

USED OIL BURNED AS A FUEL

Volume I

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## 1.0 SUMMARY

### 1.1 Sources of Used Oil

The estimated used oil generated in the U.S. is 2.2 billion gallons per year, consisting of

	<u>billion gal/yr</u>
automotive	0.46
industrial	0.38
"other"	1.36
	<u>2.2</u>

Automotive and industrial used oils generally arise from use in lubricating and hydraulic service. "Other" used or waste oils arise from a wide variety of sources, including spills, tank cleaning, recovery from water treatment processes, etc. These "other" used oils may be suitable for the preparation of fuels, but are seldom useful for re-refining to lubricating oils.

### 1.2 Disposition of Used Oil

Estimated ultimate fate of used oil is as follows:

	<u>billion gal/yr</u>
To Fuel	1.09
To Road Oil, Dust	
Control, Other Uses	0.22
To Lube Products	0.05
	<u>1.36</u>

### 1.3 Types of Facilities Burning Used Oil

There has been no comprehensive survey of U.S. facilities burning used oil. However, it is almost certain that most of the used oil is burned in steam boilers, usually blended with virgin fuels. Some used oil may be burned in cement kilns, asphalt plants, incinerators, and as a fuel component in diesel engines.

Used oil burning may be taking place in over 50,000 steam boilers, of which 35,000 are boilers rated at 5 MM (million) BTU per hour or greater.

There appears to be a growing market for small "waste oil heaters" of up to about 0.6 million BTU/hr (4.3 gal/hr) capacity for home and small commercial use, including service stations. Even though these units are small, if large numbers are sold they could consume a very significant portion of the available used oil. For example, using an average of 2000 gallons per year, 10,000 units would consume 20 million gallons of used oil, while 100,000 units would consume 200 million gallons.

#### 1.4 Assessment of the Impacts of Burning Used Oil

##### UNRESTRICTED BURNING

1. Unrestricted burning of automotive crankcase used oils will result both in significant total lead emissions (2,300 tons per year in 1985) and in some localized lead ambient air quality standard violations.
2. Unrestricted burning will also lead to undesirable emissions of total particulates, including significant quantities of barium, calcium, magnesium, phosphorous, and zinc compounds. Halide acid emissions (primarily hydrochloric) would be much higher than for virgin fuels.
3. Unrestricted burning would allow used oils containing less than 50 ppm PCB's to be burned, since these low concentrations are not controlled by EPA's TSCA regulations. Since some of these PCB contaminated used oils would be burned in boilers and furnaces not suitable for a high destruction efficiency, some PCB's would be emitted to the atmosphere, but no estimate can be made at this time of the quantity emitted.
4. Unrestricted burning in onsite boilers and furnaces of used lubricating oils collected at industrial sites would most likely result in co-burning of other organic chemical wastes found at those sites. Other used oils collected from service stations and elsewhere could also be contaminated with organic chemical wastes. Inasmuch as many or most boilers and furnaces are not suitable for high destruction efficiency, some of these organic wastes or partially combusted wastes would be emitted to the atmosphere, but no estimate can be made at this time of the quantity. Although such contamination and burning could be in violation of RCRA regulations governing waste generation, transportation, and disposal, one could assume that such practices would occur.
5. The varied and widespread sources of used oils and the difficulty in detecting oil contaminants would make it very difficult to prevent contamination with hazardous wastes and co-burning of the mixtures.

## RESTRICTED BURNING

1. Modest restrictions on used oil burning, such as requiring lead concentration to be reduced to fixed maxima, e.g. 50 or 500 ppm (compared to about 2000-8000 typical in unprocessed used oil), but allowing blending to reach this level, would have little effect on total emissions, but would almost eliminate used oil burning itself as a source of ambient air quality standard violations. However, where ambient lead levels are high because of other sources, used oil burning could still be significant under some circumstances.
2. Similarly, total emissions of other contaminants would remain almost unchanged, but localized emission and ambient air quality problems would be abated.
3. Requiring testing, e.g. for lead and PCB's, on tank truck quantities of used oil is very expensive. Requiring such testing on large storage tank quantities is feasible, but detecting unknown contaminants, if possible, would require method development.

## REPROCESSING REQUIRED TO MEET FUEL SPECIFICATIONS

1. Reprocessing to meet fixed maxima, e.g. 50 or 500 ppm lead content would avoid almost all potential lead emission problems resulting from burning, but overall environmental impact is dependent upon the means of disposal of lead-containing residues from processing.
2. Metals and other nonvolatile substances comprising the ash content of used oils would also be reduced by reprocessing methods available for reducing lead content.
3. Thermal dehydration as an adjunct to or replacement for demulsification removes not only water but also light ends, eliminating the possibility of light halogenated and other solvent emissions. However, provisions governing the fate of these light organics and contaminated water would determine overall environmental impact.
4. Vacuum distillation, not normally practiced, reduces sulfur, nitrogen, and PNA's in used oils, but these materials concentrate in the heavy residues. Overall environmental impact is dependent upon the means for residue disposal.
5. Contaminants boiling in the lube distillate range, e.g. PCB's, would be unaffected by most reprocessing steps.

6. The following steps are available for reprocessing:

- a. Settling in tanks at ambient temperatures to 200°F, with or without caustic/silicate, acid, or polymer demulsifier treatment, to remove water and particulates, including lead and polymers. Widely used, but not very efficient.
- b. Centrifugation at ambient temperatures to 200°F, with or without caustic/silicate, acid, or polymer treatment to remove water and particulates, including lead and polymers. Used in a few reprocessing plants with efficiencies comparable to careful settling.
- c. Mechanical filtration and/or fine screening to remove particulates and solid polymers. Used in some reprocessing plants for gross separation of large suspended solids.
- d. Thermal dehydration to remove water and light organics by vaporization, in either one or two steps. Used in some reprocessing plants.
- e. Chemical treatment with, e.g. 93% sulfuric acid, oxygenated solvents, and diammonium phosphate, to remove various impurities. Not now in use to meet fuel specifications.
- f. Solvent extraction, e.g. high pressure propane extraction, to separate lubricating oil type cuts from impurities. Not now in use to meet fuel specifications.
- g. Separation of a distillate cut by fractionation, thus removing a bottoms product containing lead and other inorganics, polymeric impurities, polycyclic aromatics, and many sulfur, nitrogen, and oxygen-containing compounds. Not now in use to meet fuel specifications.
- h. Clay treatment at any stage of processing to remove a variety of impurities. Some commercial use.
- i. Finishing, e.g. clay treatment or hydrotreating, to improve odor, color, and stability after other processing is complete. Not normally required to meet fuel specifications.

Fractionation and/or solvent treatment, which would be required for more severe restrictions on lead and ash content, add considerable expense to fuel preparation, reducing the value of the feedstock and making significant quantities available for re-refining. From another perspective, one could conclude that if extensive reprocessing were required for fuel preparation, the finishing steps necessary to prepare lubricants instead would be economically justified.

#### STRINGENT RESTRICTIONS

1. Placing sufficiently stringent restrictions on used oil burning to insure environmental impact essentially equivalent to virgin oil combustion, including equipment and performance specifications and licensing and testing requirements, would have a major effect on the cost of burning. Thus use of used oils as fuels would be expensive, making feedstock available for re-refining.
2. If stringent restrictions on burning were put into place too quickly, most used oils could not be marketed, resulting in environmental and waste disposal problems. However, gradual restrictions with simultaneous modernization and expansion of the re-refining industry would help to alleviate this problem for used lubricating oils. Marketing other used oils would still be a problem under this scenario.

#### OTHER CONSIDERATIONS

1. Funneling 500 million gallons per year of used oils into lubes instead of fuels could conserve more than 3 million barrels per year of petroleum because the energy requirement for re-refining is less than for preparing lube oils from virgin crude oils.
2. Re-refining and reprocessing technologies all result in the concentration of hazardous materials into byproduct or waste streams, e.g. lead, other metal and phosphorous compounds, polycyclic aromatics, etc. Wastes from processing of hazardous wastes, such as used oils that are so classified, are presumed to be hazardous unless demonstrated not to be. Environmentally sound disposal of these residues, which is under study by the U. S. Department of Energy Bartlesville Energy Technology Center and others, is vital to the future viability of re-refining and reprocessing.
3. Stack height and stack temperature are critical variables with respect to the effect of lead and other combustion emissions on ambient air quality.

### 1.5 The Effects of Environmental Regulations on Used Oil Burning

Federal environmental regulations which may affect used oil burning find their basis primarily in the following legislation:

- The Clean Air Act of 1970 (CAA) (as amended in 1974 and 1977)
- The Toxic Substances Control Act of 1976 (TSCA)
- The Resource Conservation and Recovery Act of 1976 (RCRA)

The responsibility for regulations under these acts lies primarily with the Environmental Protection Agency (EPA). Only CAA and TSCA will be further discussed in this Section since regulations relating to used oils under RCRA are still under study and are the primary subject of this report.

Regulations under CAA which may affect used oil burning are:

- National Ambient Air Quality Standards (NAAQS) for total suspended particles, SO<sub>2</sub>, NO<sub>2</sub>, and lead. The NAAQS for lead is particularly important because high lead emissions are virtually unique to automotive used oil burning and not normally a problem with virgin fuels. The NAAQS for total suspended particles is also important because used oils are often higher in ash content than normal virgin fuels, leading to potentially high particulate emissions. SO<sub>2</sub> emissions for used oils are similar to those for virgin fuels with the same sulfur content. NO<sub>x</sub> emissions for used oils are comparable to those for virgin oils.
- Prevention of Significant Deterioration (PSD). The PSD program was developed to preserve air quality in those areas where the air is better than NAAQS. It may apply to new fossil fuel boilers with more than 250 million BTU/hr heat input, smaller or larger boilers modified for used oil firing, and other new or modified facilities burning used oil. However, there is a strong possibility that sources switching from virgin to used oils may not always undergo the required permit process. Only relatively small sources, sources burning low concentrations of used oil, or sources already permitted for used oil burning would be exempt from PSD rules.

- Nonattainment Region Provisions. If new or modified major sources lie in or have an impact on a nonattainment area, they will be subject to preconstruction review. Sources with a potential emission for any applicable pollutant greater than 100 tons/yr would be governed by these provisions. Depending upon particulate and sulfur concentration, and dilution with virgin fuels, new steam boilers with a capacity as low as 20 million BTU/hr could be affected, as could similar size boilers converted to used oil firing.
- New Source Performance Standards (NSPS). Federal NSPS apply to new and modified fossil-fuel fired steam generators which have a heat input greater than 250 million BTU/hr and to certain other types of facilities. Smaller sources and existing sources are governed by state and local regulations for particulates, SO<sub>2</sub>, NO<sub>x</sub>, and other pollutants--sometimes including lead.

Of primary concern under TSCA is the relationship of PCB disposal regulations to used oil burning practices. Under these regulations:

- For PCB liquids containing 500 ppm PCB or greater, disposal is permitted only in EPA-approved incinerators.
- For PCB liquids containing 50-500 ppm, disposal is permitted in EPA-approved incinerators, in high efficiency boilers rated at a minimum of 50 million BTU/hr (under rigidly controlled combustion conditions), and in EPA-approved chemical waste landfills (approved for PCB's).
- Liquids containing less than 50 ppm are not considered PCB's (unless dilution was involved) and their burning is not regulated.

#### 1.6 Specifications for Used Oil Fuels

It is possible to use various air pollution and composition criteria to characterize used oils which can be burned with relatively little environmental risk. The following are possible specifications and criteria:

- total ash content of less than 0.3 weight %, which results in less than 0.12 grains/dry SCF emission (at zero percent excess air) meeting many, but not all, state and local regulations for particulate emissions when burning 100% used oil.
- lead content of less than 50 ppm, which would eliminate almost all local ambient air quality violations, even when burning 100% used oil.
- chlorine content of less than 0.4 weight %, which is in the normal range for used crankcase oils, indicating that no gross contamination has occurred with chlorinated solvents.
- PCB content of less than 50 ppm, which is the upper limit specified by EPA regulations under TSCA, allowing burning without Federal regulation.
- BS&W of less than 1%, which indicates an absence of substantial water or sediment which might contribute to emission or burning problems.
- flash point of greater than 140°F, corresponding to the hazardous waste classification under RCRA.
- various sulfur levels might be used, for example, less than 0.2 weight %, which would probably meet all state air emission regulations; or 0.5%, which would meet most state regulations.



## 2.0 INTRODUCTION

The rapidly increasing value of petroleum has been the principal factor in abating large scale dumping of used oils. With a few exceptions, used oils have become products of commerce or are used by the generator for fuel or other purposes. One major exception is environmentally unsound disposal by individual automobile owners who perform their own oil changes.

On the other hand, the methods of use are often questionable by reasonable environmental standards. For example, road oiling may result in contamination of surface waters and other ecological systems. Burning used oils as fuels can contribute to air pollution problems because of the emission of lead and other impurities present in the oil.

The purpose of this report is to assess the environmental impact of used oil combustion preparatory to possible promulgation of rules affecting such combustion under Subtitle C of RCRA (1). The assessment includes data available in the literature, analysis of combustion tests on steam boilers performed by RECON SYSTEMS, INC. and air dispersion modelling performed by ETA Engineering, Inc.

This report is divided into two volumes. Volume I contains the main body of the report including Section 7.0, "Supplementary Data." Many of the tables referred to in the text can be found in Section 7.0. Volume II, containing Appendices A-C, provides test and modelling details.

### 2.1 Sources of Used Oil

Projections of used oil generation in 1980, 1985, and 1990 have been prepared from lubricating oil sales projections (2) and previous used oil studies (3, 4, 5). Breakdowns and bases for these projections are presented in Tables 7-1 to 7-4. Assuming no major changes in regulations or collection practices, the following used oil quantities may be expected:

	Millions of Gal/Yr		
	1980	1985	1990
Automotive lubricants	464	458	437
Industrial lubricants	380	396	420
Subtotal - Lubricants	844	854	857
"Other"	1365	1365	1365
	2209	2219	2222

The "other" used or waste oils are derived from a variety of sources including production losses at the wellhead, recovered refinery and spill losses, tank cleaning, barge and ship cleaning, etc. These represent less than 0.5% of all virgin petroleum uses.

If regulations were promulgated to minimize wasteful disposal practices, e.g. to maximize recycling by individuals who change their own automotive crankcase oil, it might be possible to increase collectable used oil substantially.

## 2.2 Disposition of Used Oil

Used oil disposition estimates have not been updated since RECON's studies in 1974 (3). However, using the projections in Section 2.1 and recent intelligence on disposal practices, an attempt has been to revise the 1974 study to 1980 conditions. The details of this revision are shown in Table 7-5.

Ultimate disposition estimates may be summarized as follows:

### 1980 USED OIL DISPOSITION ESTIMATES Millions of Gal/Yr

<u>TOTAL OILS ENTERING SYSTEM</u>	
Automotive Lube Sales	1396
Industrial Lube Sales	1243
"Other" Used Oils	1365
	<u>4004</u>
<u>USED OIL GENERATION</u>	
Automotive	464
Industrial	380
"Other"	1365
	<u>2209</u>
<u>ULTIMATE DISPOSITION</u>	
Directly to Fuel	439
To Fuel from Proc./Re-Ref.	652
	<u>1091</u>
Directly to other uses (road oil, form oil, dust control, etc.)	146
To other uses from Proc./Re-Ref.	78
	<u>224</u>
Lube Products	45
Subtotal - Products	<u>1360</u>
Engine Consumption, Process Losses, Environmental Losses	2644
	<u>4004</u>

Under present conditions, regulations designed to increase the collection of used oil would substantially increase all of the present uses, but especially fuel use because of the lack of re-refining capacity and the environmental restraints toward road oiling, dust control and the like.

### 2.3 Properties of Used Oil

Extensive studies of the properties of thirty used motor oils have been conducted by the Bartlesville Energy Technology Center (6). The oils analyzed were composites collected in twenty states within the continental United States. Most of the physical and chemical properties measured are summarized in Tables 7-6 and 7-7 (excluding data on compound types). The following chemical properties are of major environmental importance:

<u>Contaminant</u>	<u>Weight %</u>
Lead	0.14-1.39 (1,362-13,885 ppm)
Ash	0.94-2.20
Sulfur	0.33-0.54
Chlorine	0.26-0.41

Significant but lower concentrations of barium, calcium magnesium, nitrogen, phosphorous, and zinc are also found in used motor oils, as well as trace quantities of other elements. As will be shown, lead, ash, and sulfur concentrations can be related directly to emissions resulting from used oil burning, and to some extent are regulated under Federal law. Hydrochloric acid emissions which result from the chlorine content of the oil are not so regulated.

EPA regulation of fuel additives can have a major effect on automotive used oil composition. These additives may contaminate lubricating oils on cylinder walls during engine operation. Used oil lead contamination, of course, results from this process. Another antiknock agent, methylcyclopentadiene manganese tricarbonyl (MMT), was widely used during the period 1974-1979 but has now been discontinued by EPA (8). Although manganese content of used oils may have increased during this period, it should rapidly disappear as a contaminant.

Estimates by EPA (9) would predict an average lead content in used automotive lubricating oil of less than 1000 ppm by 1985, perhaps as low as 800 ppm, based on gradual elimination of vehicles burning leaded fuels. If lead-tolerant emissions control technology were developed, lead concentrations could remain as high as 2500 ppm in 1985 and beyond, holding leaded pooled average at the present regulated level (10, 11).

Fewer data are available for industrial used oils. However, characterization of a variety of such oils, performed by ETA for the State of Illinois (7), is reported in Table 7-8. Some of the significant contaminants which appear in this particular set of data are ash (up to 0.64%), sulfur (up to 1.4%), lead (up to 1,400 ppm), zinc (up to 1,100 ppm), copper (up to 1,160 ppm), barium (up to 240 ppm), calcium (up to 1,900 ppm), phosphorous (up to 1,080 ppm), and magnesium (up to 1,000 ppm).

#### 2.4 Used Oil Collection

The most recent comprehensive survey of used oil collection was performed by RECON in 1973 (3) and included in EPA's 1974 Report to Congress (12). Since that time additional but fragmented information has been gathered by Maltezou (13), Mascetti and White (4), and by RECON (14).

Based on these studies, used oil collection can be characterized as follows:

1. Nationwide, various sources have estimated from 500 to 2000 firms operating in the used oil industry. Of these, approximately 60% or more are collectors only, while 40% or less also practice processing or re-refining.
2. Business turnover is high.
3. Most collectors tend to search for used oil on an informal basis, without contracts or a specific callback system. However, some industrial oil is collected on written or verbal contract bases.
4. Much of the collected oil is immediately disposed of untreated, e.g. to road oiling and fuel users.
5. Collection firms keep either poor records or no records, unless required to do so by state licensing or registration procedures.

6. The average small collector owns one to two trucks with capacities of between 1500 and 1800 gallons. He operates alone or with the help of one or two employees and prefers to operate within a small radius, usually 30-50 miles. Plans are to fill collection trucks at least twice a day. The average small collector recovers 400,000 to 600,000 gallons per year.
7. Collection in rural areas usually involves somewhat larger trucks, e.g., 1500-2000 gallons, and covers larger areas.
8. In recent years, more re-refiners and processors have moved to control their used oil sources by owning trucks and either hiring drivers or leasing to operators, and by setting up collection terminals remote, e.g., up to 500 miles, from their processing facilities. In the case of remote terminals, used oil is delivered to the terminal by small collection trucks and moved from the terminal to the processing facilities in trucks carrying up to 8000 gallons. The terminals may be either manned, or unmanned but well secured.
9. The street price of oil, even for the same quality oil in the same area, can fluctuate widely depending on bargaining between seller and buyer.
10. The delivered price of used oil tends to reflect its end use and especially the price of virgin fuel oil, since the most common use widely available is as a fuel. The difference between virgin fuel oil and used oil street prices reflects collection costs, processing and blending costs where practiced, and the increased cost of burning used oils. Each of these costs normally includes a profit to an intermediary.

## 2.5 Used Oil Processing

Some used oils are recycled for fuel use, road oiling and other applications with little or no treatment. However, substantial quantities of used oil undergo chemical and/or physical treatment preparatory to recycling. A series of physical and chemical treatment steps designed to prepare lubricating oil base stocks from used lubricating oils is usually designated as re-refining. Physical treatment steps, with or without chemical treatment, to prepare fuels from used oils is usually designated as used oil processing or reclaiming.

Technology available for re-refining has been extensively discussed in the literature (3, 4, 15) and will not be discussed further here. However, it should be noted that recent work by RECON (14) has confirmed previous studies showing that re-refining to produce lubes from used oil, as compared to burning used oils in boilers, could result in an overall saving of about 3 million barrels per year of petroleum.

Used oil to be burned as a fuel may sometimes be used directly with no reprocessing necessary, e.g., recovered hydraulic oils with relatively little moisture or other contamination. Used oils more heavily contaminated are sometimes burned alone or in mixtures with virgin fuels without further processing, but these usually have some detrimental effect on the combustion process, e.g., steam tube fouling, particulate emissions, or stack corrosion. Therefore, it is desirable to reprocess used oils prior to combustion.

Reprocessing is widely practiced, but reprocessing facilities differ widely in complexity and effectiveness. They range from simple storage tanks in which settling occurs to reduce BS&W (bottom sediment and water) to much more complex chemical and physical treatment steps. As shown in Table 7-9, there are more than 100 re-refining and reprocessing facilities in the U.S., most producing at least some fuels.

Some of the methods in wide use by reproprocessors are:

- Screening to remove large foreign substances and sediment.
- Settling to remove water and sediment aided by high temperatures, silicate, acid, and polymeric demulsifiers, and solvent dilution.
- Centrifugation to remove water and sediment instead of settling.
- Filtration to remove fine particles.
- Atmospheric or vacuum distillation to remove water, gasoline, and other volatile contaminants.
- Chemical treatments for special purposes using sulfuric acid, caustic, acid activated clay and other agents.

Settling for water and sediment removal is the most common method of reprocessing. Although not completely effective or universally applicable, this simple form of reprocessing does often substantially reduce the contaminant level which must be handled in combustion equipment. It is not possible to efficiently remove lead by this or similar approaches, although some lead removal does occur.

## 2.6 Used Oil Blending

As noted before, dilution of used oils, whether or not reprocessed, with clean virgin oils apparently makes them more acceptable to the user. This approach may range from sufficient dilution to completely hide the used oil, e.g., using a very high ratio of No. 6 fuel as the diluent, to minimal blending designed to barely meet local particulate codes.

Many small users do not routinely analyze their fuel oils and may unknowingly accept a fuel with used oil contamination at normal fuel prices. A high degree of dilution tends to minimize required frequency of filter and furnace cleaning and is thus difficult to detect.

On the other hand, it is believed that most used oil fuels are sold as such with the user, whether large or small, willing to accept problems which may be inherent in the combustion of used oil and used oil/virgin oil mixtures in return for a lower price.

Blending requirements to meet particulate emission regulations vary with local regulations and with the ash contents of the used and virgin oils. Some examples of barely acceptable blends follow:

- Basis: 1. 0.12 grains/dry SCF emission limit (corrected to 0% excess air)  
2. Zero ash in virgin fuel

<u>Ash in Used Oil, wt %</u>	<u>Weight Ratio of Used Oil to Virgin Oil Allowable</u>
0.3	1:0
0.6	1:1
1.2	1:3
1.8	1:5

Basis: 1. 0.1 lbs of particulate emission per  $10^6$  BTU Heat  
Input. (18,000 BTU/lb fuel)  
2. Zero ash in virgin fuel

<u>Ash in Used Oil, wt %</u>	<u>Weight Ratio of Used Oil to Virgin Oil Allowable</u>
0.18	1:0
0.3	1:0.67
0.6	1:2.33
1.2	1:5.67
1.8	1:9

It should be noted that other considerations may further restrict the amount of used oil allowable. These include lead content, as limited by the Federal Ambient Air Quality Standard, and sulfur content, often restricted by local regulations. The lead problem is discussed further in Sections 4.0 and 5.0.



## REFERENCES

1. FR 45, No. 98, May 19, 1980, page 33118.
2. Stewart, R. G. and J. L. Helm. The Lubricant Market in the 1980's - U.S. and Free World. Presented at the 1980 NPRA Annual Meeting, New Orleans, LA. March 23-25, 1980.
3. Weinstein, N. J. Waste Oil Recycling and Disposal. EPA-670-/2-74-052. August 1974. 328 pages.
4. Mascetti, G. J. and H. M. White. Utilization of Used Oil. Aerospace Report No. ATR-78(7834)-1. DOE. August 1978.
5. Bidga, Richard J. and Associates. Review of All Lubricants Used in the U.S. and Their Re-Refining Potential. DOE/BC/-30227-1. June 1980. 84 pages.
6. Cotton, F. O., M. L. Whisman, J. W. Goetzinger and J. W. Reynolds. Analysis of 30 Used Motor Oils. Hydrocarbon Processing, September 1977.
7. Yates, J. J. et al. Used Oil Recycling in Illinois: Data Book. Document No. 78/34. State of Illinois Institute of Natural Resources. Chicago. October 1978. 135 pages.
8. FR 44, No. 199, pages 58952-58965, Friday, October 12, 1979.
9. Control Techniques for Lead Air Emissions. Vol. I. Chapters 1-3. EPA-450/2-77-012. December 1977. 181 pages.
10. 40 CFR Part 80.
11. Anderson, E. V. Phasing Lead Out of Gasoline. Chem. & Eng. News. February 6, 1978. pages 12-16.
12. U.S. EPA. Waste Oil Study. Report to the Congress. April 1974. 402 pages.
13. Maltezou, S. P. Waste Oil Recycling: The New York Metropolitan Area Case. Council on the Environment of New York City. March 1976. 206 pages.
14. Weinstein, N. J. Unpublished work by RECON SYSTEMS, INC. for U.S. DOE (Contract No. DE-AC19-79BC10044) and U.S. EPA (Contract No. 68-01-4729). 1980.
15. Liroff, S. D. Management of Environmental Risk: A Limited Integrated Assessment of the Waste Oil Refining Industry. Final Report for the National Science Foundation. March 1978. 282 pages.

### 3.0 FACILITIES BURNING USED OIL

Used oil can be burned in virtually any facility that is designed for No. 6 fuel oil, and in most facilities designed for No. 4 and No. 5 fuel oils, although some modifications may be necessary in the systems designed for the lighter fuels. Used lubricating oils have also been used as a fuel for diesel engines. Descriptions of various types of facilities which can accept used oils follow.

#### 3.1 Oil- and Coal-Fired Boilers

A recent study of the "Population and Characteristics of Industrial/Commercial Boilers in the U.S." (1) concluded that:

- the total number of industrial and commercial boilers in place in 1977 was about 1,800,000 with a total firing capacity of about  $4.5 \times 10^{12}$  BTU/hr (equivalent to 1,300,000 MW thermal in the International system of Units).
- Less than one percent of the boilers exceed the existing New Source Performance Standard limiting size of  $250 \times 10^6$  BTU/hr (73.3 MW thermal), but they represent 17 percent of the installed capacity.
- About 72 percent of these boilers are classified as commercial and are used primarily for space heating in commercial and institutional buildings.
- The other 28 percent are classified as industrial boilers and are used primarily for process steam and space heating. However, because industrial boilers are generally larger, they represent 69 percent of the total firing capacity.
- The three major types of boilers are water-tube, steel fire-tube, and cast iron fire-tube. Cast iron boilers are small; steel fire-tube boilers have the greatest range of capacity; and water-tube boilers are generally the largest.
- Water-tube boilers constitute the majority of the thermal capacity.
- By fuel type, natural-gas-fired boilers comprise 45 percent of the total number; oil-fired, 37 percent; and coal-fired, 18 percent.

A summary of the distribution of various type boilers is found in Table 7-10. Various burner types used in boilers have been discussed by Mascetti (2); and possible particulate control systems by Chansky (3), but these are seldom used on oil-fired boilers.

There are no comprehensive data available to show what types of boilers are actually burning used oils, although the technical, economic, and environmental feasibility of automotive waste oil reuse as a fuel has been studied (3). However, it is possible to pinpoint those types of boilers most amenable to used oil combustion, and also those boiler types where used oil combustion is not likely. On this basis, the following comments can be made with reference to the boiler population summarized in Table 7-10.

### 3.1.1 Water-Tube Boilers

Coal-Fired - Although many of these coal units are uniquely suitable for firing used oil because they have air pollution control equipment, it is doubtful that appreciable used oil combustion is actually practiced at present. This conclusion is predicated on the fact that coal prices are generally more attractive than virgin oil or even used oil prices in areas where coal combustion is practiced. However, as Federal regulations require future conversion of some oil-fired units to coal transported from distant fields, the incentive for used oil as an auxiliary fuel will grow. It is not known whether DOE regulations will allow such use.

Residual Oil-Fired - The availability of fuel filters, air and steam assisted burners, "dirty" tanks, soot blowers on larger units, and occasionally air pollution control equipment eases conversion to used oil. On the other hand, potential tube and furnace fouling discourages most water-tube boiler owners. It is believed, however, that used oil/residual oil mixtures are burned in many "medium" size and larger water-tube units.

Distillate Oil-Fired - Few of these boilers have all of the advantages of residual oil-fired boilers for used oil combustion. Therefore, it is believed that few such boilers are fired with used oil.

Natural Gas-Fired - Boilers designed originally for natural gas are not readily converted to oil firing.

### 3.1.2 Fire-Tube Boilers (Steel and Cast Iron)

Coal-Fired - Coal-fired fire-tube boilers are generally small and it is believed that few are equipped with oil burners.

Residual-Oil Fired - Fire-tube boilers lend themselves more readily to "dirty" oil firing than do water-tube boilers. For this reason, and the reasons mentioned in the discussion of residual oil-fired water-tube boilers, it is believed that used oil is fired in many boilers of this type, most of which are "small" or "very small."

Distillate Oil-Fired - Some "small" No. 4 and No. 5 fuel fire-tube boilers are probably fired with distillate oil/ used oil mixtures, but it is doubtful that many No. 2 fuel/used oil mixtures are in use.

Natural Gas-Fired - Boilers designed originally for natural gas are not readily converted to oil firing.

In summary, it is believed that most used oil combustion takes place in boilers selected from the population summarized in Table 3-1. From Section 2.2, using 1091 million gallons per year of used oil burned at 140,000 BTU/gal ( $0.153 \times 10^{15}$  BTU), a maximum of 5.7% of this market is provided by used oils, neglecting used oil burned in cement plants, asphalt plants and other applications. If all size segments of the market were proportionately penetrated and the average blend contained 25% used oil, the total number of boilers operating on used oil and used oil/virgin oil blends would be about 58,000, based on the following calculation:

Yearly used oil consumption =  $0.153 \times 10^{15}$  BTU

Total population of boilers with  
a potential for used oil combustion = 253,650 (Table 3-1)

Yearly fuel consumption in  
above boiler population =  $2.696 \times 10^{15}$  (Table 3-1)

$\frac{0.153 \times 10^{15}}{2.696 \times 10^{15}} \times 253,650 = 57,579$  boilers

$0.25 \times 2.696 \times 10^{15}$

Table 3-1. POTENTIAL BOILER MARKET FOR USED OIL COMBUSTION

<u>TYPE</u>	<u>SIZES</u>	<u>TOTAL NUMBER</u>	<u>TOTAL CAPACITY MM BTU/HR</u>	<u>LOAD FACTOR *</u>	<u>YEARLY FUEL<sup>15</sup> CONSUMPTION, 10<sup>5</sup> F</u>
Residual Oil Water Tube	medium	1,537	281,000	0.106	0.262
	large	62	47,400	0.106	0.044
	power plant	8	19,200	0.106	0.018
Residual Oil Fire Tube	small	5,905	120,100	0.295	0.310
	very small	163,677	296,000	0.295	0.854
Distillate Oil Fire Tube	small	3,861	103,504	0.469	0.425
	very small	78,600	190,500	0.469	0.783
TOTALS		253,650	1,059,204	(0.29)	2.696

\* Assumed, but based on Reference 1, Table 2-22. Load factor refers to the fraction of the total boiler capacity actually utilized; e.g., as an average, the above boilers are utilized at full capacity 29% of the time.

This estimated total is surprisingly high, but is possible based on estimates of about 500 to 2000 collection and processing firms operating in the used oil business. If market penetration were higher in the larger and residual oil boilers and lower in the smaller and distillate oil boilers, e.g., in accord with calculations in Table 7-11, there would still be about 52,000 boilers operating on used oil or used oil/virgin oil blends. This is about 2.8% of the total boiler population of 1,800,000.

One important aspect of the possible regulation of used oil combustion is the choice of a size cutoff. The cumulative number of boilers burning used oil and the cumulative yearly used oil consumption can be summarized from the estimates in Table 7-11:

<u>Size</u> <u>Power</u> <u>Plant</u>	<u>MM BTU/hr</u>	<u>Cumulative</u>	
		<u>No. of</u> <u>Boilers</u>	<u>Used Oil</u> <u>10<sup>15</sup> BTU/yr</u>
	1500+	1	0.0006
Large	500-1500	16	0.0032
Medium	100-500	631	0.0294
Small	10-100	3,920	0.0859
Very Small	5-10	35,000	0.145
Very Small	0.4-5	52,239	0.153

Reasonable cutoff choices based on these data and the work in Section 5.0 (based on air quality predictions) appear to be:

<u>Cutoff</u>	<u>Boilers to be</u> <u>Permitted</u>		<u>% of used</u> <u>oil burned</u>
	<u>%</u>	<u>No.</u>	
5 MM BTU/hr	67.0	35,000	94.8
10 MM BTU/hr	7.5	3,920	56

Cutoff values between 5 and 10 MM BTU/hr would be reasonable, but the data is too imprecise to reasonably establish the number of boilers and the amount of used oil involved between these values.

The ownership of boilers burning used oil appears to be widely distributed among institutions (including schools and hospitals), industrial facilities, commercial facilities, and electric power plants. Many industrial facilities burn self-generated used oils from both industrial and transportation sources, usually lower in lead and ash content than collected automotive used oils, but contaminated in some instances with "industrial wastes," e.g., spent solvents.

One concern about used oil burning is whether combustion conditions are sufficiently severe to destroy potential used oil contaminants such as spent solvents (including chlorinated solvents) and PCB's. The prediction of destruction efficiencies is dependent upon such factors as the nature of the waste; the manner in which the oil and/or waste are introduced; oxidation gas composition; and time, temperature, and turbulence variations through the combustion chamber. The complexity of relationships governing destruction efficiency is convincingly discussed in a report by Manson and Unger covering design criteria for various types of incinerators (4).

In the interest of simplifying this problem under RCRA, EPA proposed retention times of two seconds or more at a combustion temperature of at least 1000°C (1832°F) with an excess oxygen of at least 2% for all hazardous wastes, except those containing halogenated aromatic hydrocarbons. They were required to be burned at least 1200°C (2192°F) and 3% excess oxygen (5). These proposed conditions were not included by EPA in the final rules published in May 1980.

It is doubtful that many boilers would meet the guidelines originally proposed by EPA for destruction of hazardous wastes. Oil-fired steam boilers and combustion processes can reach temperatures greater than 1000°C (1832°F) or even 1200°C, but retention time at these temperatures may not reach two seconds. As shown in Table 7-12, flue gas retention times in combustion chambers are dependent primarily on: the type of fuel used; the amount of excess air used; actual flame temperature; and construction details, the most important of which is the combustion chamber volume. For oil-fired boilers, two second retention time is attained for volumetric heat releases of less than 28,300 BTU per hour per cubic foot for about 10% excess air and 2500°F average flue gas temperature; and for volumetric heat releases of less than 21,000 for about 50% excess air and 2500°F average flue gas temperature. Some steam boilers may be designed for those conditions which result in two seconds retention time in the combustion chamber, but many are not. Reduced firing load on any boiler or furnace can increase retention time, particularly when air flow is decreased proportionally to fuel flow. However, reduced load decreases combustion temperature due to the greater significance of heat loss.

It cannot be assumed, therefore, that the combustion of used oil in existing steam boilers and other combustion furnaces could produce high efficiency destruction of hazardous wastes in used oils. Each combustion system must be treated on an individual basis, perhaps taking advantage in some cases of the possibility of meeting combustion efficiency and destruction efficiency requirements by higher temperature at lower retention time.

### 3.2 Small Waste Oil Heaters

There appears to be a growing market for small "waste oil heaters" of up to 0.6 million BTU/hr (4.3 gal/hr) capacity for home and small commercial use, including service stations. The units can be used to heat either air or water for space heating or other purposes.

Some of these units use conventional liquid injection burners, while other use vaporizing cup burners to minimize carryover of ash and lead. Very few data are available, but the claims for low lead emissions for the vaporizing cup burner appear to be reasonable, with lead residue remaining in the cup and requiring periodic cleaning. It is possible that the liquid injection burner also may result in low lead emission, but periodic cleaning of the combustion chamber to remove deposits is necessary.

One manufacturer claims 60,000 units sold in Europe. No reliable information is available on the number of units in the U.S. Even though these waste oil heaters are small, if large numbers are sold they could consume a very significant portion of the available used oil. For example, using an average of 2000 gallons per year, 10,000 units would consume 20 million gallons of used oil, while 100,000 units would consume 200 million gallons.

### 3.3 Cement Kilns

Extensive test work in Canada has shown that used oil can be burned as a fuel in cement kilns (6). It is believed that this practice is in use today in the U.S., but data are not available on the extent of such applications. Cement kilns are normally equipped with baghouses or electrostatic precipitators for particulate control, which should be effective in minimizing used oil particulate emissions. According to Chansky, et al (3) about 2.6 million barrels of fuel oil was used to manufacture hydraulic cement in 1967, a market large enough to accommodate about 10% of the used oil estimated by RECON to be available today for fuel.



### 3.4 Incinerators

A hypothetical study of burning used oil in municipal incinerators was conducted by Chansky, et al in 1973 (7). However, there is no known application of this approach at this time. Burning used oil in steam generating municipal incinerators is still discussed for specific projects, as is the application of used oil as a supplementary fuel for wastewater sludge incinerators. Therefore, some limited use may be found for such applications.

Liquid and gaseous incinerators with and without heat recovery are widely used in industry for waste disposal. Some used oils may be burned in these, either as a supplementary fuel or as a method for disposal of highly contaminated oils. Most recently built incinerators are equipped with scrubbers or other pollution control devices, but many of the older incinerators may not be so equipped.

### 3.5 Diesel Engines

There have been many verbal reports of used lubricating oils being used as a diesel engine fuel, but only limited data are available. One published report (8) briefly describes tests conducted on 50 to 100% light distillate from a 670°F, 27 in. Hg vacuum distillation of 23.4° API used crankcase oil.

The light distillate performed satisfactorily as a diesel fuel, but the following detrimental effects were noted:

- occasional black smoke
- a very objectionable odor
- some tar deposition in the engines.

It was concluded that light distillate recovered from used crankcase oil can be used as a diesel fuel, but that further treatment of the distillate is necessary.

Other tests on 1-5% used oil/diesel fuel blends were more promising, but deposit formation was also noted (2). According to this source, a one percent blend of used lubricating oil is being used in Coors' brewery trucks, representing the total in-house supply of available used crankcase oil.

## REFERENCES

1. Devitt et al. Population and Characteristics of Industrial/Commercial Boilers in the U.S. EPA-600/7-79-178a. August 1979. 462 pages.
2. Mascetti, G. J. and H. M. White. Utilization of Used Oil. Aerospace Report No. ATR-78(7384)-1, Prepared for U.S. DOE. August 1978. 294 pages.
3. Chansky, S. et al. Waste Automotive Lubricating Oil Reuse As A Fuel. EPA-600/5-74-032. September 1974. 215 pages.
4. Manson, L. and S. Unger. Hazardous Material Incinerator Design Criteria. EPA-600/2-79-198. October 1979. 110 pages.
5. FR 43, No. 243, pages 59008-59009. Monday, December 18, 1978.
6. Berry, E. E. et al. Experimental Burning of Waste Oil as a Fuel in Cement Manufacture. Technology Development Report EPA 4-WP-75-1, Environment Canada. June 1975. 187 pages.
7. Chansky, S. et al. Waste Automotive Lubricating Oil as a Municipal Incinerator Fuel. EPA-R2-73-293. September 1973.
8. Maizus, S. Recycling of Waste Oils. PB-243 222/7WP. NTIS, Springfield, VA. June 1975. 271 pages.



## 4.0 ASSESSMENT OF USED OIL BURNING EMISSIONS

### 4.1 Introduction

The increasing value of petroleum has heightened interest in used oils for steam boilers and other fuel applications in spite of the problems sometimes encountered with burning these used oils and used oil/virgin oil mixtures. All of the problems can be overcome but the cost of the solutions reduces the value of used oil relative to virgin fuels. Some examples are special facilities required for storage and blending, fuel filter and burner modifications, tube and refractory deposits which may reduce combustion efficiency and require frequent cleaning, and increased air emissions which may require special controls depending upon the level of emissions and regulations.

