Naval Facilities Engineering Command
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UTILIZATION OF NAVY-GENERATED WASTE OILS AS BURNER FUEL

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ABSTRACT

The manual is directed to operators and supervisors who actually perform and supervise operation and maintenance work. The manual is divided into three chapters with chapter one covering terminology, disposal, waste oil sources and Navy waste oil generation/disposition. Chapter two covers the planning of waste oil utilization. Items discussed are sources of waste oil, boiler fuel requirements, air quality considerations, economics of burning waste oil and ECIP considerations. Chapter three deals with the procedures for burning waste oil as a boiler fuel. Topics include segregation, centralized storage, treatment, water/sludge removal, fuel analysis, blending, viscosity control, burner modifications, maintenance and operation requirements along with record keeping. In general, this manual provides guidelines for the use of waste oil as a supplemental fuel in Navy boilers.

FOREWORD

This manual supplements specific equipment instruction manuals and pertinent drawings. It will provide the basic guidance required for operations and maintenance of steam generation facilities utilizing Navy waste oils.

For maximum benefit this manual should be used in conjunction with equipment manufacturer's manuals, parts lists and drawings. In case of conflict, manufacturers' recommendations, on use, care operations, adjustment and repair of specific equipment should be followed. The manual is intended for use by public works officers, supervisors, and operations personnel.

Additional information concerning procedures, suggestions, recommendations or modifications that will improve this manual are invited and should be submitted through appropriate channels to the Commander, Naval Facilities Engineering Command, (Attention: Code 165), 200 Stovall Street, Alexandria, VA 22332-2300.

This publication has been reviewed and approved in accordance with the Secretary of the Navy Instruction 5600.16 and is certified as an official publication of the Naval Facilities Engineering Command.

Donald B. Campbell

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Deputy Commander for
Public Works

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CHAPTER 1. WASTE OIL

1.1 PURPOSE. This manual provides guidelines for the use of waste oil as a supplemental fuel in Navy boilers. The subject matter is tailored to serve various groups and to meet the needs of a variety of users at different levels of management and operation.

1.2 SCOPE. Chapter 1 contains background information on waste oil generation. Chapter 2 is organized to provide information for Public Works Officers and planners. Topics include: sources of waste oil, restrictions on use as fuel, boiler fuel requirements, boiler fuels, air quality considerations, and economics of burning waste oil. Chapter 3 is designed to provide procedural information for operators using the oil as boiler fuel. Methods of segregation and centralized storage are discussed; and the need for treatment of the waste oil prior to burning is outlined. Parameters for physical/chemical testing are provided, and methods of viscosity control and of blending the waste oil into the normal boiler fuel are reviewed. The need for burner equipment modification and unique maintenance and operational requirements are discussed.

1.3 TERMINOLOGY. The following terms should be familiar to the reader.

1.3.1 Oily Waste. For the most part, oily waste comes from ship bilges and various clean-up operations. The major parts of its contents are water, solids, and other contaminants. The oil makes up only a small percentage of the mixture.

1.3.2 Waste Oil. This term refers to the oil after it has been separated from its contaminants (basically water and solids).

1.3.3 Fuel Oil Reclaimed (FOR). FOR is oil that has been processed by a Naval Supply activity through a low-temperature heating and settling facility to remove suspended water and sediment to meet appropriate specifications. FOR is then usually reissued or blended into other fuel. The military specification for FOR is given in Appendix A.

1.4 DISPOSAL. In the past, waste oils have been disposed of by either dumping them, using them for dust control, burning them during firefighting training, or contracting for their removal. Environmental regulations now prohibit either dumping them or using them for dust control. Since the waste oils have practically the same energy content or heating value as regular fuel oils of comparable densities, using them as fuel in boilers is a more productive disposal alternative. Using waste oil as boiler fuel will also reduce both new fuel oil consumptions and fuel costs.

1.5 WASTE OIL SOURCES. Large quantities of waste oils are continuously generated by Navy and Marine Corps ships/shore activities and aircraft facilities. The waste oils generated from these sources are predominantly those recovered from bilge and ballast water. These oils are composed primarily of the fuel used by the particular ship. Lubricating oils and similar materials from vehicles and ships rank second highest in quantity. Contaminated high flashpoint fuels, such as JP-5, diesel, and kerosene, rank third highest in quantities generated. Solvents and low flashpoint fuels are generated least. From the standpoint of utilization as a supplemental boiler fuel, these waste oils may be grouped into three categories:

- Light waste oils - oils recovered from ship bilge/ballast water and contaminated high flashpoint fuels; estimated to be 87 percent of the total waste oils generated throughout the Navy.

- Heavy waste oils - engine drainings, shop facility wastes, and tank cleanings; estimated to be 9 percent of the total waste oils generated throughout the Navy.

- Low flashpoint materials - most solvents and contaminated low flashpoint fuels; estimated to be 4 percent of the total waste oils generated throughout the Navy.

It should be noted that the percentages are Navywide estimates only, and may vary considerably for specific sites. Both light and heavy waste oils are suitable for boiler fuels, while low flashpoint materials are undesirable as boiler fuel for safety and environmental reasons. Of all the waste oil the Navy generates, 96 percent is therefore considered to be a desirable supplemental source of energy. These waste oils are of higher quality than the No. 6 fuel oil frequently used in boilers.

1.6 NAVY WASTE OIL GENERATION/DISPOSITION. Over a 4-year period (1980-84) NCEL has conducted a survey of waste oil generation and disposition by Navy and Marine Corps shore activities. The most recent results are given in Appendix B.

The Navy generates roughly the equivalent of 2 million MBtu of waste oil annually. Only 15 percent of this is presently burned as a boiler fuel; the remaining 85 percent is disposed of in several ways: (1) local firefighting training; (2) Naval Supply Systems Command (NAVSUP), Defense Logistics Agency (DLA), or Defense Property Disposal Office (DPDO) handle resale; (3) sold or given to haulers; (4) paid to have hauled away; or (5) stored. This illustrates the potential for more productive use of significant quantities of waste oil.

1.7 RELATED DOCUMENTS.

Alliance Technologies Corporation. "Emission Factor Documentation for AP-42: Section 1.11, Waste Oil Combustion", Draft, TRC-A87-224 Contract No. 68-02-3892, U.S. Environmental Protect ion Agency, Research Triangle Park, NC. June 1987.

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Environmental Protection Agency. 40 CFR Part 266: "Hazardous waste management system: Standards for the management of specific wastes and specific types of facilities," Federal Register, vol 50, no. 8, 11 Jan 1985.

"Federal Register". Vol. 51, No. 223, pp. 41900-41904. November 19, 1986.

Health and Safety Code", Division 20, Chapter 6.5, Article 13. California State Department of Health Services. September 17, 1986.

Naval Facilities Engineering Command. P-917: "Used Oil and Solvent Recycling Guide". Alexandria, Va., Jun 1985.

Schmidt, Paul F. (1969). "Fuel Oil Manual". New York, N.Y., Industrial Press, Inc., 1969.

VSE Corporation. "Use of Waste Oils as a Supplemental Boiler Fuel", Contract No. N62583/81-M-R421, Naval Civil Engineering Laboratory, Port Huememe, CA. September 1981.

ASTM Standards

D56	Test for Flash Point by Tag Closed Tester
D86	Distillation of Petroleum Products
D93	Test for Flash Point by Pensky-Martens Closed Tester
D95	Test for Water in Petroleum Products and Bituminous Materials by Distillation
D97	Tests for Pour Point of Petroleum Oils

D129	Test for Sulfur in Petroleum Products (General Bomb Method)
D130	Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test
D287	Test for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
D396	Standard Specification for Fuel Oils
D445	Test for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)
D473	Test for Sediment in Crude and Fuel Oils by Extraction
D482	Test for Ash from Petroleum Products
D524	Test for Ramsbottom Carbon Residue of Petroleum Products
D1266	Test for Sulfur in Petroleum Products (Lamp Method)
D1552	Test for Sulfur in Petroleum Products (High-Temperature Method)
D1659	Test for Maximum Fluidity Temperature of Residual Fuel Oil
D1796	Test for Water and Sediment in Crude Oils and Fuel Oils by Centrifuge
D2622	Test for Sulfur in Petroleum Products (X-Ray Spectrographic Method)
D3245	Test for Pumpability of Industrial Fuel Oils

1.8 ABBREVIATIONS AND DEFINITIONS.

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
Atomize	To reduce to minute particles or to a fine spray.
CHIL LIST	Consolidated Hazardous Item List
Contaminated Fuel	Fuel that has been contaminated by foreign material, such as water, sediment, other fuels, oil, and solvents and cannot be used for its intended purpose.
DEIS	Defense Energy Information System
DF, DF2, F-76	Diesel Fuel, Diesel Fuel No. 2, Naval Distillate Fuel
DLA	Defense Logistics Agency
DONUT	Waste oil raft that performs initial gravity separation
DPDO	Defense Property Disposal Office
ECIP	Energy Conservation Investment Program
EFD	Engineering Field Division

FO, FO1, FO2, FO5, FO6	Fuel Oil, Fuel Oil No. 1, Fuel Oil No. 2, Fuel Oil No. 5, Fuel Oil No. 6
FOR	Fuel Oil Reclaimed. Oil that has been processed by a Naval Supply activity through a low-temperature heating and settling facility to remove suspended water and sediment to meet appropriate specifications. It is then usually reissued or blended into other fuel. (Refer to Appendix A for military specification.)
MBtu/hr	Million Btu per hour
NAVFAC	Naval Facilities Engineering Command
NAVSUP	Naval Supply Systems Command
NEESA	Naval Energy and Environmental Support Activity
NSFO	Navy Special Fuel Oil
SUS	Saybolt Universal Seconds (a measure of viscosity)
SWOB	Ship Waste Offload Barge
UIC	Unit Identification Code
Waste Oil	The descriptive term applied to used or contaminated petroleum-based and synthetic/chemical-based oil products that are no longer suitable for use as originally intended.

CHAPTER 2. PLANNING WASTE OIL UTILIZATION

2.1 SCOPE. This chapter discusses factors to be considered and evaluated for using waste oils as burner fuel; waste oil generating sources, oil products found in waste oils, oil products which should not be burned, waste oil restrictions, and boiler fuels presently used. Air emission considerat ions, combustion considerat ions, and economic considerat ions are also discussed.

2.2 SOURCES OF WASTE OIL. The basic sources of waste oil generated at Navy activities are ships in port, aircraft fueling and maintenance activities, and other industrial/shop functions performed ashore. Collect ion and disposal can be conducted independently in various organizations or as functional elements, of an activity. Centralized collection and use of the waste oil as a fuel may be profitable for the activity.

Although over 80 percent of the volume of waste oil generated throughout the Navy is obtained from ship bilge and ballast water brought ashore, activities having no port facilities may also generate enough waste oil to make its use as a supplemental fuel a worthwhile energy conservation measure.

2.2.1 Ships in Port. The primary source of waste oil from ships is the bilge/ballast water pumped ashore. Most activities handle this waste with Waste Oil Rafts (DONUTS), which perform an initial gravity separation function. The waste oil residual obtained is either further treated by oil separation equipment, if available, or transferred to storage tanks for disposal (usually by sale).

Ships may also generate waste oil products that are brought ashore in drums and other containers. Types and quantities of this waste vary, depending upon the type of ship. Industrial-type ships, such as tenders, aircraft carriers, and large amphibious ships are the most likely generators of significant quantities. Examples of these wastes are contaminated fuels, turbine engine oils, hydraulic fluids, shop lubricants, carrier arresting gear and catapult hydraulic fluids, greases, and solvents of all kinds.

2.2.2 Aircraft-Related Functions. At Naval Air Stations, a major source of waste oil is aircraft fueling and maintenance. Contaminated fuels that are unacceptable for reuse are a main source of waste oil. In aircraft maintenance shops, fuel tanks are purged, oils drained, etc., thus generating waste oils that must be disposed. To a minor degree, these functions may be performed aboard aircraft carriers while in port and may generate some wastes to be brought ashore.

2.2.3 Industrial/Shop Functions. Large Navy activities, such as Shipyards, Aviation Depots, and Ordnance Plants, generate waste oils suitable for boiler firing. The use of these waste oils as supplemental fuel depends on the economics of collection, segregation, and treatment. Certain products used in industrial/shop facilities must not be burned. These are discussed later and are listed in Appendix D.

2.2.4 Nonindustrial Related Functions. At nonindustrial activities, waste oil is generated wherever internal combustion engine equipment is operated and maintained, as in transportation equipment shops, Navy Exchange service stations, automotive hobby shops, public works maintenance shops, and diesel generator plants.

2.2.5 Nonspecification Fuels. Another source of waste oil is fuels that cannot be issued as specification fuels because they became contaminated at storage and dispensing facilities.

2.3 WASTE OIL RESTRICTIONS. Oil products that will most likely be found in waste oils are categorized into six types in Table 2-1, and are described as follows:

2.3.1 Type A Oil Products. Type A products in Table 2-1, such as gasoline and JP-4, are undesirable as boiler fuels. Low flashpoint characteristics make these materials hazardous to handle and burn.

2.3.2 Type F Oil Products. The majority of waste oils considered here are nonpetroleum-based products. Synthetic/chemical (nonpetroleum) based products require segregated collection. Appendix D lists synthetic/chemical-based waste oils, low flashpoint materials, and halogenated solvents that should not be burned. Special precautions are required to avoid dumping solvents or residues that contain halogens into the waste oil being collected for boiler firing. Shops must segregate all halogenated compounds when practical, because high enough concentrations may result in accelerated corrosion of boiler components and produce unhealthful stack emissions. This type of waste can be added to waste oils only after the individual batch has been determined to be free of halogen. If the oil fails the tests outlined in Chapter 3, it is probably due to improper segregation and should be disposed of separately. Suspect materials are trichloroethane (O-T-6200, trichloro-trifluoroethane (MIL-C-81302), constant speed drive fluid (MIL-S-81087), and various cleaning compounds.

