	0.4	69.7
5180	Fort Jackson	SC	16430	0.4	70.1
5104	Fort George G. Mead	MD	16308	0.4	70.5
3417	Camp Le Jeune	NC	16281	0.4	70.9
518	Castle Air Force Base	CA	15786	0.4	71.3
4810	Fairchild Air Force Base	WA	15726	0.4	71.7
5139	Fort Dix	NJ	15523	0.4	72.1
1014	MacDill Air Force Base	FL	15320	0.4	72.5
1910	Barksdale Air Force Base	LA	14890	0.4	72.8
5114	Little Falls	MN	14648	0.4	73.2
3109	Trenton	NJ	14508	0.4	73.6
3710	Altus Air Force Base	OK	14504	0.4	73.9
5052	Tyndall Air Force Base	FL	14353	0.4	74.3
5179	Columbia	SC	14340	0.4	74.6
4210	Ellsworth Air Force Base	SD	14315	0.4	75.0
2142	Patuxent River	MD	14053	0.3	75.3

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5142	Santa Fe	NM	14033	0.3	75.7
5017	Vandenburg Air Force Base	CA	14024	0.3	76.0
810	Dover Air Force Base	DE	13721	0.3	76.4
5217	Bremerton	WA	13540	0.3	76.7
5220	Camp Douglas	WI	13288	0.3	77.0
5092	New Orleans	LA	13240	0.3	77.4
5140	Holloman Air Force Base	NM	13147	0.3	77.7
521	McClellan Air Force Base	CA	13047	0.3	78.0
5112	F. E. Warren Air Force Base	WY	13007	0.3	78.4
5023	George Air Force Base	CA	12635	0.3	78.7
4424	Corpus Christi	TX	12371	0.3	79.0
5155	Newark Air Force Station	OH	11901	0.3	79.3
5066	Fort Gordon	GA	11691	0.3	79.6
3613	Wright Patterson Air Force Base	OH	11630	0.3	79.9
5120	Jackson	MS	11299	0.3	80.1
1715	McConnell Air Force Base	KS	11149	0.3	80.4
5207	Portsmouth	VA	11096	0.3	80.7
3212	Kirtland Air Force Base	NM	11004	0.3	81.0
3305	Fort Drum	NY	10860	0.3	81.2
5003	Fort McClellan	AL	10509	0.3	81.5
5013	Yuma	AZ	10498	0.3	81.8
5129	Minot Air Force Base	ND	10308	0.3	82.0
5146	West Point	NY	10305	0.3	82.3
5117	Jefferson City	MO	10081	0.3	82.5
5014	Fort Huachuca	AZ	10060	0.3	82.8
5051	Hurlburt Field	FL	9921	0.2	83.0
5089	Frankfort	KY	9839	0.2	83.3
5086	Indianapolis	IN	9785	0.2	83.5
5006	North Little Rock	AR	9679	0.2	83.7

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5216	Seattle	WA	9466	0.2	84.0
510	Edwards Air Force Base	CA	9431	0.2	84.2
4721	Richmond	VA	9370	0.2	84.4
5176	Shaw Air Force Base	SC	9220	0.2	84.7
5079	Fort Sheridan	IL	9159	0.2	84.9
5010	Luke Air Force Base	AZ	8991	0.2	85.1
5101	Baltimore	MD	8814	0.2	85.3
5053	Jacksonville	FL	8748	0.2	85.6
3010	Pease Air Force Base	NH	8633	0.2	85.8
5070	Mountain Home Air Force Base	ID	8600	0.2	86.0
5087	Topeka	KS	8403	0.2	86.2
5075	Springfield	IL	8354	0.2	86.4
5203	Langley Air Force Base	VA	8144	0.2	86.6
574	NSY Long Beach	CA	8000	0.2	86.8
411	Blytheville Air Force Base	AR	7885	0.2	87.0
5081	Crane	IN	7865	0.2	87.2
5022	Beale Air Force Base	CA	7730	0.2	87.4
5005	Redstone Arsenal	AL	7642	0.2	87.6
5011	Phoenix	AZ	7635	0.2	87.8
5148	Griffiss Air Force Base	NY	7536	0.2	88.0
5205	Quantico	VA	7534	0.2	88.2
5202	Salt Lake City	UT	7403	0.2	88.3
5021	March Air Force Base	CA	7137	0.2	88.5
5047	Andrews Air Force Base	DC	7091	0.2	88.7
5162	Clackamas	OR	7074	0.2	88.9
5134	Portsmouth	NH	7060	0.2	89.0
5187	Carswell Air Force Base	TX	6931	0.2	89.2
5199	Fort Sam Houston	TX	6516	0.2	89.4
5091	England Air Force Base	LA	6010	0.1	89.5

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5178	Eastover	SC	5992	0.1	89.7
5125	Seymour Johnson Air Force Base	NC	5980	0.1	89.8
5132	Offutt Air Force Base	NE	5945	0.1	90.0
5035	Presidio of San Francisco	CA	5852	0.1	90.1
5024	Nas Moffett Field	CA	5732	0.1	90.3
5080	Grissom Air Force Base	IN	5466	0.1	90.4
5068	Grimes	IA	5435	0.1	90.5
5115	Whiteman Air Force Base	MO	5409	0.1	90.7
5046	Windsor Locks	CT	5350	0.1	90.8
5111	Selfridge ANG Base	MI	5124	0.1	90.9
5032	China Lake	CA	5038	0.1	91.1
5118	Keesler Air Force Base	MS	4965	0.1	91.2
5192	Gatesville	TX	4895	0.1	91.3
5109	Augusta	ME	4817	0.1	91.4
5177	Myrtle Beach Air Force Base	SC	4749	0.1	91.5
5213	Fort Pickett	VA	4717	0.1	91.7
5084	Jeffersonville	IN	4675	0.1	91.8
5157	Rickenbacker Air Force Base	OH	4617	0.1	91.9
5131	Devies Lake	ND	4566	0.1	92.0
5041	Aurora	CO	4542	0.1	92.1
5031	Vallejo	CA	4528	0.1	92.2
5194	Lackland Air Force Base	TX	4485	0.1	92.3
5130	Grand Forks Air Force Base	ND	4463	0.1	92.4
5008	Pine Bluff	AR	4455	0.1	92.6
5206	Yorktown	VA	4447	0.1	92.7
5133	Lincoln	NE	4445	0.1	92.8
5044	Golden	CO	4433	0.1	92.9
5019	Mather Air Force Base	CA	4422	0.1	93.0
5058	Moody Air Force Base	GA	4402	0.1	93.1

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5143	Hawthorne	NV	4355	0.1	93.2
5188	Texarkana	TX	4271	0.1	93.3
5054	Key West	FL	4126	0.1	93.4
5226	Buckhannon	WV	4110	0.1	93.5
5164	Willow Grove	PA	4089	0.1	93.6
5057	Starke	FL	4040	0.1	93.7
5073	Scott Air Force Base	IL	3937	0.1	93.8
5103	Silver Spring	MD	3900	0.1	93.9
5123	Helena	MT	3719	0.1	94.0
5099	Westover Air Force Base	MA	3698	0.1	94.1
5153	Romulus	NY	3639	0.1	94.2
1032	St. Augustine	FL	3630	0.1	94.3
5181	Rapid City	SD	3612	0.1	94.4
5141	Cannon Air Force Base	NM	3514	0.1	94.5
5136	Concord	NH	3512	0.1	94.6
5228	Warren	MI	3470	0.1	94.6
5040	Peterson Air Force Base	CO	3395	0.1	94.7
5029	Alameda	CA	3284	0.1	94.8
5147	Plattsburg Air Force Base	NY	3264	0.1	94.9
5161	Norman	OK	3250	0.1	95.0
5218	Oak Harbor	WA	3250	0.1	95.1
5201	San Antonio	TX	3217	0.1	95.1
5078	Great Lakes	IL	3190	0.1	95.2
5163	Pittsburgh	PA	3158	0.1	95.3
5055	Cecil Field	FL	3139	0.1	95.4
5072	Chanute Air Force Base	IL	3125	0.1	95.4
5060	Garden City	GA	3121	0.1	95.5
5095	Plaquemine	LA	3015	0.1	95.6
5211	Alexandria	VA	2866	0.1	95.7

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5097	Hanscom Air Force Base	MA	2857	0.1	95.7
5172	Tobyhanna	PA	2767	0.1	95.8
5119	Columbus Air Force Base	MS	2755	0.1	95.9
5195	Reese Air Force Base	TX	2699	0.1	95.9
5189	Bergstrom Air Force Base	TX	2679	0.1	96.0
5098	Otis Air Force Base	MA	2677	0.1	96.1
5085	Madison	IN	2664	0.1	96.1
5037	Herlong	CA	2646	0.1	96.2
5063	Forest Park	GA	2640	0.1	96.3
5208	Virginia Beach	VA	2604	0.1	96.3
5000	Eastaboga	AL	2570	0.1	96.4
5196	Randolph Air Force Base	TX	2550	0.1	96.5
5001	Maxwell Air Force Base	AL	2521	0.1	96.5
5197	Laughlin Air Force Base	TX	2515	0.1	96.6
5009	Williams Air Force Base	AZ	2505	0.1	96.7
572	NAS North Island	CA	2500	0.1	96.7
5034	Point Mugu	CA	2470	0.1	96.8
5175	Smithfield	RI	2452	0.1	96.8
5077	Rock Island	IL	2425	0.1	96.9
5110	Wurtsmith Air Force Base	MI	2402	0.1	97.0
5049	New Castle	DE	2381	0.1	97.0
5076	Glenview	IL	2344	0.1	97.1
5174	Davisville	RI	2322	0.1	97.1
5159	Vienna	OH	2255	0.1	97.2
5033	Limoore	CA	2228	0.1	97.2
5025	Van Nuys	CA	2213	0.1	97.3
5182	Arnold Air Force Station	TN	2200	0.1	97.4
5173	North Kingstown	RI	2181	0.1	97.4
5184	Millington	TN	2162	0.1	97.5

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5198	Dallas	TX	2146	0.1	97.5
5190	Ellington Air Force Base	TX	2117	0.1	97.6
5042	U.S. Air Force Academy	CO	2101	0.1	97.6
5193	Sheppard Air Force Base	TX	2089	0.1	97.7
5059	Dobbins Air Force Base	GA	2072	0.1	97.7
5227	Cheyenne	WY	2060	0.1	97.8
5018	Ontario	CA	2026	0.1	97.8
5082	Fort Benjamin Harrison	IN	2016	0.1	97.9
4409	Camp Mabry	TX	2000	0.0	97.9
5138	Lakehurst	NJ	1977	0.0	98.0
5108	Brunswick	ME	1931	0.0	98.0
5030	Lathrop	CA	1925	0.0	98.1
5128	Southport	NC	1924	0.0	98.1
5100	South Weymouth	MA	1870	0.0	98.2
5223	Clarksburg	WV	1854	0.0	98.2
5171	New Cumberland	PA	1848	0.0	98.3
5169	Chambersburg	PA	1790	0.0	98.3
5074	Chicago	IL	1786	0.0	98.4
5186	Columbia	TN	1765	0.0	98.4
5214	Winooski	VT	1743	0.0	98.4
5135	Manchester	NH	1702	0.0	98.5
5105	Fort Meade	MD	1697	0.0	98.5
5012	Tucson	AZ	1690	0.0	98.6
5165	Middletown	PA	1680	0.0	98.6
5036	Los Alamitos	CA	1671	0.0	98.6
5212	Bowling Green	VA	1648	0.0	98.7
5185	Kingsport	TN	1640	0.0	98.7
5093	Lake Charles	LA	1632	0.0	98.8
5083	Edinburg	IN	1617	0.0	98.8

TABLE 1 (Continued)

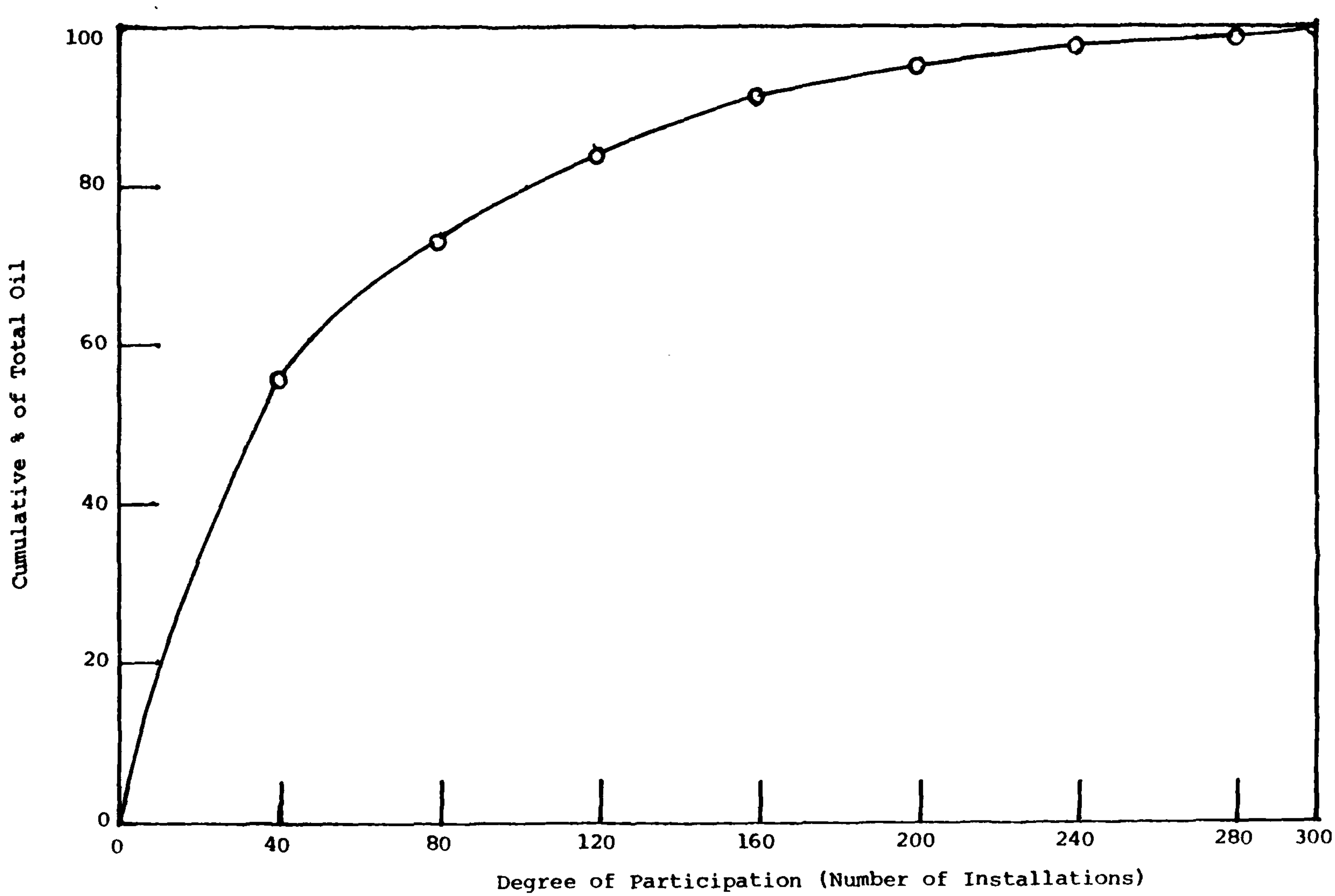
BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5096	Monroe	LA	1598	0.0	98.9
5126	Charlotte	NC	1571	0.0	98.9
5088	Fort Leavenworth	KS	1485	0.0	98.9
5150	Suffolk County ANG Base	NY	1472	0.0	99.0
5002	Birmingham Muni Airport	AL	1408	0.0	99.0
5064	Savannah	GA	1394	0.0	99.0
5149	Schenectady	NY	1394	0.0	99.1
5170	Reading	PA	1381	0.0	99.1
5026	Fresno	CA	1366	0.0	99.1
5156	Springfield Muni Airport	OH	1354	0.0	99.2
5209	Fort Story	VA	1353	0.0	99.2
5154	Brooklyn	NY	1329	0.0	99.2
5219	Milwaukee	WI	1320	0.0	99.3
5056	Orlando	FL	1291	0.0	99.3
5145	Carson City	NY	1273	0.0	99.3
5224	Valley Grove	WV	1246	0.0	99.4
5225	Parkersburg	WV	1221	0.0	99.4
5102	Annapolis	MD	1218	0.0	99.4
5048	District of Columbia	DC	1210	0.0	99.5
5043	Commerce City	CO	1200	0.0	99.5
5137	Atlantic City	NJ	1168	0.0	99.5
5215	Jericho	VT	1167	0.0	99.5
5191	Kingsville	TX	1165	0.0	99.6
5067	Sergeant Bluff	IA	1162	0.0	99.6
5222	Charleston	WV	1158	0.0	99.6
5045	Groton	CT	1147	0.0	99.7
5166	Franklin	PA	1133	0.0	99.7
5069	Mason City	IA	1100	0.0	99.7
5122	Great Falls	MT	1089	0.0	99.7

TABLE 1 (Continued)

BASE ID NUMBER	BASE NAME	ST	AMOUNT (gallons)	PERCENT OF TOTAL Gallons	CUM PERCENT
5015	Bellmont	AZ	1086	0.0	99.8
5204	Sanston	VA	1067	0.0	99.8
5167	Oakdale	PA	1063	0.0	99.8
5107	Bangor	ME	1056	0.0	99.8
5007	Fort Chaffee	AR	1047	0.0	99.9
5158	Swanton	OH	1045	0.0	99.9
5116	Bridgeton	MO	1030	0.0	99.9
5152	Newburgh	NY	1013	0.0	100.0
5160	Oklahoma City	OK	1006	0.0	100.0
5113	Duluth	MN	1003	0.0	100.0

FIGURE 2.

CUMULATIVE OIL USAGE BY INSTALLATION



both specifications were developed to include both gasoline and diesel service, the administrative service specification has stronger requirements for gasoline engines whereas the tactical specification has stronger requirements for diesel engines. Each specification contains a listing of the different viscosity grades and packaging requirements for military service.

Used oil is generated at Army installations during the servicing and overhauling of tactical, support and administrative vehicles. It is assumed that most of the used oil is generated in the maintenance of tactical vehicles, namely, during the regular changing of oil in crankcases and gearcases, which is done once or twice a year. The changes are done at Organization Maintenance Shops (OMS), which are generally at the batallion level. Used oil is also generated at the Combined Support Maintenance Shops (CSMS) during engine teardown and overhaul. The used oil is collected in drip pans, and in some instances is drained directly to tanks or else carried to storage in either tanks or drums.

As noted earlier, the regular servicing of vehicles is generally performed at the battalion level at the OMS's whereas major overhauls are performed at CSMS's. Depending on the amount of used oil, the storage can be done in either 55 gallon drums or underground storage tanks. Segregation of used lubricating oils from fluids such as transmission oils and solvents is often limited with all used fluids being collected in the same holding tanks.

The efficiency of recovery of used oil has been estimated by both government and private sources as approximately 50 to 60 percent of lubricating oil sales (References 3, 4, 5, 6). Engine combustion, leakage, and handling losses account for the 40 to 50 percent loss. A recovery factor of 50 percent is generally suggested in the literature. The potential for higher recovery exists, but the cost of higher recovery increases significantly in terms of effort and time.

DISPOSAL PRACTICES

As previously mentioned, current DoD policy calls for used lubricating oil to be sold for re-refining unless a reasonable arrangement cannot be made, in which case the used oil is to be used as a fuel supplement. However, this policy is not always implemented; according to the GAO study, the DoD does not monitor used oil collection or disposal practices to identify inefficient or incorrect practices (Reference 1). At the current time two basic routes exist for used oil disposal, on-site and off-site. Offsite disposal, as shown in Figure 1, is administered through the Defense Property Disposal Service (DPDS). DoD installations either collect used oil centrally and report it to the local Defense Property Disposal Office (DPDO) or, in the case of small volume generators, transport the oil to a DPDO yard. DPDS sells the used oil competitively to the highest bidder; in many instances, the highest bidder may not be a re-refiner. To rectify this situation, the DPDS now requires bidders to provide an end-use certificate with each bid, in order to determine if the oil will be re-refined. Analysis of the certificates for the period May 1982 through April 1983 indicates that approximately 84 percent of the total volume of 2.8 million gallons collected for offsite disposal was purchased for re-refining, while

13 percent was sold as a fuel supplement, and 3 percent was purchased for other miscellaneous uses. The DPDS currently returns 80 percent of the proceeds to the generating installation for use in their recycling and environmental program; however, under the 1982 Military Construction Codification Act, the percentage will increase to 100 percent (Reference 7, 8). The DPDS also disposes of waste oils contaminated with toxic substances, that are unsuitable for sale, through commercial hazardous waste disposal services (Reference 9).

A breakdown on a regional basis of the volume of used oil sold by DPDS during 1982 was obtained for study purposes. The onsite disposal of used oil is administered by each installation and does not pass through the DPDS. Used oil disposed on-site is usually consumed as a fuel supplement, but may also be disposed by inter-service transfer or in such activities as fire training, construction, and field exercises (simulated explosions).

