THE USE AND DISPOSAL OF ELECTRICAL INSULATING LIQUIDS

Prepared by Corporate Staff
General Electric Company
December 21, 1970

MONS 034119

THE USE AND DISPOSAL OF ELECTRICAL INSULATING LIQUIDS

Abstract

Electrical insulating liquids (EIL), their application and disposal are studied against a background of similar information relating to petroleum products in total. Lubricating oils are selected for particular attention because of their chemical and physical similarity to petroleum insulating liquids.

Naphthenic mineral oils are found to comprise over 80 percent by volume of the total usage of EIL. Polybutenes are second, at almost 10 percent. Thus, 90 percent of EIL are petroleum-based. Being relatively nontoxic and biodegradable, they represent no environmental threat when subjected to conventional secondary waste treatment.

The third largest-volume EIL group is the askarels, or polychlorobipheryls. This group has some toxic properties and contains members which have recently become suspect ecologically. Accordingly, the report contains recommendations regarding the control and disposition of askarels.

MONS 034120

INTRODUCTION

This study of the use and disposal of electrical insulating liquids has been undertaken in support of the objectives of the Electric and Nuclear Sub-Council of the National Industrial Pollution Control Council. Its purpose is to examine electrical insulating liquids (EIL) for their possible toxicological or ecological impact and, as appropriate, to provide information which may lead to advice concerning government programs which would facilitate private sector efforts directed at environmental improvement, or voluntary actions by industry. Specific areas of interest include pollution which may occur from the plants where EIL are used in manufacture of electrical apparatus, and that which may occur during use or disposal.

A variety of insulating liquids is used in electrical apparatus such as transformers, circuit breakers, capacitors, and high-voltage cable in order to optimize, for each application, a range of design parameters typified by dielectric strength, losses, dissipation factor, arc and flame suppression, heat transfer coefficient, and product life expectancy. Requirements and conditions to be met will, in a given instance, quickly narrow the practical options available to the designer down to a very few or even to a single fluid. For this reason it should be borne in mind that, even though a particular electrical insulating liquid may be characterized as containing the potential of contributing to the pollution of the environment, the socially-desirable and economically correct action may lie in the adoption of precautions and control measures rather than in the substitution of a material which would not perform the required function as well.

Representatives of many organizations, both in industry and in government (see, SOURCES OF INFORMATION), have contributed information and suggestions; their cooperation and helpfulness are acknowledged with thanks.

MONS 034121

1.0 Total Flow of Petroleum Products

Because a high percentage of the total volume of electrical insulating liquids is petroleum based, the use and disposition of EIL can best be understood against a background of the quantities of petroleum products used throughout the economy, and how they are disposed of.

Table No. 1 displays the quantities and uses of petroleum products in the U.S. for 1968 (the most recent year for which relatively complete data could be searched out). The quantity on this table of greatest interest is item 3.12, Electrical Insulating Oil. The quantity shown, 1.4 million barrels, is the total of naphthenic and polybutene EIL, and corresponds to 0.04% of "all oils."

1.1 Lubricating Oil

Lubricating oil (Table 1, Item 3.7) was chosen for a comparative study because of its similarity to electrical insulating grades of petroleum oil, and because data are available from which a reasonable estimate can be formed of what happens to lubricants throughout their life history.

Lubricants may be classified conveniently in two groups: automotive and industrial. Table No. 2 is an estimate of the usage, waste generation, and disposition of automotive lubricants throughout the country, and Table No. 3 presents similar data for industrial lubricating oils. A large portion of the waste generated is collected by scavenging firms, and the fate of this portion is indicated in Table No. 4. Table No. 5 summarizes the results of the investigation of lubricating oil waste practices. It will be noted that a little over half of all lubricating oil ends as waste, and of this half, more than half is simply dumped on the ground in one way or another -- as locally disposed waste, as road oil, in town dumps, etc.

