

CHAPTER 8

EVALUATING PETROLEUM PRODUCTS

Section I. Properties of Petroleum Products

CRITICAL PROPERTIES

The critical properties of a product determine the adequacy of that product for its intended use. When the critical properties of a product do not meet specification or use limits, the product must be reclaimed by downgrading, blending, filtering, dehydrating, or inhibiting. The following paragraphs describe critical properties and list tests performed on products to determine their suitability for use. See Appendix D for a table on probable causes of contamination / deterioration.

API GRAVITY (ASTM 287, D 1298)

Scope. These tests are run on all petroleum products, except greases, to determine their densities in terms of API gravity.

Significance. These tests are generally used as a quality control indicator, but some specifications have actual API gravity requirements. The scale was developed to eliminate the problem of working with decimals associated with specific gravity. An API gravity of 10 is equal to 1.000 specific gravity. As the API gravity goes up, its corresponding specific gravity goes down. API gravity is needed in order to select volume reduction factors to be used in fuel accounting procedures. When the API gravity of a product rises more than 0.5 (for example, MOGAS going from 59.5 to 60.1 API gravity), the cause is usually contamination by a lighter petroleum product. A drop in API gravity is generally caused by contamination with a heavier product. Results that vary more than 0.5 API indicate a problem, and

further tests must be performed to determine the cause.

APPEARANCE/WORKMANSHIP

Scope. This is a visual test performed on a product to determine if it is homogeneous, clear, bright, separated, or otherwise different from what the product should look like.

Significance. Depending on the product, it will be clear (free of suspended matter or particles), bright (sparkle in transmitted light), homogeneous (uniformly mixed), separated (stratified or bleeding), or have visual sediment or water. To make these determinations, care should be taken that nothing is overlooked. Control of such contamination requires constant vigilance. Solid and liquid contamination can lead to restriction of fuel metering points, improper seating of inlet valves, corrosion, fuel line freezing, gel formation, filter plugging, or failure to lubricate. Product containing visual sediment and water should be allowed to settle and then filtered before use.

AQUA-GLO WATER TEST (ASTM D 3240)

Scope This test is run on aviation fuels and selected ground fuels to detect harmful levels of water contamination.

Significance. Water can become a petroleum contaminant at any stage from the refinery to ultimate use. Extreme care must be taken to eliminate it from fuel. Water in aviation fuels can freeze and form ice at altitudes above 8,500 feet. The resulting ice can clog on-board fuel filters and prevent fuel flow to the engine. For this reason,

water is generally limited to 10 parts per million, maximum. If the result is higher, a resample should be taken and tested. If a resample fails, the fuel distribution system should be evaluated for proper settling times and filter elements checked. Water in diesel fuels can cause severe corrosion in cylinders and stop a diesel engine. Fuel line freezes can occur in ground equipment as well as in aircraft. Current Army policy dictates that ground fuels be filtered before use.

ASH CONTENT (ASTM D 482 AND D 874)

Scope. These tests are performed to determine the amount of ash-forming materials present in fuel oils and lubricating oils.

Significance. The plain ash test (D 482) is run on fuel oils and non-additive lubricating oils to detect contamination by inorganic matter, such as rust, sand, or metallic salts. These contaminants can abrade metal surfaces, and in the case of fuel oils, clog injection nozzles and form deposits. The sulfated ash test (D 874) is run on additive-type lubricating oils to determine the amount of additive present. Test results usually show sulfated ash in the range of 0.8 to 1.5 percent. If periodic testing reveals a decrease in percentage, additive loss is indicated. If tests on distillate fuels reveal contamination by inorganic matter, the fuels can usually be reclaimed by allowing them to settle and then filtering them. If tests on non-additive lubricating oils show contamination, the oils should be disposed of as directed. If tests on additive-type lubricating oils show loss of additive, the oils can usually be reclaimed by blending.

CARBON RESIDUE (ASTM D 189 AND D 524)

Scope. These tests are performed on distillate fuels, lubricating oils, and residual fuel oils.

Significance. The type of carbon residue resulting from the tests indicates the base of crude oil used in the refining process. A product derived from a paraffin base crude produces a H&F resi-

due, and a product derived from an asphalt or naphthalene base crude produces a L&F residue. Paraffin base products produce little carbon residue, generally in the range of 0.01 to 0.5 percent. Asphalt and naphthene base products produce residue in the range of 0.1 to 30 percent. The tests are useful in detecting residual contamination in distillate products. When residual contamination is present, the amount of residue increases. This form of contamination also causes the 50 percent to end-point results in the distillation test to be higher and product color to be darker.

- Distillate fuels that show carbon residues of 0.5 percent or less may be used in high-speed engines. Those that show residues of up to 12 percent may be used in slow-speed engines for limited periods. Carbon residue in engines can cause hot-spot ignition in combustion chambers and fuel-injector blockage. High-carbon residue fuels can be reclaimed by blending.

- Lubricating oils that show high carbon residues are poor lubricants. They are usually asphalt or mixed base products. These tend to form harmful deposits in engines. If a lubricating oil shows a high carbon residue, it should be disposed of as prescribed by regulation.

- Residual fuel oils that show high carbon residues may cause problems in heat-generating equipment. Carbon deposits formed during combustion can foul burner tips. Also, such fuel oils may smoke excessively when burned and cause severe air pollution.

CLEVELAND OPEN CUP FLASH POINT (ASTM D 92)

Scope. This test is performed on various lubricating oils, hydraulic oils, brake fluids, gear oils, and other heavy petroleum products flashing above 175°F. It is used to determine the lowest temperature at which ignition can occur.

Significance. The COC flash test is performed to ensure that low-flash point materials have not contaminated the product. In new oils, the test is used to ensure that proper refining methods have removed these low-flash materials.

The specification flash point is designed to ensure that the flash point of the product is above the expected operating temperature. In used oils, the COC flash test is used to detect the presence of low-flash point and low-boiling point contaminants. In engine lube oils, a faulty choke or poor engine timing can cause incomplete combustion of fuel in the cylinder. This unburnt fuel seeps down into the crankcase, diluting the oil and reducing its film strength causing oil burning and cylinder wall wear. The flash point usually is 50°-100°F above the specification. If test results show the oil to be slightly off specification or barely on specification, the oil probably has been diluted with a low-flash product. The dilution also reduces viscosity (ASTM D 445). New products that are off specification should be reported, and used oil found to be off specification should be disposed of according to local directives.

CLOUD POINT (ASTM D 2500)

Scope. This test is performed on diesel fuels, fuel oils, and other petroleum oils that are transparent and have a cloud point below 120

Significance. The cloud point is an indication of the behavior of an oil in certain lubricating devices. The formation of minute, waxy crystals may plug the wick through which oil flows in some lubricating devices. However, extreme low-temperature operating conditions are rarely encountered with equipment lubricated in this manner. Fuel oils and diesel fuels with high cloud point could clog fuel filters if a preheater is not used. Contamination with a heavier product can raise the cloud point.

COLOR (ASTM D 156, D 1500, D 2392)

Scope. Color tests are made on many petroleum products to detect deterioration and contamination. In some cases color tests are performed to identify products.

- Jet fuels, kerosene, and solvents are usually color tested by the Saybolt chromometer method (D 156). Undyed motor and AVGASs can

also be tested by this method. Equipment used in the test includes a Saybolt chromometer, color standards, and a daylight lamp.

- Diesel fuel, lubricating oils, and heating oils are color tested by the ASTM color scale method (D 1500). Equipment used in the test includes a light source, glass color standards, a sample container, and a viewing piece.

- Dyed AVGASs are color tested by ASTM method D 2392. Equipment used in the test includes a color comparator, fluid tubes, plungers, and aviation gasoline color standards.

- Dyed MOGAS is tested by FTMS No. 103.5. This method is similar to the method used to test dyed AVGAS. In both tests, the Hellige apparatus is used.