Current Army policy dictates that used oil should be mixed with fuel oil in a proportion of one part (or less) of used oil to five parts of new oil. Nonetheless, many installations have modified their equipment to burn used oil without dilution. The consumption of used oil as a fuel or fuel supplement has been estimated to save as much as $1.00/gallon in fuel costs. However, this cost estimate does not take into account the cost of collecting, pretreating and storing the oil. The actual cost savings are also dependent upon the degree of contamination of the oil, particularly with respect to solid and water content. The actual savings for Fort Benning have been estimated to be approximately 40 cents per gallon exclusive of the cost of collection (Reference 10).

CHAPTER 3

COLLECTION/CONTAMINATION

COLLECTION PRACTICES

Used crankcase oil is collected from vehicles during routine maintenance oil changes and during the overhaul of vehicle engines. Routine maintenance, the major source of used oil, is performed at a unit level, where the objective is to return the equipment to service as soon as possible. Moreover, routine maintenance must often be performed under adverse weather conditions. As a result a strong potential exists for contamination of the oil during the collection process.

Because of the high potential for contamination during collection, maintenance facilities at three locations were visited to better define existing collection and storage practices. Additionally, individuals experienced in used oil collection and storage practices were interviewed. The locations visited were Fort Bragg, the District of Columbia Army National Guard Combined Support Maintenance Shop and Organizational Maintenance Shops at Bolling Air Force Base, and the Maryland Army National Guard Combined Support Maintenance Shop at Havre de Grace, Maryland.

Oil Collection

Used oil is generally collected from vehicles in drip pans which are then hand-carried to the used oil storage area. Being readily available, these pans are also used to collect other vehicle fluids such as hydraulics, radiator coolants, transmission fluids and solvents. While general policy is to segregate the used oil from these other fluids, it appears that at unit level the desire to "get the job done" and minimize fluid spillage results in these fluids being mixed with the used oil. It was also pointed out that in winter conditions, heavy clothing makes careful collection and segregation difficult.

The used oil collection pans also make a ready container for trash or accidental spills, including dirt and grit. This problem appears to be especially significant at Fort Bragg where the drip pans are directly connected to the used oil storage tanks.

Oil Storage

Oil storage facilities at the unit level vary from old drums to underground tanks, with drums being used at smaller units where only a limited amount of used oil is collected and tanks at larger units. The storage areas often provide a ready disposal point for all wastes generated during maintenance activities. This situation is further compounded by the perception that the tanks are outside the responsibility of the waste oil generating unit, thus limiting concern for what is dumped into the tank.

The used oil is often collected for disposal by a contractor who removes the used oil directly from the unit oil storage tank. Because collection is directed from the installation level, there is little awareness of the process at the unit level. As a result the collected used oil varies from carefully segregated to heavily contaminated "slop" that must be disposed as a hazardous waste.

CONTAMINATION

Oil contamination occurs during usage and handling and may be both physical and chemical in nature. Lubricating oils degrade during use due to additive depletion, thermal stresses, and contamination. The chemical processes of oxidation, corrosion, hydrolysis, and polymerization contribute to degradation and contamination. The most common contaminants are moisture, dirt, solubilized metal, and other engine liquids. The extent of degradation and contamination is used to classify the oil. Waste oils are defined by the American Society of Testing and Materials (ASTM) as "oils whose characteristics have changed markedly since being originally manufactured, are not suitable for further use, and are not considered economically recyclable." Used oil is defined as "oil whose characteristics have changed since being originally manufactured, but that is still considered suitable for further use and economically recyclable" (Reference 11).

Contamination by handling occurs during maintenance, transfer, and storage operations. Contamination includes the mixing of used oil with other vehicle/industrial wastes such as solvents, hydraulic fluids, and synthetic oils. In addition the used oil may also be mixed with non-vehicular materials such as rainwater, trash, floor adsorbents, etc.

Table 2 is a summary of waste oil contaminant levels reported in the literature. High and low values are given for both military and non-military used oils. As shown in the table, both types of oil contain similar levels of contamination with two notable exceptions. The first, bottom sediment and water (BS&W), is slightly lower for the military oil. The second, total lead, is significantly lower (by a factor of 20) for military oil, most likely due to the use of diesel (unleaded) fuel.

CONCLUSIONS/RECOMMENDATIONS

Present oil collection practices do not assure a good quality used oil. Although the current policy is to segregate used oil by type, this policy is not always followed due to operational restraints (i.e., cold weather, proximity of disposal cans) and lack of enforcement. To maximize the value of used oil it is necessary to increase the level of segregation and minimize the degree of contamination during handling.

Several options are available to minimize contamination. The most obvious is enforcement of existing policy. During site visits and interviews with the DPDS, it was found that the quality of used oil was inconsistent, varying from carefully segregated to heavily contaminated. In most instances the quality can be related to the level of policy enforcement by the installation command structure. It is therefore essential to involve individuals such as the installation commander and

TABLE 2

SUMMARY OF WASTE OIL CONTAMINANT LEVELS

PARAMETER	CERL-ARMY WASTE OIL ANALYSIS RESULTS[1]		OTHER PUBLISHED WASTE OIL ANALYSIS RESULTS[2]	
	High	Low	High	Low
Specific Gravity	0.901	0.0890	0.965	0.887
Density (g/cc)	0.985	0.902	0.767	0.730
Viscosity (sus 100°F)	812	16	753	17
Flash Point (°C)	85	41	250	79
Gasoline Dilution (%)	---	---	7.2	0.8
Ash (%)	3.77	0.17	12.6	0.03
Pentane Insoluble (%)	---	---	3.33	1.18
Bottom Sediments & Water (%)	7.6	0.2	22	0.1
Specification Number	---	---	35.4	11.0
Sulfur (%)	0.83	0.31	0.65	0.21
Iron (ppm)	---	---	2,000	50
Lead (ppm)	480	10	11,200	800

[1] Reuse of Waste Oil at Army Installations (30)

[2] Reprocessing and Disposal of Waste Petroleum Oils; Utilization of Used Oils (12)

chief of maintenance in collection activities. It is also necessary to assign responsibility for collection practices at a level sufficiently high to ensure enforcement.

The use of incentives on both the installation and activity level is recommended. An incentive program is most likely to succeed if the personnel involved in vehicle maintenance are included in the reward.

Another alternative for increasing the quality of used oil collected is to educate all personnel involved in vehicle maintenance. This approach has been used successfully by the State of North Carolina in its recycling program.

Depending upon the installation, the segregation of used oil may be improved by the addition and optimum location of more storage drums and tanks. At least one container should be provided for each type of oil collected. It may also be cost effective to decentralize the location of collection containers. Whenever possible they should be adjacent to work areas.

A final recommendation made by the DPDS is that prior to collection, free water should be decanted from oil storage tanks and transferred to the installation wastewater treatment system (Reference 9). In this manner the overall system transportation cost will be reduced.

CHAPTER 4

RE-REFINING TECHNOLOGY

Used lubricating oils contain chemical and physical contaminants that are not present in crude oils. These contaminants, which include dirt, decomposed additives and dissolved metals from engine wear, make it technically and economically infeasible to re-refine used oils by virgin oil refining processes. For example, thermally unstable contaminants degrade during processing, resulting in coking and the fouling of heat exchangers and distillation columns. In addition the metal contaminants in used oil will poison the catalysts used for hydrotreating. Typical refinery operations used to purify virgin oils, such as dewaxing and deasphalting, are insufficient to purify used oils. These technical considerations, combined with the previously low cost of virgin feedstock and the relatively small size of the re-refined oil market, account for the traditional lack of interest among the major refiners in investing in the necessary modifications for re-refining.

The technical problems posed by the contaminants in used oils have led to the development of specialized technology for re-refining. Initially, reprocessing of used oil consisted primarily of the removal of insoluble contaminants by heating and settling techniques. In due time process variations such as centrifugation were developed. These early treatments cannot be classified as re-refining but rather as cleaning or reclamation techniques. As lubricating oil formulations became more sophisticated, treatments such as chemical coagulation, acid/caustic washes and clay contacting were developed. By 1960 the acid/clay process had become the industry standard.

During the next two decades, two developments impacted heavily on re-refining technology. The first was the development of high performance engines which required highly complex lubricating oils. Additives required for the new formulations were difficult to remove by conventional re-refining techniques, thus requiring higher concentrations of chemicals and more extreme operating conditions. At approximately the same time, stringent environmental regulations were developed, escalating the cost of regulatory compliance. These two developments combined to make the cost and efficacy of the traditional acid/clay process unattractive though modifications of this process are in use today.

Several re-refining technologies have been developed to replace the acid/clay process. Each technology has patented variations, many of which are commercially available for licensing. The more important of these include: vacuum distillation, solvent extraction, and chelation-filtration. Each technology consists of a pretreatment, treatment, and finishing process. One or more of the following processes are common to the majority of technologies: settling, distillation, solvent extraction, hydrotreating, filtration, and clay contacting. Each technology will be briefly described in this section and characterized in terms of yield, sensitivity, past experience, quality, environmental impact and cost. Patented processes representative of each technology will be listed.

CURRENT TECHNOLOGY

Acid/Clay

The acid/clay process, once the predominant re-refining technology in this country, is still in limited use. A flow scheme for a typical acid/clay process is shown in Figure 3. After screening and settling to remove free water, the used oil is pumped to a flash dehydrator at 300°F to remove bound water and low boiling organics (light ends). The overhead mixture is condensed and separated, the light ends going to storage while the water is sent to the wastewater disposal system.

Dehydrated oil is cooled and transferred to an acid treatment reactor maintained at 100°F. Approximately 4 to 6 percent by volume of 92 percent sulfuric acid is added. During the 24 to 48 hour detention time the acid preferentially attacks the contaminants (oxygen compounds, soluble metals, asphaltic substances, and other sulfur-based compounds) forming insoluble precipitates while leaving the paraffinic and naphthenic hydrocarbons intact. After the sludge containing most of the contaminants is settled, the excess acid is drawn from the reactor bottoms. Finishing consists of steam stripping and clay contacting. The acid-treated oil is heated to 500-600°F and pumped to an atmospheric tower where steam is used to strip any remaining light ends and mercaptans (odorous) compounds. After cooling to 400°F, a mixture of activated clay and diatomaceous earth is added to the oil, and the clay-oil mixture is filtered. The final oil product is a neutral base stock to which additives are blended to meet specific customer requirements.

Typical acid/clay process yields vary from 45 to 75 percent, depending upon operating conditions and the feed composition (Reference 12). Yield figures are normally based upon a dry weight oil basis (i.e., do not include water).

The presence of small amounts of hydraulic fluid, synthetic oil or anti-freeze does not affect the process other than by decreasing the yield of base lubricating oil. Higher levels of contamination will increase processing costs because additional materials (acid and clay) and longer detention times may be required. Toxics such as PCB's are not acceptable in feedstocks to this or any technology, due to the likelihood of product and equipment contamination.

The major disadvantage of the acid/clay process is the large volume of acid sludge generated by the process. Since the sludge contains high concentrations of soluble metals, sulfuric acid, sulfonates and other possible carcinogenic materials, its final disposal is costly. The spent clay itself is high in oil content but reportedly does not present a disposal problem. The large volumes of sludge generated and the high cost of hazardous waste disposal have made this process unattractive.

Filtration

Phillips Petroleum Company has developed a two-stage continuous re-refining process called the Philips Re-Refined Oil Process (PROP). The process, shown schematically in Figure 4, consists of chemical demetallization followed by hydrotreating (Reference 13). Used oil is

FIGURE 3. FLOW CHART FOR ACID-CLAY RE-REFINING PROCESS

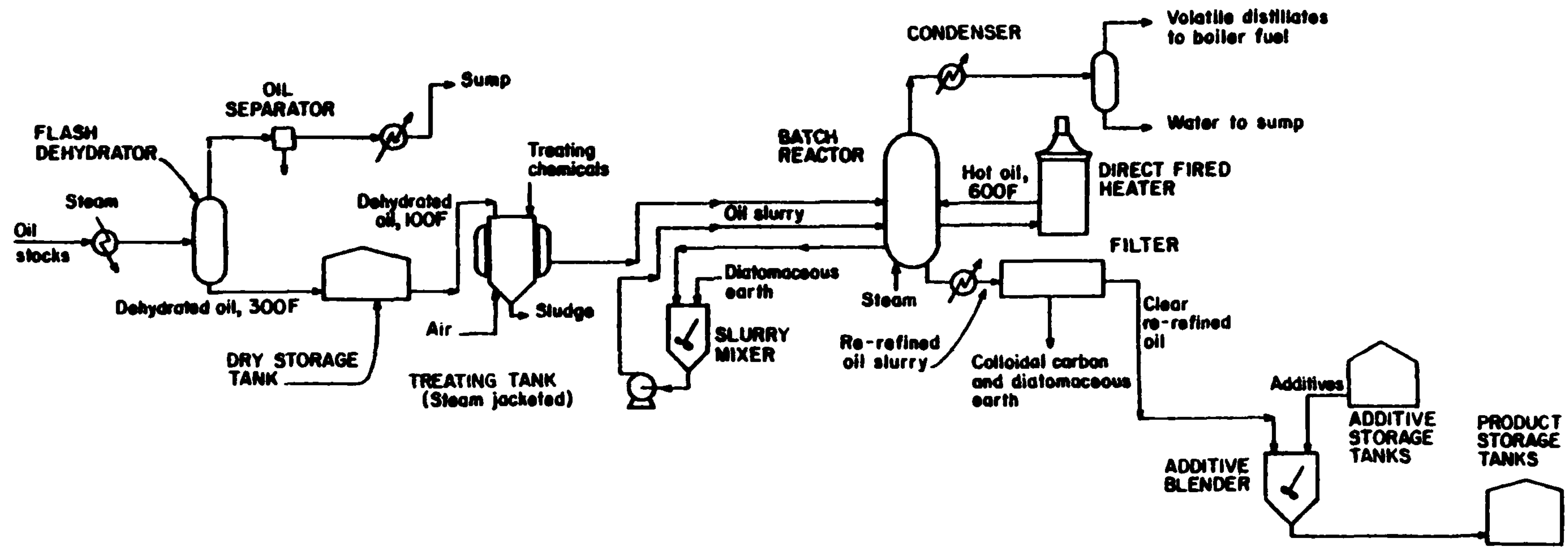
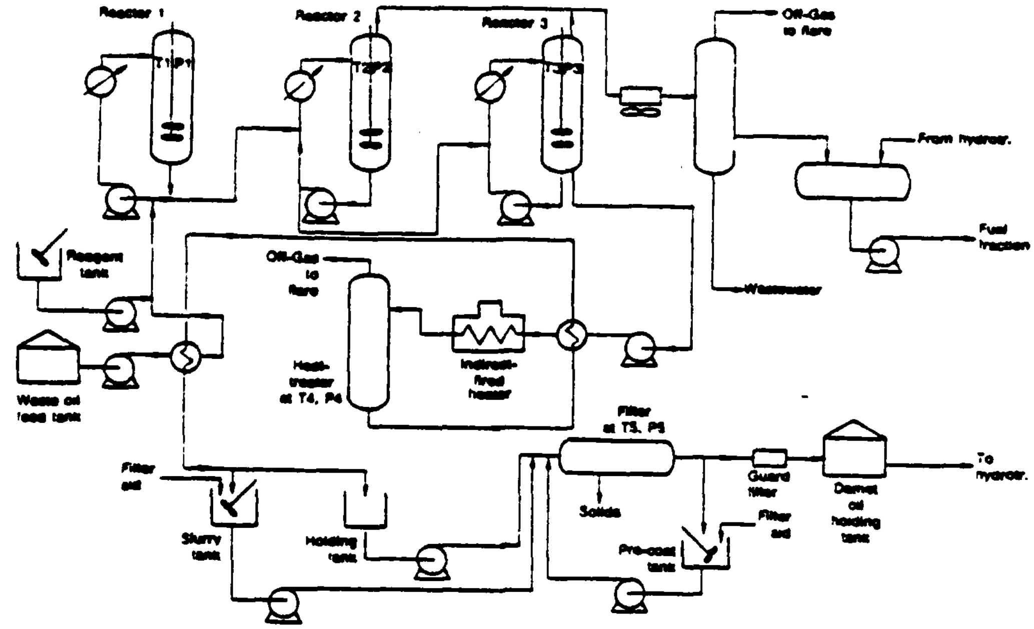
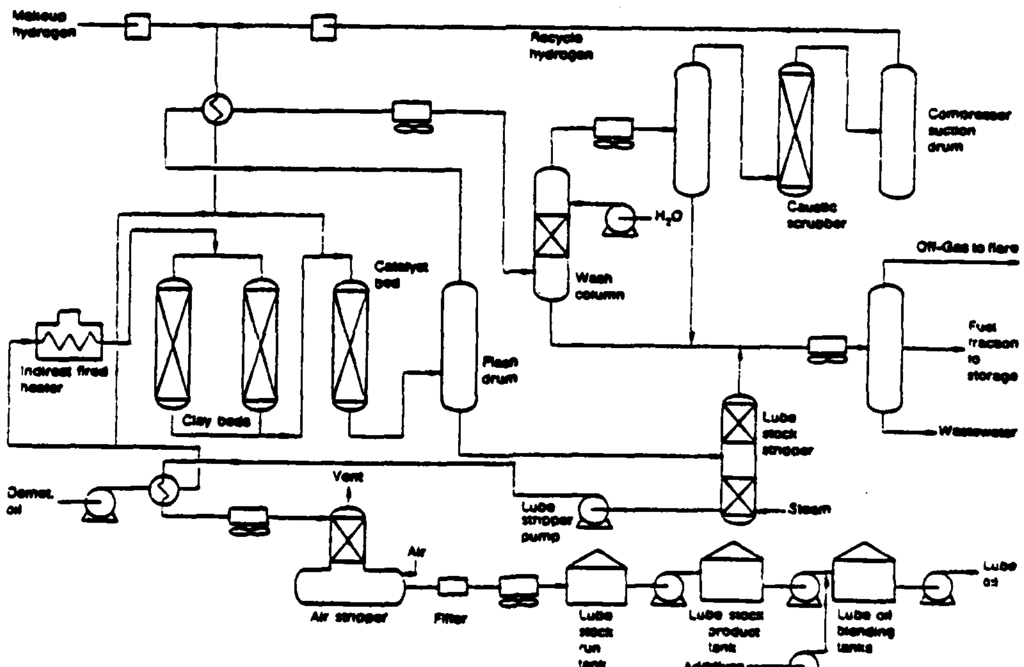


FIGURE 4. PROP PROCESS FLOW SCHEMATIC



Demetallizing section in the PROP process.



Hydrotreating section in the PROP process.

first mixed with an aqueous solution of diammonium phosphate (DAP). A 10-percent volume of water is required while the dosage of DAP is determined by the metallic content of the oil. The oil mixture is then passed through three consecutive stirred reactors operated at 210°F, 250°F and $\geq$ 300°F, respectively. The progressive increases in temperature are staged to promote the reaction of metals with DAP to form insoluble metallic phosphates and to enhance the removal of water and low boiling point organics (light ends).

The oil stream is next heat-treated to thermally degrade zinc dithiophosphate (an anti-oxidant additive in oil that is not precipitated by DAP). Filter aid (diatomaceous earth) is added and the resulting mixture passed through a vertical leaf filter. The demetallized oil is mixed with hydrogen, heated to 700°F and percolated through a guard bed of clay and activated carbon. The hot oil is then passed through a nickel-molybdate catalyst for hydrotreating. The guard bed removes inorganics and color bodies while the hydrotreating removes sulfur, nitrogen, oxygen and chloro compounds.

A final stripping step may be added to remove the remaining fuel fraction, providing control of the flash point of the final product. Unreacted hydrogen gases are passed through water and caustic scrubbers, cooled and reused. Process wastewaters and spent caustic are treated on-site or discharged to the sewer, depending upon the size of the facility. Filter cake is non-hazardous and may be disposed at a sanitary landfill.

Phillips claims that the process recovers in excess of 90 percent of feedstock; however the actual yield to date in at least one facility has been significantly lower. The North Carolina Re-Refining Company, which operates a 2 mgy plant using this process, reports that the yield of lubricating oil is 65 percent of the feed to the hydrotreater (Reference 14). The overall yield may be lower; depending upon initial water and solids content it can vary from 50 to 60 percent. The major product of the PROP process is a 20-30W viscosity base oil. Recovered light ends may be sold or used onsite for fuel.

Trace amounts of contaminants, such as hydraulic fluids and synthetic oils, do not adversely affect the process. However high phosphorus levels or silicon-based hydraulic fluids will poison the nickel-molybdate catalyst. Water in excess of the 10-percent volume required for the reactions will increase the process energy requirements, because it must be evaporated. In addition the presence of glycol (antifreeze) will cause the oil to congeal.

To date three full-scale PROP facilities have been constructed (one in North Carolina and two in Canada), and two more are being planned. All have experienced operating problems and the North Carolina facility is still operating on a financial loss basis (Reference 14). However, this plant was the prototype and the major problem has been the acquisition of oil, not technical operation.

Vacuum Distillation

The majority of current re-refining processes are based upon vacuum distillation. Major variations exist in equipment selection and the finishing and/or pretreatment processes. The use of vacuum distillation for re-refining was previously limited by coking and tar fouling problems within the distillation equipment. The optimization of pretreatment techniques have minimized the problem and allowed this technology to dominate the commercial market.

The major advantages of vacuum distillation are that no hazardous wastes are generated and several product cuts may be taken from the column, allowing a greater product selectivity (increasing cost effectiveness by tailoring the process to meet market demand). In addition most processes have high yields, varying typically from 75 to 82 percent on a dry oil feed basis.