2.0 Quantities and Usage of Electrical Insulating Liquids

Table No. 6 contains a breakdown of the principal uses of naphthenic mineral oil as an insulating liquid. The information on transformer and cable oils was derived from the market estimates of several oil producers (Reference: SOURCES OF INFORMATION, Item a-11). Switchgear (circuit-breaker) data and capacitor data were estimated from General Electric usage and assumed market position. The second column of data, that on field use, is a measure of the generation of waste oil during the use of the apparatus. The total, 8 1/2 million gallons, is equivalent to 0.8% of the waste lubricant oil shown on the previous Table (No. 5).

MONS 034122

Table No. 7 is similarly derived and presents an analysis of the total quantity of EIL according to the apparatus in which it is used. The first two entries, naphthenic oil and polybutene liquid, were added together to produce the total recorded as Item 3.12 in Table No. 1 (i.e., 57.26 million gallons is equal to 1.36 million petroleum barrels). This subtotal is 91% of the total estimated annual usage of EIL. The total is 63 million gallons, or 1.5 million barrels.

The chlorinated benzenes shown are not used alone, but as diluents for the askarels, in some applications. The category, "other", includes relatively small quantities of such materials as dibutyl sebacate and silicone oil, used in specialized apparatus of low production quantities.

Specifications and general characterization of the principal EIL are shown in Table No. 8.

3.0 Toxicology

Mineral oils and polybutenes are essentially nontoxic. The only reported danger is from inhalation of vapor or mists, in which the maximum allowable concentration is 5 parts per million.

The askarels are regarded as somewhat toxic with regard to ingestion, skin absorption, and inhalation. The maximum allowable concentration for inhalation is 0.5 parts per million. Because of the low volatility, there is little chance of harmful atmospheric concentration being developed at ordinary temperatures. Askarels may produce local skin irritations in susceptible individuals, but ordinary cleanliness constitutes an adequate safeguard against such effects. A drop of castor oil will neutralize any irritation caused by contact with the eyes. The response to excessive ingestion is to induce vomiting and see a physician.

4.0 Ecology

Mr. Claude E. ZoBell has written,
"Mineral oils are susceptible to microbial oxidation, and certain fractions undergo autoxidation. This seems to be Nature's way of remedying oil pollution in soil as well as in sea water... In controlled laboratory experiments, we find that oil-oxidizing bacteria convert an average of 30-40 percent of the carbon content of hydrocarbons into bacterial cell substance or protoplasm." (Ref. b-12).

Mineral oils and polybutenes are not known to have a long time effect upon the ecology. In the short term, the effect of large scale dumping of hydrocarbons has been well advertised in the press. Small amounts have no detrimental effects. The materials, in short, are biodegradable, exist naturally in the ecology, and are not thought to be a problem in the context of this study.

MONS 034123

The askarels, particularly those with more than 50% chlorination, have recently been identified as a possible ecological threat to marine and bird life. The attention of the industry was called to this subject in a widely distributed letter from the Monsanto Chemical Company (sole U.S. producer), under the date of February 18, 1970. Askarels introduced into the ecology are believed to act in a manner somewhat analagous to the persistent pesticides, being concentrated in successive links of the food chain.

For the short term, effects of askarels may be kept from the environment by application only in closed systems (of which transformers and capacitors are examples) and by the exercise of suitable precautions in the disposition of waste, as outlined below. For the longer term, the manufacturer is working to develop modified chlorinated biphenyls which will be biodegradable. This means that even if minute quantities are released to the environment by accidental spills, it will be possible to remove them from waste water streams in conventional secondary treatment facilities. (Reference b-15, quoting a letter from Monsanto to Congressman Ryan, June 30, 1970.)