Significance. In refining, a color test is used to determine the uniformity of a product batch. Once the product is in the distribution system, a color test is used as a quick check for deterioration and contamination. If a color test reveals a color darker than expected, the test may indicate contamination by a heavier product or deterioration due to age. If a test reveals a color lighter than expected, the test may indicate contamination by a clear or straw-colored product.

CONE PENETRATION OF GREASE (ASTM D 217)

Scope. This test is performed on greases to measure their consistency (thickness) or resistance to breakdown under force. It is generally measured as unworked (new) or worked (simulated use) penetration. The higher the penetration number, the lower the consistency or thickness.

Significance. The penetration number is used by refiners to show a uniformly produced product. Its value is related to the oil used and the base soap used. Typically, a mineral oil is mixed with a calcium, sodium, lithium, aluminum, or barium soap base. Calcium base usually has a high penetration number and aluminum is generally in a medium range. Sodium, lithium, and barium have low

penetration numbers. An increase in the penetration number can indicate an oil/soap separation of the grease in storage. Greases are graded much like oils. Table 8-1, page 8-4 reflects the NLGI

grading system for greases based on penetration range.

Table 8-1. Grades of grease

NLGI GRADE	WORKED PENETRATION RANGE MM/10
000	445-475
00	400-430
0	355-385
1	310-340
2	265-295
3	220-250
4	175-205
5	130-160
6	85-115

COPPER CORROSION (ASTM D 130)

Scope. This test is run on almost all petroleum products to check for any contaminant that could corrode copper components in equipment.

Significance. This test is a qualitative measure of the corrosiveness of a product. This corrosiveness comes from the presence of free sulfur or sulfur compounds. When properly refined, these products are non-corrosive, with ASTM D 130 ratings of 1A or 1B. Test results of greater than 1B indicate the presence of corrosive compounds. This is usually unacceptable; however, in the case of some products, short-term use of the product may be authorized. In bulk storage tanks, corrosion results from H₂S being formed in water bottoms and percolating up through the product. Off-specification corrosive fuel must be blended with a better, less corrosive fuel to bring it within acceptable limits. Sulfur tests should also be performed to determine the exact amounts of sulfur compounds present. In lube oils and hydraulic fluids, blending of off-specification corrosive product is generally

not feasible, and these products should be reported according to directives for proper disposal.

DISTILLATION (ASTM D 86)

Scope. The distillation test is performed on light distillates such as aviation turbine fuels, MOGASSs, AVGASSs, distillate fuel oils, and kerosene.

Significance. The distillation test is used to evaluate vaporization characteristics of a fuel. To obtain a fuel that has specific characteristics, controls must be established over the amount of evaporation that will take place at different boiling temperatures. As distillation progresses, the composition of the sample changes. Some liquid residue may remain after the maximum temperature is reached. This portion of the fuel may not vaporize in service; it will remove the lubricant from the cylinder walls and contribute to crankcase oil dilution. Figure 8-1 shows a typical gasoline distillation

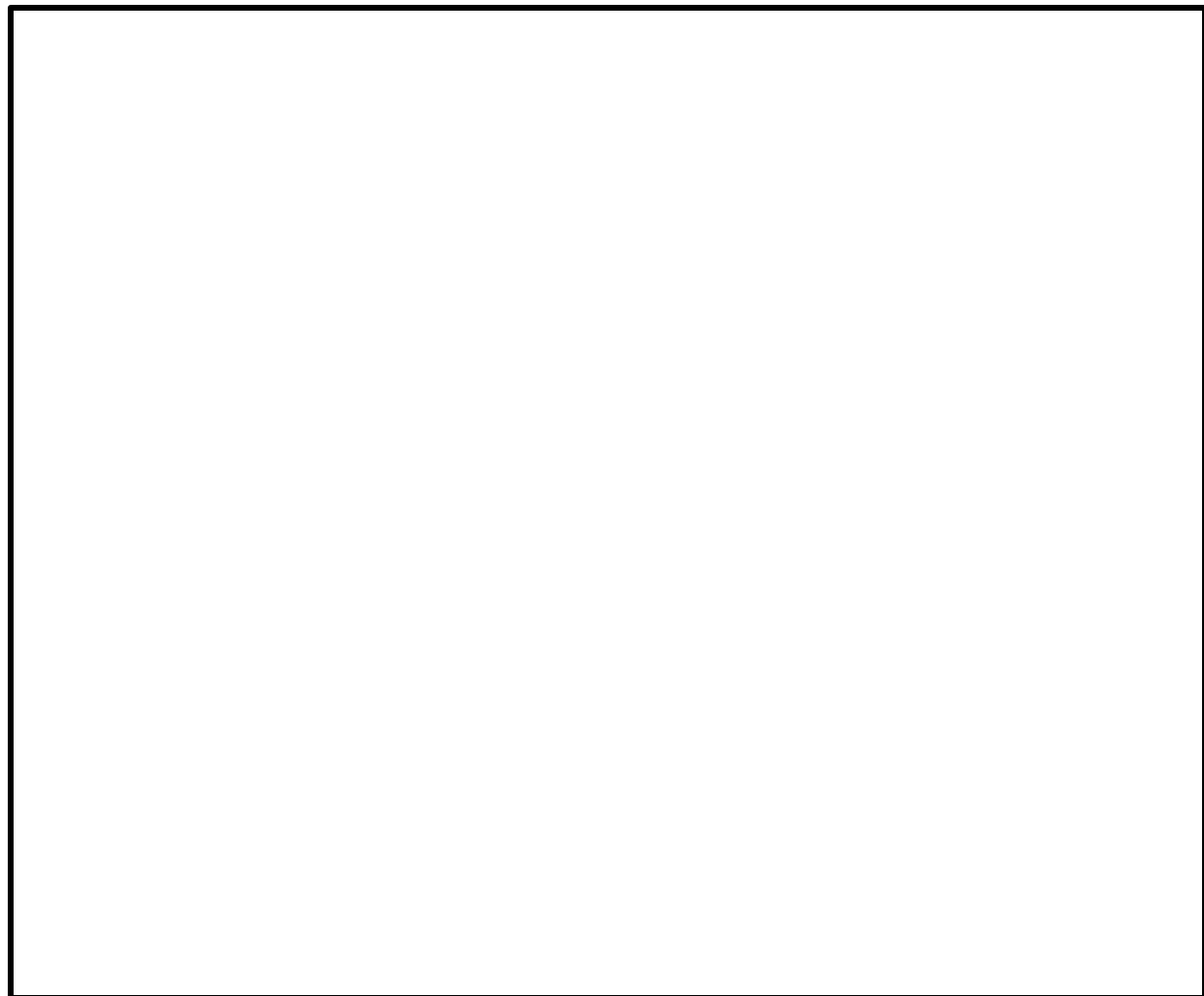
curve. The curve illustrates the significance of percentages evaporating at different stages in the boiling range and how these stages are evaluated.

- MOGAS is a complex mixture of relatively volatile hydrocarbons that have different boiling points. Easy starting, quick warmup, freedom from vapor lock, good manifold distribution,

and minimum crankcase dilution are all performance features that are directly related to volatility of the gasoline. Fuel economy depends on volatility as well as other characteristics, such as combustion behavior. Seasonal and geographic grades of fuel differ principally in vaporization tendencies.

- AVGAS which vaporizes too readily may form bubbles particularly at higher altitudes, in the fuel lines or the carburetor. The bubbles cause partial or complete blockage of the fuel supply, and the engine may operate abnormally or stall. This is known as vapor lock. Conversely, gasolines which do not completely vaporize may cause poor engine performance of other sorts. Therefore, gasolines must conform to a very narrow volatility range to be suitable for use in aircraft engines.

- Diesel fuel contaminated by a lighter product will have a lower initial boiling point and a lower flash point. A dilution of one part of light product per hundred parts of diesel fuel may drop the initial boiling point by 50°F and the flash point by 12°F.