2.3.3 Type B, C, D, and E Oil Products. These can be utilized readily as a burner fuel by either burning them straight or blending with the fuel oil in use or by providing a separate waste oil burner in the boiler. Certain basic requirements must be met, but in general, a wide range and large quantity of waste oil from these types can be reused.

TABLE 2-l
Oil Product Types

Type	Characteristics[a]	Product Examples
A. Gasolines	Hazardous, very low flashpoint	Automotive gasoline Aviation gasoline JP-4
3. Kerosenes	Clean burning light fuel, low flashpoint (lOO°F minimum), less volatile than. gasolines	FOl JP-5
C. Diesel Fuels	Flashpoint lOO°F minimum, slightly viscous	F02 Marine diesel Automotive diesel
D. Other Fuel Oils	No. 4-Moderately viscous, odoriferous, flashpoint 130°F minimum No. S-Viscous, odoriferous, flashpoint 130°F minimum No. 6-"Black oil," very viscous, odoriferous, flashpoint 140°F minimum	F04 through F06
E. Petroleum-Based Oils	Generally high flashpoint, viscous fluid or semisolid greases	Lubricating oils/greases Hydraulic fluids Transmission fluids
F. Synthetic/Chemical-Based Oils and Solvents	Similar to petroleum-based oils but may contain halogens; combustion products may be toxic and hazardous	Lubricating oils/greases Hydraulic fluids Brake fluids

[a]Flashpoint values taken from ASTM D396, Standard Specification for Fuel Oils.

2.3.4 Lubricating Oils. When disposing of used lubricating oils, the activity in question should examine the feasibility of re-refining in order to conserve natural resources. If re-refining is not economical, the oil should be used as a boiler fuel in order to recover the energy content. Other methods, such as use for dust control, are no longer allowed.

Since air emissions are directly affected by the type of fuel being burned ; local, state, or federal air pollution control agencies often restrict the fuel composition. EPA has developed the following guidelines:

Arsenic	5 ppm
Cadmiun	2 ppm
Chromium	10 ppm
Lead	100 ppm
PCBs	50 ppm
Total Halogen	4,000 ppm
Flash Point	100 °F

Waste oils meeting these specifications can be burned in any energy recovery system subject to analyses and recordkeeping requirements. However, if any specification level is exceeded, then the oil is termed "off specification used oil fuel" and can be burned only in industrial and utility boilers. In November 1986, EPA decided not to list waste oil as a hazardous waste under the Resource Conservation and Recovery Act. However, EPA intends to establish standards for waste oil and require tests for chlorine, lead, arsenic, cadmium, and chromium content, ignitability, and flashpoint.

Local and state agency requirements are often more stringent than EPA, thus waste oil composition restrictions must be evaluated on a case by case basis. For example, EPA does not list waste oil as a hazardous waste, yet some states, such as California, do consider waste oil as a hazardous waste. California requires waste oil to be managed as a hazardous waste until it has been recycled, disposed, or transported out of state; manifests may be required should the oil exceed certain purity standards, including a PCB concentration level of 5 ppm, and a lead concentration level, after January 1, 1988, of 50 ppm.

Do not limit waste oil composition restrictions solely on EPA, state, or local agency waste oil requirements; consider Occupational Health and Safety Administration (OSHA) requirements as well. While a waste oil may not be termed a hazardous waste, upon combustion these contaminants will concentrate within the boiler ash. Handling and disposal of this ash, which may now he considered hazardous according to OSHA, may require special provisions. Further waste oil con-position restrictions may be required to minimize handling and disposal problems.

2.4 BOILER FUELS PRESENTLY USED. Natural gas and liquefied petroleum gases are the first choices for fuels due to their ease of use, handling characteristics, cleanliness, and subsequent low maintenance requirements. However, the use of less desirable fuels, such as fuel oils, has become necessary due to their availability and the shortage of natural gas in some regions. Waste oils generated at Navy activities are considered attractive substitutes or supplements for fuel oils.

Consumption of natural gas, liquefied petroleum gases, fuel oils (GLO), and other energy sources are presented in Table 2-2 for Navy shore facilities. About 20 percent of the total energy consumed by Navy shore facilities is in the form of fuel oils. Generation estimates (Table 2-3) show that on an overall basis, the Navy shore facilities may substitute waste oils for over 5 percent of the total Navywide fuel oil requirements. Depending on the particular activity, as much as 100 percent of the fuel oil. requirements may be met with waste oil.

TABLE 2-2
Estimated Annual Energy Consumption by Naval and Marine Corps Activities for 1983

Type of Energy Used	Energy Consumed[a]	
	10^6 MBtu[b]	% Total
GLO		
Natural gas	27.1	16.8
Liquid petroleum gases	0.3	0.2
Fuel oils	32.2	19.8
Electricity	96.3	59.5
Coal	3.8	2.4
Steam and hot water	1.9	1.2
Fuel oil reclaimed	0.1	0.1
Total	161.7	100.0

[a]Figures are illustrative only.

[b]1 MBtu ≅ 7.37 gallons of light fuel oil.

ASTM Specification D396 (Appendix E) classifies fuel oils into grades and places limitations on properties of the oils in each grade. These grades are described as follows:

2.4.1 Grade No. 1. This fuel is termed a light distillate oil because it is capable of being vaporized at relatively low temperatures at atmospheric pressure. Its intended use is almost exclusively for domestic heating where vaporizing-type burners convert the oil to a vapor by contact with a heated surface or by radiation. High volatility of the oil is necessary to ensure that vaporization occurs with a minimum of residue. This oil is a little heavier than kerosene, but modern-day practice places both No. 1 fuel oil and kerosene in the same class.

2.4.2 Grade No. 2. This is a heavier distillate than grade No. 1 and comes from the refinery fractionating tower after the No. 1 oil. Its intended use is in atomizing-type burners, which spray the oil into a combustion chamber where the droplets burn while still in suspension. This grade of oil finds use in both domestic and medium-capacity commercial/industrial applications where its cleanliness and ease of handling sometimes justify its higher cost over that of residual oils.

2.4.3 Grade No. 4. This oil is a variable and complex mixed classification. It is usually a light residual, but it is sometimes a heavy distillate. This oil is of lower viscosity than No. 5 or No. 6 fuel oils and is intended for use in burners equipped to atomize oils of higher viscosity than domestic burners can handle. Its limited service includes use in small boilers for schools and apartment buildings, forging furnaces, and low-heat installations. Its viscosity range allows it to be pumped and atomized at relatively low temperatures requiring no preheating for handling except in extremely cold weather. A refinery usually does not attempt to produce this grade of oil because of its low sales volume.

2.4.4 Grade No. 5. This is a residual fuel of intermediate viscosity for burners capable of handling fuel more viscous than grades 1, 2, or 4 without preheating . Preheating may be necessary for use in some types of equipment for burning and for handling in cold climates.

2.4.5 Grade No. 6. This is a heavy, black residual of the refining process and is sometimes referred to as “Bunker C." It is a high viscosity oil used primarily in commercial and industrial heating. It requires preheating in the storage tank to permit pumping and additional heating at the burner to permit atomization. The equipment and maintenance required to handle this fuel usually prevents its use in small installations.

Table 1 of ASTM D396 lists the various grades of fuel oils with their respective specifications (see Appendix E).

TABLE 2-3
Waste Oil Generation and Usage by EFD

EFD[b]	Fuel Oil Usage[c] (1,000 MBtu)	Waste Oil Distribution[a]		
		Waste Oil Generated (1,000 MBtu)	Ratios (%)	
			Burned/ Generated	Generated/ Fuel Oil Used
NORTHDIV (58)	7,647	42	3.9	0.6
SOUTHDIV (81)	1,539	311	15.9	20.2
CHESDIV (28)	3,764	23	16.9	0.6
LANTDIV (78)	13,418	291	4.6	2.2
WESTDIV (96)	3,919	890	2.8	22.7
PACDIV (57)	6,757	299	63.5	4.4
TOTAL (398)	37,044	1,856	15.3	5.0

[a] For FY83, based on NCEL's waste oil generation/combustion experience survey (one gallon of waste oil ≅ 0.1357 MBtu).

[b] Figure in parentheses indicates the number of locations surveyed in each EFD.

[c] Based on FY83 DEIS II report.

2.5 AIR EMISSION CONSIDERATIONS. The applicable local, state, and federal air emission regulations must be met. However, since air emission regulations vary from state to state, and from district to district within a state, evaluate air emission restriction levels on a case by case basis; be aware that an air pollution control district may require waste oil analyses, source emission tests, permit modifications, and possibly even require health risk assessments. Modifying the existing operating permit may simply require notifying the district of a fuel change, yet it may require installation of additional air pollution control equipment, or operation improvements to meet New Source Performance Standards (NSPS), or Best Available Control Technology (BACT). Air emissions are directly affected by the type and composition of the fuel being burned, the method of burning, and the combustion efficiency of the energy recovery unit. Air pollutants of major concern from burning waste oils are particulates, lead, and organics. Particulate and lead emissions are submicron size which contribute to adverse respiratory effects and are at levels often higher than those from conventional fuel oil combustion. High emission levels can be attributed to the higher ash and lead concentrations in the waste oil. Organic emissions also contribute to adverse health affects. However, organic emissions are often the result of solvent contaminated waste oils. This can be minimized by segregating the waste oil.

Although particulate and lead emission concentrations tend to be higher in waste oils, and there is a potential for organic emissions, the combustion properties of waste oil are not significantly different from those of conventional fuels and often display the following air emissions:

2.5.1 Particulate Matter. This is the nongaseous portion of the combustion exhaust consisting of all solid and liquid material (except water droplets) suspended in the exhaust gases. It is generally defined as any material that would not pass through a very fine filter. Particulate matter can be composed of unburned fuel, sulfur compounds, carbon, ash constituents in the fuel (including many toxic metals), and even noncombustible airborne dust entering the combustion air system. Current devices to remove particulate matter include filtration, mechanical separation, and electrostatic precipitation.

2.5.2 Sulfur Dioxide. SO_2 is a nonflammable, colorless gas that can be "tasted" in concentrations of less than 1 ppm in the air. In higher concentrations it has a pungent, noxious odor. SO_2 and SO_3 are formed in the combustion process when sulfur contained in the fuel combines with oxygen from the combustion air. SO_2 and SO_3 comprise the total oxides of sulfur, generally referred to as SO_x. SO_3 is usually no more than 5 percent of the total SO_x generated. Essentially all sulfur contained in the fuel is converted into SO_2 and SO_3, and is not highly affected by boiler operating conditions or design. Although regulating the quantity of sulfur in the fuel is the primary method of controlling SO_x emissions, stack gas scrubbers can also be effective in removing SO_2 from the combustion exhaust.

2.5.3 Nitrogen Oxides. Nitric oxide (NO) and nitrogen dioxide (NO_2) are generated in the combustion process. These compounds are referred to as NO_x. NO is a colorless, odorless gas that is not considered a direct health threat in the concentrations found in the atmosphere. NO_2 is considerably more harmful and comprises typically 5 percent or less of total NO_x emitted from boiler stacks. Once in the atmosphere, however, a large fraction of the NO is converted into NO_2. NO_2 is a yellow-brown colored gas having a pungent, sweetish odor. NO_x is formed spontaneously during the combustion process when oxygen and nitrogen are present at high temperatures. Because all three (oxygen, nitrogen, and high temperatures) are essential to the combustion process, it would be difficult to prevent NO_x formation. Nitrogen is present in the combustion air and fuel itself. Lower peak flame temperatures and reduced excess oxygen, or a combination of both, have been effective in reducing NO_x formation. Future techniques will scrub NO_x from the exhaust gases before they enter the stack.

2.5.4 Carbon Monoxide. CO is a product of incomplete combustion. Its concentration in exhaust gases is usually sensitive to boiler operating conditions. Improper burner settings, deteriorated burner parts, and insufficient air for combustion can cause high CO emissions. CO is toxic, invisible, odorless, and tasteless.

2.5.5 Hydrocarbons. These are also indicative of incomplete combustion and can be greatly reduced by proper boiler operation. However, hydrocarbons cannot be entirely eliminated; trace quantities will nearly always be present, regardless of boiler operation. Hydrocarbons are active ingredients in the formation of photochemical smog, and under certain atmospheric conditions can be transformed into other potentially more hazardous derivatives.

2.5.6 Oxidants. Oxidants are oxygen-bearing substances that take part in complex chemical reactions in polluted atmospheres. Photochemical reactions that are intensified in the presence of sunlight involve nitrogen oxides (NO_x) and reactive organic substances (hydrocarbons and their derivatives) as principal chemical ingredients. These react to form new compounds like ozone and PAN (peroxyacyl nitrates), which are the major oxidants in smog. While ozone and PAN are not generated in the boiler, the principal ingredients (especially NO_x) are supplied by the exhaust gases.

2.6 COMBUSTION CONSIDERATIONS. Waste oil may be burned in a variety of energy recovery systems such as kilns, diesel engines, space heaters, or boilers. Boilers designed to burn No. 6 fuel oil and most No. 4 and No. 5 fuel oil fired boilers can be used to burn waste oils without major modifications. However, boilers designed for lighter fuels may require modifications to insure satisfactory combustion efficiencies and to ensure compliance with air emission regulations. To improve combustion efficiency and thus reduce air emissions, adjust the boiler viscosity and burner controls and pretreat the fuel. Segregate oils to minimize contaminants. Gravity separate, filter, or centrifuge oil to remove water, sludge, and solids or blend waste oil with virgin fuel oil to minimize the detrimental affects of the waste oil. These modifications are further discussed in Chapter 3.