5.0 Recommendations

In view of the suspected ecological hazard presented by polychlorinated biphenyls, it is recommended that the electrical industry employ the following guidelines in their use:

1. Provision is to be made for qualified destruction of PCB waste materials, such that there will be no release of materials to the atmosphere or to ground or surface water significant from the standpoint of toxicity or adverse ecological impact. Initially, the only process which appears to meet these requirements is incineration under carefully controlled conditions. With proper adjustment of temperature, residence time in the incinerator, and other parameters, products of combustion will be limited to HCl, CO_2, and H_2O (in the form of steam). The hydrochloric acid may be absorbed in a scrubber and the resultant solution neutralized with lime to form calcium chloride solution, $CaCl_2$. In the process described, the only effluents to the environment will be a plume of steam, carbon dioxide, and brine.

2. All liquid waste is to be held in impervious containers pending disposal.

3. Solids contaminated by PCB's are to be held in impervious containers pending disposal or purging. Purging may be accomplished by cleaning with proper fluids. The resulting contaminated liquids may be incinerated as above.

As a result of the Monsanto letter to the industry cited above, the industry is believed to have progressed a long way toward the implementation of these recommendations.

QUANTITIES AND USES OF PETROLEUM PRODUCTS IN THE U.S., 1968

Use Category — Millions of 42-gallon Barrels

	Kero-sene	Distil-late	Resid-ual	Gaso-line	Jet Fuel	Other	Total	%
1.0 Heating and Energy Conversion								
1.1 Electric Utilities		3.0	185.0				188.0	
1.2 Heating	76.2	512.0	173.0				761.2	
1.3 Industrial		45.8	135.7				181.5	
1.4 Oil Companies		9.4	39.3				48.7	
1.5 Off H'w'y Diesel		49.5					49.5	
1.6 Military (excl. Jet)		12.6	35.0				47.6	
1.7 Fuel for all other	26.7	12.6	8.3				47.6	
Total	102.9	644.9	576.3				1324.1	27.0
2.0 Transportation								
2.1 Railroads		84.1	4.3				88.4	
2.2 Highway Diesels		127.3					127.3	
2.3 Motor Vehicles				1925.4			1925.4	
2.4 Piston Aircraft				30.6			30.6	
2.5 Jet Aircraft					349.4		349.4	
2.6 Ships bunk'd in US		18.2	87.6				105.8	
Total	0	229.6	91.9	1956.0	349.4		2626.9	53.6
3.0 Material Conversion and Other								
3.1 Liquified Gases						330.6	330.6	
3.2 Still Gas						149.8	149.8	
3.3 Asphalt						141.2	141.2	
3.4 Petrochem. Feedstocks						92.9	92.9	
3.5 Coke						76.3	76.3	
3.6 Ethane, Ethylene						55.2	55.2	
3.7 Lubricants						48.5	48.5	
3.8 Special Naphthas						27.0	27.0	
3.9 Not Elsewhere listed						16.4	16.4	
3.10 Road Oil						7.1	7.1	
3.11 Wax						4.4	4.4	
3.12 Electrical Ins. Oil						1.4	1.4	
Total	0	0	0	0	0	950.8	950.8	19.4
4.0 Grand Total	102.9	874.5	668.2	1956.0	349.4	950.8	4901.8	100.0

The basic reference for the fuel oils is b-4.2 (see SOURCES OF INFORMATION); for gasoline and jet fuel (a blend of gasoline, kerosene, and distillate), b-6; "Other", b-6, b-4.4, and a-11. Some figures from other sources have been adjusted to yield totals in "final summary", reference b-4.4.

MONS 034125

TABLE NO. 2

LUBRICATING OIL -- AUTOMOTIVE

ESTIMATE OF USAGE, WASTE GENERATION, AND DISPOSITION IN THE USA

(Following the pattern observed in the Commonwealth of Massachusetts)

1968

User	(1) User Distribution, %	(2) Calc. U.S. Usage at % in (1), Million Gallons	(3) % Ending as Waste	(4) Waste, Million Gallons	(5) % of (4) Collected	(6) Waste collected, Mil. Gal.	(7) Waste uncollected, Mil. Gal.	(8) Dumped on Ground Mil. Gal.	(9) Sewered, Mil. Gal.
Service Stations Performing Oil Changes	54.9	658	63	415	87.7	364	51	45	6
Other Svc. Sta.	1.6	19	0	0	0	0	0	0	0
Car Dealers, Garages	16.1	194	90	175	88.0	154	21	20	1
Fleet Operators	18.8	226	63	142	60.0	86	56	52	4
Do-it-yourself Oil Changers	5.4	65	63	40	0	0	40	37	3
Agriculture & Marine Users	3.2	38	50	19	0	0	19	18	1
Total	100.0	1200	--	791	--	604	187	172	15

