United States
Environmental Protection
Agency

Air and Radiation

EPA420-R-99-027
August 1999

In-Use Marine Diesel Fuel

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U.S. Environmental Protection Agency

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EPA Contract No.68-C-98-170
Work Assignment No. 0-4

NOTICE

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I. Purpose

The primary goal of this task is to identify the fuel properties, particularly sulfur content for different types and grades of marine diesel fuels. Also, any variations by region were developed. The secondary goal is to characterize the use patterns of these fuels. These included variation by region and any trend analysis. For both goals, efforts were made to present the information and discuss the results separately for commercial marine fuels and recreational marine fuels. In the process of conducting this task, ICF identified critical information about the types of diesel fuels used for commercial and recreational purposes. In addition to the above information, ICF needed to clarify the terms that are used in the industry when referring to diesel marine fuels. The results of the task are presented in text and tables. The deliverable is organized as follows:

II. Summary of Important findings
III. Background on Fuels
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II. Summary of Important Findings

- The marine fuels used in recreational marine operations are primarily off-highway 2-D and on-highway 2-D. The marine fuels used in commercial marine operations are primarily distillates intermediate and residual oil. Thus, in this study to compare sulfur and fuel use information for recreational and commercial purposes, we compared data for off-highway 2-D and on-highway 2-D with distillates, intermediate and residual oil.
- The marine fuel industry uses specific names for distillate, intermediate and residual fuels. Marine diesel fuel is not a general term, but refers specifically to an intermediate type fuel.
- Diesel fuel used for recreational purposes generally has lower sulfur than diesel fuel used for commercial purposes.
- Diesel fuel used for recreational purposes is a small fraction of the diesel fuel used for commercial marine purposes.
- Fuel testing services, marinas, and refineries provided the wealth of property information on marine

fuels. Ports had no such property information.

- In a Northern California marina, No 2 on-highway is used as recreational marine fuel. In other selected marinas in parts of the country, No 2 off-highway is used. Thus, for recreational marine fuel, Northern California has much lower sulfur levels than recreational marine fuel in other parts of the country.
- Actual sulfur content for residual and intermediate marine fuels (e.g. commercial use) are not widely available.

The data and supporting information for these findings are provided below.

III. Background on Fuels

In the distillation processing (boiling off) of crude oil, there are four broad product fractions or categories generated: refinery gas (primarily methane, ethane and hydrogen), liquefied petroleum gas, (primarily propane and butane), gasoline, and distillate fuels. Each of these fuel categories boils at higher temperature ranges, until the oil will not boil without thermally decomposing. The nonboiling fraction is called residuum or residual oil.

Distillate fuels are further subdivided into several categories for specific uses. The "lightest," or lowest temperature boiling fraction (all distillate fuels broadly overlap in boiling range) is called kerosene, and is used for commercial jet turbine engines fuels, for small heaters and for wick-fed illuminating lamps. The next fraction, used during cold weather conditions for automotive or truck fuels in "compression ignition" engines, is called "diesel" fuel. The next higher boiling fraction is used for residential heating furnaces, called "home heating oil." This same boiling range oil is also used in warmer conditions as diesel fuel for larger land-based, on- and off-road engines, such as trucks, busses, earth moving and material lifting and moving equipment, farm equipment and railroad diesel locomotives. The next heavier fraction supplies fuel for industrial heaters and boilers. Finally, the "heaviest," or highest boiling distillate fractions are often blended with residual oil to make fuels for large steam boilers and, with fuel preheating, for very large compression ignition engines, such as ocean-going ships. Small and medium sized marine vessels use distillate fuels in several of these land-based categories, as described below.

IV. Clarification of Terminology for Diesel Marine Fuels

There are two basic types of marine fuels: distillate and residual. A third type of marine fuel is a mixture of these two basic types, commonly called "intermediate." Distillate fuel, as the name implies, is composed of petroleum fractions of crude oil that are separated in a refinery by a boiling process, called distillation. Residual fuel or "residuum" is the fraction that did not boil, sometimes referred to as "tar" or "petroleum pitch." Diesel fuel for marine use has the following types and grades:

TABLE 1
DIESEL FUEL TYPES FOR MARINE USE

Fuel Type	Fuel Grades	Common Industry Name
Distillate	DMX, DMA, DMB, DMC	Gas Oil or Marine Gas Oil
Intermediate	IFO 180 380	Marine Diesel Fuel or Intermediate Fuel Oil (IFO)
Residual	RMA-RML	Fuel oil or Residual Fuel Oil