Of special concern are undesirable emissions which may arise from the following sources:

- Lead and other metals commonly found in used oils as an ash constituent, with possibly some oil soluble lead compounds.
- Other inorganic elements commonly found in used oils, e.g. sulfur, nitrogen, chlorine, and bromine. These may be expected to be found in both the ash and organic fractions.
- Polynuclear aromatics (PNA's) found in all heavy fossil fuels and polycyclic organic matter (POM's) which may be emitted from combustion of fossil fuels.
- Polychlorinated biphenyls (PCB's) not normally present in used oils. The extent of contamination is unknown.
- Other organics which may be present in used oils, ranging from gasoline dilution always found in gasoline engine crankcase oils and glycol antifreeze contamination which sometimes occurs at service stations, to pesticides, halides and other solvents, and other hazardous wastes which may occasionally contaminate industrial and other used oils.

As with other fuels, emissions could also arise from incomplete combustion (carbon monoxide, hydrocarbons, carbonaceous particles, and possibly other chemical species such as dioxins). Only a very limited number of stack tests have been conducted to detect emissions from combustion of used oils. None of the tests reported have dealt with all of the above sources; in fact, it appears that no comprehensive work has been done on the postulated prevalence of PCB's and other organics in used oil and their fate in the combustion process.

#### 4.2 Combustion Tests

A summary of test work on boilers burning used oils has been compiled in Table 7-13. Nine tests performed as part of this study are included. Test details are provided in Appendix B (Volume II).

Conclusions and observations which can be drawn from this work include:

1. Used oil can be burned in mixtures with fuel oils of various types (including No. 2, No. 4 and No. 6), as 100% used oil, or as a fuel supplement in a coal-fired boiler.
2. Used oil can be burned in a variety of burner and boiler types.
3. Combustion problems can be expected with used oil, e.g. ignition, stability, burner fouling, higher particulate emissions, and furnace deposits, but these can be overcome.
4. Increased maintenance time and cost can be expected when burning used oils, e.g. requirements for cleaning filters, burners and furnace tubes. (However, these may not be a significant problem when burning low concentrations of oil, e.g. Hawaiian Electric Company has reported that they have burned waste lubricating oils in concentrations averaging about 1 percent by volume, but ranging up to 7 percent by volume, for several years with no boiler deterioration or unusual maintenance problems.)

5. Anywhere from about 20% to 100% of the lead entering a steam boiler with the fuel can be expected to be emitted from the stack. Most of the remainder of the lead is deposited on tubes and elsewhere in the combustion furnace. It is possible that some lead emissions are of a form other than particulate, e.g. aerosol or vapor. In the two instances where it was possible to account for furnace deposits (Northern States; Exxon/Mass. test) lead balances exceeded 90%. Furnace deposits may be emitted during sootblowing, where this is practiced, or they may eventually be removed during furnace and boiler cleaning to ultimate destinations varying with local practice and hazardous waste regulations.
6. In one test, over 90% of the lead was associated with particles smaller than one micron, with about 75% of these fine particles recovered from the tubes and 25% emitted directly to the atmosphere (Exxon/Mass. test).
7. Lead emissions from used oil combustion can be controlled, e.g. less than 0.2% of the lead in used oil fired with coal in a boiler equipped with an electrostatic precipitator (Northern States Power test) was emitted to the atmosphere; only about 0.03-0.05% of the lead in a waste oil fired suspension preheater cement kiln equipped with electrostatic precipitators was emitted (lead "scrubbed" by cement); and partially replacing No. 2 fuel oil with used crankcase oil bottoms in a lead smelting reverberatory furnace equipped with a baghouse did not increase lead emissions.
8. Other trace metals and elements in used oil may be expected to behave similarly to lead with regard to stack emissions, but very limited data are available.
9. Total particulate emissions in all RECON tests were less than the 0.12 grains/dry SCF called for in the 12/18/78 proposed hazardous waste incinerator standards but not included in the May 19, 1980 regulations. But tests with blended oils containing 0.48% ash and 0.91% ash approached the proposed standard (0.074 and 0.118, respectively).

10. In one RECON stack test with used industrial oil (Site A), polynuclear aromatic (PNA) emission was estimated to be  $0.02 \text{ mg/m}^3$ , compared to the OSHA limit of  $0.2 \text{ mg/m}^3$  for coal tar pitch volatiles (1). In a second test, with used crankcase oil (Site B), only naphthalene was detected at a level of  $0.005 \text{ mg/m}^3$  compared to the OSHA limit of  $50 \text{ mg/m}^3$ . No PNA emissions were detected in three additional tests. Total PNA and total hydrocarbon emissions were generally in the range previously measured by the Public Health Service for No. 2 and No. 6 fuel oils.
11. Benzo(a)pyrene (BaP) concentrations measured in various fuels generally agreed with earlier National Bureau of Standards data. No. 2 fuel oils and virgin lubricating oils tend to be low in BaP while heavier fuel oils and used oils tend to be higher. However, none of the RECON combustion tests resulted in measureable BaP emissions.

#### 4.3 Discussion of Used Oil Combustion Emissions

Emissions from each of the sources noted in Section 4.1 are discussed below. Included in this discussion are comparison of actual combustion test results to potential emissions predicated upon material balance, and some comparisons of used oil combustion with virgin oil combustion.

##### 4.3.1 Lead

Lead emissions are of primary concern because of potential health effects and the existence of both a National Ambient Air Quality Standard (NAAQS) and an OSHA standard. The NAAQS can be exceeded, as shown by modeling studies reported in Section 5.0, and it may even be possible to exceed the OSHA standard in the vicinity of a short stack boiler during downwash, as shown in Appendix C.

Stack test data summarized in Table 7-13 show lead emissions during combustion of used oil and used oil mixtures ranged from about 20% to 100% of the lead entering with the oil. As shown in Figure 7-1, there appears to be an inverse correlation between emissions, as a percent of the lead introduced with the oil, and the lead concentration in the oil. Increased lead concentration does increase the total weight of lead emitted, but the lead emitted as a percent of lead input appears to decrease.

However, it should be noted that lead not emitted during normal combustion will be emitted during soot blowing and other boiler cleaning operations, either in flue gas leaving the stack, or in recovered residues. The Hawaiian Electric tests clearly show high lead emissions during soot blowing. However, soot blowing is generally limited to large boilers and alternative cleaning methods are used in smaller units.

#### 4.3.2 Other Metals

Compounds of many metals other than lead are found in used oils in concentrations ranging from traces up to a few tenths of one percent. From the available data, it is reasonable to assume that emitted metals, other than lead, will be equal to the total in the oil fed. Some of the metals which can be expected from used motor oils are Ba, Ca, Mg, Zn, Na, Al, Cr, Cu, Fe, K, Si, and Sn. These same metals can be emitted from industrial oils, but the composition of used industrial oils vary much more from source to source than do used automotive oils. Therefore, metals emitted when burning industrial oils depend upon the composition of the particular oil being burned.

#### 4.3.3 Other Inorganic Elements

Inorganic elements other than metals which are found in used oils are sulfur, nitrogen, phosphorous, chlorine, and bromine. These elements may be present in both organic and inorganic compounds. E.g., sulfur may be found as organic sulfides, mercaptans, ring members in aromatic structures, or as inorganic sulfates or sulfites. Emission forms resulting from combustion will vary with the source.

Some examples of inorganic emissions expected from steam boilers are as follows:

##### - sulfur

Most of the sulfur in the fuel emitted as gases, primarily  $\text{SO}_2$  and some  $\text{SO}_3$  and  $\text{H}_2\text{SO}_4$ , with some sulfur in particulate emissions and boiler deposits as sulfate and possibly sulfite compounds. Approximately 0.35-0.58 lbs  $\text{SO}_2$ /MM BTU in the used oil (50-81 lbs/10<sup>3</sup> gal) would be the expected emission based on 0.33-0.54% S (from Section 2.3), but fuel sulfur is expected to increase in the future. State standards limiting fuel sulfur to 0.5% are common, with some regulations limiting residual oils to as low as 0.3% and distillate fuels to as low as 0.2%.



- nitrogen

Primarily NO and some NO<sub>2</sub> and other oxides as gaseous emissions. Particulate emissions and boiler deposits may include nitrate and nitrite compounds with the possibility of some ammonia compounds. Most of NO<sub>x</sub> emissions from oxidation of nitrogen in air, with total quantity primarily related to boiler and burner characteristics rather than fuel composition. RECON data are presented in Table 7-14.

- phosphorous

Would be expected to be emitted primarily as part of particulate compounds, e.g. phosphates. Only data available show phosphorous split between particles emitted and tube deposits (Exxon/Mass. study).

- chlorine and bromine

Organic halides, which may also include fluorides, are converted primarily to hydrochloric and hydrobromic acids during combustion. Metal halide salts may also be emitted, either unchanged from those present in the used oil or formed by reaction of cations with halide acids. The authors are not aware of any regulations pertaining to halide emissions.

- particulate emissions

Particulate emissions are primarily a function of the total ash in the fuel, including metals and other inorganics discussed above. Assuming no chemical changes and no soot from incomplete combustion, 0.3% ash in a blended oil being fired would correspond to 0.12 grain/ dry SCF (zero excess air) emission. 0.5-1.2 lbs particulate emission/MM BTU in the used oil are estimated based on 0.9-2.2% ash (from Section 2.3). Actual test data are reported in Appendix B and summarized in Table 7-15. Relatively stringent state regulations limit fuel combustion particulates to 0.1 lbs/MM BTU.

4.3.4 PNA's (and POM's)

There are no data available to indicate that PNA emissions from used oil combustion differ from similar emissions during virgin oil combustion. As shown in Tables 7-16 to 7-18, BaP [benzo(a)pyrene] concentrations in used oil are similar to unused motor oils and fuel oils. BaP was not detected during emission tests by RECON (Table 7-19). Other PNA emissions ranged from non-detectable to concentrations similar to those observed in previous experiments by the Public Health Service (Table 7-20) for combustion of No. 2 and No. 6 fuel oils.

#### 4.3.5 PCB's

PCB's are not normally present in used oils, but contamination is possible. PCB destruction should occur in very efficient boilers based on limited data from incinerator (2) and boiler tests (3). Of the products of efficient combustion, only HCl is believed to be significant.

#### 4.3.6 Halide Solvents

Halide solvents also are not normally present in used oils, but contamination is believed to be widespread. Destruction should occur in efficient boilers with HCl as an expected product. However, unlike PCB's, most halide solvents are volatile and, if necessary, can be removed from used oils by distillation steps, as will be explained later in this section.

#### 4.3.7. Other Organics

Other organics such as non-halide solvents, glycols and gasoline which contaminate used oils are normally readily combustible. Some organics such as gasoline contribute to used oil volatility, sometimes raising vapor pressure and flash point so as to require special storage facilities.

#### 4.4 Emission Factors

Emission factors for used oils are suggested in Table 4-1, supported by data tabulated in Section 7.0. These suggested emission factors are compared and made consistent with EPA published factors for lead, particulate, SO<sub>2</sub>, NO<sub>2</sub>, CO, and hydrocarbons (4). Preliminary emission factors have also been suggested for other metals, phosphorous, HCl, HBr, and PNA's.

#### 4.5 Impact on Ambient Air Quality

The impact of lead emissions on ambient air quality is covered in depth in Section 5.0, showing that under certain conditions, e.g. short stack height, lead concentrations in the vicinity of used oil combustion sources can exceed Federal Standards.

Using the suggested emission factors in Table 4-1, the modeling results in Section 5.0 can be scaled to calculate ambient air quality impact for other pollutants. This is done in Table 4-2 for the worst location, calendar quarter, and generic boiler determined by the modeling results (Southern California, 2nd Quarter, medium size boiler).

Table 4-1

## UNCONTROLLED EMISSION FACTORS FOR COMBUSTION

<u>Pollutant</u>	<u>Emission Factors, lb/10<sup>3</sup> gal</u>		<u>Comments</u>
	<u>EPA AP-42 (3)</u>	<u>Suggested for Used Oil*</u>	
<u>Pb</u>	Waste Oil 0.0075(L)	0.0075(L)	L = ppm Pb in oil. Based on 100% emission at 7.5 lbs/gal oil density.
<u>Pb</u>	Virgin Oils 0.0042(L) (Residual, Distillate)	-	Based on substantially less than 100% emissions. Avg L = 1.0 for residual oils, and 0.1 for distillate oils.
	Coal 1.6(L) lb/10 <sup>3</sup> ton (Bituminous, Anthracite)	-	Based on 80% emissions.
<u>Particulate</u>	Waste Oil 75(A)	75(A)	A = % ash in oil. Based on 100% equivalent emission at 7.5 lbs/gal oil density.
<u>Particulate</u>	Virgin Oils #6 10(S) + 3 #5 10 #4 7 Ind./Comm. Dist. 2 Domestic Dist. 2.5	-	S = % sulfur in oil. Note that used oil with approx. 0.13% ash would be equivalent to #5 fuel oil.
<u>Other Metals in Particulate</u>	Not included	0.0075(L)	L = ppm metal in oil.
<u>SO<sub>2</sub></u>	Residual Oil - 157(S) Distillate Oil - 142(S)	150(S)	S = % sulfur in oil. Suggested factor for used oil based on 100% conversion of S to SO <sub>2</sub> for 7.5 lb/gal oil density. See Table 7-17 for test results.
<u>SO<sub>3</sub></u>	All virgin oils - 2S	2S	S = % sulfur in oil.
<u>NO<sub>x</sub> (total as NO<sub>2</sub>)</u>	Residual Oils Power plant tangential - 50 Power plant other - 105 Ind./Comm. - 22+400(N) <sup>2</sup>  Ind./Comm. Dist. - 22 Domestic Dist. - 18	22	N = % nitrogen in oil. See AP-42 1.3 for further discussion of NO <sub>x</sub> emissions. See Table 7-17 for test results.
<u>Hydrocarbons (total, as CH<sub>4</sub>)</u>	All virgin oils - 1	1	See Table 7-19. RECON measurements ranged from 14 to 165 µg/g fuel <sub>3</sub> (113 avg) as compared to 1 lb/10 <sup>3</sup> gal (approx. 133 µg/g) emission factor.
<u>PNA's</u>	Not included	0.0075	Corresponds to 1 µg/g. See Table 7-19. Insufficient data to determine how PNA emissions for used oils compare to virgin oils.
<u>HCl</u>	Not included	77(C) max.	C = % chlorine in oil.
<u>HBr</u>	Not included	76(B) max.	B = % bromine in oil.
<u>P (in particulate)</u>	Not included	75(P) max.	P = % phosphorous in oil.
<u>CO</u>	5	5	CO emissions vary with combustion control on all fuels. No CO emission detected by Orsat analyses in RECON tests 1-4. Determinations by Kitagawa detector tube in runs 5-9 showed 10 to 100 ppm in the flue gas or an average of about 5 lb/10 <sup>3</sup> gal.

\* And for used oil/virgin oil mixtures.

Table 4-2

AIR QUALITY IMPACT FOR VARIOUS POLLUTANTS  
EMITTED FROM STEAM BOILERS

"Worst Case Analyses"\*

Basis: 1. Southern California, 2nd Quarter  
 2. Stack, 1.5 m diam. x 22.6 m high  
 3. Flue Gas, 25.8 m<sup>3</sup>/sec at 154°C  
 4. 1421 GPH (25% used oil), 24 hrs/day, 7 days/week

Pollutant	Emission Concentration.		Control %	g/sec	Calculated Max. Quarterly Average Ambient Air Conc., $\mu\text{g}/\text{m}^3$	Comments
	in oil					
Pb	625 ppm		0	0.63	5.0	Table 5-11, Group 3, Source 2 (75% of Pb emitted)
Pb	625 ppm		0	0.84	6.7	Table 4-1 Factor, (100% of Pb emitted)
Particulates	0.5% Ash		0	6.72	53.3	vs 60 $\mu\text{g}/\text{m}^3$ NAAQS (sec. annual mean)
Particulates	0.5% Ash		98	0.13	1.1	
SO <sub>2</sub>	0.5% S		0	13.44	106.6	vs 80 $\mu\text{g}/\text{m}^3$ NAAQS (prim. annual mean)
NO <sub>2</sub>	-		0	1.97	15.6	vs 100 $\mu\text{g}/\text{m}^3$ NAAQS (prim./sec. annual mean)
Hydrocarbons	-		0	0.09	0.7	vs 160 $\mu\text{g}/\text{m}^3$ (prim./sec. 3-hr)

\*Based on "reasonable worst case" judgments. Actually, the impact could even be increased by a factor of 10, e.g. by burning higher

The actual case used for scaling resulted in a maximum ambient air concentration for lead of  $5.0 \mu\text{g}/\text{m}^3$  (quarterly average), well in excess of the  $1.5 \mu\text{g}/\text{m}^3$  Federal Standard. For this case, using reasonable ash and sulfur concentrations, ambient air concentrations for particulates and  $\text{SO}_2$  were very significant when emissions were not controlled.

Control of particulates, e.g. by an electrostatic precipitator or baghouse, reduces the impact to almost negligible proportions.  $\text{SO}_2$  emissions could also be controlled, but the high cost makes this less likely. Expected increases in used oil sulfur concentration make it likely that  $\text{SO}_2$  emissions will be a significant problem, possibly requiring dilution with low sulfur oils prior to burning in areas where emission standards are very stringent. In the past, used oil was sometimes used in blends to reduce sulfur level in high sulfur fuels.

It must be emphasized that the data in Table 4-2 represent a "reasonable worst case analysis". Based on the information developed in Section 5.0 for various size boilers and five locations (with appropriate meteorological data), the impact in most instances will be localized and less than indicated in the table. On the other hand, individual situations could be even worse, e.g. a Pb concentration of 6250 ppm when burning 100% used oil in the case given in Table 4-2 could increase the calculated impact by a factor of ten.

#### 4.6 Reduction of Emissions by Used Oil Purification

##### 4.6.1 General

Re-refining processes, excluding clay treat or hydrotreat finishing steps, could be used to produce relatively clean fuels. These would include, for example, acid, solvent, or diammonium phosphate treatment or vacuum distillation, but this approach is expensive. If practiced, the finishing steps to produce higher-than-fuel-value lubes become justified.

#### 4.7.2 Other Inorganics

Sulfur oxide emissions can be reduced by scrubbing and other processes developed for that purpose. However, this technology is expensive and could not be readily justified. If sulfur oxide removal became necessary for burning fuel oils containing on the order of 0.5% sulfur, the value of used oil relative to low sulfur fuels such as No. 2 oil would decrease drastically, making used oils more readily available for re-refining.

Nitrogen oxide emissions from used oil combustion appear to be similar to emissions from other fuel oils. At this time, only combustion modifications appear to be warranted, providing the potential for moderate reduction in nitrogen oxides (4).

Hydrogen chloride and hydrogen bromide formed from the corresponding halides during used oil combustion can be removed by water or preferably alkaline water scrubbing. Scrubbing is not normally practiced and under present circumstances would be considered only as an adjunct to sulfur oxide and/or particulate removal.

#### 4.7.3 Hydrocarbon and PCB Emissions

Hydrocarbon emissions which may result from poor combustion of any fossil fuel, or because of the presence of refractory organics, can be reduced by combustion modifications or the addition of an afterburner. Combustion modifications which may be used include: changes in burner and furnace design to increase turbulence and/or temperature; changes in excess air, especially an increase when air used is too close to stoichiometric; downrating to increase residence time; and others. One would seldom resort to an afterburner to reduce emissions in a combustion system, but this possibility exists, especially to avoid downrating.

The same actions which reduce hydrocarbon emissions would also be expected to reduce PCB emissions. Although few data on PCB contaminated used oils in boilers are available, incineration results can be used as a guideline. These have been reviewed by Fuller et al (2), showing that temperatures in excess of 2000°F with 1.5 to 2 seconds residence time and 2-3% excess oxygen are effective.

One test program by Osag et al (3) for two steam boilers showed PCB destruction efficiencies in excess of 99% over a range of steam loads (fuel rates) when burning used oils containing from 5 to 95 ppm PCB's. During the tests, combustion zone temperatures ranged from 2480-2760°F, dwell times from 2-6 seconds, and excess oxygen from 2-8%.

## REFERENCES

1. 29 CFR 1910 Subpart 2.
2. Fuller, B. et al. Environmental Assessment of PCB's in the Atmosphere. EPA-450/3-77-045. November 1977. 266 pages.
3. Osag, T. R., J. J. Slovinski and L. R. Walz. The Measurement of PCB Emissions From an Industrial Boiler. For presentation at the 71st Annual Meeting of APCA, June 25-30, 1978. 15 pages.
4. EPA. Compilation of Air Pollutant Emission Factors. Third Edition. Part A and B with Supplement Nos. 8-10. February 1980.
5. Anon. Goodyear Develops PCB Removal Method. Chem. & Eng. News. September 1, 1980. page 9.
6. Anon. Another Route to Detoxify PCB-Contaminated Fluids Has Been Announced. Chem. Eng. September 22, 1980. page 35.
7. Chansky, S. et al. Waste Automotive Lubricating Oil Reuse as a Fuel. EPA-600/6-74-032. September 1974. 215 pages.

## 5.0 LEAD AIR QUALITY IMPACT OF BURNING USED OIL

### 5.1 Introduction

Interest in burning used oil as a fuel has been generated by the high cost of fuel oil and the need to extend oil resources. However, hazardous materials contained in used oil may be emitted to the atmosphere and widely dispersed. One pollutant of particular concern which is commonly contained in used crankcase oil is lead. To quantify the air quality impact of burning used oil, atmospheric dispersion modeling was performed to assess the impact of lead emissions resulting from used crankcase oil combustion. Comparisons were made with the National Ambient Air Quality Standard for lead. The analysis required detailed information on source physical and operating parameters, emission rates, the character and lead content of used oil, and meteorological data. A general discussion of the analysis and results follows. Additional details are presented in Appendix A.

### 5.2 Technical Approach

The technical approach employed an atmospheric dispersion model to determine quarterly ambient lead concentrations resulting from the combustion of a virgin oil/used oil mixture. These concentrations were compared to the National Ambient Air Quality Standard for lead. Concentrations were calculated at 176 receptor points centered around each emission source analyzed. This receptor grid is shown in Figure 5-1.

#### 5.2.1 Emission Data

For modeling purposes, a list of sources capable of burning used oil was developed. Much of this information was derived from the Wisconsin Department of Natural Resources' statewide inventory of emission sources burning oil.<sup>1</sup> Some of the information was also taken from the Minnesota point source inventory.<sup>2</sup> The stack height, stack diameter, exit temperature, and volumetric flow were recorded for each of these sources. This list of sources was then separated into five groups based on estimated hourly fuel usage, and these five source groups served as the base for the development of five individual generic sources.

The first four groups represent various sizes of industrial and commercial boilers. For each of these groups, the mean values of the pertinent stack parameters in the Wisconsin boiler survey, except temperature, were determined. The temperatures used for the four groups were derived from a compilation of operating parameters for oil-fired industrial and commercial boilers in the U.S.<sup>3</sup> These mean operating values were then used in the analyses for the definition of generic emissions sources.



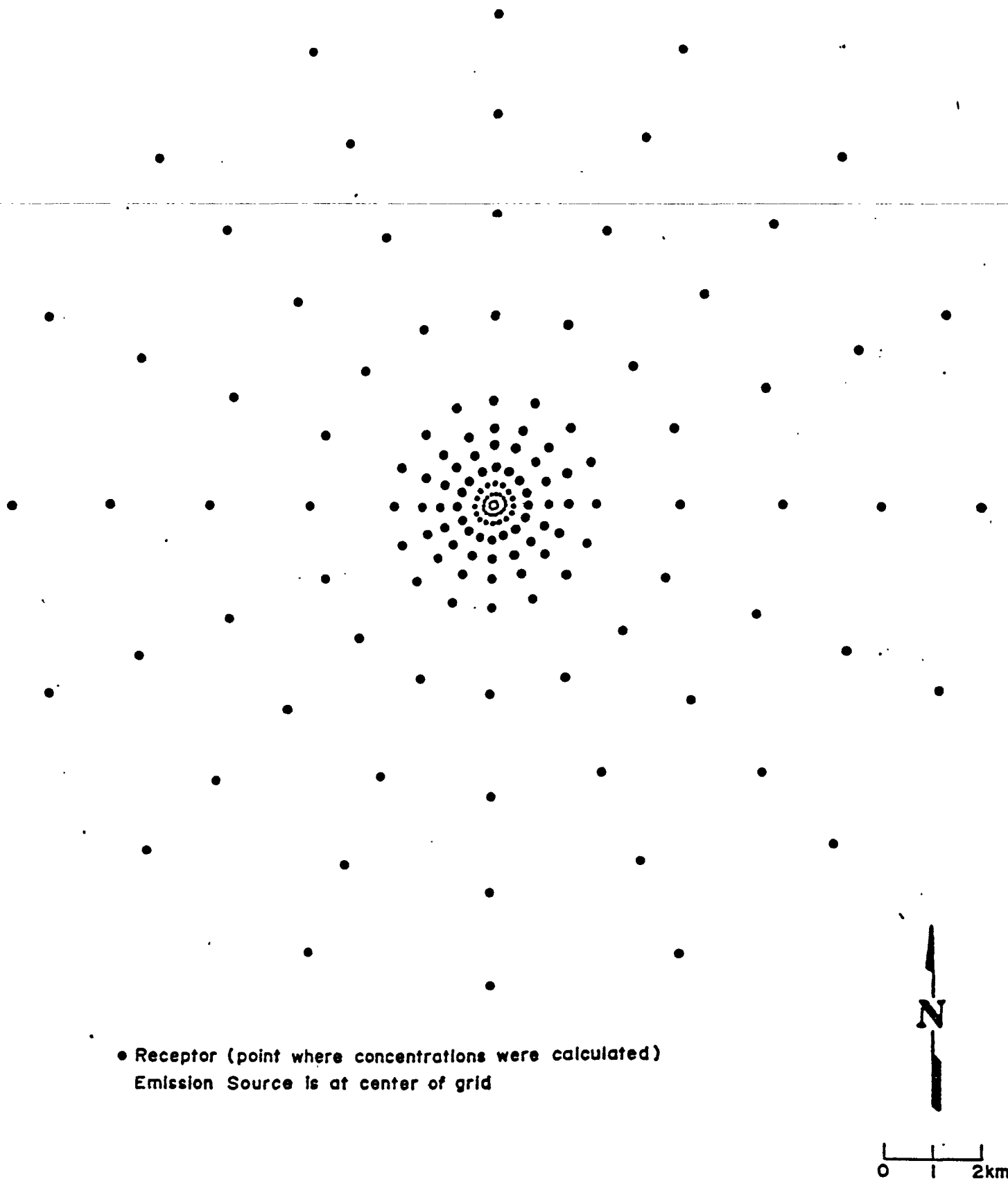


FIGURE 5-1 RECEPTOR GRID

The final generic source was defined by operating parameters for a modern utility boiler. Plant size rating was established using Minnesota point source emissions inventory data, while generic operating parameters were those developed in a recent EPA report.<sup>4</sup> These data were then used by Continental Heine, a division of Peabody Incorporated, to determine a range of typical stack dimensions based upon estimated flue gas exit velocity of 60 feet per seconds. Table 5-1 presents the resultant plant parameters.

Computation of lead emission rates for the generic sources required that numerous assumptions be made about fuel and usage. These assumptions are listed in Table 5-2. A 25% used oil to 75% virgin fuel oil mix by volume was used because this is generally the maximum used oil mixture that can be successfully burned without prior treatment before excessive operating and maintenance problems occur. Based on a conversation with the U.S. Department of Energy's Used Oil Laboratory,<sup>6</sup> an average lead content of 2500 ppm in used oil was assumed. Lead emission rates were thus calculated for each generic source based on the burning of 25% used crankcase oil. A stack emission rate of 75% of the lead content in the input fuel was used for all computer runs. Since RECON's stack test results and other published empirical evidence indicate that the average lead emission rate is approximately 50%, the estimated emissions are conservative, i.e., they provide maximum emission rate values. As discussed in a later section, ambient concentrations resulting from operating conditions or assumptions significantly different from those listed in Table 5-2 can be directly determined. This allows an investigation of an unlimited number of scenarios based on the one modeling analysis for these assumptions. For example, the ambient levels could be directly examined for used oil with a lead content of 1250 ppm instead of 2500 ppm.

## 5.2.2 Meteorological Data

To allow assessment of air quality impact under various meteorological conditions, the generic sources were analyzed using meteorological data from several regions of the country. Analyses were performed for Chicago, Illinois; Paducah, Kentucky; Denver, Colorado; Helena, Montana; and Southern California (near Santa Barbara). The meteorological data required for dispersion modeling includes the joint frequency function of wind speed, wind direction, and stability class; climatological mixing heights; and average ambient temperature. The joint frequency function data were obtained in program-compatible STAR format from the National Climatic Center located in Asheville, North Carolina. Climatological mixing height values were obtained from Holzworth's report (AP-101).<sup>7</sup> Average temperatures were obtained from local climatological summary sheets.

Table 5-1

GENERIC SOURCE OPERATING PARAMETERS FOR COMPUTER DISPERSION MODELING

Generic Source	Boiler Size Category	Fuel Fired (gal/hr)	Fuel Fired (MMBTU/hr)	Height (m)	Stack Data			Emission Rate (g/s)
					Diameter (m)	Exit Vel. (m/sec)	Outlet Temp. (°C)	
1	Very Small Commercial	35	5.4	18.3	0.8	1.7	204	0.016
2	Small Industrial	325	50.5	15.8	0.9	11.9	204	0.16
3	Medium Industrial	1500	231	25.9	1.4	20.8	204	0.66
4	Large Industrial	7600	1170	39.9	3.5	13.2	204	2.63
5	Power Plant	13300	2048	76.2	4.9	17.5	154	7.55

Table 5-2

ASSUMPTIONS USED IN EMISSION RATE CALCULATIONS

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1. A 2,500 ppm lead concentration in the used oil.
  2. Fuel mixture consists of 25% used/75% virgin fuel oil.
  3. A total of 75% of the lead in the fuel is actually emitted out the stack.
  4. Boilers operate 24 hours per day 7 days a week each quarter.
  5. Pollution control devices - none
-

### 5.2.3 Modeling Analysis

Atmospheric dispersion modeling was performed to assess the impact on quarterly average lead ambient air quality due to the combustion of used oil. A quarterly assessment was chosen to correspond with the quarterly National Ambient Air Quality Standard for lead of  $1.5 \mu\text{g}/\text{m}^3$ . The model employed for calculating quarterly ambient lead concentrations is the U.S. EPA Climatological Dispersion Model (CDMQC), available on Version 3 of the User's Network for the Applied Modeling of Air Pollution (UNAMAP) system. The CDMQC program determines long term quasi-stable pollutant concentrations at any ground level receptor point using the previously discussed emission and meteorological data. The model is applicable to urban areas, simulating urban roughness and mixing by providing an initial value of 0 z for stacks shorter than 50 meters. Further details of the model may be found in the User's Guide.<sup>8</sup> The model is recommended for lead dispersion analyses.<sup>9</sup>

Using this model, each generic emission source was analyzed using four quarters of meteorological data for the five cities previously discussed. This resulted in 100 computer analyses (5 generic sources x 4 quarters x 5 cities). For each analysis, quarterly lead concentrations were determined at each receptor point shown in Figure 5-1 for each generic source. These results were then summarized, worst case impacts were identified, and isopleth maps developed.

## 5.3 Results

### 5.3.1 Generic Source Analysis

The results of the dispersion modeling analysis for each generic source is presented in Tables 5-3 to 5-7 with a summary in Table 5-8. It should be noted that these results are based on the assumptions listed in Table 5-2. As will be explained in Section 5.3.2, these ambient concentrations may be directly proportioned to reflect alternative assumptions such as 8-hour per day operation instead of the 24-hour per day operation assumption used. The concentrations presented in these tables are the maximum values from among the concentrations calculated for each of the 176 receptors for each quarter analyzed. From these data it is clear that generic sources 2 and 3 may violate the standard and that generic sources 4 and 5 have a minimal air quality impact. The maximum impact of generic source 1 is also below the standard.

Isopleth maps of ambient lead concentrations were prepared for each generic source's maximum quarterly impact. These are depicted in Figures 5-2 through 5-6. Again, these isopleths are directly dependent on the assumptions affecting emission rate. Decreasing emissions would decrease the size of the isopleths. Additional isopleth maps are included in Appendix A.

Table 5-3  
MAXIMUM QUARTERLY LEAD IMPACT GENERIC GROUP 1  
(VERY SMALL BOILERS)

<u>City</u>	<u>Quarter</u>	<u>Maximum Lead Concentration (<math>\mu\text{g}/\text{m}^3</math>)</u>	<u>Distance and Direction of Maximum From Source</u>	
Chicago	first	0.1*	360°	0.125 KM
	second	0.2	360°	0.125 KM
	third	0.3	360°	0.125 KM
	fourth	0.2	360°	0.125 KM
Paducah	first	0.1	23°	0.125 KM
	second	0.2	23°	0.125 KM
	third	0.3	45°	0.125 KM
	fourth	0.2	360°	0.125 KM
Helena	first	0.3	90°	0.125 KM
	second	0.3	90°	0.125 KM
	third	0.3	90°	0.125 KM
	fourth	0.4	90°	0.125 KM
Denver	first	0.3	360°	0.125 KM
	second	0.2	360°	0.125 KM
	third	0.3	360°	0.125 KM
	fourth	0.3	360°	0.125 KM
So. California	first	0.2	293°	0.125 KM
	second	0.4	135°	0.125 KM
	third	0.5**	135°	0.125 KM
	fourth	0.3	293°	0.125 KM

\* Lowest concentration

\*\* Highest concentration

Table 5-4  
MAXIMUM QUARTERLY LEAD IMPACT  
GENERIC GROUP 2 (SMALL BOILERS)

<u>City</u>	<u>Quarter</u>	<u>Maximum Lead Concentration (<math>\mu\text{g}/\text{m}^3</math>)</u>	<u>Distance and Direction of Maximum From Source</u>	
Chicago	first	1.0*	360°	0.125 KM
	second	1.3	360°	0.125 KM
	third	1.6	360°	0.125 KM
	fourth	1.6	360°	0.125 KM
Paducah	first	1.0	23°	0.125 KM
	second	1.4	23°	0.125 KM
	third	1.2	45°	0.125 KM
	fourth	1.2	23°	0.125 KM
Helena	first	1.8	90°	0.125 KM
	second	2.3	90°	0.125 KM
	third	1.7	90°	0.125 KM
	fourth	2.0	90°	0.125 KM
Denver	first	1.7	360°	0.125 KM
	second	1.5	360°	0.125 KM
	third	1.8	360°	0.125 KM
	fourth	1.7	360°	0.125 KM
So. California	first	1.2	158°	0.125 KM
	second	2.5**	135°	0.125 KM
	third	2.5	135°	0.125 KM
	fourth	1.3	293°	0.125 KM

\* Lowest concentration

\*\* Highest concentration

Table 5-5

MAXIMUM QUARTERLY LEAD IMPACT  
GENERIC GROUP 3 (MEDIUM BOILERS)

<u>City</u>	<u>Quarter</u>	<u>Maximum Lead Concentration (<math>\mu\text{g}/\text{m}^3</math>)</u>	<u>Distance and Direction of Maximum From Source</u>	
Chicago	first	1.3	360°	0.125 KM
	second	1.8	360°	0.125 KM
	third	1.9	360°	0.125 KM
	fourth	1.9	360°	0.125 KM
Paducah	first	1.3	23°	0.125 KM
	second	1.8	23°	0.125 KM
	third	1.2	45°	0.125 KM
	fourth	1.4	23°	0.125 KM
Helena	first	1.8	90°	0.125 KM
	second	3.0	90°	0.125 KM
	third	1.9	90°	0.125 KM
	fourth	2.1	90°	0.125 KM
Denver	first	1.7	360°	0.125 KM
	second	1.8	360°	0.125 KM
	third	1.9	360°	0.125 KM
	fourth	1.5	360°	0.125 KM
So. California	first	1.5	158°	0.125 KM
	second	3.1**	135°	0.125 KM
	third	2.5	135°	0.125 KM
	fourth	1.1*	135°	0.125 KM

\* Lowest concentration

\*\* Highest concentration



Table 5-6

MAXIMUM QUARTERLY LEAD IMPACT  
GENERIC GROUP 4 (LARGE BOILERS)

<u>City</u>	<u>Quarter</u>	<u>Maximum Lead Concentration (<math>\mu\text{g}/\text{m}^3</math>)</u>	<u>Distance and Direction of Maximum From Source</u>	
Chicago	first	<0.1	-	-
	second	0.1	360°	2.0 KM
	third	0.1	360°	1.5 KM
	fourth	0.1	360°	4.0 KM
Paducah	first	<0.1	-	-
	second	0.1	23°	1.5 KM
	third	0.1	45°	1.5 KM
	fourth	<0.1*	-	-
Helena	first	0.1	90°	4.0 KM
	second	0.1	90°	1.5 KM
	third	0.1	90°	4.0 KM
	fourth	0.1	90°	4.0 KM
Denver	first	0.1	360°	4.0 KM
	second	0.1	360°	2.0 KM
	third	0.1	360°	2.0 KM
	fourth	<0.1	-	-
So. California	first	0.1	135°	2.0 KM
	second	0.1**	135°	0.25 KM
	third	0.1	135°	0.5 KM
	fourth	<0.1	-	-

\* Lowest concentration

\*\* Highest concentration

Table 5-7  
MAXIMUM QUARTERLY LEAD IMPACT  
GENERIC GROUP 5 (POWER PLANT BOILERS)

<u>City</u>	<u>Quarter</u>	<u>Maximum Lead Concentration (<math>\mu\text{g}/\text{m}^3</math>)</u>	<u>Distance and Direction of Maximum From Source</u>	
Chicago	first	<0.1	-	-
	second	0.1	360°	6.0 KM
	third	0.1	360°	4.0 KM
	fourth	0.1	360°	8.0 KM
Paducah	first	<0.1	-	-
	second	0.1	23°	4.0 KM
	third	0.1	45°	4.0 KM
	fourth	<0.1	-	-
Helena	first	<0.1	-	-
	second	0.1	90°	4.0 KM
	third	0.1	90°	6.0 KM
	fourth	0.1	90°	6.0 KM
Denver	first	<0.1*	-	-
	second	<0.1	-	-
	third	0.1	360°	4.0 KM
	fourth	<0.1	-	-
So. California	first	0.1	135°	6.0 KM
	second	0.1**	135°	1.5 KM
	third	0.1	135°	1.5 KM
	fourth	<0.1	-	-

\* Lowest concentration

\*\* Highest concentration

Table 5-8  
SUMMARY OF MAXIMUM LEAD AIR QUALITY IMPACTS\*

<u>Generic Group</u>	<u>Maximum Quarterly Lead Impact</u>	<u>Quarter of Maximum Impact</u>	<u>City of Impact</u>
Group 1	0.5 $\mu\text{g}/\text{m}^3$	3rd Quarter	So. California
Group 2	2.5 $\mu\text{g}/\text{m}^3$	2nd Quarter	So. California
Group 3	3.1 $\mu\text{g}/\text{m}^3$	2nd Quarter	So. California
Group 4	0.1 $\mu\text{g}/\text{m}^3$	2nd Quarter	So. California
Group 5-	0.1 $\mu\text{g}/\text{m}^3$	2nd Quarter	So. California

\*The National Ambient Air Quality Standard is 1.5  $\mu\text{g}/\text{m}^3$   
average per calendar quarter.