2.7 COMPARISON OF BURNING WASTE OIL VERSUS RE-REFINING. Recent rulings require that all waste oils be turned over to the nearby fuel supply depot to be classified as FOR for sale. Since FOR is composed primarily of contaminated distillate fuels, studies were conducted for the Naval Petroleum Office to refine FOR into diesel fuel which will command a higher price. To determine the merit of refining waste oil, the following simple analysis was made.

Let P_d, P_2, P_f, and C_r be, respectively, the price (per gallon) for diesel fuel, No. 2 fuel oil, FOR, and the cost of transporting FOR to the refinery and refining. The total net income to the Navy is compared for the following two options:

1. User buying FOR and burning it as boiler fuel:

	Revenue/ Budget	cost	Gain/ Savings
Fuel Depot	P_f	0	P_f
User	P_2	P_f	$P_2 - P_f$
Total savings to-the Navy			R_2

2. User buying refined FOR and using it as diesel fuel:

	Revenue/ Budget	cost	Gain/ Savings
Fuel Depot	P_d	c_r	$P_d - C_r$
User	P_d	P_d	0
Total savings to the Navy			$P_d - C_r$

Thus, since P_2 and P_d are usually the same, the Navy will realize less savings by the refining option, the difference being the costs for refining, Cr. In other words, for each gallon of FOR refined, the Navy loses C (about 20¢). This does not include the costs due to material losses (FOR cannot be totally converted to diesel fuel) and waste disposal (residue from refining).

In conclusion, to refine FOR into diesel fuel will cost the Navy at least C_r per gallon. For locations where FOR is generated, but there is no demand for fuel oils, it is recommended that the FOR be transported to the closest user for boiler firing. (Remember that for refining, the FOR must be transported to the refinery site, regardless.)

2.8 ECONOMICS OF BURNING WASTE OIL. The economics of burning waste oil as a supplemental fuel is of interest in public works management and in justifying facility projects for utilization of waste oil. While the specifics will be different for each activity, most of the economic factors are common, and guidelines for calculating costs and savings can be determined (see Appendix C for elements to be considered). The following required functions are computed for using the waste oil as a fuel versus selling it from a central storage tank.

Burning as a Fuel:

- collection and segregation
- transportation and centralization
- water and sludge removal
- testing
- storage
- mixing/blending

Sale:

- collection (segregation is sometime required)
- transportation and centralization
- water and sludge removal (not required in some cases)
- storage

2.8.1 Comparison of Burning Versus Sale. The following comments on the functions of these two alternatives apply to most activities:

- The cost of collection and transportation of the waste oil will be the same for both methods of disposal.
- Certain waste oil products must not be burned and must be segregated and handled separately. Under some sale contracts and other disposal methods this segregation is not required. Consequently, there may be a unique cost of segregation associated with burning.
- At most sites, the only treatment required prior to burning or sale is gravity separation of the water and solids. The costs will be about equal for both cases.
- The cost of storage for sale is unique. A tank must be dedicated for waste oil if the oil is to be sold. If water/solids removal is accomplished elsewhere, the waste oil to be burned may be placed directly into boiler fuel tanks. (A separate dedicated waste oil tank may be installed at the boiler plant for convenience.) Therefore, the cost for selling waste oil is necessarily greater than the cost for burning.

2.8.2 Cost of Burning Waste Oil   Based on the above typical cost and savings factors for use in calculating the economics of burning the waste oil are as follows:

Recurring Costs:

- o Segregation required only for burning.
- o Testing to determine safe burning properties.
- o Mixing/blending of waste oil with new fuel, if required.
- o Price that waste oil could be sold for under contract. (If waste oil is burned, the income loss from potential sale is a cost of burning.)

One-Time Costs:

- o New facilities and equipment required to use waste oil as a fuel.

Savings:

- o Cost of new fuel not purchased due to burning waste oil.

If the savings in fuel purchases are greater than recurring costs, the payback period for the one-time cost can be calculated (see Appendix C for details).

CHAPTER 3. PROCEDURES FOR BURNING WASTE OIL AS A BOILER FUEL

3.1 SCOPE. This chapter discusses segregation and collection of waste oil, centralized storage, treatment, quality control, and delivery to the boiler plant. The specifics will vary with each shore activity.* Therefore, only general discussions for each type of source are included. Fuel analyses in terms of physical/chemical constraints and tests for evaluation of the waste oil are prescribed. Blending and viscosity control of the waste oil are described to provide insight into necessary operational changes, modifications to existing equipment, and additional equipment required. Unique maintenance and operational requirements that may be encountered are discussed, and recommendations regarding recordkeeping for documentation of future waste oil burning experience are provided..

3.2 SEGREGATION. Presence of caustic, acidic, and halogenated compounds in waste oils may cause corrosion to fuel system components and produce combustion products which are harmful to the boiler and which may pollute the environment. Such compounds may come from detergents, industrial wastes, solvents, cleaning fluids, synthetics, etc. Proper segregation not only will minimize the possible hazards due to undesirable contaminants but also lessen the effort and cost of treating the waste oil.

The segregation at the source of wastes nonburnable as boiler fuels is relatively simple. Oil products that must be segregated are listed in Appendix D. The identification and separate collection of nonburnable products at shore industrial areas and shops are within the control of the activity and can be accomplished through indoctrination of personnel and by providing facilities that make segregation easy. The segregation of those wastes aboard ship before they enter the bilge is not within the control of the shore activity, but there are steps that can be taken to improve the quality of the waste pumped ashore.

3.2.1 Ship Waste Oil Segregation. Segregation is not applicable to the oily wastewater pumped from bilges. Any undesirable contaminants present in that waste will have to be accepted and, once the waste is dewatered, testing must determine if the waste oil is suitable for burning. In most cases, nonburnable type wastes in the oil will be so diluted by quantity that no problems will be encountered with burning. Nevertheless, if the hazardous oil products in use aboard ships can be identified and publicized and the ships prevailed upon to segregate such wastes and move them ashore separately, the quality of the waste oil will be improved. Waste oils brought ashore in properly labeled drum/containers can be segregated at the source if the products are identified ahead of time and containers provided.

*Waste oil is burned at many Navy activities. Contacts for these activities are listed in Appendix F.

3.2.2 Industrial Waste Oil Segregation. If an aggressive program for collecting and burning waste oil is established by an activity, publicizing the results in dollar savings and energy conservation will help in obtaining cooperation in segregation. Containers and collection at necessary frequencies must be provided to lessen the workload of separate handling. Once it becomes standard procedure in a shop to handle certain wastes separately, the procedure will continue. Original containers may be saved and reused for waste collection. Drums, with appropriate signs or labels, may be placed in or near shops for disposal of "dirty" and "clean" waste oil products. As with other types of recyclable products (such as paper and metals) the difference in time, labor, and trouble required to reclaim the item rather than throw it away is very small once it becomes part of the routine.

3.3 CENTRALIZED STORAGE. Burnable waste oil should be centralized in storage prior to delivery to the boiler plant or contractor-receiving points. It is costly to have a waste oil buyer pick up small quantities at many locations. Tank trucks or trailers may serve as mobile storage for collecting and storing the waste oil between source and boiler plant.

Unless the waste oil is stringently treated prior to burning, or unusually clean when collected, gravity separation will be required to remove water and solids. Large quantities of "clean" waste oil (e.g., contaminated jet fuel declared unusable for aircraft) generated at one time should be delivered directly to the boiler plant when possible to avoid further degradation by mixing with other waste oils.

3.4 TREATMENT--WATER/SLUDGE REMOVAL. Waste oil may contain varied amounts of water, sludge, and solids. Excessive water in oil may cause flame out; sludge and solids may plug up the fuel system, cause excessive wear in nozzle tip and pump components, etc. They must be removed from the waste oil before it can be safely fired in a boiler. At present, an oil that contains no free water* and that can pass through an 80-mesh screen filter is considered reasonably adequate for boiler firing.

Water, sludge, and solids may appear in the waste oil either in a form more or less separated from the bulk of the oil or suspended in it in various emulsified states. In general, they may be removed simply by gravity separation. By leaving the oil in a tank undisturbed for enough time, they will eventually settle at the tank bottom and can be easily removed. When sufficient time is not available, the gravity separation process may be accelerated by heating the oil to some safe temperature (e.g., with a steam coil heater to 150°F), by using a centrifuge, or by adding a commercial chemical demulsifying agent. If the waste oil appears to be a stable emulsion (having poor demulsibility by the above methods), mixing it with light fuels such as contaminated JP-5 or diesel will help accelerate the demulsification before the gravitation separation process. (The amount of light fuel to be used depends on the nature of the emulsion. Adding one part of fuel in five parts of waste oil would be a good starting point.)

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*Refer to water visibly separated from the oil as distinguished from water suspended in the oil in an emulsified state.

3.5 FUEL ANALYSIS. Waste oils obtained through proper segregation and water/sediment removal as described above are primarily mixtures of hydrocarbons. Other than the appearance, they should have properties similar to regular fuel oils. The characteristic properties of a variety of randomly selected oil samples were measured and the results are shown in Table 3-1. Based on historical data 'available from the Navy's waste oil and FOR experiences, a realistic quality control standard has been proposed as presented in Table 3-2 (in result, MIL-F-24951 has been developed and is included in Appendix A). ASTM Specifications for No. 2 and No. 4 (light) fuel oils are also included in Table 3-2 to show that waste oils are fairly similar to these oils. Since specifications are concerned only with ranges and limits, fuel oils of the same grade are likely to have different property values. The variability of properties of waste oils is expected to be even greater.

The properties directly affecting the safety and operations of a boiler are discussed below (see Appendix E for the applicable ASTM test methods):

3.5.1 Gravity (or degrees API). This is an indirect measure of the fuel density. The carbon-to-hydrogen ratio and heating value of fuel oils can be estimated reasonably well from their gravities as shown in Figure 3-1. The carbon-to-hydrogen ratio affects the combustion air requirements (the fuel-air ratio), and the heating value affects the burner firing rate. Adjustment of the burner for efficient burning will, therefore, be required when fuels of different gravities are fired.

3.5.2 Viscosity. This is a measure of the resistance of the oil to flow and atomize. t-or a burner to function properly, the fuel must be within a certain viscosity range. Since viscosity is highly temperature dependent, this is achieved by heating the oil to the appropriate temperature (see "Viscosity Control," Section 3.7).

3.5.3 Flashpoint. This is the lowest temperature at which a fuel may be ignited under specified conditions. It is, therefore, a measure of safety. The minimum flashpoint for commercial grade fuel oils is 38°C (lOO°F) (see Appendix E).

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[1] 40 CFR, Part 226.40

[2] Used oil containing more than 1000 ppm total halogens is presumed to be hazardous waste under 40 CFR, Part 266.40. This will have a large impact on the economics of oil burning.

TABLE 3-1
Properties of Some *Oils* Tested

Properties	Fuel Oil No. 6	Fuel Oil No. 5	Fuel Oil No. 2	Heavy Shale Oil	Used Lube Oil	Ship's Waste Oil	Contaminated JP5
API Gravity	23		34	22	26.1	29.1	40.6
Heating Value (HHV, Btu/lb)	19,150	18,576	19,560	18,420	19,270	19,390	19,770
Viscosity, SUS @ 100°F	324		35	150	527	60	31
Flashpoint, °F	245		168	295	370	260	145
Water and Sediment, %	0.12	0.44	< 0.1	1.0	<0.1	0.12	3.4
Carbon Residue (Ramsbottom), %	3.44		0.12	2.0	1.11	0.17	0.10
Copper Strip Corrosion	S.T.[a]		S.T.		S.T.	S.T.	S.T.
Carbon, %	86.61	85.02	86.11	85.8	85.08	86.18	86.05
Hydrogen; %	12.25	11.53	12.94	11.19	13.13	13.13	13.43
Nitrogen, %	0.24	0.33	0.022	1.95	0.074	0.008	0.004
Sulfur, %	0.28	1.31	0.082	0.46	0.44	0.081	0.086
Ash, %	0.016	0.032	< 0.001	0.007	1.36	0.001	0.001
Oxygen, % by Difference	0.60	1.78	0.85	0.59	0	0.60	0.43

[a] S.T. = slight tarnish.

TABLE 3-2
Proposed Quality Control Standard for Navy Waste Oils

Property	Proposed Quality Control Standard	ASTM Spec for Fuel Oil		Applicable ASTM Test Method
		No. 2	No. 4 Light	
Water/sediments, vol % max	1.0	0.05	0.50	D1796
Sulfur, wt % max	local regulation	0.5	----	D129 D1552 D2662
Flashpoint, °C (°F) min	38 (100)*	38 (100)	38 (100)	D93
Copper strip corrosion, max	4C*	No. 3	----	D130
Gravity (deg API, 60/60°F)	34*	30 min	30 max	D287
Viscosity, cSt at 40°C (104°F)	4*	1.9 min 3.4 max	----	D445
Distillation temperatures, 90% points °C (°F)	----	282 (540) min 338 (640) max	----	D86
Ash, wt % max	0.10*	----	0.05	D482
Carbon residue on 10% bottoms, % max	1.0*	0.35	----	D524
Pour point, °C (°F) max	-6 (20)*	-6 (20)	-6 (20)	D97

*Reference only. Not to be considered as limiting constraints.