To communicate effectively in a specialty field like "marine fuels" it is necessary to be clear on the definitions and jargon used in this industry (which is somewhat different from the fuel type names above). In the marine industry, distillate fuels are commonly called "Gas Oil" or Marine Gas Oil; residual fuels are called Marine Fuel Oil or Residual Fuel Oil; and intermediate types are called "Marine Diesel Fuel," or Intermediate Fuel Oil (IFO) (see Table 1). While the term "diesel fuel" for land based automobile and truck use is 100% distillate, in the marine industry Marine Diesel Fuel is the blend of distillate and residual oils (intermediate types). The 100% distillate type fuel in the marine industry is the Marine Gas Oil (implying by this name that it was boiled into a gas, then condensed into a liquid oil). Fuel Oil, or Residual Fuel Oil, refers to fuels that are primarily non-boiling fractions. Depending on the pressures and temperatures in refinery distillation processes, and the types of crude oils, slightly more or less gas oil that could be boiled off is left in the non-boiling fraction, creating different grades of Residual Fuel Oils. In other words, intermediate grades of fuel oil can be made directly in the distillation process or by blending with distillate. The term "intermediate" is more a colloquial term than a separate fuel type as defined by the American Society of Testing and Materials (ASTM) in the U.S., or in world standards.[12, 13, 14]

Another clarification that is necessary in this study involves the terms "recreational" versus "commercial" uses of marine vessels. The Environmental Protection Agency, EPA, has defined the terms "recreational marine engine" and "recreational vessel" in 40 CFR Part 94: Control of Emissions of Air Pollution From New CI Marine Engines at or Above 37 kW; Proposed Rule. Summarizing this definition, recreational implies "strictly for personal pleasure," or leased, rented or chartered to a group no larger than six people for their pleasure. Commercial implies a business interest in hauling, pushing or towing cargo, or servicing such cargo businesses, all for the purpose of earning money. "Racing," or "competition," is yet another category distinct from recreational and commercial. While a very few wealthy individuals may be able to own and operate ocean going large vessels, the classes of "recreational" marine vessels with compression- ignition engines are, by and large, yachts and recreational fishing boats.[13]

V. Fuels Used for Commercial and Recreational Marine Purposes

We obtained much anecdotal information related to fuel use patterns for commercial and recreational marine fuels. Sources include industry experts in fuel manufacturing and marketing[13, 20], marine fuel brokering services[12], marine fuel supply at ports[15] and marinas[16, 17, 18, 19], and marine fuel testing services.[14]

One common theme is that the world of commercial marine fuel supply is totally separate from the world of recreational marine fuels. Diesel fuel for marine applications depend on three things: engine used, cost, and availability. Commercial marine businesses have the higher volume and low-cost incentives to arrange deals with refiners to produce tailored marine fuels that are most cost effective for their engines. Commercial marine businesses arrange for fuels that involve less refining (leaving the sulfur in the fuel), and therefore lower cost than other diesel fuels. Commercial port fuel services and marine fuel broker services reported that commercial marine fuels are delivered by pipeline, boat or barge. The product that is supplied as DMA (Marine Distillate fuel A) is sometimes specially manufactured at local refineries with a higher sulfur content and lower price than land-based fuels rebranded for marine use. When that supply is short of demand, "Home Heating Oil" (No. 2 fuel oil) is used, provided the flash is above 60 degrees C, which it normally is. Similarly, DMC is sometimes supplied by local refineries from "cycle oil" (lower boiling point than No. 2 fuels), and is sometimes blended in the supply terminal from DMA and residual fuel oils.

Commercial marine fuel brokers, marine fuel testing service experts and commercial marine fuel supply services all report that DMA is the common fuel for tugboats, fishing boats, crew boats, drilling rigs, and ferry boats. Ocean-going ships that take residual fuel oil bunkers also take distillate fuels for use in auxiliary engines and sometimes for use in port. The common fuels are DMC, IFO-180 and IFO-380, depending on the specific engines in service. DMB is infrequently specified, and is not available in all ports. Where it is not available, DMA is supplied, sometimes in a barge that has transported DMC or IFO (hence, a "dirty" cargo hold that would contaminate DMA).