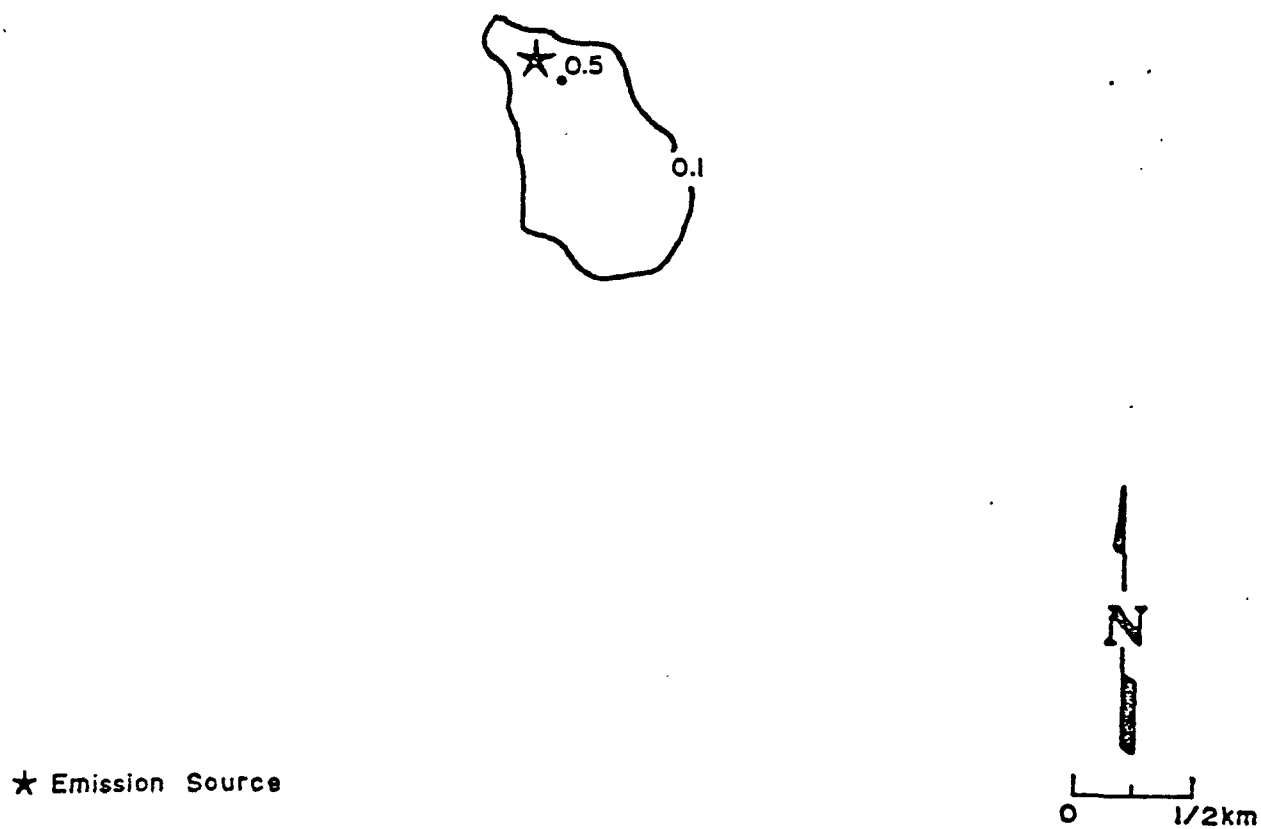


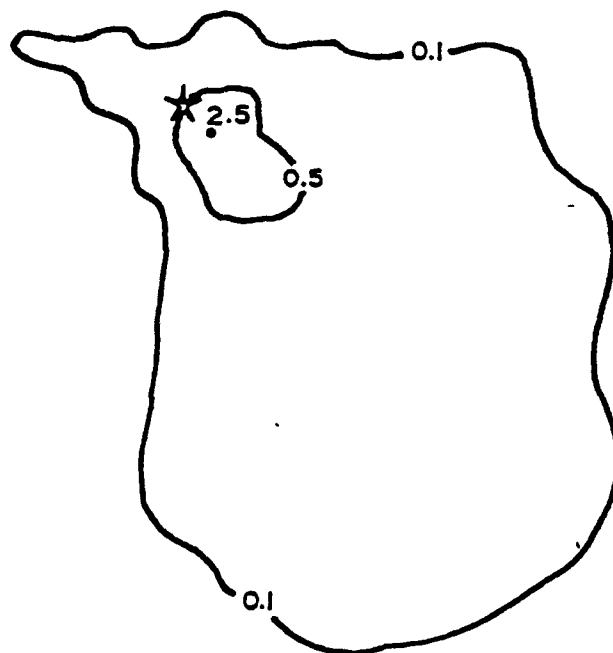
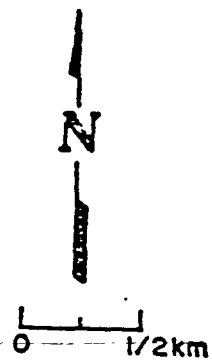
FIGURE 5-2

GENERIC SOURCE I

3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA



★ Emission Source

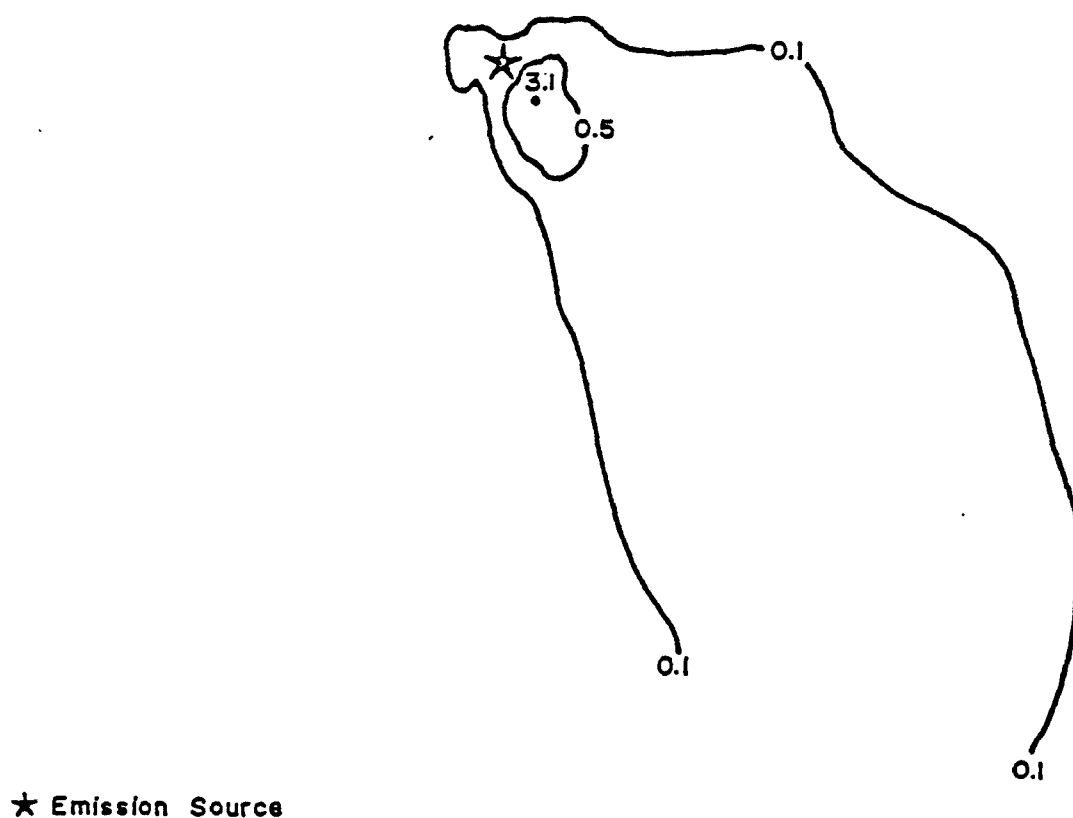
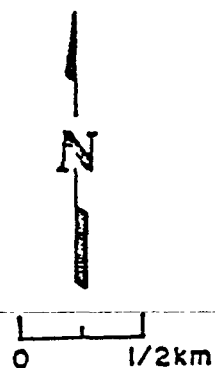
FIGURE 5-3

GENERIC SOURCE 2

2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA



★ Emission Source

FIGURE 5-4                      GENERIC SOURCE   3

2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA

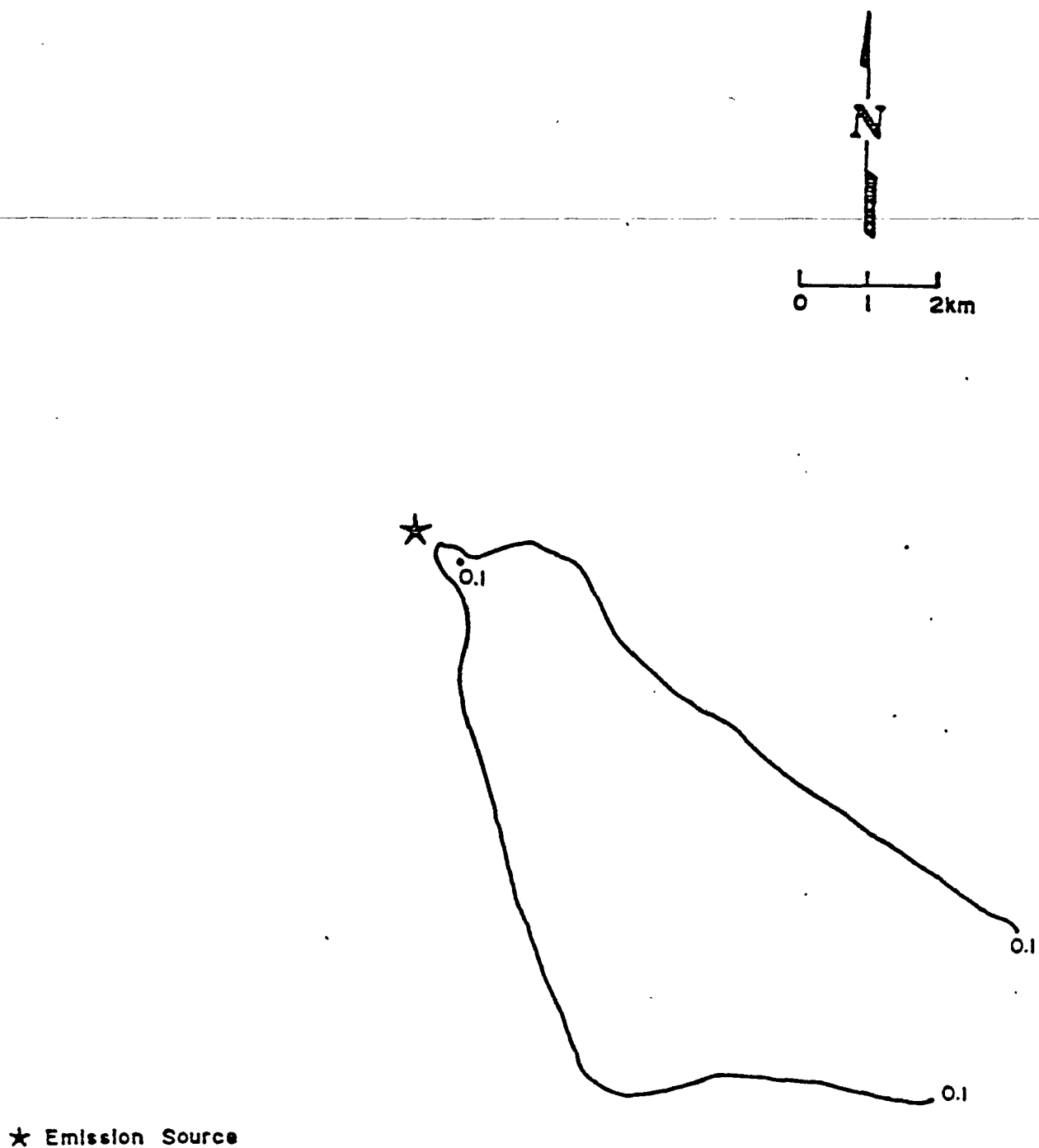


FIGURE 5-5

GENERIC SOURCE 4

2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA

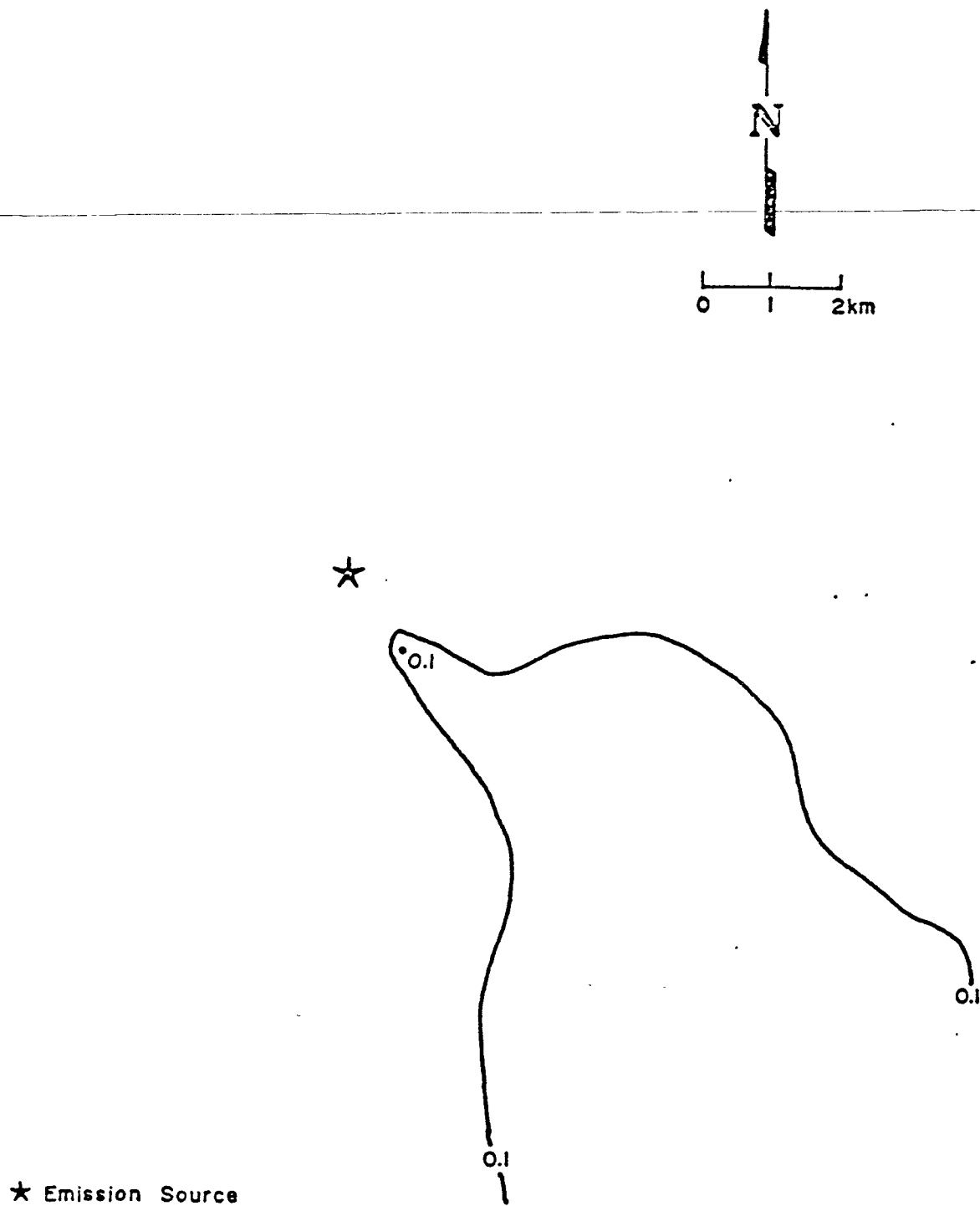


FIGURE 5-6

GENERIC SOURCE 5

2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA



The most important feature of these maps is the depiction of the area impacted. For generic sources 2 and 3, although the maximum impact is above the standard, the area impacted is exceedingly small and is located only in the immediate vicinity of the source. In many cases the area above the standard may be completely contained on plant property. In the case of generic sources 1, 2, and 3, the ambient concentration drops rapidly with distance from the plant. The impact from generic sources 4 and 5 occurs at some distance from the plant because of increased stack height and plume rise; however, the impacts are well below the standard and encompass a relatively small area.

#### 5.3.2 Extrapolation of Results for Other Assumptions

In drawing conclusions from this analysis, it may be desirable to determine ambient concentrations for assumptions different from those listed in Table 5-2. The dispersion model employed in this analysis calculates concentrations based on the Gaussian formula, which describes a direct proportion between emission rate and relative concentration. Thus it is possible to determine new receptor concentrations based on alternative assumptions (i.e., changing those listed in Table 5-2) by ratioing the values. A detailed explanation of this methodology is presented in Appendix A. An example demonstrating the use of the technique follows. Table 5-9 lists new assumptions for which it is desired to determine the maximum ambient lead concentrations for the group 3 generic source. To determine the air quality impact of this source based on these new assumptions, it is necessary to multiply the concentrations by 0.044. The results of this calculation are presented in Table 5-10. It should be noted that this scaling technique is only applicable for factors affecting emission rate; alternative stack parameters such as a different stack height cannot be assessed. As is evident from this table, the assumptions employed that change the emission rate significantly affect the resultant maximum concentration. The effect these assumptions have on maximum concentrations should be considered when drawing conclusions from this report.

#### 5.4 Sensitivity Analysis

An additional modeling analysis was performed on select source group members to assess the ability of the generic sources to represent the group they were derived from. From each group several sources were selected that characterized both the range and extremes of the emission sources contained in that group.

The operating parameters for these sources are listed by generic group in Table 5-11. Emissions for these sources were calculated based on the assumptions listed in Table 5-2 so that the results could be compared with the generic analysis.

Table 5-9

RATIOING EXAMPLE

<u>Parameter</u>	<u>Original Assumption</u>	<u>New Assumption</u>	<u>Multiplying factor</u>
Fuel Lead Content	2500 ppm	1250 ppm	0.50
Fuel Mixture	25% used	10% used	0.40
Emissions	75% emitted	50% emitted	0.67
Operation	24 hrs/7days	8hrs/7days	0.33*
Pollution Control Device	None	None	1.0

To reflect these new assumptions, concentrations should be multiplied by 0.044 (0.5 x 0.4 x 0.67 x 0.33 x 1.0).

\*Care should be taken in interpreting the results obtained by proportioning hours of operation since the meteorological conditions will vary with the time of day. These variations will have some effect on the resulting pollutant concentrations.

Table 5-10  
 MAXIMUM QUARTERLY LEAD IMPACT  
 REVISED TO REFLECT NEW ASSUMPTIONS  
GENERIC GROUP 3 (MEDIUM BOILERS)

		<u>Maximum Lead Concentrations (<math>\mu\text{g}/\text{m}^3</math>)</u>	
<u>City</u>	<u>Quarter</u>	<u>Based on Table 5-2 Assumptions</u>	<u>Based on Table 5-9 Alternate Assumptions</u>
Chicago	first	1.3	0.06
	second	1.8	0.08
	third	1.9	0.08
	fourth	1.9	0.08
Paducah	first	1.3	0.06
	second	1.8	0.08
	third	1.2	0.05
	fourth	1.4	0.06
Helena	first	1.9	0.08
	second	3.0	0.13
	third	1.9	0.08
	fourth	2.1	0.09
Denver	first	1.7	0.07
	second	1.8	0.08
	third	1.9	0.08
	fourth	1.5	0.07
So. California	first	1.5	0.07
	second	3.1**	0.14**
	third	2.5	0.11
	fourth	1.1*	0.05*

\* Lowest concentration  
 \*\* Highest concentration

Table 5-11  
SELECT SOURCES FOR SENSITIVITY ANALYSIS

Generic Group	Source Number	Stack Parameters				
		Height (m)	Diameter (m)	Vol. Flow (m <sup>3</sup> /s)	Exit Temp. (°C)	Emissions* (g/s)
1	1	7.9	0.3	0.9	79	0.033
	2	18.6	0.7	1.0	177	0.025
	3	19.8	0.8	0.9	121	0.026
	4	45.7	0.9	1.1	250	0.024
	5	12.2	0.9	0.9	316	0.018
2	1	20.7	1.4	6.1	204	0.14
	2	12.2	1.2	10.9	316	0.19
	3	50.3	1.2	11.3	260	0.10
	4	23.8	1.3	20.0	329	0.16
3	1	7.6	1.2	22.2	79	0.70
	2	22.6	1.5	25.8	154	0.63
	3	38.1	1.4	18.9	132	0.48
	4	50.6	2.0	27.4	302	0.49
	5	53.9	2.7	23.6	260	0.46
4	1	33.5	3.4	109.0	143	2.75
	2	95.1	2.4	47.2	204	1.01
	3	91.4	2.7	75.0	235	1.53
5	1	89.0	3.4	82.1	218	1.65
	2	43.3	2.4	125.3	140	2.98
	3	100.9	4.3	132.1	182	2.86

\*Based on the assumptions presented in Table 5-2.

Each of these sources was evaluated using the meteorological data that resulted in the maximum quarterly lead concentration for their generic derivative. The results of this analysis were then compared to the generic concentrations.

#### 5.4.1 Results

The results of this analysis are summarized in Table 5-12. The results indicate that a wide range of ambient concentrations result from boilers of comparable sizes. However, the extremely high concentrations from boilers that deviate significantly from the generic source value is partially due to their very short stacks. These sources are noted in Table 5-12. The effect of short stacks is to allow the plume to reach the ground quickly after release, before significant dispersion occurs. This results in high pollutant concentrations close to the source. It is thus apparent that stack height is a significant parameter affecting ambient concentrations. Although sources with very short stacks are not typical, they are not uncommon. Therefore, some consideration should be given to the concentrations obtained from boilers with short stacks.

Another very important parameter is stack gas exit temperature. The results (Tables 5-11 and 5-12) of the dispersion modeling analysis for several actual boilers listed in the Wisconsin inventory, show that ambient concentrations may exceed the lead standard for stacks with exit temperatures of about 150°C. Of course the effective stack height, which is the sum of the physical stack height plus the plume rise, is influenced by several variables including ambient temperature, stack gas exit temperature and wind speed. As the stack gas exit temperature approaches the ambient temperature, the plume buoyancy drops dramatically, which reduces plume rise and, hence, effective stack height.

To help ensure adequate dispersion, stack gas exit temperatures should not fall below 90°C. Under normal operating conditions for most common types of boilers, stack gas exit temperatures should exceed this value. Even with a good heat recovery system most stack exit temperatures will be above 90° C. The operation of a stack gas wet scrubbing unit could, however, reduce the exit temperature below 90° C.

#### 5.5 Other Considerations

In drawing conclusions from this modeling analysis, there are certain other considerations that need to be addressed beyond those already discussed in the text. These points may significantly affect ambient lead concentrations and thus should be considered when reviewing the modeling results.

Table 5-12  
RESULTS OF SENSITIVITY ANALYSIS

Generic Group	Maximum Lead Concentration Due to Source ( $\mu\text{g}/\text{m}^3$ )					Range of Maximum Concentrations ( $\mu\text{g}/\text{m}^3$ )	Generic Concentration ( $\mu\text{g}/\text{m}^3$ )
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>		
1	1.6*	0.8	0.8	<0.1	0.7 <sup>+</sup>	<0.1 - 1.6	0.5
2	1.9	2.8 <sup>+</sup>	<0.1	1.0		<0.1 - 2.8	2.5
3	13.0*	5.0	0.2	0.1	0.1	0.1 - 13.0	3.1
4	1.5	<0.1	<0.1			<0.1 - 1.5	0.1
5	<0.1	0.2	<0.1			<0.1 - 0.2	0.1

\*Stack height less than 10 meters

<sup>+</sup>Stack height between 10 and 15 meters

#### 5.5.1 Multiple Point Source

The modeling analysis in this study only addressed the air quality impact of lead emissions from a single source. Facilities often burn used oil in more than one boiler, causing lead-containing emissions to emanate from two or more stacks in close proximity to each other. The impact on air quality in this situation is a directly additive function. This case could be addressed by considering a maximum facility lead emission rate and merging emission points so they could be analyzed as a single emission point source.

Adjacent lead-emitting point sources that are not part of the same facility may also be encountered. Here, as in the case of multiple point sources within a single facility, interaction among dispersing stack plumes can cause locally high lead concentrations under certain conditions. This type of multiple-stack situation could become very complicated, and it can probably be addressed only by modeling the specific area to determine the air quality impact of burning used oil containing lead.

#### 5.5.2 Decreased Lead Content In Crankcase Drainings

Used automotive oil from crankcase drainings has been the principal source of lead-containing used oil. This is because residual amounts of lead additives (used to raise the octane in gasoline) are deposited on the engine cylinder walls, valves and pistons during the combustion process and washed away by circulating oil. As the use of lead in automotive fuels decreases, the average lead content of used crankcase oil will drop significantly, paralleling the mobile source impact level decrease. Thus, by 1985, the average lead content in used oil is expected to be about 10% of the 1975 average.<sup>10</sup>

#### 5.5.3 Pollution Control Devices

The majority of lead emissions from combustion processes are particulates in the sub-micron size range. Many pollution control devices do not efficiently collect this size particle. Furthermore, it is not known how many boilers presently burning used oil have any pollution control devices. The modeling analysis assumed no use of pollution control devices on any sources. However, with control devices that are effective on sub-micron size particles, lead emissions would be decreased dramatically, significantly reducing the impact on ambient lead concentrations. These sources could burn substantial amounts of untreated used oil with virtually no impact on lead ambient air quality.

#### 5.5.4 Building Downwash

The aerodynamic downwash of stack plumes due to building effects should be avoided for sources burning used oils, since this phenomenon causes higher ambient lead concentrations than those indicated in this report. A method to determine if downwash will occur is outlined in Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10 (EPA-450.4-77-001). Plume downwash could present serious air quality problems for sources emitting lead and other pollutants. The technique presented in this document can be used to assess the likelihood of this problem. Minimum acceptable stack characteristics (i.e., those in conformance with good engineering practice, or G.E.P.\*) may be a necessary requirement in the burning of used oil. Requiring stacks to conform to G.E.P. would also help to avoid plume impaction at short distances downwind that could result in elevated lead concentrations.

#### 5.5.5 Background Concentrations and Monitoring Data

Current background ambient lead concentrations would be of concern where sources burning used oil are under consideration. Monitoring data from the vicinity of the proposed used oil combustion source would give an accurate indication of the background ambient lead concentrations and of the maximum existing lead pollution levels encountered from other sources. However, in many cases it is likely that the monitor will not be sited to monitor the impact of the plant under study. Therefore, monitoring data may be of only marginal usefulness for this purpose, although they would show if an air quality problem does exist in the region.

#### 5.6 Conclusions

The computerized dispersion modeling performed in this study has shown that some sources burning used oil may violate the National Ambient Air Quality Standard for lead. The magnitude of the ambient concentrations varies significantly, however, depending upon several factors: fuel lead content, percent of used oil burned, hours of operation, and amount of lead actually emitted out of the stack. Stack height was also found to be an important parameter. In drawing conclusions from this report, these factors, and the other considerations previously discussed, require careful attention.

Because of the high pollutant concentrations in some used oil, the large scale indiscriminate burning of used oil could present a health hazard in certain areas. This analysis has only addressed the impact of burning used oil with respect to lead

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\*Federal Register, Vo. 44, No. 9 Friday, January 12, 1979.



emissions. Based on this analysis, there appears to be a need for some regulation or control of used oil combustion. Some sources, such as isolated power plants and sources with sub-micron particulate control devices, can burn used oil with virtually no lead air quality impact, but some smaller sources may have a significant impact.

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## REFERENCES

1. Wisconsin Department of Natural Resources Statewide Inventory of Emission Sources Burning Oil.
2. ETA Engineering, Inc. Technical Support Document for the Lead Emission Inventory of the State of Minnesota. August 1979.
3. PEDCo Environmental, Inc. Population and Characteristics of Industrial/Commercial Boilers in the U.S., EPA-600/7-79-178a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 1979.
4. PEDCo Environmental, Inc. Flue Gas Desulfurization Process Cost Assessment, prepared for Office of Planning and Evaluation of U.S. Environmental Protection Agency under Contract No. 68-01-3150, Technical Series, Area 4, Task No. 2. 1975.
5. Discussion with Brian Cooley, Peabody Continental-Heine. July 18, 1980.
6. Discussion with Dennis Brinkman, Department of Energy's Used Oil Laboratory. July 17, 1980.
7. Holzworth, G.C. Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States. AP-101. January 1972.
8. Brubaker, K.L., P. Brown, and R. R. Cirillo. Addendum to User's Guide for Climatological Dispersion Model. EPA-450/3-77-015. May 1977.
9. U.S. EPA. Development of an Example Control Strategy for Lead. EPA-450/2-79-002. April 1979.
10. U.S. EPA. Control Technique for Lead Air Emissions, Volume 1 Chapter 1-3. EPA-450/2-77-012. December 1977.

## 6.0 THE EFFECTS OF ENVIRONMENTAL REGULATIONS ON USED OIL BURNING

### 6.1 Introduction

~~Federal~~ environmental regulations which may affect used oil burning find their basis primarily in the following legislation:

- The Clean Air Act of 1970 (CAA) (as amended in 1974 and 1977)
- The Toxic Substances Control Act of 1976 (TSCA)
- The Resource Conservation and Recovery Act of 1976 (RCRA)

The responsibility for regulations under these acts lies primarily with the Environmental Protection Agency (EPA). Only CAA and TSCA will be further discussed in this section since regulations relating to used oils under RCRA are still under study and are the primary subject of this report.

### 6.2 The Clean Air Act (CAA)

The Clean Air Act was adopted in 1970 and amended in 1974 and 1977 to protect public health and welfare from any actual or potential adverse air pollution effects. Regulations under CAA which may affect used oil burning are divided into the following categories:

- Primary and Secondary National Ambient Air Quality Standards (NAAQS)
- Prevention of Significant Deterioration (PSD)
- "Nonattainment region" provisions, including offset policy
- New Source Performance Standards (NSPS)
- Emission Regulations for Diesel Engine Vehicles
- National Emission Standards for Hazardous Air Pollutants (NESHAP)
- State Implementation Plans (SIP)

Each of the categories is discussed further below.

### 6.2.1 Ambient Air Quality Standards (NAAQS)

Existing NAAQS limit ground level concentrations for sulfur dioxide ( $\text{SO}_2$ ), total suspended particles (TSP), nitrogen dioxide ( $\text{NO}_2$ ), carbon monoxide (CO), photochemical oxidants, non-methane hydrocarbons, and lead (Pb) (1). Primary NAAQS were instituted to protect the public health while secondary NAAQS are designed to protect the public welfare. Established standards are provided in Table 7-21.

Calculations in Sections 4.0 and 5.0 have already shown that NAAQS for lead, TSP, and  $\text{SO}_2$  can sometimes be approached or even exceeded in the immediate area of used oil burning facilities.  $\text{NO}_x$  emissions may also be significant but ordinarily will not approach NAAQS.

Although significant,  $\text{SO}_2$  and  $\text{NO}_x$  emissions for used oil combustion are comparable to those from virgin oils. Ambient air concentrations of CO, photochemical oxidants, and non-methane hydrocarbons should also not be affected by replacement of virgin oils with used oils. However, particulate emissions may tend to be higher depending upon the quality of the oil and dilution with virgin oils.

In summary, NAAQS for Pb and TSP are of most concern when considering used oil burning. But attention should also be directed to  $\text{SO}_2$  and  $\text{NO}_2$  NAAQS, especially to  $\text{SO}_2$  emissions if used oil sulfur concentrations increase in the future as expected.

### 6.2.2 Prevention of Significant Deterioration (PSD)

The PSD program was developed to preserve air quality in those areas where the air is better than NAAQS and to insure that future growth is consistent with the preservation of clean air. As shown in Table 7-22, the PSD regulations set forth the maximum allowable incremental changes in existing ambient levels of  $\text{SO}_2$  and TSP. Increments in Class I areas restrict severely any industrial growth; increments in Class II areas allow moderate growth; and increments in Class III areas permit the most industrial growth.

PSD regulations provide in general that new major stationary sources or major modifications must obtain a permit before construction may begin. Existing facilities are not subject to PSD regulations unless major modifications are made to a major source that would result in a "significant net increase" in that source's "potential to emit." Conversion from virgin fuels to used oils in major sources would be so regulated if "net" potential emissions exceeded EPA specified significant emission rates ("de minimis" exemption)(2). PSD rules allow the "bubble approach," use of offsetting emission reductions within a source, to avoid a new source review.

Twenty-eight major sources with the "potential to emit" 100 tons/yr or more of any air pollutant are required to undergo a preconstruction review and permit process under PSD. Included are fossil fuel-fired boilers (or combinations thereof) which have a heat input of greater than 250 million BTU/hr, municipal incinerators which are capable of charging more than 250 tons/yr, and portland cement plants. Also required to undergo the review and permit process are sources not listed but having the "potential to emit" 250 tons/yr or more of any pollutant regulated by the CAA.

The meaning of "potential to emit" has been the subject of litigation, finally resolved in EPA rulemaking published August 7, 1980(2). "Potential to emit" now refers to the maximum rate at which a source or modification would emit a pollutant with control equipment. For most oil-fired steam boilers, lacking control equipment, the "potential to emit" is in fact based on uncontrolled emissions and can be estimated from emission factors provided in Table 4-1.

The various size boilers considered in Section 5 would have the following "potential" emissions based on 100% used oil utilization with 2.2% ash and 0.5% sulfur (from Section 2.3, worst case):

Size	Fuel MM BTU/hr	<u>Total Potential to Emit, Tons/yr (uncontrolled)</u>		
		<u>Particulate</u>	<u>SO<sub>2</sub></u>	<u>NO<sub>x</sub> (as NO<sub>2</sub>)</u>
Very Small	5-10	26-52	12-23	3-7
Small	10-100	52-516	23-235	7-69
Medium	100-500	516-2581	235-1173	69-344
Large	500-1500	2581-7743	1173-3520	344-1032
Power Plant	1500+	7743+	3520+	1032+

Therefore, new or modified (by conversion to used oil) small to medium size boilers could be required to undergo the review and permit process to burn used oil in areas governed by PSD, depending upon ash and sulfur content of the blend.

### 6.2.3 Nonattainment Region Provisions

If proposed new or modified major sources lie in or impact on a nonattainment area (one which does not comply with a NAAQS) they will be subject to preconstruction review provisions of the applicable State Implementation Plan (SIP), or to a prohibition on construction if the SIP does not meet applicable requirements (3, 4). Major sources are defined as those which will have "potential" emissions greater than 100 tons/yr for any applicable pollutant.

For such new sources, EPA's emission offset policy requires that:

1. All existing major sources in the nonattainment area owned by the owner of the proposed source are in compliance with applicable emission standards.
2. Proposed emissions from the new sources are more than "offset" by a reduction of emissions from other sources in the nonattainment area.
3. The emissions offset must represent a net air quality benefit.
4. The proposed source will be subject to the lowest achievable emission rate (LAER). LAER is defined as the more stringent of either: a) the most stringent emission limitation for this type of source in any SIP in the country, or b) the lowest emission rate that can be achieved for this type of source with current technology.

Based on the "potential to emit" table in Section 6.2.2, it is anticipated that most conversions to used oil would be governed by the offset policy, depending upon ash and sulfur content and boiler size.

Presumably cases where substitution of used oils for virgin oils tend to increase particulate or other emissions would cause imposition of NSPS for all pollutants. Therefore, strict adherence to NSPS might tend to inhibit substitution of used oils for virgin oils in steam generators larger than 250 million BTU/hr. On the other hand, if no emission increase could be expected, emissions would be governed by state and local regulations.

While the Federal Standards above apply to new and modified sources (e.g. new "medium," "large," and "power plant" boilers), state standards usually apply to all boilers down to sizes classified as "very small" in this work. Some of the more stringent particulate and sulfur standards were cited in Section 4.0.

Although no NSPS now exist for steam generators firing less than 250 million BTU/hr, such standards may be expected in the future to govern industrial boilers (6), and possibly commercial boilers. The fact that there is now a NAAQS for lead suggests the possibility of future NSPS for this pollutant.

#### 6.2.5 Emission Regulations for Diesel Engine Vehicles

As discussed previously, used oils can be used as a fuel in diesel engines. Emissions from diesel engines regulated by EPA include opacity, hydrocarbons, oxides of nitrogen, and carbon monoxide (7).

No data are available for used oil as a diesel fuel component for comparison with the promulgated standards, but, as reported in Section 3.0 there have been reports of increased smoke emissions.

#### 6.2.6 National Emission Standards for Hazardous Air Pollutants (NESHAP)

NESHAP have been prepared for asbestos, beryllium, mercury, and vinyl chloride (8). Since these substances are not ordinarily constituents of used oils, they will not ordinarily be considered in used oil combustion processes unless contamination occurs.

#### 6.2.4 New Source Performance Standards (NSPS)

NSPS applies to new sources or to existing sources modified in a way that alters process capacity significantly, increases emissions, or are reconstructed at a cost equal to 50 percent of a new facility cost (5). Although existing sources need not meet NSPS, state standards are required in order to meet NAAQS. These are often less stringent than NSPS, sometimes more stringent, but in many instances are essentially equivalent to NSPS.

NSPS have been applied to many types of plants which could affect used oil combustion practices including:

- fossil-fuel fired steam generators which have a heat input greater than 250 million BTU/hr
- solid waste incinerators with a charging rate greater than 50 tons/day
- kilns and other facilities in portland cement plants
- asphalt concrete plants
- storage vessels for petroleum liquids with a storage capacity greater than 40,000 gallons
- secondary lead smelter pot furnaces of more than 550 lb capacity, blast (cupola) furnaces, and reverberatory furnaces
- incinerators that combust wastes containing more than 10% sewage sludge (dry basis) produced by municipal sewage treatment plants, or incinerators that charge more than 2205 lb/day municipal sewage sludge (dry basis)
- other chemical, metallurgical, and miscellaneous operations.

Pollutants controlled vary, but include particulates,  $SO_2$ , and  $NO_x$  for steam generators; particulates for incinerators, portland cement plants, asphalt concrete plants, secondary lead smelters, and sludge incinerators; and hydrocarbons for storage vessels. Other pollutants covered by NSPS for some plants include fluorides, visible emissions, and CO. NSPS also include test methods and procedures, and may also include monitoring provisions.



### 6.2.7 State Implementation Plans (SIP's)

Each state must prepare a SIP for attainment and maintenance of NAAQS (9). The SIP includes control strategies, evidence of legal authority, compliance schedules, contingency plans to prevent air pollution emergency episodes, provisions for an air quality surveillance system, procedures for review of new sources and modifications, procedures for source surveillance, copies of state rules and regulations, provisions for PSD, and analysis and plans for air quality maintenance areas (AQMA's) where NAAQS are exceeded.

Thus, the SIP provides the framework through which state regulations are used to insure meeting and maintaining NAAQS. The SIP must address all pollutants governed by NAAQS, including lead.

Since used oil burning contributes only a minor portion of the total pollutants in any state, this process is not dealt with directly, but rather through general restrictions on combustion processes, for example particulate and opacity requirements for steam boilers. Even total lead emissions from used oil burning are likely to be small compared to mobile sources and lead smelting operations. However, as shown in Sections 4.0 and 5.0, lead, particulate, and SO<sub>2</sub> emissions can sometimes result in approaching or exceeding NAAQS in localized areas.

### 6.3 The Toxic Substances Control Act (TSCA)

Of primary concern under TSCA is the relationship of PCB disposal regulations (10) to used oil burning practices. Under these regulations:

- For PCB liquids containing 500 ppm PCB or greater, disposal is permitted only in EPA-approved incinerators.
- For PCB liquids containing 50-500 ppm, disposal is permitted in EPA-approved incinerators, in high efficiency boilers rated at a minimum of 50 million BTU/hr (under rigidly controlled combustion conditions), and in EPA-approved chemical waste landfills (approved for PCB's).
- Liquids containing less than 50 ppm are not considered PCB's (unless dilution was involved) and their burning is not regulated.

## REFERENCES

1. 40 CFR Part 50.
2. FR 45, 52676, August 7, 1980.
3. 40 CFR Part 51, Appendix S.
4. FR 44, 3274, January 16, 1979.
5. 40 CFR Part 60.
6. Greenwood, D. R. et al. A Handbook of Key Federal Regulations and Criteria for Multimedia Environmental Control. EPA-660/7-79-175. August 1979. 288 pages.
7. 40 CFR Part 86.
8. 40 CFR Part 61.
9. 40 CFR Part 51.
10. FR 44, 31514, May 31, 1979.