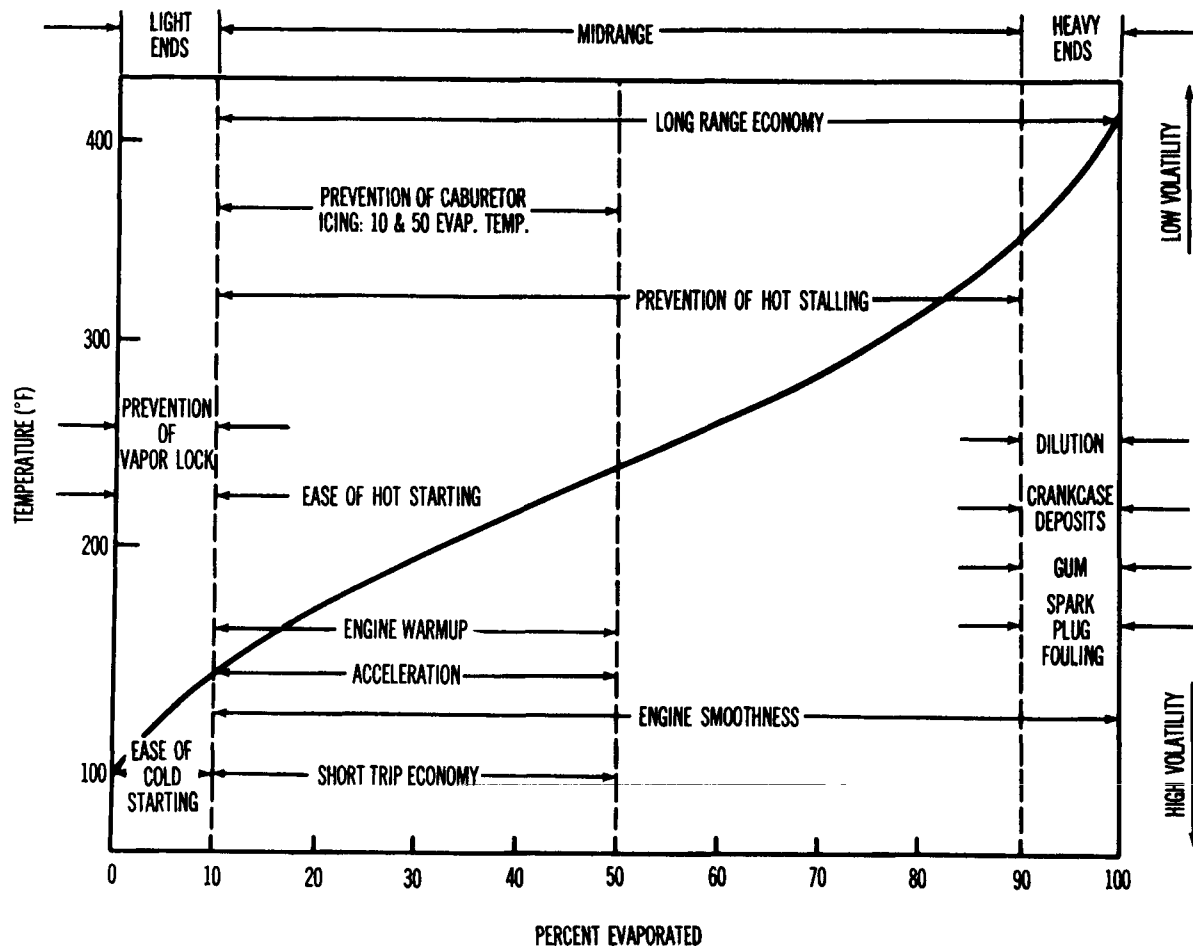


Figure 8-1. ASTM distillation curve.

(From Chemical Technology of Petroleum, by Gruse and Stevens; copyright 1960, McGraw-Hill Book Company, Inc. Used with the permission of McGraw-Hill Book Company)

DROPPING POINT OF GREASE (ASTM D 566)

Scope. This test is performed on many greases to determine the temperature at which the grease will change from a semi-solid to a liquid.

Significance. The dropping point test is useful in predicting the maximum temperature to which a grease may be subjected in use. In quality control work, it is useful in establishing a trend of results on which to base stock rotation. The dropping point is indicative of the type of thickener base. Calcium, aluminum, and lithium base greases have low to medium (175°-275°F) dropping points. Sodium and barium base greases have high dropping

points (above 275°F). Greases that fail the test should be disposed of according to regulations.

EXISTENT GUM (ASTM D 381)

Scope. The existent gum by jet evaporation test is performed on MOGAS and aircraft fuels.

Significance. High gum content indicates that the fuel might cause deposits in the induction system and sticking of intake valves. The existent gum test can tell the user the amount of oxidation that has taken place before the test was performed. Storage tanks that are vented to the atmosphere, breathe when temperatures fluctuate.

This causes the fuel to oxidize and form gum. Contaminated fuel will show an oily gum; deteriorated fuel will show a dry gum. High-gum product can be blended down to a usable level by adding a low-gum product of the same grade.

FREEZING POINT (ASTM D 2386)

Scope. This test is run on aviation fuels to determine the lowest temperature at which a fuel will flow.

Significance. Wax and excess aromatic components in fuel raise the freezing point. These

components can be present as a result of contamination or poor refining. Modern aircraft fly at high altitudes where temperatures can be as low as -67° F. At these low temperatures, wax and aromatics can freeze and clog fuel line strainers, shutting off the engine. At the procurement level, a fuel failing the freezing point test usually indicates poor refinery blending. Such fuel is rejected and reblended before shipment. In quality surveillance work, a fuel failing the freezing point test usually indicates contamination with diesel fuel or fuel oil. This can be confirmed by high distillation end points, oily gum results, and water reaction interface test failures. Fuels failing the freezing point test can be upgraded by blending with on specification product.

FUEL SYSTEM ICING INHIBITOR (FSII) (FTMS 5327.4 AND ASTM 5006 /B-2 TEST KIT)

Scope. This test is performed on jet turbine fuels that contain the inhibitor ethylene glycol monomethyl ether or diethylene glycol monomethyl ether. The B-2 test kit technique is not applicable to diesel fuel.

Significance. FSII is added to jet fuels to prevent dissolved water from freezing at high altitudes (above 8,500 feet). In 1962, the use of FSII was adopted worldwide in military jet fuels. FSII must be added at procurement at a 0.10 to 0.15 percent

volume level. It must be retained in jet fuels until end usage from 0.08 to 0.20 percent volume (use limits). FSII will drop out of fuel easily when the fuel is in contact with water. Proper quality control of jet fuel requires that contact with water be strictly avoided. If test results show that the FSII content is between 0.15 and 0.20 percent, the cause is usually testing error or blending error in the storage tank. If the result is between 0.08 and 0.10 percent, the fuel is suitable for use but should be upgraded by blending or injecting additive. If the result is less than 0.08 percent, the fuel is not suitable for use until it is upgraded. Storage procedures should be evaluated to find the source of the water contamination.

IGNITION QUALITY OF DIESEL FUELS (ASTM D 613/ D 976)

Scope. This test is made on diesel fuels to determine ignition quality, which is expressed as a cetane number. The cetane number scale is similar to the octane number scale used in rating gasoline.

Significance. When a fine spray of fuel is injected into the combustion chamber of a diesel engine, ignition does not occur immediately. The heat produced by compression varies from about 825°F at 10:1 compression ratio to about 1,050°F at 15:1 compression ratio and is the sole source of ignition. The interval between the beginning of the fuel injection and ignition is called the ignition delay period. If the delay is long, the engine may be hard to start. When the accumulated fuel ignites, the excessive energy released causes the engine to knock. The shorter the delay, the easier the engine is to start and the smoother it operates.