In contrast to commercial marine businesses, recreational boat owners have no volume leverage, and less cost-reduction incentives to arrange for special fuels. With the large overlap in boiling range with other distillate fuels, the sources of recreational marine fuels are often land-based fuels that can meet or exceed all specifications of the marine fuel. Therefore, distributors of recreational fuels take what is most available, which is truck and tractor diesel fuel and home heating fuel. Both of these fuel grades are given the designation "Number 2" (or No. 2-D diesel) fuel. All marinas, and all fuel suppliers, have reported that diesel fuel is delivered to marinas by tank truck, and the fuel is the same as provided to either on-road service stations or off-road supply stations. Some marinas[17, 18] said that their diesel fuel is dyed red (off-road) and others[19] said that it is "clear" (on-highway diesel). For example, the a Chevron diesel fuel expert[13] said that high sulfur diesel fuel is in short supply on the coasts, but much higher supply in the agriculture regions of the plains states. The fuel supply service for the St. Francis Yacht Club in San Francisco, CA[19], said that they provide only one diesel fuel, and it is clear (low sulfur on-highway fuel). In the North Eastern and North Central (Great Lakes) regions of the U.S., No. 2 "home heating oil" is commonly used for residential heating in the winter months. In these regions, the No. 2 fuel refined primarily in Gulf Coast refineries and transported north by pipeline is rebranded for certain marine fuels. On the West Coast, "on-" and "off-highway" No. 2 diesel fuel is commonly rebranded for certain marine fuel uses (See Appendix 1 for Estimate of Land Based Fuel Rebranded for Diesel Marine Fuel Use). For these reasons, the properties of land-based fuels and marine fuels will be compared and discussed in the report.

VI. Fuel Properties

A. Approach:

Fuel properties are the physical and chemical measures of fuel qualities that relate to fuel performance and handling characteristics.[11] We have analyzed fuel properties from three perspectives: specifications, actual properties and regional variations of properties. Information is provided for diesel marine fuels used in both commercial and recreational purposes. Sulfur content was of primary regulatory interest. Other properties compared include viscosity (an important determinant of fuel performance), cetane, and ash (an indication of the amount of heavy components in a fuel).

Fuel property standards are reported from six sources, as follows:

1. American Society for Testing and Materials (ASTM);[6]
2. Conseil International des Machines a Combustion (CIMAC);[7]
3. International Standards Organization (ISO);[8]
4. Platt's Guide to Petroleum Specifications;[5]
5. Major Petroleum Refining and Marketing Companies (Mobil and Shell).[9, 10, 22]

Actual properties are reported from three sources, as follows:

1. Det Norske Veritas (DNV) Petroleum Services;[2]
2. National Institute for Petroleum and Energy Research (NIPER);[3]
3. Anecdotal information from fuel marketing and brokering industry experts.

B. Results:

1. Fuel Specifications

Table 2 shows selected ASTM specifications of marine and land based fuels that are used in compression ignition engines. Specifications of interest are shown for IFO-180 and 380, DMA, DMB, DMC, and the heaviest residual fuels, RML-55. The land-based fuels are known to supply recreational marine uses. Also, Table 2 includes two "burner" fuels that are not manufactured for compression ignition engines, but as typically formulated, do serve as a source for marine fuels. One important difference between land-based distillate fuels and marine fuels, from the environmental perspective, is sulfur content. Land-based fuels are generally required by state and federal regulations to have lower sulfur levels than equivalent marine fuels. Sulfur is a naturally occurring component in varying concentrations in crude oils. In general the sulfur tends to concentrate in the higher boiling fractions. Hence, sulfur concentrations are naturally highest in residual fuel oil, lower in heavy distillates, and lowest in light distillates. Removal of sulfur in light distillates does not effect sulfur concentrations in the residual fuel oil or heavy distillates. In other words, in the manufacture of low sulfur fuels, sulfur does not shift from lighter fuels to heavier fuels. Sulfur concentrations are reduced in distillate fuels by a refining process called "hydro-treating." Sulfur in the fuel is replaced with hydrogen in a catalytic reaction that produces low sulfur fuel and hydrogen sulfide gas. The hydrogen sulfide is converted to elemental sulfur in another refinery process, and primarily sold to the chemicals and fertilizer manufacturing industries. In

some parts of the world (*e.g.* Canada, Saudi Arabia) where there is no market for sulfur, it is stockpiled on the land in huge monolithic solid blocks. When land-based fuels are rebranded for marine use, they will typically be well below the sulfur specifications of the marine fuel. The land base fuels have a much lower specification requirements (between 3 and 100 times lower) than the marine fuels. The products in the table are further described below.