The total U.S. usage, 1200 million gallons (28.6 million barrels) is derived from a 1967 survey by the Bureau of the Census -- see Sources of Information, reference b-7. The total was adjusted to 1968 usage by means of information in reference b-4.4. Percentage distributions and disposal patterns are drawn from a survey made by the Arthur D. Little Company in the Commonwealth of Massachusetts, reference b-3. Applying the Massachusetts pattern to the USA as a whole involves errors of unknown magnitude: a staff estimate by the FWQA yields a figure of 350 for the first entry in column (4) above (reference b-2), an estimate 15.7% below that derived here.

MONS 034126

LUBRICATING OIL -- INDUSTRIAL

ESTIMATE OF USAGE, WASTE GENERATION, AND DISPOSITION IN THE USA

(Following the pattern observed in the Commonwealth of Massachusetts)

1968

(Millions of Gallons)

Use Category	(1) Distribution %	(2) Calc. US Usage	(3) % Waste	(4) Vol. of Waste	(5) % Collect.	(6) Vol. Coll.	(7) Vol. Uncollect'd	(8) % Burned	(9) Vol. Burned	(10) % Sewered	(11) Volume Sewered
Lubricating Oil	51.0	426	35	149							
Hydraulic Fluid	27.4	229	20	46							
Straight Cutting Oil	10.5	88	30	26							
Soluble Curting Oil	11.1	93	30	28						100	28
Total	100.0	836(1)		249	76	189	60	1.2	3		28

Data in columns (1), (3), (5), etc. are from the A.D. Little report, Sources of Information, b-3.

(1) Bureau of Mines total lubricants, less automotive use from Table No.

TABLE NO. 3

TABLE NO. 4

FATE OF COLLECTED WASTE OIL

Estimate of U.S. Disposal Practices Based on Massachusetts Pattern

1968 Millions of Gallons

Final Disposition	Automotive Percent (1)	Automotive Volume	Industrial Percent (1)	Industrial Volume	Total Volume Collected Waste Lube Oil
Reprocessed to Fuel Oil	69.1	417	--	--	417
Used as Road Oil	21.7	131	52.6	100	231
Used on Farms	4.6	28	--	--	28
Disposed of Locally (Town Dumps or Local Roads)	--	--	47.4	89	89
Unknown	4.6	28	--	--	28
Total Collected	100	604(2)	100	189(3)	793

(1) Study of Waste Oil Disposal Practices in Massachusetts, Ref. b-3.

(2) Table No. 2

(3) Table No. 3

MONS 034128

FATE OF WASTE LUBRICATING OIL U.S., 1968

Summary of Estimates in Collected and Uncollected Categories

Ultimate Fate	Volume, Millions of Gallons	Volume, Millions of 42-gal. Barrels	Distribution, Percent of Total Lubricating Oil Used
Dumped or Applied on Ground	549	13.1	27
Poured into Sewers	43	1.0	2
Reprocessed and/or Burned	420	10.0	21
Unknown	28	0.7	1
Total Ending as Waste	1040	24.8	51
Total Used, as Memo Item	2036	48.5	100

MONS 034129

TABLE NO. 6

USE OF MINERAL OIL AS AN INSULATING LIQUID
U.S., 1968

Millions of Gallons

Apparatus	Original Equipment Use	Field Use (Make-up)	Total	Percent of Total
Transformers	39.13	7.57	46.70	92.0
Switchgear	2.07	.40	2.47	4.9
Cable	1.05	.52	1.57	3.1
Capacitors	.02	0	.02	--
Total	42.27	8.49	50.76*	100