- **Cetane number scale.** The cetane number scale is based on the ignition characteristics of two hydrocarbons (normal cetane and methyl-naphthalene). Normal cetane has a short delay period and ignites readily. It has a cetane number of 100. Methyl-naphthalene has a long delay period and does not ignite readily. It has a cetane number of 0. The cetane number of a diesel fuel is the percentage by volume of normal cetane in a blend with methyl-naphthalene that matches the ignition

quality of a reference fuel with known cetane number.

- Cetane index. If a test engine is not available or the quantity of fuel is too small for an engine test, the cetane number can be estimated from API gravity and 50 percent distillation point or calculated by using a formula or nomograph (D 976). The index value so determined is called a calculated cetane index. This method of determining approximate cetane numbers is not valid for fuels containing additives for raising cetane number or for pure hydrocarbons, synthetic fuels, alkylates, or coal-tar products.

- Reclamation of off-specification fuels. Considering laboratory results and guidance, fuels that are off specification may be downgraded or blended with fuels that are on specification.

KINEMATIC VISCOSITY (ASTM D 445)

Scope. This test is performed on diesel fuels, fuel oils, hydraulic fluids, and lubricating oils to measure the internal resistance to flow. The result is reported in cSt. Tables exist for converting kinematic viscosity in cSt to Saybolt Universal Viscosity in seconds and Saybolt Furol Viscosity in Saybolt Furol seconds, see ASTM D 2161.

Significance. A viscosity range is established for fuel and is the prime test to separate various grades. The viscosity range is needed to maintain flow conditions in the heavier (4, 5, or 6) grades. In grades 1 and 2, the viscosity determines how

well the fuel will be vaporized. Poor vaporization at the fuel nozzle can cause poor burning and carbon formation. Too low a viscosity can cause flashbacks in the burners. Viscosity test results may be high if the fuel is contaminated with a heavier fuel. The fuel should also show a darker color. When the result is lower than expected, contamination by a lighter product, such as gasoline or jet fuel, is indicated. A corresponding low initial boiling point in distillation and a low flash point will also occur. Either high- or low-viscosity problems can be corrected by blending.

SAE Weight/Grade. Viscosity in lubricating oils is used to determine the SAE weight/grade of the oil. Tables 8-2 and 8-3, page 8-8 show SAE numbers. Viscosities are expressed in cSt. Viscosity results are seldom higher than expected. Usually, low viscosity is caused by dilution or gasoline contamination. Off specification oils are changed and disposed of as permitted by regulation.

Viscosity Index. VI is a means of rating resistance to change in viscosity with change in temperature. The scale was originally set up with a paraffin base oil having a viscosity index of 100 and a cycloparaffin base oil having a viscosity index of 0. Now additives, such as polyisobutylene, are added to raise the VI to the 200 range. Multi-grade oils, such as 10W-40, have a high VI. They have a paraffin base. Polyisobutylene acts as a pour-point depressant as well as a VI improver.

Table 8-2. Crankcase oil viscosities

SAE No	VISCOSITY AT 100° C (cST)	VISCOSITY AT 40° C (cST)
10	6.2	40.2
30	11.4	105.2
40	13.5	130.4
10W-30	10.0	61.0
15W-40	14.2	106.9

Table 8-3. Gear oil viscosities

SAE No	VISCOSITY AT 100° C (cST)
75w	4.1
80w	7.0
85w	11.0
90	13.5 to 24.0
140	24.0 to 41.0
250	41.0

LEAD IN FUELS (ASTM D 2547, D 2699, D 3341, AND MIL-HDBK-200)

Scope. These tests are performed on MOGAS and AVGAS to determine the quantity of lead present. Lead determination on unleaded gasoline and jet fuel suspected of lead contamination may be determined by ASTM D 3116, D 3229, D 3237, or MIL-HDBK-200.

Significance. Lead may be present in MOGAS and AVGAS as a result of intentional blending. It may be present as a result of contamination. This contamination may occur by an accidental mixing with a leaded fuel, or it may occur because of improper storage or transport. In jet fuel, lead is a contaminant; it is never intentionally added because it forms deposits on turbine fans. These deposits can affect the balance of the fans, which may result in fan failure. ASTM methods D 2599 and D 3341 are used to determine the amount of lead in MOGAS and AVGAS. It can be used to measure lead content in the range of 0.001 to 0.020 grams of lead per liter of fuel.

NEUTRALIZATION NUMBER (ASTM D 974)

Scope. This test is performed on new oils and distillate fuels to detect any excess acid or basic components left over from refining. It is also performed on used oils to detect acid or basic increases due to oxidation.

Significance. In new oils and distillates, the test results generally will be less than 0.1, showing that mineral acids or bases were removed during refining. Higher results than allowed in specifications indicate inadequate refining. In used oils, the test measures the increase in acids formed as a product of combustion. These organic acids, although weak, can have a corrosive effect on cylinder walls and rings. Basic additives are added to new oils to help neutralize these acids. Over long periods of use, these additives will be consumed and a rise in neutralization number will occur. This rise will indicate a need to change oil.

OXIDATION STABILITY AND POTENTIAL GUM (INDUCTION PERIOD METHOD AND POTENTIAL RESIDUE METHOD) (ASTM D 525 AND D 873)

Scope. These tests are used to predict the stability of AVGAS MOGAS in long-term storage.

Significance. When gasoline is subjected to long-term storage, they tend to oxidize. To retard this process, refiners add oxidation inhibitors and remove unstable hydrocarbons as much as possible. However, the products will retain some aromatics (which are unstable) to increase octane or performance number. To measure the tendency of gasoline to oxidize and form gum, two tests are used.

- MOGAS. ASTM D 525, Oxidation Stability of Gasoline (Induction Period Method) is

used to determine stability of MOGAS under accelerated oxidation conditions. In this test, a sample is oxidized in a bomb, and the pressure is read and recorded in chart form at stated intervals until the break point is reached. (The break point is the point in the pressure-time curve that is preceded by a pressure drop of exactly 2 psi within 15 minutes and succeeded by a drop of not less than 2 psi in 15 minutes.) If a break point is observed, the decrease in induction time over a period of months can be used to determine when stocks should be rotated. If no break point is reached, the Existent Gum Test (D 381) is run and stocks are rotated while they are still on specification.

- **AVGAS.** ASTM D 873, Oxidation Stability of Aviation Fuels (Potential Residue Method) is used to determine the tendency of AVGAS to form gum and deposits under accelerated aging conditions. In this test, a sample is oxidized in a bomb, and the amounts of soluble and insoluble gums and precipitate are weighed. An increase in precipitate signals possible 1088 of tetraethyllead. Results of the tests can be used as a basis for stock rotation.

PARTICULATE CONTAMINANT IN AVIATION FUEL (ASTM D 2276, ASTM 5452, ASTM 3830)

Scope. These tests are run on aviation and ground fuels to test for the presence of excessive nonpetroleum contaminants such as dirt, sand, and metal.

Significance. From the time a fuel is refined until it is used, it comes in contact with iron, rust, sand, and other solid contaminants. Generally, fuel is allowed to settle and then filtered in order to remove these contaminants. The particulate contaminant test is performed at various distribution locations to determine the effectiveness of the cleaning process. If the test result is too high, an immediate resample should be taken as high results may be due to poor sampling technique. If a resample also fails, the entire system should be evaluated to detect the problem. The high result could be caused by inadequate settling times or

unserviceable filter elements. Specification requirements for particular products may be found in their respective military specification. Deterioration limits may be found in MIL-HDBK-200.

PENSKY-MARTENS FLASH POINT (ASTM D 93)

Scope. This test is run on fuel oils and diesel fuels and is used to verify that the fuel oil or diesel fuel meets minimum safety levels for combustible vapor formation. It is especially significant for testing fuel to be used by ships.

Significance. The flash point generally is associated with the LCL for fuel. If the fuel oil flash point drops by more than 6°F, contamination with a lighter product (gasoline or jet fuel) should be suspected. This should also show up in a lower IBP in the distillation. If the flash point goes up more than 6°F, contamination with a heavier product (heavy fuel oil or lubricating oil) should be suspected. A higher distillation end point, higher viscosity, and possibly a color change will verify this. To a limited degree, off specification product can be upgraded by blending.