No. 1-D (LS) is a land-based diesel fuel with low sulfur (LS) for "on-highway" automotive, bus and truck diesel engine use. It is used only in cold seasons and climates when engine starting may be

TABLE 2
SELECTED ASTM SPECIFICATIONS FOR COMPRESSION IGNITION FUELS

Specification	Land-Use Fuels					Marine Fuels					
	On-Highway	Diesel	Off-Highway	Heating Oil		Distillate		Intermediate[2]		Residual	
	No.1-D (LS)	No.2-D (LS)	No.2-D	No.2	No.4	DMA	DMB	DMC[1]	RME/F-25	RMG/H-35	RML 55
Flash, ^{O}C, min	38	52	52	38	55	60	60	60	60	60	60
Kinematic Viscosity[3] cSt @40 ^{O}C	min 1.3	1.9	1.9	1.9	5.5	1.5	-	-	-	-	-
	max 2.4	4.1	4.1	3.4	24.0	6.0	11.0	14	(25)	(35)	(55)
Sulfur, % mass, max	0.05	0.05	0.5	0.5	-	1.5	2.0	2.0	5.0	5.0	5.0
Cetane number, min	40	40	40	-	-	40	35	35	-	-	-
Ash, % mass, max	0.01	0.01	0.01	-	0.10	0.01	0.01	0.03	0.1- 0.15	0.15- 0.2	0.2
Typical % Distribution[4]	100	100	100	100	80-100	100	99+	80-100	12	2	0

Notes

1. DMC manufactured both as a straight-run distillate and distillate/residual blend.
2. RME-25 and RMF-25 bracket IFO-180; RMG-35 and RMH-35 bracket IFO-380.
3. Kinematic viscosity values in parenthesis, ( ), are centiStokes @ 100^{O}C.
4. Typical percent distillate is not a specification.

difficult with No. 2-D (LS) fuel. The 2-D (LS) fuel has a higher energy output and better natural "lubricity" of engine fuel injector components than No. 1-D (LS) fuel. For this reason, No. 2-D (LS) is by far the most common fuel used in diesel engines for on-highway use.[13] No. 2-D is a higher sulfur fuel that is otherwise identical to No. 2-D (LS), and is intended for "off-highway" use in diesel engine earthmoving equipment, farm equipment and small portable stationary engines for generators, compressors, machinery and pumps. No. 2-D is distinguished from its on-highway low sulfur alternate by a red dye. There is also a No.1-D higher sulfur diesel fuel that, again, is for off-highway use in cold seasons and climates. It has identical specifications as No. 1-D (LS), except for a higher sulfur limit.

No. 1 and No. 2 Fuel Oils are the "burner" fuel equivalents to the diesel engine fuels. No. 2 Fuel Oil, commonly called "No. 2 Home Heating Oil," is shown in Table 2 because it is a common source of marine distillate fuels.[12, 13, 20] For a similar reason, No. 4 Fuel Oil, an industrial furnace and boiler fuel that may contain a small amount of residual oil, is shown to compare against similar marine fuels.

Specifications for marine fuels officially carry the first letters "D" signifying "distillate fuel," or "R" signifying "residual fuels,". The second letter "M" signifies "marine fuel.". DMA is "marine distillate fuel A," and is the most common compression ignition engine fuel for small and medium sized marine engines[12] (which are fashioned after land based diesel engines[21]). DMB has some limited amount of contamination that DMA may pick up in dirty storage or transfer.[12] It is not a fuel that is intentionally manufactured.[12, 14, 15] DMC is intentionally manufactured from either heavier boiling (than No. 2 fuels) fractions of straight-run distillate, called "cycle oil," or is blended in marine fuel terminals from DMA and residual fuels.[15] No. 4 Fuel Oil has very similar properties as DMC, and where available at lower price than DMA, is rebranded as DMC. DMC is listed in the national (ASTM) and international (CIMAC, ISO) specifications as a "distillate" fuel, but may be considered an intermediate type fuel as the specifications allow blending with residual oil.

There are fifteen residual fuels in national and international specifications. Individual grades are designated by the letters A through H, K and L, and a number signifying the viscosity limit. For example, RMA-10 is "Residual Marine fuel A with a maximum viscosity (at 100 degrees C) of 10 centistokes. The most common intermediate fuel oil grades are called IFO-180 and IFO-380[13, 14]. The numbers are viscosity limits at the common fuel handling temperature of 50 degrees C, and are equivalent to 25 and 35 centistokes at 100 degrees C. Therefore, the official specifications for IFO-180 are RME-25 and RMF-25; for IFO-380 are RMG-35 and RMH-35[14]. Intermediate marine fuels may be manufactured by blending residual oil with heavy distillates or from straight run residual oil where the temperature and pressures are controlled to leave some heavy distillate in the residuum. The wide variety of intermediate and residual marine fuels reflect both the wide variety of properties of residuum from different crude oils as well as the design specifications of engine manufacturers. The large compression ignition engines that burn residual fuels are designed only for ocean-going large cargo and passenger vessels (rather than being adapted from land based diesel engines)[21].

