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Aviation Fuel Quality Control Procedures

5th Edition

Jim Gammon, Editor

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Aviation Fuel Quality Control Procedures: 5th Edition

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Foreword

This publication, *Aviation Fuel Quality Control Procedures: 5th Edition*, is sponsored by ASTM Subcommittee J on Aviation Fuels, Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants. It provides guidance on common procedures used to assess and protect aviation fuel quality. Even though the manual was not subject to full Society consensus balloting, a ballot vote by task force members of Subcommittee J was conducted before publication. The task force members who wrote or reviewed this manual are listed in the introduction.

Contents

Introduction

This manual is sponsored by ASTM International Subcommittee J on Aviation Fuels, Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants. It was written and reviewed by a task force under Section 5 on Fuel Cleanliness. The following task force membership represents a broad spectrum of interests, including oil companies, airlines, pipeline companies, third-party refueling companies, filter companies, fueling vehicle builders, consultants, aviation product distributors, and other aviation-associated organizations.

This manual provides guidance material on common procedures that are used to assess and protect aviation fuel quality. Aviation fuel, by its unique use, is one of the most carefully controlled petroleum products, and therefore, it is required to meet exacting fuel-quality standards. In many cases, the field procedure or test method listed herein is a simplified version of the corresponding ASTM method or standard practice. It should be emphasized that the formal ASTM standard method supersedes the instructions given in this publication. In other cases, when there is no ASTM procedure, a non-ASTM procedure is included to make this publication as complete a reference as possible. Some of the procedures have resulted from practical experience in dealing with numerous airport systems.

This document explains a number of ASTM test methods used as field tests. For a complete list of methods used to qualify an aviation fuel, reference should be made to the pertinent ASTM fuel specification.

Obviously, not all field situations can be predicted. However, the purpose of presenting the extra information is to acquaint the reader with as many aspects of aviation fuel handling as possible. It is the intent of this publication to provide sufficient information for fuel handlers to make an informed approach to aviation fuel quality. In particular, this manual should be useful to third-party refueling organizations and independent fixed base operators.

Ballot vote by members of ASTM Committee D02, Subcommittee J, was required for publication of this manual. However, the methods in this manual were not subjected to full Society consensus; therefore, these methods have not been subjected to collaborative study (round-robins). Detailed information can be obtained from the unabridged methods referenced throughout the manual. All methods in the manual will be periodically reviewed by the subcommittee.

The procedures presented in this manual may involve hazardous materials, operations, and equipment. This manual does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and to determine the applicability of regulatory limitations before its use.

SCOPE

This document is produced to provide both procedures and educational information regarding the handling of aviation fuels at the airport. Some elements of this document may also be applied to fuel handling at terminals and refineries. This document is not a specification. As a reference, it is not meant to cover any subject in its entirety.

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Glossary

adsorption. A separation method in which certain components are concentrated on the surface of a porous solid. Surfactants (surface active agents) are separated from jet fuel by adsorption on clay.

ambient temperature. The air temperature surrounding a specific area.

API gravity. The U.S. petroleum industry's scale and method of measuring density of petroleum products at a given temperature.

aviation gasoline (avgas). Specially blended gasoline used to power reciprocating piston aircraft engines.

clay treater. A treating unit that uses activated clay (Fuller's earth) to remove surfactants from turbine fuel.

coalescence. The property of a filter cartridge to bring together fine droplets of free and entrained water to form large droplets that are heavy enough to fall to the bottom of the filter/separator vessel.

contaminants. Substances, either foreign or native, that may be present in fuel that detract from its performance.

cyclone separator. A device that uses the principle of centrifugal force to cause the contaminant in a fuel to settle to the bottom of the vessel without the use of filter media.

density. The amount of mass (weight) in a unit volume of a material at a given temperature.

differential pressure (Delta P). The measured difference in pressure between any two points, generally at the inlet and outlet of a filter, monitor, or a filter separator.

disarming action. As applied to filter/separators, the rendering of the elements incapable of performing their designed functions; for example, coalescer elements incapable of coalescing water and separator elements incapable of separating water from fuel.

dissolved water. Water that is in solution in the fuel. This water is not free water and cannot be removed by conventional means or measured by field equipment.

effluent. Stream of fluid at the outlet of a filter or filter/separator. This is the opposite of influent.

emulsion. Liquid dispersed in another, immiscible liquid, usually in the form of droplets. (Two liquids, which will not dissolve completely into one another, mixed so that one appears as fine drops in the other.)

entrained water. Small droplets of free water in suspension that may make fuel appear hazy.

filter. Generic term for a device to remove contaminants from fuel.

filter membrane (millipore) test. A standard test in which fuel is passed through a fine filter membrane housed in a plastic holder. The cleanliness of the fuel can be determined by examining the membrane.

filter/separator. A mechanical device used to remove entrained particulate contaminants and free water from a fuel.

fixed base operator (FBO). Common title for aviation fuel dealer at the airport.

flash point. The lowest fuel temperature at which the vapor about the fuel can be ignited by an outside ignition source.

floating suction. A floating device used in a tank for drawing product from the upper level of the fuel.

free water. Water in the fuel other than dissolved water. Free water may be in the form of droplets or haze suspended in the fuel (entrained water), a water layer at the bottom of the container holding the fuel, or both. Free water may also exist in the form of an emulsion that may be so finely dispersed as to be invisible to the naked eye.

freezing point (fuel). The lowest fuel temperature at which there are no solid phase wax crystals.

haze. Undissolved free water dispersed in fuel that is visible to the eye (usually more than 30 ppm in jet fuel). Fuel appears hazy or cloudy, that is, *not* clear and bright.

hydrophilic. Water accepting or water wettable.

hydrophobic. Water repelling; lacking affinity for water.

immiscible. Liquids that are mutually insoluble. (Will not dissolve into one another.) This is the opposite of miscible.

influent. Stream of fluid at the inlet of a filter or filter/separator. This is the opposite of effluent.

metric density. Weight of a liquid measured in kilograms per cubic metre at a given temperature.

micron *(/µm)*. A unit of linear measurement. One micron is equal to 10^{-6} m, or 0.00039 in., and approximately 25,400/ttm equals 1 in. For example, the average human hair is about 100 µm in diameter.

miscible. Liquids that are mutually soluble. This is the opposite of immiscible.

monitor. A device that shows or gives warning of improper performance (noun); or to test or check performance on a continuing basis (verb).

particulate matter. Solid contaminants (e.g., dirt, rust, scale, sand, and so forth) sometimes found in fuel.

prefilter. A filter that has a high dirt-holding capacity that is installed upstream of other filtration equipment.

pressure drop. See **differential pressure**.

relative density (specific gravity). In fuel, this is the ratio of the weight of any volume of fuel to the weight of an equal volume of water.

settling time. The time allowed for water or dirt entrained in the fuel to drop to the bottom of the storage tank.

slime. Soft, jelly-like substance.

specific gravity. See **relative density**.

sump. A low point in a system for collection and removal of water and solid contaminants.

surfactants (surface active agents). Chemical substances that make it difficult to separate fuel and water and that disarm filter/separators.

suspended water. Undissolved free water that is so finely dispersed as to be invisible to the naked eye. See **haze**.

synthetic separator. Separator made of media that is synthetic mesh material with chemically bonded hydrophobic treatment.

thief (sump) pump. A small pump having a suction line that extends to the low point of a tank for the purpose of drawing off water that may have accumulated.

turbine fuel. A group of various kerosine (or more rarely, wide-cut) fuels used to power aircraft turbine engines.

water slug. A large amount of free water.

Section A | General Fuel Handling

A.1 Visual Appearance Tests

A.1.1 INTRODUCTION AND PURPOSE

The purpose of these field tests (see Secs. A.1.4.2–A.1.4.4 and Sec. A.1.7) is to detect possible water, solid contaminants, microbial debris, surfactants (surface active agents), or other petroleum products in aviation fuel by visual inspection. These contaminants may be incidental, generated within the transport or handling system, or foreign contaminants accidentally introduced because of cross-contamination from other products. These tests are not precision tests; they are considered subjective. Experience is the important element; any condition that varies is a cause for concern. Variations in the results of these tests may reveal contamination, which may affect fuel quality relating to ASTM D910, *Standard Specification for Leaded Aviation Gasolines*, or ASTM D1655, *Standard Specification for Aviation Turbine Fuels*, specifications. Questionable, unusual, or unsatisfactory results obtained from these simple tests must be reported to the appropriate authority and may require that certain specification tests must be performed to determine whether the product is indeed on specification or not.

These are the simplest tests, low cost and easy to run. In this 5th edition, more detailed information on the possible causes of unusual results is given to provide the operator with a greater ability to understand the situation and possible ramifications. It is important to mention that the key to fuel quality control is to look for change. Any observed change in any test (or even an observed odor) may indicate that a serious cross-contamination has occurred.

A.1.2 REFERENCES

ASTM D4176-04, *Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)*, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM Distillate Fuel Bar Chart, Adjunct 12-441761-12, ASTM International, West Conshohocken, PA, www.astm.org

A.1.3 DESCRIPTION OF TEST TYPES AND EQUIPMENT

a. Glass Jar—Using a clear, wide-mouth glass jar or other similar transparent container a minimum of 3 in. (7.5 cm) in diameter, the fuel is visually observed for proper appearance. A white paper or light background allows visual detection of contaminant in the fuel. A paper with black print or a bar chart (see ASTM Adjunct 12-441761-12) may be used as a background to enhance the detection of water haze.
b. White Bucket—Using a white (not tinted) porcelain-lined (or approved equal) bucket, the fuel is visually observed for proper appearance. The bucket must be of at least 8 quarts (7.5 L) capacity. (Do not use a plastic, epoxy-lined, or painted bucket for color determination.) A coin with well-defined features is a useful additional tool for further observing and evaluating a water haze. If a plastic bucket is not equipped with an internal static collector and static bonding cable, a separate cable must be provided.

A.1.4 SAMPLING METHODS

A.1.4.1 Cautions

Use care when opening any pressurized sample drain or tap to prevent splash or spill.

Operators should wear sufficient protective equipment to prevent contact with fuel, including eye protection, gloves, and appropriate clothing.

To minimize the risk of fire caused by static electricity (electrostatic discharge), conductive containers must be properly bonded to the equipment from which the sample is being drawn. This bond must be maintained for 30 s after the sample is taken if drawn from a filter vessel or a sample tap downstream of a filter vessel. When evaluating color, avoid any brightly colored objects or clothing that may affect the appearance of the sample. Staff with color blindness shall not be tasked with color assessments of fuel samples.

A.1.4.2 Procedure for Glass Jar Test (From Sample Tap or Sump Drain)

A.1.4.2.1 The jar must be clean and free of water. Any volume in the drain or sample line should be removed or displaced to ensure that an accurate sample is taken of the sump's contents. Fuel in a drain line may be better or worse than fuel flowing in the system. Preferably with the system pressurized, draw a sample as quickly as possible from a sump or sample tap. Obtaining the sample under high velocity will flush water and debris from the system better than a sample taken at low velocity.

A.1.4.2.2 Allow air bubbles to rise to the surface for 1 min and observe (see Sec. A.1.5). Do not allow a significant temperature change to take place.

A.1.4.3 Procedure for Glass Jar Test (From Bucket)

A.1.4.3.1 The jar must be clean and free of water. Immediately after taking a white bucket sample as described in Sec. A.1.4.2, dip the jar into the bucket.

A.1.4.3.2 Allow any air bubbles to rise to the surface for 1 min and observe (see Sec. A.1.5). Water will tend to sink toward the bottom of the jar.

A.1.4.4 Procedure for White Bucket Test

A.1.4.4.1 The bucket must be clean and free of water. When taking a sample from a transport trailer, wipe off any dirt from the connection of the trailer. With system pressurized (except when obtaining a sample from a transport trailer or storage tank) obtain a sample with the sample valve open as far as possible without causing a spill. Any volume in the drain or sample line should be removed or displaced to ensure that an accurate sample of what is in the sump is taken. Fill the bucket to a depth of at least 6 in. (15 cm). A static bonding cable or wire must be connected between the bucket and the sample valve or associated pipe. A coin with well-defined features should be dropped into the bucket to assist in observing haze unless a jar sample is also taken. The features of the coin will be clearly visible if there is no haze.

A.1.5 EVALUATION OF SAMPLE

A.1.5.1

The white porcelain (clear glass with titanium dioxide) bucket is the sole proper means for evaluating product color in the fuel because paints and resins affect color. New coatings may be considered equal to porcelain if properly tested by way of long-term exposure to sunlight and fuel (at least 4 weeks each) to determine that no color change takes place. The coating must be white.

A.1.5.2

If contamination is slight, swirling the sample will cause dirt or water to collect at the center of the sample container for easier observation. Observe the sample.

A.1.5.3

Look for water droplets, particles, unusual color, haze, floating materials, lace-like layers, and anything else that is not clean fuel.

A.1.5.4

If water is present, notice the color and the appearance of the surface of the water where it contacts the fuel.

A.1.5.5

Even if the sample does not appear to be cloudy, this does not ensure that the bucket is not full of water; sometimes it is 100 % water. Drop some food coloring or black coffee into the sample. If the colored liquid added settles to the bottom as a colored drop, the sample is fuel; if the colored liquid dissolves into the sample, the sample is not fuel but water. This is, of course, a serious concern, and the test results should be reported immediately to an authority to determine the proper action. Additional sampling will be required to remove all water, but in the case of a fuel delivery truck, it may be determined to simply refuse the load. It is recommended that five 1-gal samples be taken before rejecting a load of fuel. If it takes three or more samples to obtain a water-free sample (a volume more than usual) from a delivery, notify the authority having jurisdiction.

A.1.5.6

Observe the color of the sample for any change in appearance from samples previously taken. Jet fuel should be colorless to a light yellow (straw), and the color should be consistent with previous tests. Any other color indicates cross-contamination. Avgas color should be blue, green, red, or brown (or possibly purple), according to grade. The intensity of the color may vary, but the color itself should not.

A.1.5.7

Use the following tables to determine ratings for the tests and record the results. If a test result is significantly different from previous samples, report the results immediately to an authority to determine the proper action.

A.1.6 APPEARANCE DESCRIPTIONS

The following tables make it easy to report a test result for permanent records and when necessary to communicate results to others.

A.1.6.1 Particle Appearance Ratings

Rating	Rating Guide (Optional)	Description
Clear	A	No visible particles, silt, sediment, dye (unusual fuel color), rust, or solids
Slight Particulate	B–C	Some fine to small-size particles
Particulate Matter	D	Many small particles either floating or settled on bottom
Dirty	E–I	Discoloration of the sample or many particles, either floating in fuel or settled on bottom

A.1.6.2 Water Contamination Appearance Ratings

Rating	Description
Bright	No water present either as liquid in bottom, drops on jar, or haze. (Air bubbles may cause a hazy appearance immediately after sample is drawn, but haze caused by air bubbles clears within 1 min.)
Hazy	Fine water droplets dispersed through sample. If the sample warms, these may go away, but they must be reported.
Cloudy	Sample appears cloudy, milky.
Wet	Droplets or a layer of water; droplets may be found on side or bottom of container.

A.1.6.3 Other Contaminant Appearance Ratings

A.1.6.3.1 Description of Sample Appearance and Possible Causes

Surfactant or Microbial

Slime on bottom of container or at fuel–water interface, appearing as dark brown or black scum or lacy material floating in the fuel or at the interface with water. The presence of anaerobic bacteria often causes a pungent odor, similar to rotten eggs.

Other Product Cross-Contamination: Unusual Appearance, Color, or Odor Dye Contamination

Fuel dyes can cause red, green, blue, or any color combination in aviation fuel.

Fuel Aging

Darkened, discolored, and possibly more viscous, fuel with abnormal odor.

A final diagnosis should not be based on these descriptions. Further evaluation is required.

A.1.6.4 Contamination Experience

These tests have been performed at refineries, terminals, and airports for decades around the world.

A.1.6.4.1 Haze

a. When fuel cools, it may appear hazy because of dissolved water condensing out in the same way fog, haze, and clouds form in air. If the fuel is in a pipe, filter, truck tank, or pipeline and the temperature of the fuel has been reduced, a haze does not indicate that it is necessarily contaminated.
b. Fuel can hold approximately 1 part per million (ppm) of dissolved water. This water cannot be removed by filtration and is not detectable by field equipment.
c. Filter separators are designed to remove water, so haze in a filter sump sample is not unusual. It should, however, mostly separate and clear in a glass jar in 2 minutes.
d. A properly working filter separator or monitor made to EI 1581, *Specification and Qualification Procedures for Aviation Jet Fuel Filter/Separators*, or EI 1583, *Laboratory Tests and Minimum Performance Levels for Aviation Fuel Filter Monitors*, respectively, should not pass (at its outlet) more than 5 ppm of free water, which is much less than the minimum the human eye can detect, at approximately 30 ppm.
e. Because of the previous considerations, samples taken from a flowing system, after flushing the sample valve, are considered to be most informative on water content in the flowing stream. This is not to say that the first sample taken from a sump sample is not important; it is very important to show any changes in water volume the system has seen, but this does not reflect the overall quality of the fuel.
f. If a nonflowing system has seen a significant decline in temperature (e.g., a filter sump), haze in a sump sample may simply be condensation. Establish flow, clear the sump, and take another sample.

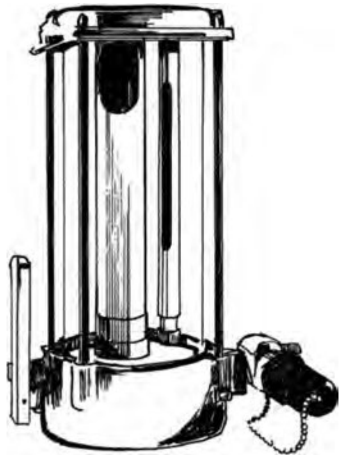
A.1.6.4.2 Particles Particles in sump samples may indicate fuel quality or equipment problems.

a. Rust usually is brown or reddish brown and is seen as either small flakes or a dust-like coating. All rust particles will react to a magnet, especially if allowed to fully dry. The size is important, as individual particles, large enough to be seen by eye, cannot pass through a filter element suitable for aviation fuel.
b. Microbe particles are typically soft. They usually have a foul odor in quantity. They usually will flatten or act as a putty when handled.
c. Hose linings can fail, and the resulting contamination may be seen as thin strips of flexible dark film or as dark particles that usually are soft but do not smear or act as a putty.
d. Tank or pipe-lining epoxy usually are seen as flat, light-colored chips.
e. Metal shavings usually indicate a failing pump, swivel, meter, or valve. Check with a magnet to help determine composition.

A.1.7 VISUAL FUEL SAMPLER VESSEL (VISIJAR)

1. In recent years, an additional method of performing the “clear and bright” or “white bucket” test has been developed, the closed-circuit sampler, also known as a visual fuel sampler or Visijar. A fuel sample is drawn from a sampling connection of a refueler or servicer monitor or filter/separator vessel (or from a fixed filter/separator or tank sump) into a Visijar and observed for water, solids, or indications of surfactants (Fig. 1).
2. The Visijar equipment is usually a 4-L (1-gal) capacity clear glass tube sandwiched between a base and hinged lid assembly. The base incorporates a drain valve and fill port. The internal surface of the base is conical in profile and finished in a white epoxy or similar fuel-resistant coating. The Visijar can be installed in sample lines from filter/separators or monitors, or in sample lines from tank sumps.
3. To operate the Visijar, ensure the glass tube is clean. Open the fill valve. The fill port is designed to cause the fuel sample to swirl around the sides of the clear glass tube. The resultant rapid movement of the fuel assists in visual detection of any free water and/or dirt particles or indication of surfactants at the bottom of the Visijar.
    a. Let the sample settle for 1 min to remove air bubbles.
    b. Inspect the bottom for water droplets, solid contaminants, hazy/cloudy condition, and/or brown slimes (see Sec. A.1.5.).

FIG. 1 Closed-circuit sampler (Visijar).



   c. If fitted with an optional self-sealing valve assembly for a chemical water detector test (see Sec. C), draw a fuel sample from the base at this time.
   d. Open the drain valve to drain the glass tube.
4. Refer to Sec. A.1.6 for Cautions and Interpretation of Test Results.

A.2 API Gravity and Metric Density

A.2.1 INTRODUCTION AND PURPOSE

This procedure describes the means for measuring the gravity or density of aviation fuel with a hydrometer. A significant change in gravity or density from what you normally see or from the manufacturer or supplier batch report may indicate contamination by another liquid product. Hydrometers may be calibrated in metric density, relative density, API gravity, or specific gravity. In this procedure, only API gravity and metric density will be discussed.

NOTE

API gravity is the primary measurement of fuel density used in the United States. Outside the United States, metric density is most commonly used. These two measures differ in several ways:

1. API gravity is like specific gravity because it is related to the density of water. Finding the weight of a volume of fuel when only API gravity is known requires the use of ASTM D1250, *Standard Guide for Use of the Petroleum Measurement Tables*, a specially designed calculator, or a specially designed computer program. Metric density is simply kilograms per cubic meter with no reference to the density of water. Finding the weight of a known volume of fuel at a set temperature when the metric density is known simply requires multiplying the volume times the metric density.

   Higher API gravity values indicate lighter fuels, whereas higher metric density values indicate heavier fuels. The program or calculator may have the ability to revise the weight calculation for a different temperature, so all you need to find the weight of a known density fuel going into the aircraft is the temperature.
2. The standard temperature (defined temperature for comparing results from different batches or products) for API gravity is 60°F, whereas the standard temperature for metric density is 15°C (59°F).
3. Fuel weight is not a quality control concern, but it is often a quality control operator's responsibility to provide this information to the pilot. It is important to note that weight changes with temperature. The mass (weight per unit volume) of the fuel can be calculated accurately only if done directly with a hydrometer in the fuel at the temperature at which it will enter the aircraft or by adjusting a previous reading of that fuel to the actual fuel temperature entering the aircraft by using a specifically designed calculator or computer program.

A.2.2 REFERENCES

ASTM D1250-08(2013)e1, *Standard Guide for Use of the Petroleum Measurement Tables* (description only; tables published separately in 12 volumes), ASTM International, West Conshohocken, PA, 2013, www.astm.org

ASTM D1298-12b, *Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method,* ASTM International, West Conshohocken, PA, 2012, www.astm.org

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ASTM E1-14, *Standard Specification for ASTM Liquid-in-Glass Thermometers,* ASTM International, West Conshohocken, PA, 2014, www.astm.org

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A.2.3 DESCRIPTION

The scale reading at the intersection of the fuel surface on a freely floating hydrometer and the temperature of the fuel at the time of the test are observed and recorded. The observed readings then are used to correct the gravity or density to the standard temperature applicable for the test.

A.2.4 EQUIPMENT

NOTE

ASTM and API have developed new standards to cover nonmercury thermometers, but nonmercury thermohydrometers (hydrometers with built-in thermometers) have only recently been covered by ASTM E2995-14 and may not yet be available from all suppliers.

NOTE

Electronic digital meters for measuring density are also available and must meet the Energy Institute's standard IP 559, *Determination of Density of Middle Distillate Fuels.*

1. ASTM hydrometer and thermometer or thermohydrometers. The old standard ASTM specified hydrometers and thermohydrometers do not normally match any specific products, so two hydrometers may be needed to cover the range of fuels available. To correct this issue, some suppliers offer special hydrometer ranges. Note showing "single span" indicates that this hydrometer covers the entire range of available fuels of this type (jet or avgas) typically found in use.
2. ASTM thermohydrometers include both a hydrometer and a thermometer in one device. ASTM plain form hydrometers, which do not contain a built-in thermometer, may be used with a separate thermometer.

3. Thermometers specified by ASTM E1-14, *Standard Specification for ASTM Liquid-in-Glass Thermometers*, are graduated in either °F or °C. The specific thermometers recommended for aviation density measurements are the ASTM 12F (mercury type, graduated in °F) or the ASTM 12C (mercury type, graduated in °C). Corresponding non-mercury thermometers are ASTM S 12F and ASTM S 12C.2. Glass, plastic, or metal hydrometer cylinder as shown in Fig. 2. Clear glass or clear plastic cylinders are preferred, except in the "spill-over" type design.

API gravity	Type	Range	ASTM	Note
Avgas	Plain form hydrometer	59–71	7H	
Avgas	Plain form hydrometer	69–81	8H	
	Plain form hydrometer	64–76	12H	Single span
Avgas	Thermohydrometer	59–71	7HL	
Avgas	Thermohydrometer	69–81	8HL	
	Thermohydrometer	64–76	258H	Single span
Jet A/A1	Plain form hydrometer	29–41	4H	
Jet A/A1	Plain form hydrometer	39–51	5H	
	Plain form hydrometer	37–49	11H	Single span
Jet A/A1	Thermohydrometer	29–41	54HL	
Jet A/A1	Thermohydrometer	39–51	55HL	
	Thermohydrometer	37–49	255H	Single span
Metric density	**Type**	**Range**	**ASTM**	**Note**
Avgas	Plain form hydrometer	650–700	312H	
Avgas	Plain form hydrometer	700–750	313H	
Avgas	No single-span hydrometer		ASTM number assigned	
Avgas	Thermohydrometer	650–700	301HL	
Avgas	Thermohydrometer	700–750	302HL	
Avgas	No single-span thermohydrometer		ASTM number assigned	
Jet A/A1	Plain form hydrometer	750–800	314H	
	Plain form hydrometer	800–850	315H	
	Plain form hydrometer	775–825	321H	Single span
Jet A/A1	Thermohydrometer	750–800	303HL	
Jet A/A1	Thermohydrometer	800–850	304HL	
	Thermohydrometer	775–825	345H	Single span[a]

[a] This thermohydrometer is not for use in very cold or very hot climates; it has a temperature range of only −10 to +40°C.

A.2.5 PROCEDURE

1. Collect the sample in a clean hydrometer cylinder and place it in a vertical position in a location free from air currents. Allow 1–2 min for air bubbles to disappear. Remove any air bubbles that remain on the surface of the sample by touching them with the corner of a clean paper towel.
2. When using a thermohydrometer, gently lower it into the sample. When it has settled, depress it about two scale divisions into the liquid and then release it. Gently spin the hydrometer when releasing it. This will assist in bringing it to rest, floating freely away from the cylinder walls. When the thermohydrometer has come to rest and the thermometer is showing a steady reading, read (this is best done by looking across the underside of the liquid surface) and record the temperature of the sample to the nearest 0.5°C or 1°F. Read the hydrometer to the nearest scale division and record the value. The correct hydrometer reading is that point on the hydrometer scale at which the principal surface of the liquid cuts the scale (Fig. 3).
3. When using a plain form hydrometer, first measure temperature with an approved thermometer. Continuously stir the sample with the thermometer taking care that the mercury or mercury substitute liquid is kept fully immersed. As soon as a steady reading is obtained, read and record the temperature of the sample to the nearest 0.5°C or 1°F and then remove the thermometer. To obtain the hydrometer reading, follow the procedure described in paragraphs 2 and 3, substituting a hydrometer for the thermohydrometer.
4. Correct the observed hydrometer reading to the standard temperature of (API) 60°F (15.5°C) or (metric) 20°C. See Fig. 4.
5. Determine the corrected gravity measurement using the ASTM tables or a specifically designed calculator or computer program and report the value as API gravity.

FIG. 2 Hydrometer cylinder and thermohydrometer for measuring API gravity.

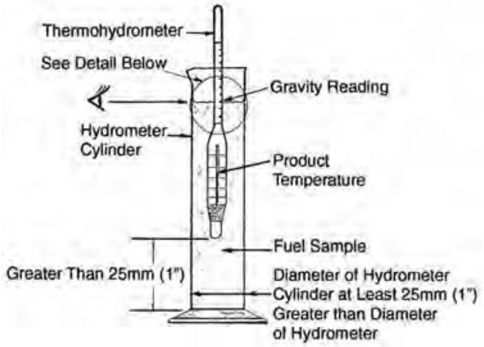


FIG. 3 Obtaining the observed hydrometer reading.

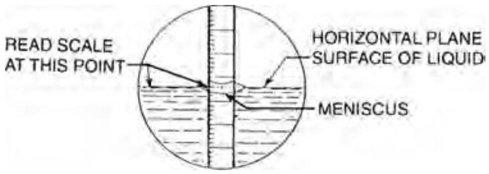
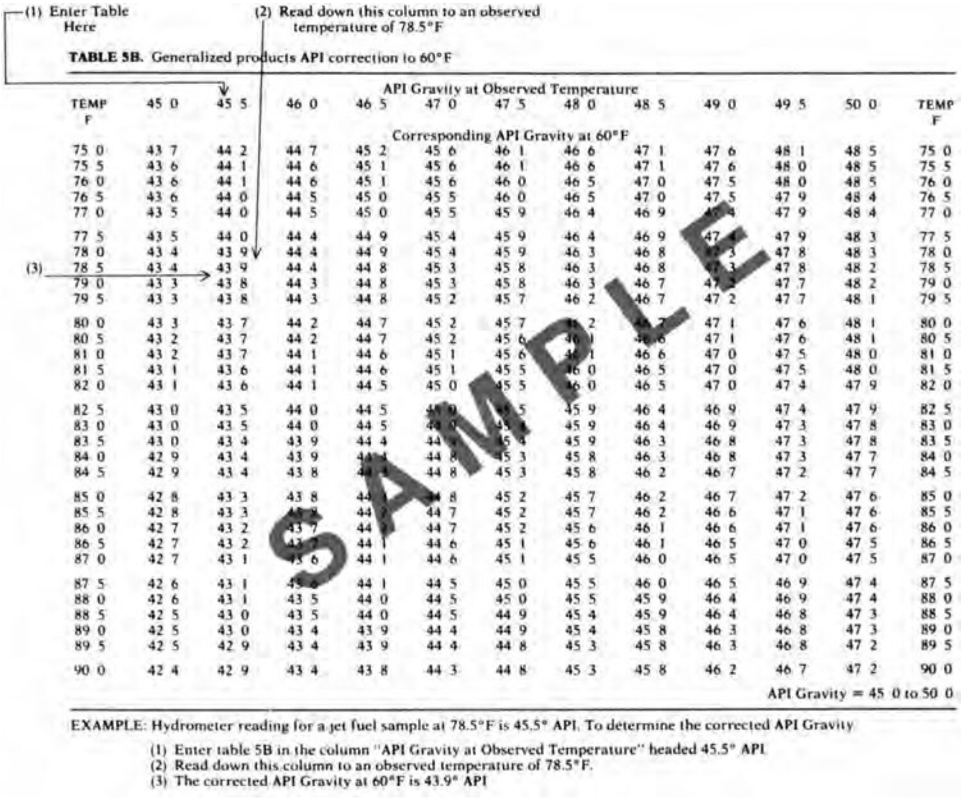


FIG. 4 Correction of observed API gravity to standard temperature. (Reprinted courtesy of the American Petroleum Institute, Washington, DC, Bulletin 1542.)