Figure 5 shows a simplified representative vacuum distillation Flow diagram. Free water is removed from the used oil by several processes including chemical addition and settling. The used oil is dehydrated by atmospheric distillation (flash evaporation) at 300°F. Light ends are then removed in a flash tank under vacuum, at temperatures near 500°F. The overhead stream is condensed and collected, for use either as fuel or as a salable product.

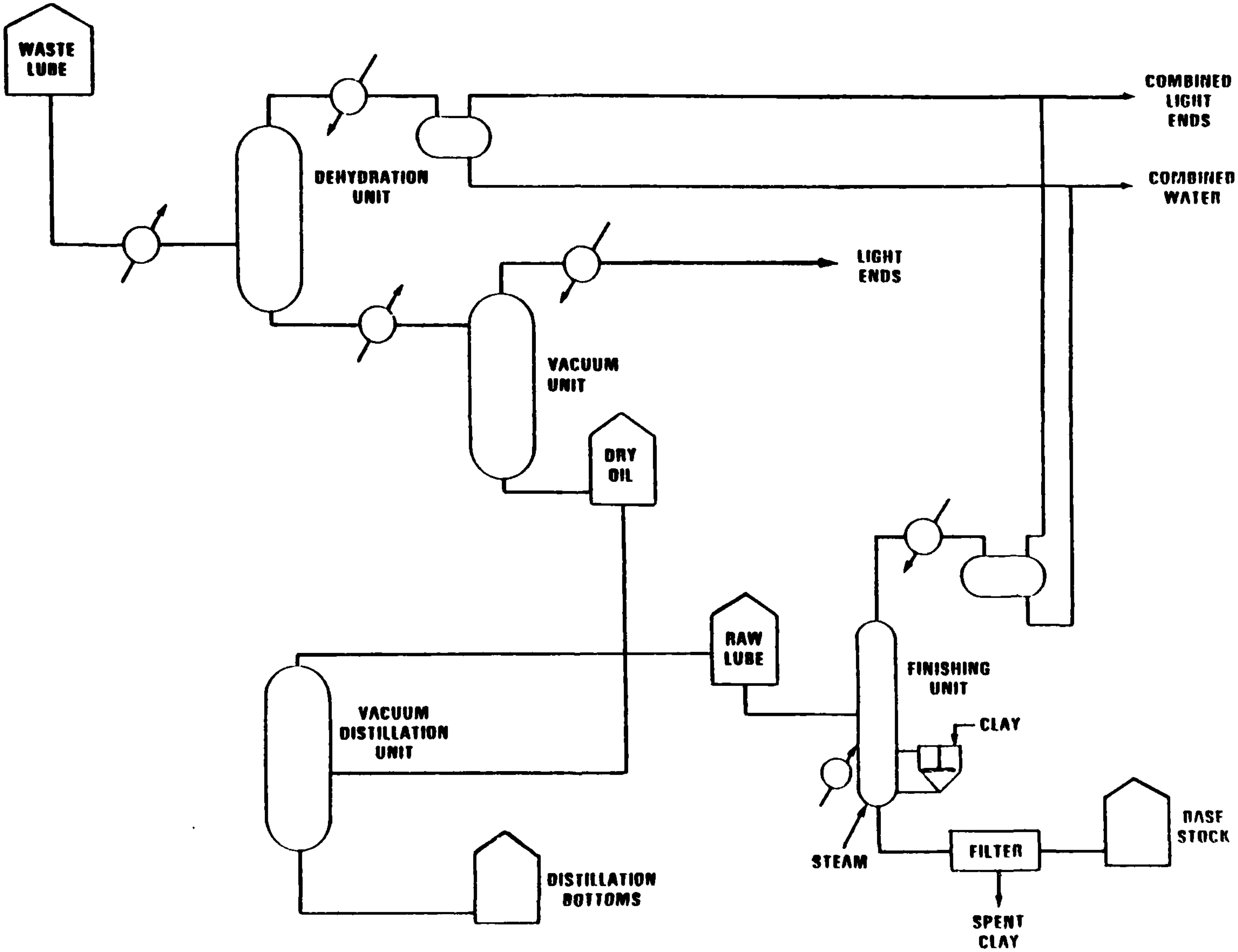
The dehydrated and stripped oil is heated and pumped to vacuum distillation, during which several product cuts are collected. Operating conditions may be varied to increase the yield of preferred products. Distillation bottoms are normally used as asphalt extenders, or blended into heavy fuel for industrial plants.

Currently available processes utilize solvent pretreatment or sophisticated equipment to minimize fouling problems; examples are the thin film (LUWA) and wiped film (Pfaudler) evaporators. Other refinements, including partial or selective condensation, multi-stage distillation and automated operation, have been developed and patented.

Finishing is normally accomplished by either hydrotreating or clay contacting. Hydrotreating is performed in essentially the same manner as described in the PROP process. Clay contacting (shown in Figure 5) is similar to that described in the acid/clay processes, the exception being that steam stripping may not always be required. Although the cost (capital and operating) and complexity of operation is slightly higher for hydrotreating than clay contacting, the need for disposal of spent clay (non-hazardous) is eliminated (Reference 15). In addition the yield of finished product is slightly higher for hydrotreating as oil is not lost through adsorption on the clay. In general the choice of finishing processes is based upon the size of the operation, availability of hydrogen (a byproduct of many chemical processing operations) and the sophistication of the plant and operating personnel.

Vacuum distillation is not sensitive to the concentrations of hydraulic fluids, synthetic oils, and other contaminants normally found in used oils. Water, as in all re-refining processes, must be removed

FIGURE 5. VACUUM DISTILLATION FLOW SCHEMATIC



and will increase processing costs. Chlorinated solvents and certain salts may cause corrosion and/or safety problems in high concentrations. Toxics such as polychlorinated biphenyls (PCB's) cannot be allowed in the feedstock (of any re-refining process) due to the likelihood of contamination of the final product and processing equipment.

At present most large re-refiners have patented their own vacuum distillation processes. In most instances these processes utilize LUWA or Pfaulder evaporators with variations in pretreatment (dehydration) and the sequences of operations. Commercially available distillation processes include those marketed by Kinetics Technology International (KTI) and Resource Technology, Inc. (RTI). Recyclon, a process offered by Leybold Heraeus, utilizes sodium to precipitate soluble contaminants. Two similar processes, the Snamprogetti (Italy) and Propane-Vacuum-Hydrogen (PVH) processes, utilize propane extraction prior to vacuum distillation to minimize column coking and fouling. To date, of the above processes only the RTI technology has been used in this country in a full-scale re-refinery.

Solvent Extraction

Numerous solvent extraction systems have been proposed for re-refining. To date only the Selectopropane process developed by the French Petroleum Institute (IFP) has been placed in production (Reference 12). This process, illustrated in Figure 6, uses propane to selectively extract the base lube stock from the additives and contaminants. The propane containing the oil is removed from the reactor overhead while the additives and contaminants are removed from the bottoms as a residue. The bottoms may be blended for use as a plant fuel or asphalt extender. The propane is recovered by vaporization at reduced pressure, and reused in the process after compression and liquefaction. Finishing consists of acid treatment and clay contacting. Although the amount of acid and clay required for finishing is much smaller than for the traditional acid/clay process, a final disposal problem still exists.

NEW TECHNOLOGY

BERC Process

The Bartlesville Energy Research Center (BERC) of the Department of Energy has developed a solvent extraction-vacuum distillation process. Although this type of process is not new, the choice of solvent, a mixture of isopropyl alcohol, methyl ethyl ketone and butyl alcohol, differs from previous approaches (Reference 16). As shown in Figure 7, the solvent is added after dehydration; the solvent-oil mixture is allowed to settle and then separated and passed through a stripper for solvent recovery. The oil is vacuum-distilled and finished by either clay contacting or hydrotreating. This process is still in the pilot stage and not yet commercially available.

Membrane Processes

The use of ultrafiltration to recover spent industrial oils is an established practice. The French Petroleum Institute (IFP) has proposed a dehydration-ultrafiltration-acid/clay process for re-refining oils

FIGURE 6. SCHEMATIC FOR THE PROPANE SOLVENT EXTRACTION PROCESS

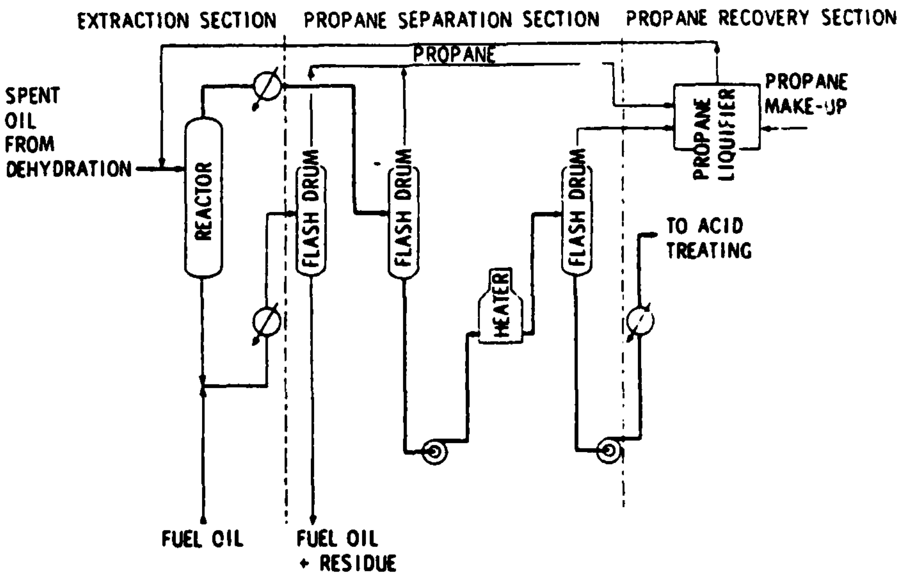
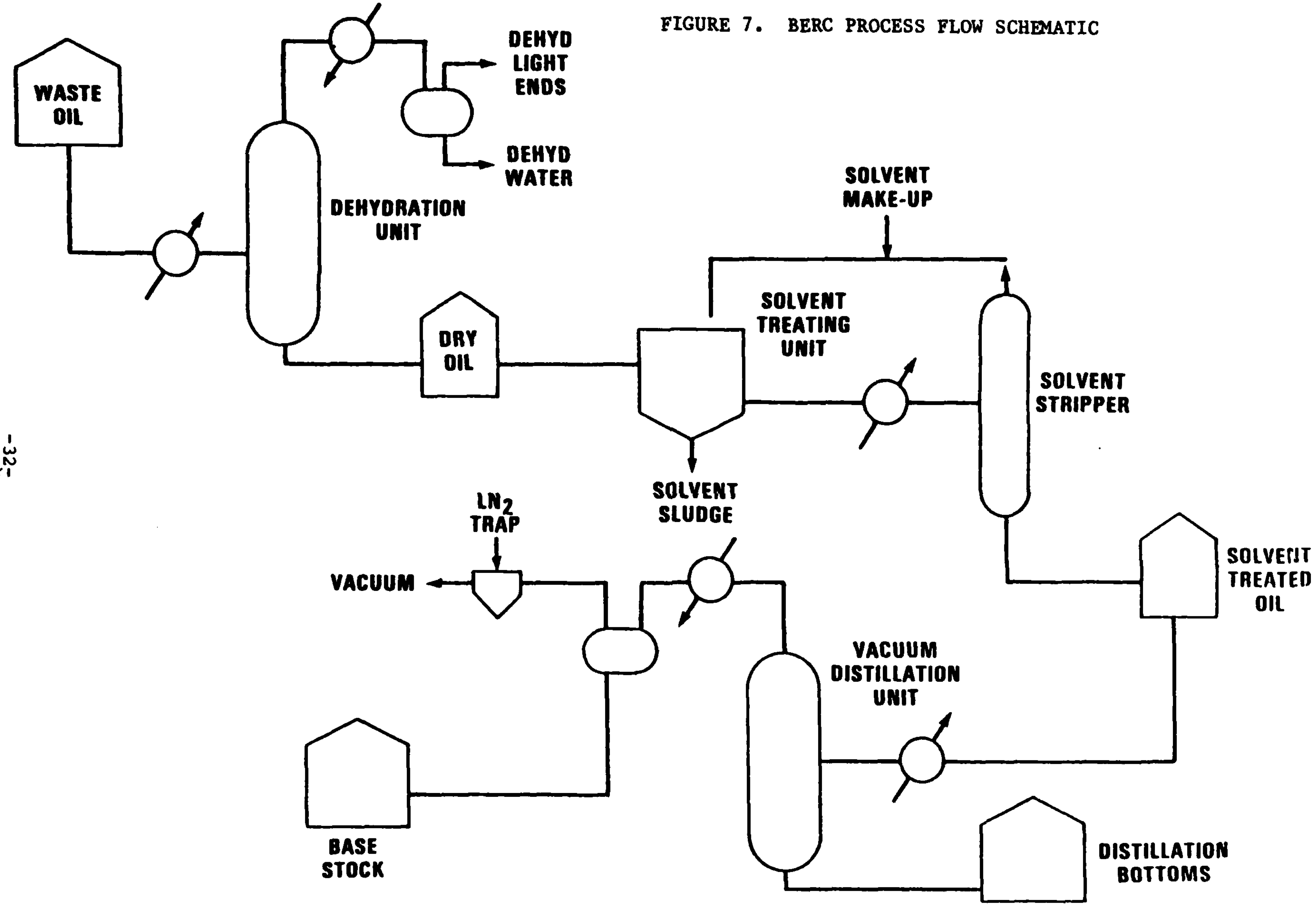


FIGURE 7. BERC PROCESS FLOW SCHEMATIC



(Reference 17). In this technology insoluble and low molecular weight materials will be passed through the membrane, while solid and high molecular materials are retained. Suggested variations in the process train include hydrotreating and polymeric adsorption.

The Michel and Pelton Company has recently proposed a combined hydrophilic-hydrophobic sub-micron filtration system for reclaiming used oils and solvents (Reference 18). They have proposed that their system be applied at the motor pool level for on-site oil reclamation; to date technical data on system performance are lacking.

Supercritical Fluid Extraction

Supercritical fluid extraction, a process which utilizes the high solubility of many low-volatile substances in supercritical fluids such as carbon dioxide, has been proposed for the reclamation of used oil. This process has been demonstrated successfully for the deasphalting of crude petroleum and as well as for other commercial applications such as caffeine extraction from coffee beans. In tests conducted at the Krupp Research Institute in Essen, West Germany, directly usable base oil, spindle oil, and gas oil (light ends) have been recovered from used oil by this process; yields were 51.0, 30.6, and 8.2 percent respectively (Reference 19). The Krupp Research Institute claims that the process is economically competitive and holds promise for future development.

COMPARISON OF VIRGIN AND RE-REFINED OILS

Since 1976 the National Bureau of Standards (NBS) has had a legislatively mandated program to develop test procedures for the determination of the equivalency of re-refined oil with new oil (Reference 20). The NBS research includes the identification of problem areas in the characterization of used oils, development of new measurement methods, and the development and evaluation of test procedures and standards for recycled oil products. The NBS program has been augmented by studies performed by the United States Army Fuels and Lubricants Research Laboratory and the United States Department of Energy.

Physical and Chemical Properties

Research has shown that measurable physical and chemical differences exist between virgin and re-refined lubricating oils. These differences include characteristics such as oxyacids, viscosity index improvers, chlorine, and additive/wear metals as well as such indicators as total acid number and saponification number (Reference 21). However, the effect of these parameters on engine performance is not well understood and has not been determined to date (Reference 21).

Re-refiners have claimed that their oil is of higher quality than virgin lubricating oil, because oxidizable and low boiling materials which form precursors for sludge formation are removed during each use cycle. While the NBS admits that re-refined oil has the potential of being superior to virgin oil, no technical background currently exists to support this conclusion (Reference 22).

Performance

Research performed by the NBS and the DOE has shown that although differences exist between virgin and re-refined oil, no differences have been identified in terms of performance. Individual fleet and engine sequencing tests have shown some re-refined oils to be superior to virgin oils; similar tests have also shown the opposite. In addition, analysis of virgin products has shown that many fail to meet their specifications. For example, tests on SF and SE virgin stocks have shown that from 10 to 20 percent of the samples are significantly different than the implied classification (Reference 22).

According to the NBS generalizations cannot be made about the comparison of virgin and re-refined oil. In most instances the comparison is dependent both upon the additive package and the nature of the base stock. Identical packages may perform differently during service due to differences in base stock properties. For this reason the final re-refined product must be individually and directly compared to the final virgin product.

Sensitivity to Mixed Basestock

A study performed by the Bartlesville Energy Research Center concluded that the feedstock shipped to re-refiners is very uniform in petroleum basestock composition for the normal combination of collected crankcase drainings, regardless of season or geographic location within the United States (Reference 23). This conclusion was based upon an analysis of 30 used motor oil composite samples collected from 20 states. With few exceptions samples contained similar levels of water, fuel dilutant, sediment, metals, antifreeze and other contaminants. These samples did not include industrial oils which are reportedly separated from used crankcase oil by the generator to maximize price.

Process Energy Requirements

Energy requirements for the processing of both virgin and used oil consist of steam, heat and electricty. The requirements for each type of processing were converted into fuel consumption values by estimating the efficiency of each processing operation (electric and steam generation, etc.) during a study performed for the United States Department of Energy (Reference 5). Process energy requirements for several re-refining processes and a typical virgin refining process (propane deasphalting - solvent extraction - solvent dewaxing - hydrotreating) are summarized in Table 3. As shown, the processing of virgin oil resulted in greater energy consumption than did the re-refining of used oil. Distillation-hydrotreating, the dominant re-refining technology, consumed only a fourth of the energy required for virgin oil refining.

QUALITY ASSURANCE

As previously mentioned, MERADCOM is responsible for vehicular oil specifications. The current specifications (MIL-L-46152B and MIL-L-2104D) define all the physical, chemical and performance testing requirements needed for final product certification. Qualification is for

TABLE 3

SUMMARY OF PROCESS ENERGY REQUIREMENTS
(REFERENCE 5)

PROCESS	Process[a] Yield, %	PROCESS ENERGY 10^6 Btu per Barrel Used Oil Feedstock[b]	PROCESS ENERGY 10^6 Btu per Barrel Fractionated Product[c]
Acid-Clay	65	0.32	0.49
Clay	60	0.30	0.50
Caustic-Clay	62[d]	0.45	0.57
Propane Solvent	70	0.95	1.35
Extraction [e]	82	0.99	1.21
Distillation-Hydrotreating	76	0.41	0.54
BERC Solvent Extraction	71	0.97	1.37
Pretreatment (3:1 Solvent to Oil Ratio)	79	0.79	1.00
Pretreatment (1:1 Solvent to Oil Ratio)	84	0.33	0.39
Pretreatment (Dehydration-Filtration)	87	0.10	0.12
Virgin Lube Oil			
Average	--	--	2.10
Minimum	--	--	1.70
Maximum	--	--	3.10

(a) Barrels of product per barrel of used oil feedstock.

(b) Standard feedstock containing 7 percent water and 4.2 percent light ends, which is typical of automotive crankcase drainings.

(c) Product is base oil, and contains no additives.

(d) Process also produces a 16 percent fuel fraction.

(e) Two different yields have been reported (see text).

a four-year period, at the end of which time a complete re-qualification may or may not be required. A portion of the specification also outlines the sampling and analytical requirement of a quality assurance program. References are made to ASTM testing procedures and other military specifications for packaging and sampling.

As part of the ongoing program previously mentioned, NBS is also developing test procedures for the characterization of used oil and evaluation of re-refined oil. NBS has recently proposed provisional monitoring procedures (physical-chemical) to assure re-refined oil quality between certifications (Reference 21). The provisional procedures are based upon the results of the certification tests and involve two levels of consistency testing. The qualified oil is first tested using primary consistency test procedures. If the oil fails the primary tests, secondary consistency test procedures are used. If the oil fails these tests, it is rejected and must be re-qualified. These and other characterization and evaluation procedures currently under development may be incorporated into the military specifications, in a determination to be made by MERADCOM at some future date.

SUMMARY

Technical problems presented with the contaminants found in used oil, the previously low crude oil prices and the relatively small market for re-refined oil products have traditionally kept the major crude refiners from entering the re-refining business. This in turn has led to the development of specialized re-refining technology. At this time the dominant re-refining technology is vacuum distillation, a technology that is insensitive to small volumes of contaminants such as water, hydraulic fluids and synthetic oils. The presence of toxic compounds such as PCB's does not present a technical problem, but must be avoided to prevent product, byproduct residue and equipment contamination.

Research conducted by the NBS and the Department of Energy has shown that although differences exist between virgin and re-refined lubricating oils, no differences can be identified between either in terms of performance. To date performance testing has indicated that final oil quality is more dependent on the additive package and its compatibility with the base oil than whether used or new oil is involved. The used oil feedstock being sent to re-refiners has been shown to be essentially similar regardless of geographic location or seasonal variations.

From an energy conservation viewpoint, the re-refining of used oil is less energy-intensive than is the refining of virgin oil. Vacuum distillation-hydrotreating, the predominant re-refining technology, was found to require approximately one-fourth the energy needed to refine virgin oil.

Military specifications used to certify re-refined and virgin oil for DoD applications also include requirements for a quality assurance program. Specific sampling and analytical procedures are referenced within the specification.