*1.21 million 42-gal. barrels

MONS 034130

TABLE NO. 7

QUANTITIES AND USES OF PRINCIPAL INSULATING LIQUIDS IN THE U.S., 1968

Millions of Gallons

Liquid	Trans-formers	Switch-gear	Capacitors	Cable	Other	Total	% of Volume
Naphthenic Mineral Oil	46.70	2.47	.02	1.57	.30	51.06	81.0
Polybutene Liquid				6.20		6.20	9.8
Askarels (PCB)	1.35		2.46			3.81	6.1
Chlorinated Benzenes	1.79		.01			1.80	2.9
Castor Oil			.10			.10	.2
Other			.01		.02	.03	---
Total	49.84	2.47	2.60	7.77	.32	63.00*	100.0
Use, Percent of Vol.	79.1	3.9	4.1	12.4	.5	100.0	

*1.5 million 42-gal. barrels

TABLE NO. 8

CLASSIFICATION OF ELECTRICAL INSULATING LIQUIDS

Application	Specification	Type of Material
Combustible		
Transformers, Oil Circuit Breakers	ASTM D1040-69 FED VV-I-530a (Note 1.3)	Naphthenic mineral oil
Capacitors, Cable	ASTM D2297-68	Naphthenic mineral oil
Capacitors, Cable	ASTM D2296-68	Polybutene oil
Cable, Low Pressure	ASTM D1818-63	Naphthenic mineral oil
Cable, High Pressure	ASTM D1819-66	Naphthenic mineral oil
Noncombustible		
Capacitors	ASTM D2233-68 (Note 2)	Polychlorinated biphenyl
Transformers, Capacitors	ASTM D2283-70a (Note 1.1, 1.2, 2.0) FED VV-I-1219 (Note 1.1, 1.2, 2.0)	Polychlorinated biphenyl mixtures with diluents

Notes:

1.0 Certain grades contain small quantities of additives which serve as antioxidants and/or scavengers for hydrogen chloride. Commonly used materials and typical concentrations are:

1.1	dicyclo-diepoxy carboxylate	0.14%
1.2	phenoxypropene oxide	0.22%
1.3	2,6 ditertiary butyl p-cresol	0.15%

2.0 Certain grades contain trichlorobenzene and/or tetrachlorobenzene as diluents.

SOURCES OF INFORMATION

(a) Helpful Individuals and Organizations

1. Dr. Thomas C. Winter, Jr., Executive Office of the President, Council on Environmental Quality, 722 Jackson Place, N.W., Washington, D.C. 20006, Tel. 8*272-4011: 382-6756. Professional Staff, CEQ; physicist; Lt. Col., U.S. Army, on assignment from Army Corps of Engineers.

2. Mr. Kenneth Biglane, Director of Oils and Hazardous Materials, Federal Water Quality Administration, Washington, D.C. Tel. 8*272-4011: 557-7660.

3. Mr. Thomas C. McMahon, Director, Division of Water Pollution Control, Department of Natural Resources, Commonwealth of Massachusetts, State Office Building, Government Center, 100 Cambridge Street, Boston, Mass. 02202, Tel. 8*263-0111: 727-3855.

4. Mr. P. N. Gammelgard, American Petroleum Institute, Washington, D.C. Tel. 8*272-4011: 296-0300. Also Mr. Jack Gould and former staffer Mr. Burhouse.

5. U.S. Coast Guard: Commander Wm. Lehr; Lt. Frederick Orthlieb, J.G. Washington, D.C., Tel. 8*272-4011: 426-1027; Commander Daniel Charter (law enforcement, records), Tel. : 426-2012; Thomas Andrews, civilian, Tel. 426-1577/8.

6. Mr. Lester S. Parker, Purchasing Specialist, Power Circuit Breaker Department, General Electric Company, Philadelphia, Pa. Dial Comm 8*245-3180.