(1) Enter Table Here

(2) Read down this column to an observed temperature of 78.5°F

(3)

TABLE 5B. Generalized products API correction to 60°F

TEMP F	API Gravity at Observed Temperature											TEMP F
	45.0	45.5	46.0	46.5	47.0	47.5	48.0	48.5	49.0	49.5	50.0	
	Corresponding API Gravity at 60°F											
75.0	43.7	44.2	44.7	45.2	45.6	46.1	46.6	47.1	47.6	48.1	48.5	75.0
75.5	43.6	44.1	44.6	45.1	45.6	46.1	46.6	47.1	47.6	48.0	48.5	75.5
76.0	43.6	44.1	44.6	45.1	45.6	46.0	46.5	47.0	47.5	48.0	48.5	76.0
76.5	43.6	44.0	44.5	45.0	45.5	46.0	46.5	47.0	47.5	47.9	48.4	76.5
77.0	43.5	44.0	44.5	45.0	45.5	45.9	46.4	46.9	47.4	47.9	48.4	77.0
77.5	43.5	44.0	44.4	44.9	45.4	45.9	46.4	46.9	47.4	47.9	48.3	77.5
78.0	43.4	43.9	44.4	44.9	45.4	45.9	46.3	46.8	47.3	47.8	48.3	78.0
78.5	43.4	43.9	44.4	44.8	45.3	45.8	46.3	46.8	47.3	47.8	48.2	78.5
79.0	43.3	43.8	44.3	44.8	45.3	45.8	46.3	46.7	47.2	47.7	48.2	79.0
79.5	43.3	43.8	44.3	44.8	45.2	45.7	46.2	46.7	47.2	47.7	48.1	79.5
80.0	43.3	43.7	44.2	44.7	45.2	45.7	46.2	46.7	47.1	47.6	48.1	80.0
80.5	43.2	43.7	44.2	44.7	45.2	45.6	46.1	46.6	47.1	47.6	48.1	80.5
81.0	43.2	43.7	44.1	44.6	45.1	45.6	46.1	46.6	47.0	47.5	48.0	81.0
81.5	43.1	43.6	44.1	44.6	45.1	45.5	46.0	46.5	47.0	47.5	48.0	81.5
82.0	43.1	43.6	44.1	44.5	45.0	45.5	46.0	46.5	47.0	47.4	47.9	82.0
82.5	43.0	43.5	44.0	44.5	44.9	45.5	45.9	46.4	46.9	47.4	47.9	82.5
83.0	43.0	43.5	44.0	44.5	44.9	[illegible]	45.9	46.4	46.9	47.3	47.8	83.0
83.5	43.0	43.4	43.9	44.4	[illegible]	45.4	45.9	46.3	46.8	47.3	47.8	83.5
84.0	42.9	43.4	43.9	[illegible]	44.8	45.3	45.8	46.3	46.8	47.3	47.7	84.0
84.5	42.9	43.4	43.8	[illegible]	44.8	45.3	45.8	46.2	46.7	47.2	47.7	84.5
85.0	42.8	43.3	43.8	[illegible]	44.8	45.2	45.7	46.2	46.7	47.2	47.6	85.0
85.5	42.8	43.3	[illegible]	44.7	44.7	45.2	45.7	46.2	46.6	47.1	47.6	85.5
86.0	42.7	43.2	43.7	[illegible]	44.7	45.2	45.6	46.1	46.6	47.1	47.6	86.0
86.5	42.7	43.2	43.7	44.1	44.6	45.1	45.6	46.1	46.5	47.0	47.5	86.5
87.0	42.7	43.1	43.6	44.1	44.6	45.1	45.5	46.0	46.5	47.0	47.5	87.0
87.5	42.6	43.1	43.6	44.1	44.5	45.0	45.5	46.0	46.5	46.9	47.4	87.5
88.0	42.6	43.1	43.5	44.0	44.5	45.0	45.5	45.9	46.4	46.9	47.4	88.0
88.5	42.5	43.0	43.5	44.0	44.5	44.9	45.4	45.9	46.4	46.8	47.3	88.5
89.0	42.5	43.0	43.4	43.9	44.4	44.9	45.4	45.8	46.3	46.8	47.3	89.0
89.5	42.5	42.9	43.4	43.9	44.4	44.8	45.3	45.8	46.3	46.8	47.2	89.5
90.0	42.4	42.9	43.4	43.8	44.3	44.8	45.3	45.8	46.2	46.7	47.2	90.0

API Gravity = 45.0 to 50.0

EXAMPLE: Hydrometer reading for a jet fuel sample at 78.5°F is 45.5° API. To determine the corrected API Gravity

(1) Enter table 5B in the column "API Gravity at Observed Temperature" headed 45.5° API

(2) Read down this column to an observed temperature of 78.5°F.

(3) The corrected API Gravity at 60°F is 43.9° API

NOTE

For digital electronic meters follow the manufacturer's procedure.

A.2.6 CAUTIONS

1. The hydrometer must float freely to obtain a correct reading. It must not come to rest against the side or bottom of the cylinder during the test. (Centering devices that cause no errors resulting from friction are available.)
2. The thermometer should not be completely removed from the liquid to read the temperature. Evaporation of liquid from the thermometer stem and bulb will lower the temperature and cause an incorrect reading.
3. Hydrometers and thermometers must be inspected periodically to ensure that they are not cracked or that there are no separations of the mercury or oil/alcohol column. In addition, inspect that the paper scale in a hydrometer has not moved. It is common for a red line to be in the glass, and this should align to a "major scale division" near the top of the scale.
4. For weight reading (pounds per gallon or kg/cm^2), avoid temperature changes that will cause a reading that is inaccurate. Fuel weight will change with temperature.

A.2.7 INTERPRETATION OF RESULTS

1. Once a batch of fuel is produced, its gravity, or density, corrected to a standard temperature does not significantly change. Although test results may differ within the method's limitations of reproducibility, a change greater than ±1.0 °API or 4 kg/M^3 should warrant an investigation to confirm that contamination has not occurred. If test results differ with supplier batch data or previous tests on that fuel by more than is usually seen at this location, but less than 1.0 API or 4 kg/M^3, heightened awareness should be exercised in evaluating other quality tests, such as the white bucket and membrane tests, and warrant notifying the authority having jurisdiction.
2. If a gravity or density reading in one set of units must be compared with one that was reported in a different set of units, use conversion tables in ASTM D1250. Alternatively, the following equations may be used to convert between °API and relative density (specific gravity) but not metric density (see Sec. A.2.1):

   Degrees API = (141.5/relative density) –131.5
   Relative density = (141.5/°API + 131.5)

3. The procedure presented here is used to help detect possible cross-contamination (by other miscible liquids) of a fuel by comparing gravity measurements. It is necessary to correct hydrometer readings to a standard temperature.
4. Another use of hydrometers at an airport is to determine fuel weight at the fueling temperature. In this

case, temperature correction must *not* be made. This measurement must be taken immediately and reported as "observed."

5. If a cross-contamination problem is suspected, the odor of the sample may also be different. The paper test (see A.10) can be used to gain more information. A different drying characteristic of the fuel sample may indicate a serious problem.

A.2.8 CALCULATING FUEL WEIGHT

A.2.8.1

Although not a consideration in fuel quality, it is often a responsibility of fuel quality personnel.

A.2.8.2

Fuel weight changes as the fuel temperature changes. It may be detailed as follows:

a. Metric Density—reverse the correction in the above to the actual temperature of the fuel being dispensed using a specially designed calculator or computer program or take a new, uncorrected reading.
b. API—Either reverse the correction and convert to pounds per gallon using a special calculator or computer program, the ASTM tables or a program—or simply use a "pounds per gallon" hydrometer on the fuel being dispensed at that temperature.

A.3 Sump Sampling

A.3.1 INTRODUCTION AND PURPOSE

The purpose of sump sampling is to check for the presence of water and other contaminants in any fuel-handling system. With adequate settling time, much of the free water and solid particles, if present, normally will drop to the tank bottom or system low point. Removal of these contaminants is accomplished by completely drawing off the water through a fully opened sump drain valve. This is done to help maintain a clean fuel environment and show any changes from the appearance of previous samples, which might indicate a fuel problem or an equipment or filter failure.

White buckets are preferred, but in some cases, stainless steel buckets are used. Please note that a white bucket is required in the detection of particulates or fuel color problems.

A.3.2 REFERENCES

ASTM D4057-12, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*, ASTM International, West Conshohocken, PA, 2012, www.astm.org

A.3.3 DESCRIPTION

Fuel is drawn off at various locations throughout a system. These samples usually are taken in a clean white bucket or similar container. The fuel volume required to effectively flush and evaluate that point of the system will depend on the design and type of equipment being sumped.

A.3.4 EQUIPMENT

1. Clean white bucket (porcelain or approved equal) or stainless steel bucket. The use of plastic (without adequate electrostatic discharge capability) or any galvanized containers is not permitted.
2. Thief or scavenger pump (for underground tanks and barges).

A.3.5 PROCEDURE

Sampling in all cases should be done in accordance with the white bucket test method (Sec. A.1.4.4). A sample may be further evaluated by the clear and bright test and the odor test methods (Sec. A.1.6). Some systems allow fast flush ability and are recommended.

1. *Aboveground Tanks*—Open drain valve quickly and fully open to ensure that the settled contaminants at the tank low point (sump) are drawn into the drain line. Sufficient, but not excessive, quantity should be drained to ensure that the pipe extending into the tank sump is completely flushed (see note after 3. Filter Vessels). Now draw a sample for evaluation. Be sure to draw fuel from the system sufficient to remove the debris or water from inside the tank, and do not flush before taking the sample, because then you will not see that contamination. Very large tanks with large drain lines may require many gallons of fuel to be drained (to displace the fuel already in the drain line) before you actually see the contaminants removed from the sump. Special consideration should be given to open, floating roof tanks that require more attention after heavy rain than a covered tank. Flat-bottom tank designs present additional problems requiring attention. These designs make it impossible to remove all the water from the bottom of the tank, even with proper sump draining. Because of these special considerations, sump sampling frequency must be tailored for each installation.
2. *Barges and Underground Tanks*—These tanks are sumped with the use of a thief or scavenger pump. The sumping of these vessels should be accomplished at the lowest point of the tank. Sufficient quantity should be pumped to ensure that the line content plus water and other contaminants have been removed. The sump samples should then be evaluated (see note after 3. Filter Vessels).
3. *Filter Vessels*—Filter vessel sumping should be done under pressure to ensure that water and other contaminants in the sump and its immediate area have been removed from the vessel. Depending on use and design of the system, frequency of sump sampling should be tailored to each facility.

NOTE

For example, 25 ft (7.62 m) of 1-in. (2.54 cm) pipe will hold about 1 gal (3.8 L), whereas the same length of 3-in. (7.62 cm) pipe will hold about 9 gal (34 L). A small drain line is preferred.

4. *Tank Trucks/Railroad Tank Cars*—The vehicle should stand undisturbed as long as practical, but no less than 10 min, to allow any water or other contaminant that might be present to settle. Sump each compartment and piping low point before unloading the vehicle. This will ensure that all water and other contaminants that may have collected at these low points will be removed from the vehicle before unloading into the system. Each sump sample should be evaluated.
5. *Aircraft Refueling Vehicles*—Vehicle low-point and filter sumps should be drained at least daily at all compartment low-point drains. Allow at least 10 min of settling. Draw off a sufficient quantity to ensure that the sump and the line going to that sump have been drained. The sump sample should be taken at a high flow rate to drain off all water and other contaminants that may have collected at or around each sump inside the compartment. The sump sample should then be evaluated.
6. *Pipe System Low Points*—Hydrant and pipeline delivery systems normally have low-point drains that can be used to remove water or other contaminants. The quantity flushed from the low-point points shall be 10–50 gal in excess of the capacity of the flushing pipework and must be removed to completely flush the low point and its drain line. Low-point samples should then be evaluated.
7. In some cases, a sump separator (sample tank) may be used for visual evaluation of fuel. In such cases, enough fuel volume should be directed to the sump separator to displace all of the fuel in the inlet line and allow adequate fuel in the sump separator to provide a representative sample. This should be done at the fastest possible velocity.

A.3.6 CAUTIONS

1. All samples should be disposed of or recycled in an approved manner.
2. Equipment should be properly bonded to prevent electrostatic spark discharge.

A.3.7 INTERPRETATION AND LIMITATION OF RESULTS

A sump sample that consists of clear and bright fuel is considered satisfactory (see NOTE). Any sump sample that is not clear and bright indicates a need for additional sumping. If, after reasonable amounts of fuel have been drained the sample is still not acceptable, supervision should be notified for further action. If a result is different than usually seen, it warrants further investigation.

Records of all sump draining should be maintained and should indicate the condition of the fuel when first evaluated and the amount and nature of any contaminant found.

NOTE

If there is any question whether the sample is fuel or water, refer to Sec. C, Water Detection.

A.4 Electrical Conductivity—Portable Meter Method

A.4.1 INTRODUCTION AND PURPOSE

Conductivity of aviation fuels, while normally very low, can be increased with the use of static dissipater additives. By sufficiently increasing the electrical conductivity, the potentially dangerously high static charges that are generated during normal pumping and filtration operations are readily dissipated and prevented from accumulating in a receiving tank. (See Sec. A.14.8, Static Dissipater Additive, for additional information.) When these additives are used, fuel conductivity should be within limits specified in the fuel specifications, for example, ASTM D1655, *Standard Specification for Aviation Turbine Fuels.*

A.4.2 REFERENCES

ASTM D1655-16a, *Standard Specification for Aviation Turbine Fuels*, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM D2624-15, *Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels,* ASTM International, West Conshohocken, PA, 2015, www.astm.org

ASTM D4306-15, *Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination*, ASTM International, West Conshohocken, PA, 2015, www.astm.org

A.4.3 DESCRIPTION

The test probe is immersed in the fuel. The conductivity of the fuel will be indicated on the meter when the instrument is energized.

A.4.4 EQUIPMENT

Both portable and in-line conductivity meters are offered by Emcee Electronics Inc. and D-2 Inc., as referenced in ASTM D2624.

A.4.5 PROCEDURE

Rinse the probe and sample container using the fuel under test. Calibrate the meter following the manufacturer's instructions. Immerse the probe in the fuel, energize the instrument, wait for approximately 3 s (see manufacturer's instructions), and read the conductivity in conductivity units (C.U.):

$$\text{C.U.} = \text{pS/m} = \text{Pico Siemens per m} = 10^{-12}\ \text{n}^{-1}/\text{m}$$

A.4.6 CAUTIONS

1. If checking conductivity within a storage tank, wait at least 30 min after pumping into the tank before inserting the equipment probe. Just before inserting the probe, bond the meter to the storage tank to prevent static discharge in case the fuel is charged.
2. Do not use the probe in areas where water may be present. If the probe has contacted moisture or wet fuel, follow the manufacturer's instructions for proper cleaning.

3. If a sampling container is used, ensure that the container is metallic and properly bonded to the instrument; see ASTM D4306 for recommended containers.
4. Ensure cleanliness of sampling container by flushing with some of the test sample.
5. The conductivity of fuels (in clear glass containers) that contain static dissipater additives is affected by sunlight and other strong light sources.
6. Conductivity is a function of temperature. Typically, conductivity will increase or decrease 1–4 C.U. per degree C or F in temperature.
7. Immediately after adding the conductivity additive, the conductivity reading will not be stable. In cases in which the conductivity additive is injected at the truck rack during loading, it may be prudent to obtain conductivity readings from the receiving location before making additive injection rate adjustments.

A.4.7 INTERPRETATION AND LIMITATION OF RESULTS

Conductivity of untreated fuel is generally less than 10 C.U. Properly treated fuel ranges between 50 and 600 C.U. These readings reflect the amount of additive in the fuel and are affected by temperature and time. Because of the effects that temperature and time have on treated fuel, discrepancies in repeatability of readings may occur.

A.5 Flash Point by Small-Scale Closed Cup Tester

A.5.1 INTRODUCTION AND PURPOSE

The small-scale closed test may be used to (1) determine whether a kerosine type jet fuel will flash at a specified temperature, (2) determine the actual flash-point temperature of the fuel, and (3) determine the presence of volatile contaminants in the fuel.

Flash point is defined as the lowest temperature of the fuel sample at which application of an ignition source causes the vapors above the sample to ignite under specified test conditions.

A.5.2 REFERENCES

ASTM D3828-16, *Standard Test Methods for Flash Point by Small Scale Closed Cup Tester,* ASTM International, West Conshohocken, PA, 2016, www.astm.org

A.5.3 DESCRIPTION

The tester is preheated and stabilized at the desired target temperature. A 2-mL sample is injected through a self-sealing filler port into the closed sample cup of the tester. After 1 min, the test flame is introduced into the sample cup and the observation of a flash or no flash is made and recorded for that target temperature. Because it is portable, this test may be used for fuels throughout the entire distribution system, from the point of fuel manufacture to the aircraft fuel tank.

A.5.4 EQUIPMENT

1. *Small-Scale Closed Cup Tester*—The complete instrument meeting all the requirements of ASTM D3828 is available commercially through laboratory supply houses.
2. *Sample Containers*—Either clean, screw-cap metal cans or clean glass bottles with tight-fitting corks or stoppers must be used.
3. *Test Flame Gas Supply*—The test flame may be fueled by either natural gas (at fixed locations) or by a portable, self-contained gas supply, for example, butane or propane cylinders.

A.5.5 METHOD A PROCEDURE—FLASH/NO FLASH TEST

1. Obtain a representative sample of the product in question by filling the sample container to approximately one quarter full, capping it, and shaking thoroughly. Discard this rinse fluid; this should be done three times. Completely fill the rinsed sample container to its maximum safe working level (usually about 95 % full) and cap it securely.
2. Connect the tester to the appropriate electrical and gas services, switch the tester on, and then turn the coarse temperature control knob fully clockwise. Observe the thermometer periodically. When the thermometer is about 5°F (2.75°C) below the target temperature, adjust heat input by turning the coarse control knob counterclockwise. After a few minutes, the indicator light will slowly cycle on and off. At this point, check the temperature; if this is not the target temperature, adjust heat input with the fine (central) control knob to obtain target temperature. When the indicator light cycles on and off, the sample cup is at target temperature.
3. Open the sample container in a draft-free location and withdraw a 2-mL sample using the present syringe. Discharge this sample to waste. Take a second 2-mL sample from the container and transfer it through the filling port orifice without losing any sample. Inject the sample into the cup by fully depressing the plunger of the syringe. Remove the syringe from the filling orifice.
4. Set a 1-min timer by rotating its knob clockwise to its stop. Open the gas control valve and light the pilot and test flames, adjusting the test flame to a 4-mm diameter (the same size as the test flame gage inscribed on the cup lid). After 1 min, apply the test flame by slowly and uniformly opening the shutter, then closing it over a period of approximately 2 s. Observe whether there is a flash at the cup opening. The sample has flashed if a large blue flame appears and spreads over the sample surface. A halo around the test flame is not a flash and should be ignored.
5. The result is recorded as a “flash at *x* temperature” or “no flash at *x* temperature.”
6. After the test, turn off the gas supply, clean the instrument, and allow it to cool off.

A.5.6 METHOD B PROCEDURE—ACTUAL FLASH POINT DETERMINATION

1. Obtain a representative sample following Method A.
2. Connect the tester and observe the temperature following Method A.
3. Open the sample container and take a second sample following Method A.
4. Set a time and observe the flash following Method A.
5. Turn off the pilot and test the flame. When the temperature drops to a safe level, remove the sample and clean the instrument. If a flash occurred in the previous test, repeat the procedure with a new specimen at a temperature 9°F (5°C) below that at which the flash was observed. If necessary, repeat this procedure until no flash is observed. If no flash occurred in the previous test, repeat the procedure with a new specimen at a temperature 9°F (5°C) above that at which no flash was observed. If necessary, repeat this procedure until a flash is observed.
6. Having established a flash within two temperatures 9°F (5°C) apart, repeat the procedure, with a new specimen for each test, raising the temperature in 2°F (1.1°C) intervals from the lower of the two temperatures until a flash is observed. Record the temperature on the thermometer as the flash point at the time the test flame application causes a distinct flash in the fuel sample cup.
7. After the test, turn off the gas supply, clean up the instrument, and allow it to cool.
8. If it is desired to correct the observed flash point for the effect of barometric pressure, refer to ASTM D3828.

A.5.7 CAUTIONS

The operator must take appropriate safety precautions during the preparation and initial application of the test flame to the sample. Samples containing low-flash material may give an abnormally strong flash when the test flame is first applied.

A.5.8 INTERPRETATION OF TEST RESULTS

The results indicate the possible presence of the following: A flash point lower than expected may be caused by contamination by small quantities of light end contamination, for example, avgas (aviation gasoline) or mogas (motor gasoline) in Jet A or Jet A-1 that can arise from poor distribution practices (e.g., 1 gal [3.8 L] of avgas in 1,000 gal [3,785 L] of Jet A may lower the flash point of the mix by 5°F [2.75° C] or more). Off-specification product can be caused by poor quality control in manufacture or transportation.

A.6 Product Identification

A.6.1 INTRODUCTION AND PURPOSE

This section describes general or field techniques used to identify aviation fuels and determine whether product mixing may have occurred.

A.6.2 REFERENCES

ASTM D910-16, *Standard Specification for Leaded Aviation Gasolines*, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM D1655-16a, *Standard Specification for Aviation Turbine Fuels*, ASTM International, West Conshohocken, PA, 2016, www.astm.org

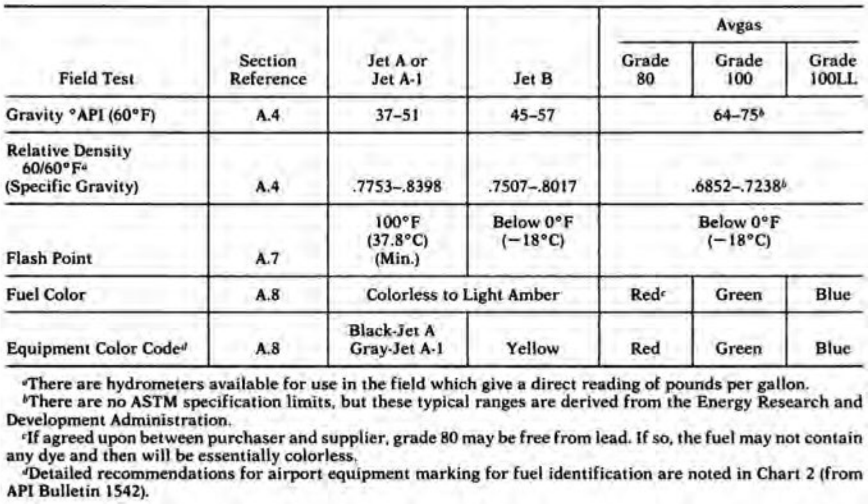
ASTM D6615-15a, *Standard Specification for Jet B Wide-Cut Aviation Turbine Fuel*, ASTM International, West Conshohocken, PA, 2015, www.astm.org

EI 1542, *Identification Markings for Dedicated Aviation Fuel Manufacturing and Distribution Facilities, Airport Storage and Mobile Fuelling Equipment*, Energy Institute, London, www.energyinst.org

A.6.3 DESCRIPTION

Chart 1 lists tests that can be performed for determining product identity or contamination of aviation fuel. Gravity and color are the only field tests on this chart commonly used for product

CHART 1 Field tests for determining product identity or contamination.



Field Test	Section Reference	Jet A or Jet A-1	Jet B	Avgas Grade 80	Avgas Grade 100	Avgas Grade 100LL
Gravity °API (60°F)	A.4	37–51	45–57	64–75[b]		
Relative Density 60/60°F[a] (Specific Gravity)	A.4	.7753–.8398	.7507–.8017	.6852–.7238[b]		
Flash Point	A.7	100°F (37.8°C) (Min.)	Below 0°F (−18°C)	Below 0°F (−18°C)		
Fuel Color	A.8	Colorless to Light Amber		Red[c]	Green	Blue
Equipment Color Code[d]	A.8	Black-Jet A Gray-Jet A-1	Yellow	Red	Green	Blue

[a] There are hydrometers available for use in the field which give a direct reading of pounds per gallon.

[b] There are no ASTM specification limits, but these typical ranges are derived from the Energy Research and Development Administration.

[c] If agreed upon between purchaser and supplier, grade 80 may be free from lead. If so, the fuel may not contain any dye and then will be essentially colorless.

[d] Detailed recommendations for airport equipment marking for fuel identification are noted in Chart 2 (from API Bulletin 1542).

identification, but some locations may be able to perform flash point. Other tests are often done, such as membrane color, but these tests are used for fuel quality and not for product identification. In cases in which there is still any doubt as to product identity, a product sample (1 gal [3.8 L] minimum in an approved sample container) should be sent to a fuel-testing laboratory for identification (see Sec. A.9, Shipment of Aviation Fuel Samples).

A.6.4 EQUIPMENT

Equipment (Chart 2) is described in Sec. A.2.4 for determining API gravity or metric density. Flash point equipment is described in Sec. A.5.4. A clear glass sample container is used for observing color (e.g., a hydrometer cylinder).

A.6.5 PROCEDURE

1. For Jet A and Jet A-1 fuels, run API gravity (or relative density) tests described in Sec. A.2 and flash-point tests described in Sec. A.5.
2. For Jet B fuels, run API gravity (or relative density) tests described in Sec. A.2.
3. For avgas fuels, run API gravity (or relative density) tests described in Sec. A.2 and the following color test:
   a. Obtain small sample (pint or quart) of avgas in a clear, glass sample container.
   b. Observe the color and appearance of the avgas. It should be clear and bright and the correct color for the specified grade (Chart 1) with no cloudiness or indication of contamination with another color (Sec. A.1).

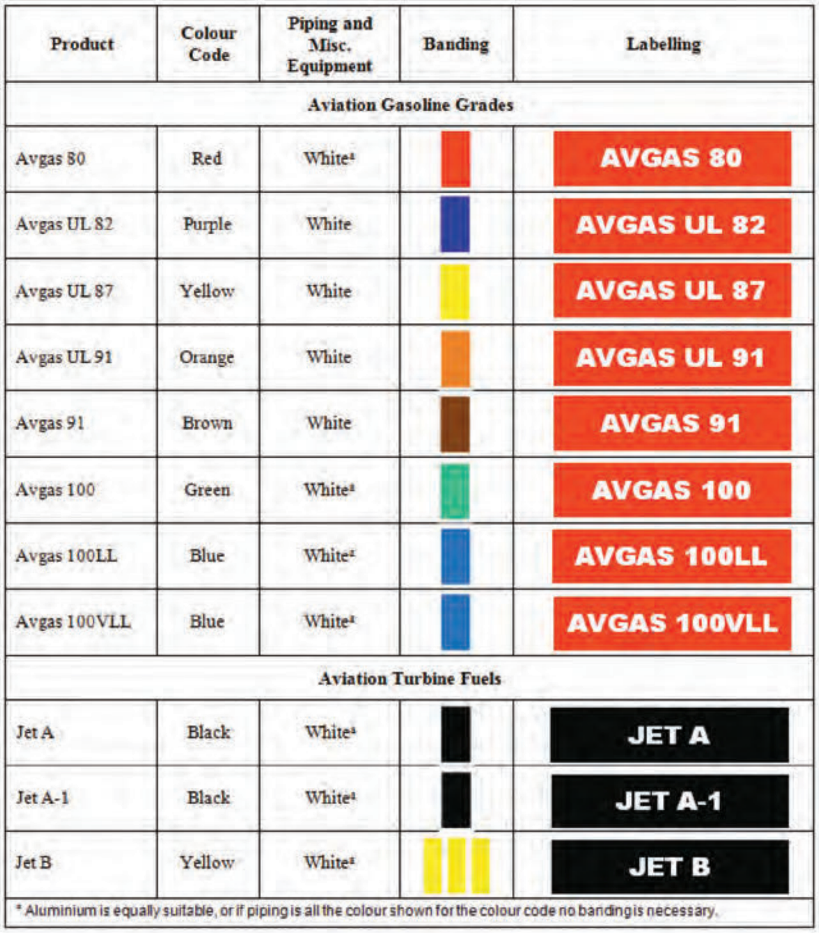
A.6.6 CAUTIONS

Be sure to properly dispose of aviation fuel samples. Safe handling procedures and regulating agency requirements must be followed.