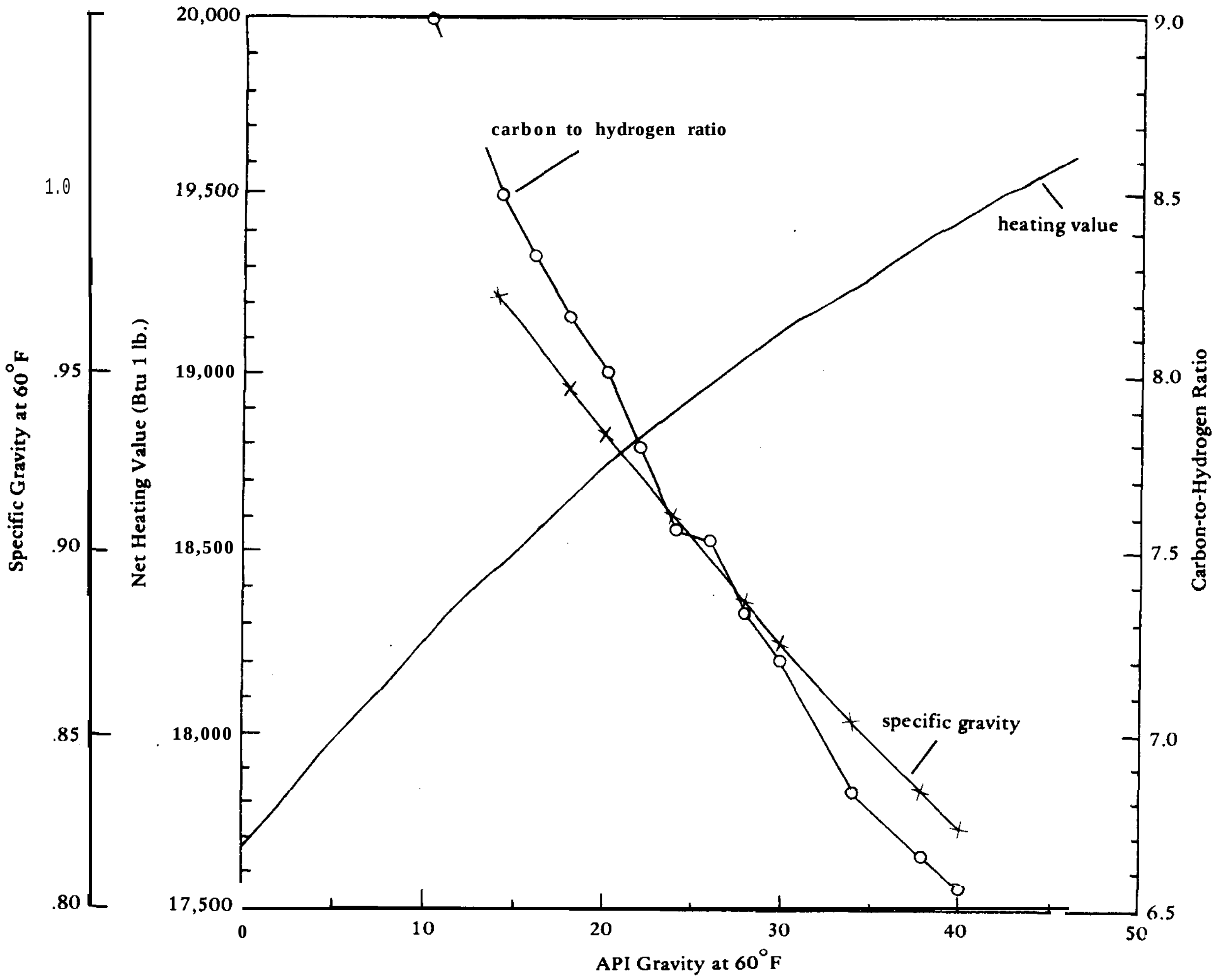


FIGURE 3-l
Relationships between heating value, carbon-to-hydrogen ratio, specific gravity, and API gravity.

3.5.4 Water and Sediment. Water in oil may cause unstable flame or flameout. Sediment may cause fuel system blockage and accelerated wear. Excessive amounts of these must not be tolerated. If the waste oil collection procedure described earlier is followed, no difficulty should be encountered during burning.

3.5.5 Chemical Contamination. Due to the uncontrollable nature of individual practice in waste oil collection, contamination by undesirable chemicals may still be possible. The following simple methods may be used to periodically determine the quality of the waste oil.

(a) Copper Corrosion Test. Maintain the oil at 50°C (122°F) and immerse a well polished sample copper strip for 3 hours. The relative corrosiveness of the oil is determined by the extent of tarnishing of the strip. For example, according to ASTM Specification D130, Detection of Copper Corrosion from Petroleum Products by the Copper Strip Method, the maximum allowable tarnish designation for commercial grade No. 1 and No. 2 fuel oils is 3, and no maximum is specified for heavier oils. A tarnishing value of 4 was reported from occasional tests of the waste oil generated in the San Diego and Norfolk areas. No adverse experience from these oils has been reported however.

(b) Copper Wire Test. The undesirable contaminants found in waste oils are primarily chlorinated compounds. This test will determine the acceptable level of chlorine in the waste oil.

A clean copper wire is heated in a clear, blue gas flame to red heat until no green shows in the flame. The wire is dipped while still hot into a sample of waste oil and then put back into the flame. If the flame turns green the oil has unacceptable levels of chlorine. For practice, a blend of 1 percent trichloroethane in DFM or other distillate fuel may be used as an example of an oil which fails this test. The oil sample should be purged of any sodium chloride prior to the test by washing with freshwater.

If an oil fails this test, it is probably due to improper segregation. It can be salvaged by blending it into known quality oil so that it becomes acceptable or is disposed of in accordance with NAVSUP Publication 4500, Consolidated Hazardous Item List.

3.5.6 Sulfur Content. Maximum allowable sulfur in oil is regulated by local authorities (e.g., 0.5 percent in California). The main ingredients of waste oil (e.g., JP-8, JP-5, F-76, lubricating oil) are primarily low sulfur materials. Therefore, the sulfur content of waste oils is usually low. Occasional determination of the sulfur content in waste oil would be adequate.

A sufficient overview of the waste oil properties can be achieved if testing is performed once or twice each month for a 6-month period. Although the physical/chemical properties of the waste oil may vary considerably between shore activities, the properties should remain fairly uniform for any one given activity. If the above properties are known, the waste oil is then somewhat predictable and necessary adjustments for burning and blending can be properly accomplished.

3.6 BLENDING. Two possible methods of blending waste oil with fuel oil are: direct and in-line blending. Direct blending is the addition of the waste oil directly into existing fuel oil tankage. If the waste oil being added to the tank is lighter than the normal fuel oil, it should be pumped in at the bottom of the tank as shown in Figure 3-2a. The lighter oil will tend to mix as it rises through the heavier oil. If the waste oil is heavier than the fuel in the tank, it should be pumped in on top as shown in Figure 3-2b. The heavier oil will tend to mix as it falls into the fuel. The tank contents should then be circulated to achieve a homogeneous mixture. Care must 'be exercised to insure that the filler pipe opening is immersed below the fuel surface in order to prevent splashing and accumulation of electrical charges and that the oil suction line is not located directly at the bottom of the tank to prevent the intake of any water or sediments. Direct blending tests show that no special attention is required to burn the waste oil, except sometimes to adjust the temperature of the blend so that its viscosity is nearly the same as that of the regular fuel oil.

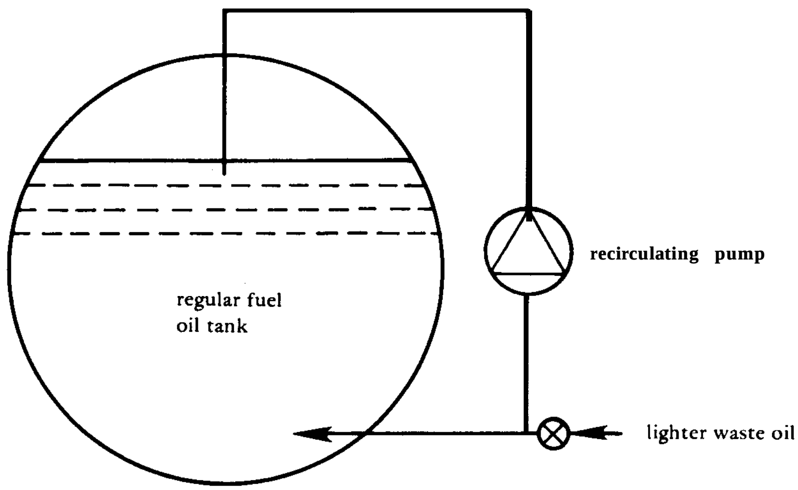
In-line blending is simple and practical with either distillate or residual fuels. Even though additional equipment is necessary, the effort and expenses are minimal. A waste oil supply and in-line blending scheme is shown schematically in Figure 3-3. In this scheme, the waste oil is introduced into the suction side of the main fuel pump of the existing system to insure thorough mixing. Temperatures are taken at three locations, and a sampling port is provided downstream of the pump so that the waste oil concentration can be measured by either the "Temperature Method" or the "Specific Gravity Method" described below. The recirculating pump near the waste oil tank is used for stirring the waste oils in the tank, as necessary, to insure a homogeneous mixture. (Depending on the specific installation, one may consider the possibility of using the existing fuel transfer pump for this purpose to cut overall cost.) Experience gained thus far shows that in-line blending is simple to implement and works in an acceptable manner.

3.6.1 Specific Gravity Method. Let γ_1, γ_2, and γ_3 be the specific gravities, respectively, of the regular fuel oil, waste oil, and their blend at the same temperature. The waste oil concentration, C, would be approximately :

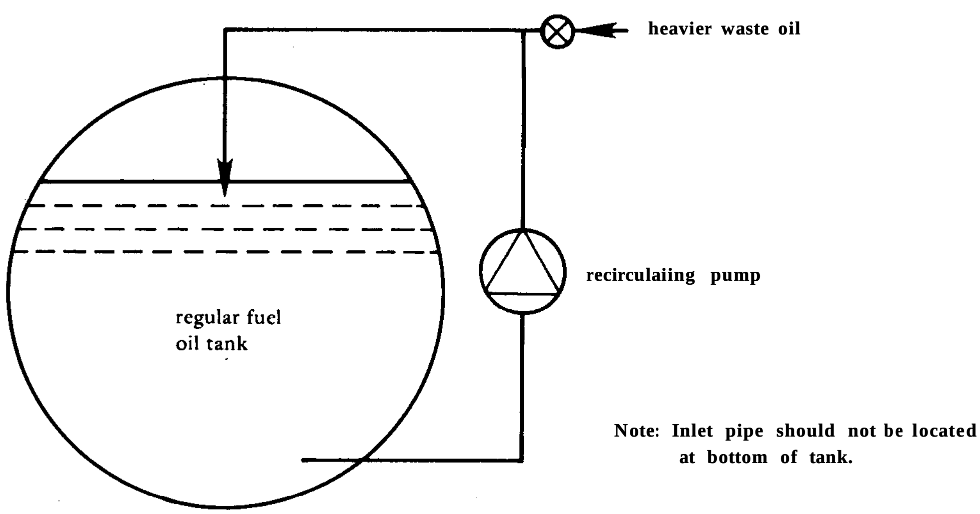
$$C = \frac{\gamma_3 - \gamma_1}{\gamma_2 - \gamma_1} \times 100\ \%$$

For this method, an ordinary hydrometer, a thermometer, a glass cylinder, and a sampling port close to the burner nozzle in the fuel system will be required. This is a one-time measurement, but the accuracy is good, the procedure is simple, and the initial investment is minimal. The accuracy of this method increases with the difference between γ_1 and γ_2.

3.6.2 Temperature Method. Let T_1, T_2, and T_3 be the temperatures, respectively, of the regular fuel oil, waste oil, and their blend. If these temperatures are measured at locations fairly close to one another and the mixing takes place without the loss or gain of heat, the waste oil concentration would be approximately:



3.2(a) Blending with waste oil lighter than regular fuel.



3.2(b) Blending with waste oil heavier than regular fuel.

FIGURE 3-2
Schemes for direct blending of waste oil with
regular fuel.

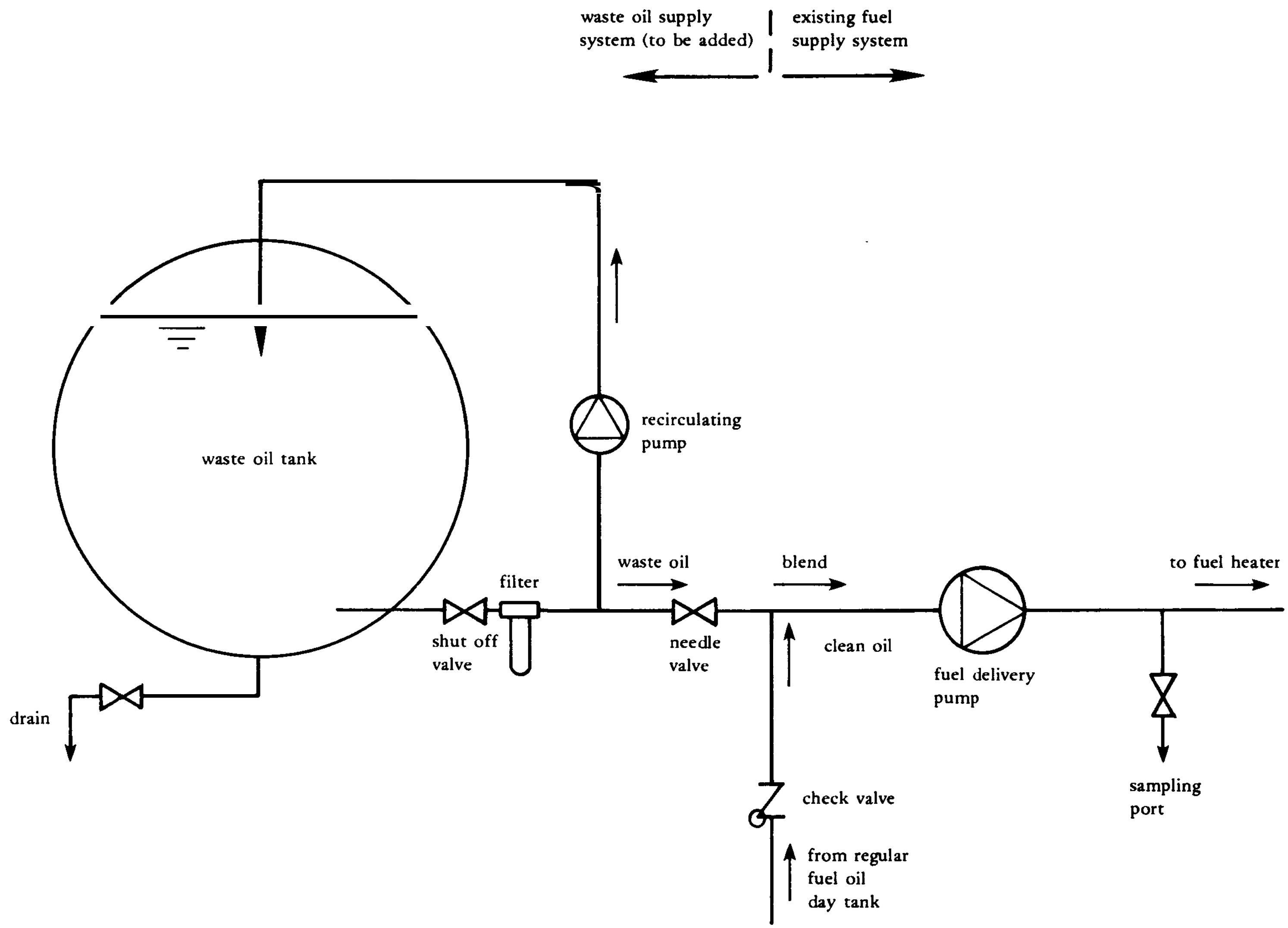


FIGURE 3-3
A scheme for in-line blending of waste oil with regular fuel.

$$C = \frac{T_3 - T_1}{T_2 - T_1} \times 100\%$$

Some inherent errors exist due to the assumptions used. This method is ideal for continuous monitoring if automatic recording devices are used and is particularly helpful when blending oils of nearly equal specific gravities.

