

Table 4 . . . Detailed Requirements for Fuel Oils^a

Grade of Fuel Oil ^b	Flash Point F	Pour Point F	Water and Sediment % by Vol.	Carbon Residue on 10% Residue %	Ash % by Wt.	Distillation Temperatures F			Saybolt Viscosity Seconds		Kinematic Viscosity Centistokes			
	Min.	Max.	Max.	Max.	Max.	10% Point	90% Point	End Point	Universal at 100 F	Fair at 122 F	at 100 F		at 122 F	
	Min.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Min.
1. A distillate oil intended for vaporizing pot-type burners and other burners requiring this grade ^c API gravity 35 (min.)	100 or Legal	0	Trace	0.15		420		625			2.2	1.4		
2. A distillate oil for general purpose domestic heating for use in burners not requiring No. 1 API gravity 28 (min.)	100 or Legal	20 ^d	0.10	0.35			675		40		(4.3)			
4. An oil for burner installations not equipped with preheating facilities	130 or Legal	20	0.50		0.10				125	45	(26.4)	5.8		
5. A residual type oil for burner installations equipped with preheating facilities	130 or Legal		1.00		0.10				150	40		32.1	(81)	
6. An oil for use in burners equipped with preheaters permitting a high viscosity fuel	150 or Legal		2.00 ^e							300	45		(638)	(92)
PS 300	150 or Legal		1.0							40	25			
PS 400	150		2.0 ^f								60			

^a Recognizing the necessity for low sulfur fuel oils used in connection with heat-treatment, non-ferrous metal, glass and ceramic furnaces and other special uses, a sulfur requirement may be specified as 0.5% for No. 1, 1.5% for No. 2, and no limit for Nos. 4, 5 and 6.

^b Other sulfur limits may be specified only by mutual agreement between the buyer and seller.

^c It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

^d Lower or higher pour points may be specified whenever required by conditions of storage or use. However, these specifications shall not require a pour point lower than 0 F under any condition.

^e No. 1 oil shall pass test for corrosion made in accordance with paragraph 15 ASTM Specifications for Fuel Oils, D 296 - 48.

^f The 10 percent point may be specified at 440 F maximum for use in other than atomizing burners.

^g The amount of water by distillation, plus the sediment by extraction, shall not exceed 2.00 percent. The amount of sediment by extraction, shall not exceed 0.50 percent. A deduction in quantity shall be made for all water and sediment in excess of 1.0 percent.

PS 300 and PS 400 are Pacific Specification numbers. Balance of table from Commercial Standard CS 12-48 and ASTM Materials Specification for Fuel Oils D 296 - 48.

PS 300 is a residual oil for use without preheating in furnaces and burners requiring a low viscosity fuel, and commonly described as light fuel oil, domestic fuel oil, or low viscosity fuel oil.

PS 400 is a residual oil for use in furnaces and burners equipped with preheaters permitting a high viscosity fuel, and commonly described as industrial fuel oil, heavy fuel oil, or high viscosity fuel oil.

coast area. These oils correspond approximately to ASTM designations No. 5 and No. 6 respectively.

Oils are classified by their viscosities. Other characteristics of fuel oils which determine their grade classification in the Commercial Standard, and their suitability for given uses are the flash point, pour point, water and sediment content, carbon residue, ash, and distillation characteristics.

The flash point of an oil is important with regard to safety in handling and in storage. The distillation characteristics determine whether or not the oil can be completely evaporated in some types of burners, and whether cracking will be likely to occur prior to combustion. A low pour point and low water content are necessary for handling

and outdoor storage in cold climates. Sediment should be low to prevent clogging of strainers. Carbon residue is related to the rate of accumulation of unburned material in some types of burners. A low viscosity allows the fuel oil to flow through supply lines readily and to be broken up into small droplets in atomizing type burners. The sulfur content is of importance because undesirable compounds of sulfur may be formed in certain industrial processes. Some of these characteristics of a fuel oil are required to lie within certain limits for each of the grades of fuel oil listed in Commercial Standard CS12-48. Some fuel oils do not fall into any of the grade classifications of the Commercial Standard because failure to comply with all of the require-

Table 5 . . . Approximate Gravity and Calorific Value of Standard Grades of Fuel Oil

Commercial Standard No.	Approximate Gravity API	Weight lb per gallon	Calorific Value Btu Per Gallon
1	38-45	6.951-6.875	137,000-132,900
2	30-40	7.296-6.870	141,800-135,800
4	12-32	8.212-7.206	153,300-140,600
5	8-20	8.448-7.778	155,900-148,100
6	6-18	8.571-7.882	157,300-149,400

ments of one grade does not automatically place the fuel oil in the next lower grade, unless it meets all of the requirements of the lower grade.

By ultimate analysis the No. 1 and No. 2 fuel oils contain 84 to 86 percent carbon, up to 1.0 percent sulfur, and the remainder predominantly hydrogen. The heavier grades of fuel oil, Nos. 4, 5 and 6, may contain as much as 88 percent carbon, as low as 11 percent hydrogen, and considerably more sulfur than is permissible in the domestic grades.