A.6.7 INTERPRETATION OF TEST RESULTS

1. Refer to Sec. A.2 for interpretation of API gravity or metric density results.

CHART 2 Airport equipment marking for fuel identification, recommendations for airport installations. Taken from API/EI Standard 1542, *Identification Markings for Dedicated Aviation Fuel Manufacturing and Distribution Facilities, Airport Storage, and Mobile Fuelling Equipment*, 9th Edition, August 2002. (Reproduced courtesy of the American Petroleum Institute.)



Product	Colour Code	Piping and Misc. Equipment	Banding	Labelling
Aviation Gasoline Grades				
Avgas 80	Red	White*	🟥	AVGAS 80
Avgas UL 82	Purple	White	🟪	AVGAS UL 82
Avgas UL 87	Yellow	White	🟨	AVGAS UL 87
Avgas UL 91	Orange	White	🟧	AVGAS UL 91
Avgas 91	Brown	White	🟫	AVGAS 91
Avgas 100	Green	White*	🟩	AVGAS 100
Avgas 100LL	Blue	White*	🟦	AVGAS 100LL
Avgas 100VLL	Blue	White*	🟦	AVGAS 100VLL
Aviation Turbine Fuels				
Jet A	Black	White*	⬛	JET A
Jet A-1	Black	White*	⬛	JET A-1
Jet B	Yellow	White*	🟨🟨🟨	JET B

* Aluminium is equally suitable, or if piping is all the colour shown for the colour code no banding is necessary.

2. Refer to Sec. A.5 for interpretation of flash-point results.
3. If jet fuel is not clear and bright, or avgas is not clear and bright as well as of the proper color, the fuel is suspect and a sample should be sent to a fuel-testing laboratory for identification.

A.7 Electrostatic Hazards in Mixing Aviation Fuels

A.7.1 INTRODUCTION AND PURPOSE

Although nonmilitary turbine-powered aircraft usually are fueled with Jet A or Jet A-1 fuels, it is sometimes necessary to refuel them with lower flash-point fuels, such as JP-4 or Jet B, as approved by the airframe manufacturer or type certificate. (Note: Flash point is not an issue with JP-5 and JP-8 turbine fuels because they have flash points similar to or greater than Jet A and Jet A-1.) When lower flash-point fuels are used, the vapor space above the mixed fuels likely is flammable and thus more easily ignited by electrostatic discharges. It is important to notify ground-fueling personnel and those responsible for their safety when an aircraft fuel system may contain fuel with a flash point less than 100°F because low-flash-point fuels vaporize and can ignite at lower temperatures. Note that the use of lower flash-point (wide-cut) fuels (JP-4 and Jet B) is being phased out, but they continue to be used particularly in areas with very low temperatures.

A.7.2 REFERENCES

No official reference is known to exist for this procedure, but some aircraft manufacturers may have individual aircraft fueling procedures.

A.7.3 DESCRIPTION

The vapor space in a turbine-powered aircraft tank contains a mixture of air and fuel vapor. For kerosine-type fuels, this mixture is seldom ignitable because the amount of fuel vapor from these fuels (Jet A and Jet A-1, as well as JP-5 and JP-8) is quite small, making the fuel-air mixture too lean to burn. When the tank is being (or has been) contaminated with or serviced with a more volatile fuel, such as avgas (or, rarely, wide-cut turbine fuel still in use at some locations; Jet B or JP-4), the vapor space mixture can fall within the flammable range.

NOTE

Aviation gasoline is not recommended for turbine-powered aircraft by any engine manufacturer.

Flammable conditions also can occur if tanks that previously had been serviced with a wide-cut (Jet B, JP-4, or similar fuel) product are fueled with a kerosine-type fuel, or when the kerosine-type product is serviced to aircraft at ambient temperatures above the flash point. The hazard associated with fueling and defueling under those conditions is the possibility of electrostatic-induced ignition.

A.7.4 CAUTIONS

The aircraft flight crew must know the type of fuel introduced into the aircraft tanks in at least the last two fuelings so that the next fueling operator can be advised if a dissimilar fuel is to be loaded.

This section is included in this manual to make fueling operators aware of the potential hazard of mixed fuels. ASTM neither endorses any procedure nor is prepared to write a recommended procedure that would eliminate hazards associated with electrostatic discharges.

A.8 Preservice Cleanliness Inspection of Fueling Equipment

A.8.1 INTRODUCTION AND PURPOSE

The proper inspection of a new, refurbished, or repaired refueler or dispenser, before placing the unit into service, is of the utmost importance to ensure that only quality fuel is to be dispensed.

Refueler tanks and dispensing equipment may contain water, solid contaminants, or a mixture of fuels or off-specification fuel after being fabricated, repaired, or tested.

A.8.2 REFERENCES

There is no known published standard for this inspection. Some aircraft-fueling companies or airlines, however, have established procedures.

A.8.3 DESCRIPTION OF INSPECTION PROCEDURES

The commissioning of equipment is basically a visual inspection of the equipment followed by a test of the first fuel to be dispensed by the unit. The fuel is tested for particulate matter and water before the equipment is put into service.

A.8.4 EQUIPMENT

The required equipment for this procedure includes a white bucket (Sec. A.1.3), field-sampling kit (Secs. B.1–B.2), and water detection kit (Secs. C.1–C.5).

A.8.5 PROCEDURE

1. Before filling the refueler, inspect all tank compartments for foreign matter and water. Clean tanks as required.

   CAUTION

   Tank cleaning must be accomplished in accordance with local, state, and national guidelines.

2. Drain all sumps and low points. Be sure to close all valves and reinstall plugs.
3. Ensure the filter elements and filter vessel accessories are properly installed and operating.
4. In the case of refuelers, fill unit approximately three-quarters full with clean product. While filling, check that there are no leaks and verify tank vents and high-level shut-off prechecks are functioning. Sample all tank and filter sumps (Sec. A.3).
5. Flush the refueler or dispenser piping system with clean fuel, taking care at first to ensure that all the air has been

removed from the system. Flush twice the volume of the fueling circuit into a downgrade fuel receptacle or tank. Check for leaks while flushing.

6. Circulate clean product in the refueler or dispenser for approximately 30 min at maximum obtainable system flow rate (not to exceed the filter rated capacity).

   CAUTION

   Fuel flow in a refueler should be accomplished by means of a proper recirculation system. Recirculating the fuel through the bottom-loading system may result in fuel circulation in the piping only. Flow should be established through the recirculation system (if so equipped) or through a drop tube designed to prevent the free fall or splashing of fuel. A test stand is preferable.

7. After circulation in step 6 is completed, take a sample of the fuel from each nozzle and filter sump. Also, take a sample from the tank sump of the refueler. Evaluate the samples for appearance, water, and particulate content (Sec. A.1). Continue circulating as necessary until samples are acceptable.
8. Check nozzle screens, clean as required, and reinstall.
9. New fuel hose must be properly prepared before use. The process has been historically located in API 1529, but has been relocated to Sec. A.15 of this publication.
10. If the product quality has deteriorated after the refueler or dispenser has been allowed to stand for a period of time, as mentioned in the new hose preparation procedures (A.15), continue fuel circulation and recheck fuel quality. Circulate until the fuel is of acceptable quality. If the fuel is not of acceptable quality, check filters and change if necessary. Repeat test starting with step 6. If fuel has been stored a long time, typically 6 months or more, the oil company or airline may require recertification to ASTM D1655 or ASTM D910.
11. Fuel soak and flushing procedures detailed in steps 9 and 10 may be bypassed only with approval by the appropriate authority as local operating conditions (equipment availability) dictate.
12. During the final recirculation step, perform a filter membrane test (Secs. B.1–B.2), check fuel for water (Secs. C.1– C.5), and record the differential pressure across the filter (Sec. D.5).
13. The following additional serviceability checks should be considered:
    a. primary and secondary pressure controls,
    b. meter calibration,
    c. brake and fueling interlocks, and
    d. other safety features.

A.9 Shipment of Aviation Fuel Samples

A.9.1 OBTAINING SAMPLES AND FLUSHING SAMPLE CANS FOR SHIPMENT TO LABORATORY

It is important that samples are taken carefully so the fuel tested at the laboratory is representative of the fuel in the system. In addition, it is critical that the sample does not contaminate or change any characteristic of the fuel sample.

A.9.1.1 Flushing Sample Cans

The sample must be in compliance with any requirements for shipping, such as those of the U.S. Department of Transportation (DOT), International Air Transportation Association (IATA), and International Civil Aviation Organization (ICAO). The can must be epoxy-lined and meet the requirements of ASTM D4306, Sec. 6, in regard to not having a negative effect on sample integrity.

It is strongly recommended to soak a full can overnight (known as "pickling") before flushing. Proper flushing requires at least three rinsings with the fuel being sampled. Fill the can about 10–20 % full (less than one-quarter full) and shake vigorously for 1 min and drain completely. Discard each rinse.

Before filling the sample can, the sample connection and hardware must be flushed to make sure the sample is representative of the fuel in the system.

A.9.2 GENERAL

There are restrictive rules and regulations that govern the shipment of hazardous materials. It should be clearly understood that all grades and types of jet fuels (both kerosine and naphtha-based), aviation gasolines (avgas), and used filter cartridges containing fuel residues currently are considered hazardous materials when shipped as cargo by air.

Containers for the transportation of samples by air shall be of an ICAO-approved design and shall be transported in accordance with the latest edition of the ICAO *Technical Instructions for the Safe Transport of Dangerous Good by Air*, the IATA *Dangerous Goods Regulations*, or local governing regulation.

Therefore, each prospective shipper of a hazardous material must contact the carrier of choice, either air, ground, or marine, for specific information necessary to meet their regulations. Sample containers should conform to the requirements of ASTM D4306.

A.9.3 REFERENCES

ASTM D4057-12, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*, ASTM International, West Conshohocken, PA, 2012, www.astm.org

ASTM D4306-15, *Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination*, ASTM International, West Conshohocken, PA, 2015, www.astm.org

U.S. Department of Transportation, 49 *CFR*, Parts 100–199, *Transportation,* U.S. Government Publishing Office, Washington, DC, 2016, www.ecfr.gov

IATA, *Dangerous Goods Regulations*, International Air Transportation Association, Quebec, Canada, 2016, www.iata.org

ICAO, *Technical Instructions for the Safe Transportation of Dangerous Goods by Air*, Doc. 9284, International Civil Aviation Organization, Montreal, Canada, 2015–2016, www.icao.int

A.10 Field Test for Contamination of Aviation Gasoline with Heavier Fuels

A.10.1 INTRODUCTION AND PURPOSE

Contamination of avgas by small amounts of heavier petroleum products, such as jet fuel, kerosine, and diesel fuel, may be difficult to detect in the field because the fuel dye masks color changes. When more sophisticated laboratory tests are unavailable, this test can provide an indication that a heavy petroleum contaminant is present in the fuel in a significant quantity.

A.10.2 REFERENCES

There is no published standard for this test. A similar procedure has been distributed by the Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation, *Detecting Jet Fuel Contamination of Avgas*, Safety Bulletin No. 1, Frederick, MD, 1981.

A.10.3 DESCRIPTION

Drops of the sample fuel and a known uncontaminated sample are each placed on a piece of paper. After the avgas evaporates, the spots are compared. The presence of a translucent (semitransparent) ring around the test fuel sample point, after a specified time interval, is a positive indication of contamination by heavier products.

A.10.4 EQUIPMENT

1. *Medicine Droppers and Clean Test Vials.* The specific type is not important, but all droppers must be the same kind and size for each test.
2. *Test Paper.* The type of paper is not critical, and any paper that will absorb the fuel drops should be satisfactory. Whatman No. 1 filter paper or standard notebook paper is acceptable.
3. Stop watch or a watch with a second hand.
4. Sample of fuel from source known to be uncontaminated (base standard).

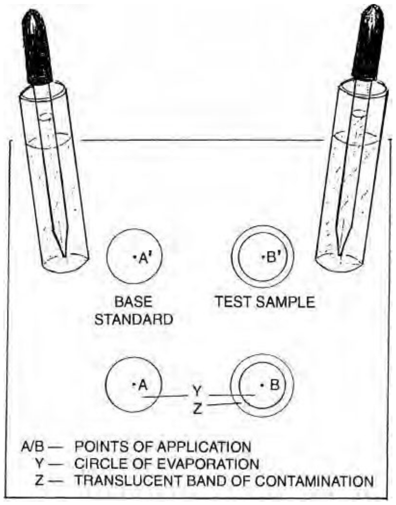
NOTE

Do not assume fuel upstream of the point of sampling is uncontaminated. It may be desirable to store a small sample of known good product for use when needed.

A.10.5 PROCEDURE

1. Although the test can be performed under a variety of conditions, advantage should be taken of any available shade or shelter.
2. Make four pencil dots about 2 in. (5 cm) apart on a piece of test paper as shown in Fig. 5. Label two adjacent dots, A and A' for the base standard, and two dots, B and B' for the test sample.
3. Fill a clean medicine dropper with the base standard. Place the filled dropper in a small empty vial or bottle for support. In a like manner, fill a second dropper with the sample to be tested.
4. With one hand, hold the test paper horizontally and with the other hand, pick up the dropper containing the base standard. Holding the dropper immediately over point A, discharge *a single* drop of gasoline. Move the dropper to A' and repeat the application. Replace the medicine dropper in its holder.
5. Immediately take the dropper containing the test sample and place single drops at points B and B' and replace this dropper.

FIG. 5 Drop testing of a known good fuel (base standard) and fuel in question (test sample).



6. As soon as the fuel is evaporated from the base standard (about 10 s at 90°F [32°C] about 30 s at 50°F [10°C]), apply second drops of base standard to A and A'. Similarly, apply drops of the test sample at B and B'.
7. Repeat the application until 5 drops have been added to each dot. After the last fuel drops have evaporated, pick up the paper and look through it toward an indirect light source and observe the four spots. If outside, hold it toward a portion of the sky away from the sun. Indoors, use a window or fluorescent or incandescent light. The inner circle (*Y* in Fig. 4) will dry rapidly. If there is contamination, the outer ring (*Z* in Fig. 4) will be translucent and remain visible for a longer period.

A.10.6 CAUTIONS

When applying the drops to the test paper, try to add the drops at the center of the spot each time and keep the drops about the same size. If more than one drop is added to a spot at the same time or if a spot is flooded in some other manner, discard the spot and begin the test again on another piece of paper.

A.10.7 INTERPRETATION AND LIMITATIONS OF RESULTS

If no translucent outer ring (*Z*) appears or it disappears before 20 s after the base standard, report "no contamination by filter paper test." If the translucent band (*Z*) of the test sample remains longer than 20 s after that of the base standard, report "contamination by filter paper test." If contamination is indicated, the fuel should be quarantined immediately for more intensive testing.

If the type of contamination is not known, some information on the contaminating product may be obtained by examining the ring, as follows:

1. *Width of Ring.* The width varies with the boiling point of the contaminating fluid. Heavier products leave narrow

distinct rings while lighter products, such as jet fuel, leave wider, fuzzier rings.

2. *Odor.* The contaminant may have a distinctive odor that may be detected after the inner ring dries.
3. *Color.* Heavy fuel oil will leave a brown deposit near the center of the spot.
4. *Effect of Temperature on Ring.* Jet fuel and kerosine evaporate at room temperature; heating oil at slightly elevated temperatures; lubricants do not evaporate at all.
5. *Test Sensitivity*. If done properly, the test is capable of detecting as little as 1 % heavy product contamination.

A.11 Fuel-Sampling Techniques

A.11.1 INTRODUCTION AND PURPOSE

This section outlines techniques for choosing containers and sampling aviation fuels. Products are sampled for various reasons, such as upon receipt, to ensure that the product is on specification; during storage, for custody transfer and pricing determination; or during storage and handling, to monitor aviation fuel quality and condition.

The quality of the fuel is determined by interpreting results of tests performed on samples of the fuel. Therefore, it is extremely important that samples accurately represent the fuel being tested or test results will be invalid.

These instructions for sampling and sample containers do not cover all cases. Therefore, judgment must be used to be sure that samples are representatives of the products to be tested. Also, if the purpose for taking the sample is not clear, additional information should be sought to ensure that the sample is taken properly and in the right container.

A.11.2 REFERENCES

ASTM D4057-12, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*, ASTM International, West Conshohocken, PA, 2012, www.astm.org

ASTM D4306-15, *Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination*, ASTM International, West Conshohocken, PA, 2015, www.astm.org

Also see Sec. A.9, Shipment of Aviation Fuel Samples.

A.11.3 DESCRIPTION

Table 1 contains a summary of the common types of samples taken for aviation fuel testing. Type and quantity of samples and sample containers must be chosen to ensure that the samples are representative of the aviation fuel in question and are satisfactory for the purpose intended, that is, testing, visual inspection, and so forth. Certain aviation fuel tests are known to be affected significantly by trace contaminants that can be introduced by an improper container. Table 2 contains a list of recommended sample containers for specific tests.

Liquid materials in tanks and other bulk containers should be sampled by the appropriate technique. The sample must be drawn through an opening that gives direct access to the bulk of liquid. This means that samples should not be drawn from nonslotted gage-tubes because nonrepresentative samples may result.

TABLE 1 Types of Samples

Type	Description
1. Spot sample	A sample taken at a specific location in a tank or other container or from a line at a specific time during a pumping operation.
2. Top sample	A spot sample obtained 6 in. (15.24 cm) below the top of the container's contents.
3. Upper sample	A spot sample obtained from the middle of the upper third of the container's contents.
4. Middle sample	A spot sample obtained from the middle of the container's contents.
5. Lower sample	A spot sample obtained from the middle of the lower third of the container's contents.
6. Bottom sample	A sample obtained at the bottom surface of the container at its lowest point.
7. Drain (sump) sample	A sample obtained from the water draw-off line or sump.
8. All levels sample	A sample obtained by submerging a closed sampler to a point as near as possible to the draw-off level, then opening the sampler and raising it at a rate such that it is three-quarters full as it emerges from the liquid.
9. Line sample	A sample drawn from a small sample connection on a line.
10. Drip sample	A "drip" or "continuous" sample is a line sample obtained by either of the following methods to produce a representative average: a. The product is allowed to drip or trickle into a container throughout the period of product transit. b. A pint sample may be drawn at regular intervals during a delivery to fill a gallon container.
11. Hose sample	A sample obtained from a refueling vehicle or dispensing cabinet delivery hose.
12. Composite sample	A sample consisting of a blend of equal portions of two or more of any of the other types of samples.
13. Multiple tank composite sample	A mixture of individual samples from several compartments of ships, barges, and so forth, which contain the same grade of fuel. The mixture is blended in proportion to the volume of material in each compartment.
14. Running sample	A sample taken from a flowing stream over time, intended to provide an average example.

TABLE 2 Summary of Container Recommendations[a]

Type of analysis	Microseparometer (MSEP)	Electrical Conductivity	Lubricity	Thermal Stability	Trace Metals
Hard borosilicate glass					
Immediate use	P	P	S	S	NR
Storage	P	P	S	NE	NR
Reuse	S	P	S	S	NR
Epoxy-lined steel					
Immediate use	P	P	S	P	NR
Storage	P	P	S	P	NR
Reuse	P	P	S	P	NR
Polytetrafluoroethylene					
Immediate use	S	NR	NR	P	P
Storage	NE	NR	NR	P	P
Reuse	NE	NR	NR	P	P
Tin-plate soldered steel (super clean only)					
Immediate Use	S	S	S	S	NR
Storage	NR	NR	NR	NR	NR
Reuse	NR	NR	NR	NR	NR
High-density linear polyethylene					
Immediate	S	NR	NR	NR	P
Storage	NR	NR	NR	NR	P
Reuse	NR	NR	NR	NR	P

Note: P = preferred; S = suitable; NR = not recommended; NE = not evaluated but may be suitable.

[a] The containers listed in this summary should not be used without consulting the appropriate paragraphs of ASTM D4306.

A.11.4 EQUIPMENT

1. Sample containers could be as follows: epoxy-coated metal containers, borosilicate (hard) glass bottles (Pyrex® is the popular brand name), polytetrafluoroethylene bottles (Teflon® is the popular brand name), polyethylene bottles, steel cans, and stainless steel beakers.
2. Closures, caps, lids, and so forth, as required.
3. Sample tags or labels.
4. Cleaning reagents, solvents, and reference fluids as required.

   NOTE
   See ASTM D4057 and ASTM D4306 for suggested materials and handling precautions for reagents, reference fluids, and solvents.

5. Sampling apparatus and hand tools, as required.

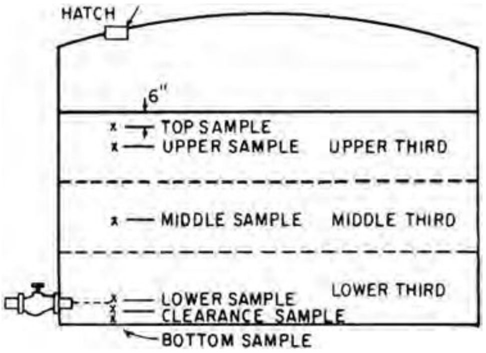
A.11.5 PROCEDURE

1. Determine for what purpose the sample is required and what tests are to be run on it. If not sure, get directions from the authority having jurisdiction.
2. Select sampling container of the appropriate size and type.
3. Inspect and clean the container according to the procedures listed in ASTM D4057 and ASTM D4306.
4. Rinse the container three times with the product to be sampled, if appropriate.
5. Inspect the sampling apparatus to be sure it is also clean. It is much simpler to keep the sampling apparatus clean if different apparatus is dedicated for different types of products, that is, aviation gasoline and jet fuel.
6. Use one of the following typical sampling methods to obtain the type of sample desired (Figs. 6-9):
   - Lowering a weighted bottle assembly or a metal bomb sampling device into the product to the desired level.
   - Drawing line samples from a sampling port on a pipeline or dock riser.

   CAUTION
   Do not disturb product flow while sampling, that is, by closing valves and so forth.

7. In addition to the general information listed above, also include the following specific information on the sample label:
   - Marine-vessel shipment—product, ship/barge, compartment, shipment or voyage number, and date;

FIG. 6 Sampling depths. The outlet location shown applies only to tanks with side outlets. It does not apply when the outlet comes from the floor of the tank or turns down into a sump.



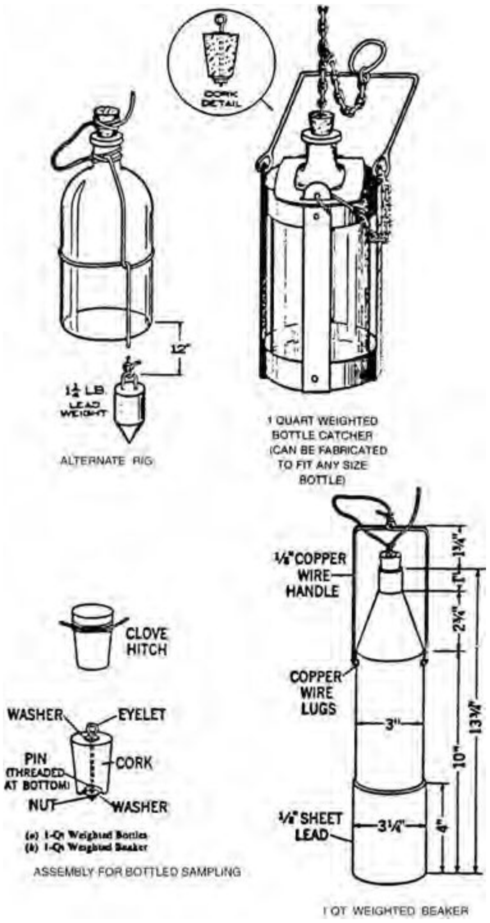
- Tank samples—product and tank number, terminal, pipeline tender or marine vessel number, wheeled vehicle delivery (tank truck) number, if applicable, and date;
- Airport samples—shipping tank number, pipeline tender number, wheeled vehicle delivery number, product source, if known, and date;
- Filter vessel samples—date, name-plate information, location, type of vessel, and vessel number;
- Aircraft samples—date, aircraft number, tank number, and flight number; and
- Delivery truck samples—Truck and trailer number, compartment number, date, and product origin.

8. Clean sampling apparatus before storing it in an appropriate location. Samples should be transported to the testing laboratory as soon as possible or stored in an appropriate cool, dark (unless the container is metal), dry location.

A.11.6 CAUTIONS

1. Fuel sampling involves hazardous materials, operations, and equipment. This section does not address all of the safety problems associated with fuel sampling. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations before use.

FIG. 7 Bottle and beaker sampling apparatus.



2. Cleanliness is absolutely essential for proper sampling. The following techniques are recommended:
   a. The sampler's hands (or gloves) must be clean.
   b. The sampling apparatus and containers must be maintained in a clean condition (and environment) and *inspected* immediately before use.

NOTE

It is not acceptable to clean containers or sampling apparatus with common soaps and detergents because residual quantities of these materials may affect certain test results. Also, common plastics should not be used for sampling any

FIG. 8 Probes for continuous sampling.

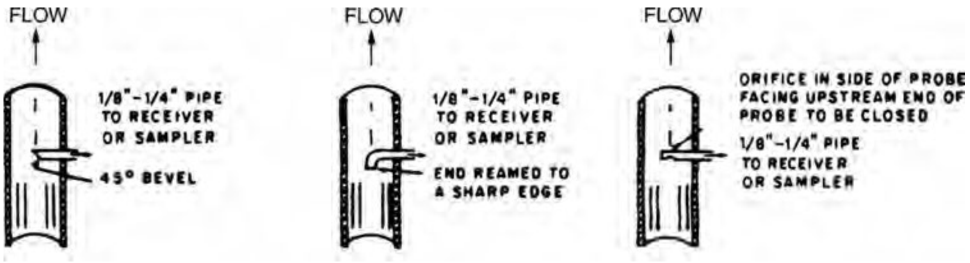
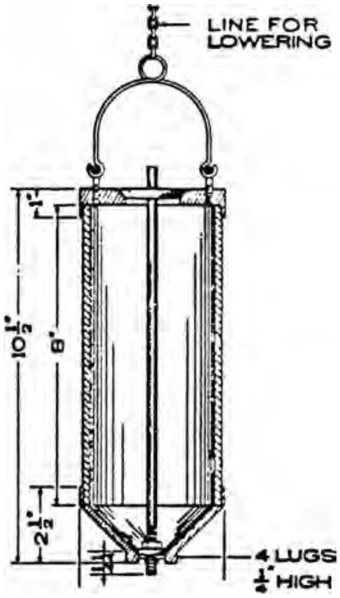


FIG. 9 Thief for sampling tank cars.



petroleum fuel. Furthermore, if a hose sample is to be taken, the hose must be cleared or flushed of all fuel present before taking the sample.

   c. Rinse the container (or intermediate containers) and sampling apparatus three times with the fuel to be sampled prior to taking the sample.
   d. All flushed fuel must be either recovered or disposed of in an approved manner.

NOTE
If taking a sump sample, no flushing is required.

   e. Seal containers immediately after filling, using the proper closures. (Review Sec. A.9 if sample is to be shipped to another location.)
   f. Label container immediately after filling, using the proper label or waterproof marker.
   g. The label should contain as much information as required to tell the person receiving it what is required from the sample. For example, the following information may be included on the label: name, volume, and grade of product; geographic location (terminal, airport, pipeline, and so forth); date and time sample taken; name of sampler; tank number, container, or vehicle, including lot number where applicable, as well as point from which sample is taken; type of sample (composite, all level, bottom, and so forth); identification number of sample; and tests requested.
   h. If the sample is sensitive to light (e.g., leaded avgas) and the testing includes determination of color, tetraethyl lead, inhibitors, stability tests, and so forth, then the sample must be protected from light. Cans are preferred, but brown bottles sometimes are used, or clear glass bottles may be used if wrapped in a material capable of keeping out the light (aluminum foil is commonly used).

NOTE
Any sample that is to be shipped to another location or that will not be tested in a short time should be protected from light.

   i. About 5 % of the sample container volume should be left empty to allow for expansion.
   j. Add precautionary labels as required by local ordinance or if shipping sample to another location for testing (review Sec. A.9).

3. The following warning statements are applicable:
   a. *Flammable Liquid (General)*
      Warning—Flammable.
      Keep away from heat, sparks, and open flame.
      Keep container closed.
      Use only with adequate ventilation.
      Avoid prolonged breathing of vapor or spray mist.
      Avoid prolonged or repeated contact with skin.
   b. *Aviation Gasoline (avgas)*
      Danger—Extremely flammable.
      Vapors harmful if inhaled.
      Vapors may cause flash fire.
      Harmful if absorbed through skin.
      Keep away from heat, sparks, and open flame.
      Keep container closed. Use with adequate ventilation.
      Avoid buildup of vapors and eliminate all sources of ignition, especially nonexplosion-proof electrical apparatus and heaters.
      Avoid prolonged breathing of vapor or spray mist.
      Avoid prolonged or repeated contact with skin.
   c. *Aviation Turbine Fuels (Jet A or Jet A-1)*
      Caution—Combustible.
      Vapor harmful.
      Keep away from heat, sparks, and open flame.
      Keep container closed.
      Use with adequate ventilation.
      Avoid breathing vapor or spray mist.
      Avoid prolonged or repeated contact with skin.
4. All flushed fuel must be either recovered or disposed of in an approved manner.

A.12 Surfactants—Surface Active Agents

A.12.1 INTRODUCTION AND PURPOSE

The purpose of this section is to provide basic information on surfactants and the need for the detection and prevention of these materials in aviation fuel systems.

A.12.2 REFERENCES

ASTM D3948-14, *Standard Test Methods for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable*

Separometer, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM D4306-15, *Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination,* ASTM International, West Conshohocken, PA, 2015, www.astm.org

A.12.3 DESCRIPTION

Surfactants are "surface-active agents," which are materials that collect at liquid-liquid or liquid-solid interfaces and cause specific things to happen. One of the best-known examples of surfactants might be dish detergent, which acts at the interface between oil and water to disperse the oil or grease into the water.