3.7 VISCOSITY CONTROL. Waste oil added to regular fuel affects the viscosity of the blend and,. hence, the fuel flow rate and nozzle spray characteristics. To minimize the requirements for burner adjustments the firing temperature of a blend should be controlled so that its viscosity is nearly the same as that of the regular fuel oil at its normal firing temperature. The viscosity variation with the temperature of typical fuel oils may be estimated by using the viscosity-temperature charts for liquid petroleum products 'in Schmidt's Fuel Oil Manual. A working chart for determining the approximate operating temperature of fuel oil blends is shown in Figure 3-4. The one on the left is used to determine the viscosity of a blend of two oils of different viscosities (all in SUS* at 100°F), and the one on the right shows the temperature variation of viscosity for oils whose viscosities at 100°F are known. The use of these graphs is illustrated in the following example:

A burner is designed for burning heavy fuel oil with a viscosity of 1,000 SUS at 100°F. This oil is heated to 180°F to achieve satisfactory firing. A light waste oil with a viscosity of 50 SUS at 100°F will be blended into the heavy fuel oil to supplement the boiler fuel. To fully utilize this light waste oil, its concentration in the blend is determined to be 30 percent. What is the satisfactory operating temperature of this blend?
From the right-hand graph of Figure 3-4, along the diagonal line labeled 1,000 SUS, we find that the viscosity of this oil at 180°F is 125 SUS. This is also the viscosity of the blend needed in order to achieve the desired performance. From the left-hand graph, a line is drawn connecting 1,000 SUS for the high viscosity component and 50 SUS for the low viscosity component to determine the viscosity of a 30 percent waste oil blend which is slightly less than 300 SUS. Again on the right-hand side of the graph, along the line labeled 300 SUS, we find that to attain 125 SUS the oil should be heated to 140°F. This is shown in the graphical construction.

3.8 BURNER MODIFICATIONS. Minor adjustments are sometimes necessary to correct unstable combustion and smoke emission similar to the routine adjustments for firing clean fuel.

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*Saybolt Universal Seconds.

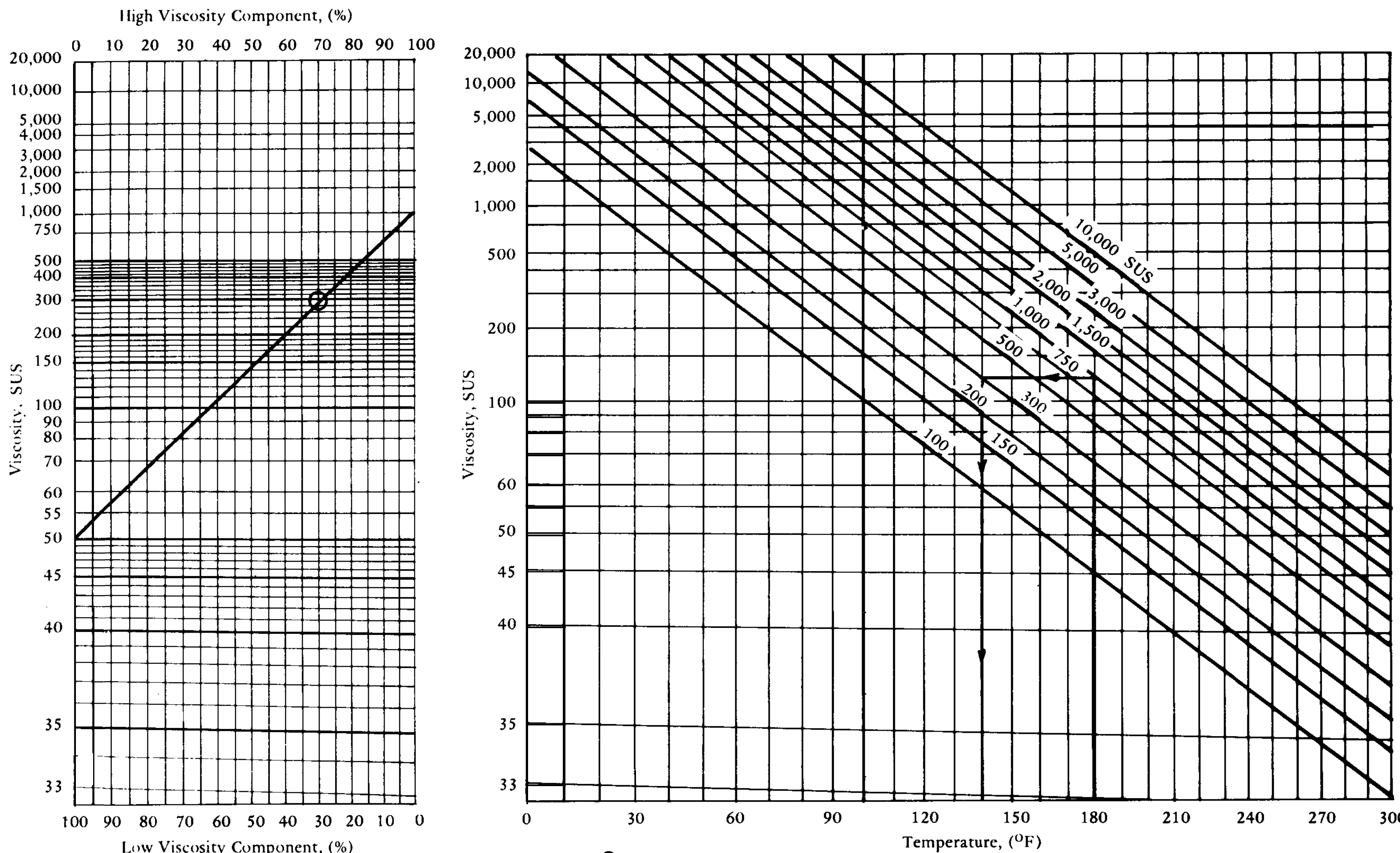

FIGURE 3-4
Charts for determination of firing temperatures for blending fuels.

3.9 MAINTENANCE AND OPERATION REQUIREMENTS. Large amounts of water and bottom sediment are commonly found in waste oils. Excessive amounts of water in oil can cause flameouts, and excessive solid concentrations can cause accelerated wear and damage to boiler equipment. Removal of water and solids from the waste oil prior to burning is essential. Gravity separation is usually satisfactory. Accelerated separation may be achieved by heating the oil, blending with other light oil, or using a centrifuge. Generally, waste oils free of water and sludge can be satisfactorily fired in boilers either straight or in blends with regular fuel oils. Problems that may be encountered in burning waste oil are:

- Fine lint buildup in barrels and nozzles which are hard to clean.
- More frequent cleaning of fuel strainers, up to four times as often. Use of a duplex strainer is highly recommended.
- Carbon deposit buildup around the nozzle tip areas due to improper burner adjustments or worn nozzle orifices (Figure 3-5).

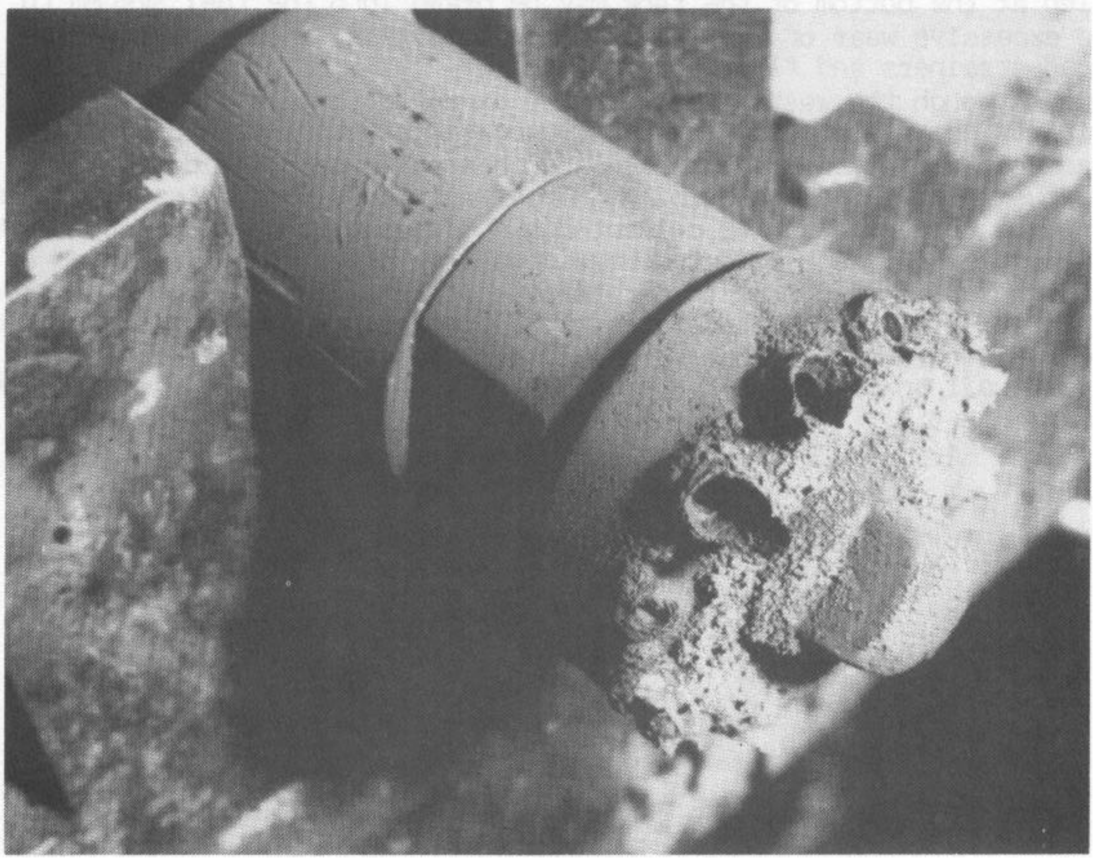

FIGURE 3-5
Nozzle tip with carbon deposit buildup.

• Rise in flue gas temperature due to deposit buildup, on heat transfer surfaces.

• Substantial ash buildup in the fire box, deposits on boiler tubes, and fly ash.

Figures 3-6 and 3-7 show typical deposits that developed on a fire-tube boiler after burning FOR for about 3,800 hours. Figure 3-8 shows similar deposits on the water tubes in the fire box of a water tube boiler after burning waste oil. White and green flaky deposits are usually seen on the boiler surf aces. These deposits are made up of compounds of aluminum, zinc, silicon, phosphorous, calcium, iron, and copper. They were believed to be from detergents, dirt, and rust picked up in the reclamation process. These deposits are easy to clean and have no adverse effects on the boiler.

Because of the usually high noncombustibles and contaminants, ash deposit problems resulting from burning used lubricating oil blends increase with its concentration. To minimize maintenance, a concentration of less than 25 percent used lube oil in the blend is recommended.

Waste oil or FOR should be drawn at a level at least 12 inches above the lowest point or the bottom of a tank. Otherwise, sediment and water settled at the bottom of the tank may be drawn into the fuel system to cause excessive wear of fuel pumps and nozzle tips, inoperative valves, and plugged strainers and flow passages.

Even though the waste oil cannot be expected to meet the standard specification of fuel oil, it can be used satisfactorily, provided some precautions are taken. Synthetic- and chemical-based liquids may be hazardous in handling and burning. These materials must be segregated at the source of generation or collected and disposed of according to NAVSUP Publication 4500: Consolidated Hazardous Item List. Identification of these liquids is discussed in Chapter 2. It is necessary that the waste oil be free from halogenated material to prevent toxic gas emissions and accelerated corrosion of the fire side surfaces of the boiler. Testing of the waste oil to determine the presence of such contaminants is discussed in Section 3.5.5.