## 7.0 SUPPLEMENTARY DATA

Supporting data for the main body of the report is found in this section. The following information is included:

<u>Table</u>	<u>Title</u>	<u>Comments</u>
7-1	Previous Estimates of Lubricating and Industrial Oil Sales in the U.S.	Summarizes lubricating oil sales estimates used as a basis by various sources to estimate used oil quantities
7-2	Previous Used Oil Generation and Collection Estimates	-
7-3	Summary of Studies on Used Oil Generation and Collection	Breakdown of "other" used or waste oil generation and collection
7-4	Used Oil Generation Projections From Lube and Other Industrial Oils	1980, 1985, 1990 projections
7-5	The Ultimate Disposal of Used Oils	-
7-6	Physical Properties of Used Motor Oils	-
7-7	Chemical Properties of Used Motor Oils	-
7-8	Industrial Used Oil Analyses	-
7-9	A Profile of Used Oil Businesses Based on a 1979 Survey	-
7-10	Size Distribution of U. S. Boilers	-
7-11	An Order of Magnitude Estimate of Boilers Burning Used Oil	-

<u>Table</u>	<u>Title</u>	<u>Comments</u>
7-12	Combustion Process Retention Times	-
7-13	Used Oil Combustion Tests	Includes both tests described in literature and recent RECON tests
7-14	SO <sub>2</sub> and NO <sub>x</sub> Emissions During RECON Tests	-
7-15	Particulate Emissions-RECON Tests	-
7-16	Benzo(a)Pyrene Concentrations in Various Oils - Data Summary	Tables 7-16 through 7-18 contain summary of both RECON and earlier analyses
7-17	Data on Benzo(a)Pyrene Concentrations in Unused and Used Motor Oils and Blended Oils	-
7-18	Data on Benzo(a)Pyrene Concentrations in Fuel Oils	-
7-19	Hydrocarbon Emissions	-
7-20	Hydrocarbon Emissions	Compares RECON data to early PHS data on PNAs
7-21	National Ambient Air Quality Standards	-
7-22	National Standards for the Prevention of Significant Deterioration of Air Quality	-
<u>Figure 7-1</u>	Lead Emitted as a Percent of Lead introduced with Fuel	Shows inverse relationship of lead emissions with lead concentration in oil

Table 7-1

PREVIOUS ESTIMATES OF LUBRICATING AND  
INDUSTRIAL OIL SALES IN THE U.S.  
Millions of Gal/Yr

	RECON 1970-71	AEROSPACE 1975	BIDGA 1978	SUN 1978
<u>Automotive Lubricating Oils*</u>				
Commercial engine oils - fleet sales	200			
Commercial engine oils - retail sales	90			616
Factory fills, automotive and farm	60			92
Private automobiles,* automobile fleets, other	736			701
	<u>1086</u>	1251	1091	<u>1409</u>
<u>Aviation Lubricating Oils</u>	8	-		11
<u>Industrial Lubricating Oils</u>				
Hydraulic and circulating system oils	325			290
Metalworking oils	150			230
Railroad engine oils	60			73
Gas engine oils	62			52
Other	129			268
	<u>726</u>			<u>913</u>
<u>Other Industrial Oils</u>				
Process oils	310			268
Electrical oils	57			85
Refrigeration oils	10			10
	<u>377</u>			<u>363</u>
<u>Federal Government</u>	<u>37</u>			<u>16</u>
GRAND TOTAL	2234	2836	2144	2712

\*including automotive hydraulic fluids and gear oils

**Table 7-2**  
PREVIOUS USED OIL GENERATION AND  
COLLECTION ESTIMATES  
Millions of Gal/Yr

	RECON - 1970-71		W.O.		W.O. Gen.		Subtract		AEROSPACE		BIGDA		SUN	
	Sales	Factor	.63	.170	Direct	Fuel	W.O. to	Env.	1975 Sales	(2) Gen.	1978 Sales	(3) Coll.	1978 Sales	(4) Sales
<u>Automotive Lube Oils</u>														
Service Stations	270		.63	170					311	196	167			
Garages, Auto														
Supply Stores	60		.63	38					68	43	90			
Discount Stores	168		.22	37					194	43	327			
Car Dealers &														
Factory Fills	162		.90	146					187	167	58			
Fleet & Commercial														
Sales	426		.53	225					491	260	449			
	<u>1086</u>			<u>616</u>	<u>19</u>		<u>148</u>		<u>1251</u>	<u>709</u>	<u>1091</u>	<u>393</u>		<u>1409</u>
<u>Other Lube &amp;</u>														
<u>Industrial Oils</u>														
Hydraulic & Circu-														
lating System Oils	325		.42	137					542	228	234			290
Metalworking Oils	150		.70	105					250	175	98			230
Railroad Engine Oils	60		.53	32					100	53	51			73
Gas Engine Oils	62		.90	56					103	93	42			52
Electrical Oils	57		.90	51					89	80	98			85
Other	494			118					501	56	530			573
	<u>1148</u>			<u>499</u>	<u>140</u>		<u>140</u>		<u>1585</u>	<u>685</u>	<u>1053</u>	<u>276</u>		<u>1303</u>
Subtotal	2234			1115	159		288		2836	1394	2144	669		2712
<u>Other Waste Oils</u>														
	-			1365	199		690		-	NA	-	NA		-
<u>GRAND TOTAL</u>				2480	358		978							

Table 7-3

SUMMARY OF STUDIES ON USED OIL  
GENERATION AND COLLECTION

Millions of Gal/Yr

	RECON 1970-71 (1)		AEROSPACE 1975 (2)	BIGDA 1978 (3)
	<u>Generated</u>	<u>Collected</u>	<u>Generated</u>	<u>Collected</u>
Lube and Other Industrial Oils	1115	668	1394	669
<u>"Other"</u>				
- Oil Spills - Marine 22 (from Coast Guard reports in 1972 assuming only 75% of spills reported)				
- Oil Losses - Marine 187 (from marine oily wastewater survey, including bilge, cargo ballast, cargo washings, tanker ballast, tanker washings)				
- Oil Losses - Production, Refining, Transportation, Use - includes oil in wastewaters (estimated as 0.5% of petroleum liquids produced and imported)	<u>1156</u>			
	<u>1365</u>	<u>476</u> *	NA	NA
	2480	1144		

\* Collected "other" oils = 1365 - 690 (losses on land, water, etc.) -  
199 (directly to fuel use) = 476

Table 7-4

USED OIL GENERATION PROJECTIONS  
LUBE AND OTHER INDUSTRIAL OILS  
Millions of Gal/Yr

	1980			1985		1990	
	<u>Sales</u>	<u>Factor</u>	<u>Gen.</u> <sup>+</sup>	<u>Sales</u>	<u>Gen.</u> <sup>+</sup>	<u>Sales</u>	<u>Gen.</u>
<u>Automotive Engine Oils</u>							
Discount Store Sales	295	0.2	59	327	65	331	66
Other Passenger							
Car Sales	274	0.5	137	240	120	182	91
Truck & Bus Sales	278	0.5	139	276	138	270	135
Factory Fill	22*	0.7	15	22*	15	21*	15
	<u>869*</u>		<u>350</u>	<u>865*</u>	<u>338</u>	<u>804*</u>	<u>307</u>
<u>Off-Road Engine Oils</u>							
Aviation	10	0.5	5	11	6	11	6
Federal Government	16	0.5	8	17	9	18	9
Farm	98	0.2	20	103	21	107	21
Construction	59	0.5	30	62	31	68	34
Mining	39	0.2	8	47	9	56	11
Miscellaneous	25*	0.1	3	32*	3	40*	4
	<u>247*</u>		<u>74</u>	<u>272*</u>	<u>79</u>	<u>300*</u>	<u>85</u>
<u>Automotive Hydraulic Fluids</u>	225*	0.1	23	241*	24	260*	26
<u>Automotive Gear Oils</u>	55*	0.3	17	57*	17	62*	19
Subtotal - Automotive	1396*		464	1435*	458	1426*	437
<u>Industrial Lubricants</u>							
<u>Hydraulic &amp; Circ.</u>							
Fluids	285	0.4	114	290	116	295	118
Compressor, Turbine,							
Bearing	90	0.6	54	92	55	94	56
Gear	90	0.4	36	92	37	94	38
Refrigeration	10	0.5	5	10	5	10	5
Marine, RR, Other							
Engines	158*	0.5	79	160*	80	172*	86
Electrical	85	0	0	90	0	95	0
Process Oils	265*	0.1	27	317*	32	393*	39
Metalworking Oils	223*	0.24	54	230*	55	236*	57
Other	37*	0.3	11	52*	16	70*	21
Subtotal - Industrial	<u>1243*</u>		<u>380</u>	<u>1333*</u>	<u>396</u>	<u>1459*</u>	<u>420</u>
GRAND TOTAL	2639		844	2768	854	2885	857

\* Sales projections based on Sun Data (4). Other projections by RECON.

<sup>+</sup> Under present used oil industry conditions--no changes in regulations. Based on previous estimates by RECON (1) and Bidga (3). Same factors used for 1980, 1985, and 1990.



Table 7-5

## THE ULTIMATE DISPOSAL OF USED OILS

	1980 ESTIMATES**					ULTIMATE DISPOSAL		
	Auto. +					Disposition By:		
	Indus. +** "Other"					Processors	Re-Refiners	
1970-1971 Estimates (1)	Automotive	Industrial	"Other"	Automotive	Industrial	Processors	Re-Refiners	
To Processors	206	158	399	256	98	(753)	-	-
To Re-Refiners	108	19	11	50	15	-	(76)	-
To Road Oils, Etc.	146	31	66	50	30	76	2	224
To Fuel	23	136	199	40	200	640	12	1091
Generated Losses*	483	344	675	396	343	1414		
	151	137	-	68	37	105		105
	634	481	675	464	380	1519		
To Consumption + Other								
Env. Losses	489	630	690	932	863	37	17	2539
Lube Products	1123	1111	1365	1396	1243	-	45	45
						0	0	4004**

\* Difference between estimated generation and oil to processors, re-refiners, and direct use for roads, fuels, etc.

\*\* Based on generation projections for automotive and industrial used oils in Table 7-4 plus 1970-71 estimate for "other" oils (1). See discussion in Section 2.2.

\*\*\* Summation of 1980 Automotive, 1980 Industrial, and 1970-71 "Other".

Equal to 2639 sales + 1365 other used oils.

Table 7-6  
PHYSICAL PROPERTIES  
OF USED MOTOR OILS (5)

	<u>Range of Measured Values</u>
Viscosity, SUS 100°F	220-1261
Viscosity, SUS 210°F	52.5-128.6
Viscosity Index	96-176
Specific Gravity, 60/60°F	0.891-0.938
BS&W, %	0.4-42
Water, %	0.4-33.8
Pentane Insolubles, %	0.74-5.02
Benzene Insolubles, %	0.49-1.86
Fuel Dilution, %	0.4-9.7
Antifreeze	Positive (26 samples) Negative (3 samples) Trace (1 sample)
Carbon Residue, %	1.82-4.43
Flash Point, °F	204-440
Pour Point, °F	(-20)-(-45)
Saponification No.	6.07-20.95
Total Base No.	1.10-2.55

Table 7-7

## SUMMARY

## CHEMICAL PROPERTIES OF USED MOTOR OILS

	LEAD	OTHER INORGANICS	PCB's	PNA's	HALIDE SOLVENTS	OTHER SOLVENTS	OTHER ORGANICS
Concentration in used oil	1,362-13,885 ppm based on 30 samples, excluding one sample at 19 ppm (5)	Ba 59-193 ppm Ca 969-3,126 ppm Mg 165-999 ppm P 672-1,393 ppm Zn 629-2,500 ppm Ash 0.94-2.20% including some samples with 10 ppm Na, Al, Cr, Cu, Fe, K, Si, Sn S 0.33-0.54% N 0.053-0.104% excluding 19 ppm Pb sample (5); Cl 2568-4077 ppm and Br 0.1-38 ppm zone avgs - Cl & Br may be organic or inorganic.	Not normally present	Polynuclear aromatics (PNA, PAH, POM) present in many fuel oils; benzo (a) pyrene (Bap) consid- ered an in- dicator; e.g. chlorine Bap in virgin #4, #5, #6 oils 2-35 ppm; used oils 3-14 ppm (7)	Not normally present, but contamination believed to be widespread e.g. dry cleaning and degreasing fluids. High chlorine values re- ported under "Other In- organics" may come at least par- tially from this source.	Other waste solvents such as alcohols, ketones, etc. are believed to be common contaminants in used oils.	Glycol antifreeze agents and other organics may be present as con- taminants. Gasoline dilution 1.2-9.7% (5). Other contaminants, e.g. pesticides, non-lubricating type waste oils, and other industrial waste liquids, may be present but de- tection is usually difficult, depend- ing upon the nature of the contaminant and concentration.
Detection methods	ASTM D 2788-72 (AA) modified by NBS (8)	Metals by AA or ES (9); P by ASTM D-1091 (10); Ash by ASTM D-482 or ASTM D-874 (sul- fated) (8); S by ASTM D-129 (9) or ASTM D-1552 (8); N by Kjeldahl; Cl and Br by NAA (8)	GC methods under develop- ment by EPA (6) and NBS	HPLC (7)	Distillation followed by GC or halide analysis of light frac- tion (ASTM D-808, D-1317, x-ray fluor., NAA)	Distillation or water ex- traction followed by GC or organic analysis in water phase, e.g. TOC or COD	Glycols-qualitative (ASTM D-2982); gasoline dilution (ASTM D-322)

Table 7-8  
INDUSTRIAL USED OIL ANALYSES (11)

Sample #	1A	2A	3A	4A	1B	2B	3B	5B	6A	7B	8B	1C	2C	3C	1D	2D	3D	4D
A.P.I. Gravity	29.3	--	--	20.7	25.8	--	33.4	28.0	--	2.1	31.0	25.7	28.8	--	28.8	30.4	29.7	22.0
Ash Content (%)	--	--	--	--	--	0.05	0.02	0.16	0.06	--	0.02	0.35	0.20	0.15	0.64	0.22	0.03	0.16
Carbon Residue (%)	--	--	--	--	--	0.1	0.2	0.6	0.4	--	0.0	1.6	0.4	0.7	1.1	0.2	0.7	2.2
SSM (%)	0.0/0.0	0.6/0.0	0.30/30.0	0.6/0.0	0.0/0.0	1.3/0.0	1.3/0.0	--	1.3/0.0	--	1.3/0.0	7.5/5.0	1.3/0.0	27.4/0.0	1.3/0.0	1.3/0.0	1.3/0.0	3.8/0.0
Pour Point (°F)	-50	0	+10	-20	+20	+5	-60	+14	-55	--	+10	+5	+15	-30	-25	-20	-10	-25
Flash Point (°F)	400	--	--	370	--	270	200	395	170	--	440	--	475	400	410	415	380	380
Fire Point (°F)	440	--	--	435	--	290	212	405	180	--	480	--	535	415	445	440	420	405
Heat of Combustion (Btu/Lb)	--	--	--	--	19,500	20,000	20,000	19,000	18,500	--	18,600	21,000	19,700	--	18,000	18,800	6,700	17,800
Viscosity (SUS @100°F)	141.3	310.8	--	324.7	1546.1	27.4	77.7	243.8	53.5	229.0	230.8	--	738.2	275.6	260.6	244.9	121.4	196.3
Viscosity (SUS @210°F)	47.4	98.7	--	75.4	126.4	10.3	19.6	72.1	44.1	83.9	49.5	--	93.5	54.0	67.4	49.6	29.8	31.8
Acid # (mg KOH/g)	--	--	--	--	--	--	0.3	1.2	1.5	--	0.2	--	0.4	--	--	2.0	0.5	--
Sulfur (%)	0.3	0.5	0.1	0.2	0.5	0.3	0.4	0.4	0.5	0.1	0.4	0.1	0.3	--	0.4	0.4	1.4	0.3
Silver (PPM)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	--	0.0	0.0	0.0	0.0
Sodium (PPM)	3	20	370	25	12	1	1	1	19	400	4	1	1	--	85	1	100	180
Zinc (PPM)	5	330	6	12	200	190	47	580	36	160	56	1100	160	--	760	600	29	12
Copper (PPM)	7	24	6	12	3	12	10	3	9	15	16	1160	140	--	140	7	2	150
Aluminum (PPM)	2	17	12	8	3	3	5	3	3	39	3	36	3	--	24	2	3	33
Barium (PPM)	5	36	36	34	220	7	13	7	45	--	10	35	240	--	120	5	17	120
Nickel (PPM)	0	0	21	0	0	0	0	0	0	4	0	27	0	--	0	0	0	5
Chromium (PPM)	4	14	31	10	5	1	7	5	16	7	3	8	6	--	16	3	2	28
Calcium (PPM)	0	220	100	200	38	82	15	0	0	0	0	180	53	--	470	0	0	1900
Iron (PPM)	24	170	190	100	6	18	21	2	31	18	1	200	20	--	85	2	42	520
Silicon (PPM)	3	16	44	32	2	2	33	2	63	22	2	62	6	--	22	2	2	90
Tin (PPM)	2	8	10	6	7	8	3	3	6	140	3	40	4	--	25	1	12	21
Lead (PPM)	1	260	7	15	4	8	3	4	11	50	4	23	8	--	1400	4	25	15
Phosphorus (PPM)	110	390	13	58	58	15	13	210	70	270	62	1080	100	--	400	200	22	150
Boron (PPM)	0	0	0	0	0	0	0	0	0	2	0	0	0	--	80	0	0	120
Magnesium (PPM)	2	25	90	26	1	1	2	3	3	11	0	45	1	--	1000	0	3	42
Vanadium (PPM)	5	10	5	8	6	0	9	6	19	7	3	4	6	--	8	3	2	8
Molybdenum (PPM)	0	1	1	1	1	1	1	1	2	16	0	19	1	--	2	1	0	7
Manganese (PPM)	3	6	124	6	3	6	4	3	7	20	3	16	3	--	9	3	69	17
Cadmium (PPM)	3	3	4	4	4	5	3	4	1	21	8	7	4	--	8	4	4	3
Titanium (PPM)	0	7	1	0	0	0	1	0	1	21	0	1	0	--	0	0	20	0

Table 7-8 (Continued)  
INDUSTRIAL USED OIL ANALYSES (11)

Sample	1A	2A	3A	4A	1B	2B	3B	4B	5B
Description	* Recycled Waste Oil	* Mixed Waste Oil	* Mixed Waste Oil	* Mixed Waste Oil	** Used Draw Oil for Punch Press	Used Cutting Oil	Mixed Waste Oil	Used Hydraulic Oil	Filtered Lube for Punch Press

Sample	6B	7B	8B	1C	2C	3C	1D	2D	3D
Description	Mixed Waste Oil	Water Soluble Oil	Used Hydraulic General Purpose	** Mixed Used Oil Separated Oil Skimmer	Light Gear Oil Used in Casting	* Fabricating Used Oil Used for Stripping & Stamping	Used Trans-mission oil From Fork Lift	Used Hydraulic Oil	Machine Oil, Not Dumped Just Topped

Sample	4D
Machine Cutting Oil - One Month Old	

A = Borg-Warner

B = General Electric

A = Borg-Warner  
B = General Electric  
C = Oil in Brass  
D = John Deere

\* Insufficient sample to complete all tests.

\*\* Volatile components prevented performing tests that required heating.

Table 7-9

## A PROFILE OF USED OIL BUSINESSES

BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				<1 MM GAL STOR.	>1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	>10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
1					X															X			-
2					X															X			-
3	X				X																	X	-
4					X															X			-
5		X			X																	X	-
6		X			X																	X	-
7					X								X					X	X	X			-
8					X															X			-
9				X	X								X					X		X			-
10					X															X			-
11																				SD		X	-
12					X															X			-
13					X															X			-
14				X	X							X	X					X		X			-
15	X				X							X										X	-
16			X		X							X								X			-
17		X			X			X		X	X	X			X	X		X		60	X		7/14/79
18					X															X			-
19												x										X	-
20	X			X	X			X		X	X	X	X		X	X		X		64	X		9/5/79
21					X									X						X			-
22				X	X													X		X		X	-
23	X																			SD		X	7/30/79
24				X	X	X				X		X	X					X		78		X	9/11/79
25				X	X																	X	-

SD = Shut down

Table 7-6 (continued)  
A PROFILE OF USED OIL BUSINESSES  
BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				1 MM GAL STOR.	1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
26					X															X			-
27	X			X				X		X		X	X		X			X		X			8/10/79
28																				X			-
29				X	X			X		X		X	X	X				X				X	8/3/79
30					X															X			-
31				X																X			-
32				X				X		X		X	X				X	X	X	50	X		8/30/79
33																						X	-
34				X										X							X		-
35																				SD		X	-
36					X																	X	-
37		X				X				X		X			X					79	X		8/29/79
38																					X		-
39					X																	X	8/24/79
40																						X	-
41	X			X		X				X		X			X					62	X		8/9/79
42	X			X				X		X		X	X		X		X				X		7/31/79
43				X										X							X		-
44																					X		-
45		X										X			X			X		SD	X		-
46	X			X				X		X		X			X	X		X				X	8/3/79
47				X						X				X						SD	X		9/5/79
48													X								X		-
49		X		X								X	X		X							X	8/30/79
50			X	X						X		X	X					X	X			X	8/29/79

Table 7-9 (continued)

## A PROFILE OF USED OIL BUSINESSES

BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				1 MM GAL STOR.	1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
51	X			X	X				X	X		X	X		X	X		X		63	X		8/14/79
52																						X	-
53														X								X	-
54																						X	-
55																						X	-
56																					X		-
57					X																X		8/2/79
58														X							X		-
59																					X		-
60				X	X																	X	-
61																					X		-
62				X	X								X								X		8/22/79
63				X	X																X		-
64					X																	X	-
65																				SD	X		8/9/79
66	X				X																X		8/31/79
67																						X	-
68				X	X																X		8/22/79
69					X																X		-
70																						X	-
71					X													X			X		-
72	X			X	X				X	X	X	X	X		X			X			X		8/7/79
73																						X	-
74				X	X					X	X	X	X					X		79	X		8/7/79
75																					X		-



Table 7-9 (continued)

## A PROFILE OF USED OIL BUSINESSES

BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				1 MM GAL STOR.	1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
76																					X		-
77					X													X			X		-
78				X									X	X				X			X		-
79														X							X		-
80																					X		-
81																						X	-
82																						X	-
83	X						X			X	X				X					57	X		8/3/79
84					X																X		-
85																					X		-
86				X				X		X	X	X		X				X	X			X	8/9/79
87	X				X		X			X		X	X		X	X		X		61	X		7/31/79
88																					X		-
89					X									X							X		-
90				X	X							X	X	X				X				X	-
91				X	X																X		8/29/79
92					X																X		-
93				X	X					X	X	X						X		50	X		8/6/79
94	X				X							X	X		X							X	8/29/79
95					X																X		8/9/79
96					X																	X	8/29/79
97																					X		-
98					X																X		-
99	X				X	X				X		X	X		X						X		9/12/79
100					X																	X	-

Table 7-9 (continued)

## A PROFILE OF USED OIL BUSINESSES

BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				1 MM GAL STOR.	1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
101				X	X									X							X		-
102														X							X		-
103				X																	X		-
104				X	X				X	X			X					X		73	X		8/7/79
105	X			X		X				X		X	X		X					56	X		8/8/79
106	X			X	X			X		X		X	X					X		72	X		8/30/79
107	X			X		X				X		X	X		X			X		78	X		9/18/79
108																					X		-
109																						X	-
110	X			X								X	X		X						X		8/29/79
111		X		X					X	X		X	X		X	X				76	X		8/6/79
112	X					X				X		X			X	X				SD	X		8/13/79
113																					X		-
114	X			X								X	X								X		8/29/79
115				X														X			X		-
116													X								X		8/ /79
117				X														X			X		-
118		X		X								X			X					80	X		-
119				X	X							X	X								X		8/7/79
120	X			X		X				X		X			X					46	X		8/29/79
121				X																	X		-
122													X								X		-
123				X									X								X		-
124				X														X				X	-
125				X														X			X		-

Table 7-9 (continued)

## A PROFILE OF USED OIL BUSINESSES

BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				1 MM GAL STOR.	1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
126				X	X				X	X	X	X	X	X				X		77	X		8/16/79
127																						X	-
128					X																	X	-
129	X					X				X	X	X	X		X	X				54	X		7/30/79
130														X								X	-
131		X	X		X		X			X	X	X	X		X			X		71	X		8/31/79
132					X																	X	-
133				X	X							X	X	X				X				X	8/30/79
134					X																	X	-
135					X																	X	-
136					X																	X	-
137																						X	-
138																						X	-
139																				SD		X	-
140																						X	-
141					X																	X	-
142	X		X	X	X		X			X	X	X	X	X	X			X		80	X		8/6/79
143																						X	-
144																						X	-
145																						X	-
146																						X	-
147																						X	-
148																						X	-
149				X																		X	-
150																						X	-

Table 7-9 (continued)

## A PROFILE OF USED OIL BUSINESSES

BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				1 MM GAL STOR.	1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
151																						X	-
152				X				X		X				X				X		78	X		8/13/79
153																					X		9/19/79
154													X								X		-
155				X									X								X		-
156	X							X		X		X	X		X					-	X		8/30/79
157					X																	X	-
158																					X		-
159		X																				X	8/29/79
160													X								X		-
161																					X		-
162																						X	-
163																					X		-
164					X																	X	8/31/79
165																					X		-
166																				SD	X		8/30/79
167																					X		-
168																					X		8/30/79
169																				SD		X	-
170																					X		-
171					X								X		X								8/29/79
172		X		X	X			X		X	X	X	X	X				X			X		10/26/79
173																						X	-
174																						X	-
175																						X	-

Table 7-9 (continued)

## A PROFILE OF USED OIL BUSINESSES

BASED ON A 1979 SURVEY (12)

	A/C RE-REF.	OTHER RE-REF.	DIST. PROC.	OTHER PROC.	COLL./STORAGE	CAPACITY				1 MM GAL STOR.	1 MM GAL STOR.	FEEDS			PRODUCTS					LAST RENOV.	E. of MISS.	W. of MISS.	RESPONSE
						0.5 MM GPY	0.5-2 MM GPY	2-10 MM GPY	10 MM GPY			AUTO	INDUSTR.	OTHER	LUBE	HYDR.	PROCESS	FUEL	ROAD OIL				
176																						X	-
177				X	X													X			X		-
178					X																X		-
179	X			X	X										X			X			X		8/10/79
180	X				X		X			X		X	X		X							X	8/10/79
181				X	X		X							X		X	X			70	X		8/2/79
182																						X	-
183																						X	-
184	X				X		X			X		X	X		X	X				79	X		8/27/79
185																						X	-
186				X	X			X		X		X	X					X			X		8/10/79
187					X																X		9/5/79

Table 7-10. SIZE DISTRIBUTION OF U. S. BOILERS

SIZE DESIGNATION*	VERY SMALL (0.4-10)	SMALL (10-100)	MEDIUM (100-500)	LARGE (500-1500)	POWER PLANT 1500+	TOTALS
MM BTU/HR						
WATER TUBE						
Coal - No.	1,705	4,862	1,579	81	16	8,24
MM BTU/HR	6,430	221,800	290,800	61,400	37,900	618,33
Residual Oil - No.	4,388	9,958	1,537	62	8	15,95
MM BTU/HR	17,900	389,400	281,800	47,400	19,200	755,70
Distillate Oil - No.	5,886	1,871	243	7	1	8,00
MM BTU/HR	15,300	64,800	44,700	5,200	2,300	132,30
Natural Gas - No.	6,030	11,193	1,925	103	40	19,29
MM BTU/HR	19,700	426,200	350,100	77,100	172,800	1,045,90
FIRE TUBE						
MM BTU/HR						
Coal - No.	113,287	1,891	-	-	-	206,15
MM BTU/HR	20,500	40,200	-	-	-	197,20
Residual Oil - No.	203,569	5,905	-	-	-	373,15
MM BTU/HR	51,300	120,100	-	-	-	468,10
Distillate Oil - No.	127,833	3,861	-	-	-	235,19
MM BTU/HR	32,200	78,600	-	-	-	301,30
Natural Gas - No.	526,291	9,863	-	-	-	936,05
MM BTU/HR	132,100	203,200	-	-	-	962,90

\* See Section 5.0 for further discussion of size designations.

Data Source: "Population and Characteristics of Industrial/Commercial Boilers in the U.S."  
(EPA-600/7-79-178a)(Tables 2-5, 2-6, 2-7) (13).

Table 7-11. AN ORDER OF MAGNITUDE ESTIMATE OF BOILERS BURNING USED OIL

	YEARLY FUEL CONSUMPTION 10 <sup>15</sup> BTU	USED OIL PENETRATION FACTOR	YEARLY		ESTIMATED BOILERS USING USED OIL No.
			USED OIL CONSUMPTION 10 <sup>15</sup> BTU	CONSUMPTION 10 <sup>15</sup> BTU	
Residual Oil W.T. medium large power plant	0.262	0.100	0.0262	0.0262	615
	0.044	0.059	0.0026	0.0026	15
	0.018	0.033	0.0006	0.0006	1
Residual Oil F.T. small very small	0.310	0.100	0.0310	0.0310	2,362
	0.854	0.069	0.0593	0.0593	45,175
Distillate Oil F.T. small very small	0.425	0.060	0.0255	0.0255	927
	0.783	0.010	0.0078	0.0078	3,144
	2.696	0.057	0.1530	0.1530	52,239

\* Assuming an average 25% used oil/75% virgin oil blend.

Table 7-12. COMBUSTION PROCESS RETENTION TIMES<sup>+</sup>

Combustion Chamber Volumetric Heat Release, (BTU)/(CFxHR) Ratio of Heat Release to Flue Gas, BTU/CF*	10,000			30,000			50,000			100,000		
	65.1	87.5	95.7	65.1	87.5	95.7	65.1	87.5	95.7	65.1	87.5	95.7
Retention time @ 1832°F	5.4	7.3	8.0	1.81	2.43	2.66	1.08	1.46	1.59	0.54	0.73	0.80
Retention time @ 2000°F	5.0	6.8	7.4	1.68	2.26	2.47	1.01	1.36	1.48	0.50	0.68	0.74
Retention time @ 2192°F	4.7	6.3	6.9	1.56	2.10	2.29	0.94	1.26	1.38	0.47	0.63	0.69
Retention time @ 2500°F	4.2	5.6	6.2	1.40	1.88	2.02	0.84	1.13	1.23	0.42	0.56	0.62
Retention time @ 3000°F	3.6	4.8	5.3	1.20	1.61	1.76	0.72	0.97	1.06	0.36	0.48	0.53

\* 65.1 BTU/CF  $\approx$  50% xs air; 87.5  $\approx$  10% xs air; 95.7  $\approx$  0% xs air for No. 2 through No. 6 fuel oils.

+ Boxed areas represent potentially useful ranges of conditions for incineration of hazardous wastes.



Table 7-13. USED OIL COMBUSTION TESTS

Test	Blend <sup>+</sup>	Elemental Balances <sup>*</sup>	Ambient Air Concentration
Mobil April 1969 (14)	5% WO/95% No. 6 (additional tests up to 100% WO) 5 GPH WO 481 ppm Pb	Pb - 55%	Pb - 0.5 $\mu\text{g}/\text{m}^3$ max. monthly mean ground level for 100 ft. disch. ht stack calc.; max. monthly for 35 ft. disch. ht. stack calc. to be approx. 1.0 $\mu\text{g}/\text{m}^3$
Humble 1968-69 (15)	100% WO 100 GPH WO	-	Pb - 0.06 $\mu\text{g}/\text{m}^3$ at all sampling points for 35 ft stack; 0.67 $\mu\text{g}/\text{m}^3$ measured during 10 min. soot blow
Shell 1969 (16)	75% WO 225 GPH WO  <u>Pb in fuel</u> 10,000 ppm Pb 8,000 ppm Pb 5,000 ppm Pb	   Pb 28-34% 20-26% 42-49%	Pb - 1.1-2.3 $\mu\text{g}/\text{m}^3$ measured during WO firing at one station for 130 ft. stack; 0.02-0.22 $\mu\text{g}/\text{m}^3$ avg. monthly geom. mean (24 hr sample period) for 310 ft. eff. stack ht, or 0.85-8.46 $\mu\text{g}/\text{m}^3$ 30 min. max. conc.
Amoco Sept 1969 (17)	40% WO/60% Bunker C; 7.5 GPH WO	-	-
Gulf 1969 (18)	25% WO/75% No. 2 1 GPH WO 2800 ppm Pb	Pb - up to 28%	Pb - max. ground level 4 $\mu\text{g}/\text{m}^3$ for 15 ft. stack
Northern States Power Co. 1973 (19)	155 GPH WO (6% of BTU input)/ 18 T/hr coal 187 ppm Pb equiv. in bottom ash	Pb - 95.2% in hopper flyash; 3.3% in bottom ash	-

\* % in flyash unless otherwise indicated.

+ WO = used oil; FO = fuel oil.

Table 7-13. (Continued) USED OIL COMBUSTION TESTS

Test	Blend <sup>+</sup>	Elemental Balances <sup>*</sup>	Ambient Air Concentration
Hawaiian Electric Co. 1974 (20)	6.07-14.87% WO/ LSFO; 255-290 GPH WO  Pb in fuel 7 ppm Pb 492 ppm Pb 418 ppm Pb 1490 ppm Pb 4 ppm Pb	Zn - 60% S - 95%  Pb 100% 39, 47% 51, 52, 50% 36, 31% 100%	Pb - 0.015 $\mu\text{g}/\text{m}^3$ max. calc. for 2 m/sec wind speed, 1 m from source, 53.35 m (175 ft) eff. stack ht.
St. Lawrence Cement 1972 (21, 22))	Up to 1000 GPH WO (% unknown)/ No. 6 FO	Pb - 89.2% <sup>*</sup> Zn - 100% <sup>*</sup> Br - 72.2% <sup>*</sup> *in recovered clinker and dust	No increase in Pb, Zn, P emissions during WO burning
1972 Test (23)	1-15% WO/No. 6 FO; 3.9-62.3 GPH WO  Pb in fuel <sup>*</sup> 1500 ppm Pb 1000 ppm Pb 500 ppm Pb 300 ppm Pb 100 ppm Pb	Pb 19% 24% 36% 44% 54%	Calc. Max. Avg. seasonal Pb <sub>3</sub> conc. $\mu\text{g}/\text{m}^3$ — 0.54 0.46 0.34 0.25 0.11 25 ft. stack - max. 10 min. ground level conc. approx. 10 times seasonal conc.
*Approx. 245 GPH total fuel			
Exxon tests for Mass. 1972 (24)	100% WO 7.5 GPH WO 4200 ppm Pb	Stack Wt % Pb 29 Ca 44 P 50 Zn 38 Fe 35 Ba 50	Tubes Wt % 62 25 40 38 50 50

Table 7-13. (Continued) USED OIL COMBUSTION TESTS<sup>#</sup>

Test	Blend <sup>+</sup>	Elemental Balances <sup>*</sup>	Ambient Air Concentration
RECON 1978 Site A, Test #1	33 GPH No. 2 Oil 3 ppm Pb	Pb - 80%	-
RECON 1978 Site A, Test #2	15-25% WO (Industrial) 4.6-7.7 GPH WO 13 ppm Pb	Pb - 44% Cu - 49% S - 87% Ni, Na, Fe, Al, Cr, Zn, Mg 100%	-
RECON 1978 Site B, Test #3	8% WO 1 GPH WO 157 ppm Pb	S - 91% Ni, Na, Fe, Pb, Cu, Al, Cr, Zn, Mg 100%	-
RECON 1978 Site C, Test #4	140 GPH No. 6 Oil 2 ppm Pb	Pb - 100%	-
RECON 1978 Site C, Test #5	9.72% WO 13 GPH WO 227 ppm Pb	Pb - 42% S - 84%	-
RECON 1978 Site C, Test #6	60.4% WO 86 GPH WO 1398 ppm Pb	Pb - 35% S - 89%	-
RECON 1978 Site C, Test #7	20.8% WO (Reprocessed) 28 GPH WO 132 ppm Pb	Pb - 23% S - 114%	-
RECON 1978 Site C, Test #8	100% WO (Reprocessed) 131 GPH WO 627 ppm Pb	Pb - 97% S - 121%	-
RECON 1978 Site C, Test #9	20.6% WO (Industrial) 27 GPH WO 3 ppm Pb	Pb - 100% S - 111%	-

<sup>#</sup>See Appendix B, Volume II for RECON test details.

Table 7-14

SO<sub>2</sub> AND NO<sub>x</sub> EMISSIONS DURING RECON TESTS

RUN NO.	FUEL		SO <sub>2</sub>			NO		
	GPH	% S	grams/ hr S	lbs SO <sub>2</sub> /10 <sup>3</sup> gal	150 (S) *	grams/ hr N	lbs/hr NO <sub>2</sub>	lbs NO <sub>2</sub> /10 <sup>3</sup> gal
1 (#2 Oil)	33.0	0.16	232	1.021	24	52	0.376	11.4
2	30.6	0.17	148	0.651	25.5	52	0.376	12.3
3	12.8	0.25	95	0.418	37.5	35	0.253	19.8
4 (#6 Oil)	140	0.30	1595	7.020	45	440	3.184	22.7
5	134	0.31	1187	5.224	46.5	506	3.662	27.3
6	142	0.35	1517	6.677	52.5	351	2.540	17.9
7	136	0.31	1639	7.214	46.5	309	2.236	16.4
8	131	0.36	1939	8.534	54	343	2.482	18.9
9	133	0.27	1336	5.880	40.5	385	2.786	20.9

\*Emission factor from Table 4-1.

Table 7-15. PARTICULATE EMISSIONS-RECON TESTS

Fuel	Run No.	% Ash	Sample No.	Dry Gas Composition % by Vol.			Avg. % O <sub>2</sub>	Gas Vol. correction to zero xs air*	Avg. Emissions grains/dscf <sup>+</sup>	Emissions Corrected to zero xs air grains/dscf <sup>+</sup>	Ratio of Ac To Calc. Em sions From
				CO <sub>2</sub>	O <sub>2</sub>	N <sub>2</sub>					
#2 Fuel Oil (FO)	1	0.02	1	7.5	12.5	80.0	13.0	0.3812	0.0179	0.047	>>1
	2		2	7.0	13.5	79.5					
15-25% Ind. WO in FO	2	0.13	1	7.0	14.0	79.0	11.0	0.4764	0.0329	0.069	>>1
			2	-	-	-					
			3	11.0	8.0	81.0					
8% Crankcase Oil in FO	3	0.04	1	9.0	10.0	81.0	10.0	0.5240	0.0310	0.059	>>1
			2	-	-	-					
			3	-	-	-					
#6 Fuel Oil (FO)	4	0.01	1	12.0	12.0	76.0	9.8	0.5335	0.0062	0.012	>>1
			2	-	-	-					
			3	11.5	7.5	81.0					
9.72% Crankcase Oil in FO	5	0.09	1	11.0	7.2	81.8	6.6	0.6858	0.0139	0.020	1.32
			2	-	-	-					
			3	11.5	6.0	82.5					
60.4% Crankcase Oil in FO	6	0.48	1	9.5	8.5	82.0	7.5	0.6430	0.0476	0.074	0.63
			2	8.0	8.0	84.0					
			3	10.0	6.0	84.0					
20.8% Reproc. Oil in FO	7	0.20	1	9.75	7.0	83.25	5.3	0.7477	0.0283	0.038	1.09
			2	11.0	5.0	84.0					
			3	7.5	4.0	88.5					
100% Reprocessed Oil	8	0.91	1	8.5	5.5	86.0	6.0	0.7144	0.0841	0.118	0.50
			2	9.0	6.5	84.5					
			3	-	-	-					
20.6% Inc. WO in FO	9	0.05	1	11.4	6.0	82.6	5.8	0.7239	0.0145	0.020	2.05
			2	-	-	-					
			3	7.0	5.5	87.5					

\*Correction =  $[100 - (\%O_2)(4.76)]/100$ 

+filter catch only - EPA Method 5

Table 7-16. BENZO(a) PYRENE CONCENTRATIONS  
IN VARIOUS OILS - DATA SUMMARY\*

Virgin #2 oils	0.03-0.6 $\mu\text{g/g}$
Virgin #4 oil	2.1
Virgin #5 oils	2.8-3.3
Virgin #6 oils	2.9-44
Unused motor oil basestocks	0.03-0.28
Used motor oils and waste oils	3.2-28
Used diesel motor oil	<0.15
Used synthetic motor oil	16
Used oil (new car dealer)	0.7
Unused re-refined motor oil basestock	2.1
Used industrial oil	5.9
Reprocessed used oil	10.5
Used oil/fuel oil blends	1.6-3.0

\*See Tables 7-17 and 7-18 for details.