POUR POINT OF PETROLEUM OILS (ASTM D 97)

Scope. This test is performed on most petroleum products. It can also test the fluidity of a residual fuel oil at specified temperatures.

Significance. The tests are important in determining the use of products in cold climates. The pour point of a petroleum specimen is an index of the lowest temperature of its utility for certain applications. If a product will not pour below a certain temperature, it will have restricted use. Products that have a pour point that does not meet specifications usually are contaminated by a heavier product.

PRECIPITATION NUMBER (ASTM D 91)

Scope. This test is run on selected new oils to test for undesirable asphalt-base components. In used oil, it is used as a contamination indicator.

Significance. When lubricating oils are produced, they contain primarily paraffin base, heat-resistant components. Asphalt base products are unstable and are excluded from these lubricants. Precipitation number is used to quickly measure any asphalt base products in a lubricant. Test results generally show no more than traces in a sample. In used oils, the test measures oxidized components, such as dust and dirt, in the oil and can indicate how well the filter is cleaning the oil.

REID VAPOR PRESSURE (ASTM D 323)

Scope. The RVP test is run on JP-4 and gasoline to ensure the product will vaporize when required.

Significance. Vapor pressure must be at a level that will ensure the fuel vaporizes in the carburetor. If the pressure is too high, fuel will vaporize in the fuel line, causing vapor lock, and the engine will not run. Also, fuel in storage with too high an RVP will evaporate excessively. If the vapor pressure is too low, fuel will enter the carburetor as a liquid, causing oil dilution and incomplete combustion. RVP is directly related to temperature. For this reason, refiners adjust gasoline vapor pressures to fit the season. If the RVP of an AVGAS is too high, contamination with a higher RVP MOGAS is suspected. If the RVP of a gasoline is too low, contamination with a heavier product or deterioration due to weathering is indicated. The distillation test IBP and 10 percent points will be high when the RVP is lower, and deterioration is indicated. If caused by contamination, the distillation end point will be high. If the RVP of JP-4 is too high, gasoline contamination is indicated. Lead contamination should be suspected. If JP-4 RVP is too low, the same problem indicated by a low gasoline RVP exists. Generally, RVP problems can be solved by blending with on specification product.

SMOKE POINT (ASTM D 1322)

Scope. This test is run on aviation turbine fuel.

Significance. Smoke point of jet fuels is a property similar to the burning quality of kerosene, and tests are made in a lamp as in the case of kerosene. Excessive smoke can usually be observed when a jet aircraft takes off. Smoke consists of particles of free carbon suspended in the gases of combustion. This free carbon would not be seen if perfect mixing of fuel and air could be obtained, and there would be no deposits of carbon in combustors. Two types of carbon are deposited—soft and fluffy (amorphous) and hard and crystalline (graphitic). The hard variety can damage turbine engine fans and fuel injectors. Of several tests tried, the height of a flame at the point where smoking begins appears to give the best correlation with the tendency to deposit carbon.

SULFUR IN PETROLEUM PRODUCTS (ASTM D 129, D 1266, D 1552, AND D 2622)

Scope. Sulfur content tests are performed on all petroleum products. These tests are required usually because of pollution laws that restrict the amount of sulfur dioxide-producing elements in products.

Significance. Sulfur is an impurity in all petroleum products. Its presence can be either good or bad. In gear oils and cutting oils, it is desirable to have sulfur compounds present because they increase the lubricating film strength of the oil. In gasoline, diesel fuels, fuel oils, jet fuels, solvents, and lubricants, sulfur is undesirable. In the case of fuels, sulfur will oxidize to form sulfur dioxide in the combustion chamber. This test is especially critical on these products because of EPA regulations. This gas combines with water, also a combustion by-product, to form sulfurous or sulfuric acid. These acids are corrosive to metal engine parts. Sulfur dioxide also is an air pollutant that EPA closely monitors. In the case of leaded gasoline, sulfur reduces the effectiveness of the lead compounds. Sulfur is kept to a minimum by using a

low-sulfur crude oil (generally less than 2 percent). In refining, the distillates usually carry over only a minute amount of sulfur. The resulting residuals are then treated to reduce the sulfur content. In general, the sulfur content in gasoline ranges from 0.02 to 0.05 percent; in distillate fuels, 0.10 to 1.07 percent; and in residuals, up to 3.0 percent. Fuels with high sulfur content can be upgraded by blending with a low sulfur product of the same grade. If blending is not possible, permission can usually be obtained to burn the high sulfur fuel for a limited time.

TAG CLOSED CUP FLASH TEST (ASTM D 56)

Scope. This test is run on kerosene, solvents, JP-8, and commercial jet fuels. Liquids that flash below 100°F are considered flammable.

Significance. Flash point can be lower when the product is contaminated by a lighter product such as a gasoline or light jet fuel. This test is critical because many types of equipment run on fuels with a specific minimum flash point. Use of a lower flash point product can result in explosions or fires. A product with a low flash point should be upgraded by blending before it is used.

THERMAL STABILITY (ASTM D 1660 AND D 3241)

Scope. These tests are run on aircraft turbine fuels to check for resistance to thermal breakdown.

Significance. Thermal stability is the resistance of fuels to chemical and physical change upon exposure to high temperatures that tend to decompose them. Thermal stability of fuels under high temperatures has become increasingly important in the transition of jet aircraft from subsonic to supersonic speeds. Fuel is expected to perform a cooling function by providing a heat sink; that is, by absorbing the heat generated in high-speed flight. Fuel cannot do this unless it resists decomposition. A coke-like substance forms in thermally unstable fuels and plugs fuel jets and

manifolds. Aircraft fuels are routinely exposed to test temperatures of -65° to 400°F. Presence of aromatics and olefin components are restricted in jet fuels because they are less heat resistant. Low thermal stability is usually caused by contamination with a MOGAS or AVGAS that contains these undesirable components. This problem can usually be corrected by blending with better product.

WATER AND SEDIMENT (ASTM D 95, D 1796, AND D 2709)

Scope. These tests are run to determine the amount of water in crude, fuel, and lubricating oils (D 95), the amount of water and sediment in crude and fuel oils (D 1796), and the amount of water and sediment in diesel and other distillate fuels (D 2709).

Significance. Water and sediment that accumulate in ship cargo tanks and in shore tanks affect quality and quantity. Excessive sediment can plug burner tips and prevent fuel from vaporizing properly. This is also true for injectors in diesel engines. Water in fuel may freeze and clog fuel lines. Water in lubricating oils can corrode metal surfaces and cause a loss of additives. Water and sediment can be removed by letting the product settle and filtering it. Drummed and canned stock contaminated by water or sediment or both must be disposed of as prescribed by regulations.

WATER REACTION (ASTM D 1094)

Scope. This test is performed on aviation fuels to determine the presence of excess alcohol or aromatic components and to evaluate the presence of surfactants on the fuel/water interface.

Significance. The water layer in the test is initially set at 20 milliliters. If the level increases in the test, this indicates the presence of alcohol. If the water layer decreases from 20 milliliters, the presence of aromatics is indicated. Aromatics absorb water, and excess amounts of them will cause excess water to be held in fuel. This water will freeze at high altitudes, clogging fuel lines. For these reasons, a water level change value is

set in aircraft fuel specifications. The interface ratings are set to measure the effect of surfactants in the fuel. These surfactants can cause excess sediment and water retention, which causes fuel filter clogging. There is a correlation between the WSIM rating or the MSEP surfactant rating and the interface rating. As the WSIM/MSEP rating

goes down from 90, the interface rating goes up. Experience has shown the following relative correlation (see Table 8-4). Any result above 1b can indicate a problem, but the result should be double-checked with clean cylinders and new buffer solution.