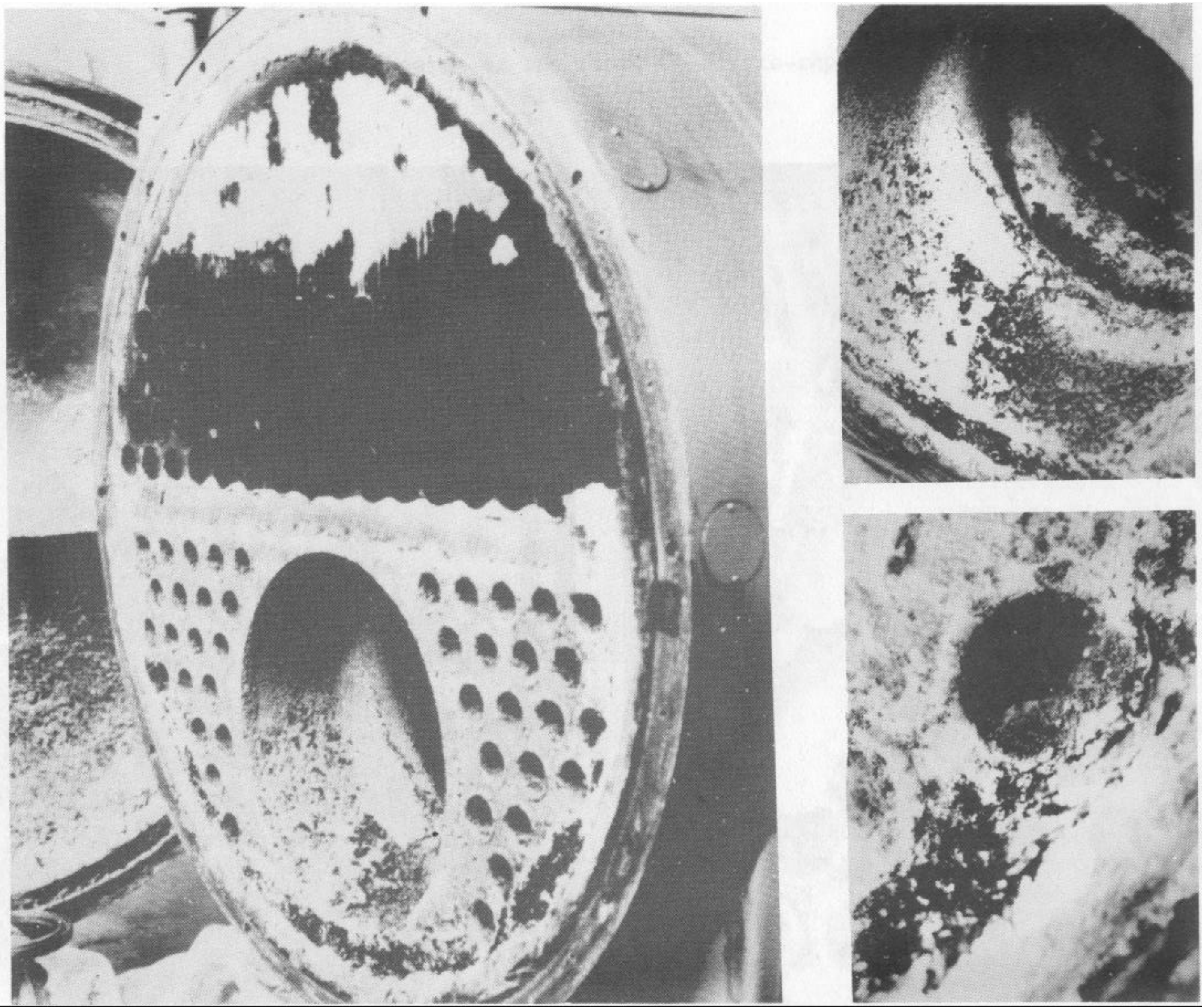

FIGURE 3-6
Typical deposits at the back of a fire-tube boiler after burning FOR.

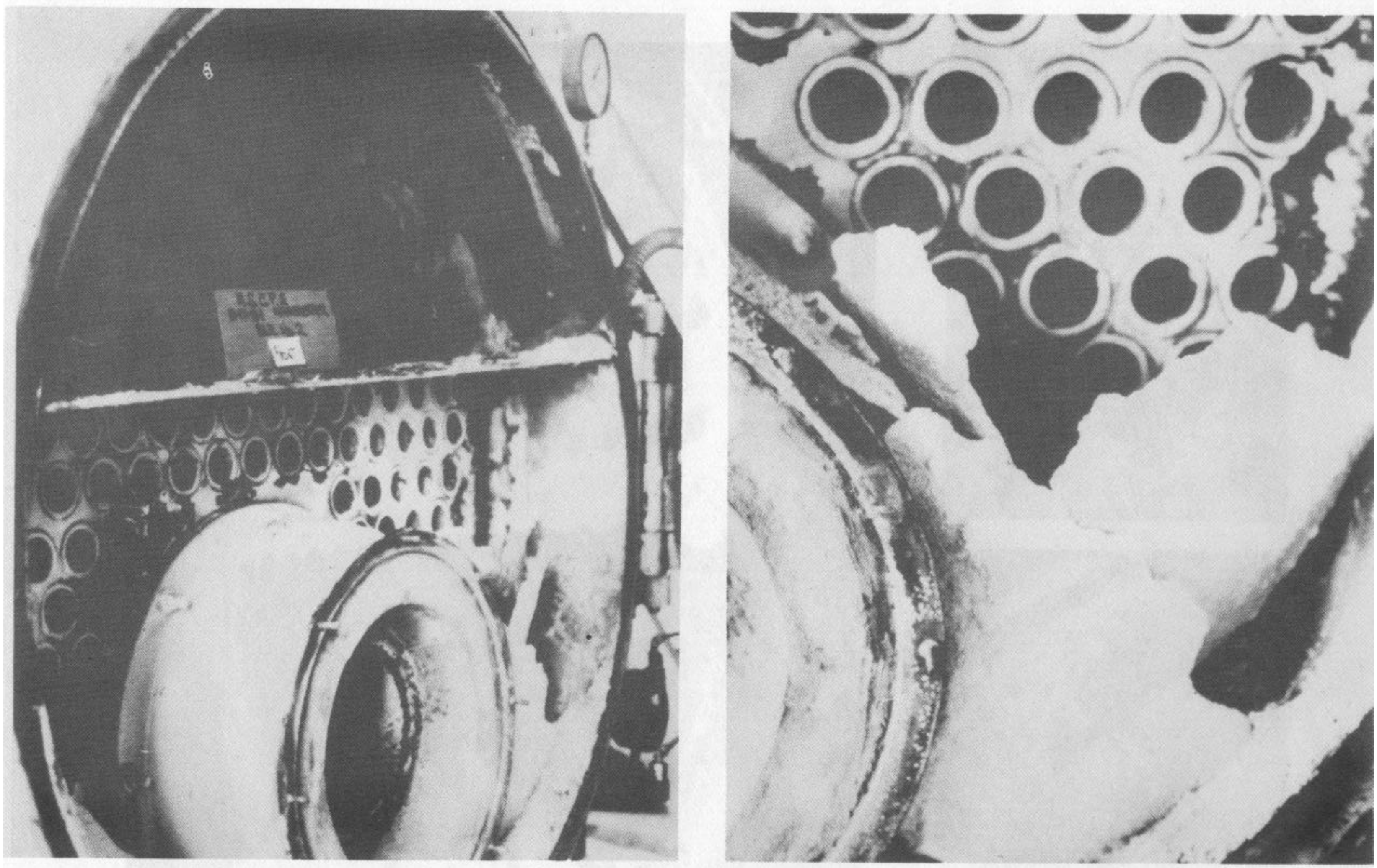

FIGURE 3-7
Typical deposits at the front of a fire-tube boiler after burning FOR.

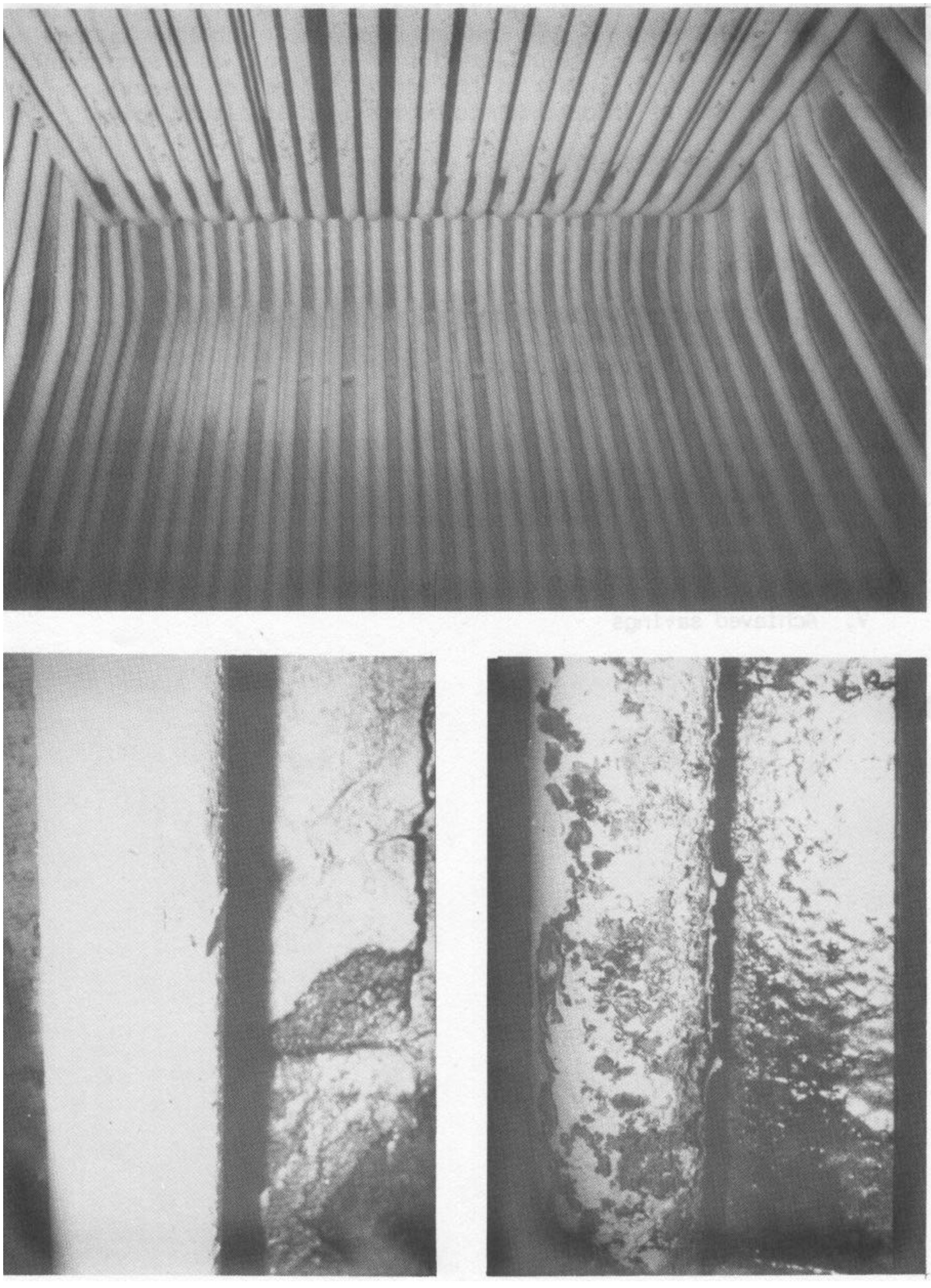

FIGURE 3-8
Typical ash deposits on boiler tubes of a water-tube boiler after burning waste oil

3.10 RECORD KEEPING. In order to (1) further its use, (2) improve upon current technique and procedure, and (3) show achieved dollar savings, information pertaining to the utilization of waste oil as a supplemental fuel should be included as part of the record for boiler operations. A recommended outline of information to be recorded is listed below:

I Sources of waste oil

II. Quantity of waste oil burned

III. Quality control

A. Methods of segregation
B. Treatment methods
C. Physical/chemical testing
D. Blending methods

IV. Effects of use and unique maintenance and operation requirements

A. Problems in operation
B. Unusual maintenance requirements
C. Equipment modification and adjustment requirements
D. Stack emissions

v. Achieved savings

APPENDIX A

MILITARY SPECIFICATION FOR FUEL OIL RECLAIMED

MILITARY SPECIFICATION

FUEL OIL RECLAIMED

This specification is approved for use by the Department of the Navy.

1. SCOPE

1.1 Scope. This specification covers Fuel Oil Reclaimed (Stock Number NSN 9140-01-068-6903) which is produced as a product of Navy reclamation operations (product use is described in 6.1).

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of sale by the Navy, form a part of the specification to the extent specified herein.

STANDARDS

FEDERAL
FED-STD-791 - Lubricants, liquids Fuels, and Related Products: Methods of Testing

MILITARY
MIL-STD-290 - Packaging, Packing and Marking Petroleum and Related Products

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of sale by the Navy shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
D 88 - Saybolt Viscosity
D 93 - Flash Point by Pensky-Martens Closed Tester
D 97 - Pour Point
D 129 - Sulfur in Petroleum Products by the Bomb Method
D 270 - Sampling Petroleum and Petroleum Products
D 287 - API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
D 445 - Viscosity of-Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)

D 473 - Sediment in Crude and Fuel Oils by Extraction
D 874 - Sulfated Ash from Lubricating Oils and Additives
D 1796 - Water and Sediment

(The ASTM methods listed above are included in parts 23 or 24 of the Annual Book of ASTM Standards and are available individually. Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

3. REQUIREMENTS

3.1 Material. Fuel Oil Reclaimed shall consist of a mixture of distillates and residual fuel and may contain waste lubricants or other recycled products.