Table 7-17. DATA ON BENZO(a)PYRENE CONCENTRATIONS IN  
UNUSED AND USED MOTOR OILS AND BLENDED OILS

Sample No.	Description	B(a)P Conc. <u>ug/g</u>		Reference
---	Unused (virgin) motor oil basestock	0.28		25
---	Unused (virgin) motor oil basestock	0.03		26
228	Unused re-refined motor oil basestock	2.1	$\pm 1.2$	7
---	Used motor oil (1,400 miles)	5.8		27
---	Used motor oil (3,000 miles)	28.		28
203	Used motor oil (composite)	12.	$\pm 3$	7
222	Re-refiner's feedstock waste oil (sampling period A)	12.	$\pm 2$	7
226	Re-refiner's feedstock waste oil (sampling period B)	8.8	$\pm 1.2$	7
231	Service station (station A) waste oil	5.2	$\pm 0.4$	7
212	Service station (station B) waste oil	3.2	$\pm 0.6$	7
230	Used motor oil (unleaded, 4,145 miles)	14.	$\pm 2$	7
224	Used diesel motor oil (3,000 miles)	0.15		7
223	Used synthetic motor oil (23,000 miles)	16.	$\pm 1$	7
78-168	Used crankcase oil	5.7	$\pm 0.5$	RECON Test* (Site C)
78-25	15-25% used industrial oil in #2 fuel oil	3.0	$\pm 0.4$	RECON Test* (Site A)
78-28	Used crankcase oil (new car dealer)	0.7	$\pm 0.1$	RECON Test* (Site B)
78-27	8% used crankcase oil (new car dealer) in #2 fuel oil	1.6	$\pm 0.1$	RECON Test* (Site B)
78-170	Used industrial oil	5.9	$\pm 0.2$	RECON Test* (Site C)

\* Analysis by NBS

Table 7-18. DATA ON BENZO(a)PYRENE CONCENTRATIONS IN FUEL OILS

<u>Sample No.</u>	<u>Description</u>	<u>B(a)P Conc.</u> <u><math>\mu\text{g/g}</math></u>	<u>Reference</u>
---	No. 2 virgin distillate heating oil	0.6	29
78-26	No. 2 fuel oil	0.5 $\pm$ 0.1	RECON Test (Site A)
---	Virgin distillate heating oil	0.03	26
---	No. 2 virgin distillate diesel oil	0.03	26
220	No. 4 virgin residual fuel oil (source A)	2.1 $\pm$ 0.3	7
214	No. 5 virgin residual fuel oil (source B)	2.8 $\pm$ 0.1	7
229	No. 5 virgin residual fuel oil (duplicate of source B)	3.3 $\pm$ 0.6	7
225	No. 5 recycled fuel oil (source A)	8.4 $\pm$ 0.8	7
227	No. 5 recycled fuel oil (source B)	3.7 $\pm$ 0.4	7
---	No. 6 virgin residual fuel oil (Bunker C)	44.0	29
201	No. 6 virgin residual fuel oil (Bunker C, source A)	27 $\pm$ 3	7
213	No. 6 virgin residual fuel oil (Bunker C, source B)	35. $\pm$ 2	7
78-167	No. 6 fuel oil	2.86 $\pm$ 0.06	RECON Test (Site C)
78-169	Reprocessed used oil	10.5 $\pm$ 1.0	RECON Test (Site C)

\* Analysis by NBS



Table 7-19. HYDROCARBON EMISSIONS# - RECON

Site	Run	Fuel*	Polynuclear Aromatics, $\mu\text{g/g}$ fuel				Total	ppm <sup>+</sup>	Total Gaseous Hydrocarbons as CH <sub>4</sub> $\mu\text{g/g}$ fuel (avg)
			Naphthalene	Phenanthracene	2,3, Benzanthrene	Unidentified			
----	Blank	----	ND	ND	ND	ND	-	-	-
A	1	#2	-	-	-	-	-	8	134
A	2	15-25% WO/#2	ND	0.034	0.034	1.234	1.30	9	164
B	3	8% CCO/#2	0.13	ND	ND	ND	0.13	<1	<14
C	4	#6	ND	ND	NDD	ND	ND	11	165
C	5	9.72% CCO/#6	-	-	-	-	-	5,7	93
C	6	60.4% CCO/#6	ND	ND	ND	ND	ND	10,11	165
C	7	20.8% RO/#6	-	-	-	-	-	5,5	73
C	8	RO	ND	ND	ND	ND	ND	7,11	152
C	9	20.6% WO/#6	-	-	-	-	-	4,4	60
A	--	Tube Deposits ( $\mu\text{g/g}$ deposit)	ND	0.3	ND	18.7	19.0	-	-

Air Pollutant Emission Factor for virgin residual and distillate fuel oils = 1 lb/10<sup>3</sup> gal = 133  $\mu\text{g/g}$  (Table 4-1)

+ by volume as CH<sub>4</sub>

\* #2 = #2 fuel oil; #6 = #6 fuel oil; WO = industrial used oil; CCO = used crankcase oil; RO = reprocessed used oil

# Biphenyl, Anthracene, Fluoranthene, Chrysene, Pyrene, Benzo(a)Pyrene, PCB's ND in all cases

ND = not detected

Table 7-20. HYDROCARBON EMISSIONS  
micrograms/gram fuel (ug/g)

Run	Fuel	Work By	N	BaP	P	B(ghi)P	Cor	A	Phen	Fluor	B	C	BA	PCB	UI	Total PNA Detected	Total Gaseous Hydrocarbons	Total BSO
-	#2 Fuel Oil	PHS(30)	-	ND	0.006- 0.077	ND	ND	ND	0.38	0.003- 0.21	-	-	-	-	-	0.004- 0.67	-	58- 344
1	#2 Fuel Oil	RECON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	134	-
2	15-25% WO/#2	RECON	ND	ND	ND	-	-	ND	0.034	ND	ND	ND	0.034	ND	1.234	1.30	164	-
3	8% CCO/#2	RECON	0.13	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	0.13	< 14	-
-	#6 Fuel Oil	PHS(30)	-	0.002	0.012	ND	ND	ND	0.074	0.011	-	-	-	-	-	0.312	-	136
4	#6 Fuel Oil	RECON	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	165	-
5	9.72% CCO/#6	RECON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93	-
6	60.4% CCO/#6	RECON	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	165	-
7	20.8% RO/#6	RECON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	73	-
8	RO	RECON	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	152	-
9	20.6% WO/#6	RECON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	-

N = Naphthalene  
BaP = Benzo(a)Pyrene  
P = Pyrene  
B(ghi)P = Benzo(ghi)Perylene  
Cor = Coronene  
A = Anthracene  
Phen = Phenanthrene  
Fluor = Fluoranthrene  
B = Biphenyl  
C = Chrysene  
BA = 2,3 Benzanthrene  
PCB = Polychlorinated Biphenyls  
UI = Unidentified GC peaks  
PNA = Polynuclear Aromatics  
BSO = Benzene soluble Organics (by  
extraction of particulate and  
dry ice-alcohol condensate)  
ND = Not detected  
CCO = Used crankcase oil  
WO = Waste oil  
RO = Re processed used oil

Table 7-21

**NATIONAL AMBIENT AIR QUALITY STANDARDS**

<u>Air Pollutant</u>	<u>Averaging Period</u>	<u>Maximum Allowable Concentrations*</u>			
		<u>Primary Standard</u>		<u>Secondary Standard</u>	
		<u>(ug/m<sup>3</sup>)</u>	<u>(ppm)</u>	<u>(ug/m<sup>3</sup>)</u>	<u>(ppm)</u>
Sulfur Dioxide	Annual Arithmetic Mean	80	0.03	-	-
	24-hour	365	0.14	-	-
	3-hour	-	-	1300	0.50
Total Suspended Particulates	Annual Geometric Mean	75	-	60	-
	24-hour	260	-	150	-
Carbon Monoxide	8-hour	10000	9.0	10000	9.0
	1-hour	40000	35.0	40000	35.0
Photochemical Oxidants	1-hour	160	0.08	160	0.08
Nitrogen Dioxide	Annual Arithmetic Mean	100	0.05	100	0.05
Nonmethane Hydrocarbons	3-hour (6 to 9 a.m.)	160	0.24	160	0.24
Lead and its compounds	1 calendar quarter	1.5	-	1.5	-

\* Other than annual periods, maximum allowable concentrations may be exceeded no more than once per calendar year.

Table 7-22

NATIONAL STANDARDS FOR THE PREVENTION OF  
SIGNIFICANT DETERIORATION OF AIR QUALITY

Air Pollutant	Averaging Period	Maximum Allowable Increments*					
		Class I ( $\mu\text{g}/\text{m}^3$ )	(ppm)	Class II ( $\mu\text{g}/\text{m}^3$ )	(ppm)	Class III ( $\mu\text{g}/\text{m}^3$ )	(ppm)
Sulfur Dioxide	Annual Arithmetic Mean	2	0.001	20	0.008	40	0.016
	24-hour	8	0.003	91	0.036	182	0.071
	3-hour	25	0.010	512	0.201	700	0.270
Total Suspended Particulates	Annual Geometric Mean	5	-	19	-	37	-
	24-hour	10	-	37	-	75	-

\* Note: 1) Increments refer to the maximum allowable increase of ambient air pollutant concentrations over baseline concentrations.

- 2) Baseline concentration is that ambient concentration level which exists at the time of the first permit application based on available air quality data, taking into account the effect of all projected emissions from any major emitting facility which commenced construction prior to January 6, 1975, but has not begun operation before the date of the baseline concentration determination.
- 3) The total ambient concentration shall not exceed the respective national secondary or primary ambient air quality standard whichever is lower.
- 4) Other than annual periods, maximum allowable increases may be exceeded once per calendar year.
- 5) All areas are initially designated Class II areas, except international parks, national wilderness areas and national memorial parks greater than 5,000 acres in size, national parks greater than 6,000 acres in size, which are designated as Class I areas, all other areas previously designated as Class I, and non-attainment areas.

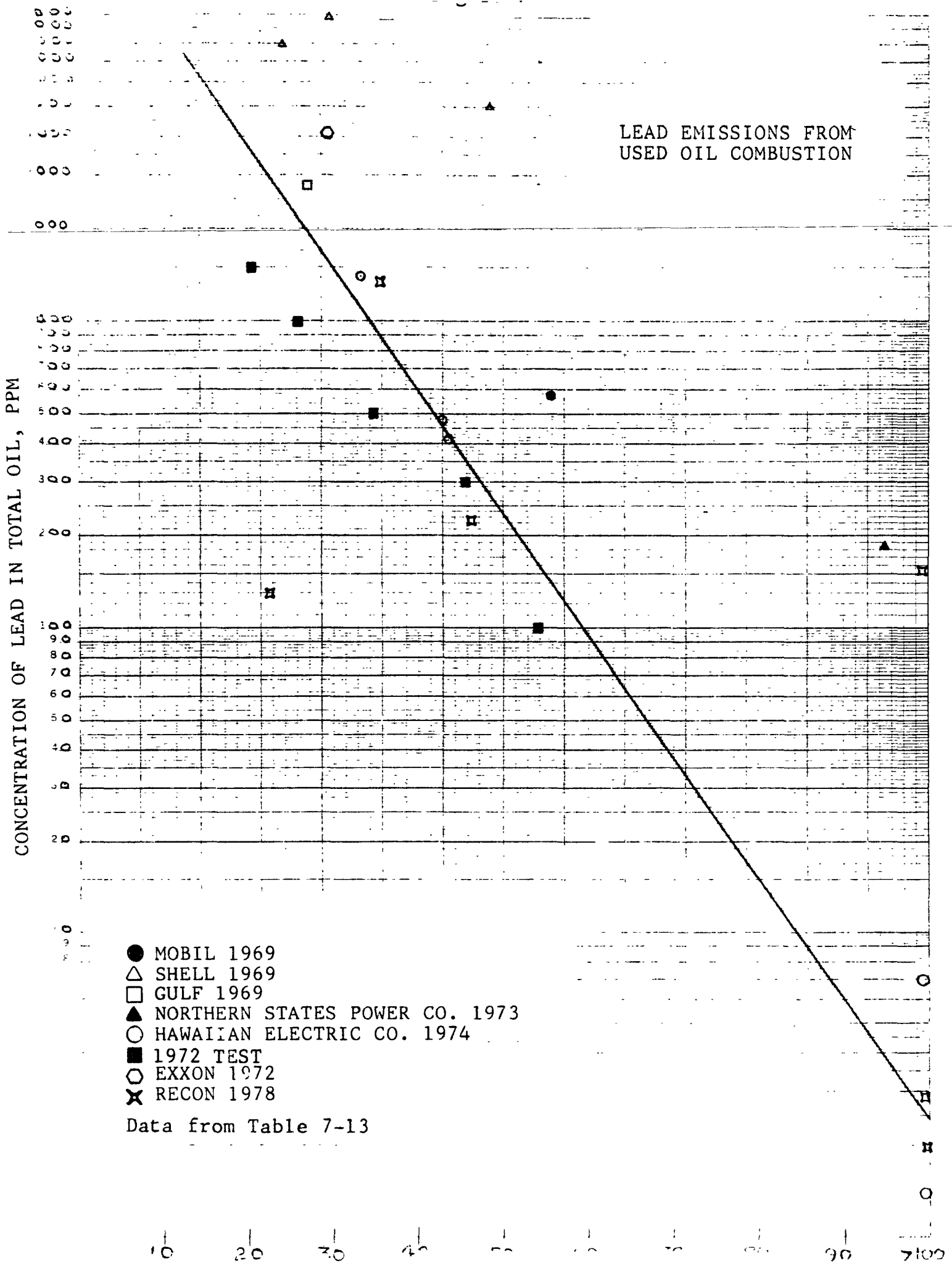
# LEAD EMISSIONS FROM USED OIL COMBUSTION

CONCENTRATION OF LEAD IN TOTAL OIL, PPM

- MOBIL 1969
- △ SHELL 1969
- GULF 1969
- ▲ NORTHERN STATES POWER CO. 1973
- HAWAIIAN ELECTRIC CO. 1974
- 1972 TEST
- EXXON 1972
- ✕ RECON 1978

Data from Table 7-13

LEAD EMITTED AS A PERCENT OF LEAD IN 1969 GULF FUEL



## REFERENCES

1. Weinstein, N. J. Waste Oil Recycling and Disposal. EPA-670/2-74-052. August 1974. 323 pages.
2. Mascetti, G. J. and H. H. White. Utilization of Used Oil. ~~Aerospace Report No. AFR-78(7834)-1. DOE. August 1978.~~
3. Bidga, Richard J. and Associates. Review of All Lubricants Used in the U. S. and Their Re-Refining Potential. DOE/BC/30227-1. June 1980. 84 pages.
4. Stewart, R. G. and J. L. Helm. The Lubricant Market in the 1980's - U. S. and Free World. Presented at the 1980 NPRA Annual Meeting, New Orleans, LA. March 23-25, 1980.
5. Cotton, F. O., M. L. Whisman, J. W. Goetzinger and J. W. Reynolds. Analysis of 30 Used Motor Oils. Hydrocarbon Processing, September 1977.
6. FR 44, 31514-31568, May 31, 1979.
7. May, W. E. and J. M. Brown. The Analysis of Some Residual Fuel Oil and Some Waste Lubricating Oils by a High Performance Liquid Chromatographic Procedure. Measurements and Standards for Recycled Oil - II. NBS Special Publication 556. D. A. Becker, Editor. September 1979.
8. Becker, D. A. and J. J. Comeford. Recycled Oil Program: Phase I - Test Procedures for Recycled Oil Used as Burner Fuel. NBSIR 78-1453. February 1979.
9. Whisman, M. L., J. W. Goetzinger, and F. O. Cotton. Waste Lubricating Oil Research: An Investigation of Several Re-refining Methods. RI-7884. U. S. Bureau of Mines. 1974.
10. Cotton, F. O., D. W. Brinkman, J. W. Reynolds, J. W. Goetzinger, and M. L. Whisman. Pilot-Scale Used Oil Re-Refining Using a Solvent Treatment/Distillation Process. BEFC/RI-79/14. January 1980.
11. Yates, J. J. et al. Used Oil Recycling in Illinois: Data Book. Document No. 78/34. State of Illinois Institute of Natural Resources. Chicago. October 1978. 135 pages.
12. Weinstein, N. J. Unpublished work by RECON SYSTEMS, INC. for U. S. DOE (Contract No. DE-AC19-79BC10044) and U. S. EPA (Contract No. 68-01-4739). 1980.

13. Devitt et al. Population and Characteristics of Industrial/Commercial Boilers in the U. S. EPA-600/7-79-178a. August 1979. 282 pages.
14. API Publication No. 4036. Mobil Tests. Final Report of the Task Force on Used Oil Disposal. August 1970. 44 pages.
15. API. Humble Tests. Op. Cit.
16. API. Shell Tests. Op. Cit.
17. API. Amoco Tests. Op. Cit.
18. API. Gulf Tests. Op. Cit.
19. API. Northern States Tests. Waste Oil Roundup--No. 3. Committee on Disposal of Waste Products. September 1974.
20. API Publication No. 1588. Hawaiian Electric Tests. Energy From Used Lubricating Oils. Task force on Utilization of Waste Lubricating Oils. October 1975. 135 pages.
21. Berry. E. E., MacDonald, L. P. and Skinner, D. J. Experimental Burning of Waste Oil as a Fuel in Cement Manufacture. Technology Development Report EPS 4-WP-75-1. Environment Canada. June 1975. 187 pages.
22. Berry, E. E. and MacDonald, L. P. Experimental Burning of Used Automotive Crankcase Oil in a Dry-Process Cement Kiln. Journal of Hazardous Materials 1, 137-156. 1975/76.
23. Confidential source.
24. Chappell, G. A. Waste Oil Reprocessing. Project No. 72-5. Prepared for Division of Water Pollution Control. Commonwealth of Massachusetts. January 1973.
25. Gross, G. P. Gasoline Composition and Vehicle Exhaust Gas Polynuclear Aromatic Content. Final Report No. CRC- APRAC, Project No. CAPE-6-68, 1974.
26. Graf, W. and Winter, C. Archiv. fur Hygiene und Bakteriologie, 152, 289, 1968.

27. Sullivan, J. B. Marine Pollution Monitoring (Petroleum). Proceedings of a Workshop, NBS Special Publication 409, 1974. 261 pages.
28. Brown, R. A. et al. Rapid Methods of Analysis for Trace Quantities of Polynuclear Aromatic Hydrocarbons and Phenols in Automobile Exhaust, Gasoline and Crankcase Oil. Final Report No. CRC-APRAC, Project No. CAPE-12-68. 1971.
29. Pancirov, R. J. and R. A. Brown. Proceedings, Conference on Prevention and Control of Oil Spills. San Francisco, CA. 1975. Pages 103-113.
30. Hangebrauck, R. P. et al. Sources of Polynuclear Aromatics in the Atmosphere. NAPCA Publication No. 999-AP-33. Public Health Service, Durham, NC. 1967. 43 pages.



USED OIL BURNED AS A FUEL

Volume II

Appendices

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This publication (SW-892) was prepared by Recon Systems, Inc.  
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Division and the Office of Solid Waste.

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## VOLUME II

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APPENDIX C LEAD EMISSIONS DURING DOWNWASH

APPENDIX A  
DISPERSION MODELING ANALYSIS OF THE LEAD AIR QUALITY  
IMPACT OF BURNING USED OIL

SOURCE DATA

The average volumetric flue gas flow rate and the stack gas exit temperature were used to calculate an average mass flow of flue gas for each boiler size category. A conservative rate of fuel flow was then determined by assuming that the flue gas mass flow was equivalent to the theoretical air requirement, based on the heating value of the fuel. This assumption leads to a calculated fuel firing rate slightly higher than the actual firing rate and thus to a maximum estimate of emissions.

Finally, it was assumed that 25% by volume of the fuel would be replaced by used oil with a heating value of 150,000 Btu/gallon; the mean value from data in the Used Oil Recycling in Illinois Data Book.<sup>\*</sup> The theoretical air plus 12% excess air required for combustion of this oil would be 128.6 lb of air/gallon of fuel fired (Chapter 13, Table 15, ASHRAE 1972 Handbook of Fundamentals).

DISPERSION MODELING ANALYSES

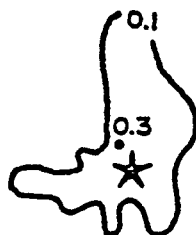
Atmospheric dispersion modeling was performed to assess the impact on quarterly average lead air quality due to the combustion of used oil. A quarterly assessment was chosen because of its consistency with the averaging time for the U.S. EPA National Ambient Air Quality Standard for Lead.

Isopleth Maps

Upon the completion of these analyses with the various meteorological data, the quarterly concentrations for each generic point source were examined. The overall maximum atmospheric lead concentration was identified for each point source modeled. For each city or region analyzed, isopleth maps were developed for each generic source's maximum quarter. These are presented in Figures 1 through 25. The figures are ordered such that the first five depict isopleths for the maximum quarterly impact of generic source 1 for each of the four cities and one region analyzed, the second five are for generic source 2, etc. Besides indicating the point of maximum concentration, the figures depict both the area impacted and the variability of these impacts under various meteorological conditions. It should be noted, however, that these isopleths are based on concentrations resulting from the assumptions listed in Table 5-2. As in the case of maximum concentrations,

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<sup>\*</sup>John J. Yates et al, Used Oil Recycling in Illinois Data Book. Illinois Institute of Natural Resources. October 1978.



★ Emission Source

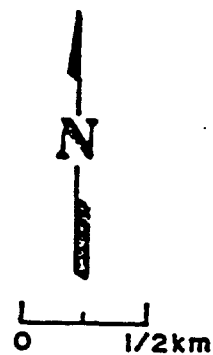
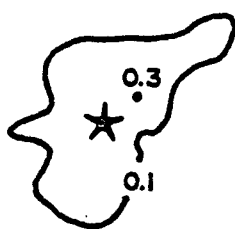


FIGURE I                      GENERIC SOURCE I

3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

CHICAGO

METEOROLOGICAL DATA



★ Emission Source



FIGURE 2  
GENERIC SOURCE 1  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
PADUCAH  
METEOROLOGICAL DATA



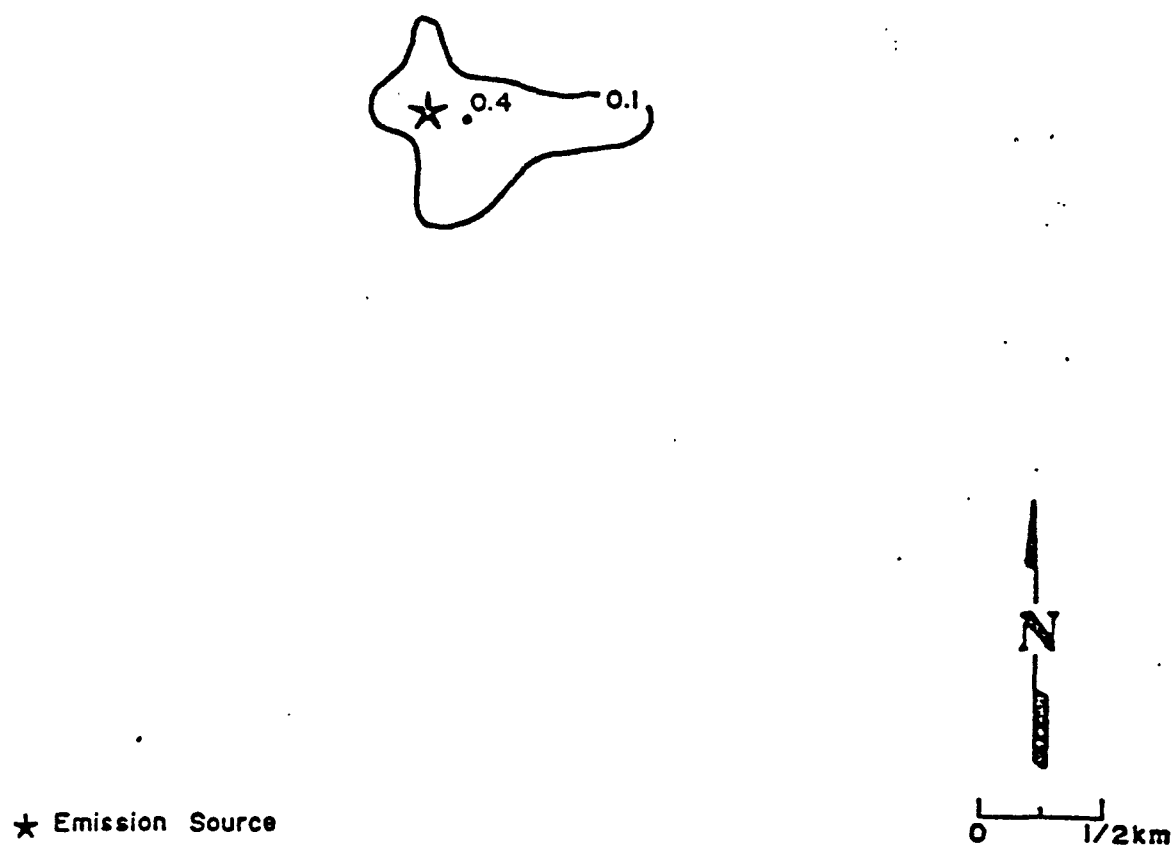
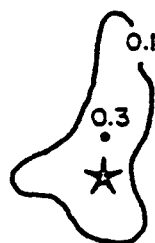


FIGURE 3                      GENERIC SOURCE 1  
4th QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
HELENA  
METEOROLOGICAL DATA



★ Emission Source



FIGURE 4                      GENERIC SOURCE 1

3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

DENVER

METEOROLOGICAL DATA

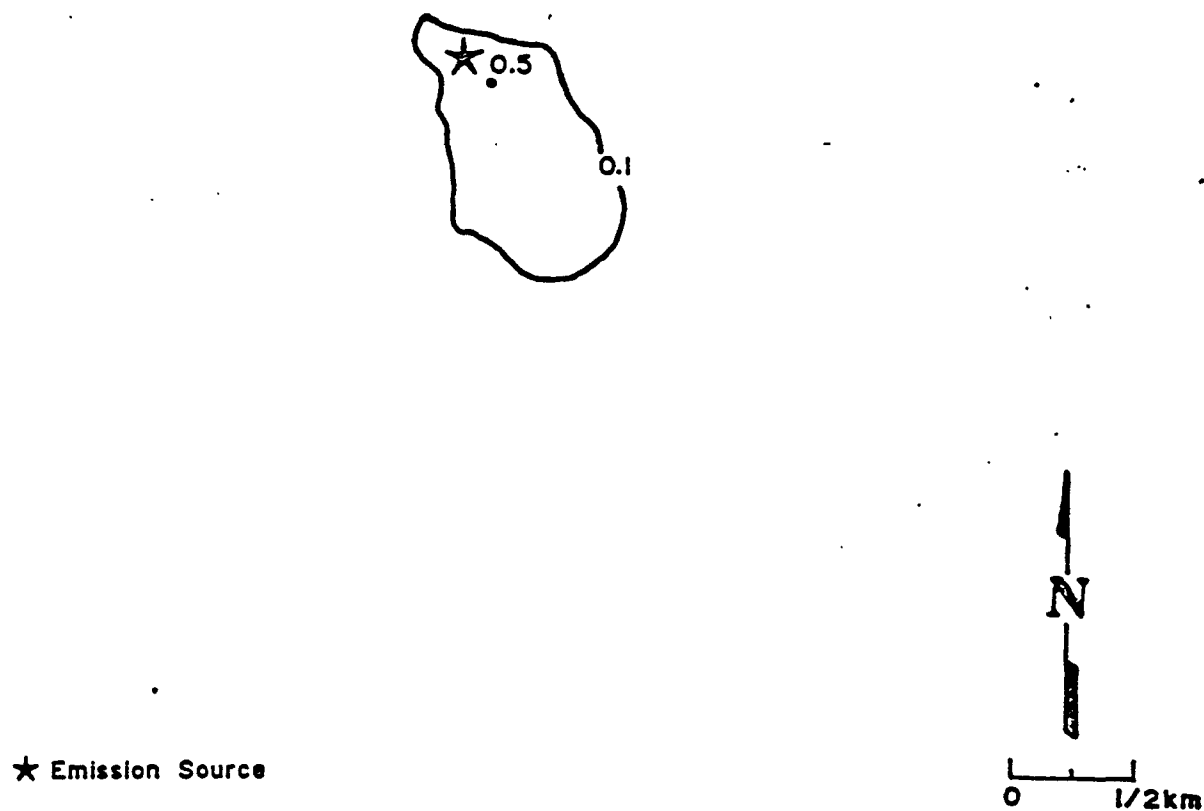


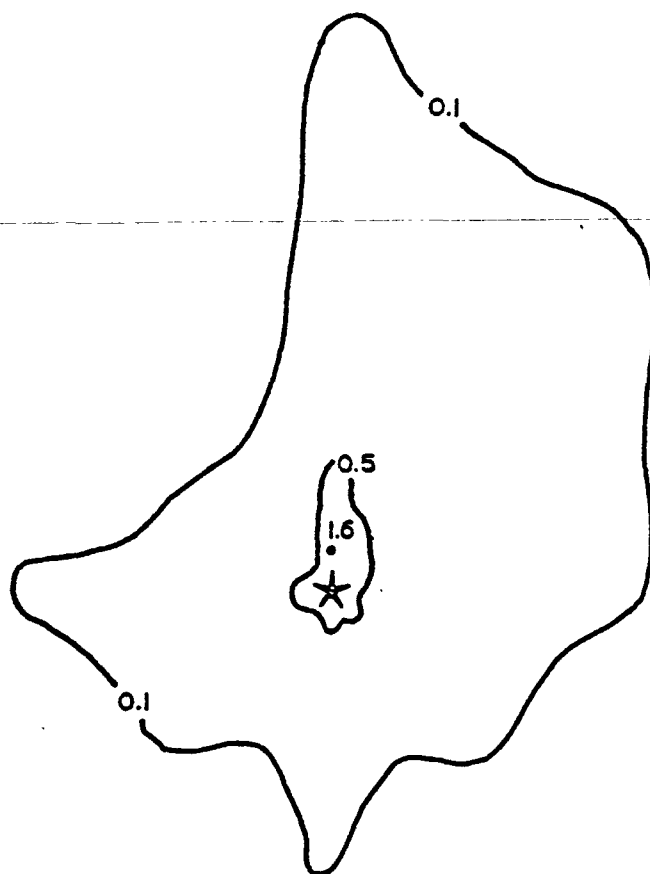
FIGURE 5

GÉNERIC SOURCE I

3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA



★ Emission Source

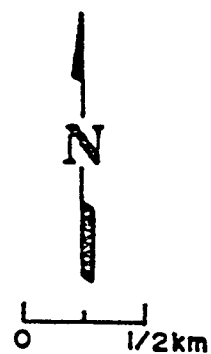
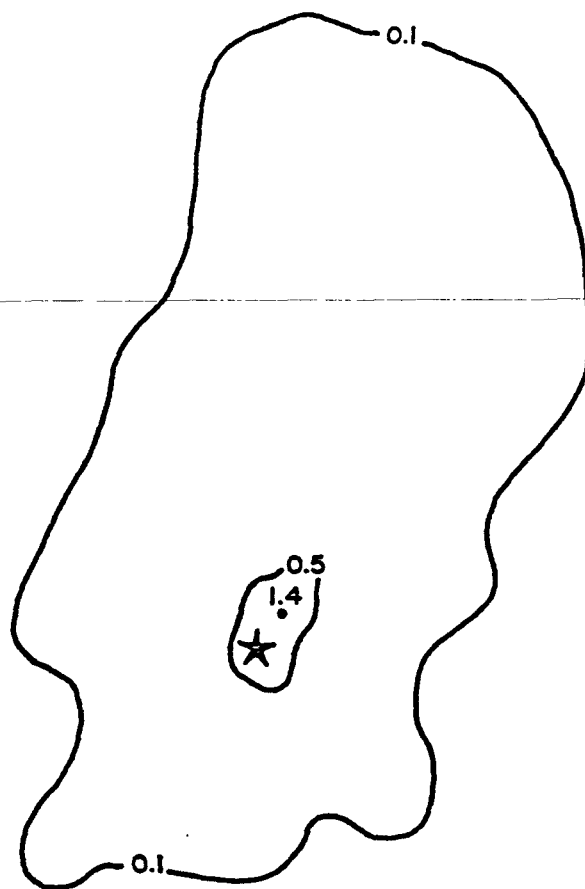
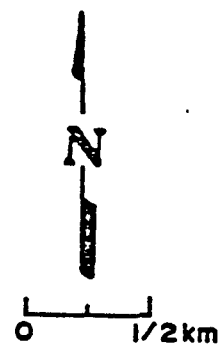


FIGURE 6                      GENERIC SOURCE 2  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
CHICAGO  
METEOROLOGICAL DATA



★ Emission Source



.FIGURE 7  
GENERIC SOURCE 2  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
PADUCAH  
METEOROLOGICAL DATA

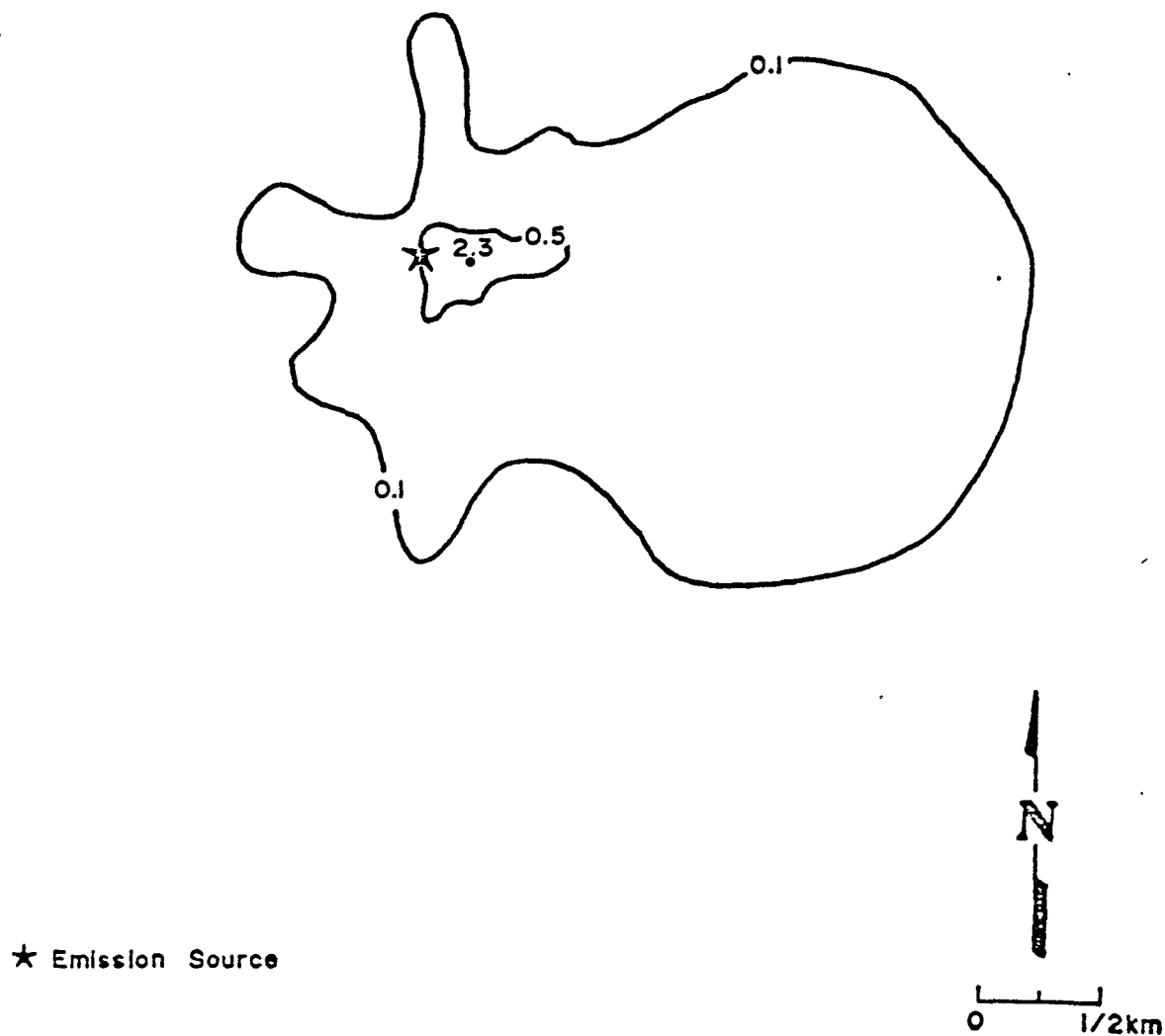


FIGURE 8  
GENERIC SOURCE 2  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
HELENA  
METEOROLOGICAL DATA

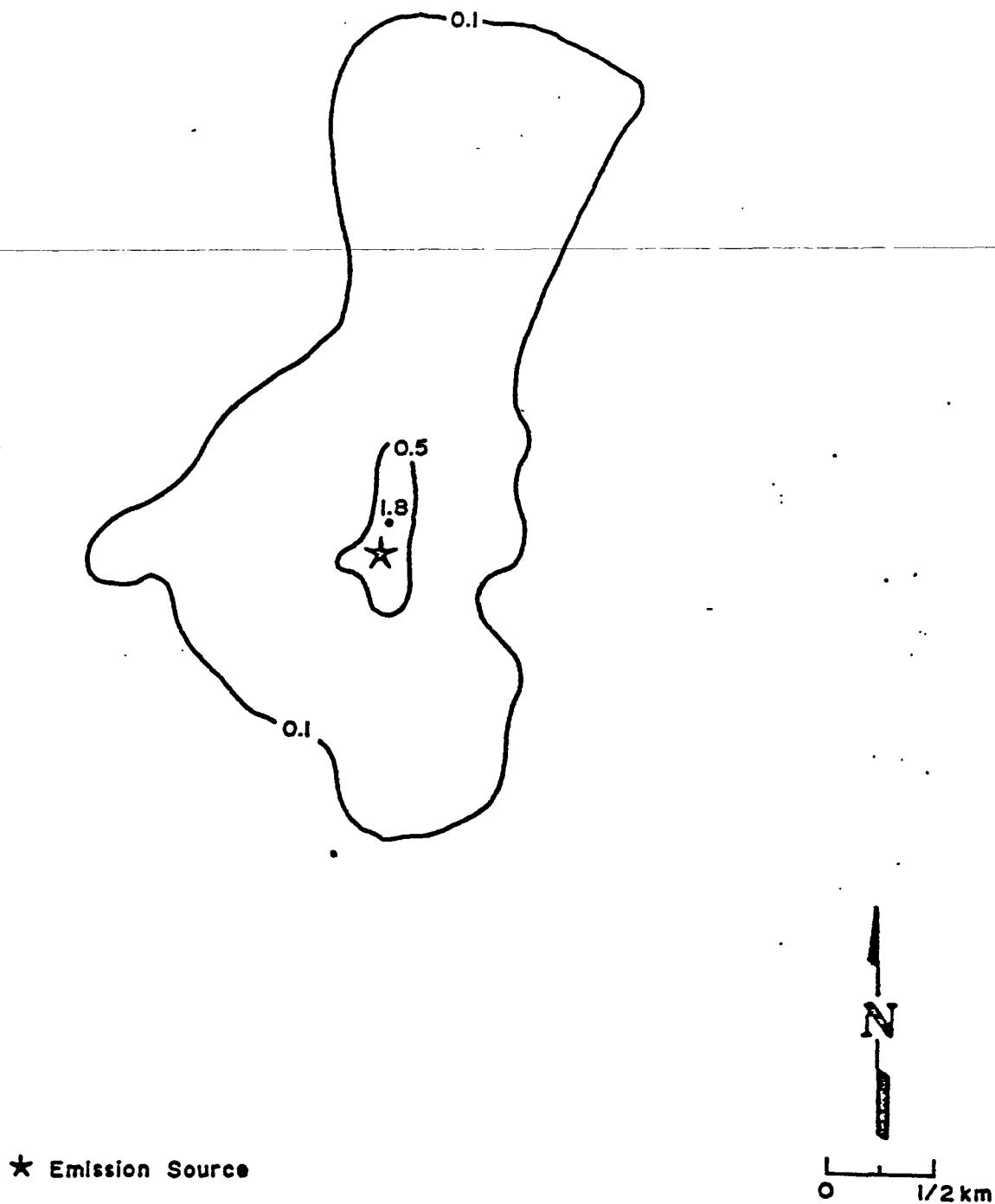
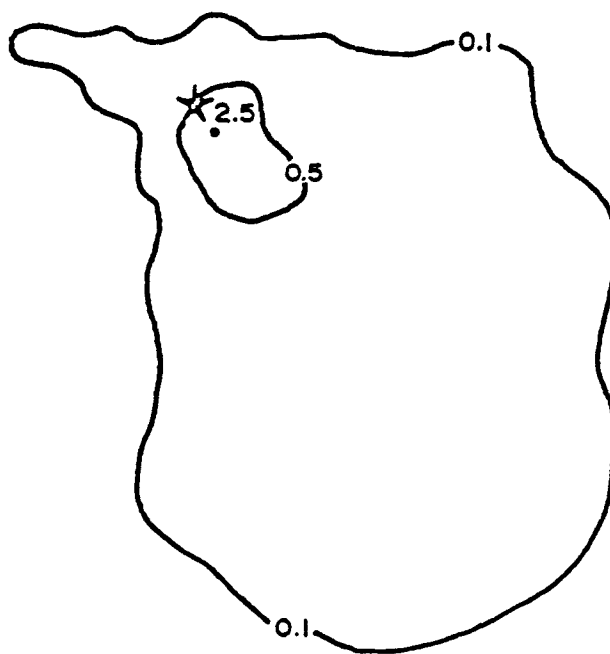