As shown in Table 2, in all cases, marine fuels are required for safety and insurance reasons[21] to have a minimum flash of 60 degrees C.

Table 3 shows a comparison of specifications from different sources for some of these fuels. ASTM is the U.S. national standard comparable to CIMAC and ISO for international trade. Platt's publishes worldwide prices of various fuels, and to assure an understanding of the relationship between price and product, they publish a "Guide to Petroleum Specifications."[5] These "specifications" are a mix of

international standards and common sub-grades. Terms like "Gasoil," and DDO (Distillate Diesel Oil) are used in some countries

TABLE 3
FUEL SPECIFICATIONS COMPARISON

	ASTM	CIMAC	ISO	PLATTS	MOBIL	SHELL	Sterling Marine Fuels
No2-D On Hwy							
Flash	52			60	51.7		
V_{min}	1.9			-	1.9		
V_{max}	4.1			-	4.1		
Sulfur	0.05			0.05	0.05		
Ash	0.01			-	-		
No2							
Flash	38			54.4-60	51.7	38	45
V_{min}	1.9			-	1.9	1.9	1.7
V_{max}	3.4			-	4.1	3.4	3.4
Sulfur	0.50			0.2-0.5	0.5	0.5	0.5
Ash	-			-	-	-	0.01
DMA							
V_{min}	1.5	1.5	1.5	-	1.9	-	
V_{max}	6.0	6.0	6.0	-	6.0	7.0	
Sulfur	1.5	1.5	1.5	0.5	1.0	1.0	
Ash	0.01	0.01	0.01		0.01	0.01	
DMB							
V_{min}	-	2.5	-		-	-	
V_{max}	11.0	11.0	11.0		11.0	11.0	
Sulfur	2.0	2.0	2.0		1.5	1.5	
Ash	0.01	0.01	0.01		0.01	0.01	
DMC							
V_{min}	-	-	-	-	-	-	
V_{max}	14.0	14.0	14.0	-	14.0	13.0	
Sulfur	2.0	2.0	2.0	1.0-2.0	1.8	1.8	
Ash	0.01	0.03	0.05	0.01-0.05	0.05	0.02	
IFO-180							
V_{min}	-	(15.0)	-	-	-	-	
V_{max}	(25.0)	(25.0)	(25.0)	(25.0)	(25.0)	(25.0)	
Sulfur	5.0	5.0	5.0	2.5-4.0	4.3	4.0	
Ash	0.10-0.15	0.10-0.15	0.10-0.15	0.1-0.2	0.10-0.15	0.10	
RMH-45							
V_{min}	-	-	-	-	-	-	
V_{max}	(45.0)	(45.0)	(45.0)	420-970	(45.0)	(45.0)	
Sulfur	5.0	5.0	5.0	2.5-3.5	5.0	5.0	
Ash	0.20	0.20	0.20	-	0.20	0.10	

Note 1. All marine fuels have a minimum flash specificity of 60 °C. Note 2. Viscosities in parentheses ( ) are cSt @ 100 °C.

to designate "Marine Distillate Fuel" or DMA; "Marine Diesel Oil" (MDO) and Intermediate Fuel Oil (IFO) are used for low viscosity Residual Marine fuel oils. Also, Table 3 presents examples of internal fuel manufacturing and marketing company specifications (Mobil, Shell, Sterling)[9, 10, 22]. Note that for marine fuels, the company specifications for sulfur are more stringent than the sulfur specifications from the other organizations.

2. Fuel Actual Properties

Table 4 compares the actual properties of land and marine distillate fuels with the ASTM specifications for Marine Distillate Fuels DMA, DMB and DMC. Concerning marine distillate fuels, DNV Petroleum Services performs a service to the marine industry by sampling and testing marine fuels from many suppliers in ports throughout the world. The data shown for 1997 includes 967 samples taken in 27 ports in the U.S. The average value is a simple arithmetic average of all sample results. The low and high values are the lowest and highest single results from all tests. Note that in some cases the result exceeds the specification for that fuel grade. Of particular note is that the average sulfur level of marine distillate fuels is half or less the maximum specification. These averages are somewhat of a "dumbbell" average of the individual measurements, which shows that the fuel is either a rebranded No. 2-D on- or off-highway fuel, or a manufactured marine fuel that "crowds" the sulfur specification. DNV Petroleum Services also tests for sulfur for intermediate and residual marine fuels, however, such information is only available to member subscribers. DNV do not test flash because it virtually always exceeds the specification of 60 degrees C. Average ash content of all three marine distillate fuels also show that very little heavier distillate components, and virtually no residual components are commonly blended into marine distillate fuels, even though DMB allows for residual contamination and DMC allows for residual blending.