CHAPTER 5

THE RE-REFINING INDUSTRY

HISTORICAL PERSPECTIVE

The reclamation of used lubricating oils in the United States dates back to 1915. At that time only heating and settling were required treatments to return the oils to their original quality. During and after World War I the Armed Forces used this and other simple processes to recover aircraft engine lubrication oil. In 1932, American Airlines started a "closed loop" recycling system in which used aircraft lubrication oils were reprocessed and returned for company use. This program proved successful, resulting in a 20 percent savings in lubrication costs and provided a stimulus for the use of re-refined oils in other industries. By 1939 more than 11 mgy of used oil were being reprocessed (Reference 24).

During World War II the Army Air Corps developed a large scale "closed loop" recycling system for aircraft lubricating oils. Re-refined oil was used without restriction in the continental United States throughout the war without any recorded harmful effects on engine wear, life, or cleanliness (Reference 24). The use of re-refined oil continued after the war and by 1949 nearly one quarter of all Air Force engine oil was re-refined. However, the development of jet aircraft which required more complex synthetic lubricants eliminated this market for re-refined oils.

With the advent of the jet age, the emphasis on re-refining was switched to automotive lubricating oils. By 1960, approximately 300 mgy or 20 percent of the domestic market was composed of re-refined oils. At that time between 125 and 150 re-refiners were in operation and the prospects for continued growth appeared favorable. Today, however, the number of re-refiners in operation is less than 20 and their combined output has been estimated at only 100 mgy (Reference 25).

A number of factors contributed to the decline of the re-refining industry. The development of high performance automotive engines led to the formulation of more complex lubricating oils. The additives in these oils proved more difficult and costly to re-refine. At the same time overcapacity in the virgin oil market brought lubricating oil prices down. In addition, the collection of used oil became more costly partially due to competition from other uses such as road oiling and blending for fuel oil, and partially due to the decentralization of collection points as mass retailers replaced service stations as major oil distributors. Finally, a series of government regulations and policies severely affected the industry.

The advent of environmental laws, especially those regulating sludge disposal, drastically increased the cost of re-refining. In many instances the cost of investment for compliance with the regulations was beyond the resources of the firms. In addition, military specifications for lubricating oils evolved to an extent that prohibited the use of re-refined oils, thereby eliminating not only the military market but many state, local, and industrial markets which utilized the military specifications for procurement purposes. A Federal Excise Tax on virgin oil was also applied to re-refined oils in which virgin stock was used for blending; this also increased the final cost of the finished product. Finally, in 1964, the Federal Trade Commission, in an effort to protect the consumer, required that all re-refined oil products be labeled "made from previously used oil," which according to the re-refiners indicated an inferior quality product to the consumer, thereby reducing product marketability.

The result of all these factors was an increase in investment and processing costs and a decrease in market size. Many re-refiners were small, marginally profitable, family-run operations which could not afford the increased cost of doing business and were therefore eliminated.

CURRENT INDUSTRY BASE

Today the re-refining industry consists of approximately 5-6 major firms combined with a slightly larger number of smaller firms. In many instances re-refining is only a small portion of a larger business (i.e., collection, virgin product distribution, blending of fuel oils, etc.). The major problem of the industry appears to be collection of a sufficient quantity of good quality feedstock. In order to guarantee their feedstock supply, most re-refiners have developed their own collection networks. Depending upon the size of the re-refiner, these networks may consist of local truck collection routes or even nationwide rail collection systems.

Some re-refiners have entered into "closed loop" or custom re-refining contracts to ensure their feedstock supply. The purchasers of custom re-refining services include railroads, automobile manufacturers and commercial enterprises which maintain large transportation fleets. The type of operation varies from a true closed loop, in which oil is segregated during storage and processing, to a quasi-closed loop in which a selling price-credit arrangement is used rather than actual oil segregation. Most re-refiners require minimum volumes varying from 0.006 to 0.10 mgy for a true closed-loop type of service. One re-refiner deals exclusively in custom re-refining, while most re-refiners combine this service with their normal operations. Packaging and additive packages vary and are usually determined by the customer.

The majority of re-refiners in operation today have invested heavily in modern technology. The predominant technology with few exceptions is vacuum distillation; most re-refiners have either developed their own version of the process or have licensed one of several available patented processes. The major differences between these processes are either in the choice of distillation equipment or in the dehydration and finishing operations. A few re-refiners have managed to maintain older technologies (acid/clay) by finding environmentally acceptable sludge disposal methods.

INTERVIEW RESULTS

The majority of re-refiners identified through the Association of Petroleum Re-refiners (APR) were interviewed in person or by telephone. A series of questions were asked concerning collection, processing, economic regulation, certification and attitude to a DoD contracting opportunity. A list of contacted re-refiners, their location, and type/capacity of operation is shown in Table 4. With few exceptions, all re-refiners cooperated during the interview, although varying amounts of information were withheld due to the competitive nature of the industry. Results of the interviews are summarized issue by issue in this chapter.

A DoD Contract

Essentially all re-refiners would be willing to participate in a DoD re-refining contract, the single exception being a firm already processing at full capacity, in which re-refining was only a minor part of the total operation. A large majority of re-refiners would be willing to participate in either a closed or quasi-closed loop arrangement and referenced similar existing contracts. However, several re-refiners were willing to participate only in a quasi-closed arrangement, and questioned both the technical and economic feasibility of a true closed loop contract. Surprisingly, this view was not related to company size, and was shared by two large firms that had previously found true closed-loop contracts unattractive primarily due to administrative problems.

Excess Capacity

Nearly all re-refiners have excess capacity; in fact, this appears to be their largest problem. Heavy investment in modern technology has led to large fixed overhead costs that can only be alleviated by increasing the utilization of existing capacity. Although few firms would reveal quantitatively their excess capacity, all indicated that they would have no problem processing any amount of DoD oil. Indeed, by commercial standards, the potentially available volume of used oil ($\leq$ 5 mgy) could easily be handled by a single large plant.

Collection

As previously mentioned, most re-refiners have developed their own collection networks. These vary from single truck collections within a 600-mile radius to large truck and rail fleets in operation nationwide. The extent of collection varies from pickups at local gas stations to bulk lots from industrial customers. In general, the firms having the most extensive collection networks have the fewest problems in obtaining sufficient feedstocks for their plants. Re-refiners forced to compete on the open market are often underbid by fuel oil blenders who take advantage of their lower operating costs.

Contamination

At low levels, the contamination of used oil with water, solids, hydraulic fluids or synthetic oils does not present a technical problem

TABLE 4. CONTACTED RE-REFINERS

COMPANY	LOCATION	PROCESS	CAPACITY (mgy)
Booth Oil Company	Buffalo, NY	Vacuum Distillation (LUWA Evaporator)	5
Motor Oils Refining Co.	McCook, IL	Vacuum Distillation (Pfaudler Evaporator)	15-20
Cam-Or, Inc.	Westville, IN	Vacuum Distillation (Pfaudler Evaporator)	15-16
	Houston, TX	(Pfaudler Evaporator)	10
Energy Resources, Ltd.	Shippensburgh, PA	Vacuum Distillation (thin-film Evaporator)	15
North Carolina Oil Re-refining	Garner, NC	Phillips Process	2
Central Refining Co.	Springfield, IL	Vacuum Distillation (LUWA Evaporator)	N.R.
Jackson Oil Products	Jackson, MS	Acid/Clay	N.R.
Louisiana Oil Refining Co.	Baton Rouge, LA	Vacuum Distillation	N.R.
Resource Technology, Inc.	Shawnee Mission, KN	Vacuum Distillation (RTI Process)	N.R.
Consolidated Recycling	Troy, IN	Vacuum Distillation	N.R.
Warden Oil Company	Minneapolis, MN	Clay Contacting	2.5
Lakewood Oil Service, Inc.	Fontana, CA	Vacuum Distillation (RTI Process)	10
Dearborn Re-refining	Dearborn, MI	--	N.R.

N.R. = Not Reported

to re-refiners. Although several re-refiners will not accept oil with a water content that is 20 percent or greater, most did not appear to be overly concerned. However, contamination with toxics is a problem affecting all re-refiners. The contamination of equipment and oil stocks with toxics may be excessively costly to manage and is potentially dangerous. In many instances re-refiners have purchased used oil contaminated with chlorinated solvents and have then been unable to identify the sources. This type of problem has led the larger re-refiners to install onsite laboratories and to segregate newly arrived oils for anticipated screening. In the case of smaller re-refiners only spot checks are economically feasible and business is therefore conducted with established (trusted) customers. In some cases a certified analysis of used oil is required at the time of purchase. Contamination considerations make closed-loop operations attractive to some re-refiners since the quality control burden for the used oil remains with the generator.

Certification

All re-refiners were familiar with the military specifications; only one re-refiner is currently certified, whereas two other re-refiners are in the process of conducting certification tests. In general the attitudes about certification costs can be correlated with the size of the company. Larger re-refiners tend to consider certification as part of the cost of doing business and would not require that cost to be directly included in a DoD contract. In some instances, the cost of certification would be assumed by the additive supplier and passed on in subsequent additive purchases. However, almost all the smaller re-refiners claimed that the cost of certification is prohibitive and must be included either directly or indirectly in a DoD contract through volume and price guarantees. In any case all re-refiners agree that the cost of certification and any other government requirements (QA testing, packaging, etc.) would eventually be passed on to the government in the processing cost.

Environmental Impact

Without exception all re-refiners claim that their processes do not generate hazardous wastes; many refiners said that the major reason for conversion to modern technology was to eliminate or reduce the generation of hazardous wastes. In the case of the two remaining plants using the acid/clay process, the acid sludge is purportedly mixed with other waste materials resulting in a waste that tests as non-hazardous. The majority of the plants using the vacuum distillation process claim to reuse all waste materials except for water, which is either treated on-site or discharged to the sewer depending upon the size of the plant.

Several re-refiners ventured the opinion that the DoD was most likely in violation of existing air quality laws by burning waste oils. One re-refiner referenced proposed rules in New York and New Jersey that would limit the amount of metals and halogens in oil used for fuel.

Economics

Re-refining is a capital-intensive business. The minimum size plant that is economical is dependent on the price of used oil and the value of lubricating oil. One re-refiner estimated that a minimum economic plant size was 1 mgy, but that the packaging and quality assurance program needed to meet military specifications would require a 5 mgy plant to cover overhead costs.

All re-refiners were asked to estimate roughly the processing cost for a DoD contract. The actual cost would be dependent upon the quantity and quality of oil re-refined and the prevailing used and virgin oil market conditions, in addition to the desired viscosity and packaging of the final product. Estimates of processing fees for base stock lubricating oil varied from $0.35 to $1.10 per gallon of product. Several re-refiners estimated the cost of finished oil at $1.50 to $2.10 per gallon including packaging. As would be expected the cost estimates tended to reflect the amount of excess capacity at each location. The highest estimate was made by a re-refiner operating near full capacity. Several re-refiners refused to estimate costs but assured that they would be competitive.

CONCLUSIONS AND IMPLICATIONS

It is apparent from the interviews that the re-refining of DoD oil is viewed as an attractive opportunity by the industry. The use of either a closed loop or quasi-closed loop arrangement is acceptable to most re-refiners; in fact several already have similar contracts with industry. The actual contract arrangement should therefore be selected on the basis of technical and economic merit.

Due to regulatory and market pressures the state-of-the-art technology used in the industry is advanced; most of the ineffective or environmentally unsound re-refining operations have been eliminated. Certification should therefore present no technical problems to the re-refiners. The cost of certification will be passed on to the government either directly or indirectly.

At this time the cost of re-refining is heavily dependent on market conditions. Most re-refiners have invested in modern technology and require large volumes of feedstock to maintain economic operation. Therefore bidding on DoD re-refining contracts should be highly competitive.

Most re-refiners have developed their own collection systems to ensure a sufficient feedstock supply. In many instances the collection networks are extensive. The economics of utilizing these networks may be favorable when compared to the establishment of a DoD network, as is discussed later in this report.

CHAPTER 6

ECONOMIC ANALYSIS OF A DoD OIL RE-REFINING SYSTEM

The preceding chapters have addressed the specific issues of the generation and disposal of used oil, collection practices, re-refining technology and the industry itself. As a final element of this investigation, an economic analysis has been structured to illustrate the cost of a used oil re-refining capability within the DoD establishment. The economic analysis has been designed to incorporate all the major cost elements of recycling and re-refining, including transportation as well as collection, storage and processing. The result is a total system cost analysis that is used to examine the cost sensitivity of regionalization, throughput rate, and degree of participation on a total system basis.

APPROACH

The total system cost analysis was structured using the concept for movement of waste oil from source to re-refiner to consumer. The sources of used oil are DoD lube oil consumers, who would also be the consumers of a re-refined oil product. Source (on-site) storage facilities are provided to receive and store used oil in a manner that is environmentally acceptable and consistent with oil segregation and minimization of contamination.

The concept as shown in Figure 8 provides for three levels of regionalization, selected to provide a geographic transition from local and regional re-refining locations to a single national location (Levels 1 to 3, respectively). The re-refining locations selected at each level of regionalization (7 for Level 1, 3 for Level 2, and 1 for Level 3) reflect in part the present re-refining industry base. Two transport modes -- truck or multimodal -- are considered based upon the least cost. The multimodal mode uses both truck and rail haul transport. The cost of the rail mode also includes the throughput at a rail terminal, which includes truck offloading, interim storage and rail tank car loading.

The total system cost analysis was conducted using a computer model, developed by ES, to facilitate cost evaluations for used oil collection, transport, re-refining, and re-distribution. The model (called the ES Commodity Movement Economic Analysis Model or ESCOMECAM), contains the following elements:

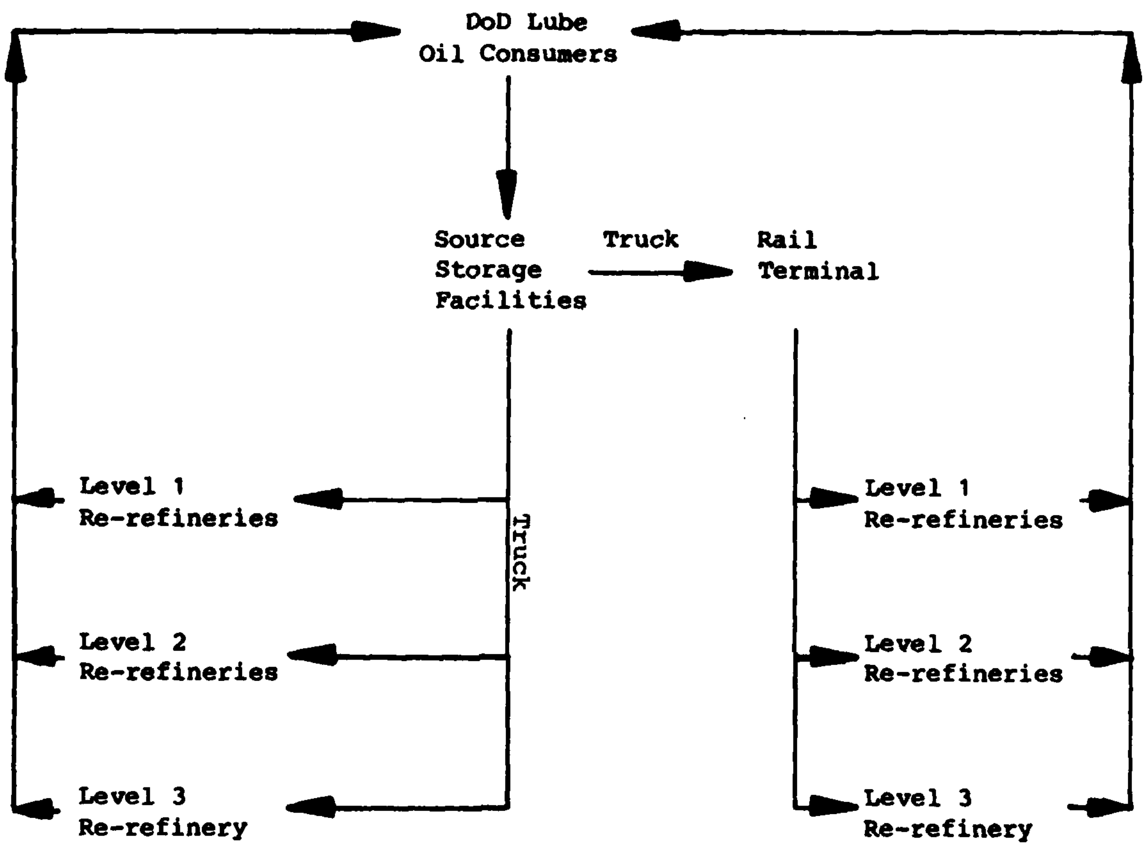
(1) An origin-destination matrix, containing rail and highway distances between each of the DoD lube oil consumers found in the data base (see below) and the closest re-refining location.

(2) Cost functions for source storage, collection, transport, re-refining and back-haul.

(3) A modal least cost selection subroutine, to ensure that the lesser of truck or rail haul costs were incorporated into the analysis.

(4) Subroutines for calculating unit and total cost by individual source or by all sources ranked from largest to smallest.

FIGURE 8. CONCEPT FOR TOTAL SYSTEM COST ANALYSIS



Notes:

1. Truck or rail haul to be used as cost-effective

2. Locations assumed for re-refining plans

   - o Level 1: New York, North Carolina, Texas, Minnesota, Illinois, California and Pennsylvania
   - o Level 2: California, Texas and Pennsylvania
   - o Level 3: Illinois

A series of sensitivity analyses were conducted with the total system cost analyses model. The variables considered were: the oil recovery factor (what percent of total oil used within an installation is recovered as used oil); the level of regionalization; and the degree of participation. The assumptions used to develop the total system cost analyses are presented below.

ASSUMPTIONS

The evaluation of the recycling and re-refining system alternatives was based on vehicle lubricating oil demand data received from the Defense Fuel Supply Center (DFSC), which provided projected direct oil purchases by depots and the individual installations. Additionally, actual oil drawn from depot stocks of the Defense General Supply Center (DGSC) for FY 82 was incorporated into the data obtained from DFSC. Oils destined for use in Europe (New Cumberland Army Depot) were excluded from the analyses along with lubricating oil purchased for use in non-military activities, primarily at U.S. Postal Service Vehicle Maintenance Facilities. The types of lubricating oil used to quantify the analysis are listed in Table 5.

For the purposes of the analysis each of the 299 installations was assumed to be an individual used oil source, although at many installations oil is collected at each activity. The volume of used oil from each source available for re-refining was varied during analysis from a reference oil recovery factor (used oil recovered divided by total oil purchased) of 0.3 to 0.6. The reference factor of 0.3 represents the present amount of used oil disposed through the DPDS, based on DFSC and DGSC procurement data. The peak value of 0.6 represents the highest literature estimate of optimal used oil recovery and minimal loss during use.

A number of basic assumptions were necessary to develop the economic analysis. Used oil was assumed to be acceptable for re-refining, with no chlorinated hydrocarbons or other toxics present to cause the used oil to be classified as a hazardous waste. The water content of the used oil was assumed to average 7 percent, with trace amounts of non-lubricating oil components (hydraulic fluid, solvents, etc.) present. The distribution of the re-refined oil and collection of used oils at each source was assumed to be handled using DLA or installation facilities, with existing transportation facilities available for transport of the used oil and re-refined oil.

It was assumed that existing installation collection and storage procedures were maintained at each source, excepting that the segregation of non-lubricants from the used oil would be actively pursued. To simplify the analysis, it was assumed that a central storage facility with necessary spill control provisions would be available at each source. The configuration of this central storage area was based on the rate of used oil generation. For sources generating less than 2,000 gallons per year, a drum storage area was assumed; otherwise underground tanks were specified (Appendix A). The maximum accumulation time was set at 6 months.

TABLE 5

LUBRICATING OIL PRODUCTS INCLUDED IN ANALYSIS
OF RE-REFINING ECONOMICS

MILITARY SYMBOL	PRODUCT NOMENCLATURE	MIL SPEC
OE/HDO-10	Lube Oil, Internal Combustion Engine, Tactical Service	MIL-L-2104C & Am. 1
OE/HDO-30	Lube Oil, Internal Combustion Engine, Tactical Service	MIL-L-2104C & Am. 1
OE/HDO-40	Lube Oil, Internal Combustion Engine, Tactical Service	MIL-L-2104C & Am. 1
OE/HDO-50	Lube Oil, Internal Combustion Engine, Tactical Service	MIL-L-2104C & Am. 1
10W	Lube Oil, Internal Combustion Engine	MIL-L-46152B & Am. 1
30W	Lube Oil, Internal Combustion Engine	MIL-L-46152B & Am. 1
10W30	Lube Oil, Multi-Grade, Internal Combustion Engine	MIL-L-46152B & Am. 1
15W40	Lube Oil, Multi-Grade, Internal Combustion Engine	MIL-L-46152B & Am. 1

Source:

DFSC, Oil Contract Bulletin, DLA-600-82-0100 (1982 July 01 thru 1983 June 30)

Two transport modes were used for the economic analysis: truck and rail. The typical tanker truck (18-wheeler) can haul a 5,000 to 6,000-gallon payload; the typical rail tanker car, 10,000 to 30,000 gallons. It was assumed with truck transport that the used oil was carried in bulk and that the hauler carried equipment on the tanker to pump the used oil from underground tanks; however, for drum storage it was assumed that the drums would have to be individually pumped into the tanker at additional cost.