Surfactants in hydrocarbon fuels can be the result of naphthenate or sulfonate carried over from a refinery; can result from cross-contamination with other fuels; or can be in the form of additives, such as corrosion inhibitors, dispersants, and static dissipaters. Surfactants can cause jet fuel-handling problems because of their tendency to form fuel-water hazes and their ability to degrade the performance of filter/separators. For these reasons, fuel-manufacturing procedures and handling practices are closely controlled and monitored.

Some additives are injected by the refineries for the protection of manufacturing and transportation facilities. Other approved additives may be introduced at intermediate distribution plants or at the point of aircraft fueling. Approved surfactant-type additives are tested and usually do not have adverse effects on properly designed filtration systems of ground storage and dispensing equipment. In high enough concentrations, however, and especially when mixed with other components not usually present in jet fuel, they can disarm the filter/separators of ground-fueling equipment that could allow free water to be pumped into aircraft fuel systems.

A.12.4 DETECTION

Normally, evidence of surfactants is after-the-fact, that is, after gross contamination has occurred and a sudsy-like liquid appears in tank or filter sump drains. Following are some symptoms of possible surfactant contamination:

1. Excess dirt or free water detected downstream of the filtration system.
2. Hazy fuel samples.
3. Brownish-colored water in tank or filter sump drainings.
4. A lace-like material at the fuel-water interface of tank or filter/separator sump drainings.
5. In aircraft, erratic operation of the fuel quantity gages is an indicator of possible surfactant or microbiological growth buildup on the fuel quantity gauge probes.
6. Single-element test shows the coalescer to be disarmed (see Sec. D.7).
7. Tests for water separation characteristics (microseparometer [MSEP]) of the fuel yield unsatisfactory results (see Sec. A.13).

Following is a simple test that will alert an operator to the possibility of surfactant contamination: Take a sample in an appropriate container. If it is hazy, allow the sample to settle for about 3 min. If the haze has disappeared and water does not accumulate at the sample container bottom, the haze most likely was caused by entrained air. Within 3 min, if water appears as the haze clears up, surfactant should not be suspected. If the haze fails to clear up in this time, the presence of surfactants should be suspected and further investigation should be made.

The white bucket test (Sec. A.1.4.3 and A.1.4.4) is particularly helpful in detecting the presence of surfactants in fuel systems. Microbiological growths have many of the visual characteristics of surfactants and only laboratory tests can determine the type of contamination found. Fuel samples taken for laboratory evaluation should include the fuel-water interface, and the sample should be obtained in a clean, epoxy-coated sample can.

A.12.5 PREVENTION

The best methods for the prevention of surfactant contamination are proper manufacturing, transportation, filtration, and good housekeeping. If surfactants are a continuing problem, clay treatment should be considered to adsorb and thus remove the surfactants.

A.13 Microseparometer

A.13.1 INTRODUCTION AND PURPOSE

This test provides a rapid means to rate the ability of jet fuel to release entrained or emulsified water when passed through fiberglass coalescing material.

This test commonly is used to evaluate the performance of clay treating vessels (Secs. A.12 and D.8) that remove surfactants from jet fuel and to identify jet fuels that may contain significant levels of surfactant that would disarm coalescer cartridges.

A.13.2 REFERENCES

ASTM D3948-14, *Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer,* ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM D4306-15, *Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination*, ASTM International, West Conshohocken, PA, 2015, www.astm.org

Kirklin, P., Edmondson, F., Dukek, W., and Morse, F., *Development of the Portable Water Separometer for the WSIM Test*, SAE Technical Paper 851870, 1985, http://papers.sae.org/851870/

A.13.3 DESCRIPTION

A fuel sample is processed semiautomatically through the microseparometer instrument. Using a portion of the fuel sample, a reference level of 100 is established. Another portion of the fuel sample is then mixed with water and forced through a fiberglass coalescing media using a sequence of timed events controlled by the instrument. This portion then is compared with the 100 reference level established by the first portion. The resultant numerical value, termed the "MSEP rating," indicates the relative ease of coalescing water from the fuel. The test takes about 5 min to run.

NOTE

The correct terminology for water separation characteristics obtained using the microseparometer is MSEP rating. In the field, people tend to refer to all water separation ratings as the water separation index modified (WSIM) number. Technically, the WSIM number should be applied only to ratings that were obtained from the water separometer, which was described in the now-obsolete ASTM D2550 method superseded by the microseparometer (ASTM D3948).

A.13.4 EQUIPMENT

Equipment is manufactured by EMCEE Electronics, Inc., 520 Cypress Avenue, Venice, FL 34285. The equipment consists of the following:

1. Microseparometer instrument
2. Reusable items that initially are furnished with the microseparometer and used for each test, including
   a. 50/microlitres (µl) pipette, and
   b. catch pan.
3. Consumable items are available in kit form from the manufacturer, including
   a. Alumicel® coalescer,
   b. syringe,
   c. syringe plug,
   d. plastic tip for the 50/microlitres (µl) pipette,
   e. double distilled water, and
   f. lint-free wipes.

A.13.5 PROCEDURE

Detailed instructions are contained in ASTM D3948 and in the manufacturer's operating instructions furnished with each microseparometer instrument. In general terms, the procedure is as follows:

1. Condition the syringe and mixer shaft by adding a portion of fuel sample to the syringe and placing the syringe in the mixer. After mixing stops, discard the fuel but retain the syringe.

   NOTE

   This operation is performed twice.

2. Fill the syringe with 50 mL of fresh fuel sample, add 50/microlitres (µl) of distilled water, and place the syringe in the mixer.
3. Fill the vial halfway with fuel sample and insert into the instrument well. Align the white mark on the vial to the black mark in front of the well.
4. Activate the mixer to create the water-fuel emulsion.
5. Adjust the meter to a 100 reference level using the fuel sample in the vial placed in the instrument well in step 3.
6. When the mixer stops, remove the syringe from the mixer, insert the plunger into the barrel to the 50-mL mark, replace the syringe plug with an Alumicel® coalescer, and place the syringe assembly in the syringe drive.
7. The meter will activate for 10 s during which time, if necessary, the meter can be adjusted to the 100 reference level.
8. Remove the vial from the instrument well and discard the fuel sample but retain the vial.
9. The syringe drive mechanism will activate, forcing the water-fuel emulsion through the Alumicel® coalescer. Using the retained vial, collect the last 15 mL of processed fuel sample from the Alumicel® coalescer and place the vial in the instrument well, aligning the marks.
10. After 56 s, preceded by a steady tone, the display will activate. After an additional 5 s or when another 1 s tone sounds, read and record the displayed value as the MSEP rating.

A.13.6 CAUTIONS

1. *Do not* reuse the consumable items. Subsequent tests using these items could cause erroneous results.
2. The outside of the vials must be kept clean and free of external surface contamination (such as fingerprints) by wiping with a lint-free material. Because the clarity of the fuel sample determines the MSEP rating, any surface contamination would result in a lower reading.
3. The fuel sample temperature should be kept between 65 and 85°F (18 and 29°C) and should not vary more than 5°F (2.75°C) during the entire test cycle.
4. If the fuel sample is not clear and bright between these temperatures, do not run the test.
5. The alignment of the fuel sample vial in the instrument well must be the same during the adjustment period when the 100 reference level is attained in Sec. A.13.5, step 5 and when the final MSEP Rating is read in Sec. A.13.5, step 10. This is accomplished by orienting the label on the vial in the same direction during both steps.

A.13.7 CLEANLINESS GUIDELINES FOR DOWNSTREAM MSEP TESTING

A.13.7.1 Introduction

The cleanliness of aviation turbine fuel is an essential performance requirement. A key element in preventing dirt and water contamination is to minimize or eliminate surfactants. ASTM D1655, *Standard Specification for Aviation Turbine Fuels*, Table 1, contains the ASTM D3948 MSEP requirement to prevent surfactant contamination at the point of manufacture, and ASTM D1655, Appendix X1.13.2.2, includes the requirement for the prevention of downstream surfactant contamination.

A.13.7.2 General Surfactant Cleanliness Guidelines

1. Cleanliness requires the relative absence of free water and solid particulates. Water or dirt contamination in fuel onboard an aircraft represents a potential threat to flight safety and can cause long-term problems in areas such as wear, corrosion, and plugging of filters and other narrow-tolerance parts. The cleanliness of aviation turbine fuel is protected in part by allowing time for dirt and water to settle during fuel distribution and by the routine use of effective filtration that removes both dirt and water. Generally, the fuel-handling system filters the fuel several

times between manufacture and use, with the final filtration occurring as the fuel is loaded onto an aircraft.

2. A key element in aviation turbine fuel quality is to minimize surfactant contamination, which can compromise the ability of fuel-handling systems to remove dirt and water. Surfactants tend to increase the settling time of suspended solids and water droplets, decrease particulate filter effectiveness, and adsorb on the surfaces of filter/coalescers, thereby interfering with water removal. Surfactants also can lift rust and dirt from surfaces, increasing the solids level in the fuel.
3. Unlike most other fuel properties, fuel cleanliness is dynamic, constantly changing during transportation and distribution. Jet fuel should be transported in a manner that minimizes contamination from water, dirt, and surfactants as much as possible while in the distribution system. Fuel cleanliness reduces filtration costs and reduces the potential failure of filtration components that could lead to an unsafe condition. Filtration systems and airport quality control programs should be designed to ensure that solid particulates, surfactants, and free water are adequately removed before loading the fuel into aircraft. To determine the level of surfactant contamination in the fuel, ASTM D3948 MSEP testing should be used at appropriate points through the distribution system and as part of the airport quality control program.
4. Results of ASTM D3948 testing are not to be used as the sole reason for rejection of fuel; however, they can indicate a mandatory need for further diligent investigation or remedial action, such as passing the fuel through a clay adsorption unit to remove surfactants. The fuel may be rejected in the absence of satisfactory ASTM D3948 test results, however, if no documented evidence is presented that a detailed investigation was carried out demonstrating that the fuel was free of excess water and dirt and can be delivered into aircraft in a clean condition.
5. Because distribution systems can be complex and employ a variety of methods of transporting the fuel, sampling points and methodologies should be established as a result of a technical assessment designed to ensure that fuel cleanliness is maintained throughout the system to the point of delivery into the aircraft. Because transport systems vary in their basic nature (e.g., water-borne transport versus a multiproduct pipeline versus a dedicated pipeline) and also in their detailed operating conditions, the parties assuming custody of the fuel should evaluate their particular systems and establish suitable testing requirements.

A.14 Aviation Fuel Additives

A.14.1 INTRODUCTION AND PURPOSE

A number of additives may be present in aviation fuels for various reasons. The purpose of this section is to briefly acquaint the reader with the different additives and why they may be present. Additives and their uses must meet the requirements of the appropriate ASTM aviation fuel specification.

The purpose of using an additive is to either add a feature (such as identifying specific avgas grades) or to improve a specific quality or performance parameter or fuel characteristic over that achieved by refining and blending (such as fuel anti-icing or static conductivity).

A.14.1.1 Storage and Handling

Additives should be stored and handled appropriately as indicated by the applicable material safety data sheet (MSDS). Premixing of additives together into a "cocktail" is not recommended because reactions can take place between the additives, reducing their effectiveness or causing other problems.

A.14.2 REFERENCES

ASTM D910-16, *Standard Specification for Leaded Aviation Gasolines,* ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM D1655-16a, *Standard Specification for Aviation Turbine Fuels*, ASTM International, West Conshohocken, PA, 2016, www.astm.org

ASTM D5006-11(2016), *Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels*, ASTM International, West Conshohocken, PA, 2016, http://www.astm.org

ASTM D6227-14, *Standard Specification for Unleaded Aviation Gasoline Containing a Nonhydrocarbon Component*, ASTM International, West Conshohocken, PA, 2014, www.astm.org

NOTE

82UL Avgas is not a direct replacement for Avgas 80.

ASTM D6469-14, *Standard Guide for Microbial Contamination in Fuels and Fuel Systems*, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM D6615-15a, *Standard Specification for Jet B Wide-Cut Aviation Turbine Fuel,* ASTM International, West Conshohocken, PA, 2015, www.astm.org

IATA, *Guidelines on Microbiological Contamination in Aircraft Fuel Tanks*, Issue 1, International Air Transportation Association, Quebec, Canada, November 2003, www.iata.org

Salvatore, R., *Significance of Tests for Petroleum Products, MNL1-8th*, ASTM International, West Conshohocken, PA, 2010, http://dx.doi.org/10.1520/MNL1-8TH-EB

Additives that Typically Are Injected into the Fuel at or Downstream of the Refinery

A.14.3 TETRAETHYL LEAD (TEL)

A.14.3.1 Purpose

Tetraethyl lead (TEL) is an antiknock compound used in most aviation gasolines (avgas) to improve the antiknock characteristics of the avgas, resulting in higher octane and performance numbers. The newest grade, 82UL, does not contain lead, and some other grades of avgas may not contain TEL.

A.14.3.2 Precautions

a. TEL antiknock compound is classified as very toxic. Careful controls are required during its storage, handling, and use, which are available in the TEL suppliers, MSDS documentation.
b. The concentration of TEL in aviation gasoline is controlled by the specifications (ASTM D910). At these levels, the hazardous classification of the gasoline is unaffected by the presence of TEL. Tanks used for the storage of leaded aviation gasoline, however, after extended use, may pose risks related to the presence of TEL or derivatives (chemicals formed by degradation of these compounds) in deposits. Precautions therefore should be taken when entering, cleaning, repairing, or disposing of leaded gasoline tanks or piping. Details are available from TEL suppliers.

A.14.4 COLOR DYES

A.14.4.1 Purpose

Dyes are added to avgas for two reasons: to differentiate between avgas grades (see Sec. A.6) and because dye is required in any fuel containing lead.

Dyes are not allowed in jet fuel.

A.14.4.2 Precautions

If jet fuel or avgas appears to be different in color than the normal color seen (see Sec. A.6), there may have been an inadvertent mixing with another product. For example, jet fuel with a reddish appearance may have been contaminated with some amount of red-dyed diesel fuel (or other red liquid). (Note: U.S. off-road untaxed diesel is dyed red.) Avgas with a color different from the usual color may have been mixed with a different grade of avgas or another product.

a. Refer to the manufacturers' MSDS information for safety precautions.

A.14.5 ANTIOXIDANT

A.14.5.1 Purpose

Antioxidant is added to some aviation gasolines and some jet fuels. In aviation gasolines, antioxidant prevents the formation of gum and the precipitation of lead compounds. In some jet fuels, antioxidant is added to prevent the formation of peroxides, which can adversely affect thermal stability and storage stability and degrade elastomers (seals).

a. Refer to the manufacturers' MSDS information for safety precautions.

A.14.6 METAL DEACTIVATOR

A.14.6.1 Purpose

Metal deactivator may be used in jet fuels to prevent certain metallic materials (such as copper) from accelerating the degradation of thermal stability.

a. Refer to the manufacturers' MSDS information for safety precautions.

A.14.7 CORROSION INHIBITOR

A.14.7.1 Purpose

Corrosion inhibitor/lubricity improver (CI/LI) additive is used to minimize corrosion of pipelines, tanks, and other parts in contact with fuels in which trace amounts of water may be present. CI/LI additive also provides improvements in the lubricating properties ("lubricity") of jet fuels. In general, military fuels require the addition of an approved CI/LI additive. Civilian jet fuels normally do not contain CI/LI additive, but the use of specific additives is permitted by both ASTM D1655 and ASTM D910.

a. Refer to the manufacturers' MSDS information for safety precautions.

Additives that Typically Are Injected into the Fuel Downstream of the Refinery

A.14.8 STATIC DISSIPATER ADDITIVE (SDA)

SDA also is known as antistatic additive or conductivity improver additive.

NOTE

Static electrical charges can cause dangerous sparks, which can lead to ignition of fuel vapors. The important action is to bond all components in the system so that no *difference* in electrical charge potential exists. For example, the overwing nozzle must be mechanically and electrically bonded to the aircraft. Static conductive hose is not used to accomplish overwing nozzle bonding because it does not constitute a reliable and auditable means of ensuring that there is no difference in electrical potential between the nozzle and the aircraft.

A.14.8.1 Purpose

Because static electrical charges can build up in fuels moving through fuel systems, particularly through filters, SDA can be added to jet fuels to increase the electrical conductivity of the fuel to reduce the time that it takes for electrical charge to dissipate.

A.14.8.2 Precautions

If the fuel is treated with static dissipater additive, the additive level or the effectiveness of the additive in the fuel can be reduced as the additive moves through the distribution system. The electrical conductivity level of the additized fuel is measured at various locations, with a handheld meter, or with an in-line conductivity meter. If the conductivity level drops below the customer's prescribed limits, readditizing within approved specification limits is necessary.

a. Refer to the manufacturers' MSDS information for safety precautions.
b. Immediately after adding the conductivity additive, the conductivity readings may not be stable. In cases in which

the conductivity additive is injected at the truck rack during loading, it may be prudent to obtain feedback on the conductivity reading from the receiving location before making additive injection rate adjustments.

A.14.9 FUEL SYSTEM ICING INHIBITOR (FSII)

A.14.9.1 Purpose

In cold climate operations, or as aircraft ascend to altitude even in tropical latitudes, the temperature of fuel in wing tanks and other tanks can drop well below freezing (0°C, 32°F). As fuel cools, roughly one part per million of dissolved water comes out of solution as free water for every 1°F of temperature drop. Certain aircraft without fuel system heaters require that FSII be properly blended into the fuel to prevent the free water from freezing in the fuel system, which could cause blockage of filters and fine passages by the formation of ice crystals.

NOTE

The following information on basic care in the handling and injection of FSII applies to both DiEGME (diethylene glycol monomethyl ether) additive and isopropanol (alcohol-type) additive, because they both are chemically aggressive and sensitive to water. This applies whether the additive is injected at the airport or at an off-airport fuel terminal.

NOTE

DiEGME and isopropanol are both permitted in avgas.

A.14.9.2 Precautions

a. DiEGME dissolves into fuel, but with difficulty. It must be finely dispersed into the fuel flow proportionally as fine droplets to get sufficient surface area to promote rapid dissolving of the additive into the fuel before droplets settle to the bottom. Injection should not be immediately upstream of any filter vessel. To prevent additive loss or filter damage, it is best to inject DiEGME upstream of some form of high-shear device (such as a control valve) or through an atomizing nozzle. FSII additive does not fully dissolve into fuel containing free water because part of it dissolves in the free water, so it is best to additize downstream of a filter separator or water-absorbing filter.

b. As stated, DiEGME does not fully dissolve in “wet fuel” (i.e., fuel containing free water) even with proper additive injection equipment. In fuel containing free water, the DiEGME will preferentially dissolve in the water, resulting in a lower than expected concentration of DiEGME in the fuel and water bottoms containing high DiEGME concentrations. Free water should be minimized upstream of DiEGME injection in the fuel system.

   NOTE

   The following instruction in basic care of handling FSII applies to both the DiEGME additive used in turbine fuel and the alcohol-type additives used in avgas fuels because they are both chemically aggressive and sensitive to water.

c. As free water drops out of FSII-treated fuels FSII concentrates in the water (up to about 60 % FSII/40 % water). This mixture has the solvency of paint remover and can damage filter separators and tank linings and can accelerate pipe and tank corrosion. (The use of FSII is incompatible with water-absorbing elements because FSII-water mixtures can dissolve water-absorbing media forming a viscous material known in the aviation industry as “APPL” or “apple” jelly or media migration.) The resulting FSII concentration in the fuel is decreased. Concentration of DiEGME-type FSII can be determined by ASTM D5006, but no simple field test has been developed to measure isopropanol-type FSII concentration in avgas.

d. It is important to prevent water and moist air from entering the FSII additive tank because water dissolves readily into the additive, which becomes FSII-saturated free water in the FSII-additized fuel with the same issues described previously. A desiccant vent device should be used in the air vent, or dry nitrogen can be added to prevent entrance of moist air to the FSII additive storage tank.

e. FSII, either by itself or mixed with water, can be corrosive to aluminum and degrade fiberglass tanks and epoxy-type tank linings. It should not be allowed to remain in tank bottoms, low points, or filter/separator sumps. In FSII-treated fuel, the water in the tank bottoms and sumps should be drained daily.

f. FSII should be stored in stainless steel or Teflon®-coated tanks because of its corrosive nature. Because laboratory testing shows that the long-term stability of DiEGME is questionable even in sealed containers, it is recommended that DiEGME stocks be rotated as frequently as possible. DiEGME should be fully retested for quality conformance at least annually.

g. Refer to the manufacturers’ MSDS information for safety precautions.

h. Water bottoms drained from tanks in cases in which the fuel contains FSII may be regarded as hazardous material and treated as such during water-bottom disposal.

A.14.10 BIOCIDE

A.14.10.1 Purpose

A biocide may be added to jet fuel in aircraft fuel tanks only on an as-needed basis to treat microbiological growth (commonly referred to as “bugs” or microbial growth). Biocides typically are used in cases in which aircraft tanks have been infested with microbiological growth. The only biocidal additives presently approved for use in aviation fuels are Biobor® JF and KATHON™ FP 1.5.

Treatment of fuel in storage tanks requires approval by the oil company and any airlines serviced.

A.14.10.2 Precautions

a. Refer to the manufacturers’ MSDS information for safety precautions.

b. In cases in which such an additive is used in the fuel, the approval status of the biocide and associated conditions must be checked for the specific aircraft and engine to be operated.
c. After treatment with a biocide, debris or "slime" may be released into the fuel system, possibly plugging filter elements.
d. Biocides can partition between fuel and water. Appropriate care should be taken in disposing of any water drains from a biocide-treated system.
e. Refer to the IATA *Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks*.

A.14.11 +100 ADDITIVE (JP-8 + 100) (PRESENTLY BEING DISCONTINUED BY THE USAF)

Several additives of this type are approved by different oil companies and aircraft and engine manufacturers, including GE Betz SPEC-AID 8Q462, AeroShell Performance Additive 101, and Turboline® FS100C.

A.14.11.1 Purpose

The +100 additive is added to JP-8 fuel to produce the JP-8 + 100-grade jet fuel (NATO F-37 jet fuel). The +100 additive increases the high-temperature performance of the jet fuel with the result that some high-performance engines run much cleaner and require significantly less maintenance than with JP-8. Benefits with +100 additive also are found with Jet A in certain helicopters in civilian application.

This additive is not yet fully approved for general usage in commercial aircraft. The additive is not compatible with some filtration because it can impact water coalescence.

A.14.11.2 Precautions

Fuel containing the +100 additive must be segregated from filtration systems designed to handle untreated fuel.

A.14.12 LEAK DETECTION ADDITIVE (TRACER "A")

A.14.12.1 Purpose

Leak detection additive is added on a one-time basis to fuel pipelines, storage, distribution, and aircraft-refueling hydrant systems to check for possible fuel leaks. Tracer "A" is a gaseous compound that rapidly dissolves into the fuel and vapor space of the tank. It has no effect on aviation fuel characteristics.

a. Refer to the manufacturer's MSDS information for safety precautions as well as environmental regulations regarding use of the additive.

A.15 Flushing New Aviation Fueling Hoses

When placing a new hose in service, or putting a hose back in service after a period of time out of service, it is important to properly clean and flush the hose to prevent contamination and to prevent manufacturing materials from reaching the aircraft.

A.15.1 PROCEDURE

The hose should be filled completely and then soaked in fuel for a minimum of 1 h, then fully drained. This fuel should be inspected visually for any color change or visible contamination. This procedure should be conducted at least two times and should be continued until a clean, clear sample is obtained. Dispose of soak fuel. Do not return soak fuel to the fuel system. After a successful soak, 500 gal of fuel should be recirculated to storage through the hose, and the nozzle strainer should be checked for signs of contamination or hose deterioration before fueling. Refer to EI-1529.

Section B | Particulate Detection

B.1 Filter Membrane Test—Colorimetric

B.1.1 INTRODUCTION AND PURPOSE

Particulate content is not included in the ASTM aviation fuel specifications. Rather it is expected to be part of any into-plane requirement. However, most equipment and airframe companies desire a particulate content of less than 0.5 mg/l at the skin of the aircraft. Filters remove the particulate contamination to below the desired limit.

Particulate contamination of aviation fuels may be indicated by passing a measured volume of fuel through a standard white filter membrane and evaluating the color of the membrane against a standardized color chart with numbers ranging from 0 for the lightest through 10 for the darkest. At the same time, the color can be evaluated for change with respect to previous tests. This test provides a standard means for communicating filter membrane colors.

Color change also can indicate nonparticulate contamination.

B.1.2 REFERENCES

ASTM D2276-06(2014)/API/IP-216, *Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling,* ASTM International, West Conshohocken, PA, 2014, www.astm.org

B.1.3 DESCRIPTION

The test is performed by withdrawing a fuel sample at a pressurized sampling point on a flowing system. The fuel sample is drawn through a filter membrane (and paper support pad) having a pore size rating of 0.8/micron (µm). Fuel contaminate is indicated by comparing the color and the intensity of the color of the filter membrane after fuel passage. It is sometimes desirable to simultaneously perform filter membrane tests on the inlet and outlet sampling points of various filtration equipment, storage tanks, or pipeline segments.

B.1.4 EQUIPMENT

Equipment is available from several commercial sources that are on file with ASTM. In the United States, known suppliers of kits and field monitors are Gammon Technical Products, Inc. (Manasquan, NJ) and Millipore Corp. (Bedford, MA).

The following equipment is required: field-sampling kit (Fig. 1); field monitors each containing one 37-mm diameter, 0.8-micrometer (micron) membrane backed by a 34-mm-diameter support pad; electrically bondable receiving container (graduated or known/proven capacity); and a color-rating booklet (ASTM D2276, Appendix X, and Fig. 2). Optional equipment includes the SGTP-3940 Color and Particle Assessment Rating Guide, available from Gammon Technical Products, Inc.

B.1.5 CAUTIONS

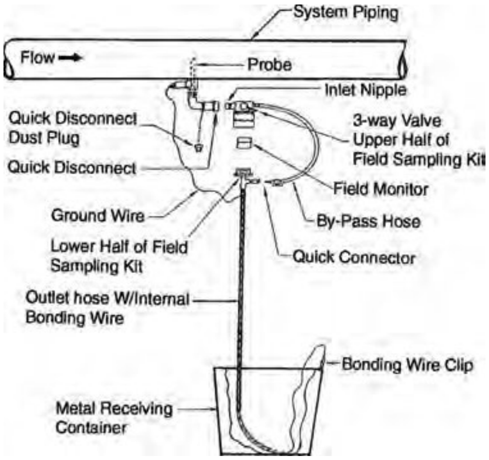
The sampling unit must be properly bonded to both the sampling connection and the measuring container to minimize the hazards of static-charged fuel in the container and static buildup on the apparatus. The test requires extreme care in sampling.

1. Failure to properly flush the field-sampling kit and the sample tap before testing can lead to erroneous results.
2. *Do not* operate valves in the system during the test.
3. Avoid starting and stopping pumps during the test.
4. Do not open the field monitor on-site after the test.
5. Be sure to measure the sample volume through the membrane accurately.
6. Removal of fuel remaining in the field monitor must be done with care to avoid damage to the test membranes. Damaged membranes are not acceptable for analysis.
7. Do not exceed 689 kPa (100 psi) unless you are using a special high-pressure housing.
8. Line flow rate in the main system should not be below 50 % of rated capacity.
9. When drying the membrane, locate it away from potential ignition sources.

B.1.6 EQUIPMENT PREPARATION

1. A permanently installed connection is strongly recommended at the sampling point and will include a quick disconnect that will accept the fitting on the inlet of the field-sampling kit. Components should be made of aluminum or stainless steel and the threaded connections sealed

FIG. 1 Typical test setup of a field-sampling kit.



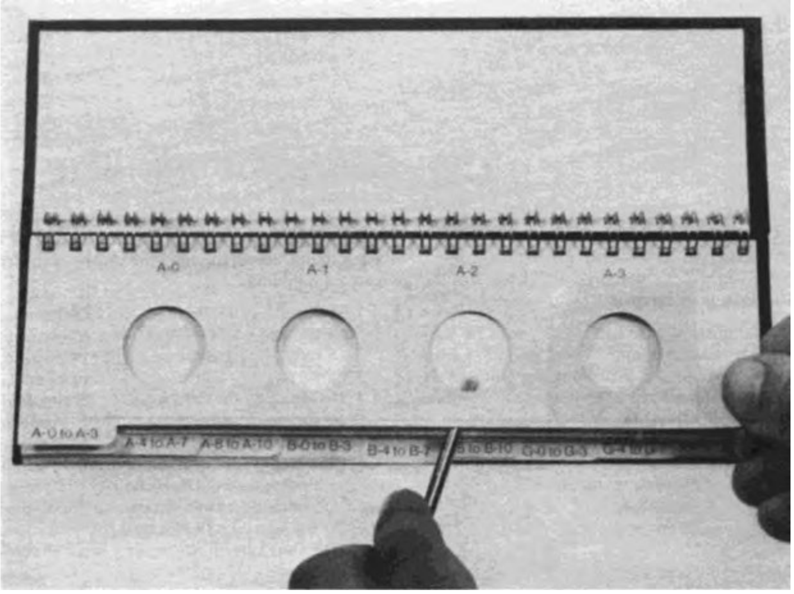
with Teflon® tape. A sampling probe projecting into the fuel stream will help prevent trapped particles in the pipe from influencing results. A dust plug should be installed in the quick disconnect between tests.