3.2 Physical and chemical requirements. Fuel Oil Reclaimed shall conform to the physical and chemical requirements given in Table-1. Any requests for waivers from these requirements will be addressed to Navy Petroleum Office for approval.

TABLE-l- Chemical and Physical Requirements

Characteristics	Requirements	FED-STD 791 Test Method	Test Method
API Gravity @ 60°F (hydrometer) (range)	25-40		ASTM D 287
Viscosity at 104°F (40°C) Kinematic, centistokes (range)	2.0 - 15.0		ASTM D 445
Viscosity @ 122°F (50°) Saybolt Universal (range)	30 - 90		ASTM D 88
Flash point, °F (min)	130°F (55°oC)		ASTM D 93
Pour Point., °F (max)	20°F(-6.7°C)		ASTM D 97
Sulfated Ash, percent (max)	0.15		ASTM D 874
Water & Sediment, percent (Max)	2.0		ASTM D 1796
Neutrality	Neutral	5101	
Sediment Percent (max)	0.5		ASTM D 473
Chlorinated Material 1/	No Green Flame		
Sulfur content, percent (max)	2.0		D 129 2/ or or other approved ASTM method
Explosiveness, Percent (max)	50	1151.1	

Arsenic	5 PPM Max	3040*/3050
Cadmium	2 PPM Max	EPA SW-846
Chromium	10 PPM Max	& proposed
Lead	100 PPM Max	method for evaluating solid waste
Total Halogen	4,000 PPM Max	ASTM D 806-81

*Recommended only for non-sedimentacious oils.

1/ FOR shall be essentially free of chlorinated material. To determine the presence of chlorinated material, a clean copper wire is heated in a clear blue gas flame, to red heat, until no green shows in the flame. The wire is dipped while still hot, into a sample of FOR and then put back into the flame. No green shall show in the flame. (For practice, a blend of 1% of Trichloroethane in F76 or other distillate fuel may be used as an example of an oil which fails this test also. The oil should be purged of any sodium chloride by washing with fresh water.)

2/ In the U.S.A., sulfur limits shall be as specified by the Environmental Protection Agency, state or community where the fuel is to be used, whichever is more restrictive. In foreign countries, the sulfur limit shall conform to the limit established in the Status of Forces Agreement.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the purchase order, the Navy is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified in the purchase order, the Navy may use its own or any other facilities suitable for the performance of the inspection requirements specified herein.

4.2 Bulk lot. An indefinite quantity of a homogeneous mixture of Fuel Oil Reclaimed offered for acceptance in a single isolated container. Upper, middle and lower samples will be taken as described in ASTM D 270. Section 14. Samples may be cornposited to a single sample if the lot is homogeneous. If the lot is' not homogeneous, specification tests will be performed separately on the upper, middle and lower samples.

4.3 Homogeneity. The homogeneity of product will be determined by measuring API gravity using ASTM test method D 287. Lots will be considered homogeneous if the determinations for the upper, middle and lower samples do not vary from the average by more than 0.5 for API gravity..

4.4 Sampling. Take samples for tests in accordance with ASTM method D 270.

4.5 Inspection. Perform inspection in accordance with 9601 of FED-STD-791.

4.6 Classification of tests. All tests are quality conformance tests.

4.7 Test methods. Perform tests in accordance with Table 1.

5. PREPARATION FOR DELIVERY

5.1 Packaging, packing and marking. Unless otherwise specified in the purchase order packaging, packing and marketing shall be performed in accordance with MIL-STD-290.

6. NOTES

6.1 Intended use. Fuel Oil Reclaimed can be used as a substitute for Burner Fuel Oil (FED-SPEC W-F-815D), either directly or as a blend in stationary fuel-burning furnaces for heating buildings, for the generation of steam or for other purposes.

6.2 Navy responsibilities. The Navy is responsible for assuring that the Fuel Oil Reclaimed meets all the requirements listed in Table 1.

6.3 User responsibilities. The user is responsible for any on site blending and all operational or equipment modifications necessary to assure that the Fuel Oil Reclaimed is burned in a safe and efficient manner.

Preparing activity:
Navy - SA

Project No. 9140-N105

Custodian:
Navy - SA.
Review activities:
To be determined
User activities:
To be determined

APPENDIX B

ENERGY USAGE AND WASTE OIL GENERATION/USAGE BY LOCATIONS SURVEYED

Location	Energy Usage			Waste Oil Distribution			
	Fuel Oil (MBtu)	All Fuel/ All Energy (%)	Fuel Oil/ All Fuel (%)	Waste Oil (MBtu)	WO/F0 (%)	Burned/ Generated (%)	Disposal Method
NORTHDIV							
Bloomfield, CT (1)	10,058	22.1	42.0				
New London, CT (4)	1,341,982	44.0	100.0	15,739	1.2	0	A
Glenview, IL (1)	228,865	65.3	97.9	?	0.0	-	-
Great Lakes, IL (6)	9,347	63.8	0.4	1,710	18.3	0	A
Crane, IN (1)	481,728	47.0	99.1	1,305	0.3	23	A,E
Indianapolis, IN (1)	48,146	24.2	45.4	738	1.5	100	E
Olathe, KS (2)	5,924	53.4	20.5	0	0.0	-	-
Brunswick, ME (1)	342,000	47.7	100.0	1,995	0.6	0	A
Cutler, ME (1)	271,797	81.7	100.0	1,018	0.4	0	A
Winter Harbor, ME (1)	43,229	32.6	100.0	29	0.1	0	A
Bedford, HA (1)	40,728	34.5	91.7				
Pittsfield, HA (1)	74,504	26.3	63.6				
South Weymouth, MA (1)	89,311	49.5	78.7	1,108	1.2	49	B,D,E
Minneapolis, MN (2)	59,966	36.2	15.3				
St. Paul, MN (1)	0	29.4	0.0				
Kansas City, MO (1)	0	49.7	0.0	0	0.0	-	-
Portsmouth, NH (1)	1,303,851	74.1	100.0	3,596	0.0	0	A
Colts Neck, NJ (1)	147,570	43.7	99.3	543	0.4	0	A
Lakehurst, NJ (2)	460,693	57.6	100.0	1,985	0.4	10	D,E
Trenton, NJ (1)	153,447	24.4	100.0	0	0.0	-	-
Bethpage, NY (1)	231,340	31.2	63.4				
Brooklyn, NY (1)	46,364	39.2	39.4	7	0.0	0	B
Calverton, NY (1)	252,520	36.0	99.7				
Garden City, NY (1)	6,740	35.7	84.9	0	0.0	-	-
Rochester, NY (1)	0	33.8	0.0				
Scotia, NY (1)	24,705	42.7	79.8	0	0.0	-	-
Ravenna, OH (1)	4,256	55.8	9.3	0	0.0	-	-
Toledo, OH (1)	336	19.2	0.6				
Mechanicsburg, PA (1)	300,387	32.2	90.3	305	0.1	0	A
Philadelphia, PA (10)	524,794	59.6	15.2	10,335	2.0	0	A,B
Warminster, PA (1)	98,248	27.1	77.0	543	0.6	0	A
Willow Grove, PA (1)	28,948	46.1	24.9	950	3.3	0	A
Davisville, RI (1)	28,351	43.6	54.9	678	0.0	0	A
Newport, RI (5)	987,309	52.6	87.4	2687	0.3	0	A
LANTDIV							
Louisville, KY (1)	0	42.0	0.0	1,628	-	0	A
Alleghany Ballistics Lab (1)	214,204	54.7	100.0				
Camp Lejeune, NC (2)	1,174,355	42.5	55.1	13,570	1.2	0	A
Cherry Point, NC (2)	157,420	29.2	20.4	46,003	29.2	0	A,D

continued

Location	Energy Usage			Waste Oil Distribution			
	Fuel Oil Only (Mbtu)	All Fuel/ All Energy (%)	Fuel Oil/ All Fuel (%)	Waste Oil (MBtu)	**WO/FO** (%)	Burned/ Generated (%)	Disposal Method
LANTDIV (continued)							
Chesapeake, VA (2)	29,073	16.4	99.0				
Dam Neck, VA (3)	301,300	38.1	100.0				
Driver, VA (1)	2,742	1.7	100.0				
Little Creek, VA (1)	789,940	46.0	83.2	6,160	0.8	0	F
Norfolk, VA (18)	4,262,183	38.1	92.9	17,380	0.4	0	F
Oceana, VA (1)	440,694	39.8	78.0	13,569	3.1	0	D,F
Portsmouth, VA (4)	1,771,459	45.8	86.8	145,878	8.2	0	A
Virginia Beach, VA (1)	48,444	19.5	100.0	430	0.9	0	A
Yorktown, VA (2)	420,356	50.7	100.0	1,085	0.3	0	F
Sugar Grove, WV (2)	2,444	13.7	21.8	20	0.8	0	D
Bermuda (3)	284,710	79.2	99.4	163	0.1	0	?
Guantanamo Bay, CU (5)	1,813,792	100.0	100.0	13,569	0.8	100	E
Keflavik, ICLD (3)	405,684	54.7	43.3	2,714	0.7	0	D
La Meddalena, IT (1)	5,706	11.7	87.1				
Naples, IT (3)	97,561	21.7	99.4	560	0.6	0	B
Sigonella, IT (2)	51,289	12.7	94.6	0	0.0	-	-
Argentia, NFLD (1)	161,127	62.7	100.0	244	0.2	0	B
Rota, SP (2)	614,203	64.3	100.0	27,519	4.5	0	A
Brawdy Wales, UK (1)	37,790	44.6	100.0	556	1.5	0	C
Edzell, UK (1)	98,808	35.3	93.5	27	0.0	0	B
Holy Loch, UK (1)	12,321	25.0	79.4				
London, UK (1)	15,262	20.3	76.1	7	0.0	0	B,D
St. Mawgan, UK (1)	0	100.0	0.0				
Thurso, UK (1)	14,748	11.9	100.0	45	0.3	0	B,D
Bahrain Is, Bahrain (1)	0	0.0	-				
Nea Makri, GR (1)	142,512	70.0	100.0				
Souda Bay, GR (1)	4,251	16.5	100.0	136	3.2	0	D
Galeta Is, PN (1)	0	0.0	-				
Antigua, AC	4,920	16.7	100.0	27	0.5	0	D
Rodman, CZ (1)	1,786	1.0	100.0				
Balboa, CZ	0	0.0	-				
Roosevelt Roads, PR (3)	34,464	3.0	93.9				
Sabana Seca, PR (1)	2,550	2.0	100.0	204	8.0	0	B
PACDIV							
Barbers Point, HI (2)	20,013	7.5	91.1	1,357	6.8	0	
Barking Sands, HI (1)	17,289	14.0	100.0	814	4.7	50	D,E
Camp H.M. Smith, HI (2)	9,985	4.7	96.1	14	0.1	0	A
Honolulu, HI (1)	17,601	2.9	100.0	15	0.1	100	E
Kaneohe Bay, HI (1)	59,491	6.7	96.2	3,460	5.8	100	E
Lualualei, HI (1)	2,298	2.0	100.0	28	1.2	0	B
Pearl Harbor, HI (13)	332,908	9.1	75.2	234,881	70.6	79	E
Atsugi, JA (1)	370,497	52.4	100.0	1,254	0.3	0	A
Iwakuni, JA (1)	219,112	35.8	100.0	8,142	3.7	0	B,D
(Camp S.D. Butler) Okinawa, JA (3)	567,059	21.5	99.4	136	0.0	0	B

continued

Location	Energy Usage			Waste Oil Distribution			
	Fuel Oil Only (MBtu)	All Fuel/ All Energy (%)	Fuel Oil/ All Fuel (%)	Waste Oil (MBtu)	WO/FO (%)	Burned/ Generated (%)	Disposal Method
PACDIV (continued)							
Sasebo, JA (1)	73,807	32.7	95.7				
Tokyo, JA (1)	25,274	53.0	87.0				
Yokosuka, JA (6)	1,325,827	49.1	100.0	19,677	1.5	2	A,E
Cubi Point, BP (1)	378,885	68.1	100.0	7,353	1.9	0	A,D
San Miguel, BP (1)	291,291	97.5	100.0				
Subic Bay, BP (6)	1,850,827	62.7	100.0	180	0.0	0	A,D
Agana, GQ (1)	14,953	4.7	100.0				
Guam, GQ (9)	80,111	2.9	100.0	20,530	25.6	0	A,D
Chinhae, KS (1)	23,675	42.5	100.0				
Diego Garcia, IO (1)	504,057	100.0	100.0				
Midway (2)	132,714	100.0	100.0	333	0.3	0	B,D
Harold E. Holt, AUS (1)	439,266	91.2	100.0	679	0.2	0	C
CHESDIV							
Annapolis, MD (5)	38,478	40.7	5.3	0	0.0	-	
Bethesda, MD (2)	583,317	33.9	46.0	769	0.1	?	A,E
Indian Head, MD (3)	879,186	90.0	64.8	951	0.1	0	A
Patuxent River, MD (3)	585,292	38.6	99.6	19,000	3.2	14	A,D,E
St. Inigoes, MD (1)	2,548	3.5	100.0				
Solomons Is, MD (2)	8,081	18.7	100.0				
Thurmont, MD (1)	16,313	22.4	100.0				
White Oak, MD (1)	76,511	40.6	40.9	407	0.5	0	B
Arlington, VA (1)	0	47.0	0.0	0	0.0	-	-
Dahlgren, VA (1)	86,956	17.0	100.0	543	0.6	0	A
Quantico, VA (1)	271,557	57.9	22.2	950	0.3	100	D,E
Washington, DC (7)	1,215,605	38.6	83.4	475	<0.1	63	A,E
SOUTHDIV							
Wetumka, AL (1)	0	0.0	-	0	-	-	-
Lewisville, AR (1)	0	0.0	-	0	-	-	-
Cecil Field, FL (1)	26,806	27.8	10.7	13,569	51	0	A
Homestead, FL (1)	764	1.7	97.8	8	1	0	B
Fort Lauderdale, FL (1)	0	0.0	-	14	-	0	B
Jacksonville, FL (6)	11,748	35.9	1.3	20,353	173	0	A,D
Key West, FL (3)	16,796	1.8	99.4	8,141	48	0	A
Mayport, FL (3)	365,433	18.3	99.7	54,280	0	16	E
Milton, FL (1)	0	33.9	0.0	678	-	0	A,D
Orlando, FL (3)	20,821	12.9	10.6	950	5	0	A
Panama City, FL (1)	20,417	13.4	74.1	4,038	20	0	C
Pensacola, FL (7)	69,695	65.9	2.7	8,142	0	0	A
Saddlebunch Keys, FL (1)	0	0.0	-	0	-	-	
Albany, GA (1)	3,690	31.7	1.2	6,784	184	0	A
Athens, GA (1)	416	26.2	2.0	14	3	0	B
Atlanta, GA (1)	854	31.9	3.1	1,018	119	0	A,D
Hawkinsville, GA (1)	0	0.0	-	0	-	-	-
Kings Bay, GA (1)	51,386	13.0	100.0	1,357	3	0	B
Savannah, GA (1)	0	0.0	-	0	-	-	-
New Orleans, LA (10)	6,164	18.3	3.1	1,153	19	0	A