National Institute for Petroleum and Energy Research (NIPER), a BDM Petroleum Technologies affiliate, conducts annual surveys of Diesel Fuel Oils[3]. The data shown in Table 4 is the actual properties for No. 2-D on-highway (low sulfur) and off-highway diesel fuels. These fuels are chosen for comparison with marine distillate fuels because they are often supplied, rebranded, as a marine fuel that are often used as recreational marine fuels. The NIPER data indicates the intended use for the fuels in the following categories: City Bus, Truck/Tractor, Railroad, and Stationary/Marine. There are no cases of a Stationary/Marine use for any of the fuels other than No. 2-D off-highway in the 1994, 1995 and 1998 reports. The data in table 4 are averages for all uses (i.e. fuels are apparently not manufactured differently for marine use, even though marine fuel specifications allow higher sulfur levels). The average sulfur content of the fuels intended for Stationary/Marine (only 3 measurements) were nearly identical to the average for all uses.

TABLE 4
DISTILLATE FUEL ACTUAL PROPERTIES
COMPARED WITH MARINE FUEL SPECIFICATIONS

	ASTM Specifications			1997 DNV Petroleum Services[1]			1997 No. 2-D NIPER	
	DMA	**DMB**	**DMC**	**DMA**	**DMB**	**DMC**	**On-Hwy**	**Off-Hwy**
Flash, ^{O}C, min	60	60	60	–[2]	–[2]	–[2]	AV 73 LO HI 56 109	73 54 104
Kinematic Viscosity cSt @40 ^{O}C	min 1.5 max 6.0	- 11.0	- 14	AV 3.2 LO HI 2 10	4.5 3 14	6 3 15	AV 2.63 LO HI 1.90 4.10	2.79 2.00 4.73
Sulfur, % mass	1.5	2.0	2.0	AV 0.36 LO HI 0.00 1.66	0.91 0.00 2.02	1.04 0.01 2.28	AV 0.35 LO HI 0.004 0.947	0.293 0.028 1.000
Ash, % mass max	0.01	0.01	0.03	AV 0.00 LO HI 0.00 0.04	0.00 0.00 0.03	0.01 0.00 0.11	AV 0.002 LO HI 0.000 0.010	0.002 0.000 0.010
Cetane number (min)	40	35	35	-	-	-	AV 44.8 LO HI 40.0 50.8	45.8 39.4 57.0

Note 1. Average, Lowest and Highest result from 195 DMA, 437 DMB and 335 DMC samples from 27 US ports. The number of DMB samples exceed the number of DMA and DMC samples because the clients who requested the testing operate large ocean-going ships and the most common distillate fuel used by ocean-going ships is DMB. For the medium and small engine vessels, such as tugs, fishing boats, ferries, etc., the most predominant marine fuel is still DMA.
Note 2. Virtually always greater than 60 ^{O}F.

3. Fuel Property Variations and Trends

Table 5 shows regional variations in marine fuel properties by East Coast (PADD district 1), Great Lakes (PADD II), Gulf Coast (PADD III), and the West Coast (PADD V). The DNV Petroleum Services data includes twelve ports in PADD I, one U.S. Port in PADD II (Detroit, we added Montreal to provide more complete data), eight ports in PADD III, zero ports in PADD IV (Rocky Mountains), and five ports in PADD V. NIPER data is divided into U.S. regions that approximate PAD districts. Note that there is very little variation in sulfur, viscosity and ash for DMA and No. 2-D on- and off-highway fuels. There is significant variation for DMB and DMC. We believe that this reflects available sources of fuel blending stocks. PADD II marine fuels more closely resemble No. 2-D off-highway fuel than any other PAD district. PADD II also has considerably less refining industry than PADD I, III and V. As mentioned above, the higher sulfur marine fuels are specially manufactured in refineries or blended in marine fuel terminals only for larger contracts. In general, the larger supply of distillate fuels (No. 2 fuels) are rebranded for marine use.

In terms of historical sulfur content trends, the NIPER 1998 Diesel Fuel Oils study shows that off-highway No. 2-D fuel sulfur levels have remained fairly constant for the past fifteen years. The DNV Fuel Quality Statistics for Marine Distillates is a first-time report, so we have no historical perspective on these marine fuels.