Table 8-4. WSIM/MSEP- Interface rating correlation

WSIM/MSEP	INTERFACE RATING
90 and above	1
80 to 90	1b
70 to 80	2
60 to 70	3
Below 60	4

WATER SEPARATION CHARACTERISTICS: WSIM OR MSEP SURFACTANTS (ASTM D 2550, D 3948)

Scope. A water separation characteristics test is performed on aviation turbine fuels to determine the presence of surfactants and predict filter/separators problems resulting from these surfactants.

Significance. Occasionally in the refining of turbine fuels, sulfonates and naphthenates are retained in small quantities. These surfactants can cause fuels to retain water in emulsions that are difficult to separate using filter/separators. Thus, the water can get into aircraft fuel tanks. This water can freeze at high altitudes or reduce the FSII protection in the fuel. Jet fuels should never be batched in multiproduct pipelines immediately behind MOGAS or AVGAS. Additives in these fuels tend to coat the pipeline and are picked up by the next product in the line. These additives (corrosion inhibitors, lead scavengers) are very active surfactants in jet fuel and will cause the fuel to fail the water separation characteristics test (WSIM or MSEP) and the water reaction inter-

face test. A SDA will also cause the fuel to fail the WSIM or MSEP test. Correlation exists between the WSIM/MSEP rating and the water reaction interface rating. WSIM/MSEP ratings should be tempered with the history of the fuel. If the ratings are on the base stock, the results are valid. However, if the fuel has moved through multiproduct lines or if an SDA has been added, the results will be invalid. Off specification fuel should be allowed to settle for at least one hour per foot in depth before being retested. If it is still off specification, the fuel should be passed through a filter/separators containing new filter/coalescer elements. The fuel could also be clay treated, but this would remove all of the additives, and new additives would have to be introduced.

NOTE: The microseparameter technique (ASTM D 3948) will eventually replace the WSIM (ASTM D 2550). It is necessary to list both techniques until the new apparatus is supplied to the laboratories.

CONDUCTIVITY (ASTM D 2624)

Scope. This test is performed on JP-4 and JP-8 turbine fuels containing a SDA.

Significance. The ability of a fuel to dissipate electrical charges that have been generated during pumping and filtering operations is controlled by its electrical conductivity, which depends upon its content of ion species. If the fuel conductivity is sufficiently high, charges dissipate fast enough to prevent their accumulation and dangerously high potentials at a fuel dispensing point. The use of

SDA can increase fuel conductivity to safe levels. SDA is added to JP-4 or JP-8 turbine fuels in very small proportions so that its effectiveness can be diminished by blending with other fuels that do not contain SDA. Moreover, conductivity can be affected by filtering and transferring operations and by temperature changes. For this reason, the fuel sample for the conductivity test is taken close to where the fuel enters the aircraft.

SECTION II Identification of Unknown Products

GENERAL

In addition to routine analyses of petroleum products, tests are often needed to identify captured petroleum stocks, products that have been marked improperly, or products that have been stored so long that markings have become illegible. The unknown product must be identified as to type, and classified as to intended use by tests described in Section I of this chapter. This is done by comparing the unknown product specifications with the specifications established for its intended use. The use of the product is important. One that does not meet deterioration-use limits for a particular purpose must not be used for that purpose unless specifically authorized.

CLASSIFICATION BY GRAVITY

For convenience in identifying unknowns, an arbitrary division of products can be based on API gravity (see Figure 8-2, page 8-14). A test for API gravity is usually the first test made on an unknown product. Products which have a gravity of 35 ° API or higher and which are subjected to the distillation test are classified as light distillates. Products which have a gravity lower than 35° API and which are not subjected to the distillation test are classified as heavy distillates. This is an arbitrary division for convenience only. This division does not necessarily hold true for all petroleum products.

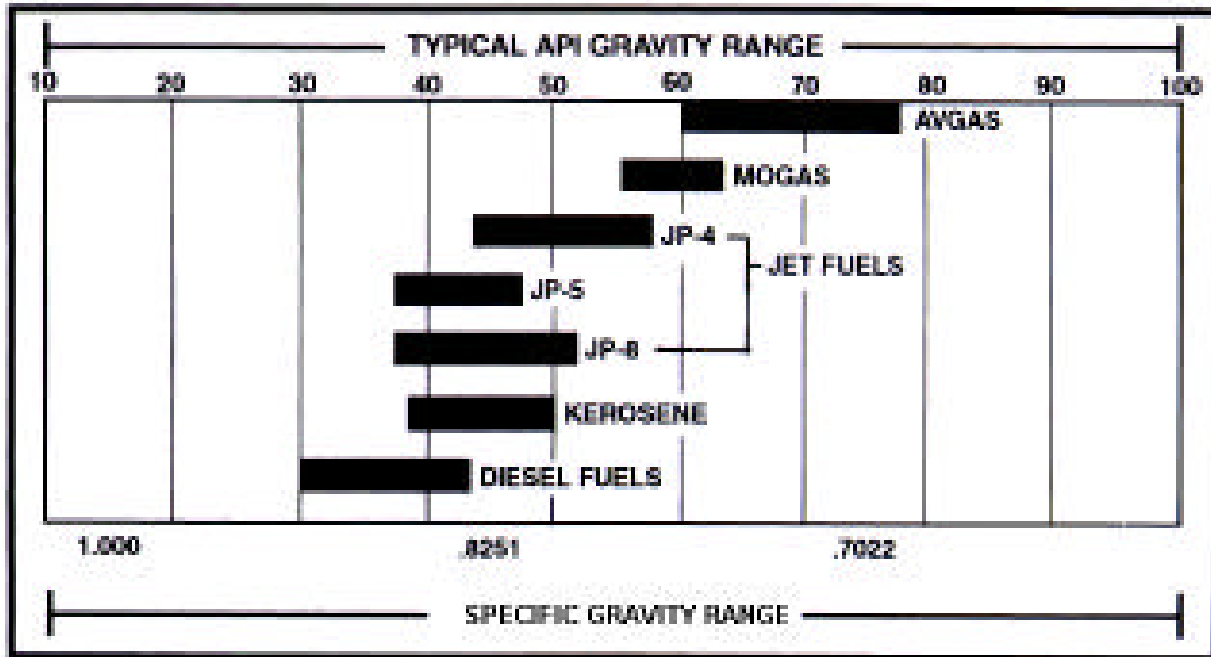


Figure 8-2. API gravity scale for petroleum products

LIGHT DISTILLATES

Gasoline. The first test for light distillates is a visual inspection. If the unknown has the characteristic odor and appearance of gasoline, the sample container should be recapped and refrigerated as soon as possible for the RVP test. If the product is red, green, or blue, it may be 80, 100/130, or 100/130LL AVGAS or a light product commingled with AVGAS. If the product is another color, it may be ordinary AVGAS specification, ASTM D 4814. RVP test and distillation separate these fuels into classes A, B, C, D, and E. Specifications ASTM D 4814 and MIL-G-3056 give the requirements that must be met if the unknown is to be used as gasoline. Colors may be confusing as some unleaded automotive gasoline are green and blue, and in some areas, diesel fuel is colored.

Water-White Products. Water-white products include some jet fuels, kerosenes, benzene, naphtha, solvents, and unleaded gasoline. Unleaded

gasoline is not always white; colors that have been noted in the field include yellow, orange, blue, green, blue-green, and red. Any combination of tests for API gravity, RVP, and distillation will aid in separating products.

- Naphtha (D-95, type I, grades A and B) is separated by API gravity. API gravity is also extremely important in testing jet fuels because of maximum and minimum specification limitations.
- Distillation is the key test in separation of other products in this category. Each product has a distinctive distillation curve.
 - API gravity and RVP tests will definitely separate JP-4 and kerosene.
 - API gravity and RVP tests will separate JP-4 and JP-5.
 - MIL-T-5624 (JP-4), ASTM D 3699 (kerosene), VV-B-231 and MIL-B-3137 (benzene), ASTM D 91 and TT-N-97 (naphtha), and P-D-680 (dry-cleaning solvent) give the requirements to be met if the unknown is to be used as any of the products named above.