2. Check all equipment for contamination and clean as necessary.
3. Prepare the field monitor by installing a new support pad (with the rounded edge upward) in the recess having the molded spokes. Place an approved membrane on the support pad. Be sure to use tweezers when handling the pads to avoid contamination. Press the top half of the monitor into position to clamp the outer edge of the membrane. Install a blue dust plug at the inlet port and a red plug at the outlet port of the monitor until it is to be used.

B.1.7 TEST PROCEDURE

1. Separate the halves of the field-sampling kit housing.
2. Remove the dust plugs from the field monitor. Retain plugs in a clean area for reinstallation after test.
3. Place the field monitor in the lower section of the field-sampling kit with the inlet side up and the outlet (spoke side) down.
4. Reassemble the halves of the field-sampling kit housing. Make certain the connection is hand tight; extreme force is not necessary and is not desirable.
5. Place the three-way valve selector in the *off* position (or turn all valves off) and connect the bypass hose and the outlet hose.
6. Place the outlet hose in the receiving container. Connect the grounding wire from the field-sampling kit to the system piping and to the receiving container.
7. Remove the dust plug from the sampling quick disconnect on the main piping and connect the field-sampling kit.
8. Fuel should be flowing past the sampling point at a steady rate not less than 50 % of the highest normal flow rate of the system.
9. Open all valves on the sampling connection. Slowly turn the valve to the *flush* position.
10. Flush a minimum of 1 gal of fuel through the field-sampling kit (unless other means of flushing is provided). If the sampling connection is remote from the main system piping (e.g., a smaller sampling line extended some distance from the main line), the quantity flushed should be a minimum of ten times the sampling line volume.
11. Turn the valve to the *off* position.
12. Remove the field-sampling kit outlet hose from the receiving container. If the container is not large enough to hold the discharged fuel resulting from the following steps

FIG. 2 Color-rating booklet.



in the test procedure, empty the contents in an approved manner.

13. Place the field-sampling kit outlet hose into the empty receiving container.
14. Turn the valve to the *test* position.
15. Measure and record the exact volume of fuel collected. Unit of measure is the operator's choice. When possible, collect a minimum of 3.8 L (1 gal), but to facilitate comparison from earlier and repetitive tests, the volume should be approximately equal.
16. Turn the valve(s) to the *off* position.
17. To protect against electrostatic discharge, allow all equipment, including the receiving container and contents, to stand for a minimum of 1 min.
18. Disconnect the field-sampling kit inlet hose from the sampling quick disconnect and disconnect the bonding wire and bypass hose. Replace the dust plug in the sampling quick disconnect.
19. Turn the valve to the *flush* position and drain the residual fuel from the field-sampling kit into the receiving container.
20. Remove the outlet hose from the receiving container and empty contents in an approved manner.
21. Separate the halves of the field-sampling kit and remove the plastic monitor.
22. Remove remaining fuel from the plastic monitor using the suction device supplied with the field-sampling kit. Make certain that suction is applied gently and only to the outlet (spoke) side of the monitor to prevent damage to the filter membranes. *Do not open the plastic field monitor.*
23. Reinstall colored dust plugs in the field monitor.
24. Wipe the outside of the field monitor dry of fuel. Mark or segregate as needed for identification.
25. Wipe the field-sampling kit dry and store all components.
26. Open the monitor in a clean environment, remove the membrane, and dry it before rating its color. To raise the membrane from its cavity in the outlet half of the field monitor, gently push upward through the outlet hole against the support pad using a toothpick or other small diameter probe, enabling the membrane to be grasped with tweezers.
27. To dry the membrane for rating, proceed as follows: Remove the membrane from the monitor with tweezers. Dry the membrane by placing it carefully on an absorbent paper on a nonflammable heat source, such as a radiator, or by letting it air-dry for 3 h in a clean environment. Dryness can be estimated by comparing the white color of the outer portion of the test membrane with a new membrane.

    CAUTION
    Keep the drying membrane away from ignition sources.

28. If it is desired to rate the membrane while it is wet, immediately rate the membrane after removing it from the monitor.
29. Select the color that most closely matches the sample. In matching, be careful that the viewing angle is nearly perpendicular and that shadows are not cast unevenly on the surfaces being compared. Ratings should be done in a location shielded from direct sunlight.

B.1.8 TEST REPORT

1. Report the match by scale letter and rating number, such as B-1, G-3, A-4. If the shade is between two rating numbers, report the lower number. If the membrane color does not conform to any of the standard scales (A, B, or G), establish the shade to the nearest rating number and report the color.
2. Report the sample volume used.
3. If the sample was not taken under rated flow conditions, report the flow conditions and sampling pressures.
4. Report whether the membrane was rated wet or dry.
5. Report the test location and position in the system.

B.1.9 INTERPRETATION OF TEST RESULTS

The color ratings obtained in this test hold no technical significance; it is a comparative test. The most valuable use of this test is in comparison, based either on long-term experience at a location or on previous test results obtained on the same fuel by the supplier. Specifically, a darker color membrane or a membrane having a color that compares with a different color scale (A, B, or G) than usual are both indicators that contamination may have occurred in the fuel. Comparing these unusual test results with the supplier's test results may indicate that this batch of fuel is simply different from previous batches but is acceptable, or that the fuel has been contaminated somewhere in the transfer. Depending on the amount of difference, this could warrant additional testing to determine whether other fuel characteristics have been affected, such as MSEP and thermal stability.

In addition, if little or no improvement in dark membrane color is seen in tests conducted before and after a filter, this result indicates that the filter element has failed or is being bypassed, the dirt is too small for the filter to remove, or the color arises from color bodies, which are fuel soluble dye-like components.

When color bodies are suspected of causing the membrane color, this can be tested by placing two membranes "piggyback" in the same plastic monitor and performing the test in the standard manner. If both membranes have the same color after the test, this indicates that color bodies are in the fuel. A darker top membrane indicates that filterable contaminant is trapped by the top membrane. When the bottom membrane is dark, but not as dark as the top membrane, this indicates that both filterable contaminant and color bodies are present.

Wet color ratings may be of value to a trained observer familiar with local conditions. Only dry ratings should be reported, however, when color ratings are employed as a communications tool. Dry membranes appear lighter in color and have a lower color rating.

When evaluating a membrane for color, the reading reverts to the lower number of color. For example, a membrane color between an A2 and an A3 is reported as an A2.

Report any other change compared with previous tests. Such changes may be considered serious problems of cross-contamination with other liquid products.

Microscopic inspection of the membrane can provide additional information on contamination by, for example, rust, flakes, or sand.

B.2 Membrane Filtration—Gravimetric

B.2.1 INTRODUCTION AND PURPOSE

The purpose of this test is to determine the weight of particulate matter in jet fuel.

B.2.2 REFERENCES

ASTM D2276-06(2014)/IP-216, *Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling.* ASTM International, West Conshohocken, PA, 2014, www.astm.org

ASTM D5452-12, *Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration,* ASTM International, West Conshohocken, PA, 2012, www.astm.org

B.2.3 DESCRIPTION

Using a field-sampling kit, a measured volume of fuel is passed through a pair of matched weight filter membranes in a field monitor. The field monitor is then removed from the field-sampling kit and forwarded to a qualified laboratory for weighing.

B.2.4 EQUIPMENT

Equipment is available from a number of commercial sources that are on file with ASTM. In the United States, known suppliers are Gammon Technical Products, Inc., and Millipore Corp.

1. Field-sampling kit (Fig. 3).
2. Field monitor containing two matched weight filter membranes (37-mm diameter, 0.8/micron [μm]) plus support pad or backup pad (Fig. 4).
3. Receiving container (graduated or known/proven capacity, unless fuel is metered through the field-sampling kit).

FIG. 3 Typical test setup of a field-sampling kit.

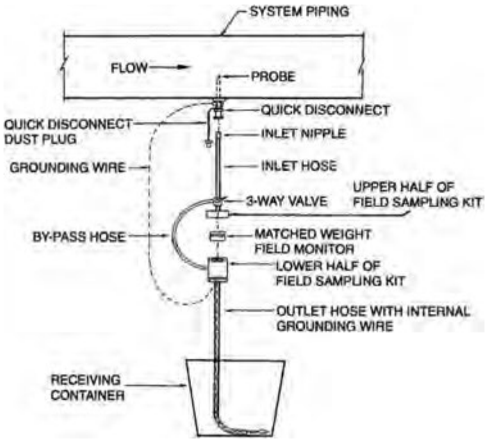
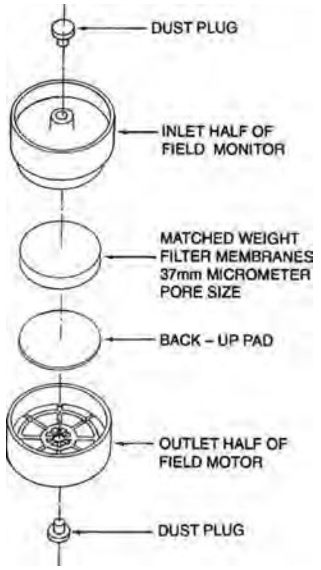


FIG. 4 Matched-weight field monitor (shown disassembled).



B.2.5 EQUIPMENT PREPARATION

1. Check the condition of the field-sampling kit for any contaminants, especially the inlet nipple and inside housing. If required, connect the sampling kit to a fuel source and thoroughly flush.
2. Check the sampling connection in the system piping at the point at which the sample is to be taken. If any visible contamination is present, wipe thoroughly with a clean cloth or paper towel.
3. Be sure the field monitor is the correct type and that protective dust plugs are in place. Do not use if plugs are missing.
4. If the field-sampling kit is not equipped with a three-way valve with *off*, *flush*, and *test* positions, connect to the sampling point in the system piping and perform the pretest flushing operation (Sec. B.2.6, step 10).

B.2.6 PROCEDURE

CAUTION

The operating pressure for this test must *not* exceed 689 kPa (100 psi), unless the high-pressure housing is used, in which case the pressure should not exceed 3,103 kPa (450 psi). The selector valve always should be turned *slowly* from one position to another. If the valve were turned rapidly, this could rupture the filter membrane.

1. Separate the halves of the field-sampling kit housing.
2. Remove dust plugs from the matched-weight field monitor. Retain in a clean area for reinstallation after the test.
3. Place the matched-weight field monitor in the lower section of the field-sampling kit housing with the inlet side up and the spoke side down.
4. Reassemble the halves of the field-sampling kit housing. Make certain the connection is hand tight; extreme force is not necessary and is not desirable.

5. Place the three-way valve selector in the *off* position and connect the bypass hose and the outlet hose.
6. Place the outlet hose in the receiving container. Connect the bonding wire from the field-sampling kit to the system piping and to the receiving container.
7. Remove the dust plug from the sampling quick disconnect and connect the field-sampling kit.
8. Fuel should be flowing past the sampling point at a steady rate not less than 50 % of the highest normal flow rate of the system.
9. Open all valves on the sampling connection. Slowly turn the valve to the *flush* position.
10. Flush a minimum of 2 L (0.5 gal) of fuel through the field-sampling kit (unless other means of flushing is provided). If the sampling connection is remote from the main system piping (e.g., a smaller sampling line extended some distance from the main line), the quantity flushed should be a minimum of ten times the sampling line volume.
11. Turn the valve to the *off* position.
12. Remove field-sampling kit outlet hose from the receiving container and empty the contents in an approved manner if the container is not large enough to hold the discharged fuel from the following steps in the test procedure.
13. Place the field-sampling kit outlet hose into the empty receiving container.
14. Turn the valve to the *test* position.
15. Measure and record the exact volume of fuel collected. Unit of measure is the operator's choice. When possible, collect a minimum of 3.8 L (1 gal).
16. Turn valve(s) to the *off* position.
17. To protect against electrostatic discharge, allow all equipment, including the receiving container and contents, to stand for a minimum of 1 min.
18. Disconnect the field-sampling kit inlet hose from the sampling quick disconnect and disconnect the bonding wire and bypass hose. Replace the dust plug in the sampling quick disconnect.
19. Turn the valve to the *flush* position and drain residual fuel from the field-sampling kit into the receiving container.
20. Remove the outlet hose from the receiving container and empty contents in an approved manner.
21. Separate the halves of the field-sampling kit and remove the plastic monitor.
22. Remove the remaining fuel from the plastic monitor using the suction device supplied with the field-sampling kit. Make certain that suction is applied gently and only to the outlet (spoke) side of the monitor to prevent damage to the filter membranes. *Do not open the plastic field monitor.*
23. Reinstall the colored dust plugs in the field monitor.
24. Wipe the outside of the field monitor dry of fuel.
25. Wipe the field-sampling kit dry and store all components.
26. Prepare an identification label or data sheet containing the following information: date, organization, facility, location, sampling point, and volume collected.

EXAMPLE

Date	7/1/16
Organization	ABC Fueling Company
Facility	XYZ Airport
Location	Tank Farm
Sampling point	Incoming receipt, Tank 1
Volume collected	1 U.S. gal

27. Forward the field monitor with the information in the previous example to a qualified laboratory for weighing according to ASTM D2276-06/IP216.

B.2.7 CAUTIONS

The test requires extreme care in sampling. Erroneous interpretations can result from failing to properly flush the field-sampling kit and the sample tap before sampling, operating the valves during the test, starting or stopping pumps during the test, opening the field monitor on-site, failing to promptly replace dust plugs in the field monitor, or failing to accurately measure the sample throughput. Removal of residual fuel from the field monitor must be done with care to avoid damage to the test membranes. Damaged membranes are not acceptable for analysis.

B.2.8 EVALUATING TEST RESULTS

Results in terms of mg/gal or mg/L will be reported by the qualified laboratory. Significance of the results reported depends on where the sample was taken. Some guidance material is offered as follows:

1. Test results from sampling points in airport storage systems may vary depending on facility features. For example, if storage tanks and piping are internally coated (e.g., epoxy) lower readings can be expected than those obtained from an uncoated system. In either case, test results should be compared with previous readings obtained from the same sampling point. A significant increase over previous readings requires investigation.
2. The test can be used to check the effectiveness of filtration equipment. In this case, samples are taken upstream and downstream of the filter at the same time, and the results should be compared. If the upstream sample result shows a substantial amount of contaminant, the downstream sample result should be significantly lower. In this case, no reduction in contaminant level indicates possible failure of the filtration equipment. If the upstream sample results show little or no contaminant, no valid conclusions regarding the effectiveness of the filtration equipment can be reached.

   Records of test results should be maintained for comparison with those of past and future tests performed at the same sampling point. Those records are vital to the operator in observing trends in contaminant level (Sec. B.3).
3. Also see Sec. B.1.9.

B.3 Membrane Filtration Records

B.3.1 INTRODUCTION AND PURPOSE

Establishing and maintaining a record of membrane filtration tests provides a history of normal and abnormal filter and fuel conditions.

B.3.2 REFERENCES

ASTM D2276-06(2014)/IP/EI-216, *Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling,* ASTM International, West Conshohocken, PA, 2014, www.astm.org

B.3.3 DESCRIPTION

Filter membranes used for color ratings or records of membrane weights should be retained in local files for at least 1 year. Membrane records should indicate, at a minimum, the following: (1) sampling point, (2) date of test, (3) sample volume, and (4) dry color rating (or weight).

The membrane records also may include the following fuel system information, as applicable: (1) wet color rating, (2) length of sampling time, (3) line pressure, (4) differential pressure across the filter and the type of filter, (5) flow rate, (6) throughput, and (7) element change date.

Filing membrane records may be by individual sampling points or any other convenient, orderly method.

B.3.4 CAUTIONS

Filter membranes should be filed in protective transparent plastic bags or sheets to prevent color changes resulting from dust or mishandling. Prolonged exposure to strong light can cause color fading.

Section C | Water Detection

C.1 Shell Water Detector

C.1.1 INTRODUCTION AND USE

The Shell water detector determines low levels of suspended (undissolved) water in jet fuels.

C.1.2 REFERENCES

There is no known published test standard on this subject.

C.1.3 DESCRIPTION

A sample of jet fuel is drawn by syringe through a capsule fitted with a disk of water-sensitive paper. The paper changes color if suspended water is present.

C.1.4 EQUIPMENT

1. A standard calibrated polyethylene or nylon syringe of 5-mL capacity, with a record-type (thin blunt tube) end fitting. A 10-mL sample may be taken to obtain a more sensitive reading.
2. A disposable Shell water detector capsule containing a disk of filter paper treated with water-sensitive chemicals. The detector capsules are available, in the United States, from Gammon Technical Products, Inc., PO Box 400, Manasquan, NJ, 08736 (Tel: 908-223-4600) and their distributors in the United Kingdom, A. Searle & Company, 24 Bourne Industrial Park, Bourne Rd., Crayford, UK, DA1 4B2 (Tel: +44(6)1322 5919).
3. Clean, dry sample container, for example, 100-mL beaker.

C.1.5 PROCEDURE (FIG. 1)

1. Collect a fuel sample in the sample container.
2. Examine the detector capsule to confirm that the paper is a uniform yellow color. If not, the capsule should be replaced from a fresh supply.
3. Fit the capsule to a clean syringe and immerse it into the fuel sample.
4. Slowly withdraw the syringe plunger until the fuel sample reaches the 5-mL mark.
5. Examine the paper disk in the capsule for any difference in color between the inner wetted portion and the outer portion that is protected by the plastic molding.

C.1.6 CAUTIONS

1. The response of Shell water detector capsules to suspended water tends to deteriorate after approximately 9 months. Thus, allowing for shipping time, it is suggested that only a 6-month supply be ordered at any time. The expiration date (month/year) is marked on the bottom of each tube of capsules and also on one end of each box of the tubes.
2. It is important that the capsule container be closed and sealed immediately after removal of the test capsule to prevent discoloration of the remaining capsules resulting from moisture in the air. Unused capsules should not be carried outside of the container.
3. Capsules shall be used only once.

C.1.7 INTERPRETATION OF TEST RESULTS

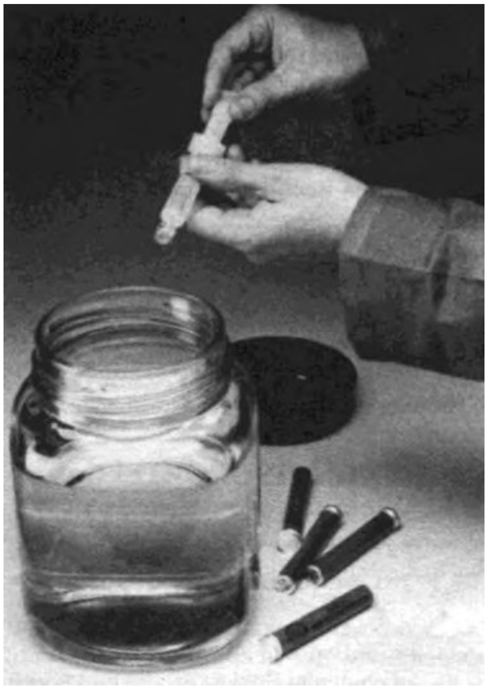
The presence of suspended water is indicated by a change in color of the inner wetted portion of the paper disk. The resulting color change becomes progressively more evident with increasing suspended water content until at approximately 30 ppm (or 20 ppm for a 10-mL sample) a distinct green color is obtained. At low water contamination levels, a yellow-green color is obtained, changing to blue-green and finally blue-black at very high water contamination levels.

C.2 Velcon Hydrokit®

C.2.1 INTRODUCTION AND PURPOSE

The Velcon Hydrokit® is a simple test for suspended water in commercial jet fuel. It indicates the presence of more than 15 or 30 ppm by volume of suspended water (two sensitivity levels are available) by a change in color of water sensitive powder in a sample tube. It is used principally as a final water check at the aircraft refueling point. It may be used for quick checks of suspended water anywhere in the delivery system.

FIG. 1 A 5-mL syringe and detector capsule. (Reprinted courtesy of Shell International Trading Co., London, England.)



C.2.2 REFERENCES

There is no known published standard for this test.

C.2.3 DESCRIPTION

The sample of jet fuel is drawn by vacuum into a stoppered test tube where the fuel contacts the Hydrokit® powder. The color change of the powder is compared with a standard color card for a pass or fail decision—that is, whether the sample contains more or less than 15/30 ppm of suspended water.

C.2.4 EQUIPMENT

Hydrokit® consists of a small evacuated test tube containing sufficient water-sensitive powder to react with 10 mL of fuel. Both a reusable fuel sample bottle and needle assembly (to puncture the rubber stopper) are included to obtain the fuel sample.

For availability of Hydrokit®, address inquiries to Velcon Filters, Inc., 1210 Garden of the Gods Rd., Colorado Springs, CO 80907 (Telephone: 719-531-5855) or its distributors.

C.2.5 PROCEDURE (FIG. 2)

1. Inspect the sample bottle to ensure that it is clean and dry.
2. Fill the bottle about half full with fuel directly from the fueling unit (downstream of filter/separator or at fueling nozzle). Make sure no moisture gets into the bottle.
3. Insert the plastic needle holder into the sample bottle immediately.
4. Insert the glass Hydrokit® tube with stopper down into the needle holder assembly. Press the tube firmly onto the needle, forcing the needle through the stopper. Hold the tube until the fuel flow stops. When the tube is held vertically with the stopper on top, fuel should reach a point above the black line on the tube.
5. Remove the tube from the needle assembly. Shake vigorously for 15 s. Allow to settle 2 min and compare the powder color to the color standard.

C.2.6 CAUTIONS

If the fuel does not enter the tube or if the fuel level in the tube does not reach the level noted in procedures, the tube has leaked (lost vacuum) and should be discarded. Repeat the test on a new fuel sample with a new Hydrokit® tube.

Do not use tubes beyond the expiration time stamped on the box.

C.2.7 INTERPRETATION AND LIMITATIONS OF RESULTS

Compare the Hydrokit® powder with the color standard immediately after the 2-min settling time. A pink color as dark or darker than the "fail" standard indicates more than 15/30 ppm suspended water in the fuel. Delivery of fuel should be stopped to determine the source of the excess suspended water. If the Hydrokit® powder is lighter than the "fail" color standard, the fuel has less than 15/30 ppm suspended water. The results showing less than 15 ppm or less than 30 ppm of water depend on which Hydrokit® is being used

The comparison with the color standard must be made at 2 min after shaking the sample. Powder in the fuel gradually will darken with time; thus, color comparison after extended time is not valid. If the result is doubtful, repeat with a new tube and fuel sample.

C.3 Gammon Aqua-Glo® Water Detection Test and the Digital Aqua-Glo®, Hydro-Light Pad Reader

C.3.1 INTRODUCTION AND PURPOSE

The undissolved water content (in ppm) of turbine fuel can be measured accurately using the Gammon Aqua-Glo® Water Detection Test and Digital Aqua-Glo® Hydro-Light Pad Reader. One of its primary uses is to monitor the performance of devices designed to remove water from turbine fuels, for example, filter/separators. It also may be used to measure the undissolved water content of fuel anywhere in the distribution system.

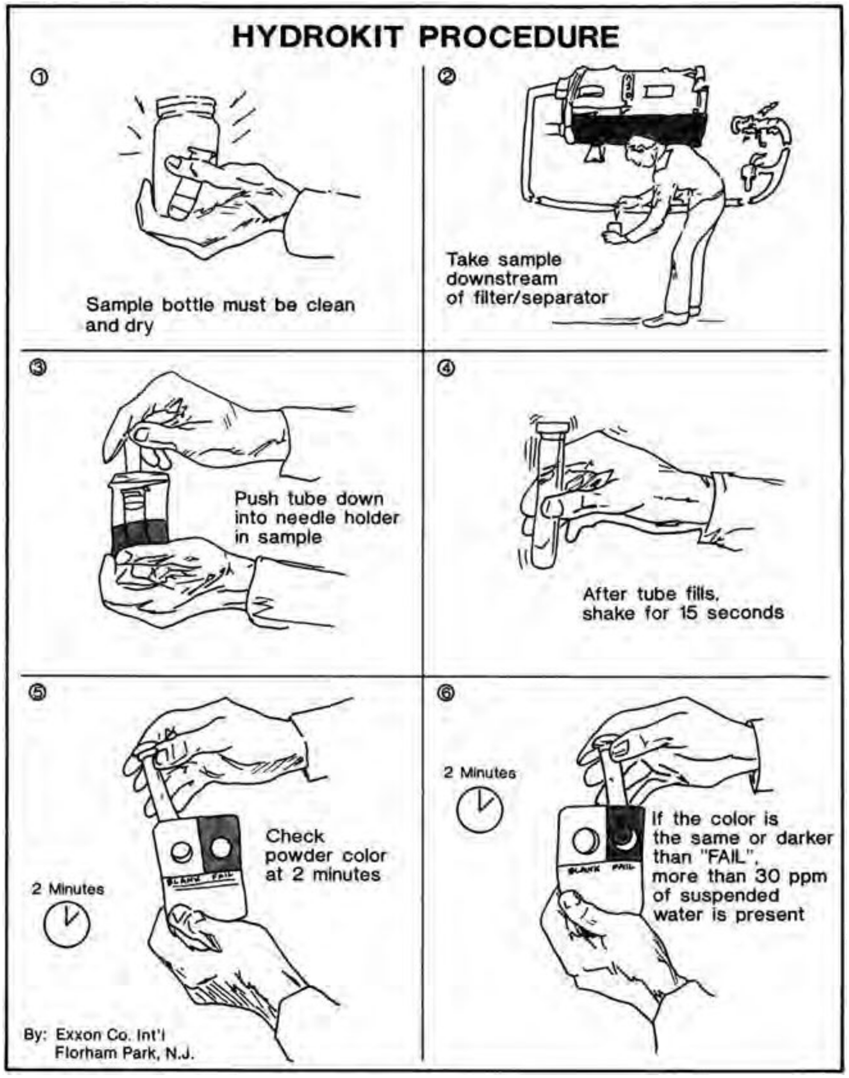
C.3.2 REFERENCES

ASTM D3240-15, *Standard Test Method for Undissolved Water in Aviation Turbine Fuels*, ASTM International, West Conshohocken, PA, 2015, www.astm.org

C.3.3 DESCRIPTION

1. A 500-mL sample of fuel from a flowing fuel line is drawn directly through the detector pad at a quick-disconnect fitting.

FIG. 2 Hydrokit® procedure. (Reprinted courtesy of Exxon Mobil.)



2. Undissolved (free) water in the fuel will react with the chemical on the test pad. When the pad is subsequently illuminated by ultraviolet light, the coating will glow a bright yellow-green if any water was in the fuel sample. The brightness increases with larger amounts of free water in the fuel. The ultraviolet light illuminated pad is compared with a known standard, called the fluorescing standard, using a photocell comparator. The free water in the fuel sample is indicated in ppm by volume. The test covers a range from 0 to 12 ppm of water. The upper limit can be increased to 60 ppm by decreasing the sample size to 100 mL.

C.3.4 CAUTIONS

1. The fuel sample must be drawn from the flowing fuel system directly through the test pad. Large errors may result if fuel is first collected in a sample container and then tested.
2. Sample lines should be as short as possible. Sampling connections that are so long that temperature differences exist between collected fuel and fuel in the system will cause errors. Temperature has a substantial influence on dissolved water in jet fuel. As a rule, 1 ppm of water will come out of solution for every 1°F (0.55°C) reduction in temperature. Typical jet fuel can hold about 70 ppm of water in solution at 70°F (21°C). If the sample of this fuel is cooled to 60°F (15.5°C), the dissolved water content is decreased to 60 ppm and the free water content is increased by 10 ppm.
3. Do not expose the water detector pad to the atmosphere until just before use. Humidity or water droplets on the pad will cause errors.
4. Never touch the pad; use tweezers.
5. Never use the fluorescing standard or calibrating standard from one instrument in another instrument because they must be matched at the factory.

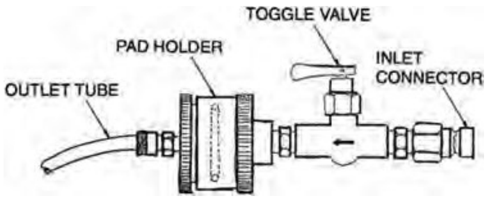
C.3.5 EQUIPMENT

1. Aqua-Glo® Series II, III, or V Water Detector Kit, Model GTP-322 (or GTP-323), the Digital AquaGlo® or the Hydro Lite is required for this procedure. There is no difference in the water-measuring components of Series II, III, or V kits. The Series III has an improved ultraviolet light source, and the Series V has an improved power supply and is more field repairable.
2. Water Detector Pad (25-mm diameter), Model GTP-25. Apparatus is available from Gammon Technical Products, Inc., PO Box 400, Manasquan, NJ 08736.

C.3.5.1 Equipment Preparation

1. Check the condition of the water detector pad holder, especially the inlet nipple and inside of holder, for any dirt or water. If required, connect the assembly to a fuel source and thoroughly flush (Fig. 3).
2. Check the sampling connection in the system piping where the sample is to be taken. If any visible dirt or water is present, wipe thoroughly with a clean cloth or paper towel.
3. Calibrate the analog Aqua-Glo® instrument (digital instruments do not require separate calibration). The calibrating standard that corresponds to a given undissolved water content is placed in the test-pad window. Turn on the lamp. The ultraviolet light can be checked by moving the light-adjusting lever from one extreme to another. The photocell comparator meter needle should swing widely when this is done. Null the photocell comparator by slowly moving the light-adjusting lever until there is a steady reading at zero. *Always move the light-adjusting lever in the same direction when zeroing the photocell comparator during calibration or testing to eliminate errors caused by play in the lever mechanism.* If the reading obtained does not agree with the calibrating standard rating, adjust the photocell comparator. Remove the plug screw on the side of the comparator at the 45° bend. Insert a small screwdriver and adjust as necessary. Repeat the previous procedure until the reading obtained agrees with the calibrating standard rating. The instrument calibration should be checked frequently enough to ensure accuracy (see manufacturer's instructions). When the calibration check is completed, turn off the lamp. The calibrating standard is matched to each specific Aqua-Glo® instrument and should not be used on a different instrument.
4. If the meter is slow to respond, remove the four screws on the battery cover plate located on the instrument pack and replace the 9V transistor battery.