It was assumed for rail transport that the used oil would have to be hauled by truck to an existing rail terminal for transfer to rail cars. (At larger bases having rail terminals, trucks will be needed to collect and transfer oil from the activities to the terminals). The minimum haul distance for rail transport was set at the economic breakeven point between rail and truck transport, determined in this analysis to be about 630 miles, and the minimum source generation rate for using rail transportation was set at 20,000 gallons of used oil per year.

For purposes of this evaluation it was assumed that the existing spare capacity at commercial re-refining plants would be utilized to process DoD used oil. Re-refiners were selected on a geographic basis by proximity to sources as required for the levels of regionalization. The choice of location was in no way intended to show preference for any individual re-refiner and in many instances several are available at the specified location.

This evaluation was also not intended to be limited to the excess capacity of commercial re-refiners. A DoD owned and operated re-refinery would be equivalent to a Level 3 regional facility due to economic limitations. The minimum economically feasible new re-refining facility has been estimated at 5-5.5 mgy (References 26, 27). Because the maximum estimated volume of DoD used oil available for re-refining was estimated at 2.4 mgy (assuming an oil recovery factor of 0.6 and a total of 4.02 million gallons of oil used each year, Chapter 2), only a centrally located re-refinery would be feasible. Therefore the evaluation for a Level 3 regional facility is viewed in this analysis as analogous to that required for a government-owned re-refinery.

After re-refining it was assumed that the oil would be loaded into 55-gallon containers and palletized for delivery back to the originating source. Back-haul transport was assumed to be by the same mode as was the transport to the re-refinery. It was further assumed that rail transport would be by tankcar, when in actuality a boxcar would be used to transfer palletized drums.

COST FUNCTIONS

Cost functions were developed for each step in the re-refining process, using the assumptions outlined in the previous section. The derivation of the cost functions is presented in Appendix A and summarized below.

Source Storage

At a minimum collection frequency of twice per year, storage facility costs were calculated for a 2,000 gallon per year drum storage facility and 4,000 and 20,000 gallon per year underground tank storage facilities. Based on these calculated costs, a storage facility cost function was developed (Appendix A) and shown in Table 6 and Figure 9, which is based on the assumption that storage facility costs, as a function of annual used oil generation, decrease to about $0.10 per gallon at 20,000 gallons per year and are assumed to be constant thereafter.

Transfer

For rail transport a local truck haul to an existing rail terminal was assumed. The transfer haul cost was based on the calculated costs of ownership and operation of a tractor trailer unit for an average haul distance of 25 miles. Rail terminal costs were developed by calculating the fixed and variable throughput costs of a terminal on a per gallon basis. It was also assumed that existing terminals would be used where needed, and that the bulk oil throughput would be a modest fraction of total throughput. The resulting rail transfer costs are presented in Table 6, and amount to $0.095/gallon.

In the case of truck transport, no transfer costs were assumed for pickups from tanks (4,000 gallons per year or greater used oil generation); however, with drums (1,000 to 4,000 gallons per year of used oil generation), a cost was assumed to cover the transfer of oil from the drums to the truck. This transfer cost was calculated based on the labor costs involved, and is $0.053/gallon as shown in Table 6.

Transport

Rail transport costs were derived from current rail tariffs for bulk transport (10,000 gallons) of liquids for distances of 165 to 2969 miles, as obtained from a tariff consultant (Reference 28). Tariff costs are based on DoD supplied tank cars; it was assumed that the rail transport cost with DoD rolling stock was 20 percent less than by the current tariff structure (Reference 29). Based on these tariffs, a unit price (dollars per gallon of used oil) function was calculated by a linear regression of the rail tariffs. The resulting cost function is presented in Figure 10.

Truck transport costs were developed by calculating the fixed and operating costs with haul distances of 25, 75, 125, and 175 miles. The resulting costs were initially calculated in terms of cost per gallon-mile and plotted against haul distance (Figure 11). From analysis of this plot it was determined that the breakpoint between local and long distance truck hauls occurred at 200 miles and that haul costs (dollar per gallon-mile) increased linearly for distances greater than 200 miles. For distances less than 200 miles, the cost function was calculated by a linear regression of the calculated truck transport costs. The resulting truck transport cost function is presented in Figure 12.

TABLE 6

SOURCE AND TRANSFER COST FUNCTIONS

TRANSPORT MODE	USED OIL GENERATION RANGE gallons/year	COST FUNCTION ($/gallon used oil)
Rail		
o Haul from Source to Railroad	NA	$0.086
o Railhead Throughput	NA	0.009
o Total Transfer	NA	0.095
Truck		
o Pickup from Drum Storage	1,000-3,999	0,053
o Pickup from Tank Storage	4,000 & greater	No transfer cost

FIGURE 9. SOURCE STORAGE COST FUNCTION

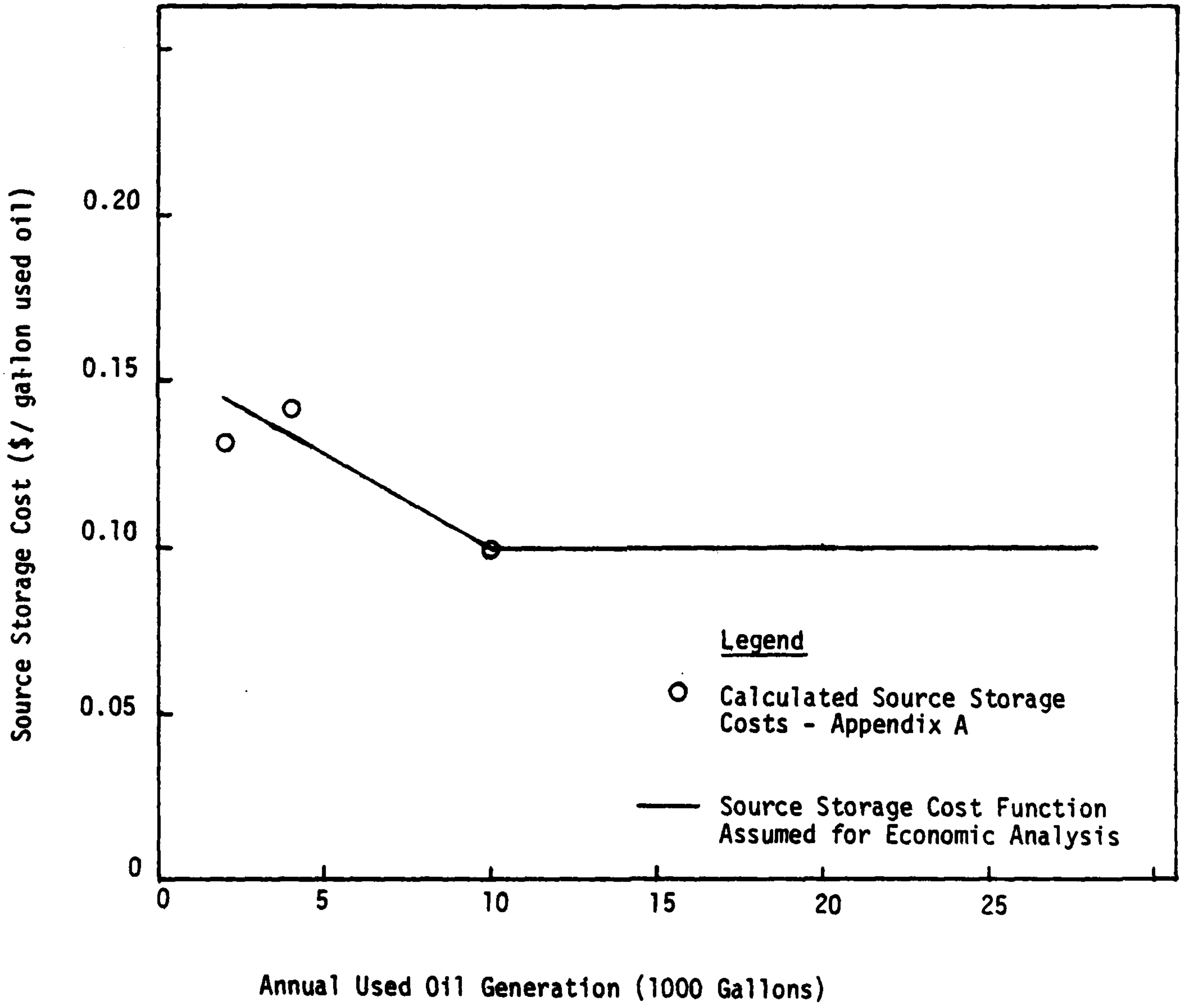


FIGURE 10. RAIL TRANSPORT COST FUNCTION

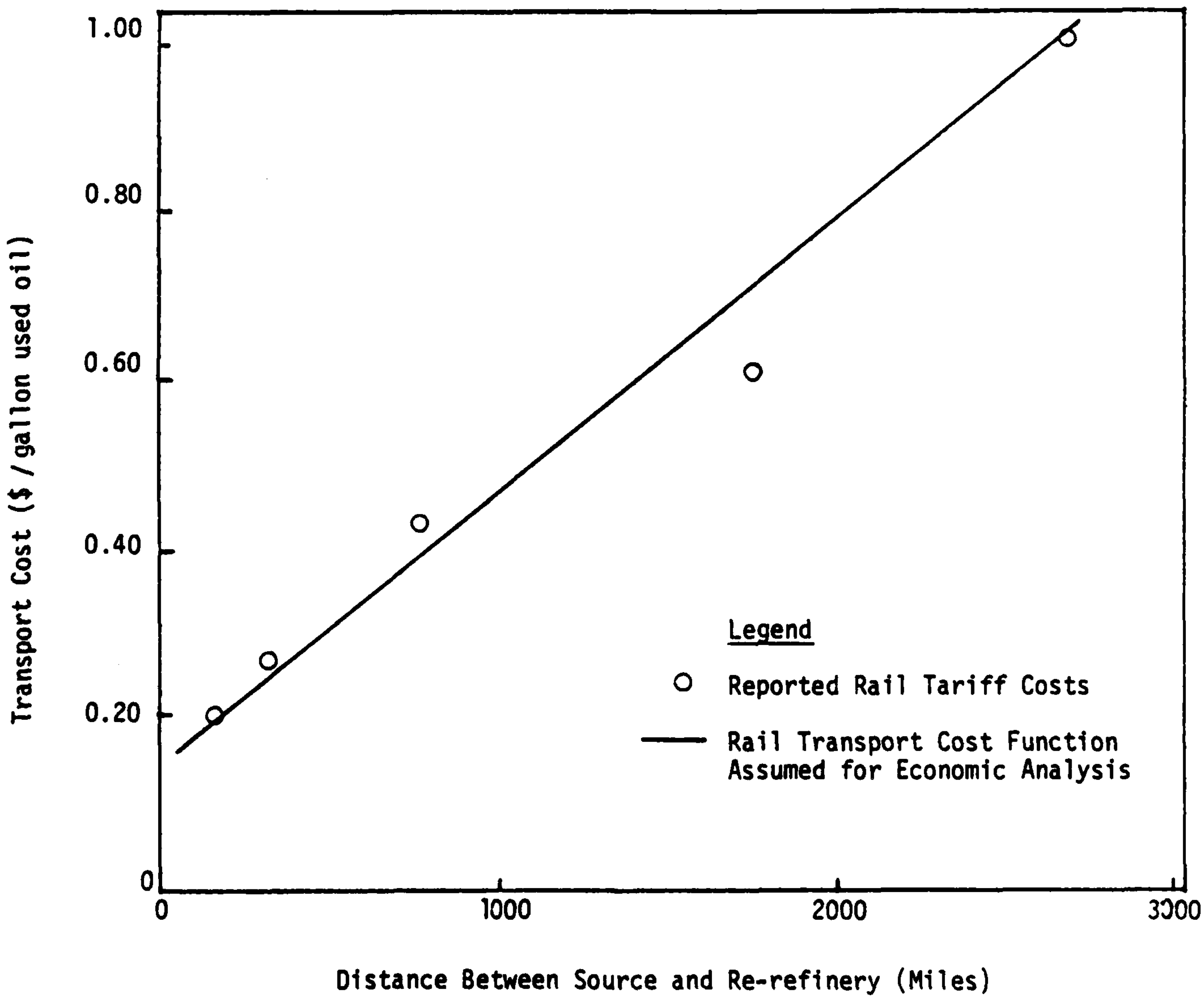


FIGURE 11. TRUCK TRANSPORT COST FUNCTION

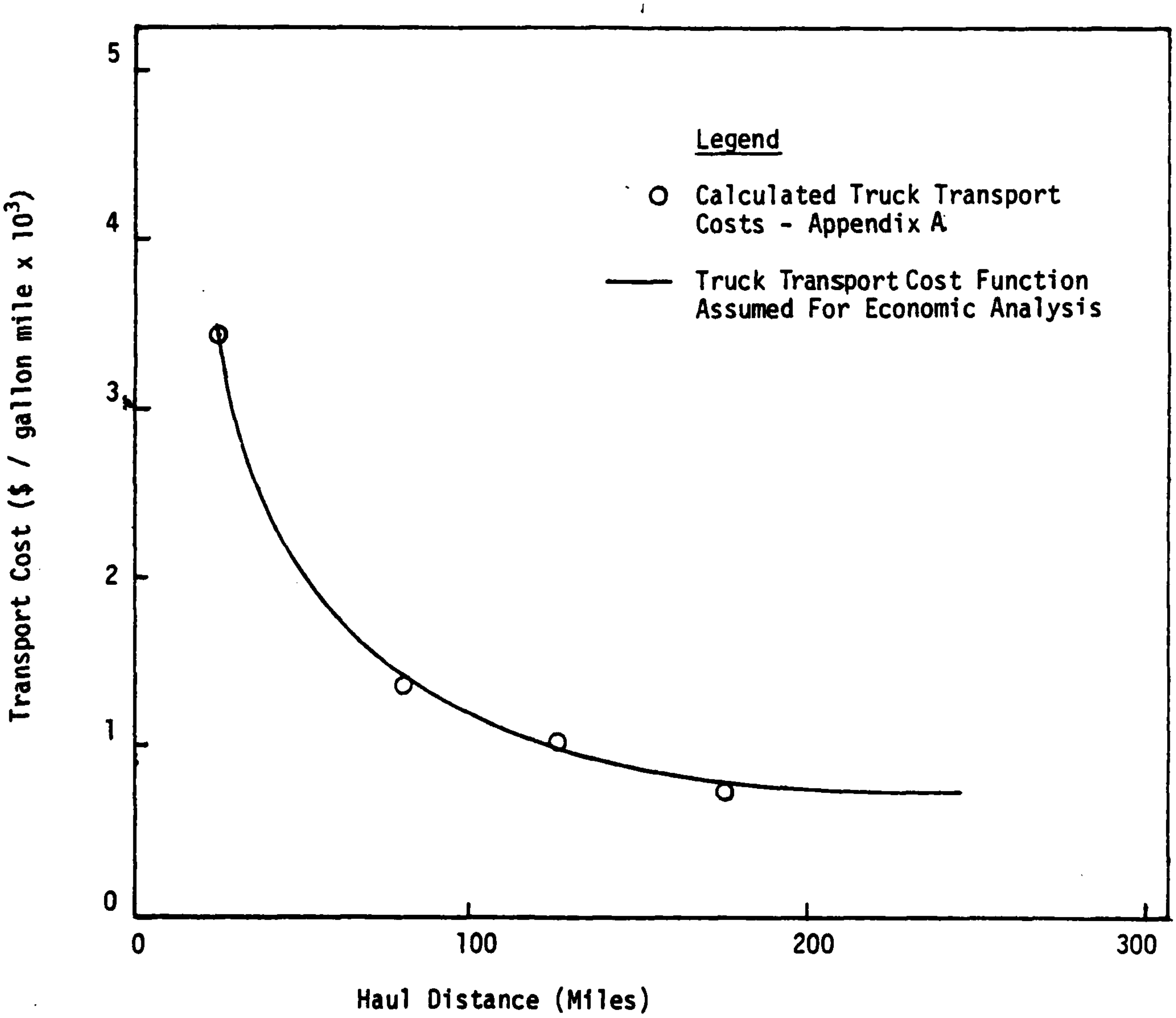
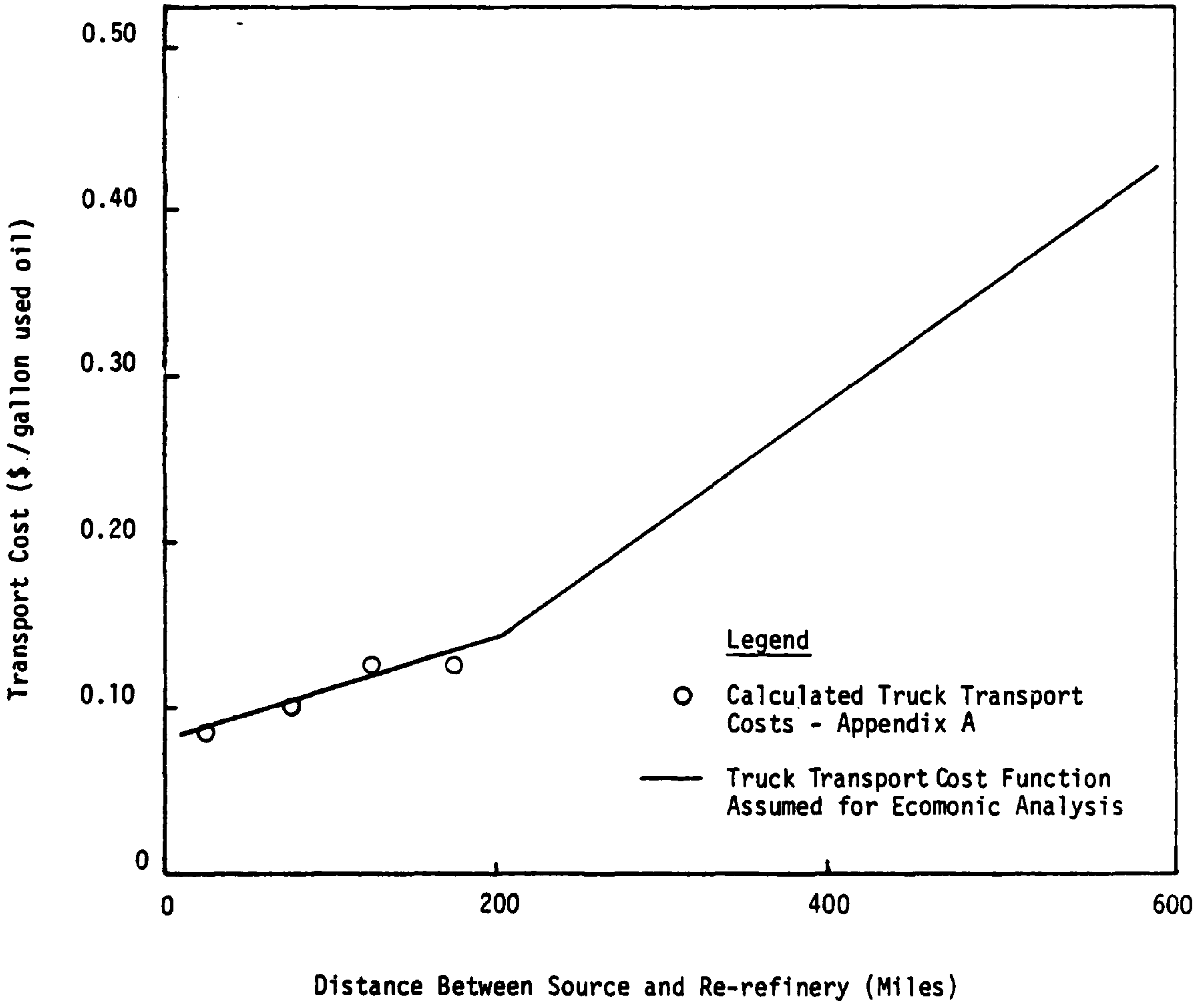


FIGURE 12. TRUCK TRANSPORT COST FUNCTION



Based on the assumption that rail transport would only be used where it was economically competitive with truck transport, the calculated truck transport function was plotted along with the combined rail transfer and transport function (Figure 13) to determine the economic breakpoint between the two transport modes. Based on this plot, a minimum rail transport distance of 630 miles was estabished.

Re-refining Costs

Re-refining costs were calculated for each of the seven selected re-refineries, using information obtained from re-refiners and from published data. The cost elements considered included capital, utility, operating and waste disposal costs. To these were added the costs for an additive package and for packaging in 55-gallon containers. The resulting cost estimates for the individual plants varied from $1.27 to $1.72 per gallon of re-refined product (median $1.62 per gallon). These costs are assumed to be scale-independent inasmuch as excess capacity is involved (with the exception of a single centralized re-refiner (Level 3) in which a small cost reduction was assumed. The yields (gallon of re-refined product per gallon of used oil) varied from 0.54 to 0.73 (median of 0.70).

Backhaul Transport

Unit return costs (per gallon-mile) were assumed to be the same as the used oil transport costs. Backhaul was by the same mode as the used oil transport and the re-refined oil was returned to the originating installation as defined in Table 1. In actuality the cost would differ since re-refined oil is transported in palletized 55-gallon drums, not tanker cars.