FIGURE 9  
GENERIC SOURCE 2  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
DENVER  
METEOROLOGICAL DATA



★ Emission Source

FIGURE 10

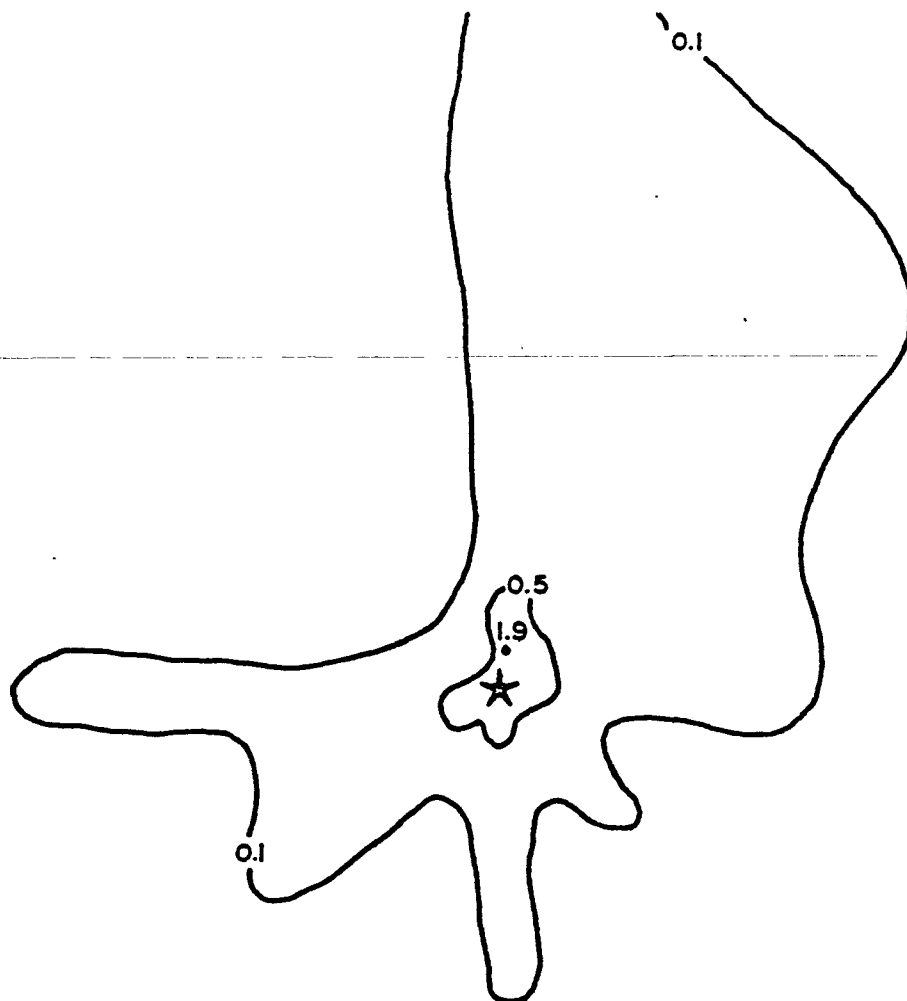
GENERIC SOURCE 2

2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA





★ Emission Source

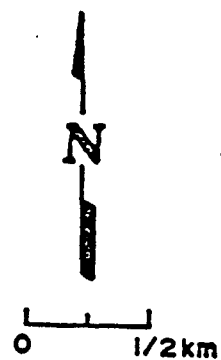
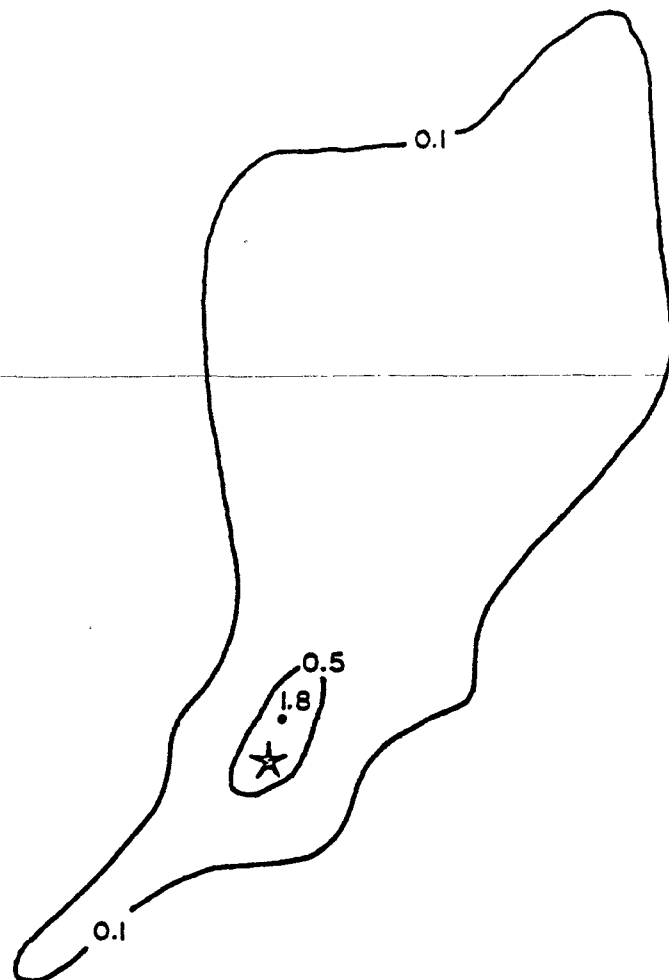


FIGURE 11                      GENERIC SOURCE 3  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
CHICAGO  
METEOROLOGICAL DATA



★ Emission Source

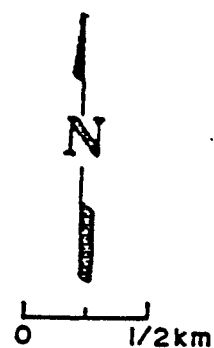
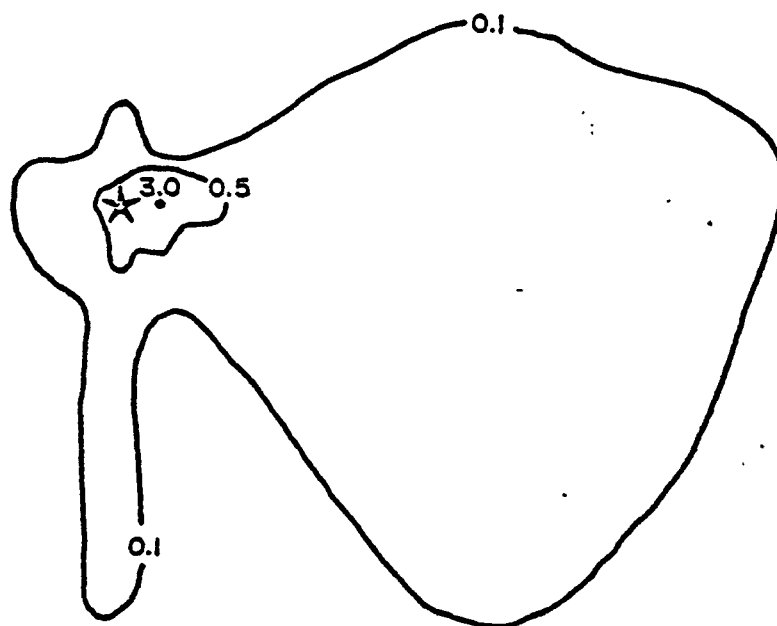
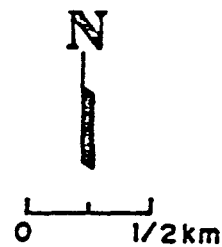
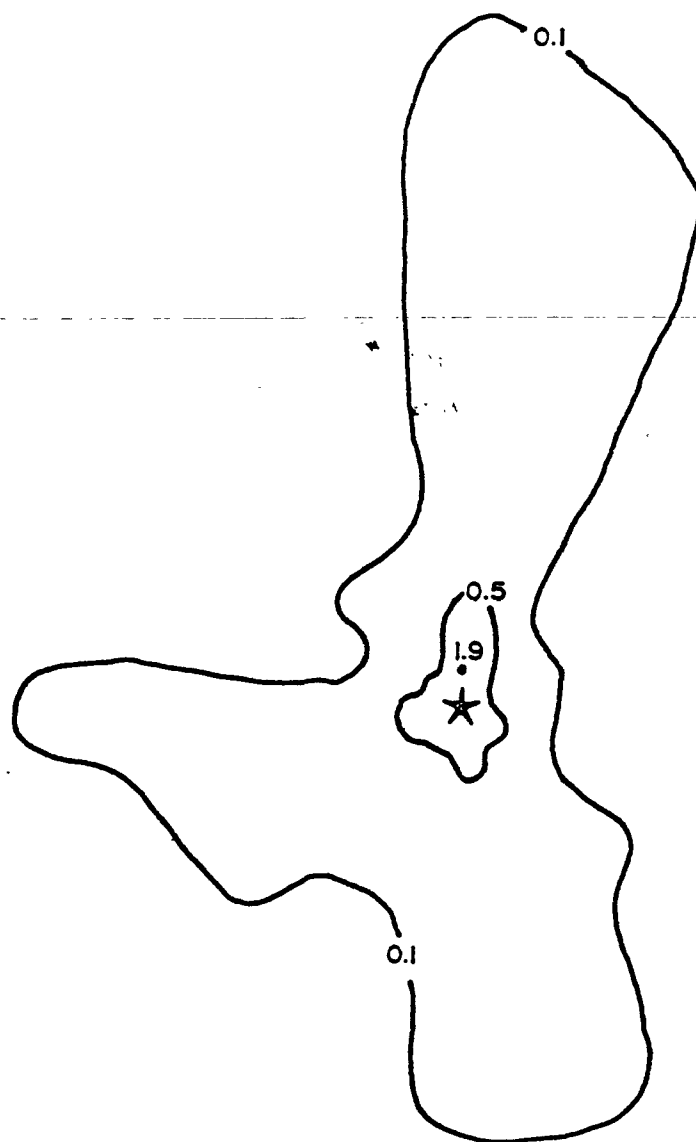


FIGURE 12                      GENERIC SOURCE 3  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
PADUCAH  
METEOROLOGICAL DATA



★ Emission Source

FIGURE 13                      GENERIC SOURCE 3  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
HELENA  
METEOROLOGICAL DATA



★ Emission Source

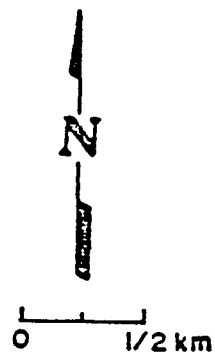
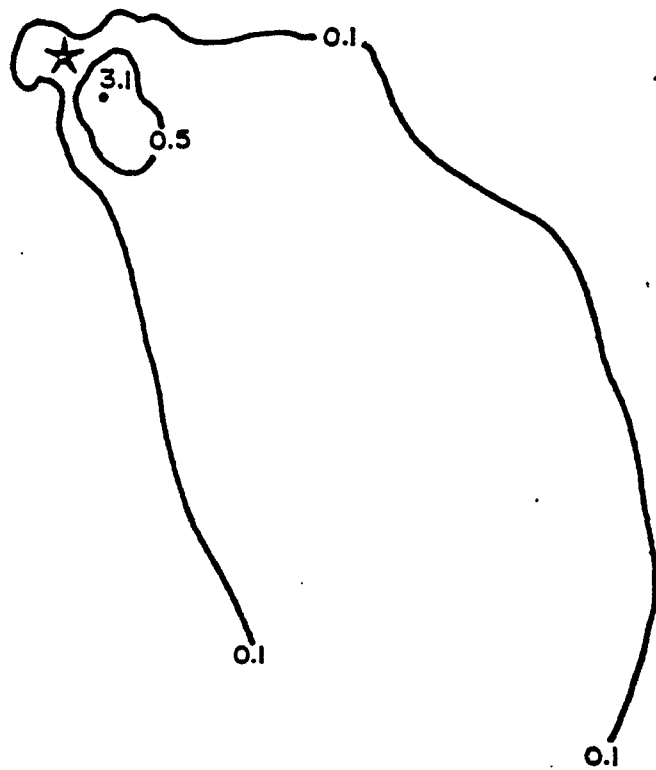
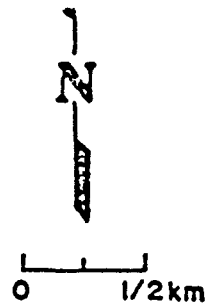


FIGURE 14                      GENERIC SOURCE 3  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
DENVER  
METEOROLOGICAL DATA



★ Emission Source

FIGURE 15

GENERIC SOURCE 3

2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA

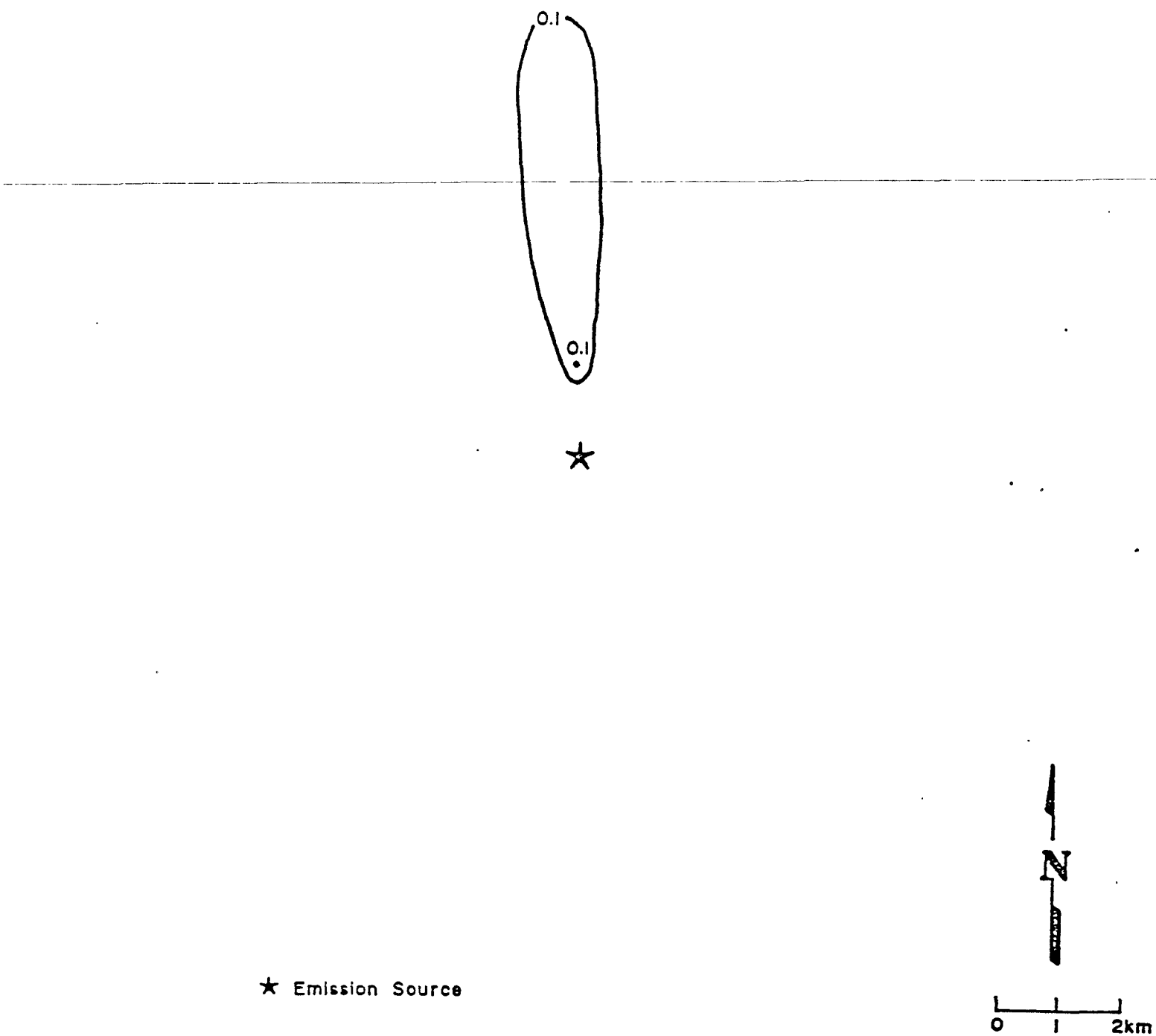


FIGURE 16                      GENERIC SOURCE 4  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
CHICAGO  
METEOROLOGICAL DATA

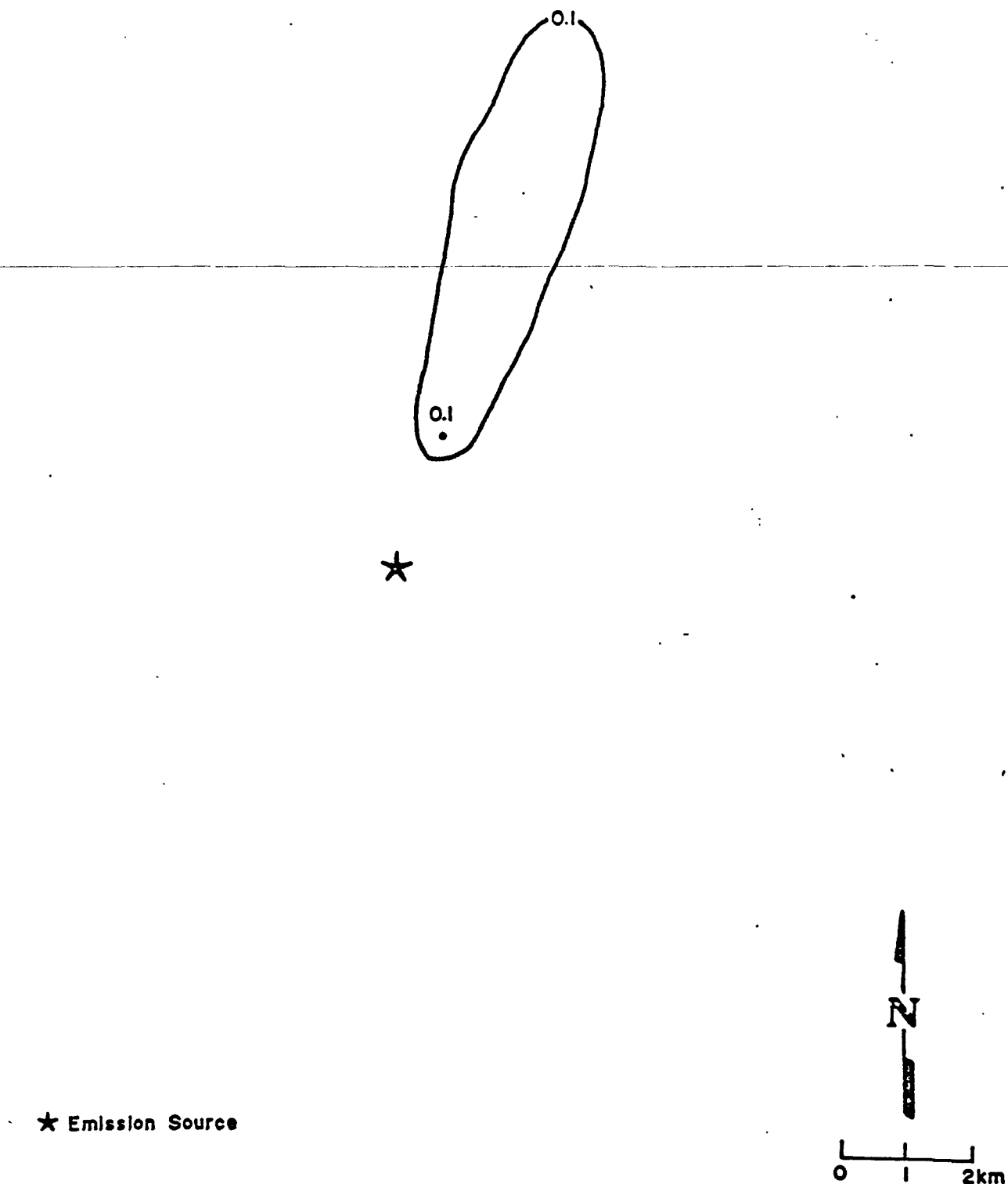


FIGURE 17                      GENERIC SOURCE 4  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
PADUCAH  
METEOROLOGICAL DATA

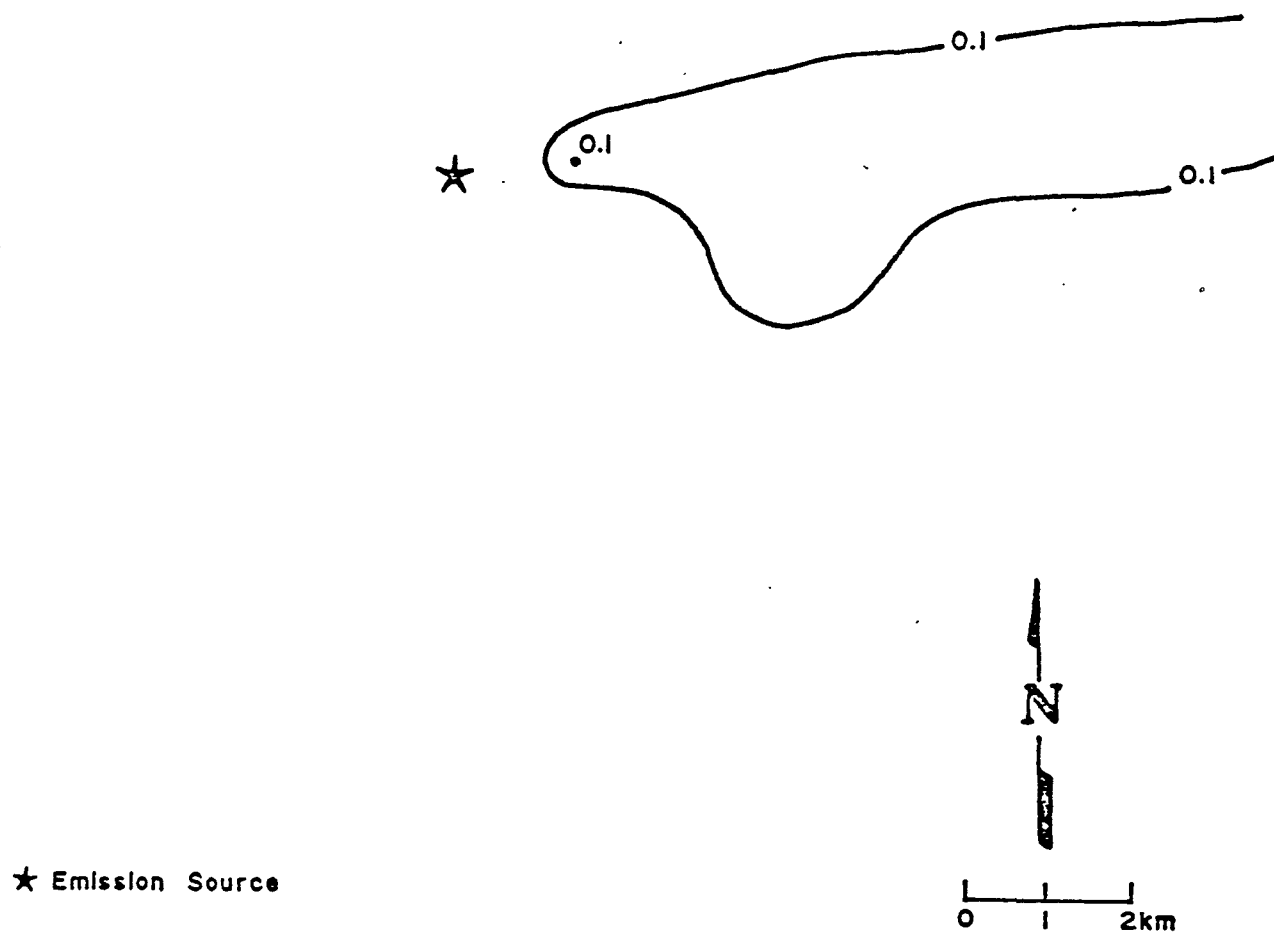


FIGURE 18                      GENERIC SOURCE 4  
2nd    QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
HELENA  
METEOROLOGICAL DATA



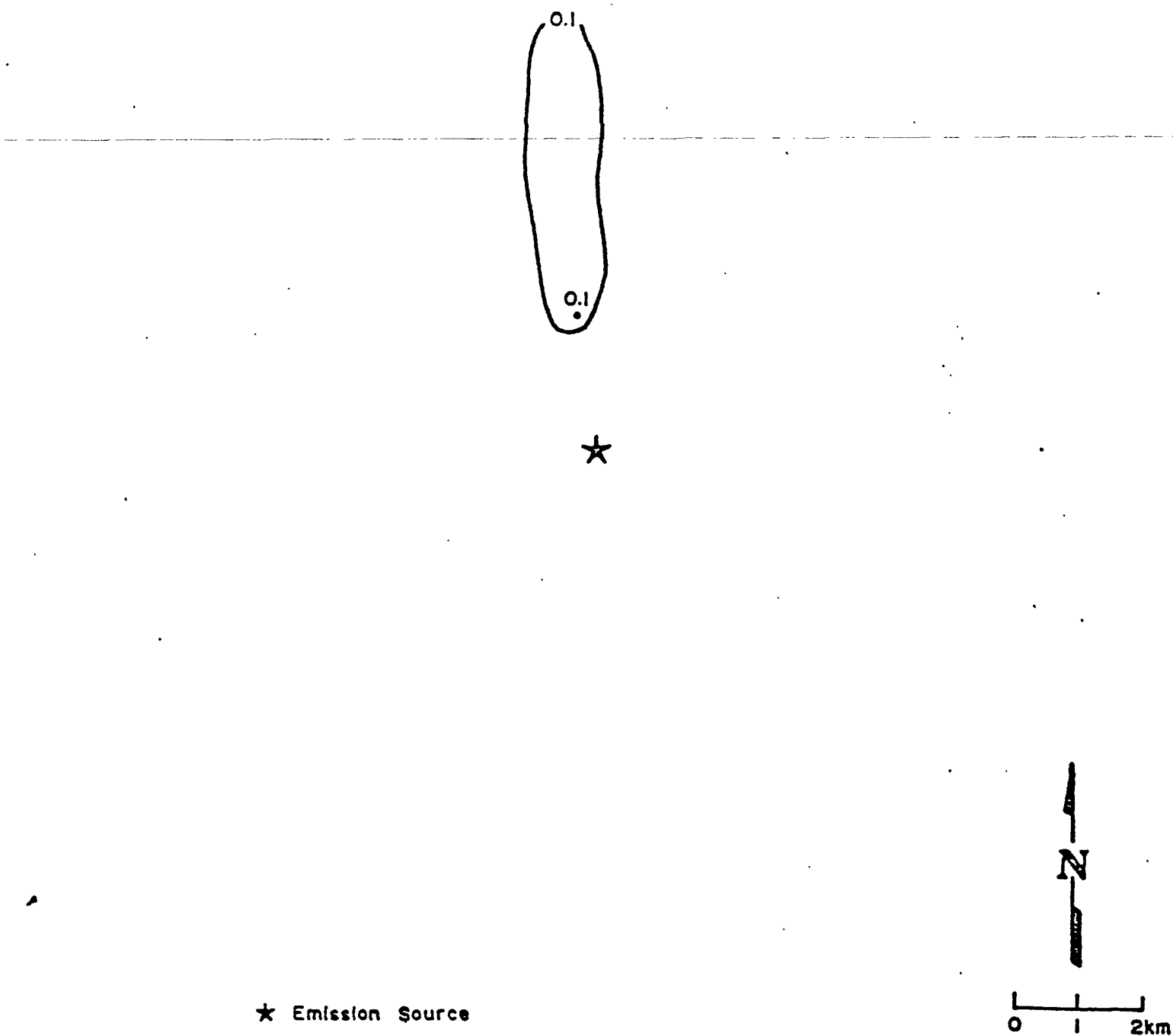


FIGURE 19                      GENERIC SOURCE 4  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
DENVER  
METEOROLOGICAL DATA

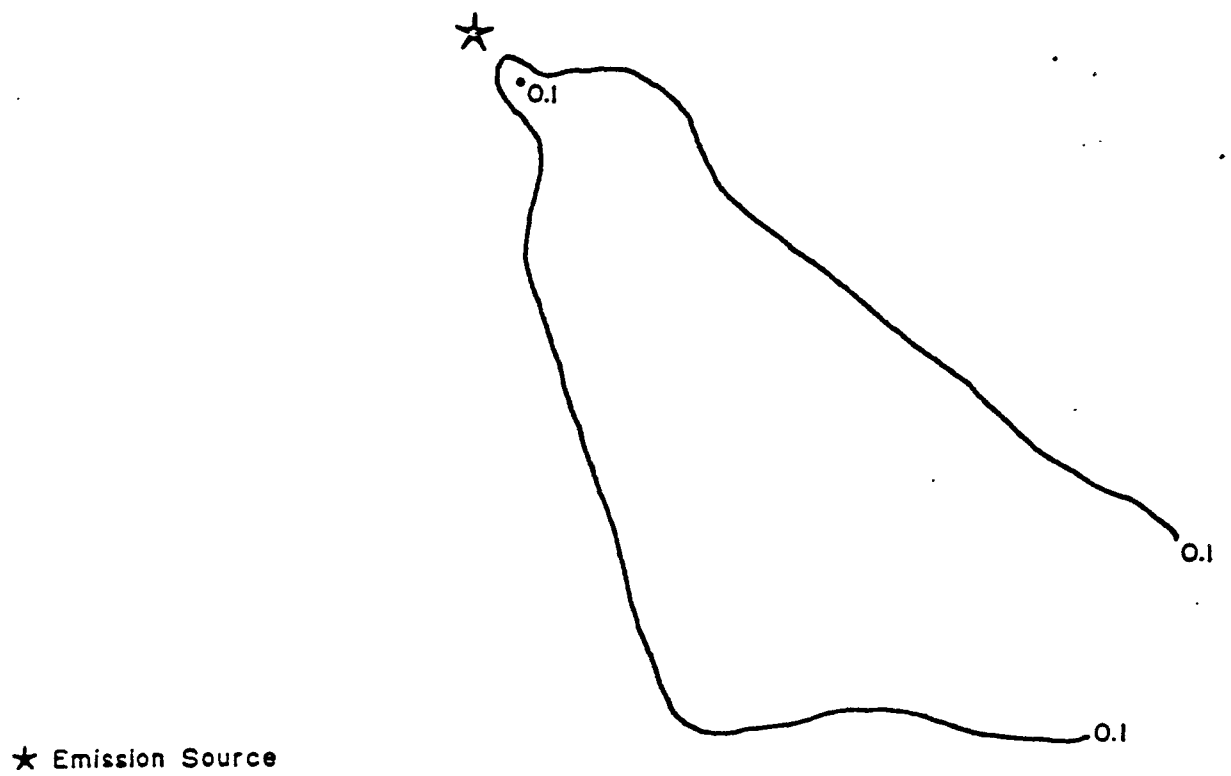
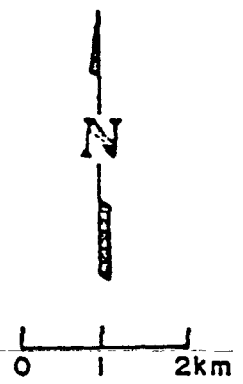


FIGURE 20

GENERIC SOURCE 4

2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$

SO. CALIFORNIA

METEOROLOGICAL DATA

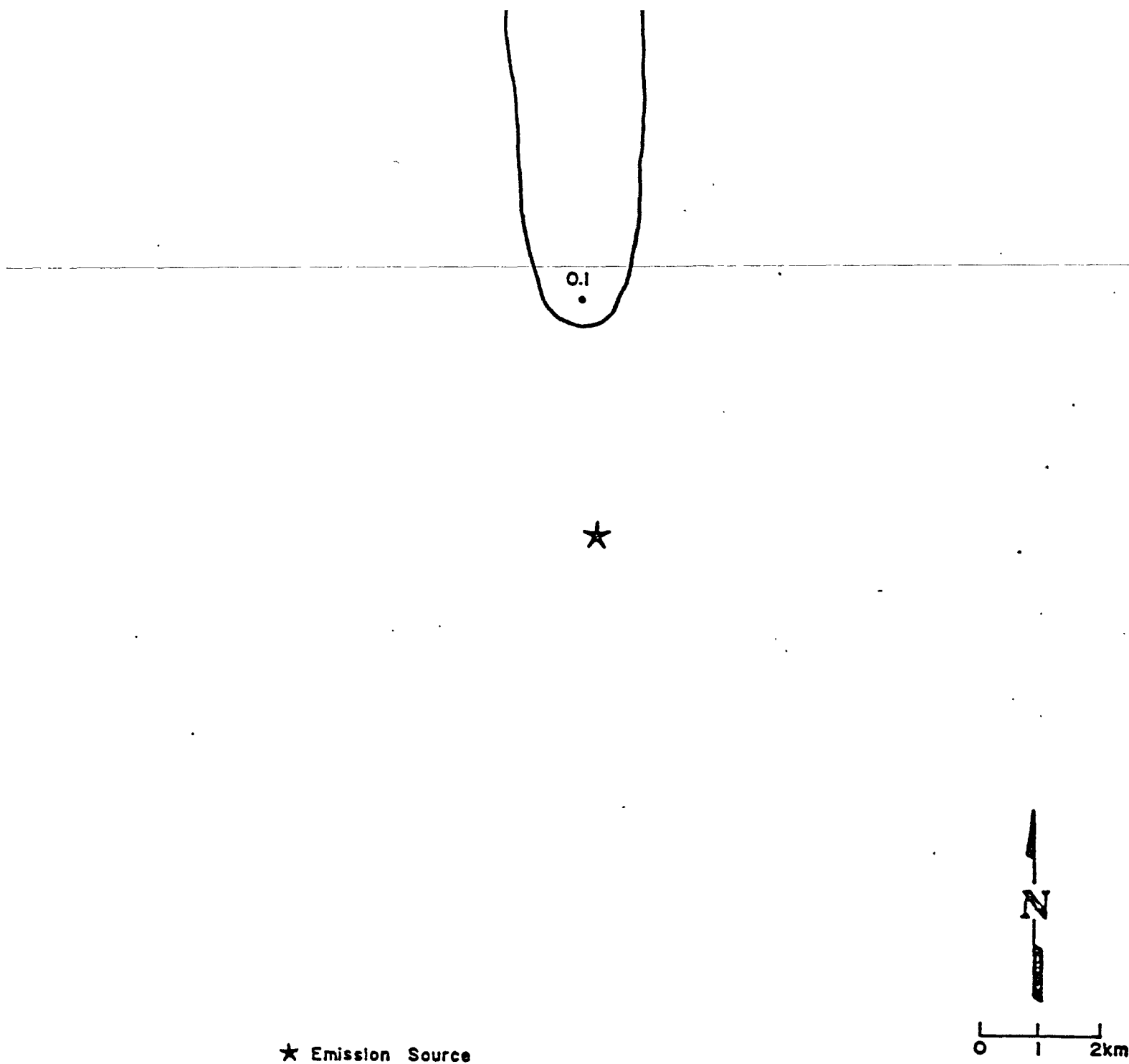


FIGURE 21  
GENERIC SOURCE 5  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
CHICAGO

METEOROLOGICAL DATA

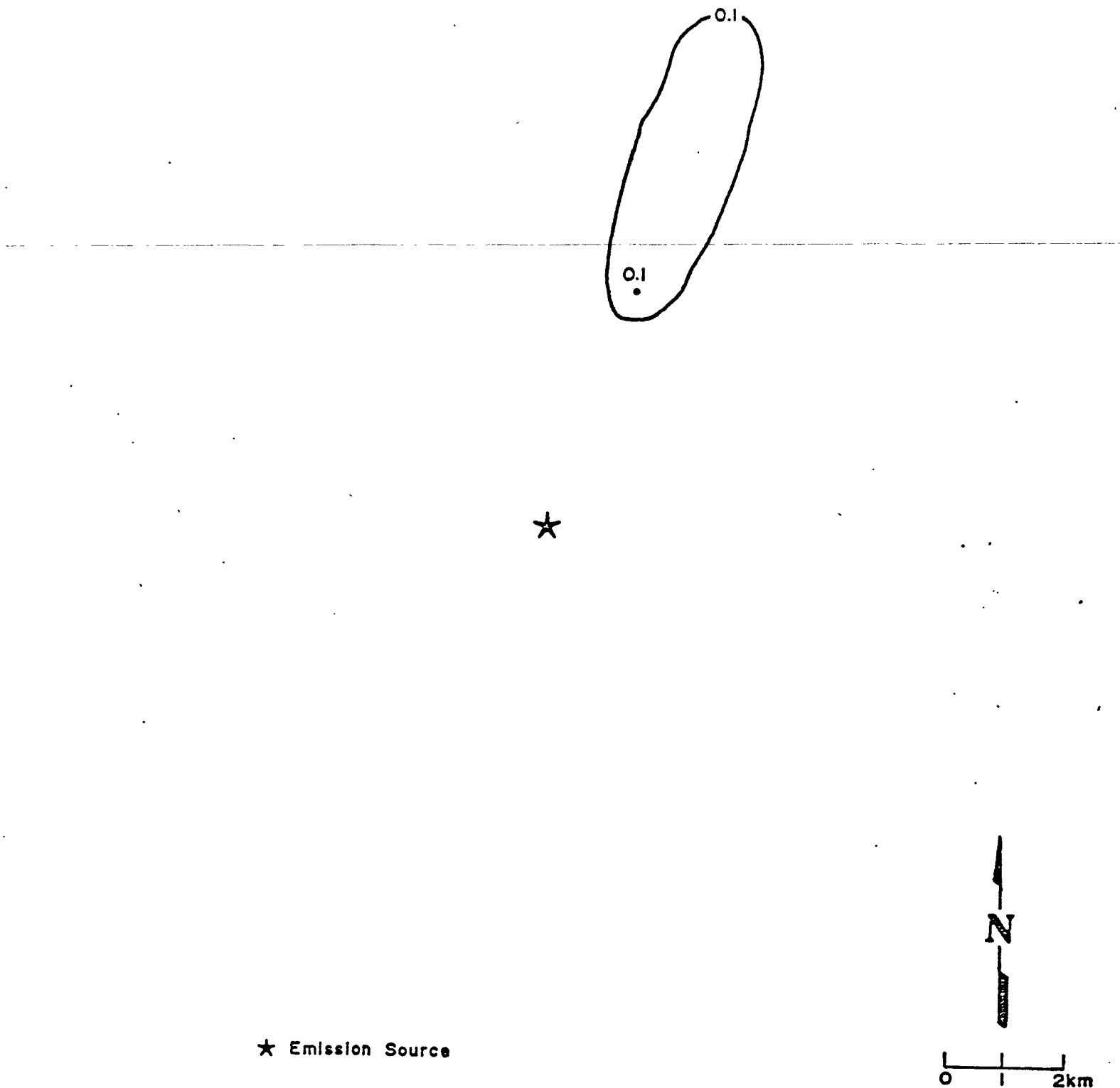


FIGURE 22                      GENERIC SOURCE 5  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
PADUCAH  
METEOROLOGICAL DATA

★ Emission Source

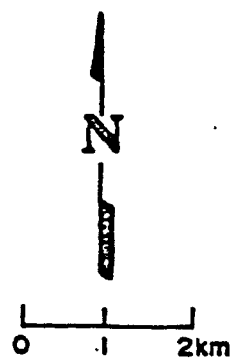


FIGURE 23                      GENERIC SOURCE 5  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
HELENA  
METEOROLOGICAL DATA

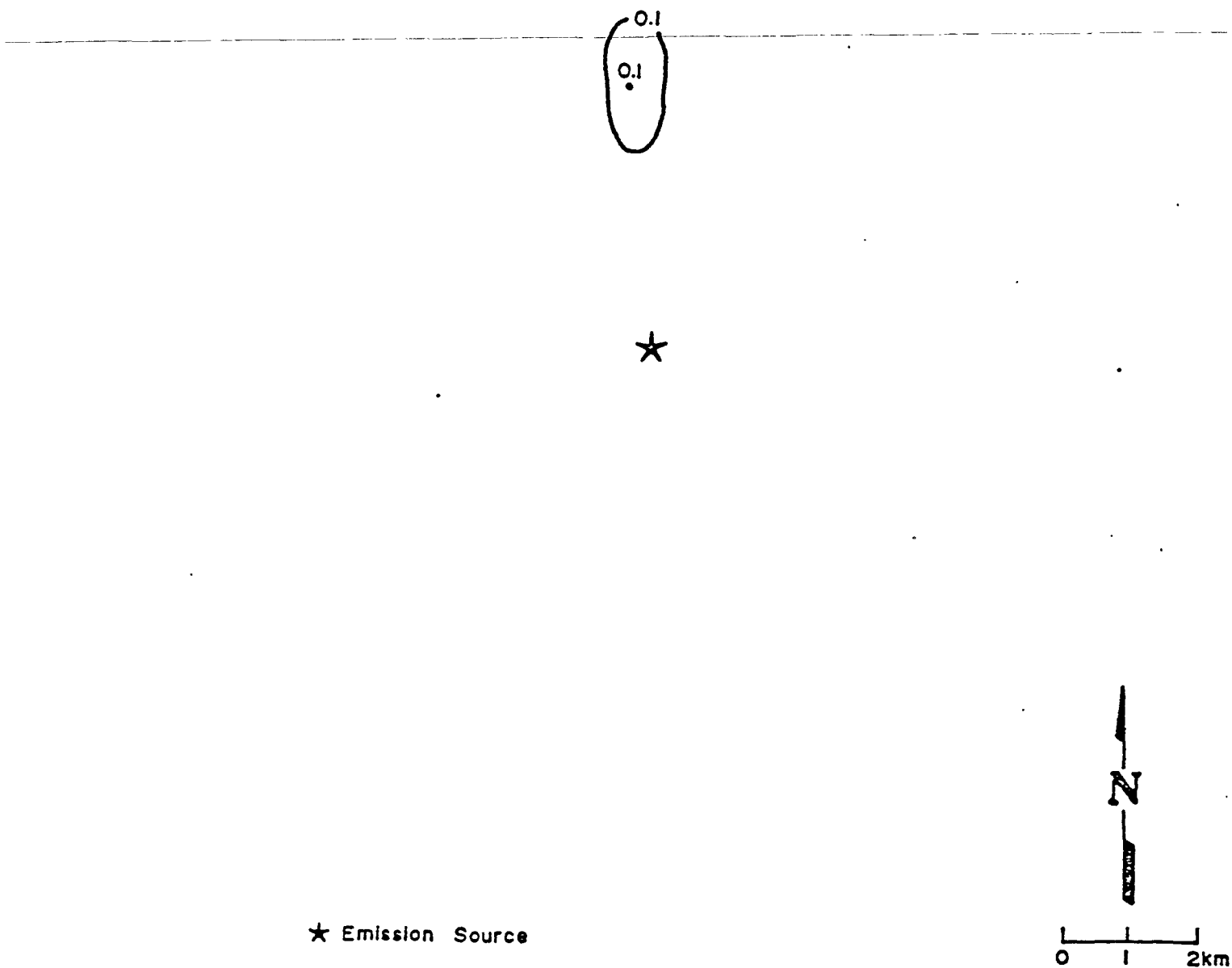


FIGURE 24                      GENERIC SOURCE 5  
3rd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
DENVER  
METEOROLOGICAL DATA

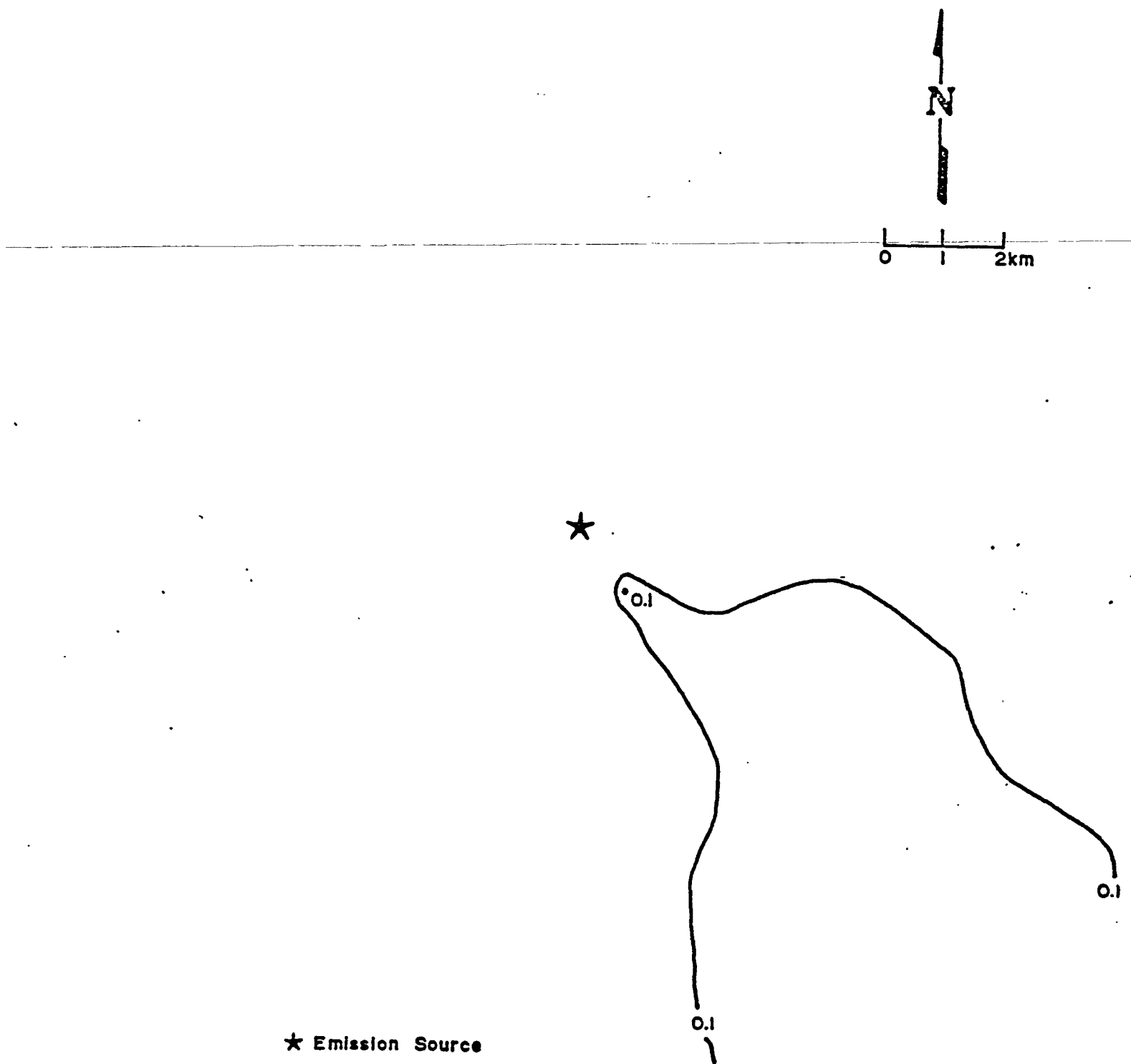


FIGURE 25                      GENERIC SOURCE 5  
2nd QUARTER AMBIENT LEAD CONCENTRATIONS  $\mu\text{g}/\text{m}^3$   
SO. CALIFORNIA  
METEOROLOGICAL DATA

the isopleths will change, possibly significantly, depending on the assumptions employed. Assumptions that lower emissions [i.e. fewer hours of operation, lower percent of used oil burned, etc.] will result in smaller isopleths located closer to the source. Assumptions that increase emissions will tend to expand the isopleths.