Diesel and Burner Fuels. (Straw-Colored Products).

- If it is impossible to identify an unknown as either diesel or burner fuel, the identity of the unknown should be reported as burner fuel. Burner fuel is less critical in its use requirements than diesel fuel.

- Distillation, flash point, pour point, and viscosity tests usually simplify the identification and separate the identity of diesel fuels.

- Separation of grades 1 and 2 of burner fuels from diesel fuels is difficult. API gravity and viscosity tests are important.

- Specifications MIL-F-16884, ASTM D 396 and CID A-A-52557 provide the requirements for diesel and burner fuel.

HEAVY DISTILLATES

There are two categories of heavy distillates: burner fuels and lubricating and specialty oils. Burner fuels are readily separated from lubricating and specialty oils on the basis of relatively low flash point (below 220°F). Three key tests are used to identify and classify lubricating oils and specialty products. Viscosity tests provide information that can be used to recommend a product for a specific use. The saponification number and plain ash tests group the product according to general use. Results of saponification number and ash content tests permit heavy distillates to be divided into three groups:

- Group A distillates are those with a saponification number less than 2.0 and an ash content greater than 0.05 percent.

- Group B distillates are those with a saponification number greater than 2.0.

- Group C distillates are those with a saponification number less than 2.0 and an ash content less than 0.05 percent.

GROUP A DISTILLATES

Types of Products. Group A products include straight mineral oils containing organic additives

or residual fuel oils. The group includes the following products:

- Residual burner fuels, heavy and Navy grades.
- MS 9000-series engine oils (diesel).
- OE-series engine oils (internal combustion).
- Preservative engine oils (PE).

Separation of Types. Fuel oils are easily separated from the remaining group A products by testing the flash points, which are considerably lower. Results of a viscosity test determine the grades of the products.

MS-9000, OE and PE Series. MS 9000-series oils, OE and PE, can be classified to a degree by viscosity. However, each series contains products with identical ratings. Therefore, the possibility exists that the product could meet the specification for one product in each series. If this happens, the product should be recommended as the applicable OE product (least critical).

The applicable specification gives the requirements for the unknown to be recommended for a particular use.

GROUP B DISTILLATES

Types of Oils. Test results yielding a saponification number greater than 2.0 show that certain oils should be considered as follows:

- MS 4065 oil, viscosity 65-80 SSU at 210°F, below rapeseed.
- MS 6135 oil, viscosity 120-150 SSU at 210°F, tallow.
- MS 7105 oil, viscosity 95-110 SSU at 210°F, tallow or lard.
- MS 8190 oil, viscosity 180-200 SSU at 130°F, lard.
- Sulfurized cutting oil.
- Soluble cutting oil.
- Hypoid gear oil.
- Other gear oils.

Separation of Types. Group B distillates are separated according to the following guidelines.

- The MS oils, except MS 4065 and MS 8190, can be separated easily by viscosity. A further separation of these two oils can be based on the percentage of fatty oils required.
- Sulfurized cutting oils can be separated from other products in this group by their extremely high saponification numbers and large sulfur content. The applicable specification gives the requirements if the product is to be recommended for a particular use.
- Soluble cutting oils can be distinguished by their solubility in water.
- Gear oils can be separated in several ways. Subzero gear oil can be separated by its low pour point, high ash content, and viscosity at -65°F.

GROUP C DISTILLATES

Types of Oils. Group C products are straight mineral oils containing additives that do not form ash. Additives of this kind include pour point depressants, viscosity index improvers, and oxidation inhibitors. The group includes types of oils as follows:

- MS 1000-series aircraft engine oils.
- MS 2000-series general-purpose oils.
- MS 3000-series general-purpose oils.
- MS 5000-series steam cylinder oils.
- Specialty oils.

Separation of Types. The viscosity test separates most of the oils in this group. Oils whose viscosity ranges overlap are discussed below.

- MS 3000 and MS 5000 oils can be separated by a combination of results from the VI, pour point, and carbon residue tests. MS 5000-series oils usually have much higher flash points than others in the group.
- There are several instances where a 2000-series product will have overlapping specifications with a 3000-series product. If positive identification is not possible, the unknown should be recommended for use as a 2000-series product.
- The applicable specification gives requirements to be met if the product is to be recommended for a particular use.

REPORTS AND RECOMMENDATIONS

When the tests for identifying or classifying an unknown product have been completed, the laboratory performing the tests prepares a letter of identification for the requesting agency. The letter contains identifying information and recommendations for the use, reclamation, or other disposition of the product. A copy of DA Form 2077, Petroleum Products Laboratory Analysis Report accompanies the letter, indicating all test results. Any necessary charts or graphs should also be included. If a product cannot be identified or reclaimed and is unfit for any military use, the laboratory should recommend that it be disposed of, unless otherwise instructed by higher authority. The disposition of any product that has been condemned for military use is a responsibility of the owning department. Further correspondence relative to this product should be between the activity having possession of the product and the department owning it.

Section III Product Reclamation and Disposition

GENERAL

Reclamation is a procedure that will restore or change the quality of a contaminated or off-

specification product so that it will meet the specification of the original product or a lower grade

product. The process of reclamation, when properly applied, will result in downgrading, blending, purification, or dehydration. Reclamation may be recommended by the laboratory when products are identified or classified or when contaminated or deteriorated products are analyzed.

FACTORS AFFECTING RECLAMATION

Reclamation may not be undertaken without specific approval from the technical activity of the owning department. The following factors must be carefully considered before reclamation is recommended:

- What contaminating agents are present, source of contaminants, and degree of contamination?
- Probable end use of the product in its present condition. Consideration must be given to laboratory analysis, purchase specification, established deterioration use limits, and safety factors.
 - Feasibility of removing or canceling undesirable effects of contaminants to make the product usable.
 - Location, type of storage, and quantity of off-specification product.
 - Probable need for the reclaimed petroleum product.
 - Availability of time, materials, equipment, funds, and labor necessary to reclaim the product.
 - Benefits derived by the government through the reclamation of products that otherwise might be classified as hazardous waste.

RECLAMATION TECHNIQUES

Downgrading. Downgrading is the procedure by which an off-specification or slightly contaminated product is approved for use as a lower grade of a similar petroleum product.

Blending. Blending for reclamation is the procedure by which an off-specification product is mixed with on-specification stocks to produce a product of intermediate grade or quality that is wholly within use limits. However, it is unlikely

that an old product deficient in many of its critical properties could be brought within use limits. Everything depends on whether the quality of fresh stocks is much better or only slightly better than that of the old stock. Unless all critical properties can be brought up to use limits, downgrading or other types of disposition must be considered (MIL-HDBK-200).

Dehydration. Dehydration is the removal of water by a filtering or settling process. Free water settles out of most light products if allowed to stand undisturbed for about 24 hours. Excess water can then be drawn off, and the water that remains, except dissolved water, can be removed by adequate filter/separators. Warming residual products may help to break emulsions, permitting the water content to be removed as free water.

Filtration or Purification. Filtration or purification is the removal of contaminating agents by settling, filtration, or a filter/ separator. Coarse particles of dirt, mill scale, and rust settle out of light products if allowed to stand undisturbed after receipt. A minimum tank settling period of 2 hours is required for all aviation fuels, automotive gasoline, and diesel fuels after fresh stocks have been added. At least 24 hours is advisable for heavy products such as burner fuels. In addition, the product should be subjected to visual or quality tests prior to issue. Fine particles can be removed by adequate filter/separators.

IMPROVING CRITICAL PROPERTIES

Some critical properties of a few petroleum products that may be improved by use of reclamation techniques are shown below. The requirements for these products can be obtained from the appropriate military specification. The use limits can be obtained from the latest revision of MIL-HDBK-200.