Regarding seasonal variations, NIPER data shows special summer and winter fuels; however, there are too few winter samples to draw any conclusions.

VII. Fuel Usage

A. Approach:

The available data sources for diesel fuel use come primarily from the Department of Energy, Energy Information Administration[1]. Annual reports are available in hard copy and on the Internet. We also found a survey of recreational boat and fuel use conducted by Price Waterhouse in 1991 for the U.S. Fish and Wildlife Service and U.S. Coast Guard [4]. All other sources of information about marine fuel use are anecdotal, from fuel manufacturing&marketing [13, 20], testing[14], brokering[12] and supply people[15, 16, 17, 18, 19], nationwide.

B. Results:

1. Use of Vessel Bunkering and Recreational Marine Fuels

For a general picture of marine fuel usage, Table 6 shows five years of data from EIA "Consumption Estimates, State Energy Data Report."[1] on vessel bunkering fuel use. The most recent data available is the year 1997. The fuel categories reported are "distillate fuel oils" and "residual fuel oils." Distillates would cover DMA, DMB, DMC and any other distillate fuels used in the fueling of commercial (marine shipping) and private boats, such as, pleasure craft, fishing boats, tugboats, and ocean-going vessels

(excluding the Armed Forces). The "residual fuel oil" category includes both intermediate (IFO) and residual fuels. There is no breakdown of intermediate and residual fuel use.

TABLE 5
REGIONAL VARIATIONS
1997 DATA*

	SULFUR					VISCOSITY					ASH				
	DMA	**DMB**	**DMC**	**No2 ON**	**No2 OFF**	**DMA**	**DMB**	**DMC**	**No2 ON**	**No2 OFF**	**DMA**	**DMB**	**DMC**	**No2 ON**	**No2 OFF**
PADD I	0.39	0.68	0.90	0.036	0.231	3.1	3.7	5.3	2.75	2.60	0.00	0.00	0.01	0.001	0.001
PADD II	0.31	0.38	0.39	0.036	0.249	2.6	2.9	3.0	2.66	2.82	0.00	0.00	0.00	0.003	0.005
PADD III	0.36	0.93	1.02	0.035	0.430	3.2	4.2	5.2	2.92	2.88	0.00	0.00	0.01	0.003	0.003
PADD V	0.36	1.19	1.18	0.031	-	3.7	7.1	7.6	2.58	-	0.01	0.01	0.01	0.001	-
US	0.36	0.91	1.04	0.035	0.293	3.2	4.5	6.0	2.70	2.79	0.00	0.00	0.01	0.001	0.002

* Data for DMA, DMB, DMC provided by DNV Petroleum Services. Data for No2 on and off highway provided by NIPER.

TABLE 6
RELATIVE PRODUCTION SUPPLY OF VESSEL BUNKERING FUELS
FOR DOMESTIC CONSUMPTION*
(THOUSAND GALLONS)

	1993	1994	1995	1996	1997
Marine Distillate Fuel Oil	2,043,745	2,026,899	1,978,105	2,177,608	2,107,561
Marine Residual Fuel Oil	6,269,882	5,944,838	6,431,238	5,804,977	4,789,861
Total Marine Fuel	8,313,627	7,971,737	8,409,343	7,982,585	6,897,422
Distillate % of Total Marine	24.6	25.4	23.5	27.3	30.6

* Consumption estimates, State Energy Data Report, DOE's Energy Information Administrator.

Marine distillate fuel sales have remained roughly constant over the five year 1993 to 1997. Residual fuel oil sales have generally declined over this period, so the proportion of marine distillate to residual fuel sales has increased from about 25% in 1993 to over 30% in 1997. Marine distillate fuel sales have remained about the same from 1993-1997.

Diesel fuel use for recreational boating was estimated in a National Recreational Boating Survey (1992) [4] to be approximately 65 million gallons per year in the U.S. Recreational diesel fuel use is also provided state by state.

2. Fuel Use Regional Variations

Table 7 shows a regional breakdown of marine fuel sales from the 1997 EIA data[1]. Distillate fuel oil sales data includes fuel used for pleasure crafts. The Price Waterhouse survey in 1991[4] provided a diesel fuel use by state, which can be grouped by PAD Districts for comparison with the EIA data. While the years of the two data sources is different, marine distillate fuel sales have remained fairly constant since 1991 (as shown in Table 6), so the comparison is reasonably valid.