#### DATA TRANSFORMATION FOR OTHER OPERATING CONDITIONS OR ASSUMPTIONS

The CDMQC computer program calculates concentrations at each receptor using the Gaussian formula. The Gaussian formula describes a directly proportional relationship between emission rate and resultant ambient concentrations. Thus, it is possible to determine the concentration at any receptor point for a different lead emission rate by multiplying the original receptor concentrations by the ratio of the lead emission rates. Expressed algebraically, this becomes:

$$X_{pb_2} = X_{pb_1} \frac{Q_{pb_2}}{Q_{pb_1}}$$

where:

$Q_{pb_1}$  = original lead emission rate (g/s)

$Q_{pb_2}$  = new lead emission rate (g/s)

$X_{pb_1}$  = given receptor lead concentration  $\mu\text{g}/\text{m}^3$

$X_{pb_2}$  = new receptor lead concentration  $\mu\text{g}/\text{m}^3$

The overall scaling factor is the product of all individual factors that affect the emission rate. In other words, the ratio  $Q_{pb_2}/Q_{pb_1}$  is the product of the ratios of the five assumptions listed in Table 5-2. Thus, Equation 1 becomes:

$$X_{pb_2} = X_{pb_1} \times \frac{\text{new hours operation}}{24 \text{ hrs} \times 7 \text{ days}} \times \frac{\text{new fuel lead content}}{2500 \text{ ppm}} \times \frac{\text{new \% used oil burned}}{25\%} \times \frac{\text{new \% lead emitted out stack}}{75\%} \times \frac{1 - \text{new control device efficiency}}{1}$$

The impact of changing these five assumptions that directly affect emission rate can thus be analyzed for their individual and/or overall effects on receptor concentrations without additional computer analyses. This results in the ability to



analyze the air quality impact of various operating scenarios based on a single computer modeling analysis.

#### Scaling Methodology

In the modeling analyses, five assumptions were used that directly affected emission rates. These are listed in Table 5-2 in the main body of the text. To determine the effects of other assumptions upon calculated concentrations, the methodology depicted in Equation 2 has been used in Table A-1 to determine a ratioing factor to revise receptor concentrations to reflect new assumptions. Table A-1 provides an example of how Equation 2 is employed to find the ratioing factor necessary to revise the data presented in this report for other operating conditions. Obviously, not all factors need be changed, and not all factors must be less than one; these will be functions of the situation being analyzed. The final scaling factor is the product of the individual proportioning factors. This product (0.044 in Table A-1) is then used as the multiplier to scale the existing modeled concentrations to reflect new conditions. This scaling procedure will correctly estimate the effects of any change(s) in assumptions or operating parameters upon the calculated ambient lead concentrations presented in this report.

Table A-1

EXAMPLE OF METHOD FOR DETERMINING RATIOING FACTOR

	Hours of Operation* Hrs. per Day x Days per Week	Actual Lead Emitted, %	Fuel Lead Content, ppm	Percent Used Oil Burned	Pollution Control Device
Revised Conditions ( $Q_{pb2}$ )	8 x 7	50	1250	10	None
Modeled Conditions ( $Q_{pb1}$ )	24 x 7	75	2500	25	None
Ratio	$\frac{56}{168}$	$\frac{50}{75}$	$\frac{1250}{2500}$	$\frac{10}{25}$	$\frac{1}{1}$
Scaling Factor	x	x	x	x	x
	0.333	0.677	0.500	0.400	1.0 = 0.044

\*Care should be taken in interpreting the results obtained by proportioning hours of operation since the meteorological conditions will vary depending upon the time of day. These variations will have some effect on the resulting pollutant concentrations.



## APPENDIX B

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### USED OIL COMBUSTION TESTS PERFORMED BY CONTRACTOR

---

RECON performed nine combustion tests at three locations. A summary description of the used and virgin oils burned is provided in Table 1. Further details are provided in Tables 2 and 3. Additional data on emissions are found in Section 4.0, Volume I.

Table 1

## OIL PROPERTIES

SITE A <sup>1</sup>									
Avg. Vol. %	Test No.	OAPI	Rate		Pb ppm	S wt. %	N wt. %	Ash wt. %	
			GPM	lb/hr					
#2 Fuel Oil (FO)	100	1	33.6	0.550	236	3	0.16	0.22	0.02
Industrial Waste Oil in FO	15-25	2	31.1	0.510	222	13	0.17	0.20	0.13
SITE B <sup>1</sup>									
Crankcase Oil in FO	8	3	33.7	0.213	91.3	157	0.25	0.20	0.04
#2 Fuel OIL (FO)	100	-	32.4	-	-	<1	0.24	0.26	0.005
Crankcase Oil	100	-	-	-	-	345	0.26	-	0.03
SITE C <sup>2</sup>									
#6 Fuel Oil (FO)	100	4	26.5	2.33	1043	2	0.30	<0.01	0.01
Crankcase Oil in FO	9.72	5	-	2.24	1005	227	0.31	<0.01	0.09
Crankcase Oil in FO	60.4	6	-	2.37	1061	1398	0.35	<0.01	0.48
Reprocessed Oil in FO	20.8	7	-	2.26	1010	132	0.31	<0.01	0.20
Reprocessed Oil	100	8	26.7	2.19	979	627	0.36	<0.01	0.91
Industrial Waste Oil in FO	20.6	9	-	2.22	992	<3	0.27	<0.01	0.05
Crankcase Oil	100	-	26.1	-	-	2310	0.39	<0.01	0.79
Industrial Waste Oil	100	-	27.4	-	-	5	0.14	<0.01	0.22

Notes: 1. Underlined values estimated by calculation from fuel oil and waste oil compositions.  
 2. Underlined values by calculation from values for 100% fuel oil, 100% crankcase oil, 100% reprocessed oil, and 100% industrial oil.

# Fuel Analyses for Site C

Sample No.	78-133	78-134	78-135	78-136
Description	#6 Fuel Oil	Crankcase Oil	Reprocessed Oil	Industrial Waste Oil
Test No.	4	*	8 <sup>+</sup>	7
Gravity, API @ 60°F	26.5	26.1	26.7	27.4
Fire Point, COC	310°F		320°F	470°F
Flash Point, COC	285°F	**	300°F	435°F
Visc., SU @100°F	189 sec.		214 sec.	Drips
Visc., SF @122°F		18.7 sec.		21.1 sec.
Pour Point, ASTM minus 30°F	minus 30°F	minus 30°F	minus 30°F	minus 25°F
Carbon Res., Con.	1.05%	1.70%	1.61%	0.19%
Sulfur, ASTM	0.30%	0.39%	0.36%	0.14%
Water & Sediment	0.1%	8.0%	0.5%	8.0%
B.T.U. per pound	19312	17541	19140	18269
B.T.U. per gallon	144012	131139	142555	135468
Acid number, MGKOH/GRAM	0.11	2.44	2.02	0.93
Nitrogen	less 0.01%	less 0.01%	less 0.01%	less 0.01%
Chloride	none found	0.34%	trace	2.01%
Ash	0.01%	0.79%	0.91%	0.22%
Vanadium	18 ppm	less 1 ppm	less 1 ppm	less 1 ppm
Sodium	21 ppm	84 ppm	297 ppm	11 ppm
Iron	2 ppm	91 ppm	152 ppm	12 ppm
Lead	2 ppm	2310 ppm	627 ppm	less 5 ppm
Copper	1 ppm	63 ppm	55 ppm	10 ppm
Chromium	1 ppm	4 ppm	11 ppm	less 1 ppm
Aluminium	4 ppm	13 ppm	27 ppm	less 1 ppm
Nickel	4 ppm	1 ppm	4 ppm	less 1 ppm
Silver	1 ppm	nil	nil	nil
Tin	4 ppm	5 ppm	10 ppm	less 5 ppm
Silica	less 1 ppm	2 ppm	32 ppm	4 ppm
Boron	11 ppm	3 ppm	37 ppm	9 ppm
Sodium	2 ppm	100 ppm	300 ppm	3 ppm
Phosphorous	40 ppm	466 ppm	520 ppm	16 ppm
Zinc	6 ppm	171 ppm	252 ppm	140 ppm
Calcium	5 ppm	620 ppm	960 ppm	30 ppm
Barium	less 50 ppm	80 ppm	160 ppm	less 50 ppm
Magnesium	4 ppm	143 ppm	356 ppm	6 ppm

\*\* Starts to boil at 200°F.

\* Used in mixture with #6 fuel oil in test nos. 5 and 6.

+ Also used in mixture with #6 fuel oil in test no. 7.

≠ Used in mixture with #6 fuel oil in test no. 9.

Table 3

## OIL COMPOSITIONS FOR TESTS 4-9 (SITE C)

TEST	4	5*	6*	7*	8	9*
FUEL DESCRIPTION	#6 Fuel Oil (FO)	FO/9.72 Vol. % Crankcase	FO/60.4 Vol. % Crankcase	FO/20.8 Vol. % Repr. Oil	100% Repr. Oil	FO/20.6 Vol Ind. Waste
lb. used oil/lb. fuel oil	0	0.1080	1.530	0.2623	-	0.2578
IMPURITIES						
ASH	100	860	4817	1970	9100	530
S	3000	3088	3544	3125	3600	2672
N	<100	<100	<100	<100	<100	<100
Cl	ND	331	2056	-	-	4120
Fe	2	11	56	33	152	4
Pb	2	227	1398	132	627	<3
Cu	1	7	38	2	55	3
Cr	1	1.3	2.8	3	11	<2
Al	4	5	9	9	27	<5
Ni	4	3.7	2.2	4	4	<5
Ag	1	<1	<1	<1	-	1
Sn	4	4.1	4.6	5	10	<5
Silica	<1	<2	<3	<8	32	<2
B	11	10	6	16	37	11
Na	2	12	61	64	300	1.3
P	40	82	298	140	520	35
Zn	6	22	106	57	252	33
Ca	5	65	377	203	960	10
Ba	<50	<60	<100	<90	160	<50
Mg	4	18	88	77	356	4.4

\*By calculation from used oil and virgin oil compositions

Table 4. ELEMENTAL BALANCES - TEST NO. 1 (SITE A)

TOTAL SAMPLE SOLIDS	Ni	V	Na	Fe	Pb	Cu	Al	Cr	Ag	Sn	Zn	Ba	Mg	S	N
ON FILTER, mg	12.9	0.01	ND	0.89	0.08	0.01	3.86	0.02	ND	0.10	0.11	0	4.03	-	-
RESIDUE, * mg	87.2	0.009- 0.029	ND	0.44- 1.40	2.41- 7.65	0.03- 0.095	0.05- 0.16	0.01- 0.03	ND	ND	0.01- 0.03	ND	0.03- 0.095	-	-
TOTAL, mg	100.1	0.02- 0.04	-	5.4- 6.4	3.3- 8.5	0.11	3.9- 4.0	0.03- 0.05	-	-	0.12- 0.14	-	4.1	-	-
GAS SAMPLE, SCF <sup>+</sup>	40.2														
TOTAL GAS FLOW, SCFM <sup>+</sup>	1560														
SCM/hr <sup>+</sup>	2652														
EMISSIONS, ** mg/SCM grams/hr	87.9 233	0.03 0.07	- -	5.2 14	0.097 0.26	0.066 0.18	3.4 9	0.04 0.11	- -	- -	0.11 0.29	- -	3.6 9.5	66 ppmv 232	34 ppmv 52
FUEL RATE, lbs/hr	235.8														
CONC. IN FUEL, ppm	200 <sup>++</sup>	<1	<1	<1	3	<1	<1	<1	<1	<1	<1	<1	<1	1600	2200
INLET, grams/hr	21	0.1	0.1	0.1	0.32	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	171	236
EMISSIONS INLET	>1	-	-	>1	>1	>1	>1	>1	-	-	>1	-	>1	1.36	-

\* Probe Wash + Wet Catch. Quantities provided for elements (except Pb) are based on analysis of probe wash residue + aliquot of wet catch.

Minimum is quantity measured; maximum is quantity calculated assuming probe wash quantity = 0.

<sup>+</sup>SCFM (70°F, 1 atm) x 1.7 = SCM/hr (70°F, 1 atm)

<sup>#</sup> 0.1 mg/l in wet catch

\*\* Emissions based on average of range given above

<sup>++</sup> Total ash



Table 5. ELEMENTAL BALANCES - TEST NO. 2 (SITE A)

TOTAL SAMPLE SOLIDS	Ni	V	Na	Fe	Pb	Cu	Al	Cr	Ag	Sn	Zn	Ba	Mg	S	N
ON FILTER, mg	40.2	0.03	ND	13.75	6.17	0.21	0.16	9.86	0.04	ND	0.04	0.36	0.14	5.15	-
RESIDUE, * mg	125.1	0.016- 0.062	ND	0.40- 1.56	2.25- 8.75	0.04 <sup>#</sup>	0.03- 0.12	0.09- 0.35	0.01- 0.04	ND	0.03- 0.12	ND	0.05- 0.19	-	-
TOTAL, mg	165.3	0.05- 0.09	-	14.2- 15.3	8.4- 14.9	0.25	0.19- 0.28	10.0- 10.2	0.05- 0.08	-	0.39- 0.48	-	5.2- 5.3	-	-
GAS SAMPLE, SCF <sup>+</sup>	41.33														
TOTAL GAS FLOW, SCFM <sup>+</sup> SCM/hr <sup>+</sup>	1600 2720														
EMISSIONS, ** mg/SCM grams/hr	141.2 384	0.06 0.16	- -	12.6 34	10.0 27	0.21 0.57	0.20 0.54	8.6 23	0.06 0.16	- -	0.37 1.0	- -	4.5 12	41 ppmv 148	33 ppmv 52
FUEL RATE, lbs/hr	222														
CONC. IN FUEL, ppm	1300 <sup>++</sup>	<1	<1	5	227	13	11	5	<1	<1	<1	<1	<1	1700	2000
INLET, grams/hr	131	0.1	0.1	0.5	23	1.31	1.11	0.5	0.1	0.1	0.1	0.1	0.1	171	202
EMISSIONS INLET	>>1	>>1	-	>>1	1.17	0.44	0.49	>>1	>>1	-	>>1	-	>>1	0.87	-

\* Probe Wash + Wet Catch. Quantities provided for elements (except Pb) are based on analysis of probe wash residue + aliquot of wet catch.

Minimum is quantity measured; maximum is quantity calculated assuming probe wash quantity = 0.

<sup>+</sup>SCFM (70°F, 1 atm) x 1.7 = SCM/hr (70°F, 1 atm)

<sup>#</sup> 0.1 mg/l in wet catch

\*\* Emissions based on average of range given above

<sup>++</sup> Total ash

Table 6. ELEMENTAL BALANCES - TEST NO. 3 (SITE B)

TOTAL SAMPLE	SOLIDS	Ni	V	Na	Fe	Pb	Cu	Al	Cr	Ag	Sn	Zn	Ba	Mg	S	N
ON FILTER, mg	99.6	0.02	ND	10.5	2.92	23.8	0.59	0.86	0.09	ND	0.40	8.40	1.27	7.12	-	-
RESIDUE, *	134.6	0.007-	ND	0.46-	2.38-	0.49 <sup>#</sup>	0.03-	0.06-	0.01-	ND	ND	0.02-	ND	0.04-	-	-
	0.022			1.45	7.48		0.09	0.19	0.03			0.06		0.13		
TOTAL, mg	234.2	0.03-	-	11.0-	5.3-	24.2	0.62-	0.92-	0.10-	-	-	8.42-	-	7.16-	-	-
	0.04			12.0	10.4		0.68	1.05	0.12			8.46		7.25		
GAS SAMPLE, SCF <sup>+</sup>	58.46															
TOTAL GAS FLOW, SCFM <sup>+</sup>	514															
	874															
EMISSIONS, **	141.5	0.021	-	6.9	4.7	14.6	0.39	0.59	0.066	-	-	5.10	-	4.35	82 ppmv	69 ppmv
	123.7	0.02	-	6.0	4.1	12.8	0.34	0.52	0.058	-	-	4.5	-	3.8	95	35
FUEL RATE, lbs/hr	91.3															
CONC. IN FUEL, ppm	400 <sup>++</sup>	<1	<1	2	11	157	5	<1	<1	<1	<1	60	<1	10	2500	2000
INLET, grams/hr	16.58	0.04	0.04	0.08	0.46	6.51	0.21	0.04	0.04	0.04	0.04	2.5	0.04	0.41	104	83
EMISSIONS INLET	>1	>1	-	>1	>1	>1	>1	>1	>1	-	-	>1	-	>1	0.91	-

\* Probe Wash + Wet Catch. Quantities provided for elements (except Pb) are based on analysis of probe wash residue + aliquot of wet catch.

Minimum is quantity measured; maximum is quantity calculated assuming probe wash quantity = 0.

<sup>+</sup>SCFM (70°F, 1 atm) x 1.7 = SCM/hr (70°F, 1 atm)<sup>#</sup> 0.1 mg/l in wet catch<sup>\*\*</sup> Emissions based on average of range given above<sup>++</sup> Total ash

Table 7. EMISSIONS - TEST NOS. 4-9 (SITE C)

TEST NO.	4	5	6	7	8	9
DRY CATCH <sup>+</sup>						
TOTAL, mg	22.4	50.3	186.1	91.1	309.1	53.1
Pb, mg	0.17	6.8	37.7	13.9	43.1	4.3
OTHER ELEMENTS WHICH MAY BE PRESENT IN QUANTITIES >1 mg	B, Mg, Al, Ca, Na, Fe, Ni, V	Mg, Si, Al, Ca, Na, B, P, Fe, V, Zn	B, Mg, Al, Ca, Na, Zn, Ba, P, Si, Fe, V, Cu	Mg, Si, Al, Ca, Na, B, P, Fe, V, Zn	Mg, Si, Al, Ca, Na, Zn, Ba, B, P, Fe, Cu	B, Mg, Al, Ca, Na, P, Fe, Ni, Cu, Zn
WET CATCH						
TOTAL, mg	33.5	29.8	43.4	62.3	12.4	22.2
Pb, mg	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
TOTAL CATCH						
TOTAL Pb	55.9	80.1	229.5	153.4	321.5	75.3
GAS SAMPLE, SCF <sup>+</sup>	0.2	6.8	37.7	13.9	43.1	4.3
GAS FLOW, SCFM <sup>+</sup>	60.0	57.7	62.4	54.2	62.7	54.6
SCM/hr <sup>+</sup>	6,200	6,190	6,590	5,810	6,560	5,920
	10,540	10,523	11,203	9,877	11,152	10,064
PARTICULATE EMISSIONS <sup>#</sup>						
TOTAL, mg/SCM	32.90	49.02	129.9	99.9	181.1	48.70
Pb, mg/SCM	0.12	4.16	21.3	9.06	24.3	2.78
TOTAL, grams/hr	347	516	1,455	987	2,019	490
Pb, grams/hr	1.2	43.8	239	89.5	271	28.0
GASEOUS EMISSIONS						
SO <sub>2</sub> , ppmv	114	85	102	125	131	100
NO <sub>x</sub> , ppmv	72	83	54	54	53	66
S(in SO <sub>2</sub> ), grams/hr	1,595	1,187	1,517	1,639	1,939	1,336
N(in NO <sub>x</sub> ), grams/hr	440	506	351	309	343	385

<sup>+</sup> SCFM (70°F, 1 atm) x 1.7 = SCM/hr (70°F, 1 atm)<sup>#</sup> Excludes organics

Table 8. IMPURITY INPUT AND BALANCES - TEST NOS. 4-9 (SITE C)

IN NO.	4		5		6		7		8		9	
	INPUT	BALANCE <sup>+</sup>	INPUT	BALANCE <sup>+</sup>	INPUT	BALANCE <sup>+</sup>	INPUT	BALANCE <sup>+</sup>	INPUT	BALANCE <sup>+</sup>	INPUT	BALANCE <sup>+</sup>
JEL RATE, lbs/hr in	1043	-	1005	-	1061	-	1010	-	979	-	992	-
SH, ppm in	100		860		4817		1970		9100		530	
SH, grams/hr in	47	7.38	392	1.32	2322	0.63	904	1.09	4040	0.50	239	2.05
LEMENTS, grams/hr in												
Fe	0.9		5.0		27		15		67		1.8	
Pb	0.9	1.33			674		61		278		<1.4	>>1
Cu	0.5		104	0.42	18		0.9	0.23	24	0.97	1.4	
Cr	0.5		3.2				1.3		4.9		<0.9	
Al	2		0.6		4.3		4.1		12		<2.3	
Ni	2		2.3		1.1		1.8		1.8		<2.3	
Ag	0.5		<0.5		<0.5		<0.5		-		0.5	
Sn	2		1.9		2.2		2.3		4.4		<2.3	
Silica <sup>*</sup>	<0.5		<0.9		<1.5		<0.4		14		<0.9	
B	5		4.6		2.9		7.3		16		5	
Na	0.9		5.5								0.6	
P	19		37		29		29		133		16	
Zn	3		10		144		64		231		15	
Ca	2		30		51		26		112		4.5	
Ba	<24		<27		182		93		426		<23	
Mg	2		8		<48		<41		71		2.0	
S	1421	0.89	1408	0.84	1708	0.89	1434	1.14	1598	1.21	1202	1.11
N	<47		<46		<48		<46		<45		<45	
Cl	-		151		991		-		-		1854	

SiO<sub>2</sub>  
See Table 7. EMISSION ÷ INPUT

### TESTS AT SITES A AND B

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Used oil combustion tests were conducted at two sites (A and B) in the Midwest during the week of March 27, 1978. Conditions were as follows:

Test No.	Site	Boiler	Oil
1	A	Kewanee 200 hp Fire Tube (1975, retubed	No. 2 oil
2	A	1977)	No. 2 oil/ industrial used oil mixture
3	B	Cleaver-Brooks 100 hp Fire Tube (1976)	No. 2 oil/ crankcase oil mixture

The data obtained follows.

~~Stack Sampling Reports~~

For Site A

EPA Test No. 1

- Particulates
- SO<sub>2</sub>
- NO<sub>x</sub>

# Fuel Analyses For Site A

Sample No.	78-33	78-34	78-44
	Test No. 1 Fuel	Test No. 2 Fuel	Untreated
	#2 Fuel Oil	#2 Fuel/Industrial Used Oil	Industrial Used Oil
GRAVITY, API @60°F	33.6	31.1	---
FLASH POINT, COC	164°F	188°F	---
FIRE POINT, COC	182°F	202°F	---
POUR POINT, ASTM	MINUS 10°F	MINUS 40°F	---
CARBON RES., CON.	0.05%	0.50%	---
SULFUR, ASTM	0.16%	0.17%	TOO WET
WATER & SEDIMENT	NIL	1.0%	90.0%
B.T.U. PER POUND	19662	19764	---
B.T.U. PER GALLON	140308	143209	---
NICKEL	1 PPM	1 PPM	---
ACID NUMBER	0.04 MGKO/GR.	0.35 MGKOH/GR	---
NITROGEN	0.22%	0.20%	---
CHLORINE	NIL	NIL	---
ASH	0.02%	0.13%	TOO WET
VANADIUM	LESS 1 PPM	LESS 1 PPM	---
SODIUM	LESS 1 PPM	5 PPM	---
VISC., SU @100°F	34.4 SEC.	47.3 SEC.	---
IRON	LESS 1 PPM	227 PPM	OVER 1000 PPM
LEAD	3 PPM	13 PPM	67 PPM
COPPER	LESS 1 PPM	11 PPM	64 PPM
CHROMIUM	LESS 1 PPM	LESS 1 PPM	6 PPM
ALUMINIUM	LESS 1 PPM	5 PPM	22 PPM
NICKEL	LESS 1 PPM	LESS 1 PPM	3 PPM
SILVER	LESS 1 PPM	LESS 1 PPM	LESS 1 PPM
TIN	LESS 1 PPM	LESS 1 PPM	11 PPM
SILICA	LESS 1 PPM	29 PPM	145 PPM
BORON	LESS 1 PPM	LESS 1 PPM	3 PPM
SODIUM	LESS 1 PPM	5 PPM	287 PPM
PHOSPHOROUS	LESS 1 PPM	90 PPM	360 PPM
ZINC	LESS 1 PPM	LESS 1 PPM	150 PPM
CALCIUM	LESS 1 PPM	140 PPM	1350 PPM
BARIUM	LESS 1 PPM	LESS 1 PPM	10 PPM
MAGNESIUM	LESS 1 PPM	LESS 1 PPM	10 PPM

# VELOCITY AND FLOW RATE DATA

Sample No.	1	2
Date	3/28/78	-----
Time	1040- 1130	1233- 1255
Stack Diameter (inches)	18-1/2	-----
Stack Cross Section (Sq.ft.)	1.87	-----
Barometric ("Hg)	29.30	-----
Average Stack Temperature (°F)	240	256
Stack Pressure ("H <sub>2</sub> O-gage)	0.0	0.0
Moisture (% Vol.)	6.5	6.2
Average Velocity (Ft./sec.)	18.8	20.3
Average Velocity (Ft./min.)	1130	1220
Actual Flow Rate (ACFM)	2110	2280
Standard Flow Rate (SCFM)	1560	1650
Dry Standard Flow Rate (DSCFM)	1460	1550

Standard Conditions are 70°F, 29.92"Hg



PARTICULATE AND CONDENSIBLE EMISSIONS

Sample No.	1	2
Date	3/28/78	-----
Time	1040- 1130	1233- 1255
<u>Sampling Data</u>		
Nozzle Size (inches)	1/2	-----
No. of Sampling Points	6+	4
Sampling Time (minutes)	35.75	20.5
Sample Volume (dscf)	37.6	22.3
% Isokinetic	99	93
<u>Emissions Data</u>		
Front Half Catch		
Grains/dscf	0.0130	0.0227
Pound/hour	0.16	0.30
Organic Impinger Catch		
Grains/dscf	0.0000	0.0000
Pound/hour	0.00	0.00
Aqueous Impinger Catch		
Grains/dscf	0.0280	0.0424
Pound/hour	0.35	0.56
Total Catch		
Grains/dscf	0.0410	0.0651
Pound/hour	0.51	0.86

SO<sub>x</sub> EMISSIONS

Sample No.

1

2

Date

3/28/'88 -----

Time

1045-  
11051230-  
1250Sampling Data

Nozzle Size (inches)

1/4 -----

No. of Sampling Points

1 -----

Sampling Time (minutes)

20

20

Sample Volume (dscf)

18.4

21.5

% Moisture\*

6.5

6.2

% Isokinetic

-

-

SO<sub>x</sub> EmissionsSO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub> (as H<sub>2</sub>SO<sub>4</sub>)

lbs/dscf

-

-

PPMV

-

-

SO<sub>2</sub>

lbs/dscf

-

-

PPMV

-

-

SO<sub>2</sub> + SO<sub>3</sub> + H<sub>2</sub>SO<sub>4</sub> (as SO<sub>2</sub>)

lbs/dscf

11.2 (10<sup>-6</sup>)12.6 (10<sup>-6</sup>)

PPMV

62

70

\*Taken from particulate tests

NO<sub>x</sub> EMISSIONS

Sample No.	1
Date	3/28/78
Time	1045

Sampling Data

Initial Temperature, °F	56
Initial Absolute Pressure, "Hg	8.3
Final Temperature, °F	56
Final Absolute Pressure, "Hg	29.27
Sample Volume, std. mls	1415

NO<sub>x</sub> Emissions

NO<sub>x</sub> as NO<sub>2</sub>

lbs/dscf	8.74(10 <sup>-6</sup> )
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ppmv	34
------	----

~~EPA Test No. 2~~

B-17

VELOCITY AND FLOW RATE DATA

Sample No.	1	2	3
Date	3/27/78	-----	-----
Time	1641- 1810	1846- 1928	2037- 2129
Stack Diameter (inches)	18-1/2	-----	-----
Stack Cross Section (Sq.ft.)	1.87	-----	-----
Barometric ("Hg)	29.31	-----	-----
Average Stack Temperature (°F)	246	246	233
Stack Pressure ("H <sub>2</sub> O-gage)	0.0	0.0	0.0
Moisture (% Vol.)	6.3	6.4	6.2
Average Velocity (Ft./sec.)	17.1	19.4	19.2
Average Velocity (Ft./min.)			
Actual Flow Rate (ACFM)	1920	2180	2160
Standard Flow Rate (SCFM)	1410	1600	1620
Dry Standard Flow Rate (DSCFM)	1320	1500	1520

Standard Conditions are 70°F, 29.92"Hg

PARTICULATE AND CONDENSIBLE EMISSIONS

Sample No.	1	2	3
Date	3/27/78	-----	-----
Time	1641- 1810	1846- 1928	2037- 2129
<u>Sampling Data</u>			
Nozzle Size (inches)	3/8	1/2	1/2
No. of Sampling Points	8	8	8
Sampling Time (minutes)	80	37.73	48
Sample Volume (dscf)	49.0	38.69	45.7
% Isokinetic	113	94	86
<u>Emissions Data</u>			
Front Half Catch			
Grains/dscf	0.0466	0.0304	0.0218
Pound/hour	0.53	0.39	0.28
Organic Impinger Catch			
Grains/dscf	0.0010	0.0000	*
Pound/hour	0.01	0.00	*
Aqueous Impinger Catch			
Grains/dscf	0.0190	0.0353	0.0216
Pound/hour	0.22	0.45	0.28
Total Catch			
Grains/dscf	0.0666	0.0657	*
Pound/hour	0.76	0.84	*

\*Part of aqueous catch not evaporated--used for  
POM analysis not yet completed.

SO<sub>x</sub> EMISSIONS

Sample No.	1	2	3
Date	3/27/78	-----	-----
Time	1640- 1717	1900- 1924	2035- 2112
<u>Sampling Data</u>			
Nozzle Size (inches)	1/4	-----	-----
No. of Sampling Points	1	-----	-----
Sampling Time (minutes)	37	19	32
Sample Volume (dscf)	27.1	13.8	32.9
% Moisture*	6.3	6.4	6.2
% Isokinetic	-	-	-
<u>SO<sub>x</sub> Emissions</u>			
<u>SO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub> (as H<sub>2</sub>SO<sub>4</sub>)</u>			
lbs/dscf	-	-	-
PPMV	-	-	-
<u>SO<sub>2</sub></u>			
lbs/dscf	-	-	-
PPMV	-	-	-
<u>SO<sub>2</sub> + SO<sub>3</sub> + H<sub>2</sub>SO<sub>4</sub> (as SO<sub>2</sub>)</u>			
lbs/dscf	7.01(10 <sup>-6</sup> )	7.61(10 <sup>-6</sup> )	7.51(10 <sup>-6</sup> )
PPMV	39	42	42

\*Taken from particulate tests

NO<sub>x</sub> EMISSIONS

Sample No.

1

2

Date

3/27/78-----

Time

1703

2140

Sampling Data

Initial Temperature, °F

59

54

Initial Absolute Pressure, "Hg

8.16

8.17

Final Temperature, °F

51

55

Final Absolute Pressure, "Hg

~1.0

~1.0

Sample Volume, std. mls

1447

1426

NO<sub>x</sub> EmissionsNO<sub>x</sub> as NO<sub>2</sub>

lbs/dscf

9.41(10<sup>-6</sup>)7.53(10<sup>-6</sup>)

ppmv

36

29



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Stack Sampling Report

For Site B

- Particulates
- SO<sub>2</sub>
- NO<sub>x</sub>

EPA Test No. 3

# Fuel Analyses For Site B

Sample No.	78-37	78-38	78-42
		Test No. 3 Fuel	
	<u>#2 Fuel Oil</u>	<u>#2 Fuel/Automotive Used Oil</u>	<u>Automotive Used Oil*</u>
GRAVITY, API @60°F	32.4	33.7	—
FLASH POINT, COC	163°F	184°F	—
FIRE POINT, COC	190°F	198°F	—
POUR POINT, ASTM	MINUS 20°F	MINUS 20°F	—
CARBON RES., CON.	0.05%	0.11%	—
SULFUR, ASTM	0.24%	0.25%	0.26%
WATER & SEDIMENT	NIL	0.8%	0.1%
B.T.U. PER POUND	19253	19374	—
B.T.U. PER GALLON	138410	138175	—
NICKEL	LESS 1 PPM	LESS 1 PPM	—
ACID NUMBER	0.07 MGKOH/GR.	0.24 MGKOH/GR.	—
NITROGEN	0.26%	0.20%	—
CHLORINE	NIL	NIL	—
ASH	0.005%	0.04%	0.03%
VANADIUM	LESS 1 PPM	LESS 1 PPM	—
SODIUM	LESS 1 PPM	2 PPM	—
VISC., SU @100°F	34.3 SEC.	36.2 SEC.	—
IRON	LESS 1 PPM	11 PPM	121 PPM
LEAD	LESS 1 PPM	157 PPM	345 PPM
COPPER	LESS 1 PPM	5 PPM	126 PPM
CHROMIUM	LESS 1 PPM	LESS 1 PPM	1 PPM
ALUMINIUM	LESS 1 PPM	LESS 1 PPM	11 PPM
NICKEL	LESS 1 PPM	LESS 1 PPM	LESS 1 PPM
SILVER	LESS 1 PPM	LESS 1 PPM	LESS 1 PPM
TIN	LESS 1 PPM	LESS 1 PPM	6 PPM
SILICA	LESS 1 PPM	LESS 1 PPM	17 PPM
BORON	LESS 1 PPM	LESS 1 PPM	21 PPM
SODIUM	LESS 1 PPM	2 PPM	25 PPM
PHOSPHOROUS	LESS 1 PPM	40 PPM	530 PPM
ZINC	LESS 1 PPM	60 PPM	550 PPM
CALCIUM	LESS 1 PPM	LESS 1 PPM	180 PPM
BARIUM	LESS 1 PPM	LESS 1 PPM	30 PPM
MAGNESIUM	LESS 1 PPM	10 PPM	130 PPM

\*New car dealer

VELOCITY AND FLOW RATE DATA

Sample No.	1	2	3
Date	3/29/78	-----	-----
Time	1215- 1359	1415- 1556	1555- 1627
Stack Diameter (inches)	12	-----	-----
Stack Cross Section (Sq.ft.)	0.785	-----	-----
Barometric ("Hg)	30.27	-----	-----
Average Stack Temperature (°F)	278	275	325
Stack Pressure ("H <sub>2</sub> O-gage)	0	-----	-----
Moisture (% Vol.)	7.3	7.6	10.3
Average Velocity (Ft./sec.)	15.0	15.0	22.3
Average Velocity (Ft./min.)	898	897	1340
Actual Flow Rate (ACFM)	705	704	1050
Standard Flow Rate (SCFM)	512	514	717
Dry Standard Flow Rate (DSCFM)	475	475	643

Note - Sample No. 3 based on one port--boiler in serious unsteady state condition.