7. Mr. James M. Dicht, U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 20240, Tel. 8*272-4011: 557-4843.

8. Mr. Jacob Levin; Mr. Wesley Koster, Petrochemical and Coal Division, Business and Defense Services Administration, Washington, D.C. Tel. 8*272-4011: ST3-9200 Ext. 5221 (Levin) and Ext. 4843 (Koster); also Mr. Magnuson, who writes Chemical Industry Reports, Ext. 3464.

9. Mr. John Nace, Marine Systems and Defense Facilities Sales and Engineering, GE, Schenectady, Bldg. 2, Room 706A, Ext. 5-4702.

10. Mr. L. R. Patterson, Manager - Small Industrial Capacitor Engineering, Fort Edward Plant, Industrial and Power Capacitor Department, General Electric Company, Hudson Falls, N.Y., Dial Comm 8*232-8226.

11. Mr. E. L. Raab, Mgr. - Materials Laboratory, General Electric Company, Pittsfield, Mass., Dial Comm 8*234-2275.

12. Mr. F. Curtis Tucker, Consultant - Chemical and Petroleum Sales, Purchasing-Consulting, General Electric Company, New York Office. Dial Comm 8*222-2480.

13. J. J. Ferry, Industrial Hygienist, Industrial Clinic, General Electric Company, Schenectady, N. Y. Dial Comm 8*235-2004.

(b) Publications

1. Environmental Quality, The First Annual Report of the Council on Environmental Quality, U.S. Gov't. Printing Office, August, 1970.

2. Clean Water for the 1970's, A Status Report, June, 1970, U.S. Dept. of the Interior, Federal Water Quality Administration, U.S. Govt. Prntg. Off.

3. Study of Waste Oil Disposal Practices in Massachusetts, Report to Commonwealth of Massachusetts, Division of Water Pollution Control, January, 1969, C-70698, by Arthur D. Little, Inc.

4.0 Mineral Industry Surveys, U.S. Department of the Interior, Bureau of Mines, Washington, D.C. 20240.

4.1 Idem, Petroleum Statement, Monthly, March 18, 1969 (Preliminary)
4.2 Idem, Fuel Oil Shipments, Annual, Sept. 17, 1969
4.3 Idem, Liquified Petroleum Gas Shipments, Annual, Oct. 13, 1969
4.4 Idem, Petroleum Statement, Annual, Dec. 16, 1969 (1968 Final Summary)
4.5 Idem, Petroleum Statement, Monthly, March 24, 1970
4.6 Idem, Asphalt Shipments, Annual, June 11, 1970
4.7 Idem, Liquified Petroleum Gas Sales, Annual, September 30, 1970

5. Statistical Abstract of the United States, 1969, Table 758.

6. U.S. Department of Commerce, 1969 Business Statistics, pp 167, 168, 169.

7. Sales of Lubricating and Industrial Oils and Greases 1967, Nov. 21, 1968, Series MA-29C(67)-1, U.S. Department of Commerce, Bureau of the Census, Industry Division, Washington, D.C. 20233.

8.0 The New York Times:

Oil Dumping: A Plan to Keep the Ocean Blue, Not Black, by William D. Smith, November 8, 1970.

9.0 The Wall Street Journal:

November 13, 1970

10. Important! Oil Pollution Questions, U.S. Coast Guard, September, 1970, Nautical Queries.

11. Cleaning Our Environment: The Chemical Basis for Action (book) American Chemical Society, Washington, D.C., 1969.

12. The Occurrence, Effects, and Fate of Oil Polluting the Sea Int. J. Wat. Poll. Pergamon Press 1963 Vol. 7, pp 173-198. Printed in Great Britain.

13. Combating Pollution Created by Oil Spills - Vol. I: Methods, Arthur D. Little, Inc. 30 June, 1969, U.S. Dept. of Commerce Clearinghouse No. AD69663.

14. Letter to Electrical Industry from Monsanto Chemical Company, February 18, 1970.

15. Congressional Record - House H10214, October 14, 1970.