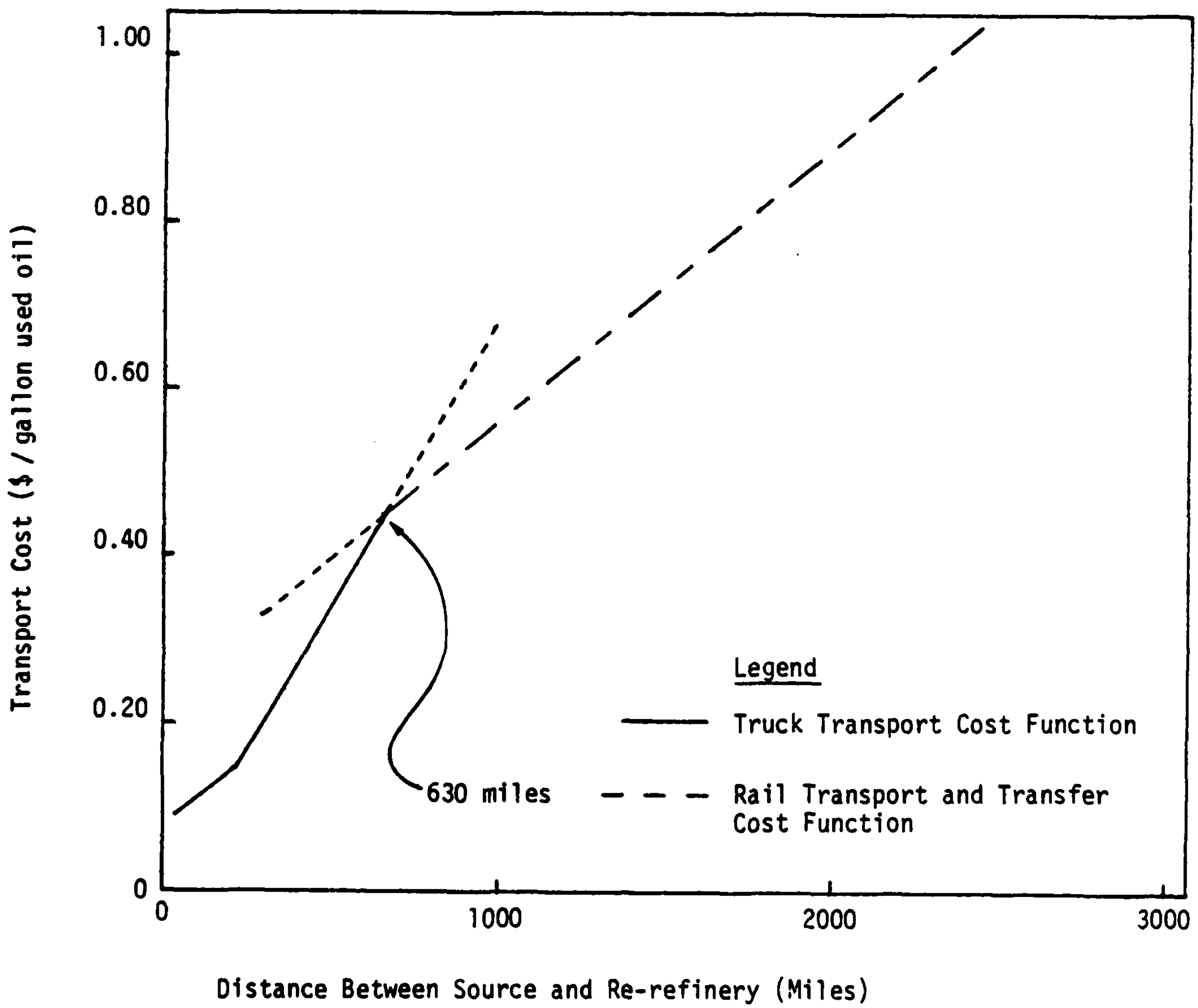
CONTRACT/MANAGEMENT

Precedents for closed-loop recycling exist within the DoD. During World War II and into the early 1950's, closed loop re-refining was practiced extensively. Unfortunately these contracts are unavailable due to the lengthy time lapse. However, a sample of the existing DoD contract for closed-loop recovery of silver (photographic processing) was obtained and has been used to develop contract/management estimates for re-refining of used oil.

The following elements for a DoD re-refining contract were outlined using the sample contract format:

- Property accountability: define property record requirements and procedure for review of contractor's records. Define need/role for Defense Contract Administration Service (DCCAS).
- Storage areas: define security requirements for storage areas to be provided if used for (a) quasi-closed loop and (b) closed loop storage. Define approval procedures for storage areas proposed by contractor.
- Definition of government property: define what is and isn't government property at each step in the contractor's re-refining operation. Materials to be addressed include: raw used oil,

FIGURE 13. MULTIMODAL TRANSPORT COST FUNCTION (TRUCK OR RAIL)



product oil and waste fractions. Will depend upon type of contract, true closed-loop or quasi closed-loop.

- o Government representatives to be present: define the specific occasions when government representatives must be present, e.g., during movements of oil to/from storage areas, when additives are added, during quality control/quality assurance (QC/QA) sampling and analysis, etc.
- o Duties of Defense Contract Administration Service (DCAS).
- o Quality assurance requirements: includes characterization of used oil, quality control testing during processing and certification of final product.
- o Packaging: includes final packaging containers and procedure requirements.
- o Environmentally acceptable disposal of byproducts and wastes.
- o Shipping and delivery schedules and responsibilities for both the DoD and contractor.
- o Documentation and administrative requirements including schedule of payments.

Preliminary government manpower requirements to administer and implement a DoD oil re-refining system were estimated based upon the sample contract. Manhour requirements were estimated for contract administration, sampling and analysis, quality control and reporting. Three operational areas were considered: en route to the re-refinery, at the re-refinery, and at the installations receiving the re-refined product. The total estimated manpower requirements for a re-refining operation are 900 man-days. The functional breakdown is approximately 10 percent for contract administration, 45 percent for sampling and analyses, 25 percent for quality control and 20 percent for reporting. The impact of the estimated manpower requirements would amount to $0.03-0.05 per gallon of used oil or $0.05-0.08 per gallon of re-refined oil. For purposes of the economic analysis a cost of $0.08 per gallon of re-refined oil was used.

RESULTS

A summary of the 299 installations identified as lube oil consumers was presented in Table 1 of Chapter 2. As was noted earlier about 80 percent of the oil consumption is associated with a third of the installations, while 90 percent of the oil consumption is associated with approximately one half of the installations. The majority of the installations are widely dispersed from a geographic standpoint and relatively small in size. One third of the consumers use less than 3000 gallons of oil per year, while over 60 percent use less than 10,000 gallons per year. The results presented herein are based upon all consumers using a minimum of 1000 gallons of oil (299 installations) per year regardless of location or quantity.

The results of the economic analysis were generated in three formats:

- o Cost analysis by source, showing the costs assigned for on-site storage, transfer, haul, re-refining and back-haul as well as total costs of re-refined product.

- Total cost and unit (per gallon) cost for each source, and a composite volume-weighted average unit cost for all sources.
- Cumulative used oil generation and unit costs for all sources at recovery factors of 0.3 and 0.6.

Results were generated in these formats for each level of regionalization (Levels 1, 2 and 3) and oil recovery factor (0.3 and 0.6) and are summarized in Table 7 and Figures 14 and 15. The results do not include the government administrative cost of $0.08 per gallon of re-refined product, which may be slightly different at each level ($0.05-0.08 per gallon).

It is apparent from the results of Table 7 that the total system cost of a re-refined oil product increases with the level of regionalization. For example, in the cases where 60 percent of the oil consumption is recovered, the total annual system cost increases from $4,274,100 at Level 1 to $5,037,700 at Level 2 and $6,543,100 at Level 3. The increases relative to Level 1 are 18 and 53 percent respectively. The transportation costs (haul plus back-haul), amounting to 35 to 39 percent of the total system cost for Levels 1 and 2, increase to 57 percent at Level 3 (backhaul transportation costs would be high in an actual system). Thus the transportation costs have a significant impact on total system costs even at Levels 1 and 2, and amount to over half the total system cost for re-refined product at Level 3.

The unit cost estimates developed at the two oil recovery factors (0.3 and 0.6) can be used to exemplify the sensitivity of system cost to scale for the installations considered. Briefly, the costs are decreased in any given case as the oil recovery factor is increased (see Table 7). The majority of the decrease in unit cost is directly attributable to a corresponding decrease in the transport cost (as a percent of the total cost) as shown in Table 7. For example, at an oil recovery factor of 0.3, the unit cost for a Level 1 re-refined oil is $3.08/gallon and 44 percent of the total cost is attributable to transportation. However, at an oil recovery factor of 0.6, the corresponding cost is $2.65/gallon while 35 percent is due to transportation. The decrease is due to the fact that a larger source volume can be transported more cost-efficiently. Many of the small volume users are penalized by partial load truck shipments and/or are unable to satisfy minimum volumes required for rail transport. In general, the efficiency of transportation increases with the efficiency of collection.

The variation in unit cost of re-refined product is evident from the data presented in Table 7 and the curves in Figures 14 and 15. The results indicate that the cumulative-basis unit costs tend to increase with increasing degree of participation (i.e., percent recovery) to a maximal level. This trend is due to both volume and geographic considerations. As shown in the figures the cumulative unit cost increases dramatically as total participation is approached (80-100 percent). During the calculation for the figures, installations were added in order of descending volume; the low volume sources were added last. Inspection of the figures reveals that the optimum cutoff point is at 80 percent of the used oil generation for an oil recovery factor of 0.3 and 90 percent for a recovery factor of 0.6. Both points are approximately

TABLE 7

SUMMARY OF TOTAL SYSTEM ECONOMIC ANALYSIS RESULTS

LEVEL	OIL RECOVERY FACTOR	USED OIL RECYCLED (gal year)	TOTAL COST ($/year)	TRANSPORT COST (% of total)	UNIT COST[1] ($/gallon)
1	0.3	1,205,400	2,492,800	44.0	3.08
	0.6	2,410,900	4,272,100	35.1	2.65
2	0.3	1,205,400	2,993,300	48.2	3.51
	0.6	2,410,900	5,037,700	38.9	2.96
3	0.3	1,205,400	4,241,900	66.8	5.03
	0.6	2,410,900	6,543,100	57.3	3.88

Notes:

[1] For all 299 installations. Cost excludes estimated $0.08 per gallon for government administrative costs.

FIGURE 14.

IMPACT OF REGIONALIZATION AND DEGREE OF PARTICIPATION ON UNIT COST OF RE-REFINED PRODUCT (OIL RECOVERY FACTOR = 0.3)

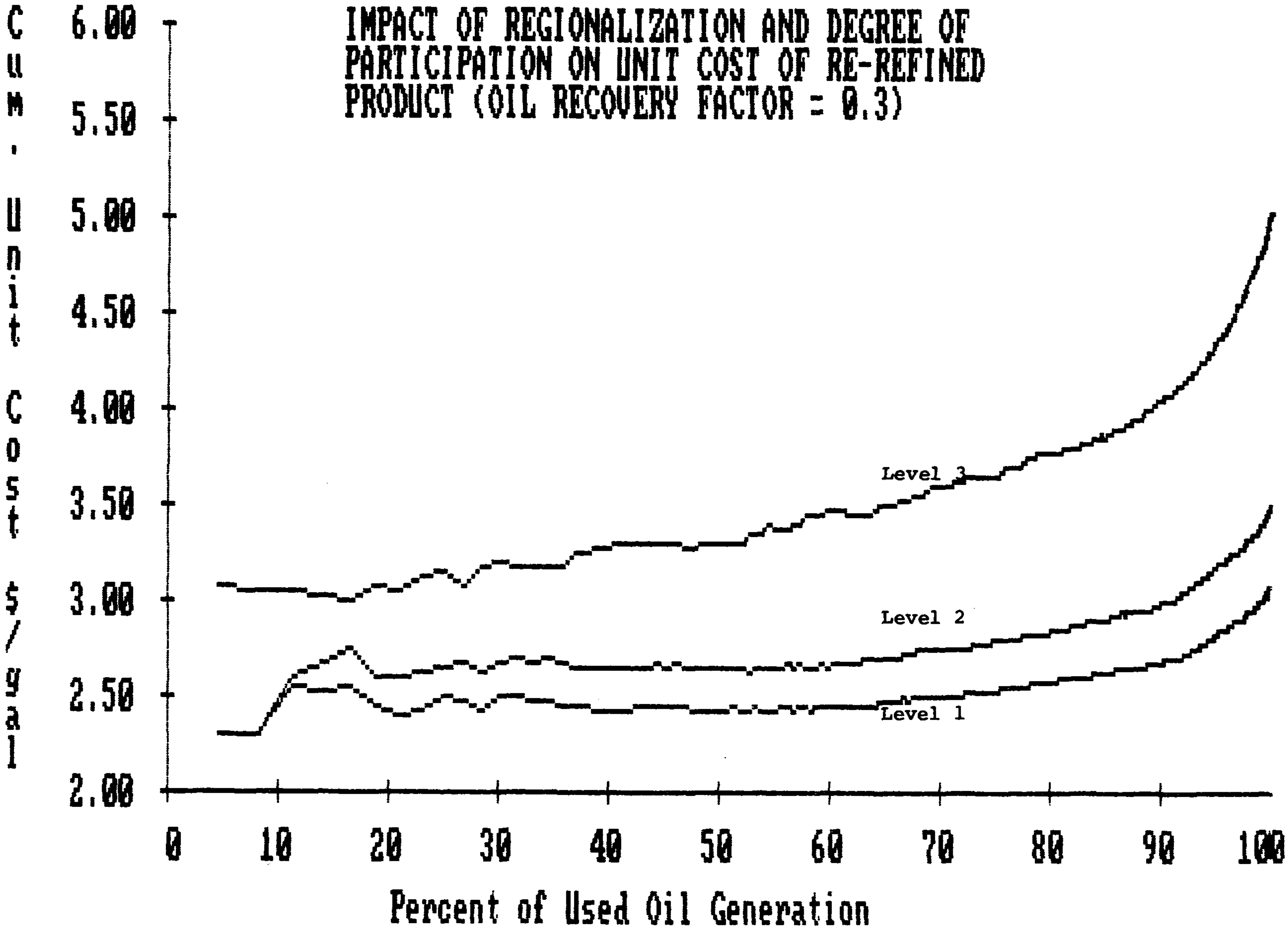
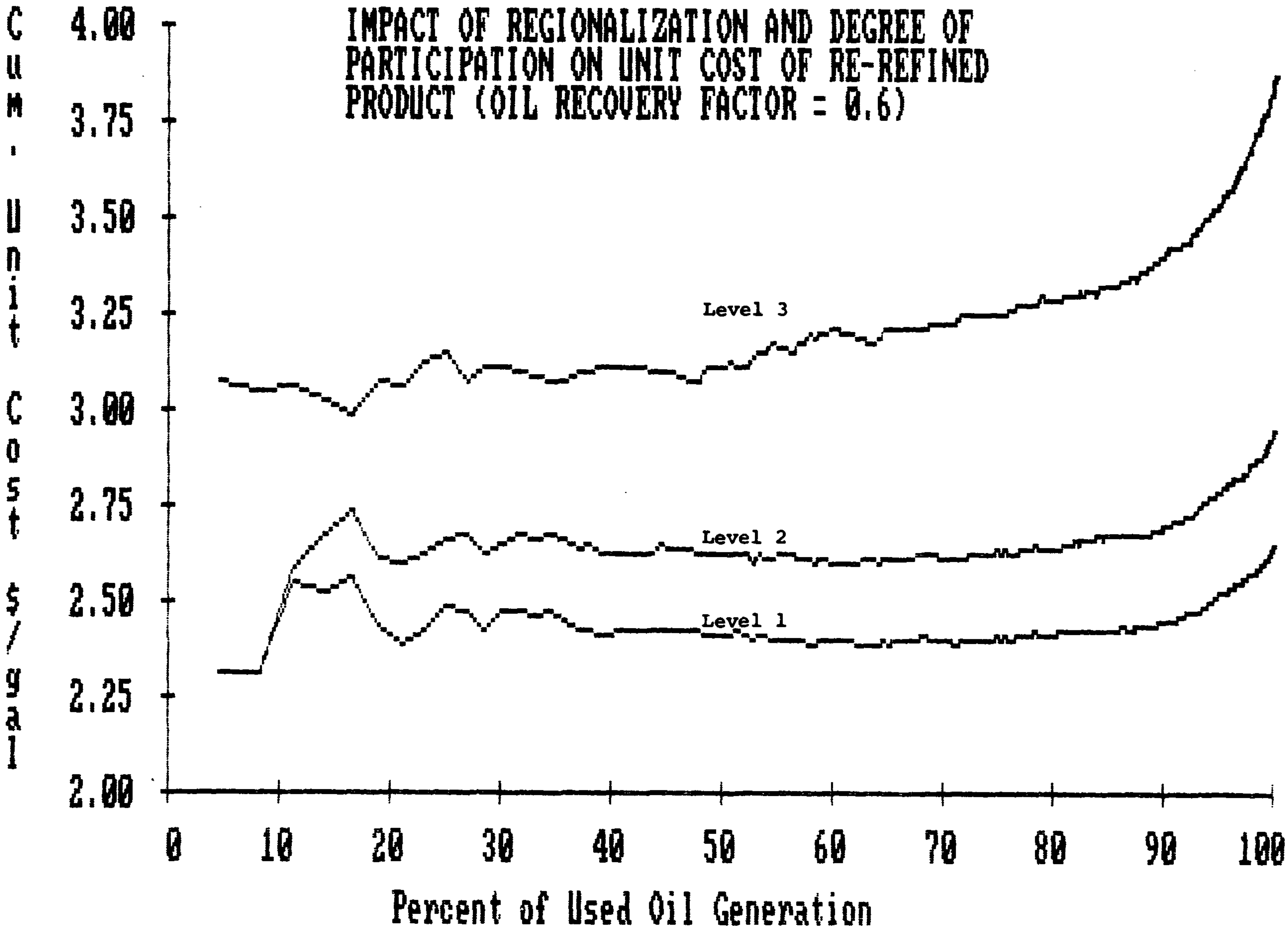


FIGURE 15.

IMPACT OF REGIONALIZATION AND DEGREE OF PARTICIPATION ON UNIT COST OF RE-REFINED PRODUCT (OIL RECOVERY FACTOR = 0.6)



equivalent to installations recycling 3,500 gallons/year of oil. Figure 2, the plot of cumulative oil usage by installation, shows that the optimum cutoff point corresponds to participation by one half of the installations for a recovery factor of 0.3 and one third of the installations for a recovery factor of 0.6. Table 8 summarizes the results of this preliminary optimization.

An attempt was made to determine the optimum geographic radius for oil collection around existing re-refiners. Initial plots of unit cost as a function of haul distance for all re-refiners were inconclusive, resulting in a wide scattering of data points. Examination of the data revealed that unit cost is affected by a variety of factors including volume, efficiency of transportation, and cost and yield factors at each individual re-refinery. Subsequent plots for a single re-refinery in which the low volume users (< 3500 gallons) were eliminated were also inconclusive (multiple linear regression failed to provide a correlation). The results of this analysis show that the relationship between haul distance and unit cost is based upon many local factors, the most important being volume and transportation efficiency. The optimum geographic radius for oil collection around a re-refinery is site specific and can not be generalized.

The results in Table 8 indicate on an overall basis that from 1.0 to 2.2 million gallons of oil can be recovered and re-refined annually for a unit cost of $2.50 to $2.66 per gallon at Level 1 inclusive of government administrative costs. These quantities of oil could be obtained from one third to one half of the largest used oil consumers, if the oil recovery varied between 30 and 60 percent of new oil consumption. An additional 241,000 gallons could be recovered annually from the balance of the generators, but with the effect of increasing the overall unit cost by 20 to 50 cents per gallon.

All of the above costs are for a Level 1 (decentralized) DoD oil re-refining system incorporating the services of seven re-refineries around the nation. The cost impact of regionalization to Level 2 (three re-refineries) would be 30 to 43 cents per gallon, whereas the cost impact of Level 3 would be an additional $1.25 to $1.92 per gallon. It is apparent from the economic analysis presented herein that the major emphasis of any DoD oil re-refining program should be to minimize transportation costs. The full implications of this total system cost analysis are discussed in Chapter 7.

TABLE 8

PRELIMINARY OPTIMIZATION OF ECONOMIC ANALYSIS

LEVEL	OIL RECOVERY FACTOR	PERCENT OF DoD USED OIL RECYCLED[1]	USED OIL RECYCLED (gallons/year)	UNIT COST ($/gallon)
1	0.3	80	964,300	2.58
	0.6	90	2,169.800	2.45
2	0.3	80	964,300	2.80
	0.6	90	2,169,800	2.70
3	0.3	80	964,300	3.80
	0.6	90	2,169,800	3.45

[1] Based on total volume of the 299 installations listed in Table 1.

CHAPTER 7

DISCUSSION

The critical issues to which this investigation was directed include regionalization, ownership and operation of re-refining facilities, the limitations of the re-refining industry, the form of contracting, and substitution of re-refined for virgin oil. This chapter is a synopsis of the key results and their implications for a DoD re-refining system.

REGIONALIZATION

The impact of regionalization on the cost of re-refined product was given primary emphasis in this investigation. The economic analysis of Chapter 6 has shown that the total system cost of a re-refined product increases with the level of regionalization, primarily due to the increasing burden of transportation.

Yet another factor impacting the total system cost of re-refined product is the degree to which the smaller installations would participate. The unit cost of re-refined product was found to increase with increasing participation for all levels of regionalization. This increase was most significant as total participation was approached. Preliminary optimization indicates that total participation is not cost effective and a cutoff point exists for installations recycling less than 3,500 gallons of used oil per year. At an oil recovery factor of 0.3, this corresponds to the participation of one half of all installations.