FIG. 3 Test setup for a water detector pad holder.



C.3.6 PROCEDURE

1. Connect the empty pad holder assembly to the sampling quick-disconnect and flush at least 1 gal (3.78 L) through the assembly.
2. Disconnect and separate the halves of the pad holder.
3. Carefully tear open the protective envelope and remove the water detector pad with the tweezers supplied in the kit. *Do not touch the pad with your finger.* If the pad is orange, it is suitable for the test. If it is yellow, it has spoiled and should not be used because an excessively high water content will be indicated.

NOTE
Do not remove the test pad from the hermetically sealed package until ready for use. Do not allow any water droplets to come into contact with the pad (from rain, sneezing, coughing, and so forth). Exposure of the test pad to the atmosphere, especially on humid days, will ruin the pad in a matter of minutes.

4. Place the water detector pad (orange side up) in the recess of the outlet half of the pad holder. Use the thumbnail of the other hand to hold it in place as the tweezers are released (Fig. 4).
5. Reassemble the pad holder; hand tighten to prevent bypassing.
6. Turn the toggle valve to the closed position.
7. Connect the pad holder assembly to the sampling quick-disconnect.
8. Place outlet hose in the calibrated bottle that is provided in the kit.
9. Open the toggle valve and any in-line valves.
10. Collect 500 mL of fuel in the calibrated bottle and close the toggle valve. Dispose of this fuel in an approved manner.

NOTE
A flow rate of 600–800 mL/min is recommended for greatest accuracy (about 45 s for 500 mL). To prevent higher flow rates, a throttling valve should be installed in the sampling connection.

11. Close any in-line valves. Disconnect the pad holder assembly from the sampling quick-disconnect and separate the two halves of the pad holder. If the toggle valve is opened and the two halves then are separated, the water detector pad is less likely to stay in the inlet half.
12. Remove the water detector pad with tweezers and press between clean dry paper towels to remove excess fuel.

FIG. 4 Proper placement of the water detector pad in the pad holder.

A suitable procedure is to press firmly three or four times using the heel of the hand, moving the pad with tweezers each time.

NOTE
For maximum accuracy, the test pad should be read within 3 min.

13. Using tweezers, place the pad under the test-pad flap of the comparator chamber. The coated side must face the hole in the chamber. Turn on the lamp. While pressing the photocell button, null the photocell comparator by slowly moving the light-adjusting lever until there is a steady reading at zero. Always move the light-adjusting lever in the same direction when zeroing the photocell comparator to eliminate errors caused by play in the lever mechanism. Turn off the instrument light immediately after use to conserve battery power.
14. Record the ppm as indicated by the lever position on the scale. Also record the sample volume.
15. Wipe the test-pad holder dry of fuel and replace it in the carrying case.

C.3.6.1 Digital Aqua-Glo® and Hydro-Light Pad Readers

The Hydro-Light Pad can also be read by the Digital Aqua-Glo® or the Hydro-Light Pad Reader. See the individual manufacturer's instructions on the operation of the reader.

C.3.7 EVALUATION OF TEST RESULTS

If conditions do not permit collecting 500 mL, or if readings higher than 12 ppm are expected, accurate results can be obtained for any volume of fuel between 100 and 500 mL by correcting the reading using the following equation:

Free water, ppm = [(scale reading in ppm) × 500 sample volume in mL]/reduced test volume size in mL.

For example, if it was impossible to "zero" (center) the analog meter using a 500-mL sample, or the digital pad reader's reading is over 12 ppm, repeat the test with a new water detector pad and a smaller sample volume, such as 100 mL. This results in a range of 60 ppm. If the sample volume is 250 mL, the range is 2–24 ppm.

If the water content exceeds 12 ppm, it will be impossible to zero the analog meter and the digital pad readers will not be accurate over 12 ppm because higher volumes of water will not cause a regular progressive increase in the reaction on the pad. To measure up to 60 ppm, repeat the complete test using a new water detector pad, but take a sample volume of only 100 mL, and use the previous equation.

C.4 CASRI Water Detector

C.4.1 INTRODUCTION AND USE

The CASRI water detector determines low levels of suspended (undissolved) water in jet fuels.

C.4.2 REFERENCES

There is no known published test standard on this subject.

C.4.3 DESCRIPTION

A sample of jet fuel is drawn by syringe through a capsule fitted with a disk of water-sensitive paper. The paper changes color if suspended water is present.

C.4.4 EQUIPMENT

1. A standard calibrated polyethylene or nylon syringe of 5-mL capacity, with a record-type (thin blunt tube) end fitting.
2. A disposable CASRI water detector capsule containing a disk of filter paper treated with water-sensitive chemicals.
3. A clean dry sample container, for example, 100-mL beaker.

C.4.5 PROCEDURE

1. Collect a fuel sample in the sample container.
2. Examine the detector capsule to confirm that the paper is a uniform yellow color. If not, the capsule should be replaced from a fresh supply.
3. Fit the capsule firmly to a clean syringe and immerse it into the fuel sample.
4. Slowly withdraw the syringe plunger until the fuel sample reaches the 5-mL mark.
5. Immediately examine the paper disk in the capsule for any difference in color between the inner wetted portion and the outer portion that is protected by the plastic molding.

C.4.6 CAUTIONS

1. It is important that the capsule container be closed and sealed immediately after removal of the test capsule to prevent discoloration of the remaining capsules by moisture in the air. Unused capsules should not be carried outside of the container.
2. Capsules shall be used only once.

C.4.7 INTERPRETATION OF TEST RESULTS

1. When the suspended water content ranges from 5 ppm to 10 ppm, the color of the center is greenish-yellow or some dispersed greenish-yellow spots appear on the center position.
2. When the suspended water content is about 15 ppm, the color of the center is yellowish-green or many dispersed yellowish-green spots appear on the center portion
3. When the suspended water content is about 30 ppm, the color of the center changes to green markedly or many dispersed green spots appear on the center portion.
4. When the suspended water content is more than 30 ppm, with increasing water content, the color of the center can change to blue-green, blue, or blue-black (the color of the center portion changes color entirely).
5. With increasing water content, the colors of the center can change to greenish-yellow, yellowish-green, green, and blue-green or blue-black. A chart is available from the manufacturer for reading the range of readings, but the amount of color change does not exactly correlate to the water content. This test only offers a visual check.

C.5 Aquadis® Water Microdetector

C.5.1 INTRODUCTION

The Aquadis® Water Microdetector is a laboratory and field test device manufactured by Kaveri Baag, Mumbai, India (www.kaveribaag.com) and used to determine the presence of finely dispersed undissolved or suspended water in aviation turbine fuels in concentrations lower than those normally detectable by water-finding paste or by visual examination.

The use of this equipment enables aviation-fueling personnel to determine whether the suspended water content of fuel delivered to aircraft is below the limit of 15/30 ppm as a go, no-go test.

C.5.2 REFERENCES

There is no known published test standard on this subject.

C.5.3 DESCRIPTION

Consists of a two-piece transparent gelatin capsule containing a grayish-white water-sensitive powder and a clear glass stoppered sampling tube of 10 mL capacity.

C.5.4 EQUIPMENT

1. Gelatin capsule and glass jar.
2. Kaveri Baag Corp., Mumbai, India, +91 22 25 78 29 12, info@kaveribaag.com, http://www.kaveribaag.com/microdetector-suspended-free-water.php

C.5.5 PROCEDURE

1. Draw 10 mL fuel into glass sampling tube, making sure tube is clean and dry.
2. Check that there is no discoloration of the capsule.
3. Empty the contents of one capsule into the sample, close stopper, and shake the sampling jar for 5 s.
4. Stand sample for 0.5 min (30 s).

C.5.6 CAUTIONS

1. Do not allow any cross-contamination or temperature change to take place between sample taking and testing. Do the test immediately. Color blind personnel should not evaluate the results.

C.5.7 INTERPRETATION OF TEST RESULTS

1. White or gray results ensure less than 15 ppm.
2. Faintly pink results indicate between 10 and 15 ppm, or more.
3. Bright pink results indicate 30 ppm or more.
4. Ensure that the sample contains free water at 15 ppm or more. The intensity of the pink color increases with the rise in suspended water content.

C.6 POZ-T Water Detector

C.6.1 INTRODUCTION

The POZ-T Water Detector test is designed to determine the presence of water in aviation fuel (jet fuel and aviation gasoline) that is invisible by naked-eye emulsion of water.

C.6.2 REFERENCES

There is no known published test standard on this subject.

C.6.3 DESCRIPTION

The method is based on color change of the indicator element when it is in contact with water emulsion in aviation fuel. The number appears on a yellow layer of the indicator stamps (from cyan to blue) and the staining intensity indicates the water content of the emulsion. The appearance of dark spots on a white layer of the indicator and the degree of darkening indicates the presence of other contaminations.

C.6.4 EQUIPMENT

1. Sampling holding container—flask of colorless, transparent, thick-walled glass with a wide mouth with a capacity of 500–100 cm^3.
2. The POZ-T device consists of a syringe dispenser with an indicator showing the open or closed position of the sensor.
3. Quality indicator fuel (IKT) made of two rectangular pieces of analytical tape stacked in two layers and fastened together along one edge.
4. Detector made with white construction paper and protected from contamination with a film.

C.6.5 PROCEDURE

1. The test should be carried out under conditions that preclude contamination of the sample fuel precipitation and dust. Before the test, the device is flushed by passing fuel through it containing no water and contaminations, in accordance with the manufacturer's operating instructions.
2. The POZ-T device is set to the *open* position with the IKT toward the inlet closing the lever.
3. A pretest can be done with fuel that is free of water and contamination by submerging the indicator in fuel and within 7–10 s providing suction by drawing back on the syringe. After fuel passes through, keep the indicator submerged in fuel for 2–3 s. At temperatures −0°C, increase the duration by 5 s for every 10°C. For example, when the fuel temperature is −30°C, the duration should be 3 s + 15 s = 18 s.
4. Taking the POZ-T from the fuel, remove the indicator from the sensor. The test fuel is removed from the syringe by pressing on the piston rod.
5. In the event of a negative result, the analysis can be repeated with a new IKT.
6. Fuel containing visible water, ice, or low-temperature solid contaminations is not recommended for evaluation by this device to avoid contamination of the sensor-calibrated holes.

C.6.6 CAUTIONS

Do not allow any cross-contamination or temperature change to take place between sample taking and testing. Do the test immediately.

C.6.7 EVALUATION AND INTERPRETATION OF RESULTS

The presence of a reaction water in fuel is determined as follows (see manufacturer's instructions for a chart).

On the second (yellow) layer of the IKT:

1. No reaction means no water.
2. One mark is slight water.
3. Two marks or two blue marks and a third light mark is considered a caution level. Three marks is a fail or rejection.

The POZ-T also detects solid contaminants. These will be seen on the first layer of the IKT as dark gray or brown spots.

C.7 YPF Water Detector

C.7.1 INTRODUCTION AND USE

The YPF water detector determines low levels of suspended (undissolved) water in jet fuels.

C.7.2 REFERENCES

There is no known published test standard on this subject.

C.7.3 DESCRIPTION

A sample of jet fuel is drawn by syringe through a capsule fitted with a disk of water-sensitive paper. The paper changes color if suspended water is present.

C.7.4 EQUIPMENT

1. A standard, calibrated polyethylene or nylon syringe of 5-mL capacity, with a record-type (thin blunt tube) end fitting. A 10-mL sample may be taken to obtain a more sensitive reading.
2. A disposable YPF water detector capsule containing a disk of filter paper treated with water-sensitive chemicals.
3. Clean, dry sample container, for example, 100-mL beaker.

C.7.5 PROCEDURE (FIG. 1)

1. Collect a fuel sample in the sample container.
2. Examine the detector capsule to confirm that the paper is a uniform yellow color. If not, the capsule should be replaced from a fresh supply.
3. Fit the capsule to a clean syringe and immerse it into the fuel sample.
4. Slowly withdraw the syringe plunger until the fuel sample reaches the 20-mL mark.
5. Examine the paper disk in the capsule for any difference in color between the inner wetted portion and the outer portion that is protected by the plastic molding.

C.7.6 CAUTIONS

1. Be sure the capsule is not spoiled or past its expiry date.
2. It is important that the capsule container be closed and sealed immediately after removal of the test capsule to prevent discoloration of the remaining capsules by moisture in the air. Unused capsules should not be carried outside of the container.
3. Capsules shall be used only once.

C.7.7 INTERPRETATION OF TEST RESULTS

The presence of suspended water is indicated by a change in color of the inner wetted portion of the paper disk. The resulting color change becomes progressively more evident with increasing suspended water content until approximately 30 ppm. Blue-black indication shows very high water contamination levels.

C.8 Water Detection Paste

C.8.1 INTRODUCTION AND PURPOSE

Water detection pastes are used to determine the depth of water at the bottom of a storage tank. Water detection pastes do not respond to suspended or dissolved water in fuels. Many pastes do not detect water-alcohol mixtures.

Standard water paste does not detect water if a significant amount of DiEGME (an anti-icing additive, such as FSII or Prist®) is present. Special modified water-finding paste is available for use in fuels containing this type of additive. Prist® is a registered trademark of Prist Aerospace Products, Inc., a division of CSD Inc.

C.8.2 REFERENCES

API, Chapter 3, Section 1A, "Standard Practice for the Manual Gauging of Petroleum and Petroleum Products," *Manual o f Petroleum Measurement Standards*, American Petroleum Institute, Washington, DC, 2002, p. 28.

C.8.3 DESCRIPTION

A water-reactive paste is applied to a gage tape or stick to determine the fuel-water interface. The paste will change color if it contacts water.

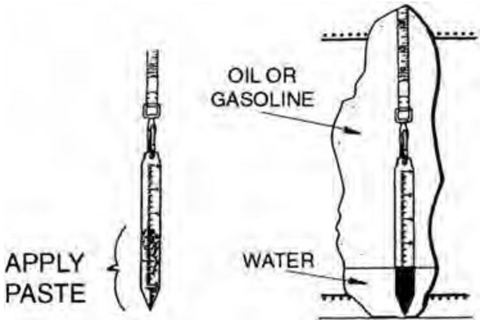
C.8.4 EQUIPMENT

A calibrated stick or gage tape of sufficient length to reach from the gage hatch to the tank bottom, along with water detection paste is required for this procedure.

C.8.5 PROCEDURE

1. Apply a thin coating of water-detection paste to the gage several inches above and below the suspected interface level (Fig. 5).
2. Carefully lower the gage or stick through the fuel (in a vertical plane) until it lightly touches the tank bottom. Hold it in this position for a minimum of 10 s at a low point or sump bottom.
3. Remove the gage and observe the color difference in the paste. The water level will be indicated clearly by

FIG. 5 Application of water detection paste.



a definite color change where the water contacts the paste.

C.8.6 CAUTIONS

1. Avoid rapid lowering of the gage tape through the product to prevent tilting of the plumb bob that could result in inaccurate readings.
2. Maintain tape contact with the gage hatch to prevent static charges.
3. Periodically check the reactivity of the paste.

C.8.7 INTERPRETATION OF TEST RESULTS

The water depth is indicated by a color change of the paste. The volume can be calculated using tank or vessel tables.

Section D | Filtration Equipment

D.1 Filtration Equipment—General

D.1.1 INTRODUCTION AND PURPOSE

This section describes filter vessels and filter element media that may be used at aviation fuel-handling facilities. This topic is sufficiently complex that only the highlights can be considered herein. Taking inspiration from this ASTM Manual 5, the Energy Institute recently published a new guidance document (EI 1550) to communicate to the typical user many of the issues that should be appreciated in using fuel filters for the supply of aviation fuel.

D.1.2 REFERENCES

API/IP/EI 1582, *Specification for Similarity for EI 1581, Aviation Jet Fuel Filter Separators*, Energy Institute, London, www.energyinst.org

EI 1550, *Handbook on Equipment Used for the Maintenance and Delivery of Clean Aviation Fuel*, Energy Institute, London, www.energyinst.org

EI 1581, *Specification and Qualification Procedures for Aviation Jet Fuel Filter Separators*, Energy Institute, London, www.energyinst.org

EI 1583, *Specifications and Qualification Procedures for Aviation Fuel Filter Monitors with Absorbent Type Elements* Energy Institute, London, www.energyinst.org

EI 1590, *Specifications and Qualification Procedures for Aviation Fuel Microfilters*, Energy Institute, London, www.energyinst.org

EI/JIG 1530, *Quality Assurance Requirements for the Manufacture, Storage and Distribution of Aviation Fuel to Airports,* Energy Institute, London, www.energyinst.org

MIL-PRF-81380E, *Performance Specification: Filter/Monitor, Contamination, Aviation Fuel Dispensing System,* Military Performance Specification, 2005.

D.1.3 DESCRIPTION

D.1.3.1 Filter/Separator Vessels

Filter/separators are used to remove solids and water from fuel. In the simplest case, they contain two types of elements: coalescers (first stage) and separators (second stage). Flow is normally from inside to outside through the coalescers, and outside to inside through the separators. Fig. 1 shows a typical vertical filter/separator vessel. The arrows show the direction of fuel movement through the elements.

a. *Coalescers.* Coalescer elements combine extremely small water droplets into large drops that fall by gravity into the vessel sump. On the outside of each coalescer is a "sock" (knitted cotton or synthetic material) that assists in coalescing the water drops. Solid particles are also filtered from the fuel by the coalescer. Coalescer elements are usually either all fiberglass or are a combination of pleated paper and fiberglass. In the combination fiberglass and pleated paper/microfiberglass coalescers, the pleated section on the inside of the element filters solids before the fuel reaches the fiberglass. The pleated section protects the fiberglass so that it can coalesce water better because solids entrapment eventually will degrade fiberglass coalescing performance.

b. *Separators.* Separator elements are made from water repellent (hydrophobic) media that allow fuel to pass but that block the passage of previously coalesced water drops. Separators normally are made with a Teflon®-coated screen (TCS), a synthetic screen or silicone-treated paper in pleated or cylindrical form. Following are descriptions of the various types of separators:
   - *TCS Separators.* The element is typically 100 or 200 mesh stainless steel or Monel wire screen that is coated with Teflon® material. These separators, with proper handling and cleaning, can be reused (see Sec. D.4).
   - *Synthetic Separators.* The media in these elements is synthetic mesh material with chemically bonded hydrophobic treatment. These separators, with proper handling and cleaning like the TCS separators, can be reused (see Sec. D.4).

D.1.3.2 Particulate Filter Vessels

Particulate filters (sometimes called micronic filters or prefilters) remove solid particles from the fuel. These vessels are not designed to remove water. Typical elements for these units are the pleated

FIG. 1 Vertical filter/separator vessel.

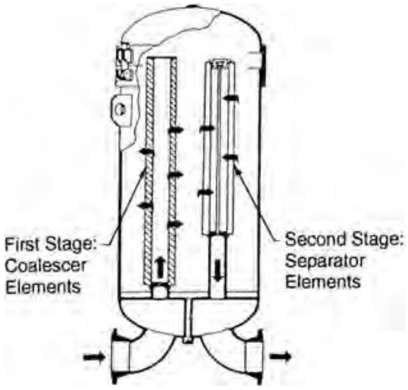
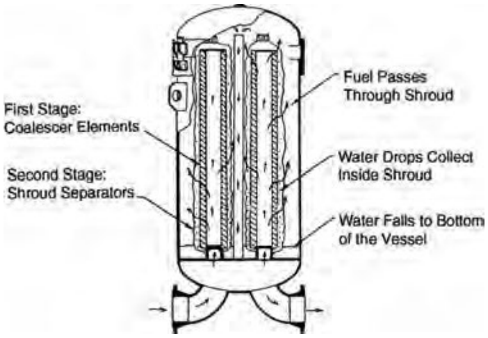


FIG. 2 Filter/separator vessel with shrouds.



paper type and are designated in terms of micron rating. The micron ratings indicate that a vast majority of particles larger than the rating will be removed. Micron ratings of filter elements are not determined by all manufacturers based on the same criteria. For this reason, EI 1590 was developed to provide a consistent basis for measuring and specifying the micron ratings of aviation fuel particulate filters. Several micron ratings are available, but the typical elements used for aviation fuel are 5/micron (µm) or less. Pleated paper provides more surface area in the elements for longer service life. Particulate filters function primarily to extend the service life of coalescers in filter/separators installed downstream of the particulate filters.

D.1.3.3 Clay Treatment Vessels

Clay treaters are used to remove surfactants from the fuel, which otherwise could "disarm" filter/separator elements located downstream of the clay vessel. The clay (Fullers's earth or attapulgus clay) can be in bulk or packed in elements (bags or canisters). The clay usually is 60- to 90-mesh grain size and is designated as a low volatile material (LVM). LVM treatment of the clay makes it more resistant to "disarming" by water. Water has a detrimental effect on clay performance by blocking off flow. Clay removes surfactants by adsorption not by filtration. Excessive flow rates are undesirable. The service life of clay is determined by comparing surfactant levels upstream and downstream of the clay treatment vessel. This can be done by interfacial tension (IFT) or through MSEP. Differential pressure is really not a good method for determining the service life of clay.

Refer to EI 1550, Annex F.

D.1.3.4 Dehydrator Vessels

Dehydrators (commonly referred to as hay packs) remove large particulate matter and bulk water from the fuel before all other filtration. They are effective in protecting clay elements from water. The media used in dehydrators is a special excelsior or other combination of media that promotes coalescence and dirt removal. The media is packed into the vessel and held in place by special containment devices.

D.1.3.5 Monitor Vessels

NOTE

Because of the changing nature of the EI/IP standards in regard to this form of filtration, refer to the latest standard (IP 1583), which may be more current than this document.

NOTE

Water-absorbing elements *should not* be used in fuel containing an anti-icing additive, also known as DiEGME, FSII, or Prist®. Prist® is a registered trademark of Prist Aerospace Products, a division of CSD, Inc.

A filter monitor is a vessel containing absorbent filter elements. A filter monitor is intended to continuously remove dirt and water from aviation fuel to a level acceptable for fueling modern aircraft. It also is intended to restrict the flow of fuel if the level of dirt or water is unacceptable.

Filter monitor elements have short service life with wet fuel so they usually are used downstream of coalescer/separator systems. They often include the last filtration of jet fuel before it is placed on an aircraft.

Filter monitors are generally effective for removing dirt and water contamination from aviation fuel but must not, by themselves, be viewed as fail-safe devices. Because the water absorption performance of filter monitor elements can degrade in service, a filter monitor must be regarded as no more than one component in a comprehensive system to control aviation fuel contamination.

Monitors, usually located downstream of filter or filter/separator vessels, are "insurance" vessels. These elements are changed out when the differential pressure reaches a certain level; the manufacturer normally recommends a 15–25 psi differential (103–167 kPa).

D.1.3.6 Strainers

Strainers are screens installed before nozzles, valves, pumps, and other mechanical equipment to remove coarse particulate matter. They do not provide the filtration and water removal functions of the other equipment in this section.

D.1.3.7 Suggested Vessel Sequence

At a jet fuel–receiving station downstream of a pipeline where relatively large amounts of water, particulate matter, and surfactants might be present in jet fuel, the suggested sequence of vessels is as follows:

NOTE

The following sequence may be altered to suit local conditions. For example, in high-dirt/low-water locations, reversing the order of the prefilter and dehydrator and using an oversized prefilter may be advantageous. If water is not considered to be a likely problem, the dehydrator may be eliminated.

First—Coarse coalescer, or dehydrator (hay pack) vessel, to remove most of the bulk water. This protects the downstream clay (water blocks flow through clay when it makes contact, causing the fuel velocity in the remaining clay to be increased and greatly reducing the ability of the clay to remove surfactants). Dehydrators (hay packs) are used primarily at locations where severe water contamination may be expected.

Second—Particulate filter (micronic or prefilter) vessel to remove dirt and so forth and to protect the clay vessel from becoming plugged with particulate matter.

NOTE

Oversizing the dehydrator and particulate filter vessels is recommended to improve efficiencies of water and particulate removal and to increase the time between media change outs.

Third—Clay treatment vessel to remove surfactants, thereby protecting the downstream filter/separator vessel. Clay vessels also may be oversized if advisable because of the level of surfactants expected.

Fourth—Filter/separator vessel with acceptable water defense protection to remove any remaining water and particulate matter, getting the fuel to the cleanliness level required at the airport. The filter/separator vessel will remove any clay fines that might migrate from the clay vessel.

NOTE

If local conditions indicate that a monitor vessel should be included in this sequence, it should be positioned last.

EI 1550 is available to provide more detail concerning the various options typically used for aviation fuel filtration.

D.2 Filter Element Installation Procedure

D.2.1 INTRODUCTION AND PURPOSE

The purpose of this procedure is to ensure that filter elements (that include coalescer, separator, micronic, and clay treatment elements) are installed correctly to prevent bypassing or malfunctioning of the elements.

D.2.2 REFERENCES

There is no known published test standard on this subject. Most manufacturers include element installation instructions in their equipment operating manuals, and instruction sheets usually are included in the element shipping cartons.

D.2.3 DESCRIPTION

New filter elements are installed in filter vessels just before start-up. Elements are replaced when the differential pressure reaches the recommended change-out point, the recommended service life has been reached, the elements become disarmed (see Sec. D.7), or there is reason to suspect that the elements need changing (possible rupture, bypass, unacceptable filter membrane rating, and so forth).

D.2.4 EQUIPMENT

A new set of the correct elements and a new cover gasket should be available before the vessel is opened. A supply of clean cloth is needed to wipe foreign matter from the vessel interior. Use proper personal protective equipment (PPE) when removing and installing filter elements.

D.2.5 PROCEDURE

Following are the general steps for replacing micronic filter elements, clay elements, and coalescer and separator elements. Specific comments on coalescer and separator elements follow these general steps.

1. Shut off the pump.
2. Turn off power to the electric sump or drain the heater if the vessel is so equipped.
3. Close the inlet and outlet valves.
4. Open the top vent and drain the housing through the bottom drain. Drain the inlet compartment also if so equipped.

   NOTE

   Dispose of drained fuel in accordance with proper hazardous material protocols.

   CAUTION

   Because of differing vessel designs, it is important to identify and open the proper drain valves.

5. When drained completely, open the cover, and before disturbing elements, allow 10 min for relaxation of accumulated static electricity charges.
6. Remove the spider, if installed, and then remove all of the elements.
7. Inspect the interior of the dome cover for evidence of soot or contamination (see Sec. D.3).
8. Inspect the elements as you remove them. Look for damaged gaskets and media. Visible particles may be sand, microbes, or rust. Rubber or metal from failing valves, pumps, or meters also may be present and indicate other fuel system problems.
9. Wipe off or wash down any foreign matter from the vessel interior and the cover with clean cloth soaked in product or clean water.

   CAUTION

   Do not use soap or detergents to clean the inside of the vessel. Remove all cleaning material.

10. Before installing the new elements, the vessel should be inspected or tested in accordance with Sec. D.3.
11. Install elements with clean hardware (spacers, end caps, and so forth) as per the manufacturer's or conversion kit instructions. Note the following five types of element instructions.

CAUTION

Do not touch the outer surface of an element with your bare hands or any greasy materials. When installing elements, open the plastic bags at the open ends of the elements and slide the bags back a few inches. Leave the bags on the elements for handling purposes during installation. After the elements have been installed, remove the plastic bags *slowly* to prevent static discharge.

- *Threaded Base Coalescers.* Thread the coalescers by hand onto the adapters, which are installed in the vessel, until you feel the gaskets seal on the adapter knife edges. Turn each element with both hands, gripping the end cap only, until it is hand tight and then remove the plastic bag. If the end of the coalesce has a square fitting, use the proper adapter and wrench to tighten it to the manufacturer's recommended torque value.
- *Open-End Coalescers.* Install elements carefully so they seal around the pilot guides on the inlet holes. Remove plastic bags and install cover plates or spacers as needed on the tie rods. Install rubber gasket, flat washer, lock washer, and nut on the tie rod. Hand tighten the nut and then use a wrench to tighten it to manufacturer's recommended torque value, or until the lock washer is flattened and the rubber washer begins to curl up around the outer edge. *Do not over torque.*
- *Separator Elements.* Separator elements are normally TCS type or synthetic screen. TCS or synthetic separators may be removed, inspected, cleaned (and repaired as required), and tested each time the coalescer elements are changed, depending on manufacturer's instructions. Synthetic separators may need to be discarded. Also see Sec. D.4 for maintenance procedures. Elements that do not test satisfactorily should be replaced.

CAUTION

Do not touch the separator media with bare hands. It is recommended that separators be handled only at the end caps.

- *Clay Canisters and Micronic Elements.* Tighten nuts on tie rods to manufacturer's recommended torque value. *Do not over torque.*

CAUTION

A careful inspection of the hardware that supports and seals the elements is recommended. If a small portion of the fuel can bypass the clay, the overall effectiveness of the treatment is reduced substantially.

Some hardware that is designed to hold bag elements is only marginally effective in sealing canister elements. If the hardware was designed to hold canisters, it is probably totally ineffective for bag-type elements.