Due to variation in the constituents of different fuel oils and the different refining methods used, the API gravities and calorific values of the different grades of fuel oil cover a range in each grade with some overlapping between domestic grades and between commercial and industrial grades. API gravity, generally used when referring to specific gravity of oil, is obtained by the following formula in which the term *specific gravity at 60/60 F* indicates the ratio of the weight of a given volume of oil at 60 F to the weight of the same volume of water at 60 F:

$$\text{Degrees API} = \frac{141.5}{\text{specific gravity at 60/60 F}} - 131.5$$

The API gravity of water at 60 F is 10.0. The relation between the API gravity of fuel oils and their calorific value is shown in Table 5. Grades No. 1 and No. 2, which are distillates, are used predominantly in domestic heating equipment whereas grades 5 and 6 are used in commercial and industrial burners. Grade 6 requires preheating to increase its fluidity and to permit atomization, whereas grade 5 may be used in some burners without preheating. Grade 4 fuel oil does not require preheating and can even be burned satisfactorily in a limited number of domestic burners.

Sources and Properties of Residual Fuel Oils

Fuel oils Nos. 5 and 6 always contain residues remaining from the refining of crude oils. No. 4 oil will sometimes consist entirely of heavy distillates but generally contains residual stocks.

The residues may be classified, in accordance with their previous processing, as straight-run, vacuum-flashed, or cracked residues. Straight-run residues are the materials in crude oil that cannot be distilled at atmospheric pressure without appreciable decomposition and hence are removed as bottom fractions from crude topping units. These materials, often referred to as *topped* or *reduced* crude, are sometimes blended into fuel oil, but more frequently are processed, either by vacuum distillation or by thermal cracking, to produce additional distillates. Residues from vacuum distillation processes are widely used as residual fuel blending stocks. Vacuum-flashed residues from some crudes must be subjected to a mild thermal cracking, known as viscosity-

breaking, before they can profitably be blended into fuel oils. Residues produced by thermal cracking of straight-run or vacuum-flashed residues or by thermal reforming of heavy naphthas, also are used in residual fuel oils.

In processing reduced crudes and other stocks that yield residual fuel-blending stocks, the refiner evaluates the severity of treatment against, among other factors, the effect on certain properties of the residues. Perhaps the most significant of these properties is viscosity. Maintenance of fuel viscosity within a certain range by preheating of the oil is necessary to obtain satisfactory combustion efficiency with most burners for heavy oil. In most instances there is a maximum temperature to which the oil should be preheated. Consequently a maximum viscosity is usually placed on the finished product.

The second property of oil that is markedly sensitive to refining procedures is specific gravity. Residues may have gravities on either side of API 10, i.e., they may be either lighter or heavier than water. Since residual fuels in many instances are stored and used in the presence of water the densities of the fuel oils must differ sufficiently from water to assure their separation into distinct layers.

The limits imposed by viscosity and specific gravity specifications are met in part by refining practices and in part by blending residues with distillates. These distillates may be straight-run gas oils and distillates produced by thermal or catalytic cracking. Blending of residues and distillates generally entails down-grading of the latter. Consequently efforts are made to reduce to a minimum the quantities of *cutter stock* (the refinery term for distillates used for this purpose) necessary to meet manufacturing specifications. Heavy catalytically- or thermally-cracked distillates are generally used as cutter stock, not only because they are of less value for further processing than straight-run gas oils, but also because they have greater solvency for asphaltic materials in cracked residues.

This discussion of residual fuel oils has been concerned principally with No. 6 fuel oil, the heaviest grade of residual fuel. Two other grades of residual fuels, Nos. 4 and 5, are produced and marketed. These fuels have lower viscosities and higher gravities than No. 6 fuel oil. Generally these specifications are met by increasing the ratio of cutter stock to residue, but occasionally these lighter fuels are made by blending No. 6 and No. 2 fuel oils.

Sometimes No. 4 oil will consist entirely of heavy distillates but generally this grade of fuel contains residual stocks. Due to their higher distillate content both No. 4 and No. 5 grades bring higher prices than No. 6 fuel oil, and frequently they are priced on a different basis, i.e., in cents-per-gallon rather than dollars-per-barrel.

Oil Burning Indexes

A number of indexes have been used, or proposed, as an indication of the burning qualities of distillate fuel oils based on one or more physical measurements made on the oil. These may be summarized as follows:

A. Indexes based on a single physical test: (1) API gravity; (2) Aniline point; (3) Institute of Petroleum smoke test; (4) Carbon-Hydrogen ratio based on flue gas analysis or ultimate analysis; and (5) Percent aromatics determined by sulfuric acid absorption tests.

B. Indexes based on two or more physical tests: (1) Diesel index based on API gravity and aniline point; (2) Institute of Petroleum cetane number based on the API gravity and 50 percent distillation point; (3) Universal Oil Products characterization factor based on specific gravity and average