Data analysis revealed that the optimum geographic radius for used oil collection around a re-refinery is site specific. The relationship between haul distance and unit cost of re-refined product is complex, consisting of many localized variables such as oil volume, transportation efficiency and the cost/yield factors for individual re-refiners. The determination of the optimum geographic radius for each re-refinery requires the collection of detailed information beyond the scope of this study.

The unit cost of the re-refined oil was also found to be relatively sensitive to differences in scale (fraction of oil recovery) at each individual installation. In general the unit cost decreased as the oil recovery increased. This was found to be due to the more efficient transportation available for larger source volumes of oil.

In summation, the total volume of oil re-refined was not found to be the critical system parameter; rather, the cost of transportation of used oil and re-refined product throughout the system impacted most significantly on the total system cost. The cost of transportation was found to be interdependent on many local variables such as collection efficiency, degree of participation, source volumes, and distance. Therefore, the target economic volume of oil for re-refining is site specific and cannot be generalized.

OWNERSHIP/OPERATION

Three operational scenarios have been proposed for DoD re-refining: utilization of excess capacity at virgin oil refiners; utilization of a government-owned and operated (or contractor-operated) facility; and utilization of excess capacity at selected independent re-refiners on a contract basis. The first option, the use of virgin refiners, would require costly equipment modifications by these operators to overcome technical problems. Even if a centralized (Level 3) system were to be implemented, the total volume of DoD used oil generation is unlikely to be sufficient to economically justify this approach to a re-refiner.

The minimum economic plant size for re-refining to DoD specifications has been estimated at about 5 mgy. According to information developed in this report the maximum volume of used oil available within DoD would be from 1.2 to 2.4 mgy. Allowing for data uncertainty the total volume is still significantly less than 5 mgy. Also because of the limited used oil generation within DoD, only a single centralized government-owned re-refinery would be practical; this level of regionalization (Level 3) has already been shown to be the least economical.

Of the available options, the use of excess capacity at selected re-refiners through competitive bidding is the most practical for the DoD.

RE-REFINING INDUSTRY

Due to regulatory and market pressures, the vast majority of re-refiners have invested in modern technology. This technology is both economically and technically efficient, with minimal environmental impact. Investment in modern technology has led to large fixed overhead costs that can be alleviated only by maximizing plant utilization. For this reason oil re-refiners with excess capacity (essentially all) expressed strong interest in obtaining DoD contracts; therefore bidding should be highly competitive.

Currently only one re-refiner is certified for producing oil meeting military specifications; however, two more are in the process of certification. Due to the high level of technology utilized in the industry today, certification is not viewed as a technical problem; however, the cost of certification without question will be directly or indirectly passed on to the DoD.

Quality assurance provisions are a part of the military specifications. Most large re-refiners have in place some form of QA/QC program. The cost of upgrading the existing programs to military specifications will also be directly or indirectly passed on to the DoD.

FORM OF CONTRACTING

Several re-refiners currently have closed-loop or custom contracts in place with private industrial clients. The majority of re-refiners are willing to participate in a true closed-loop contract (segregated storage and processing), the only requirement being a minimum volume varying from 6,000 to 100,000 gallons per year depending upon the size of their facilities. However, a few re-refiners indicated that they would only participate in quasi closed-loop contracts. Contracts that are of this form would incorporate a selling price-credit arrangement in which oil would not be segregated. The service costs for true closed-loop re-refining are generally higher, i.e., less cost-favorable to the government.

The only clear advantage of a true closed-loop contract is the guarantee of feedstock quality. However, the necessity of this guarantee is questionable, as a DOE study has found that vehicular used oil feedstock was consistent throughout the United States regardless of geographic or seasonal variations. Therefore the only rationale for closed-loop contracting would seem to be for the segregation of industrial from vehicular oils, a practice already common since most generators segregate these types of oil to increase their value.

According to MERADCOM, the Command charged with developing military specifications, the mixing of military and non-military feedstocks is acceptable provided that feedstock characteristics are reported. In other words, at the time of certification a breakdown of used oil sources (i.e. percent gas stations and fleet operations) must be reported. Any major variations in this used oil breakdown during the certification period must also be reported to MERADCOM.

VIRGIN VS. RE-REFINED OIL

The cost of new oil to DoD installations varies with the oil type (viscosity), packaging, point of delivery, and type of purchase. Large volume users (approximately 25 percent of the installations) may purchase oil directly from the supplier, while small volume users must purchase oil through the DGSC depot system. According to the DFSC FY82 Bulletin, prices for large volume users varied from $2.27 to $3.07 per gallon for a 55-gallon drum. All FOB destination prices for 55-gallon drums in the bulletin were weight averaged (by volume). The average cost was found to be $2.47 per gallon.

A computer printout of lubricating oil purchases through the DGSC depot system for FY82 was obtained and analyzed. It was determined that over three million gallons of oil were sold to DoD installations during FY82 at an average price of $3.49 per gallon. All large-volume users purchased additional oil through the depot system, many in excess of the volume purchased directly from the supplier. The price of a depot-supplied 55-gallon drum of lubricating oil was found to vary from $3.04 to $3.49 per gallon. Under the depot system the price of lubricating oil is independent of delivery distance since system transportation/administrative costs are averaged in a surcharge.

The preceding comments indicate that there is no available average cost of new oil for DoD installations. The weight averaged cost for direct purchase can not be used since all installations purchase oil from the depot system. The actual price of oil is largely dependent on the type of purchase and is most likely closer to $3.00 to $3.50 per gallon.

The cost of re-refined oil packaged and delivered on the same basis was estimated at $2.58 per gallon (Level 1, oil collection factor = 0.3). This price does not include an estimated government contract administration cost of $0.08 per gallon ($0.05-0.08 per gallon depending on the contract and the volume involved). Thus for purposes of this investigation, the best estimate of unit cost for re-refined oil is $2.66 per gallon; which is less than the $3.00-$3.50 depot cost of virgin oil but higher than the $2.47 direct purchase cost.

The savings attendant to combustion of used oil as a fuel supplement is assumed to be equal to the base price of fuel oil, which has been $0.80 to $1.10 per gallon. However, the true savings are actually much less because the used oil must be pretreated, separated sludges must be disposed, equipment must be maintained, and oil burners must be modified. In addition, contaminants such as water have a negative impact on the BTU value. A true cost comparison would involve these and other considerations and is beyond the scope of this study. Fort Benning, an installation which burns used oil, estimates the actual cost savings at only $0.40 per gallon, before collection costs are deducted. When the cost of re-refining is combined with a 40 cent per gallon cost savings for burning of used oil, the total of $2.87 (true cost of recycling versus burning) is between the depot and direct purchase price of virgin oil. If the price of collection is also included the cost incentive to re-refine is obvious.

Anticipated future environmental regulations may limit or prohibit the consumption of used oil as a fuel supplement. For example, recently proposed legislation in the State of New York would limit the concentrations of lead and halogens in fuel oil to levels far lower than are present in used oil (even at a 1:5 dilution).

DoD POLICY

The current DoD used oil policy is both favorable to re-refining and adequate for control of the disposal of used oil. However, as disclosed in the GAO report, the DoD policy is not uniformly followed at all installations. While re-refining is economically justifiable based upon current DoD installation practices, the consistent enforcement of the existing policy would result in the more cost-effective reuse of this oil. The burning of fuel oil —as long as it continues to be environmentally acceptable-- should be limited to specific situations in which re-refining can be shown to be uneconomical.

From a more fundamental standpoint, waste oil collection practices in DoD are in need of improvement segregation should be used to minimize contamination. Although the collection and quality assurance of used oil is the responsibility of each generating installation, the DoD is charged with providing guidance through policy. Several options are available to minimize contamination and maximize re-refining. One option would be to educate all personnel as to the advantages of used oil segregation, a practice applied sucessfully by the State of North Carolina in their recycling program. According to the DPDS the key to good collection (quantity and quality) is in the attitude of the installation commander and the chief of maintenance. It is essential to involve these individuals in all aspects of planning and implementing an oil recovery program at an installation. It is also necessary to assign responsibility for collection at a level of command sufficiently high to ensure policy enforcement.

Among the most important options is the development of an installation incentive program. To define a suitable incentive program it is first necessary to define the boundary conditions (what can and cannot be changed) within existing DoD policy and practices. Such an investigation is beyond the scope of this study; however, several conceptual incentives are presented for consideration. The most obvious incentive is to reward the installation directly by cash savings in the purchase of lubricating oil. This program would involve the assignment of credits based upon the volume and quality of used oil collected; the credits would be used towards the purchase of re-refined oil. Installation needs in excess of the credits would have to be met by the purchase of higher priced virgin oil. In addition the cost of disposal of heavily contaminated oil (hazardous waste) would be directly billed to the installation rather than paid through DPDS funds, thereby providing an incentive to minimize contamination. An additional incentive would be provided if the savings were passed down to the company level. This could involve improvements in housing, recreation, or working conditions (garages). It is imperative that the personnel involved in collection be allowed to see tangible rewards of improved collection practices.

PILOT STUDY

This study was intended to determine the overall feasibility of re-refining within the DoD. In the course of this investigation it was necessary to make many simplifying assumptions. As discussed previously the target economic volume of oil required to justify re-refining and the optimum geographic radius for oil collection are dependent on local factors and are thus site specific. The data base developed for this report is inadequate for that determination. An additional study is needed to obtain the local data (installation, transportation, and re-refining) required for that determination. Results of the additional study should be utilized to conduct a pilot scale demonstration to obtain the operating experience necessary for a full-scale DoD operation. Attempts to initiate a full-scale operation or define policy without the benefit of pilot experience are viewed as unrealistic.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following conclusions were developed from this investigation:

- Re-refined lubricating oil has been proven to meet military specifications.
- The re-refining of DoD's used lubricating oil may be economically feasible under selected conditions.
- The re-refinery capacity exists today on a decentralized, regionalized, or centralized basis for handling the quantities expected from a DoD oil recovery program.
- The cost of transportation to a centralized re-refinery serving the continental United States would raise the total cost of a gallon of re-refined oil to uneconomical levels.
- The added cost of true closed-loop re-refining (as compared with quasi-closed loop) is unjustifiable from a quality assurance standpoint.
- The target economic volume of oil required for re-refining and the optimum geographic radius for used oil collection are based upon local factors and cannot be generalized.
- Total participation of all installations in a re-refining program is not cost effective since low volume oil users increase the unit cost of re-refined oil.
- Increasing the efficiency of oil collection (volume and quality) will reduce the unit cost of re-refined oil.
- Although current DoD policy encourages re-refining practices, additional policy development and implementation as well as improved facilities are needed in the areas of collection and segregation of used oil.
- The energy cost to produce a gallon of re-refined oil meeting military specifications is approximately one-fourth that required to refine virgin crude to produce a gallon of military specification oil.
- At the installation level, increased command emphasis, education and an incentive program based upon quantity and quality of oil collected will increase capture and minimize contamination.

RECOMMENDATIONS

The following recommendations are based upon the findings of this investigation:

- DoD used oil policy should be uniformly enforced.
- DoD collection practices should be improved by policy modifications which provide installation incentive and education programs.
- An additional study should be undertaken to collect the detailed local data needed to determine the target economic volume and optimial geographic oil collection radius for re-refining.

- The recycling and re-refining of used oil should be demonstrated on a pilot basis at a large user installation, or several installations based upon the above mentioned study, to collect the detailed operating experience necessary for a full-DoD operation.
- The long-term contracting provisions of the Military Construction Codification Act (PL 97-214) should be exploited to permit 4 to 8 year re-refining contracts to amortize the cost of qualification of process and product.
- A spot quality test should be developed for used oil at the point of collection.
- An installation cash-incentive program based on the cost differential between re-refined and virgin oil should be developed.

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APPENDIX A

COST FUNCTION ASSUMPTIONS

I. OUTLINE OF SYSTEM REQUIREMENTS - COLLECTION AND TRANSFER

1. Sources:

1.1 Define sources as locations accumulating, say $\geq$5% of consumption in a region or a minimum 1,000 gallons/year.

1.2 At each source, assume that a minimum 2-tank storage/accumulation system is needed,

- o one tank only for crankcase oil
- o second tank for "all other".

1.3 Size tank systems at 1,000 gal/tank or 5,000 gal/tank depending on scale; else provide drum storage pad.

1.4 Assume all tanks are underground installations with gravel bedding, etc.

1.5 Assume pick-up frequency is every six months; size of installation is based upon scale.

2. Truck haul:

2.1 Assume trucks are provided by contractor and used on a "milk route" basis five days per week during each of two collection periods per year.

2.2 Assume further that: all collection in each period is accomplished over a two-week period, by bulk tank trucks capable of carrying 6,000-gal payload (18-wheelers); and that the number of trucks required will vary with the volume to be collected. This allows us to estimate costs on a per-hour basis.

2.3 All trucks will carry pumping equipment and can empty below-ground tanks on a self-contained basis.

2.4 All drummed oil will be emptied by a local pump system.

2.5 All truck hauls will be emptied into dedicated storage tanks at either a railhead location (for haul to a Level Two or Level Three re-refinery) or else by truck to a Level One re-refinery.

2.6 For purposes of estimating truck productivity, assume that a truck is operable as follows:

- o one hour per source for loading
- o one hour for unloading
- o 25 mph between sources
- o 50 mph over the road
- o 10 hour day, terminal-to-terminal

3. Re-refinery plants: assume oil storage tanks are part of physical plant; allow one week off-loading.

4. Railhead terminal:

4.1 Assume that dedicated tankage is available on an interim basis to allow accumulation of oil over the two-week-per-quarter collection period.

4.2 Assume that tank cars containing 35-ton payloads (say 10,000 gallons) are filled and moved in unit trains to the re-refining plant; the demurrage time is one week at the railhead terminal and one week at the re-refinery.

II. ESTIMATED COSTS BY SOURCE

"Source"-related improvements are assumed to be as follows, in each case with the appropriate spill prevention and control measures incorporated:

Generation (crankcase oil)	Use
≤ 10 drums/6 months (1000 gal/6 months)	Drum storage pad, concrete with roof, 10 ft x 3 ft
≤ 2000 gal/6 months	Use 2, 1000-gal tanks
≤ 10,000 gal/6 months	Use 2, 5000-gal tanks

1. Drum storage pad: concrete pad with shed roof; curbs to contain spillage; sump.

1.1	Concrete in place: 10 ft x 3 ft x 8 in	0.74 cu yd
	0.74 cu yd x $600/cu yd =	450
1.2	Roof @ $15/sq ft =	450
1.3	Appurtenances (pump, etc.)	600
	SUBTOTAL, say	1500
1.4	Overhead @ 15%	225
1.5	Profit @ 10% (of 1725)	175
1.6	TOTAL	1900

2. Tankage (2 @ 1,000 gallon each):

2.1	Tankage @ $2/gal, 2 x 1,000 x 2 =	$4,000
2.2	Foundation @ 5 cu yd concrete @ $300 =	1,500
2.3	Appurtenances @ 8% of $5,500	440
	SUBTOTAL	5,940
2.4	Overhead @ 15%	$ 890
2.5	Profit @ 10% (5,940 + 890)	680
2.6	TOTAL	$7,510

3. Tankage (2 @ 5,000 gal ea):

3.1	Tankage @ $1.60/gal, 2 x 5,000 x 1.60 =	16,000
3.2	Foundation - 20 cu yd @ $300	6,000
3.3	Appurtenances @ 8% of $22,000	1,760
	SUBTOTAL	23,760
3.4	Overhead @ 15%	3,560
	SUBTOTAL	27,320
3.5	Profit @ 10%	2,730
3.6	TOTAL	30,050

4. Cost per gallon: assume annual cost of owning and maintaining storage facilities equals 5% of first cost, and annual yield equals 3 x design storage capacity. (Does not imply three pickups/year, only that total capacity may be utilized.)

4.1 Drum storage: cost = ($1,900 x 0.05)/(3.0 x 250)
= $0.13/gallon

4.2 two 1000-gal tanks: cost = ($7,510 x 0.05)/(3 x 1000)
= $0.13/gallon

4.3 two 5000-gal tanks: cost = ($30,050 x 0.05)/(3.0 x 5000)
= $0.10/gal

∴ Plot and use equation of the line.

III. ESTIMATED COST BY TRUCK HAUL

The truck haul cost analysis is structured to allow determination of unit cost ($/gallon) for pickup and transport. Four operating patterns are assumed:

#1 Local "milk route," moving an average 100 miles per day, making six pickups totalling say 6,000 gallons, returning to plant or railhead as needed during the day and each night; average haul distance is say 25 miles.

#2 Four pickups daily, totalling 5,000 gallons, moving 100 miles in metro area @ 25 mph and 50 miles @ 50 mph to plant or railhead, returning to base each night; average haul distance is say 75 miles.

#3 Four pickups daily, totally say 4,000 gallons, moving 50 miles in metro area and 100 miles to plant or railhead, returning to base each night. Average haul distance is say 125 miles total.

#4 Two pickups daily, totalling say 4,000 gallons, moving 50 miles in metro area and 150 miles to plant or railhead, returning to base each night. Average haul distance is say 175 miles.

The cost analysis strategy is to: estimate costs on a useful life basis; then allocate the lifetime costs for the number of gallons hauled in each operating pattern to obtain a unit cost.

1. Equipment: Tractor-trailer rig (18-wheeler) hauling 6,000-gallon pay load.

2. Assumptions:

- o Tractor-trailer remain as one unit
- o 90% availability
- o 25% driver overtime (10-hr days)
- o Contract hauler interest @ 15%
- o Tractor cost = $75,000; life = 10,000 hours
- o Trailer cost = $50,000; life = 20,000 hours

3. Hauled gallonage by operating pattern-per tractor

#1 - 6000 gal/10 hr x 10^4 hr = 6 x 10^6 gal over 25 mi
#2 - 5000 gal/10 hr x 10^4 hr = 5 x 10^6 gal over 75 mi
#3 - 4000 gal/10 hr x 10^4 hr = 4 x 10^6 gal over 125 mi
#4 - 4000/gal/10 hr x 10^4 hr = 4 x 10^6 gal over 175 mi

Note that hauled gallonage per trailer is double the above; also, 10,000 hour operation @ 2600 hr/year is about four years, for trucks; eight years for trailers.

4. Cost of Ownership (Fixed Costs)

		Truck	Trailer	Total
1.	Base investment	$75,000	$50,000	$125,000
2.	Fed. invest. tax credit (10% + 10%)	15,000	10,000	25,000
3.	Net investment	60,000	40,000	100,000
4.	Resale value @ 20%	12,000	8,000	20,000
5.	Net deprec. amount	$48,000	$32,000	$80,000
6.	Hourly deprec'n ($/hr)	4.80	1.60	6.40
7.	Interest on net investment @ 15%/yr for 2600 hr/yr	3.46	2.31	5.77
8.	Taxes @ 5% of base	1.44	0.96	2.40
9.	Insurance @ 6.5% of base	1.88	1.25	3.13
10.	Total hourly fixed cost (#6, 7, 8 and 9)	$11.58	$6.12	$17.70

5. Cost of Operation (Variable Costs)

	Truck	Trailer	Total
11. Repairs, Maint. & Supplies @ 2/3 of #6 (hrly deprec'n)	$3.20	$1.05	$4.25
12. Fuel @ 8 gph @ $1/gal	8.00	----	8.00
13. Lubricants and filters @ 15% of #12	1.20		1.20
14. Total hrly operating costs	$12.40	$1.05	$13.45

6. Cost of Labor

15. Driver salary (hrly average including 25% OT)* @ 9.90	----	----	9.90
16. Salary overhead @ 25%			2.42
17. Total hourly labor rate			$12.32

7. Summary of Hourly Costs

10. Fixed costs	$17.70
14. Operating costs	13.45
17. Labor cost	12.32
18. Subtotal	43.47
19. Overhead @ 10%	4.35
20. Subtotal	47.82
21. Profit @ 8%	3.83
22. Total hourly cost	$51.65

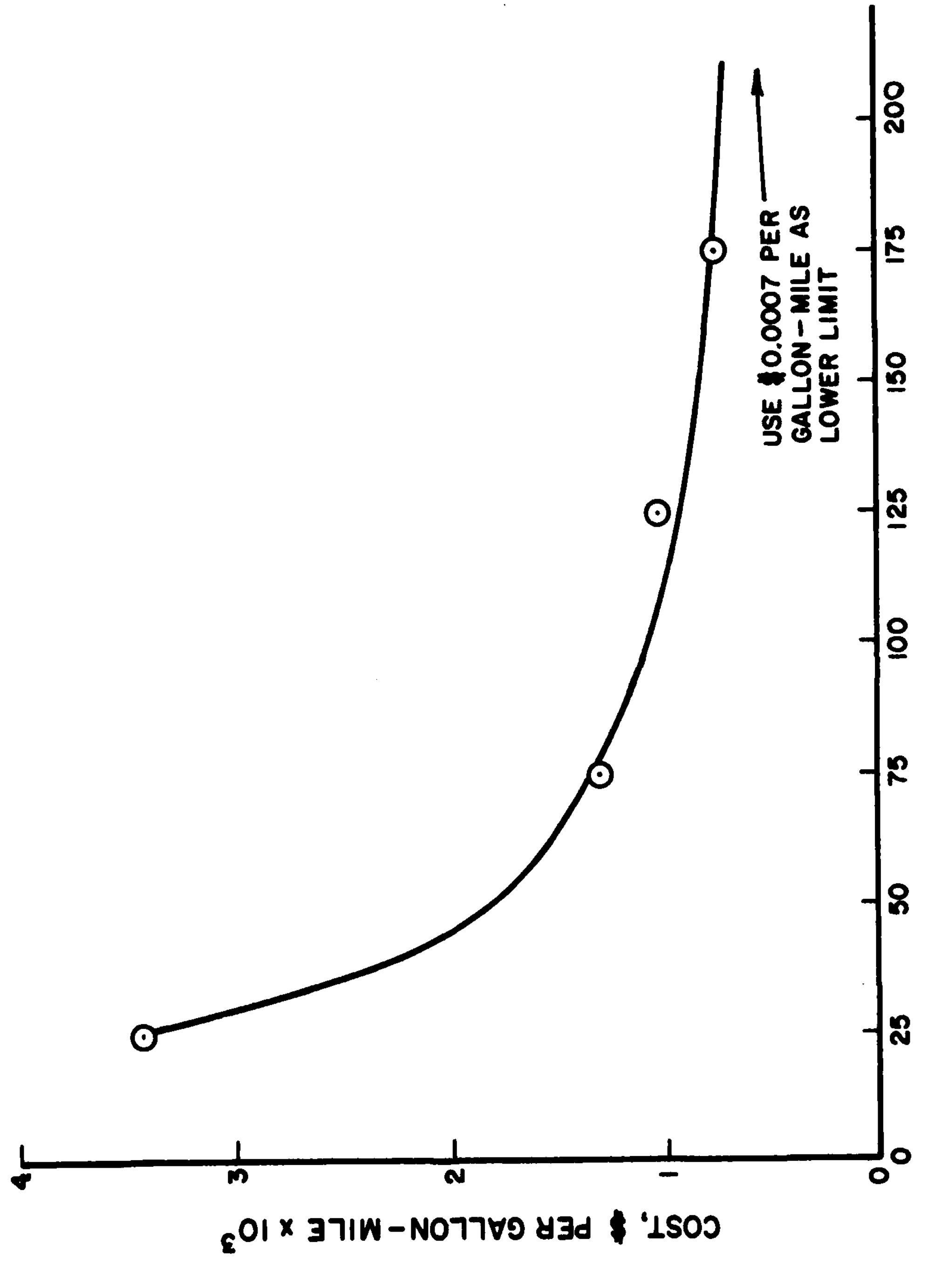
8. Costs by operating pattern (10^4 hr; $51.65/hr)

Pattern	Miles	Gallons	Cost/gal	Cost/gal-mi	Cost/ton-mi
#1	25	6×10^6	$0.0861	$0.00344	$0.860
#2	75	5×10^6	0.1033	0.00138	$0.345
#3	125	4×10^6	0.1291	0.00103	$0.258
#4	175	4×10^6	0.1291	0.000738	$0.185

*Ton = 250 gal; gal = 8.0 lb.