Standard Conditions are 70°F, 29.92"Hg

A-24

B-24

PARTICULATE AND CONDENSIBLE EMISSIONS

Sample No.	1	2	3
Date	3/29/78	-----	-----
Time	1215- 1359	1415- 1556	1555- 1627
<u>Sampling Data</u>			
Nozzle Size (inches)	1/2	-----	-----
No. of Sampling Points	8	8	4
Sampling Time (minutes)	64	64	32
Sample Volume (dscf)	52.8	54.0	36.5
% Isokinetic	100	103	102
<u>Emissions Data</u>			
Front Half Catch			
Grains/dscf	0.0314	0.0306	0.1801
Pound/hour	0.13	0.13	0.99
Organic Impinger Catch			
Grains/dscf	-	0.0000	0.0000
Pound/hour	-	0.00	0.00
Aqueous Impinger Catch			
Grains/dscf	-	0.0362	0.0124
Pound/hour	-	0.15	0.07
Total Catch			
Grains/dscf	-	0.0668	0.1925
Pound/hour	-	0.28	1.06

Note - Sample No. 3 based on one port--boiler in serious unsteady state condition.

## SO<sub>2</sub> EMISSIONS

Sample No.	1	2	3
Date	3/29/78	-----	-----
Time	1216- 1245	1420- 1448	1556- 1622
<u>Sampling Data</u>			
Nozzle Size (inches)	1/4	-----	-----
No. of Sampling Points	1	-----	-----
Sampling Time (minutes)	29	28	27
Sample Volume (dscf)	31.0	29.7	30.3
% Moisture	5.1	6.3	13.9

## SO<sub>x</sub> Emissions Data

SO <sub>2</sub>			
<u>Lbs/dscf</u>	14.9 (10 <sup>-6</sup> )	14.3 (10 <sup>-6</sup> )	1.27 (10 <sup>-6</sup> )
ppmv	84	79	6.5

Note - Sample No. 3 based on one port--boiler in serious unsteady state condition.

NO<sub>x</sub> EMISSIONS

Sample No.	1	2	3
Date	3/29/78	-----	-----
Time	1320	4125	1605

Sampling Data

Initial Temperature, °F	51	55	56
Initial Absolute Pressure, "Hg	9.23	9.27	9.27
Final Temperature, °F	70	70	70
Final Absolute Pressure, "Hg	28.92	29.39	29.39
Sample Volume, std. mls	1273	1307	1307

NO<sub>x</sub> EmissionsNO<sub>x</sub> as NO<sub>2</sub>

lbs/dscf	15.4(10 <sup>-6</sup> )	21.1(10 <sup>-6</sup> )	6.3(10 <sup>-6</sup> )
ppmv	58	80	23

Note - Sample No. 3 based on one port--boiler in serious unsteady state condition.

### OBSERVATIONS

Red emissions were observed at beginning of sample No. 3. The test was terminated halfway through because the boiler had gotten into a serious unsteady state condition. Atomization was reportedly lost.

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## WASTE OIL COMBUSTION TEST REPORT

EPA Contract No.: 68-01-4739

Site: C Test Nos.: 4-9

### INTRODUCTION

The site chosen for tests 4-9 included a nominal 18,000 #/hr steam boiler fired on #6 fuel. The purpose of this report is to document the physical and logistic aspects of the tests.

### BOILER DESCRIPTION

Of several boilers in the power plant, the boiler selected was a Titusville water-tube type with superheater. The output is a nominal 18,000 #/hr of superheated steam @ 450 PSI @ 545° to 550° F. It includes a Ljungstrom rotary preheater. The burner is a Peabody (S/N 347241) with an Enco nozzle assembly #410 (steam atomizing type) normally operating at 24 PSI fuel oil pressure and 50 PSI steam pressure. The temperature of the feed water was approximately 380° F.

For the purposes of this test, this boiler was manually controlled at 17,500 #/hr steam @ 460 PSI, which represented approximately 15% of the plant's total output.

### Waste Fuel Oil--Source and Description

Approximately 1000 gallons of recently collected service station oil was purchased. The loading of the waste oil into the leased tank truck was witnessed and supervised by RECON. A perusal of the dealers' collection records showed 5500 gallons total pickup for the previous day with 5100 gallons coming from service stations (16 pickups--primarily crankcase oil), and 400 gallons coming from automatic transmission fluid). (This results in an estimated 90% crankcase oil, 5% ATC and 5% solvents, etc.)

In addition, approximately 1500 gallons of reprocessed waste oil was purchased. Their raw feed oil is 80-90% crankcase oil with some hydraulics and some spillage. They reprocess this oil by heating to 240° F and then pass it through high efficiency filters.



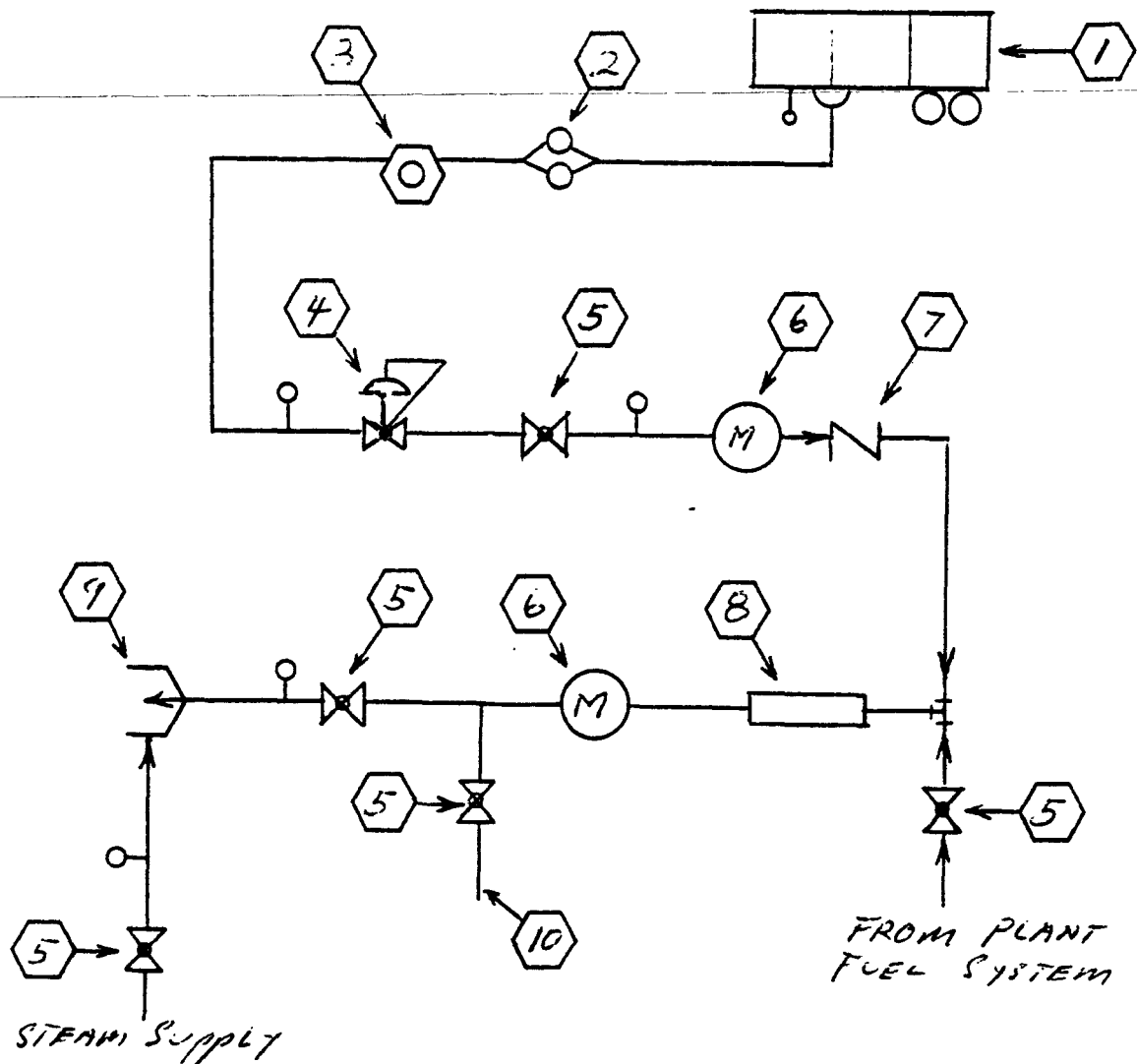
For test run #9, several drums of waste lubricant and hydraulic oils were collected from the plant site and transferred into a 300 gallon tank. The oils were dirty, with high water content. Analyses for all of the waste oils are included in this report.

#### Fuel Handling, Storage, Piping

It was decided to use a leased tank truck (3 compartment) both for delivery and temporary storage on the site. The tank truck first picked up the 1500 gallons of reprocessed oil, storing this oil in the first compartment. It then proceeded to pick up 1000 gallons of crankcase oil under RECON supervision, storing this oil in compartment #2. The truck then proceeded to the site where the test fuel lines were connected. This was accomplished on the first day of the tests (May 16, 1978). See attached sketch for piping schematic.

Before each test the boiler was fired on 100% virgin fuel oil (#6) overnight. Each morning the test fuel oil was introduced into the blender to the approximate desired ratio and the entire fuel oil system balanced out to provide 17,500 #/hr steam output. During the test the ratio of the fuels was checked and adjusted to the desired value.

Fuel System  
 Fuel Tank  
 Fuel Line  
 Fuel Valve  
 Fuel Meter  
 Fuel Blower



- |                              |                       |
|------------------------------|-----------------------|
| ① 3 COMPARTMENT TANK TRUCK   | ⑥ FUEL METER          |
| ② DOUBLE BOWL STRAINER       | ⑦ CHECK VALVE         |
| ③ POSITIVE DISPLACEMENT PUMP | ⑧ STATIC BLENDER      |
| ④ PRESSURE REDUCER           | ⑨ BURNER NOZZLE ASS'Y |
| ⑤ GLOBE VALVE                | ⑩ SAMPLE LINE         |

The fuel line equipment included:

1. A double bowl strainer.
2. A Viking model FH-32 internal gear rotary pump (1725 RPM) with internal bypass valve.
3. A Fisher 1/2" model 95H-40 pressure regulator.
4. Two Kent Metron 1/2" BPC fuel meters (high temperature). One measured test fuel flow and the other total fuel flow.
5. A Ross motionless mixer model LLPD 1" x 6" element (static blender).

#### METER CALIBRATION

During Test #8 (100% reprocessed oil) the opportunity was available to evaluate the relative accuracy of the fuel meters, since they were in series. The total fuel meter showed 550.27 gallons, while the test meter showed 551.31 gallons over the same period of time. The test fuel meter read 0.19% high and the total meter 0.19% low as compared to the average of these readings.

At the conclusion of Test #6, a calibration sample resulted in the total meter indicating 2.16 gallons and the test meter 2.13 gallons.

For this evaluation, the total meter was +0.7% above the average, while the test meter was 0.7% below the average.

The volume of the calibration sample was measured as approximately 5.5% higher than the indicated average. However, it was noted that the sample taken was aerated and this probably contributed to the high volume. The meters are reported by the manufacturer to be accurate to  $\pm 2\%$ .

BLEND, DESIRED & TEST FUEL

Site	Test #	Date 1978	Test Fuel (1)	Desired	Actual	High	Low	Flow GPM (avg)	Opacity (chart)
C	4	5/16	None (1)	0	0	0	0	2.33	0
C	5	5/17	Raw Crankcase Oil	10	9.72	13	6	2.24	0
C	6	5/18	Raw Crankcase Oil	60	60.4	65	55	2.37	<5
C	7	5/19	Reprocessed Oil	20	20.8	25	16	2.26	0
C	8	5/22	Reprocessed Oil	100	100	-	-	2.19	5
C	9	5/23	Mixed Industrial Waste Oil	20	20.6	22	17	2.22	0

Notes

- (1) The base fuel in all cases was #6 fuel oil. Approximately one gallon of Nutmeg No. 7D24 combustion catalyst blended per 6800 gallons of fuel oil.
- (2) The waste oil required additional excess air with the amount increasing with increase in blend ratio. Adjustment was made for clearest stack (visual and chart reading).
- (3) There was no soot blowing during the tests.
- (4) The boiler was manually controlled for 17,500 #/hr steam output in all cases.

STACK SAMPLING  
RESULTS FOR SITE C

STACK SAMPLING REPORT FOR SITE C

EPA Test No. 4 (100% No. 6 Oil)

- Particulates

---

- SO<sub>2</sub>

- NO<sub>x</sub>

VELOCITY AND FLOW RATE DATA -- EPA Test No. 4 (100% No. 6 Oil)

Sample No.	1	2	3
Date	5/16/78	-----	-----
Time	0944- 1103	1151- 1333	1445- 1600
Stack Diameter (inches)	33	-----	-----
Stack Cross Section (Sq.ft.)	5.94	-----	-----
Barometric ("Hg)	29.83	29.83	29.83
Average Stack Temperature (°F)	595	593	594
Stack Pressure ("H <sub>2</sub> O-gage)	-0.3	-0.3	-0.3
Moisture (% Vol.)	7.0	7.7	8.0
Average Velocity (Ft./sec.)	34.5	33.0	34.7
Actual Flow Rate (ACFM)	12,300	11,800	12,400
Standard Flow Rate (SCFM)	6,160	5,900	6,200
Dry Standard Flow Rate (DSCFM)	5,730	5,450	5,700

Standard Conditions are 70°F, 29.92"Hg -

PARTICULATE AND CONDENSIBLE EMISSIONS -- EPA Test No. 4  
(100% No. 6 Oil)

Sample No.	1	2	3
Date	5/16/78	-----	-----
Time	0944- 1103	1151- 1333	1445- 1600
<u>Sampling Data</u>			
Nozzle Size (inches)	3/8	3/8	3/8
No. of Sampling Points	24	24	24
Sampling Time (minutes)	72	72	72
Sample Volume (dscf)	54.6	52.6	55.2
% Isokinetic	103	104	104
<u>Emissions Data</u>			
Front Half Catch			
Grains/dscf	0.0057	0.0067	0.0063
Pound/hour	0.28	0.31	0.31
Organic Impinger Catch			
Grains/dscf	0.0012	0.0038	0.0003
Pound/hour	0.06	0.18	0.01
Aqueous Impinger Catch			
Grains/dscf	0.0025	0.0140	0.0093
Pound/hour	0.12	0.65	0.45
Total Catch			
Grains/dscf	0.0094	0.0245	0.0159
Pound/hour	0.46	1.14	0.77



SO<sub>x</sub> EMISSIONS -- EPA Test No. 4 (100% No. 6 Oil)

Sample No.	1	2	3
Date	5/16/78-----		
Time	1030- 1100	1210- 1240	1355- 1425

Sampling Data

No. of Sampling Points	1-----		
Sampling Time (minutes)	30	30	30
Sample Volume (dscf)	21.5	19.9	21.1
% Moisture	8.4	9.8	9.4

SO<sub>x</sub> Emissions

SO <sub>2</sub> lbs/dscf	16.8(10 <sup>-6</sup> )	18.5(10 <sup>-6</sup> )	21.2(10 <sup>-6</sup> )
ppmv	91	99	114

NO<sub>x</sub> EMISSIONS -- EPA Test No. 4 (100% No. 6 Oil)

Sample No.	1	2	3
Date	5/16/78	-----	-----
Time	1120	1315	1547

Sampling Data

Initial Temperature, °F	60	60	60
Initial Absolute Pressure, "Hg	9.83	9.53	8.53
Final Temperature, °F	78	72	84
Final Absolute Pressure, "Hg	30.01	29.74	29.32
Sample Volume, std. mls	1286	1310	1307

NO<sub>x</sub> Emissions (as NO<sub>2</sub>)

lbs/dscf	17.2(10 <sup>-6</sup> )	17.7(10 <sup>-6</sup> )	19.0(10 <sup>-6</sup> )
ppmv	66	67	72

STACK SAMPLING REPORT FOR SITE C

EPA Test No. 5 (10% Raw Crankcase Oil)

---

- Particulates

- SO<sub>2</sub>

- NO<sub>x</sub>

VELOCITY AND FLOW RATE DATA -- EPA Test No. 5 (10% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/17/78-----		
Time	1025- 1145	1207- 1322	1559- 1713
Stack Diameter (inches)	33-----		
Stack Cross Section (Sq.ft.)	5.94-----		
Barometric ("Hg)	29.93	29.95	29.95
Average Stack Temperature (°F)	597	595	572
Stack Pressure ("H <sub>2</sub> O-gage)	-0.3	-0.3	-0.3
Moisture (% Vol.)	7.2	7.3	7.3
Average Velocity (Ft./sec.)	34.7	34.6	34.3
Average Velocity (Ft./min.)			
Actual Flow Rate (ACFM)	12,400	12,300	12,200
Standard Flow Rate (SCFM)	6,200	6,190	6,270
Dry Standard Flow Rate (DSCFM)	5,780	5,740	5,810

Standard Conditions are 70°F, 29.92"Hg

PARTICULATE AND CONDENSIBLE EMISSIONS -- EPA Test No. 5  
(10% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/17/78-----		
Time	1025- 1145	1207- 1322	1559- 1713
<u>Sampling Data</u>			
Nozzle Size (inches)	3/8	3/8	3/8
No. of Sampling Points	24	24	24
Sampling Time (minutes)	72	72	72
Sample Volume (dscf)	55.3	53.5	54.6
% Isokinetic	104	100	101
<u>Emissions Data</u>			
Front Half Catch			
Grains/dscf	0.0138	0.0145	0.0135
Pound/hour	0.68	0.71	0.67
Organic Impinger Catch			
Grains/dscf	0.0009	0.0014	0.0033
Pound/hour	0.04	0.07	0.16
Aqueous Impinger Catch			
Grains/dscf	0.0100	0.0086	0.0082
Pound/hour	0.50	0.42	0.41
Total Catch			
Grains/dscf	0.0247	0.0245	0.0250
Pound/hour	1.22	1.20	1.24

SO<sub>x</sub> EMISSIONS -- EPA Test No. 5 (10% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/17/78-----		
Time	1035- 1107	1205- 1240	1352- 1427

Sampling Data

No. of Sampling Points	1-----		
Sampling Time (minutes)	32	35	35
Sample Volume (dscf)	22.4	21.4	24.8
% Moisture	11.2	8.3	5.2

SO<sub>x</sub> Emissions

SO <sub>2</sub>			
lbs/dscf	23.4(10 <sup>-6</sup> )	15.7(10 <sup>-6</sup> )	9.94(10 <sup>-6</sup> )
ppmv	123	85	56

NO<sub>x</sub> EMISSIONS -- EPA Test No. 5 (10% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/17/78-----		
Time	1115	1250	1440

Sampling Data

Initial Temperature, °F	65	68	65
Initial Absolute Pressure, "Hg	8.93	9.95	9.15
Final Temperature, °F	84	89	82
Final Absolute Pressure, "Hg	29.33	30.33	29.92
Sample Volume, std. mls	1287	1270	1318

NO<sub>x</sub> Emissions (as NO<sub>2</sub>)

lbs/dscf	19.1(10 <sup>-6</sup> )	21.7(10 <sup>-6</sup> )	18.6(10 <sup>-6</sup> )
ppmv	73	83	71

## Stack Sampling Report for Site C

---

EPA Test No. 6 (60% Raw Crankcase Oil)

- Particulates
- SO<sub>2</sub>
- NO<sub>x</sub>



VELOCITY AND FLOW RATE DATA -- EPA Test No. 6 (60% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/18/78-----		
Time	0944- 1106	1143- 1258	1351- 1516
Stack Diameter (inches)	33-----		
Stack Cross Section (Sq.ft.)	5.94-----		
Barometric ("Hg)	30.04	30.02	30.00
Average Stack Temperature (°F)	648	653	658
Stack Pressure ("H <sub>2</sub> O-gage)	-0.35	-0.35	-0.35
Moisture (% Vol.)	7.4	7.1	7.4
Average Velocity (Ft./sec.)	37.9	39.0	38.9
Average Velocity (Ft./min.)			
Actual Flow Rate (ACFM)	13,500	13,900	13,900
Standard Flow Rate (SCFM)	6,490	6,630	6,590
Dry Standard Flow Rate (DSCFM)	6,010	6,150	6,100

Standard Conditions are 70°F, 29.92 "Hg

PARTICULATE AND CONDENSIBLE EMISSIONS -- EPA Test No. 6  
(60% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/18/78	-----	-----
Time	0944- 1106	1143- 1258	1351- 1516
<u>Sampling Data</u>			
Nozzle Size (inches)	3/8"	3/8"	3/8"
No. of Sampling Points	24	24	24
Sampling Time (minutes)	72	72	72
Sample Volume (dscf)	56.3	58.7	57.8
% Isokinetic	101	102	102
<u>Emissions Data</u>			
Front Half Catch			
Grains/dscf	0.0480	0.0452	0.0496
Pound/hour	2.47	2.38	2.59
Organic Impinger Catch			
Grains/dscf	0.0053	0.0036	0.0031
Pound/hour	0.27	0.19	0.16
Aqueous Impinger Catch			
Grains/dscf	0.0094	0.0095	0.0116
Pound/hour	0.48	0.50	0.61
Total Catch			
Grains/dscf	0.0627	0.0583	0.0643
Pound/hour	3.22	3.07	3.36

SO<sub>x</sub> EMISSIONS -- EPA Test No. 6 (60% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/18/78-----		
Time	0945- 1027	1138- 1203	1415- 1442

Sampling Data

No. of Sampling Points	1-----		
Sampling Time (minutes)	30	25	27
Sample Volume (dscf)	22.9	17.9	11.2
% Moisture	7.8	10.3	9.6

SO<sub>x</sub> Emissions

SO <sub>2</sub>			
lbs/dscf	18.9(10 <sup>-6</sup> )	24.7(10 <sup>-6</sup> )	19.1(10 <sup>-6</sup> )
ppmv	103	131	102

NO<sub>x</sub> EMISSIONS -- EPA Tsst No. 6 (60% Raw Crankcase Oil)

Sample No.	1	2	3
Date	5/18/78-----		

Time	1055	1250	~1500
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Sampling Data

Initial Temperature, °F	72	75	75
Initial Absolute Pressure, "Hg	12.34	9.85	9.00
Final Temperature, °F	82	89	92
Final Absolute Pressure, "Hg	28.86	29.66	30.13
Sample Volume, std. mls.	1054	1241	1316

NO<sub>x</sub> Emissions (as NO<sub>2</sub>)

lbs/dscf	13.5(10 <sup>-6</sup> )	16.5(10 <sup>-6</sup> )	14.2(10 <sup>-6</sup> )
ppmv	52	63	54

STACK SAMPLING REPORT FOR SITE C

EPA Test No. 7 (20% Reprocessed Oil)

---

- Particulates

- SO<sub>2</sub>

- NO<sub>x</sub>

VELOCITY AND FLOW RATE DATA -- EPA Test No. 7 (20% Reprocessed Oil)

Sample No.	1	2	3
Date	5/19/78-----		
Time	0910- 1026	1112- 1227	1313- 1428
Stack Diameter (inches)	33-----		
Stack Cross Section (Sq.ft.)	5.94-----		
Barometric ("Hg)	30.04	30.04	30.02
Average Stack Temperature (°F)	648	648	658
Stack Pressure ("H <sub>2</sub> O-gage)	-0.3	-0.3	-0.3
Moisture (% Vol.)	6.9	7.3	6.3
Average Velocity (Ft./sec.)	34.4	33.9	35.1
Average Velocity (Ft./min.)			
Actual Flow Rate (ACFM)	12,300	12,100	12,500
Standard Flow Rate (SCFM)	5,890	5,810	5,950
Dry Standard Flow Rate (DSCFM)	5,460	5,360	5,570

Standard Conditions are 70°F, 29.92"Hg

PARTICULATE AND CONDENSIBLE EMISSIONS -- EPA Test No. 7  
(20% Reprocessed Oil)

Sample No.	1	2	3
Date	5/19/78-----		

Time	0910- 1026	1112- 1227	1313- 1428
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Sampling Data

Nozzle Size (inches)	3/8	3/8	3/8
No. of Sampling Points	24	24	24
Sampling Time (minutes)	71	72	72
Sample Volume (dscf)	51.1	50.2	49.3
% Isokinetic	102	102	95

Emissions Data

Front Half Catch Grains/dscf	0.0272	0.0279	0.0297
Pound/hour	1.27	1.28	1.42
Organic Impinger Catch Grains/dscf	0.0007	0.0000	0.0000
Pound/hour	0.03	0.00	0.00
Aqueous Impinger Catch Grains/dscf	0.0009	0.0191	0.0067
Pound/hour	0.04	0.88	0.32
Total Catch Grains/dscf	0.0288	0.0470	0.0364
Pound/hour	1.34	2.16	1.74

SO<sub>x</sub> EMISSIONS -- EPA Test No. 7 (20% Reprocessed Oil)

Sample No.	1	2	3
Date	5/19/78-----		
Time	0905- 0932	1045- 1112	1405- 1432

Sampling Data

No. of Sampling Points	1	1	1
Sampling Time (minutes)	27	27	27
Sample Volume (dscf)	19.7	19.6	19.0
% Moisture	9.3	4.5	7.1

SO<sub>x</sub> Emissions

SO <sub>2</sub> — lbs/dscf	21.8(10 <sup>-6</sup> )	22.1(10 <sup>-6</sup> )	21.5(10 <sup>-6</sup> )
ppmv	117	125	118



NO<sub>x</sub> EMISSIONS -- EPA Test No. 7 (20% Reprocessed Oil)

Sample No.	1	2	3
Date	5/19/78-----		
Time	~1000	~1200	1430

Sampling Data

Initial Temperature, °F	81	85	90
Initial Absolute Pressure, "Hg	9.54	9.87	9.75
Final Temperature, °F	70	70	85
Final Absolute Pressure, "Hg	28.56	30.05	30.29
Sample Volume, std. mls	1264	1345	1319

NO<sub>x</sub> Emissions (as NO<sub>2</sub>)

lbs/dscf	17.3(10 <sup>-6</sup> )	14.2(10 <sup>-6</sup> )	17.8(10 <sup>-6</sup> )
ppmv	66	54	69

Stack Sampling Report for Site C

EPA Test No. 8 (100% Reprocessed Oil)

- Particulates
- SO<sub>2</sub>
- NO<sub>x</sub>

VELOCITY AND FLOW RATE DATA -- EPA Test No. 8 (100% Reprocessed Oil)

Sample No.	1	2	3
Date	5/22/78	-----	-----
Time	0944- 1101	1131- 1246	1346- 1501
Stack Diameter (inches)	33	-----	-----
Stack Cross Section (Sq.ft.)	5.94		
Barometric ("Hg)	30.13	30.13	30.09
Average Stack Temperature (°F)	622	626	626
Stack Pressure ("H <sub>2</sub> O-gage)	-0.3	-0.3	-0.3
Moisture (% Vol.)	5.7	6.3	7.2
Average Velocity (Ft./sec.)	33.6	35.9	37.5
Average Velocity (Ft./min.)			
Actual Flow Rate (ACFM)	12,000	12,800	13,400
Standard Flow Rate (SCFM)	5,890	6,280	6,560
Dry Standard Flow Rate (DSCFM)	5,550	5,860	6,090

Standard Conditions are 70°F, 29.92"Hg

PARTICULATE AND CONDENSIBLE EMISSIONS -- EPA Test No. 8  
(100% Reprocessed Oil)

Sample No.	1	2	3
Date	5/22/78-----		
Time	0944- 1101	1131- 1246	1346- 1501
<u>Sampling Data</u>			
Nozzle Size (inches)	3/8	3/8	3/8
No. of Sampling Points	24	24	24
Sampling Time (minutes)	72	72	72
Sample Volume (dscf)	49.3	52.4	58.2
% Isokinetic	97	96	103
<u>Emissions Data</u>			
Front Half Catch			
Grains/dscf	0.0842	0.0864	0.0818
Pound/hour	4.01	4.34	4.27
Organic Impinger Catch			
Grains/dscf	0.0018	0.0001	0.0012
Pound/hour	0.09	0.01	0.06
Aqueous Impinger Catch			
Grains/dscf	0.0045	0.0027	0.0124
Pound/hour	0.21	0.14	0.65
Total Catch			
Grains/dscf	0.0905	0.0892	0.0818
Pound/hour	4.31	4.49	4.98

SO<sub>x</sub> EMISSIONS-- EPA Test No. 8 (100% Reprocessed Oil)

Sample No.	1	2	3
Date	5/22/78-----		
Time	1038- 1108	1215- 1245	1355- 1422

Sampling Data

No. of Sampling Points	1	1	1
Sampling Time (minutes)	30	30	27
Sample Volume (dscf)	19.3	21.8	19.4
% Moisture	10.5	7.0	4.7

SO<sub>x</sub> Emissions

SO <sub>2</sub>			
lbs/dscf	20.5 (10 <sup>-6</sup> )	25.2 (10 <sup>-6</sup> )	23.3 (10 <sup>-6</sup> )
ppmv	108	139	131

NO<sub>x</sub> EMISSIONS -- EPA Test No. 8 (100% Reprocessed Oil)

Sample No.	1	2	3
Date	5/22/78-----		
Time	1110	~ 1200	~ 1400

Sampling Data

Initial Temperature, °F	80	82	78
Initial Absolute Pressure, "Hg	9.33	9.13	9.49
Final Temperature, °F	68	77	85
Final Absolute Pressure, "Hg	29.55	30.32	29.02
Sample Volume, std. mls	1349	1381	1241

NO<sub>x</sub> Emissions (as NO<sub>2</sub>)

lbs/dscf	11.9 (10 <sup>-6</sup> )	13.0 (10 <sup>-6</sup> )	13.7 (10 <sup>-6</sup> )
ppmv	46	50	53

STACK SAMPLING REPORT FOR SITE C

EPA Test No. 9 (20% Industrial Oil)

---

- Particulates

- SO<sub>2</sub>

- NO<sub>x</sub>

VELOCITY AND FLOW RATE DATA -- EPA Test No. 9 (20% Industrial Oil)

Sample No.	1	2	3
Date	5/23/78-----		
Time	0935- 1049	1116- 1232	1348- 1501
Stack Diameter (inches)	33-----		
Stack Cross Section (Sq.ft.)	5.94-----		
Barometric ("Hg)	30.12	30.12	30.11
Average Stack Temperature (°F)	637	651	654
Stack Pressure ("H <sub>2</sub> O-gage)	-0.3	-0.3	-0.3
Moisture (% Vol.)	7.2	6.7	7.4
Average Velocity (Ft./sec.)	34.2	36.7	37.6
Average Velocity (Ft./min.)			
Actual Flow Rate (ACFM)	12,200	13,100	13,400
Standard Flow Rate (SCFM)	5,920	6,270	6,400
Dry Standard Flow Rate (DSCFM)	5,490	5,850	5,930

Standard Conditions are 70°F, 29.92"Hg



PARTICULATE AND CONDENSIBLE EMISSIONS -- EPA Test No. 9  
(20% Industrial Oil)

Sample No.	1	2	3
Date	5/23/78-----		

Time	0935- 1049	1116- 1232	1348- 1501
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Sampling Data

Nozzle Size (inches)	3/8	3/8	3/8
No. of Sampling Points	24	24	24
Sampling Time (minutes)	72	72	72
Sample Volume (dscf)	50.7	55.0	50.3
% Isokinetic	99	104	91

Emissions Data

Front Half Catch			
Grains/dscf	0.0161	0.0132	0.0142
Pound/hour	0.76	0.66	0.72
Organic Impinger Catch			
Grains/dscf	0.0013	0.0013	0.0004
Pound/hour	0.06	0.07	0.02
Aqueous Impinger Catch			
Grains/dscf	0.0067	0.0044	0.0012
Pound/hour	0.32	0.15	0.06
Total Catch			
Grains/dscf	0.0241	0.0189	0.0158
Pound/hour	1.13	0.88	0.80

SO<sub>x</sub> EMISSIONS -- EPA Test No. 9 (20% Industrial Oil)

Sample No.	1	2	3
Date	5/23/78-----		
Time	0935- 1005	1105- 1130	1429- 1459

Sampling Data

No. of Sampling Points	1	1	1
Sampling Time (minutes)	30	25	30
Sample Volume (dscf)	23.0	18.9	21.0
% Moisture	9.7	5.2	13.0

SO<sub>x</sub> Emissions

SO <sub>2</sub> lbs/dscf	18.7(10 <sup>-6</sup> )	19.9(10 <sup>-6</sup> )	20.1(10 <sup>-6</sup> )
ppmv	100	112	103

NO<sub>x</sub> EMISSIONS -- EPA Test No. 9 (20% Industrial Oil)

Sample No.	1	2	3
Date	5/23/78-----		
Time	~ 1000	1335	~ 1400

Sampling Data

Initial Temperature, °F	82	84	82
Initial Absolute Pressure, "Hg	9.82	10.12	9.51
Final Temperature, °F	72	72	72
Final Absolute Pressure, "Hg	28.54	30.03	28.38
Sample Volume, std. mls.	1238	1319	1248

NO<sub>x</sub> Emissions (as NO<sub>2</sub>)

lbs/dscf	17.3(10 <sup>-6</sup> )	15.0(10 <sup>-6</sup> )	17.5(10 <sup>-6</sup> )
ppmv	66	58	67

## APPENDIX C

### LEAD EMISSIONS DURING DOWNWASH

Lead emissions should meet two criteria: 1.) The ambient air quality standard of  $1.5 \mu\text{g}/\text{m}^3$  averaged over a calendar quarter (FR 43, October 5, 1978); and 2.) the OSHA standard of  $50 \mu\text{g}/\text{m}^3$  based on an eight hour time weighted average (FR 43, November 14, 1978).

Problems in meeting the ambient air quality standard are discussed in Section 5.0.

As shown in the following analysis, it may be possible to approach or even exceed the OSHA lead standard when burning in a furnace with a short stack during a condition known as downwash. This phenomenon occurs when aerodynamic turbulence induced by a building causes a pollutant emitted from an elevated source to be mixed rapidly toward the ground, resulting in higher ground-level concentrations immediately to the lee of the building than would otherwise occur. This problem is analyzed in "Guidelines for Air Quality Maintenance Planning and Analysis. Vol. 10 (Revised): Procedures for Evaluating Air Quality Impact of New Stationary Sources," EPA 450/4-77-001, Oct. 1977.\* The EPA analysis of downwash, combined with the OSHA standard, has been used to calculate lead concentration in used oils and used oil blends which could result in greater than  $50 \mu\text{g}/\text{m}^3$  lead concentration.

Downwash may occur when

$$h_s = h_b + 1.5 a \quad (1)$$

where  $h_s$  = stack height, meters

$h_b$  = building height, meters

$a$  = lesser of either building height or maximum building width, meters

\*Available from NTIS as PB-274 087

Under this condition, the maximum 1-hour ground-level concentration of lead may be estimated as

$$x_1 = \frac{Q}{(1.5)(A)(U)} \quad (2)$$

where

$x_1$  = maximum 1-hour ground-level concentration,  $\text{g}/\text{m}^3$   
 $Q$  = maximum emission rate for the time of concern,  $\text{g}/\text{sec}$ .

$A$  = cross sectional area of the building normal to the wind,  $\text{m}^2$

$U$  = wind velocity,  $\text{m}/\text{sec}$ .

For the worst case, assume

$U = 3 \text{ m}/\text{sec}$  (EPA recommendation)

$A = 3\text{m}$  high x  $3\text{m}$  wide (building cross section seldom smaller--note that with  $7.5\text{m}$  stack height there is no downdraft for  $3\text{x}3\text{x}3\text{m}$  building)

$$\text{Then } x_1 = \frac{Q}{(1.5)(9)(3)} = \frac{Q}{40.5} \quad (3)$$

$$Q = (FP) \frac{454}{3600} (10^{-6})$$

Where  $F$  = fuel rate,  $\text{lbs}/\text{hr}$

$P$  = pollutant in oil,  $\text{ppm}$  by weight

Substituting (3) into (2)

$$x_1 = \frac{(FP)(454)10^{-6}}{(40.5)(3600)} = 0.003114 \times 10^{-6} FP \quad (4)$$

For lead, assume  $x_1 = 50 \times 10^{-6} \text{ g}/\text{m}^3$  (OSHA standard for 8 hr. average).

$$\text{Then } FP = \frac{50 \times 10^{-6}}{0.003114 \times 10^{-6}} = 16,057 \quad (5)$$

For example:

Total Oil Rate, lbs/hr (virgin + used)	Allowable Pb In Blend ppm	Allowable % Used Oil For 0 ppm Pb In Virgin Oil	
		for 10,000 ppm in used oil	for 1000 ppm in used oil
home, small commercial	10	1605	16
"very small boiler"	100	161	1.6
"small boiler"	1,000	16	0.16
"medium boiler"	10,000	1.6	-
"power plant"	100,000	0.2	-

Clearly, under downwash conditions it is possible to exceed 50  $\mu\text{g}/\text{m}^3$  ground-level concentration, e.g. in a boiler burning 1000 lbs/hr (about 133 GPH) of oil containing greater than 1.6% used oil with a lead concentration of only 1000 ppm. However, the OSHA standard would be exceeded only if the downwash condition persisted, e.g. for eight hours. Stack heights insufficient to overcome terrain interception could lead to similar problems at some distance from the combustion source.

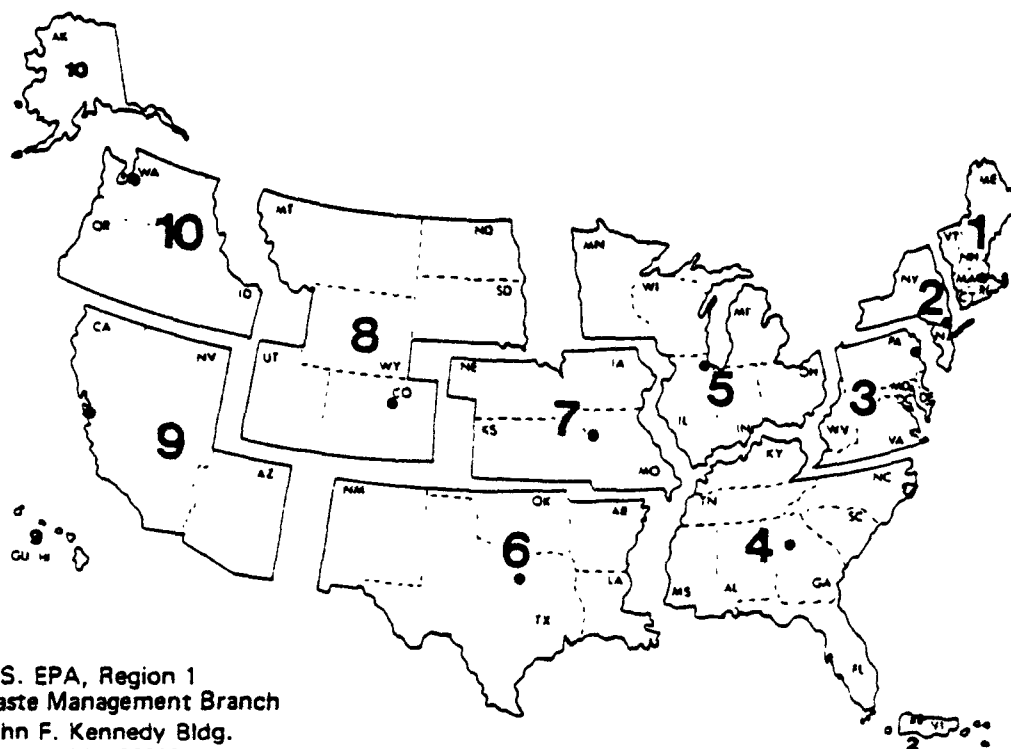
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U.S. Environmental Protection Agency  
Region 5, Library (PL-12J)  
77 West Jackson Boulevard, 12th Floor  
Chicago, IL 60604-3590

# EPA REGIONS

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U.S. EPA, Region 1  
Waste Management Branch  
John F. Kennedy Bldg.  
Boston, MA 02203  
617-223-5775

U.S. EPA, Region 2  
Solid Waste Branch  
26 Federal Plaza  
New York, NY 10007  
212-264-0503

U.S. EPA, Region 3  
Hazardous Materials Branch  
6th and Walnut Sts.  
Philadelphia, PA 19106  
215-597-7370

U.S. EPA, Region 4  
Residuals Management Br.  
345 Courtland St., N.E.  
Atlanta, GA 30365  
404-881-3016

U.S. EPA, Region 5  
Waste Management Branch  
230 South Dearborn St.  
Chicago, IL 60604  
312-353-2197

U.S. EPA, Region 6  
Solid Waste Branch  
1201 Elm St.  
Dallas, TX 75270  
214-767-2645

U.S. EPA, Region 7  
Hazardous Materials Branch  
324 East 11th St.  
Kansas City, MO 64108  
816-374-3307

U.S. EPA, Region 8  
Waste Management Branch  
1860 Lincoln St.  
Denver, CO 80295  
303-837-2221

U.S. EPA, Region 9  
Hazardous Materials Branch  
215 Fremont St.  
San Francisco, CA 94105  
415-556-4606

U.S. EPA, Region 10  
Waste Management Branch  
1200 6th Ave.  
Seattle, WA 98101  
206-442-1260