- *Bag-Type Clay Elements.* The inside liner (ID) of a bag element is a fabric that may be permanently supported by a porous plastic tube (type A element) or temporarily by a heavy fiber tube (type B element). Install elements in stacks with as many layers as required using special care to keep the fabric end discs flat to avoid bypassing through creases. Do not drop the elements in place, but use a firm downward motion to promote settling and stabilization of the clay. If the stack is too high to install the cap, raise and then firmly lower the elements a few inches to promote further settling. Type A elements must be installed with the porous tube in place. Type B elements are installed by lowering the element over the perforated support tube. The fiber tube will be forced upward out of the element. Install the spring-loaded top cap in accordance with the manufacturer's instruction.

CAUTION

Never remove the fiber tube from the type B element before installing it. Do not remove type B elements from the vessel and expect to reinstall them because the fiber tubes cannot be reinserted in the bags.

Never attempt to install bag-type elements in a vessel that was designed for canister elements unless special bag-holding hardware is used.

Spring cap "hang-up" is a common problem. This is caused by the I.D. liner fabric catching on the top end of the porous tube of type B elements. The I.D. of the spring-loaded cap then wedges against this fabric, resulting in the entire cap being "hung-up" so that it cannot follow the clay downward as it settles. The same problem can occur with type A elements with the fabric catching on the top of the perforated support tube assembly. To avoid this problem, the fabric of the top element must be pushed downward by hand until it is clear of the edge of the support tube before the spring cap is installed.

12. Install the spider over the tie rods or end bolts. Then tighten nuts on the tie rods (end bolts) to help hold the elements securely in place.
13. Install a new cover gasket.
14. Check cover gasket for proper alignment. Replace cover and secure tightly using a cross-pattern process. Stencil or otherwise mark the date of the element change on the outside of the vessel.
15. Close the manual drain valve.
16. Open the manual air eliminator valve if so equipped.
17. Leave the inlet and outlet valves closed.
18. Preferably, gravity fill the vessel; if this is not feasible, start the system pump (perform steps 18 and 19 together).
19. *Slightly* open the inlet valve allowing the vessel to *slowly* fill with fuel (the slower the better) to avoid static electricity charging of the fuel or fuel misting, either of which could lead to an internal fire or explosion.
20. If the vessel has a manual air eliminator valve, leave the valve open until the fuel flows from the opening; then close it quickly. If the vessel has an automatic air eliminator, the vessel is full when the eliminator stops discharging air. Check for fuel leaks.
21. When the vessel is filled with fuel, fully open the inlet valve and *slowly* open the outlet valve. Then turn the power on to the sump or drain heater of the filter/separator (if so equipped).

22. If the vessel is the final stage of filtration before refueling aircraft, then fuel should be recirculated through the vessel at normal flow for at least 15 min to help clear the system of possible contaminants.
23. When flow has been established, record a differential pressure reading. If there is no differential pressure or it is lower than expected, the system should be shut down and the vessel should be inspected for broken seals, ruptured or charred elements, omitted elements, or improperly installed elements. If the differential pressure is higher than expected, contact the element manufacturer or representative.
24. A good practice is to perform a filter membrane test downstream of the vessel in accordance with Sec. B.1.

D.3 Filter Accessory Maintenance

D.3.1 INTRODUCTION AND PURPOSE

The proper operation of the accessory equipment on a filter vessel is a key factor in obtaining reliable performance from the filter. This section outlines the periodic normal maintenance requirements and procedures for filter vessel accessories. Among these accessories are differential pressure gages, sump floats and probes, shutoff valves, air eliminators, pressure relief valves, drain and sample valves, sump heaters, and sight gage glasses (Fig. 3).

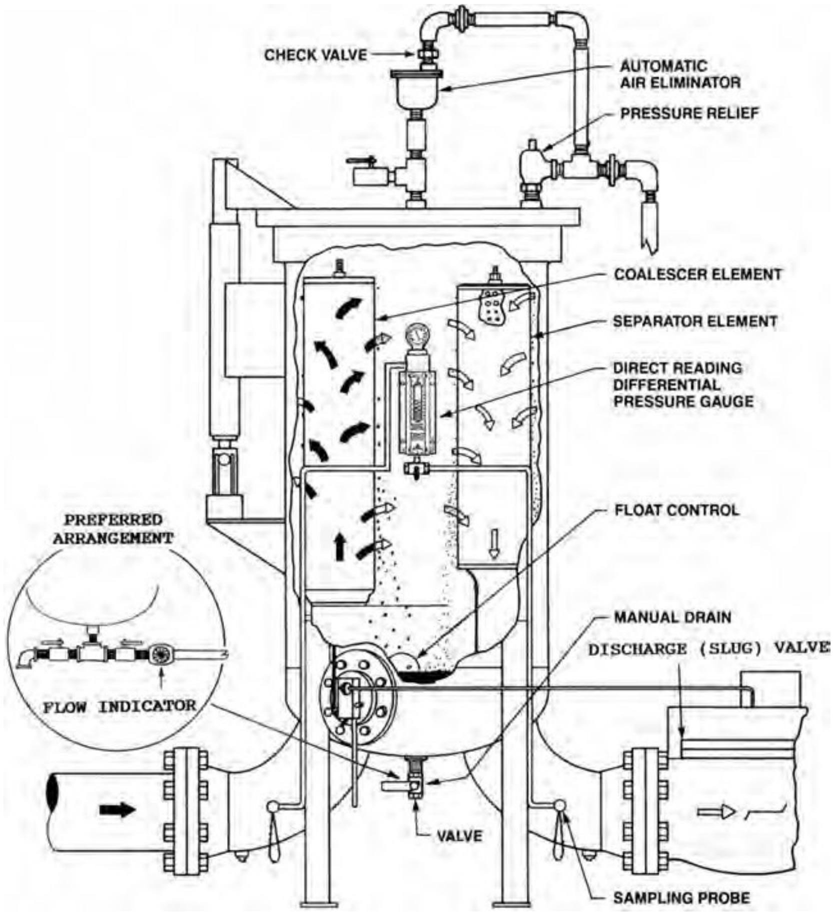
D.3.2 REFERENCES

There is no known standard method for performing this maintenance. This section should be read in conjunction with Secs. D.2, D.5, and D.6 that detail procedures for checking filter element replacement, differential pressure, and automatic water slug systems.

D.3.3 ACCESSORY MAINTENANCE

1. *Differential Pressure Gage*
    a. Periodically check that gage lines and valves in lines are not air-bound, plugged, or restricted.
    b. Some direct reading gages have small filters in their inlets. They must be clean to ensure proper gage operation and avoid sluggish response. Replace as necessary.
    c. Where three-way valves are used, be sure that the various positions are correctly marked and verify that the valve handle shows the correct valve position.

FIG. 3 Typical vertical two-stage filter/separator, per EI 1581, showing some accessory equipment.



d. Periodically, or if gage readings are suspect, remove the gage and test it against a known reference; replace or repair as required.
e. If a piston-type direct reading gage shows evidence of internal contamination or sluggish operation, the gage should be disassembled and cleaned. Be sure that the manufacturer's repair instructions are followed.

NOTE
EI 1581 requires that a three-way test valve be present on the outlet (lower) fitting of piston-type differential pressure gages. This allows the incoming (filter outlet) pressure to be shut off and the area under the piston to be vented to atmospheric pressure by way of a proper catch system to prevent a spill of the fuel. The piston then will be driven down by system pressure to the bottom of its travel, and this can be observed to ensure that no damage or debris inhibits the smooth operation of the piston or spring assembly. If the piston does not move smoothly, the piston and glass tube can be cleaned in accordance with the manufacturer's recommendation.

The next test is to return the valve to the operating position and stop all flow in the system. The piston should return to the *zero* position. If not, either cleaning, as noted, or replacement of the spring may be required.

2. *Sump Float or Probe*—See Sec. D.6 for instructions on the periodic testing of this equipment.

   A float or probe is installed in the sump of the vessel to detect a buildup of water in the sump. At a predetermined water level, the float or probe will actuate (close) the flow control (slug) valve or shut down the flow.
3. *Flow Control (Slug) Valve*—See Sec. D.6 for instructions on the periodic testing of this equipment.

   The flow control valve at the outlet of the filter vessel will automatically shut down the system if the float/probe signals that an excessive amount of water has accumulated in the sump.
4. *Air Eliminator*—The ability to remove air can be checked when a filter vessel is being filled after maintenance, or in some cases when the pump is first started up, by noting that air is being expelled from the air eliminator outlet piping. Only a relatively small amount of liquid should be expelled with the air, and there should be no leakage of liquid after the air is expelled. In cases in which the air eliminator is piped to a closed system, a sight gage should be installed in the line to determine whether liquid product is leaking through the air eliminator.

   The air eliminator also should be removed, the unit should be inspected, and the float action should be checked according to the manufacturer's instructions.

   CAUTION
   It is recommended that a check valve be installed on the *outlet side* of the eliminator to prevent air from reentering the vessel.

   When the vessel is opened, note whether a stain ring or soot shows on the internal upper wall or top cover. This could indicate the air eliminator is not working properly. Air is being trapped in the vessel or bleeding back through the air eliminator and its outlet check valve if the vessel happens to be at the high point in the system. Air trapped in the vessel can lead to an explosion if sufficient static charge is generated to cause an internal spark.
5. *Pressure Relief Valve*—The valve should be removed periodically and tested to see that it operates at the set pressure.

   CAUTION
   The set pressure must never be higher than the filter's design or maximum working pressure.
6. *Drain and Sample Valves*—These valves should be repaired or replaced when leakage or operation difficulty is noted. The use of ball valves is desirable because they permit rapid opening to full flow, enable rapid closing, and have less tendency to trap rust and dirt.
7. *Sump Heaters*—In areas where the temperature goes below freezing, electrical jacketing or immersion heaters may be necessary to prevent water from freezing in the sump and water drain-off lines. Heaters should be activated and checked according to the manufacturer's instructions before the onset of cold weather and periodically during the winter.

   CAUTION
   Before the vessel is taken out of service for maintenance, be sure to turn off and lock out electrical power.
8. *Sight Glasses*—Sight glasses sometimes are installed on filters to show when water is building up in the bottom of the vessel. They must be periodically flushed or disassembled to clean the glass so that the water-fuel interface can be readily seen.

D.4 Teflon®-Coated Screen (TCS) and Synthetic Separators

D.4.1 INTRODUCTION AND PURPOSE

The purpose of this procedure is to evaluate Teflon®-coated screen (TCS) and synthetic material separators for serviceability. Procedures are described for cleaning and repairing Teflon® separators, which typically can be cleaned and reused multiples times. See the manufacturer's instructions.

D.4.2 REFERENCES

There is no known published test standard on this subject. Cleaning procedures are published by some filter element manufacturers.

D.4.3 DESCRIPTION

When coalescer elements are changed in accordance with Procedure D.2.5, and at other times when the performance of TCS or synthetic elements is in question or it is desirable to verify the proper condition of the separator elements. This verification is done by visually inspecting; testing with running water; and, if necessary, cleaning and repairing the elements.

D.4.4 EQUIPMENT

The following equipment is required for this procedure: container of clean jet fuel, clean cloth or *soft* fiber brush, tap water, and two-part epoxy, if necessary.

D.4.5 PROCEDURE

D.4.5.1 General

1. If the filter/separator vessel is not open, follow the procedure outlined in Sec. D.2.5, steps 1–7.
2. Remove spiders, if installed, and carefully remove the separator elements.

   CAUTION

   In removing the separator elements, care must be taken to avoid touching the surface of the screen. Skin oils may disarm the separator elements. A clean cloth or nitrile gloves should be used while holding the elements to facilitate their removal.

3. Visually examine each element. It should appear clean, without any collection of dirt, particulate matter, "slime," or "foam." No cuts, tears, abrasions, or deformations should be visible.
4. If any dirt or other matter is present, the cleaning procedure should be followed.
5. If any cuts, tears, and so forth are present, the repairing procedure should be followed after cleaning.

D.4.5.2 Cleaning Procedure

1. Submerge the element in a container of clean jet fuel and gently scrub the entire surface with a soft fiber brush or lint-free cloth.
2. If foreign material is present, it may be necessary to change the fuel to ensure that clean, uncontaminated fuel is used as a final rinse.
3. Inspect the element to ensure that it is clean. If any foreign matter is noted, repeat steps 1 and 2. If any cuts, tears, nicks, and so forth are noted on the surface, proceed with the repairing procedure; otherwise, proceed with the water-testing procedure.

D.4.5.3 Repairing Procedure

NOTE

If the screen surface shows a cut, nick, tear, and so forth, larger than 0.125 in., the element *should not be* repaired.

1. If the hole in the separator is small, coating the damaged area with two-part epoxy may repair it. First clean the area around the cut with isopropyl alcohol. Epoxy will not stick to Teflon®, so the epoxy must be worked into the screen to provide a mechanical lock. A tool must be used to force the epoxy into the hole and the immediate surrounding mesh. Ensure that the proper PPE is used when cleaning and repairing separators.
2. After the repair has been made and the epoxy has fully cured, the element must be tested in accordance with the water-testing procedure.

D.4.5.4 Water-Testing Procedure

1. Be sure that the separator is fuel-wetted before performing this test by completely immersing the separator in clean fuel. Hold the element by the end cap at an approximate 45° angle and gradually pour clean water over the entire screen surface while slowly rotating the element.

   CAUTION

   Do not spray the water and do not let it fall more than 3 in. (7.62 cm) before contacting the separator because the splashing will make interpretation of the results difficult.

2. Examine the screen as the water flows over it. It should bead and roll off the surface without wetting the surface. This beading is similar to water drops on a waxed automobile finish. If the water "wets" the surface and penetrates into the screen, the surface must be cleaned again.
3. If the element successfully passes this test, it may be reinstalled in the filter vessel after a final rinse in clean fuel to remove any water traces. Care should again be exercised to prevent touching the screen with anything other than a clean cloth or nitrile gloves.
4. If the element fails the water-testing procedure, washing with hot water may be attempted. Using pressurized hot water, *not steam*, spray the area that has not passed the water test. It may be necessary to also rescrub the area with a clean cloth or soft fiber brush. Allow the element to dry thoroughly and then repeat the water-testing procedure, after fuel-wetting the separator.
5. If the element cannot pass this test, it must be discarded and replaced with an acceptable element.

D.5 Differential Pressure—Delta P or DP

D.5.1 INTRODUCTION AND USE

The purpose of observing differential pressure across a filter vessel is to monitor the changing condition of the elements. Establishing and maintaining a record of differential pressure readings across filters provides a history, so that element change times can be determined and abnormal conditions detected.

D.5.2 REFERENCES

ATA Specification 103, *Standard for Jet Fuel Quality Control at Airports,* Sections 2-4.3,2-7.2, and 2-8.3.3 and Form 103.06, Air Transport Association of America, 2015, https://publications.airlines.org

EI 1550, *Handbook on Equipment Used for the Maintenance and Delivery of Clean Aviation Fuel*, Chapter 19.

EI 1581, *Specification and Qualification Procedures for Aviation Jet Fuel Filter Separators*, paragraphs 3.1.4.2 and 3.2.4.2, Energy Institute, London, www.energyinst.org

D.5.3 DESCRIPTION

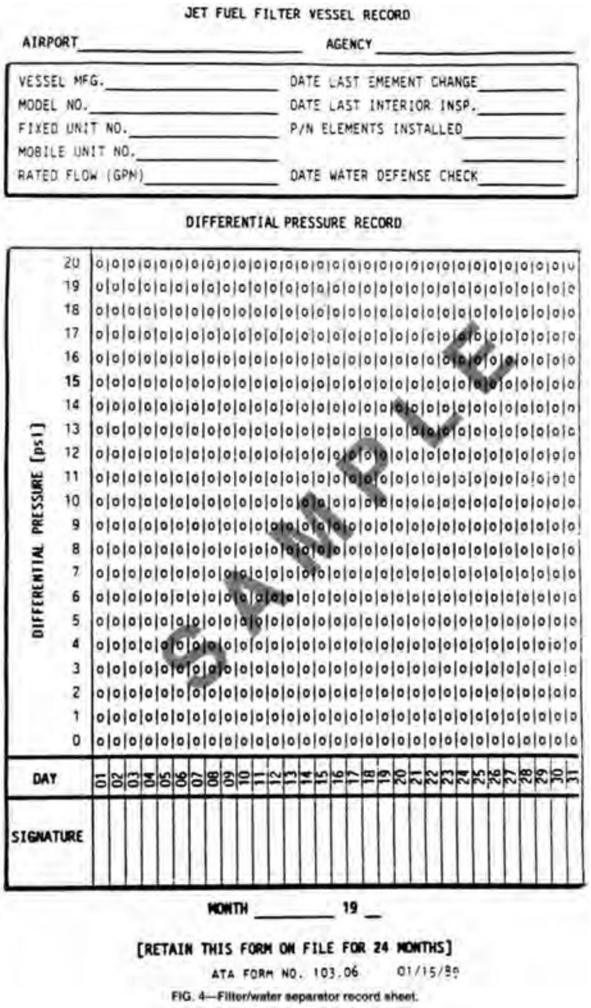
1. Whenever fuel passes through a filter, a drop in pressure occurs across the element. (At any fixed flow rate, the absolute pressure upstream of the element is higher than the absolute pressure downstream of the element.) This may be quite minimal with new filter elements, normally ranging from less than 1 to 7 psi (7–48 kPa) at rated flow. As the elements collect solids or contaminant from the fuel, the drop in pressure across them gradually increases. The difference in pressure between inlet and outlet of the filter vessel should be monitored daily and recorded no less than weekly (more often on filters in critical applications). This differential pressure is one of the more apparent indications of filter element plugging. If the differential pressure increases suddenly, it could indicate plugging of the elements and unusual contaminant levels, which can indicate that a serious contamination level is present. If the differential pressure decreases suddenly, it could indicate an element rupture or bypassing, which is cause for immediate system shutdown and investigation. Maximum allowable differential pressure is specified by the element manufacturer, usually 15–25 psi (103–172 kPa), at which point the filter elements should be replaced in accordance with Sec. D.2.
2. Differential pressure readings across filters should be recorded, either as a column of figures or, preferably, as a line graph with information on fuel source, batch tank, and so forth. This record provides an immediate indication of abnormal filter differential pressure. It also may help identify shipments or receipts of contaminated fuel or storage tank contamination. It alerts fuel handlers to impending element failure, thereby allowing corrective action to be scheduled before actual failure.
3. Throughput should be recorded at the time of any filter inspection or element change (also may be recorded as a running usage) to establish normal and abnormal filter element life.
4. Fig. 4 is a suggested form for recording differential pressure, throughput, and filter element data. Some users may additionally plot volume throughput on the horizontal axis.

D.5.4 EQUIPMENT

Each filter vessel should be equipped with pressure taps on the inlet and outlet sides of the filter. These taps may supply pressure sensing to a common gage by means of a three-way valve (off-inlet-outlet), or to a direct reading differential pressure gage accurate to ±1 psi (±7 kPa). Some operators prefer two separate pressure gages for reading inlet and outlet pressure, but this is not recommended as multiple readings may add confusion.

Differential pressure also can be monitored electronically through connections to a differential pressure gage or pressure transducers. Differential pressure monitoring equipment is available that will correct for variable flow and adjust the reading to show differential pressure corrected to rated flow conditions. These devices have available options for connections to control systems to alarm or shut down systems if there is an elevation or sudden decrease in differential pressure.

FIG. 4 Filter/water separator record sheet. (Courtesy of A4A, Washington, DC.)



JET FUEL FILTER VESSEL RECORD

AIRPORT ________ AGENCY ________

VESSEL MFG. ________ DATE LAST EMEMENT CHANGE ________
MODEL NO. ________ DATE LAST INTERIOR INSP. ________
FIXED UNIT NO. ________ P/N ELEMENTS INSTALLED ________
MOBILE UNIT NO. ________ ________
RATED FLOW (GPM) ________ DATE WATER DEFENSE CHECK ________

DIFFERENTIAL PRESSURE RECORD

DIFFERENTIAL PRESSURE (psi)
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

DAY 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

SIGNATURE

MONTH ________ 19 _

[RETAIN THIS FORM ON FILE FOR 24 MONTHS]

ATA FORM NO. 103.06 01/15/89

FIG. 4—Filter/water separator record sheet.

D.5.5 PROCEDURE

Establish steady flow through the filter vessel at the normally used flow rate. If a valve arrangement to a common gage is used, read the inlet pressure. Next, read the outlet pressure. Subtract the outlet pressure from the inlet pressure.

This is the differential pressure that should be recorded. If a direct reading gage is used, read the differential pressure directly from the gage and record it. Observed differential pressure at other than normal full-system flow rates should be converted to the normal flow rate differential pressure by means of a graph, spreadsheet, or mathematical formulas supplied by the filter manufacturer or through the use of corrected differential devices described in Sec. D.5.4.

D.5.6 CAUTIONS

1. Differential pressure varies with flow rate. Always record differential pressure at a common flow rate close to the maximum normally used.
2. Industry operating standards require DP to be corrected to maximum achievable flow rate.
3. Differential pressure across some filter elements will remain fairly constant until they begin to become plugged and then will rise at a fast rate. When an abnormal rise in differential pressure occurs, that filter should be monitored on a more frequent basis until the elements are changed or the situation has been rectified. Zero differential pressure or a sudden decrease in DP is not normal and always should be investigated because it may indicate that a filter element has burst, collapsed, or come loose from its mounting.
4. Differential pressure readings that remain at a constant level over an abnormal period of time may indicate improper element installation, a faulty gage, blocked or restricted pressure-sensing lines, blocked or dirty internal gage filter elements, and so forth.
5. The handles on some three-way valves do not accurately indicate the actual operating position of the valve. Care must be taken to ensure that readings made are dynamic pressure and not blocked pressure in the lines.
6. Operation of filter vessels above the manufacturer's recommended maximum differential pressure, usually 15–25 psi (103–172 kPa), can result in element rupture, collapse, or bypass.

D.6 Automatic Water Slug Systems

D.6.1 INTRODUCTION AND PURPOSE

This section describes the equipment, operation, and testing procedures for automatic water slug systems.

D.6.2 REFERENCE

There is no known published standard on this procedure.

D.6.3 DESCRIPTION

A fuel discharge valve (or slug valve) is installed in a system to stop fuel flow when water reaches a predetermined level in the filter/separator vessel.

CAUTION

On some older systems, an additional function was provided that automatically would open a drain on the filtration unit to drain any accumulated water. For many reasons, including environmental concerns, this additional function is *not r ecommended* and should be removed.

1. *Float-Operated System*—This system is actuated by a signal from a float with a sealed air and fluid chamber, which, when properly balanced, will sink in fuel and float in water. The float remains in the downward position, permitting fuel flow until enough water accumulates in the sump to raise the float. As the float rises to its maximum level, it repositions a pilot valve that closes the fuel discharge (slug) valve or operates an electrical switch to stop fuel flow. To restart fuel flow, the operator must manually drain the accumulated water from the sump, allowing the float to return to the downward position.
2. *Electric Exposed or Sealed-Probe-Operated System*—This system consists of an electric probe installed in the filter/separator sump that actuates a relay system to stop fuel flow when sufficient water accumulates. Water must be drained off manually before fuel flow can resume. The internal contacts of these units also may be used to activate audio or visual alarms in addition to or instead of the previously noted action.

The different applications and uses of these automatic water slug systems are summarized in Table 1.

D.6.4 TESTING EQUIPMENT

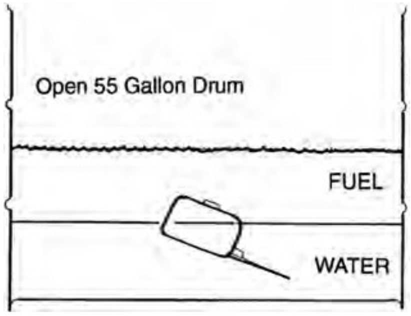
Equipment required may vary depending on the type of water slug system being tested but may include the following:

1. A special pump with sufficient output pressure to overcome static head pressure to inject water into the water sump of the filter/separator through the water drain valve.
2. A hose of sufficient pressure rating to connect the above pump to the water drain valve.
3. A container of approximately 3 gal (11.4 L) volume, calibrated to show at least gallon markings, to hold water used for injection into the filter/separator water sump.
4. A test bulb to inject water into the test cavity of an electrical water detection probe.
5. An ohmmeter or multimeter to measure electrical continuity.

TABLE 1 Control System Summary

Type	Power signal	Usual application	Action
A. Float	Compressed air	Mobile	Closes fuel discharge (slug) valve
B. Float	Electrical	Mobile/stationary	Closes fuel discharge (slug) valve and/or stops pump and/or provides alarm signals
C. Float	Hydraulic	Stationary	Closes fuel discharge (slug) valve
D. Probe	Electrical control of air deadman	Mobile	Closes fuel discharge (slug)/valve and/or provides alarm signals
E. Probe	Electrical control ofelectric deadman	Mobile	Closes fuel discharge (slug) valve and/or provides alarm signals
F. Probe	Electrical	Stationary	Closes fuel discharge (slug) valve and/or stops pump and/or provides alarm signals

FIG. 5 Example of a float buoyancy test.



6. A test container for checking the proper buoyancy of float mechanism (Fig. 5).

D.6.5 GENERAL PRECAUTIONS

1. Good housekeeping procedures prescribe complete removal of sump water to prevent microbiological growth. The unit should be drained through the manual water drain valve at least daily. It should be emphasized that the automatic systems previously described *do not* operate until there is a substantial quantity of water in the sump of the unit. Therefore, they do not replace the requirement for manually draining all the water from these sumps.
2. Ensure that the pilot valve (float control valve) is installed with the correct side facing up. If it is mounted upside down, the fuel discharge (slug) valve will operate improperly.
3. Proper actions must be taken to ensure that any fuel or fuel-water mixture is properly collected and disposed of in accordance with applicable federal, state, and local environmental regulations.

D.6.6 PROCEDURES

D.6.6.1 Mobile Units

All mobile systems should be tested while the fuel system is pressurized and flowing on a test stand (not while fueling an aircraft) using the following procedures:

1. *Float Operated Systems*—See Table 1, types A and B.

   CAUTION

   When performing these, or similar, float system tests *never* connect the test equipment directly to any city, public, or other domestic water supply system. The fuel pressure can be greater than the water system pressure, and fuel could be forced into the water supply, contaminating it. Additionally, there is no positive means to verify how much water has actually been put into the sump and therefore no way to be sure to remove the same amount.

2. *Water Injection Procedure*
   a. Flush product through the manual drain line and valve from the filter/separator to ensure all dirt and foreign material has been removed.
   b. Connect equipment noted in Secs. D.6.4, items 1 and 2, to the manual drain valve to inject a measured amount of clean fresh water.
   c. The following assumes that the sump volume of a filter/coalescer and separator system is less than 1 gal (4 L). Testing of systems with significantly different sump volume should be scaled as appropriate. While maintaining system pressure, slowly inject 3 qt (3 L) of water through the manual drain valve. Close the drain valve and depress the deadman control to test system operation. If the system activates, stop flow at once. Inject another qt (1 L) of water and attempt to restart flow. The system should not operate. *Do not* inject more than 1 gal (4 L) of water. The system is considered unacceptable if fuel flow resumes after injecting 1 gal (4 L) of water. Further investigation is required by qualified repair personnel, and the system should be retested and accepted before returning the unit to service.
   d. If flow does not restart after the injection of the water, then this portion of the operation is considered acceptable.
   e. Drain, collect, and measure (by volume) all the water injected. Depress the deadman control to test that the system flow activates. The system is considered unacceptable if fuel flow does not resume when test water is removed. Further investigation is required by qualified repair personnel, and the system should be retested and accepted before returning the unit to service.
   f. Remove the specialized test equipment. Drain an additional 1 gal (4 L) of product to ensure that all water is removed, and then stop the flow of product and return the system to normal operation. Dispose of the water and any fuel collected in accordance with applicable environmental regulations.

   CAUTION

   After testing the float and pilot assembly, ensure that all ports are free of water before reassembly.

   NOTE

   Some floats, when manufactured, are carefully weighted (to have the correct buoyancy) with an internal liquid, oil, or water. Do not remove the oil or water from the inside of these floats.

   When testing mobile float systems, always inject a measured amount of water and never more than 1 gal (4 L). The *same* amount of water should be recovered after test completion.

3. *Mechanical Test Procedure*
   a. Recirculate fuel within the system or, if a hydrant servicer, through a test connection or into a refueler at the desired flow rate.
   b. Operate the mechanical override device (test mechanism) in accordance with manufacturer's instructions until the product flow control system operates to stop the recirculating flow. (This may be through means of

pneumatic or electrical solenoids or a combination of such solenoids or operators.)

c. If the recirculating flow through the system does not stop when the test mechanism is operated, the automatic system is malfunctioning and further checking must be made by qualified repair personnel.

d. If the recirculating flow has stopped, slowly return the test mechanism to its original position. The fuel flow should resume. If flow does not resume, the system is malfunctioning and further investigation is required by qualified repair personnel before the system can be returned to service.

e. Stop the pump or release the deadman control as required to stop all flow through the system and return all system valves to normal operational positions.

CAUTION

The manual test mechanism on the float pilot valve only checks the operation of the pilot valve assembly. It does not check whether the float is buoyant in water. (Ballast types of float valves *do* check the buoyancy of the float. The manual override device on this type of unit lifts the ballast from the float, which allows it to float in fuel. Releasing the ballast back to the float causes it to sink in fuel but float in water.)

f. The next time the filter/separator is opened, the float assembly should be removed and its buoyancy checked by verifying that it will rise in water and sink in jet fuel. This may be accomplished by removing the float assembly from the filter/separator and testing in a container, as shown in Fig. 5.

NOTE

As an alternative to the previous instructions, when the unit is out of service and open, the sump may be filled with jet fuel until the float is covered with jet fuel, and then water slowly may be added to the sump. The float should sink in fuel but float on water. If the float does not float on water, the float or its mechanism is malfunctioning and further investigation is required by qualified repair personnel before the system can be returned to service.