Notes: Above costs include collection stops as well as haul costs.

*Base salary @ $9/hr; 8 hr base + 2 hr OT = $9.90/hr avg.



COST, $ PER GALLON-MILE x 10^3
0
1
2
3
4
HAUL DISTANCE, MILES (ONE-WAY)
0
25
50
75
100
125
150
175
200
USE $0.0007 PER GALLON-MILE AS LOWER LIMIT

IV. RAILHEAD TERMINAL

The railhead terminal is presumably used on a year-round basis for storage and throughput of bulk commodities, solid, liquid, etc. As a result, a DoD oil re-refining operation would generate shipments passing through, so to speak, in the following steps:

(1) Offloading from 6,000-gal trucks into storage tanks that have been cleaned of prior contents.

(2) Storage until tank cars of 10,000-gallon payload are assembled and filled, then moved out. Trucks arrive on a two-week schedule; cars are loaded in one week.

(3) Re-refined oil is then brought back through the terminal, stored and hauled out by truck, with rail car unloading on a one-week basis and truck loading on a two-week basis.

It is also assumed that the terminal is of sufficient size that the waste oil throughput is a modest fraction of the total throughput of a bulk liquid handling terminal. It is further assumed that the terminal is capaole of handling at least 1 million gallons per day of bulk liquids, i.e., the loading and unloading of about 20 tank cars @ 60,000 gallon capacity each day.

The approach used below is to estimate the fixed and variable throughput costs of the terminal on a per-gallon basis, then factor-in markup based upon an assumed utilization factor and a profit allowance.

1. Equipment: Assume yard has 1500 ft of spur storage area, pump station, 10 mg storage capacity in 10, one mg tanks, unloading and loading station with spill prevention, control and containment, full site improvements, etc.

2. Assumptions:

- o Storage fee is based on use of one 1 mg tank for 2 weeks
- o Other costs are allocated on basis of 1 mgd throughput, 260 days annually, and a 75% "productivity" factor.
- o Interest @ 12%.

3. Capital Cost Estimate

a.	Site improvements (rail sidings, dock, parking areas, maintenance, adm, etc.)	\$2,000,000 (@ 30-yr life)
b.	Tank farm: 10 tanks @ 1 mg each @ \$0.40/gallon of capacity, including earthwork, foundation, reinforced concrete, controls, pumps, etc.	4,000,000 (@ 20-yr life)
c.	Machinery: two yard engines at \$75,000 each.	150,000 (@ 20-yr life)

d. Totals: \$1,500,000 @ 30-yr life
\$4,150,000 @ 20-yr life

4. Amortized cost @ 12%

- o $1,500,000 x 0.12414 = $186,210/yr
- o $4,150,000 x 0.13388 = $555,602/yr

$741,812/yr

5. Labor Schedule (260 day per year schedule)

Class'n	No.	Base Salary	Total Burdened Salary
Adm	2	$24,000/yr	(@ 25% burden) 60,000
Liquid transfer	4	18,000	90,000
Maintenance exc. site	2	15,000	37,500
Site maint.	2	12,000	30,000
Security	2	15,000	37,500
			$255,000/yr

6. Operating Costs

Repairs, Maintenance & Supplies @ 15% of amort. cost	$111,300/yr
Fuel - 10 gph x 260 x 8 hr/da @ $1.00/gal	20,800
Utilities & Hazardous Waste Disposal	100,000
	$232,100/yr

7. Total Costs

Subtotal #4, 5, & 6; say	$1,228,800/yr
Overhead @ 10%	122,900/yr
Subtotal	1,351,700/yr
Profit @ 10%	135,200/yr
	$1,486,900/yr

8. Allocated Costs

- o Assume storage capacity utilization cost is based upon % of time assigned to a user, fraction of annual facility cost assignable to the tankage, and productivity factor.
  - oo Each storage tank is assumed to be allocated 7% of facility costs, productivity is 75%, and assumed quantity stored over two-week period is 800,000 gal, or 80% of capacity
  - oo Thus, storage tank utilization cost
    = (0.07)(1,486,900)(2/52)(1/0.75)
    = $5,337
  - oo And, cost per gallon stored
    = $5,337/800,000
    = $0.00667 per gallon ($1.67/ton)

- o Assume nonstorage terminal costs are 1.00-(10)(0.07) or 30% of user cost, and are allocated based upon throughput and productivity factor.

  - oo Thus, nonstorage terminal costs
    = [(0.30)(1,486,900)]/[(1,000,000)(260)(0.75]
    = $0.00229 per gallon ($0.57/ton)

- o Therefore, assume total railhead terminal costs
  = $0.00667 + 0.00229
  = $0.00896 say <u>$0.01 per gallon</u> ($2.50/ton)

V. RAILROAD TRANSPORT COSTS

Rail transport costs are regulated under ICC, and tariff structures are so complex that special consultants must be retained to obtain exact tariffs.

To develop working estimates of rates applicable to bulk waste oil transport, Transportation Traffic Services, a tariff consultant was hired to develop costs for shipment of used oil.

The Chief of Transportation of DLA, Mr. Gary Beatty advised that 10,000 DoD rail tank cars are available. Exact details on costs would have to be worked out at the time the cars were required. However, for purposes of this study, we can reduce the private sector tariff costs by 20% since under Title 49 US Code Section 1071, a carrier can quote a reduced rate to the US Government.

It was further assumed that the return of re-refined oil would be equal to the cost of shipping used oil. In actuality, re-refined oil would be packaged in 5-gallon cans or 55-gallon drums on pallets, not tank cars; however, this would require a flat car and different tariff structures - the cost of estimating tariffs was beyond the project budget.

ENGINEERING-SCIENCE

TWO FLINT HILL • 10521 ROSEHAVEN STREET • FAIRFAX, VIRGINIA 22030 • 703/591-7575

TELEX 67-5428

17 March 1983
ES Job #36088

Mr. Mark Hartsell
Transportation Traffic Services, Inc.
1120 Wayne Avenue
Silver Spring, Maryland 20910

Subject: Development of class rates for rail shipment of bulk waste oil

Dear Mr. Hartsell:

As a follow-up to our telecon today, please accept this letter as authorization to develop class rates for the rail shipment of bulk waste oil, as described below. This authorization is for your organization's services at a rate of $32 per hour, up to a limit of $125.

Class rates and approximate mileages are needed so that we can develop a transportation cost versus distance curve. We suggest the following origin-desitnations for this purpose:

Origin	Destination
Baltimore, MD	Richmond, VA
Baltimore, MD	Pittsburgh, PA
Baltimore, MD	Chicago, IL
Baltimore, MD	Denver, CO
Baltimore, MD	Los Angeles, CA

Please let me know if additional information is required, and please send your invoice to me, attention P.O. No. 36088.

Sincerely yours,

ENGINEERING-SCIENCE

Timothy G. Shea

Timothy G. Shea, Ph.D. P.E.

TGS/alo

Call: Vernon Marquardi
Transpo Traffic
565-0500

Rate Data: Class 35, 26,000 lb/car min.

Origin	Destination	¢ Per 100 lb	Miles
Balto	Chi	678	767
Balto	Pitts	420	313
Balto	Rich	317	165
Balto	Denver	965	1750
Balto	L.A.	1675	2969

Rate basis numbers to all exc. L.A. reflect shortest route.

Railroad Rates
Class 35, 26,000 lb/car min (3,500 gal)

Origin	Dest.	Miles	¢/100 lb	¢/ton	$/gal	$/gal-mi
Balt	Rich	165	317	6340	0.2536	.001537
Balt	Pitts	313	420	8400	0.336	.0010735
Balt	Chi	767	678	13,560	0.5424	.0007072
Balt	Denver	1750	965	19,300	0.772	.0004411
Balt	L.A.	2969	1675	33,500	1.340	.0004513

Reduce by 20% for U.S. Gov't, Title 49 U.S. Code. Sec. 1071; therefore, rates are:

Miles	$/gal
165	0.20288
313	0.2688
767	0.43392
1750	0.6176
2969	1.072

AD-A136 641 FEASIBILITY OF DEPARTMENT OF DEFENSE USED LUBRICATING OIL RE-REFINING(U) CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL J KUBAREWICZ ET AL. DEC 83 2/2

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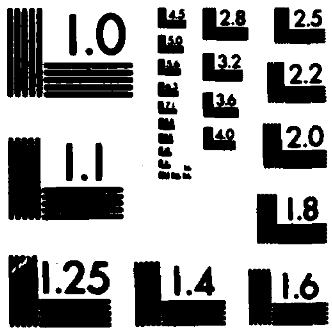

MICROCOPY RESOLUTION TEST CHART
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APPENDIX B

SAMPLE CONTRACT AND MANAGEMENT ESTIMATES

This appendix addresses the elements of a form of contract for procurement of DoD used oil re-refining services, and also examines the estimated DoD personnel burden for administration of a DoD used re-refining system. The organizational framework within which such a system has been evaluated herein as follows:

1. The accumulation of used oil at DoD sources is done under the direction of DoD personnel.

2. Used oil is collected twice yearly and hauled to the re-refinery directly by truck or indirectly by truck to a rail terminal for rail shipment to the re-refinery.

3. The used oil is collected into lots and sampled and analyzed on a lot basis so that a re-refining plan can be formulated.

4. All truck haul, rail terminal and rail transport services are provided by contractors other than the re-refiner. That is, the re-refining contract is assumed to pertain only to the re-refining of used oil received at the re-refinery gate.

5. The re-refining is done on a closed loop or quasi-closed loop basis, whichever is more cost-favorable to the government.

6. All re-refined oil is packaged in either 5-gallon or 55-gallon containers, to be specified in the schedule set forth in the contract.

The following elements of a contract for re-refining services were outlined using the contract format of Solicitation No. DLA 710-83-R-0006.

A. GENERAL

1. Property Accountability: define property record requirements and procedure for review of contractor's records. Define need/role for a Commercial Surveillance Firm Representative (CSFR).

2. Storage Areas: define security requirements for storage areas to be provided if used for (a) quasi-closed loop and (b) closed loop storage. Define approval procedures for storage areas proposed by contractor.

3. Definition of Government Property: define what is and isn't government property at each step in the contractor's re-refining operation. Materials to be addressed include: raw used oil, product oil and waste fractions.

4. Government Representatives to be Present: define the specific occasions when government representatives must be present, e.g., during movements of oil to/from storage areas, when additives are added, during quality control/quality assurance (QC/QA), sampling and analysis, etc.

5. Duties of Defense Contract Administration Service (DCAS): define activity periods and duties for CSFR/DCAA (see also Paragraph A.4 above).

B. WORK REQUIREMENTS

1. Contractor to provide facilities, labor, material, equipment, supplies, security, and re-refining capacity for all used oil of DoD origin received F.O.B.

2. Contractor to provide QC/QA for any re-refined oil prior to packaging.

3. Contractor to provide packaging containers labelled to DoD specifications; contractor to package oil in 5 or 55-gallon containers as per military specification MIL-STD-290 in accordance with schedule provided by DoD at time of shipment to re-refinery.

4. Contractor to maintain technical expertise to re-refine oil to specifications.

5. Contractor to present a "Plan for Re-refining Operations" (PRO) for each shipment, to be approved in advance by the designated government representative. The PRO is to contain a schedule of all activities.

C. DESCRIPTION/SPECIFICATIONS

1. Government to deliver to the contractor, FOB, his re-refinery, used oil deemed suitable for re-refining into an acceptable product. Used oil is to be supplied in truck-trailer or rail tank car lots. Each lot is to be gross weighed upon receipt in the presence of a government representative, and a lot number assigned. Records are to be prepared.

2. Government to accumulate the material, and notify the contractor within (   ) days of when a shipment is to be made, and how much is being shipped, and where the re-refined oil is to be delivered.

3. Contractor shall accept used oil within (   ) hours of delivery. The schedule for re-refining set forth in the PRO is to be followed.

4. Contractor shall have a facility capable of receiving, securely storing and maintaining the integrity of the government-supplied waste oil. The government representative shall approve same.

5. Contractor must have the technical and production competence to process the oil in accordance with accepted re-refining practices. The government representative shall be present, etc., in accordance with . Sampling shall be in accordance with procedures set forth in MIL-STD-290.

6. Contractor shall recycle or dispose of all byproducts and waste products, including bottom sediments and water in an environmentally acceptable manner.

D. PROCESSING SCHEDULE AND PROGRESS REPORTS

1. Contractor shall submit a PRO within ( ) days after notice of shipment by government representative.

2. Contractor shall submit monthly Receiving/Production Reports as required providing the information set forth in ___________.

E. ADMINISTRATION AND PAYMENT

1. Payment shall be made upon delivery and acceptance of the refined oil FOB the re-refinery.

2. The contractor shall prepare an invoice which must cite the quality of oil processed and all other pertinent information required by ___________. Original invoice will be forwarded to ___, with information copies to ______________.

F. PROJECT OFFICE

1. The following is designated as the Project Office:___________.

G. COMMERCIAL REPRESENTATIVE (OR DCAA)

1. The Commercial Surveillance Firm retained by the government is ______________.

H. DEFINITIONS

1. Define all pertinent technical and contractual terms. Technical terms include: used oil, re-refining, gross yield, byproducts, etc. Contractual terms include: administrative officer, procuring contract officer, and commercial surveillance firm representative.

I. SAMPLING PROCEDURES

1. Sampling schedules and procedures for all used and re-refined oil must conform with MIL-STD-105, MIL-L-46152B, and MIL-L-2104D.

J. NO FAULT CLAUSE

1. The government cautions that the used oil shipped for re-refining may be corrosive, reactive, ignitable, or exhibit other

hazardous or toxic properties. The government assumes no liability, etc. The contractor agrees to hold harmless and indemnify the government, etc.

K. CONFLICT OF INTEREST

1. This clause is to define what constitutes a conflict of interest between the re-refiner and the surveillance contractor in terms of sampling and analytical services.

L. QUALITY CONTROL/INSPECTION SPECIFICATIONS

1. Scope: establishes minimum requirements only; applicable to all contractors and their subcontractors.

2. Requirements: contractor shall provide a quality control program from time of receipt to final delivery. Contractaor's program shall be prepared within (   ) days of notice-of-award, and be approved by ______________. Any changes in the quality control program must be submitted in writing to ____________ for approval. The quality control program must meet minimum standards as set by the pertinent military specifications.

3. Measuring and Sampling: the contractor shall maintain scales for determining gross weight of deliveries and shipments. All sampling equipment shall be maintained in accordance with ___________________.

4. Production/Process Controls: controls shall be maintained by the contractor to ensure that production runs shall produce acceptable re-refined oil. The process controls shall be in written form and available to the government representative in order that periodic evaluations of compliance and adequacy can be made. Government recognizes that proprietary rights and house methods are an integral part of the re-refining industry, etc.

5. Inspection Status/Identification: contractor to maintain a system.

6. Damaged Government-furnished Materials: contractor shall segregate and report any shipments found unsuitable for processing under the terms of this contract.

7. Government Inspection at Subcontractor or Vendor Facilities: government reserves the right to inspect at source supplies, production facilities, etc., as represented in cases wherein processing is not conducted, performed or completed at the prime contractor's facility, etc.

8. Government Review and Evaluation: the contractor's quality control system and the re-refined oil generated thereby shall be subject to the evaluation and verification by the government representative, etc.

M. PRODUCT SPECIFICATIONS

1. All re-refined oil produced as a result of this contract shall be in conformance with MIL-STD-290 (packaging) and either MIL-L-2104D, or MIL-46152B (quality).

ESTIMATED MANPOWER REQUIREMENTS

A preliminary analysis was made of the annual government manpower requirements to administer and implement a DoD oil re-refining system using the preceding form of contract. The estimate was developed assuming an annual volume of used oil varying from 1.0mm to 2.4mm gallons, and two processing cycles each year requiring 50 to 60 working days annually.

The estimate is presented in Table B-1 and the manhour requirements are classified in terms of contract administration, sampling and analysis, quality control and resporting and other functions. Also, three operational areas are considered: en route to the re-refinery, at the re-refinery, and at the depots/installations receiving the re-refined product.

The estimated manpower requirements for a 1.0 to 2.4mm gallon system are 900 mandays. Approximately 45 percent of this effort would be expended at the sources and en-route, and another 50 percent at the re-refinery locations. The functional requirements amount to about 10 percent for contract administration, 45 percent for sampling and analysis, 25 percent for quality control, and 20 percent for reporting. The cost burden for these manpower requirements amount to about $200,000 annually at an average manpower cost of $220 per manday, inclusive of salary costs, overhead and expenses. The impact of the estimated manpower requirement would amount to $0.03 to $0.05 per gallon of used oil, or $0.05 to $0.08 per gallon for re-refined oil. For purposes of the economic analysis of Chapter 6, a cost impact of $0.08 per gallon of re-refined oil is used.

TABLE B-1

ESTIMATED ANNUAL GOVERNMENT MANPOWER REQUIREMENTS
FOR A DoD OIL RE-REFINING SYSTEM

	MANDAYS by ACTIVITY				
Operational Area	Contracts Admin.	Sampling & Analysis	Quality Control	Reporting; Other	Total Mandays
En route to re-refinery					
o On-site collection[1]			90		90
o Hauling[2]	20			20	40
o Marshalling[3]	20	200	50	10	280
					410
At re-refinery					
o Receiving[4]				40	40
o Storage[5]				40	40
o Processing[6]	40	60	60	20	180
o Blending[7]		120	20	20	160
o Packaging			10		10
o Shipping				20	20
					450
At depots					
o Receiving				20	20
o Inventory control				20	20
					40
Totals	80	380	230	210	900

TABLE B-1

(Notes)

Notes:

1 Allow one manday/installation - year for training on collection, segregation, etc.

2 Hauling by contractor forces; assume ~ 1,000 truck haul operations are required.

3 Marshalling is assumed to involve the aggregation of ~ 1,000 truckloads through a sampling analysis/QC procedure into 150 lots for shipment to the re-refinery.

4 Re-refinery receiving operations occur over four 2-week periods each year.

5 Storage operations will extend over an additional four 2-week periods each year.

6 Processing extends over 60 working days each year.

7 Assumes product acceptance testing takes place after blending.

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Kubarewicz, John
Feasibility of Department of Defense used lubricating oil re-refining / by John Kubarewicz, Timothy Shea, Walter J. Mikucki. -- Champaign, Ill : Construction Engineering Research Laboratory ; available from NTIS, 1983.
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1. Petroleum waste--recycling. 2. Lubricating oils. I. Shea, Timothy. II. Mikucki, Walter J. III. Title. IV. Series: Technical report (Construction Engineering Research Laboratory); N-171.

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