Aviation Gasoline. AVGAS properties include the following.

- Performance number
- Existent gum, mg/100 ml

- Residue, percent (maximum)
- Vapor pressure, psi
- TEL, ml/US gallons

Jet Fuels. Jet fuel properties include the following.

- Existent gum, mg/100 ml:
- Steam jet (JP-4, JP-5)
- Vapor pressure, psi: (JP-4)
- Fuel system icing inhibitor
- Static dissipating additive (JP-4, JP-8)

Combat Automotive Gasoline. Combat automotive gasoline properties include the following.

- Unwashed gum, mg/100 ml
- Vapor pressure, psi:
- Type I
- Type II
- Octane number
- Lead/US gallons

Kerosene. The critical property for kerosene is the flash point.

Diesel Fuels/Fuel Oils. Diesel fuel oil properties include the following.

- API gravity
- Flashpoint
- Bottom sediment and water (FO)
- Particulate contamination (DF)

APPROXIMATING A BLENDING RATIO

Figure 8-3 illustrates a specimen graph that can be used instead of a formula to approximate a blending ratio. Other properties with appropriate scales can be substituted. The results provide only pilot blends, and each pilot blend must be tested and adjusted as needed. It is a good practice to allow a safety factor in any reclamation blending.

Problem. Prepare a pilot blend of fresh, on-specification MOGAS containing 4 mg gum/100 ml and off-specification MOGAS containing 26 mg

gum/100 ml to produce a mixture containing 7 mg gum/100 ml.

Solution. Prepare a graph showing percentage of on-specification stock across the top from 100 to 0 and percentage of off-specification stock across the bottom 0 to 100. Show gum content (or other property on a suitable scale) at both ends of graph from 30 to 0. Draw a line across the graph

at the point that represents required gum content 7 mg/100 ml. Draw a line from the point that represents gum content of 4 mg/100 ml on the left-hand scale to the point that represents gum content of 26 mg/100 ml on the righthand scale. Project the point of intersection between the sloping line and the 7 mg/100 ml line to the top and bottom scales, and read approximate percentage of fresh and old stocks for the pilot blend.

DOWNGRADING AND REGRADING

MIL-HDBK-200 contains thorough descriptions of the critical properties, use limits, downgrading, and regrading requirements for petroleum products. A few of the important points are as follows:

Jet Fuels. Jet fuels are not readily downgraded or regraded, even with blending. Because of the many limitations imposed on jet fuels, it is recommended that downgrading of these fuels not be attempted, except for ground use when possible.

Combat Automotive Gasoline. Combat automotive gasoline may be downgraded to ASTM D-4814, commercial grade fuel.

Kerosene. Kerosene containing more than 1 percent of distillate fuel, or more than 0.1 percent of residual fuel, and not passing the lamp test, should be downgraded. Blend grade K-1 (low sulfur) Kerosene with DL2 for winter use in diesel consuming equipment, or as a burner fuel. Blend grade K-2 (regular) Kerosene with burner oils and use as heating fuel. Care must be taken to main-

tain flash point and sulfur requirements within use limits.

speed diesel engines ashore, or for USE as boiler fuel ashore.

Marine Diesel Fuel. Marine diesel fuel that fails to meet carbon residue and distillation requirements should be downgraded for use in low-

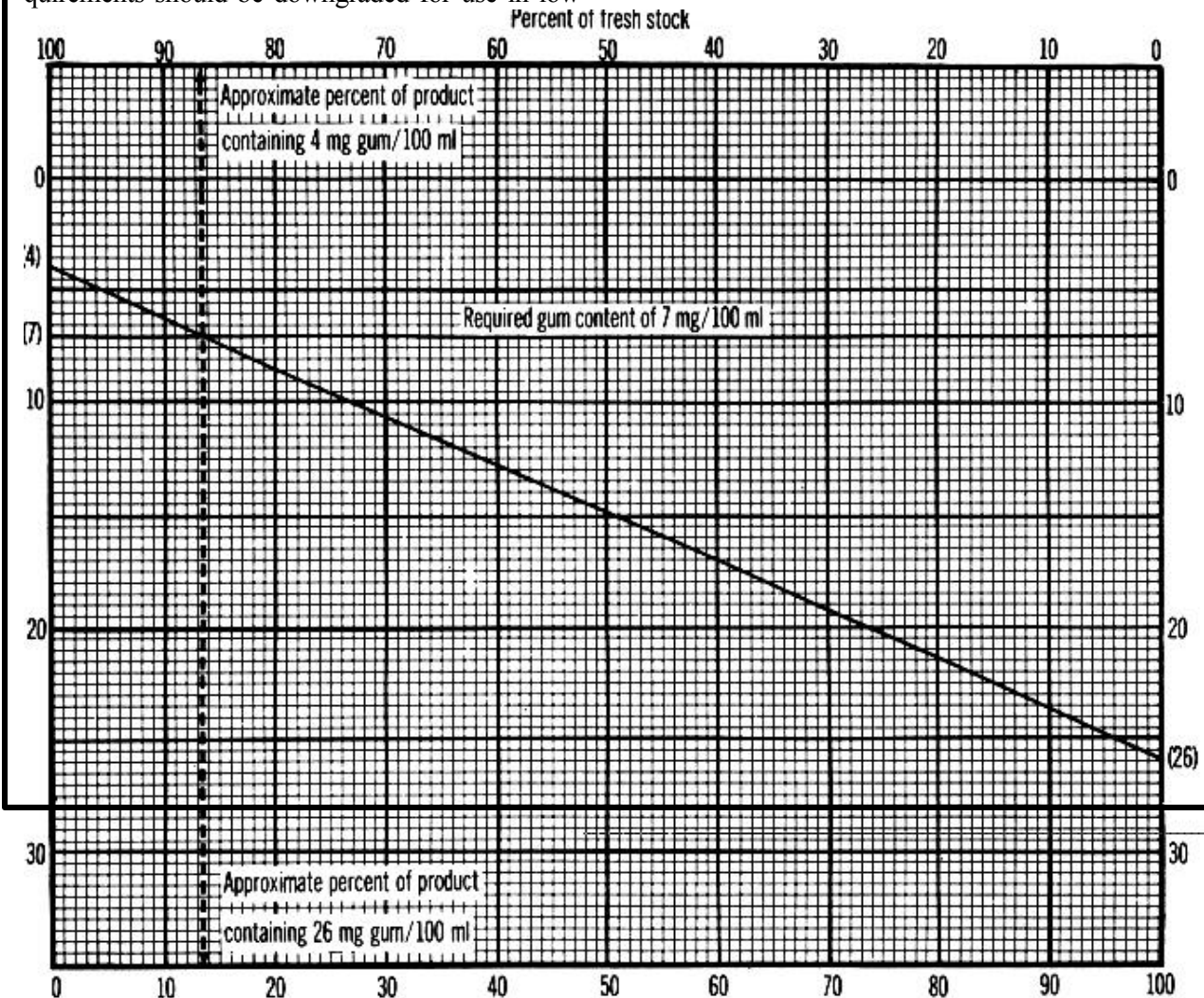


Figure 8-3. Specimen graph to approximate a blending ratio.

DISPOSITION PROCEDURES

When a DLA-owned product does not meet specification limits at intermediate storage points, the activity having physical possession of the product will contact the Defense Fuel Supply Center, for a decision about its use or disposition. When an Army-owned product does not meet

use limits at the location of use, the US Army Petroleum Center, New Cumberland, PA 17070, should be contacted for a decision concerning its use or disposition. The request for disposition instructions should include the following information:

- Specification and grade.

- Quantity.
- Location.
- Date of receipt.
- Name of manufacturer, contract number, batch number, qualification number, and date of manufacture.
 - Type of container or storage.
 - Accountable military department.
 - Need for replacement product.
 - Detail laboratory test results.
 - Recommended alternate use, disposition, or recovery measures.