continued

Location	Energy Usage			Waste Oil Distribution			
	Fuel Oil Only (MBtu)	All Fuel/ All Energy (%)	Fuel Oil/ All Fuel (%)	Waste Oil (MBtu)	WO/FO (%)	Burned/ Generated (%)	Disposal Method
SOUTHDIV (continued)							
Gulfport, MS (2)	0	27.5	0.0	1,954	-	0	A
Hollandale, MS (1)	0	0.0		0	-	0	-
Meridian, MS (1)	0	26.9	0.0	543	-	0	B
Pascagoula, MS (1)	0	14.5	0.0	0	-	0	-
Truth or Consequences, NM (1)	0	0.0	-	0	-	-	-
Beaufort, SC (2)	54,874	24.7	22.7	2,629	5	0	A
Charleston, SC (12)	843,248	32.0	43.2	175,340	0	23	B,C
Parris Is, SC (1)	28,347	70.2	3.4	679	0	0	A
Bristol, TN (1)	8,562	2.5	98.0				
Memphis/Millington, TN (4)	8,638	50.6	0.8	882	10	0	A,D
Archer City, TX (1)	0	0.0	-	0	-	-	-
Chase Field, TX (1)	0	14.6	0.0	1,729	-	0	A,D
Corpus Christi, TX (2)	0	27.3	0.0	841	-	0	A
Dallas, TX (3)	0	33.3	0.0	2,578	-	0	A
Kingsville, TX (1)	0	12.7	0.0	2,476	-	0	B
McGregor, TX (1)	0	41.7	0.0				
Andros Is, Bahamas (1)	242,929	100.0	100.0	489	0.2	50	D,E
WESTDIV							
Adak, AK (2)	1,219,258	100.0	100.0	8,142	0.7	100	E
Barrow, AK (1)	0	100.0	0.0	0	-	-	-
Maricopa, AZ (1)	0	0.0	-	0	-	-	
Yuma, AZ (1)	190	15.2	0.2	5,780	3042.1	0	A,D
Alameda, CA (3)	173,378	44.7	16.4	22,610	13.0	0	A,D
Big Sur, CA (1)	9,307	44.6	78.9	2	0.0	0	A
Barstow, CA (1)	82,339	48.7	27.8	25,254	30.7	0	A
Camp Pendleton, CA (2)	267,550	42.7	21.3	13,025	4.9	0	A
Centerville Beach, CA (1)	29,145	43.5	85.4	6	0.0	0	B
China Lake, CA (1)	33,396	40.6	4.9	5,428	16.3	75	D,E
Chula Vista, CA (1)	0	0.0	-				
Concord, CA (1)	31,775	36.9	32.9	407	1.3	0	A
Corona, CA (1)	0	11.6	0.0				
El Centro, CA (1)	2,420	12.0	11.6	204	8.4	0	A,D
El Toro, CA (1)	11,490	30.5	3.1	27,137	236.2	0	A,D
Fallbrook, CA (1)	1,062	17.4	16.3	3	0.3	0	B
Lemoore, CA (3)	7,015	32.5	1.8	5,427	77.4	0	B
Long Beach, CA (3)	4,042	31.8	0.4	203,528	5035.3	0	B
Miramar, CA (1)	135,410	30.8	49.6	33,921	25.1	20	D,E,F
Moffett Field, CA (1)	0	35.0	0.0	6,784	-	0	A,D
Monterey, CA (2)	1,469	38.4	0.7	20	1.4	0	A
Oakland, CA (4)	57,638	38.1	13.2	113,998	197.8	0	A
Pasadena, CA (1)	0	30.6	0.0	0	-	-	-
Pt. Mugu, CA (1)	119,183	29.0	35.8	3,256	2.7	0	D
Pomona, CA (1)	0	10.2	0.0				
Port Hueneme, CA (3)	8,672	24.5	3.7	3,731	43.0	0	A
San Bruno, CA (1)	0	20.9	0.0	0		-	-
San Diego, CA (22)	56,160	28.0	1.8	254,021	452.3	0	F
San Francisco, CA (3)	3,764	56.9	0.7	0	0.0	-	-
Seal Beach, CA (1)	0	24.1	0.0	271	-	0	C
Skaggs Island, CA (1)	1,088	27.1	4.4				-
Stockton, CA (1)	0	13.1	0.0	136	-	0	B

continued

Location	Energy Usage			Waste Oil Distribution			
	Fuel Oil Only **(MBtu)**	All Fuel/ All Energy (%)	Fuel Oil/ All Fuel (%)	Waste Oil (MBtu)	**WO/FO** (%)	Burned/ Generated (%)	Disposal Method
Sunnyvale, CA (1)	0	16.1	0.0	0	-	-	-
Treasure Island, CA (1)	36,101	64.2	9.2	0	0.0	-	-
Twentynine Palms, CA (1)	30,551	39.8	8.5	17,922	58.7	0	A
Vallejo, CA (4)	0	41.0	0.0	8,141	-	0	A
Bayview, ID (1)	0	0.0	-				
Fallon, NV (1)	146,684	53.4	78.6	8,005	5.5	74	D,E
Cooshead, OR (1)	8,496	31.0	100.0	47	0.6	0	B
Magna, UT (1)	0	73.3	0.0				
Bangor, WA (4)	178,415	23.2	34.5	20,353	11.4	0	F
Bremerton, WA (4)	1,149,986	38.3	88.5	88,195	7.6	0.2	E,F
Jim Creek, WA (1)	1,588	1.0	100.0				
Keyport, WA (1)	33,328	35.3	916.2	6,785	20.4	0	A
Manchester, WA (1)	13,650	65.1	100.0				
Oak Harbor, WA (1)	223	45.1	2.8				
Pacific Beach, WA (1)	11,492	30.8	100.0	90	0.8	0	F
Seattle, WA (2)	24,498	52.7	11.0	204	0.8	0	F
Whidbey Island, WA (2)	28,136	37.2	6.2	6,784	24.1	0	A,D

Notes : Figure in parentheses indicates number of activities surveyed at each location. Based on information found in CY83 report of DEIS II supplied by NEESA. One gallon of waste oil = 0.1357 MBtu. Disposition method notation: A = NAVSUP, DPDO or DLA handles resale; B = Sell or give to haulers; C = Pay to have hauled away; D = Used for local firefighting training; E = Used as an alternate boiler fuel; F = Give or sell to fuel depot for processing.

APPENDIX C

CONSIDERATIONS FOR BURNING WASTE OIL

CONSIDERATIONS FOR BURNING WASTE OIL

1. Waste Oil Generated

Sources	Amounts (gal./yr)
Ship Wastewater Treatment	____
Aircraft Maintenance	____
Transportation Shop	____
Navy Exchange Service Station	____
Auto Hobby Shop	____
Other Industrial Areas	____
Total Quantity/yr	____

2. Potential of Waste Oil Burning

$$\frac{\text{Waste oil generated/yr}}{\text{Fuel oil burned/yr}} \times 100\% = \text{\% of fuel oil requirements met with waste oil}$$

3. Capability for Burning Waste Oil

Oil-burning Boilers	
Number	____
Size	____
Type of Burner Equipment	____
Mode of Operation	____
Total Fuel Oil Requirement	____
Fuel Storage	
Capacity	____
Type of Handling Equipment	____
Blending Required	Yes _ No _
Fuel Testing	
In-house	Yes _ No _
Out of house	Yes_ No_
Evaluations	

4. Analysis of Waste Oil Generated

API Gravity	____
Water and Sediment Content	____
Flashpoint	____
Viscosity	____
Sulphur Content	____
Chlorine/Copper Wire Test	____

continued

5. Economic Analysis for Burning Waste Oil

a. $ savings/yr = quantity of waste oil generated/yr x (unit price of new fuel - sale price of waste oil) $________

b. Initial investment $________

C. Recurring costs/yr figured from following: $________

Function	Labor			Material cost	Total cost
	Hours	Rate	cost		
Nonburnable Waste Segregation Waste Oil Testing Mixing/Blending Other (site specific)					
Total					

d. net annual $ savings* = $ savings /yr - recurring costs/yr $________

e. Simple Payback Period (yr) =

$$\frac{\text{Initial investment for one time project}}{\text{net savings}}$$ $________

*Savings should exceed cost of burning the waste oil.

APPENDIX D

OIL PRODUCTS NOT TO BE USED FOR BOILER FIRING

Product Type A (Gasoline and Solvents)	Specification
Acetone, Technical	O-A-51F
Amyl Acetate	TT-A-511C
Amyl Alcohol, Secondary	TT-A-516D
Benzene, (Benzol), Technical	W-B-231C
Benzene, Nitration Grade	MIL-B-3137
Butyl Acetate, Normal	TT-B-838A
Butyl Acetate, Secondary	TT-B-840B
Butyl Alcohol, Normal	TT-B-846B
Butyl Alcohol, Secondary	TT-B-848B
Cleaning Compound, Solvent, Heavy Duty	O-C-1824
Cleaning Compound, Solvent	O-C-1889
1,1,1 - Trichloroethane, Technical Inhibited (Methyl Chloroform)	O-T-620C
Dry Cleaning Solvent	P-D-680
Ether, Petroleum, Technical Grade	O-E-751B
Ethyl Acetate, Technical	TT-E-751C
Ethylene Glycol Monobutyl Ether	TT-E-776B
Gasoline, Automotive	W-G-76B
Gasoline, Unleaded	W-G-109A
Gasoline, Automotive, Leaded and Unleaded	W-G-1690A
Gasoline, Automotive, Combat	MIL-G-3056D
Gasoline, Aviation Grades	MIL-G-5572E

Product Type F (Synthetic/Chemical Based Oils & Halogenated Solvents)	Specification
Brake Fluid, Automotive	W-B-680B
Brake Fluid, Silicone, Automotive, All-weather, Operational and Preservative	MIL-B-46167
Cutting Fluids Sulfurized Fatty & Mineral Oils	W-C-850A
Grease, Silicone for use with Ammunition	MIL-G-14931
Grease, Molybdenum Disulfide	MIL-G-21164C
Grease, Silicone	MIL-G-46886
Grease, Lubricating, Halofluorocarbon	MIL-G-47219
Hydraulic Fluid, Arresting Gear	MIL-H-5559A
Hydraulic Fluid, Nonpetroleum Base, Aircraft	MIL-H-8446B
Hydraulic Fluid, Polar Type Automotive Brake	MIL-H-13910B
Hydraulic Fluid, Fire Resistant	MIL-H-19457B
Hydraulic Fluid, Catapult	MIL-H-22072A
Hydraulic Fluid, Rust Inhibited, Fire-resistant, Synthetic Hydrocarbon Base	MIL-H-46170
Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft	MIL-H-83282A
Hydraulic Fluid, Fire Resistant, Phosphate Ester Base, Aircraft	MIL-H-83306
Insulating Fluid, Electrical (Non-Combustible)	w-1-1219
Lubricating Oil, Instrument, Aircraft, Low Volatility	MIL-L-6085A
Lubricating Oil, Aircraft Turbine Engines, Synthetic Base	MIL-L-7808G
Lubricating Oil, Synthetic (for mechanical time fuses)	MIL-L-11734C
Lubricating Oil, Aircraft Turbine Engines, Synthetic Base	MIL-L-23699B
Lubricant, Molybdenum Disulfide in Isopropanol	MIL-L-24478
Lubricating Oil,' Molybdenum Disulfide, Silicone Base, High Temperature	MIL-L-25681C

Product Type F (Synthetic/Chemical Based Oils & Halogenated Solvents	Specification
Lubricating Oil, Aircraft Turbine Engine, Ester Base	MIL-L-27502
Lubricating Oil, Instrument, Minus 65 Deg. to Plus 400 Deg.F	MIL-L-27694A
Lubricating, Fluorocarbon Telomer Dispersion (for use with ammunition)	MIL-L-60326
Lubricating Oil, Aircraft Turbine Engine, Polyphenyl Ether Base	MIL-L-87100
Silicone, Fluid, Chlorinated Phenyl Methyl Polysiloxane	MIL-S-81087B
Cleaning Compound, Solvent, Trichlorotrifluoroethane	MIL-C-81302C

(From: Naval Supply Systems Command. NAVSUP Publication 4500: Consolidated hazardous item list (CHIL LIST). Alexandria, Va., 1 Apr 1976.)

APPENDIX E

STANDARD SPECIFICATION FOR FUEL OILS

1. Use current edition of ASTM D 396, "Standard Specification for Fuel Oils."

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