While marine distillate fuel sales are strong in all PAD Districts with the exception of the Rocky Mountains (PADD IV), residual fuels are apparently not used to a large extent on the Great Lakes (PADD II). Note that the proportion of distillate to residual fuel sales is very different on the West Coast (PADD V) relative to the East Coast (PADD I) and Gulf Coast (PADD III). Whether these fuel sales differences on the East, West and Gulf Coasts are representative of actual fuel use in these three areas is not known. It is not uncommon for large ocean-going cargo vessels to "round-trip" bunker at the port supplying the lowest cost fuel. Therefore, the apparent decline in U.S. sales of residual bunker fuels may reflect an actual decline in use or a shift of supply from U.S. ports to foreign ports. Distillate fuels, on the other hand, are largely used in the same PAD District as supplied.

Recreational distillate fuel sales are predominantly on the East Coast (PADD I). Nearly 65% of recreational diesel fuel use is in PADD I, about 21% on PADD V, West Coast, and only 6 to 7% used in

Central U.S. (PADD II) and Gulf Coast (PADD III). There is no significant distillate fuel use in the Rocky Mountain States (PADD IV).

Note that total U.S. marine distillate fuel sales are only 6% of the total transportation distillate fuel sales, while vessel bunkering is the only transportation use of residual fuels. Recreational diesel fuel use is less than 0.2% of total transportation distillate fuels.

Finally, we have found no readily available data sources complete enough to show seasonal trends in marine fuel use.

TABLE 7
REGIONAL VARIATIONS IN MARINE FUEL PRODUCT SUPPLIED FOR DOMESTIC CONSUMPTION (THOUSAND GALLONS PER DAY)

	Distillate Fuel Oil[1] (1997)	Residual Fuel Oil[1] (1997)	Recreational Diesel Use[2] (1991)	Percent of Distillate over Distillate and Residual
PADD I	1,378	3,665	115	27%
PADD II	1,263	68	13	95%
PADD III	2,259	5,014	11	31%
PADD IV	<1	0	<1	-
PADD V	873	4,376	38	17%
USA	5,774	13,123	178	31%

Note 1. EIA "Fuel Oil and Kerosene Sales 1997"
Note 2. Price Waterhouse "National Recreation Boating Survey," June 30, 1992

Appendix 1
Estimate of Land Based Fuel Rebranded for Diesel Marine Fuel Use

ICF contacted representatives from major oil companies (e.g., Texaco, Chevron) and requested a ballpark estimate of how much of the marine distillate fuel (e.g., DMA) was refined and blended originally from a land based fuel or alternatively what percent of the land-based distillate fuel ends-up being used for marine distillate (e.g., DMA). In general, the contacts agreed with our assessment that a large portion of both commercial and recreational marine distillate fuels are rebranded land-based distillate fuels. For example, DMA is supplied as rebranded No. 2 on- and off-highway fuel, and in the north and north-eastern states, DMA may be rebranded No. 2 home heating fuel. ICF's original estimate was that as much as 90% of the DMA and DMB was manufactured originally as a land-based fuel, primarily as No. 2D high sulfur (off-highway) and rebranded for marine use. This estimate is based on the few refineries close enough to major marine ports to enter special supply agreements, the large volume of land based distillate fuel versus marine fuel, and the close comparison of marine distillate fuel properties with land based fuel properties (NIPER). Also, ICF estimated that 0.5% of the No. 2D fuel in the land-based market is used as distillate components in marine diesel fuel (blend of residual fuel oil and distillate fuel). The Texaco representative commented that the percentage of land based No. 2 diesel (0.5%) sold into the marine diesel oil market is maybe too high. Many refiners produce a distallate type product that cannot be sold as No. 2D for a variety of reasons (API gravity, color), but can be rebranded into DMA.

DATA SOURCES

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13. Telecon: John D. Bacha, Consulting Scientist, Fuels Technology, Chevron Products Company, Richmond, CA (510)242-2126.

14. Telecon: Rudolph Kassinger, DNV Petroleum Services, Teanech, NJ, (201) 833-1990.

15. Telecon: Bob Williams, Manager, BP-Coastal, Port Newark, NJ, (973) 465-2427.

16. Lynn Cates, Fuel Services for Corpus Christi, TX, (512) 881-9977.

17. Telecon: Les Shook, Southwest Services, Corpus Christi, TX, (512) 887-9898.

18. Telecon: George Smith, Manager, City of Elizabeth Municipal Marina, Elizabeth, NJ, (908) 820-4296.

19. Telecon: Chris Kaplan, City Yachts, San Francisco, CA, (415) 567-8880.

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22. Lubricants and Fuels in Ships, Chapter 14 Marine Fuels: Specifications (EPA provided).