D.6.6.2 Electrical Probe Systems

Several types of water probes are available and different test procedures are used for each one. Basically, they constitute three types: units in which water is injected into a nonpressurized internal chamber to simulate water contact, units with a built-in water pump that displaces a small amount of water into the actual fuel-wetted surfaces under pressure, and units that are mounted into a drain-line assembly to allow the probe to be isolated from the pressurized system while water is added (not under pressure) to test the actual fuel-wetted surfaces.

1. *Water Injection Procedure: Units with Sealed Internal Nonpressurized Test Chambers*—Sealed electrical probe systems normally are fitted with 0.25 in. (6.3 mm) petcocks through which water may be injected inside the probe (Fig. 6). The process to test them follows:
   a. Fill a test bulb noted in Sec. D.6.4.3 with about 2 cups of water.
   b. Attach the discharge end of the test bulb to the inlet petcock.
   c. While recirculating fuel at the desired flow rate, open the inlet and outlet petcocks and slowly squeeze water into the probe through the lower petcock. When the water reaches the internal surface of the probe, the fuel flow should stop.

   The system is malfunctioning if the flow of fuel has not stopped before water exiting from the upper petcock. Drain all water injected and stop the flow of fuel in the system. Further investigation is required by qualified repair personnel before the system can be returned to service.

   d. If the system has stopped the fuel flow, remove the test bulb and completely drain the probe of all water. The system fuel flow should resume. Stop the flow of product and return the system to normal operation, removing all test equipment connected and closing both petcocks.

CAUTIONS

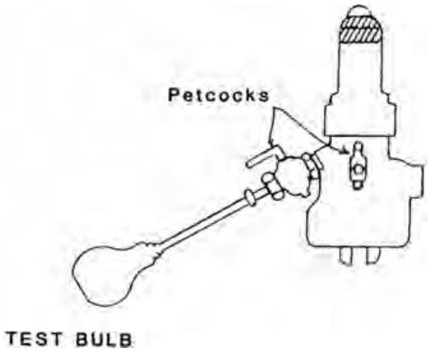
The electrical power circuits to the probe must be shut off and tagged out by qualified personnel to ensure that they are not energized during the removal and cleaning of the probe.

After reinstallation of the probe, the electrical continuity between the probe and the case of the filter/separator should be verified with an ohmmeter.

   e. The next time the filter/separator is drained or opened, the probe assembly should be removed and cleaned with fine steel wool or abrasive cloth (e.g., Scotchbrite™ 3M) to ensure that all electrical surfaces are conductive.

2. *Water Injection Procedure: Units with Built-in Test Pump*
   a. Remove the cover and remove the test pump by rotating the pump one quarter-turn and pulling out. Handle the test pump by only the large diameter when removing.

FIG. 6 Setup for testing the sealed electrical probe.



b. Unscrew the plunger from the pump and fill with clean fresh water, holding and using a finger to cover the small hole on the outlet on the end. Replace the plunger and turn the pump in two full turns. Never unscrew the plunger while it is installed.

c. Reinstall the pump and turn the plunger inward to inject the water.

After testing, it may be necessary to flush the water from the pump in cold climates. To do so, simply repeat the process with fuel instead of water.

3. *Water Injection Procedure: Units in Drain Lines with Isolation Valves*
   a. Turn off the isolation valve. This valve isolates the drain assembly from the filter vessel.
   b. Open the drain valve and the upper filling valve and drain all fuel. Close the drain valve.
   c. Pour water into the upper fill valve.
   d. After testing, drain all water, close open valves, and reopen the isolation valve.

D.6.6.3 Stationary Units

Because of the volume of water required, as well as flow rates and pressures encountered, stationary units should *not* be tested by injecting water into the filter vessel sump. Most float-operated systems of type C (Table 1) are equipped with an external test mechanism. This test mechanism will physically raise the float (or ballast in newer type floats) inside the unit to enable verification of the correct operation of the automatic system. The following procedure should be followed in testing this type system.

1. *Normal Procedure*

a. Start the pump to pressurize the system and establish normal flow rate.

CAUTION

Be sure the vent port from the pilot valve (float control valve) is unobstructed. Sometimes this vent is plugged during shipment to prevent dirt or debris from getting into the pilot valve assembly. If the vent is plugged for any reason, improper operation of the fuel discharge valve will occur.

b. Operate the test mechanism, observing the valve position indicator, if installed, on the fuel discharge (slug) valve. The discharge valve should close, stopping all flow (Fig. 7), as the test mechanism raises the float to its raised position.

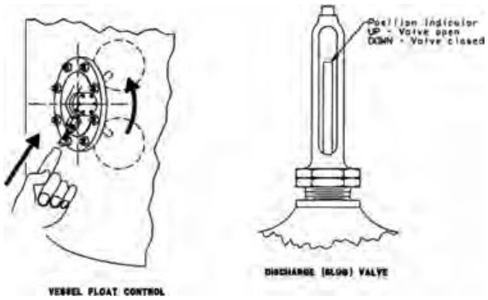
NOTE

If no position indicator is installed, pressure on the downstream system will drop. In addition, the cessation of flow frequently can be heard, especially as the fuel discharge (slug) valve closes.

c. If flow is not stopped when the test mechanism is operated, the system is malfunctioning and further checking will be required by qualified repair personnel.

d. While slowly returning the test mechanism to its original position, the fuel discharge (slug) valve should open, thus restoring flow. If flow is not restored, the system is malfunctioning and further investigation is required by qualified repair personnel before the system can be returned to service.

FIG. 7 Operating the float control manual test mechanism. Observe the fuel discharge valve position indicator.



e. Turn off the pump to stop all flow through the system and return all system valves to normal operational positions.

CAUTION

The manual test mechanism on the float pilot valve only checks the operation of the pilot valve assembly. It does not check whether or not the float will rise in water. (Newer types of float valves, ballast type, *will* check the capability of the float to rise. The manual override device on this type of unit lifts the ballast from the float, which then allows the float to rise in fuel. Releasing the ballast back to the float will allow the float to rise only in water.)

f. The next time the filter/separator is opened, the float assembly should be removed and its buoyancy checked in accordance with Sec. D.6.6.1 (“2. Water Injection Procedure”).

2. *Procedure for Systems with Probes*—If the stationary system is equipped with a probe, the procedure used under electrical probes on mobile equipment as per Sec. D.6.6.1 (“2. Water Injection Procedure”), may be used. This type of electrical probe may be connected to perform various operations, such as activating an alarm or a warning light, stopping the pump, or closing the discharge (slug) valve. The testing of this type of unit is performed in the same manner as that specified under mobile equipment.

CAUTIONS

It must be ensured that the electrical power circuits to the probe are shut off and tagged to ensure they are not energized during the removal and cleaning of the probe. It may be necessary for an electrician to disconnect the probe from the power source.

After reinstallation of the probe, the electrical continuity between the probe and the case of the filter/separator shall be verified with an ohmmeter.

a. The next time the filter/separator is drained or opened, the probe assembly should be removed and cleaned with fine steel wool to ensure that all electrical surfaces are conductive.

D.7 Single-Element Test for Coalescer Elements

D.7.1 INTRODUCTION AND PURPOSE

Coalescer elements in filter/separator vessels coalesce undissolved water into large droplets that fall into the sump of a filter vessel by gravity. Coalescer elements can become "disarmed" (lose their ability to coalesce water) by the adsorption of trace fuel components or contaminants (surfactants) even when the differential pressure across the element is low. The single-element test was developed to observe the coalescing capability of a set of elements in a filter/separator system by testing the water coalescence of one of the elements. The continued use of the remaining elements can be judged by the results of this test.

D.7.2 REFERENCES

There is no known published test standard on this subject.

D.7.3 DESCRIPTION

A coalescer element is removed from a filter/coalescer and separator vessel that was in field service. The element is removed using extreme care to avoid damage or contamination (such as barehand contact with the outer white sock). The element is installed in the single-element test apparatus, where its performance is evaluated when challenged with a controlled emulsion of fuel and water.

D.7.4 TEST EQUIPMENT

D.7.4.1 Products and Supplies

Test equipment, supplies, and other requirements include the following:

1. Gammon Model GTP-359 Single-Element Tester, available from Gammon Technical Products, Inc., PO Box 400, Manasquan, NJ 08736 (Tel: 732-223-4600).

   NOTE

   This procedure is based on the only known commercially available tester: the Gammon Single-Element Tester. It should be possible to substitute an equivalent tester if available.

2. A source of flowing jet fuel. This may be supplied by a refueling truck or any other dedicated source that can deliver fuel for at least 10 min at 50 psi (344 kPa) and at the rated flow rate of the element to be tested. Ideally, the fuel used for this test should be the same fuel as the element handled in service.
3. One gal (4 L) or more of clean water, such as drinking (potable) water contained in a suitable container, such as a bucket that is free of particulates and surfactants.
4. A safe and secure site isolated from ignition sources. This procedure is based on the only known commercially available tester: the Gammon Single-Element Tester. It should be possible to substitute an equivalent tester if available.

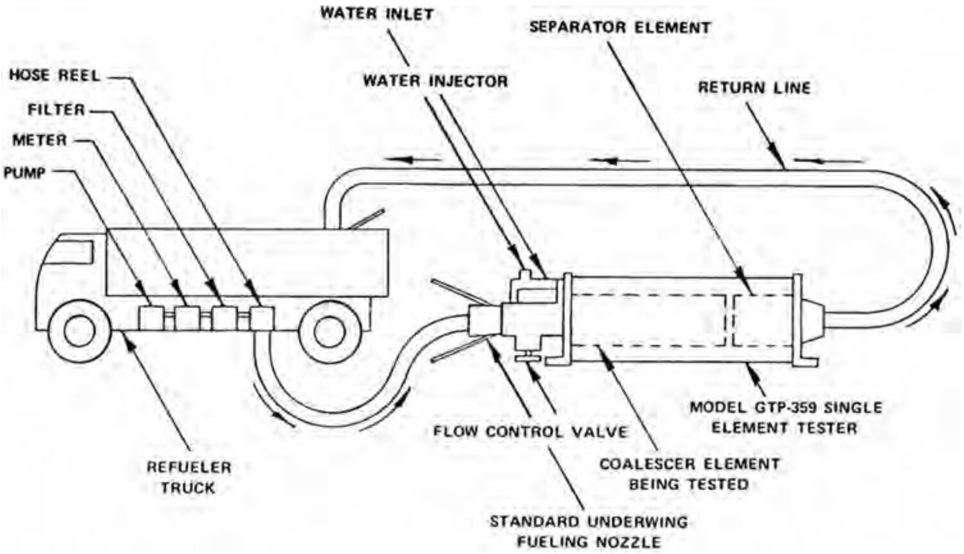
D.7.4.2 Equipment Preparation

1. Arrange the tester in the manner shown in Fig. 8. A dedicated refueling truck is shown as the source of jet fuel in Fig. 8, although other arrangements may be made. The pump, meter, hose, and refueling nozzle on the truck are required to supply fuel at the required flow rate.

   NOTE

   The pressure control valve on a refueler is normally set so that the pressure at the refueling nozzle will not exceed 50 psi (344 kPa). This pressure control feature is required to protect the single-element tester.

FIG. 8 Single-element tester connected to a refueler truck.



2. Attach a bonding wire between the tester and the fuel source.
3. The fuel flowing from the tester may be recirculated into the truck tank as shown in Fig. 8, or it may be directed to some other receiver, depending on local policy and facilities.
4. Install a coalescer element in the tester, being careful to avoid skin contact with the element. Torque it to the manufacturer's specifications. Elements that have mechanical damage are not suitable for testing.

   NOTE
   Adaptors are available from the tester manufacturer to mount any coalescer element that flows from inside to outside in the single-element tester.

5. Place the water supply in a bucket or other suitable container and secure the water suction tube in the bucket.
6. Close the water supply valve and the tester chamber drain valve. Open the chamber air vent valve.
7. Close the flow control valve by turning the knob in the direction stamped onto the valve body.
8. When fuel pressure has been established, slowly open the valve on the refueling nozzle. The flow rate is very slow while the test chamber is filling because, with the flow control valve closed (see step 7), the only flow is through a 0.25 in. (6.3 mm) port in the eductor. This slow fill rate is required to prevent the development of excessive electrostatic charges.
9. Close the air vent valve when the chamber is full.

   NOTE
   For safety, it is important that all air be vented from the chamber.

10. Check the fuel flow rate by timing the truck (or other) meter, as appropriate. Adjust the flow control valve until the flow rate is correct for the coalescer being tested.

    NOTE
    The correct flow rate is the maximum flow rate that the element can experience at the particular operation where it is used. If the maximum flow rate of the system is 600 gal per min (gpm) (2,300 L/min) and there are ten coalescer elements in the system, then the single-element test should be run at 60 gpm (230 L/min). However, if the filter/separator is rated at 600 gallons per minute (gpm) (2,300 L/min) but the pumping system is incapable of exceeding 400 gpm (1,500 L/min), the test should be run at 40 gpm (150 L/min).

11. Before initiating water injection, be sure any preexisting water has stopped coming from the element media.

D.7.5 CAUTIONS

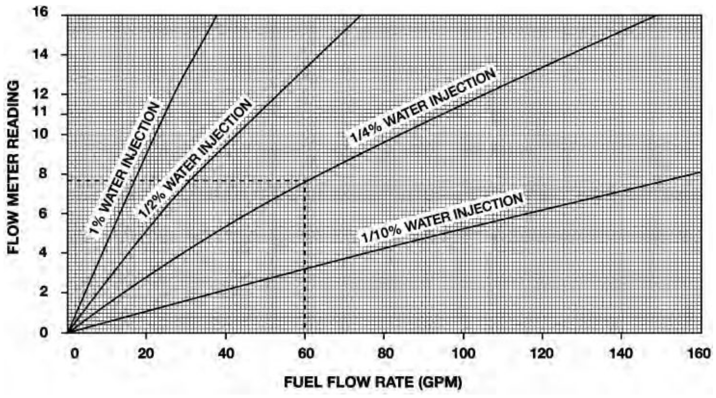
1. Water can wash surfactants out of a coalescer causing it to recover its ability to coalesce water. Therefore, the visual evaluation of coalescence must be made immediately upon the introduction of test water.
2. The test chamber must be filled slowly to avoid electrostatic charge buildup. A fill rate of no more than 5 % of element rated flow is recommended.
3. When water drops are viewed through the wall of a curved chamber, the true sizes are distorted. A scale located inside of the chamber near the droplets permits their true size to be assessed.

D.7.6 TEST PROCEDURE

1. Observe the outside of the element in the transparent chamber and report evidence of water drops and their color. Also refer to step 4 of these test procedures. Do not proceed with water injection until fuel flowing through the coalesce element is clear and free of any signs of water.
2. Record the differential pressure across the element.
3. Adjust the valve on the water flow meter until the required injection rate is established.

   NOTE
   Fig. 9 has a set of curves that show the water meter reading that is necessary to obtain various injection rates for various fuel flow rates.

FIG. 9 Water flow injection chart for single-element tester Model GTP-359. Reprinted courtesy of Gammon Technical Products, Inc., Manasquan, NJ.



4. Closely observe the test coalescer as water is being injected to look for the following indications of element failure:
    a. Haze from any part of the element means that fine water droplets are not coalescing, indicating damage to the element or that surfactants are present and causing a water-fuel emulsion to form. Haze often has the appearance of smoke and the word "smoke" generally is used to describe a failed condition.
    b. Clusters of water drops that look like a bunch of grapes (called "graping") are really water films surrounding fuel (like a balloon). A coalescer that performs this way has failed; the water film will shatter into hundreds of fine droplets that cannot be removed by the separator.
    c. Slimes are evidence of surfactant contamination or microorganism debris. Even if the element coalesces properly, it must be considered unsatisfactory.
    d. If an element performs well except that haze or smoke appears to come from the end gaskets, recheck the seating and torque (to manufacturer's recommendations) and repeat the test. If the smoke cannot be eliminated, then the element should be discarded and a different element should be tested.
    e. If haze appears at the bond between the coalescing media and the end cap, the entire set should be rejected. Note that droplets are often somewhat smaller very near the ends of elements than elsewhere. This is not generally a cause for concern as long as the droplets appear as discrete droplets and not haze or smoke.
5. In addition to the visual assessment, measure the effluent-free water content 15 s after seeing the first water droplets coming from the coalescer. If the reading is greater than 15 ppm, the elements should be replaced.
6. In the case of failing results, it can be useful to drain a water and fuel sample from the single-element tester as soon as enough water is available and as soon as it is possible to take an IFT reading. A low IFT reading on this sample will prove that surfactants are present.
7. Report the results of all observations.
8. Close the nozzle valve, stop the pump, open the test chamber drain valve to dispense water and fuel to a suitable container, and open the vent valve. Dispose of the water-fuel mixture in an appropriate manner.
9. When the fuel level falls below the coalescer, remove it from the chamber.

D.7.7 INTERPRETATION OF TEST RESULTS

1. Generally speaking, if the water droplets average at least one-half the size of the droplets from a new element, the remaining elements in the filter/separator may be continued in service. Different models of coalescing elements produce different sizes of water drops when they are working properly, so it is not possible to set absolute droplet size limits.
2. If any slime flushes out of the test element, the entire set of elements should be removed from service because this indicates that they are grossly contaminated by surfactants or microbial growth. Such elements may coalesce water at the time of the single-element test, but they are no longer reliable.
3. Any evidence of haze or smoke from the coalescing media is reason to immediately stop the test and replace all of the coalescers in the filter/separator.
4. Occasionally, coalescers create clusters of droplets that look like a bunch of grapes (called "graping"). The droplets are actually water films with fuel inside. Elements that have this problem (all coalescers in the vessel can be assumed to have the same condition) should be discarded because the water films (droplets) break on contact with the separator elements, generating very fine droplets that pass onward through the separators.

D.8 Clay Treatment

D.8.1 INTRODUCTION AND PURPOSE

This section describes the reason for using clay media in certain aviation fuel-handling facilities and recommends the procedure for determining when the clay media should be changed out.

D.8.2 REFERENCES

There is no known published test standard on this subject.

D.8.3 DESCRIPTION

Clay treatment vessels, where used, are located upstream of filter/separators. The clay removes surfactants from the fuel, thereby protecting the filter/separators. The clay treatment vessels are usually the element-type vessels, containing either clay bags or clay canister elements.

Surface active agents (surfactants, see Sec. A.12) can disarm elements in filter/separator vessels, thereby preventing the filter/separator from efficiently removing water from aviation fuels. The more common surfactants come from the following sources:

1. Naphthenic and sulfonic acids arise from natural components of crude oil.
2. Pipelines, transport trucks, ships, and barges can generate residuals from motor gasoline and heating oil additives that adsorb on pipe or tank walls. Pipeline corrosion inhibitors, some of which are approved additives for aviation fuel, are also weak surfactants. Biofuel residuals from transport trucks or pipelines are also sources of surfactants.
3. Maintenance materials produce soaps, detergents, and steam-cleaning residues. Rust preventatives and descaling chemicals usually are surfactants or combine to form surfactants.

Clay particles are normally 60–90 mesh in size (about 300–170/micron). Each particle is made up of hundreds of microscopic attapulgite crystals that are bound together in a porous cluster by kiln treating under carefully controlled temperature conditions.

The clay particles remove surfactants from the fuel by adsorption (adhesion of the surfactant material to the surface of the clay particles). The longer the fuel is in contact with the clay (residence time) the more efficient the clay is in removing surfactants. Normally, the bags and canisters are flow rated at about 5–7 gpm (19–27 L/min) per element. Reducing the flow rate through each clay element can, in some cases, significantly increase the life and effectiveness of the clay. In one instance, reducing the flow rate by 2 gpm (7 L/m) per element increased the time between change-outs by a factor of five.

D.8.4 EQUIPMENT

The following equipment is required for this procedure: SwIFT Kit made by Parker Velcon Filters, Colorado Springs, Colorado.

D.8.5 PROCEDURE

Various methods are used to predict when clay elements should be changed. Among these are throughput, time, and differential pressure increase across the clay vessel and comparison of filter membrane tests taken upstream and downstream of the clay vessel. None of which are reliable compared with the following preferred method.

Because clay media is used to remove surfactants, the most reliable indicator for determining when to change the clay media is a reduction in its surfactant removal efficiency. This efficiency is best obtained by periodically taking simultaneous upstream and downstream fuel samples from the clay treatment vessel and then analyzing the two samples for an indication that the surfactant level is less downstream of the clay than upstream. MSEP (see Sec. A.13) has been the most practical method to determine clay life, but less costly methods are available. IFT is one method used by the filter manufacturers to determine when clay is spent. Other field tests are available such as the SwiftKit (Parker Velcon, Colorado Springs, CO). This test is based on IFT and is a quick and cost-effective method of evaluating clay performance. Clay performance should be evaluated annually at a minimum.

D.8.6 CAUTIONS

1. The interpretations are guidelines for helping to predict when clay media should be changed. The number ratings listed are for illustrative purposes only and are not to be interpreted as either good, surfactant-free fuel or, conversely, as surfactant-laden fuel.
2. In addition to using the difference in MSEP ratings as guidelines for changing clay, the performance of the downstream filter/separator also should be monitored. If indications are that the coalescer elements are disarmed, it would be wise to assume that the clay elements upstream are in need of changing.
3. Clay elements can be disarmed by large amounts of water. In cases in which this situation could occur, it is a common practice to place a coarse water separator such as a dehydrator (hay pack) upstream of the clay treatment vessel.

D.8.7 INTERPRETATION OF TEST RESULTS

The downstream MSEP or IFT rating is compared to the upstream rating. For example, interpretations of the results might be as follows:

1. If both ratings are high (90 MSEP or above or 35 IFT or above), draw no conclusions. This indicates relatively surfactant-free fuel entering and leaving the clay treatment vessel.
2. If the upstream rating is low (80 MSEP or below or 25 IFT or below) and the downstream rating is high (90 MSEP or above or 35 IFT or above), the clay media is still effectively removing surfactants and need not be changed.
3. If the upstream rating is low (80 MSEP or below or 25 IFT or below) and the downstream rating is also low (80 or below or 25 IFT or below), the clay media is not removing surfactants and should be changed. Clay media would ideally be changed before this condition occurs.
4. If an unusual condition occurs, such as high upstream ratings but lower downstream ratings, this also can indicate a possible upset condition. For example, entrained water in the influent fuel may be "flushing out" adsorbed surfactants from the clay media. In such cases, further investigation is required.

Section E | Microbial Contamination Detection

E.1 Laboratory Methods and Field Kits

E.1.1 INTRODUCTION AND PURPOSE

This section describes accepted laboratory test methods as well as field test kits that can be used to detect microbial contamination in fuel facilities. Microorganisms can enter the fuel system in many ways and can cause a variety of problems. These problems can occur anywhere in the world. The purpose of this section is to explain the nature of the problem and to define accepted means of detection. The tests listed herein were chosen because of wide use in the industry. All possible tests are not shown. Inclusion of a test in this section does not mean to imply that it is an accepted test by any airline, aircraft manufacturer, or oil company.

Some of the test methods discussed within this document also can be found discussed in the industry documents listed in Sec. E.1.2., "References" When possible, it is strongly recommended that the user reference the industry document that is applicable to their regions of operation. Treatment of contaminated systems must be done in accordance with environmental law and the aircraft manufacturer's requirements, airline, and oil company standards. These vary.

E.1.2 REFERENCES

ASTM D6469-14, *Standard Guide for Microbial Contamination in Fuels and Fuel Systems*, ASTM International, West Conshohocken, PA, 2014, www.astm.org

ATA Specification 103, *Standard for Jet Fuel Quality Control at Airports,* Airlines for America (Air Transport Association of America), 2015, https://publications.airlines.org

EI/JIG 1530, *Quality Assurance Requirements for the Manufacture, Storage and Distribution of Aviation Fuels to Airports*, Energy Institute, London, https://www.energyinst.org

IATA, *Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks*, 5th ed., International Air Transportation Association, Quebec, Canada, www.iata.org

Passman, F. J., *Fuel and Fuel System Microbiology: Fundamentals, Diagnosis, and Contamination Control*, MNL47, ASTM International, West Conshohocken, PA, 2003, doi:10.1520/MNL47-EB

E.1.3 DESCRIPTION

Opportunities for bacteria and fungi (also referred to as "microorganisms" or "microbes") to enter the aviation fuel supply, storage, and distribution system as well as aircraft generally occur after the refining process. Although microorganisms may have entered a fuel system, water and fuel are necessary for the microbes to become viable and grow. Without meeting the minimum water requirement, microbes will become dormant (inactive) and move with the flow of fuel until a source of water is located or the fuel is consumed. In addition to water, microorganisms require a source of energy and carbon for growth and development. Aviation fuel is well suited for this because the hydrocarbon fuel becomes the source of energy and the carbon from the fuel is used for cellular growth and development. As long as water and aviation fuel are available in sufficient quantities, microbes will settle in a safe low-flow area and will secrete a biosurfactant to form an emulsion at the fuel-water interface for metabolic activities that support the growth and development of the microorganisms and biofilm.

Once established, the impact microbes can have on fuel storage tanks, delivery systems, and aircraft can vary depending on the severity of the contamination. Problems associated with microbial contamination include dark spots, growth on surfaces (spotting), clogging and disarming of coalescing filters, dark-colored water bottoms or smelly "black water," and in extreme cases, fuel tank corrosion. Uplifting microbially contaminated fuel from a fuel farm, refueling truck, or hydrant system can lead to the aircraft becoming contaminated. Once established in the aircraft fuel system, microorganisms can cause a variety of problems, including clogging of engine fuel filters, erratic fuel quantity readings in the flight deck, and corrosion of fuel tank structures and plumbing.

Microbes that are found in fuel systems are microscopic in size (typically several microns in length) and can be bacteria, yeasts, or molds; yeasts and molds are collectively referred to as fungi. These microbes are found in nature, but they can form viable colonies in fuel tanks and distribution systems. Bacteria are single-cell organisms. Some species of bacteria can survive only in the presence of oxygen (i.e., aerobic bacteria), whereas other species of bacteria can live only in the absence of oxygen (i.e., anaerobic bacteria). During conditions in which water or energy are inadequate, bacteria have the ability to become inactive (dormant) as a natural form of preservation until environmental conditions are adequate to resume metabolic activity. Fungus (sing.)/fungi (pl.) are terms used to describe single-celled microorganisms—yeast—or filamentous microorganisms—mold—that are larger than bacteria and will grow to form fungal mats. Fungi and some bacteria produce spores that are equivalent to immature and inactive reproductive cells (seeds) that germinate and grow in the presence of water. Once a spore germinates in water, fungi grow by using fuel for food, along with trace materials in the water and dissolved oxygen.

Severe microbial contamination generally can be detected without the aid of special test equipment. Characteristics such as odor or discoloration of water samples or "leopard" spotting of filter water separator coalescer elements are an indication of a microbial contamination problem. Field test kits can be used to detect microbial contamination long before microbial levels become operationally and economically severe. These test kits can be useful in a routine monitoring program that can provide an early warning sign for fuel systems in cases in which contamination from microorganisms is likely. Once microbial contamination has been detected, some test kit(s) can be used to detect the source of contamination, which often is upstream of the detection point, although this may prove elusive. Some of the test kits listed in Sec. E.1.4 are useful for trend monitoring. Microbial contamination traditionally is measured and reported as colony forming units (cfu) per unit volume of sample (i.e., litre [L] or millilitre [mL]). A sample is added to a growth medium, which is incubated for a period of several days; visible colonies of growth are allowed to develop and then are counted. In addition to the more traditional methods, rapid techniques have been developed that measure other indicators of microbial contamination.

Although microbes are nearly always present in the fuel system, if the amount of water present is low or minimized, these microbes will not proliferate and will not cause operational problems. Aviation fuel systems should be designed to facilitate the draining of all free water. Regular water draining and good housekeeping in conjunction with a well-designed scavenge system are the most practical means to minimize microbial contamination. In systems in which water is present, however, microbial proliferation is likely, and this can lead to operational problems and unacceptable levels of contamination in fuel.

Laboratory test methods and field test kits described in the remainder of this section may assist in the detection of active microbes. A brief description of each test is given. Refer to the suppliers for more detailed information.

E.1.4 PROCEDURES AND EQUIPMENT

E.1.4.1 Laboratory Test Methods

1. ASTM D6974-16, *Standard Practice for Enumeration of Viable Bacteria and Fungi in Liquid Fuels—Filtration and Culture Procedures*, West Conshohocken, PA, 2016, www.astm.org
2. IP 385-99, "Determination of the Viable Aerobic Microbial Content of Fuels and Fuel Components Boiling Below 390°C—Filtration and Culture Method," *Fuel and Fuel System Microbiology: Fundamentals, Diagnosis, and Contamination Control, MNL47,* F. J. Passman, Ed., West Conshohocken, PA, 2003, www.astm.org

ASTM D6974 and IP 385 are used to determine the viable microbial content in fuel. A fuel sample is filtered through membrane filters. Viable microbes collected on the membranes are then incubated on a growth medium. After the incubation period, the colonies are counted and reported in terms of colony forming units (cfu) per litre (L) of fuel or millilitre (mL) of water.

A number of the field test kits listed in Sec. E.1.4.2 now also are published as ASTM standard methods that can be used both in the laboratory and the field. See the following for further details.

E.1.4.2 Field Test Kits

E.1.4.2.1 Products

1. Product: Microbe Lab
   Manufacturer: ECHA Microbiology, UK
   Distributor: Eastern Petroleum Supplies Ltd.
   Tel UK: +44(0)621 773292
   Fax UK: +44 (0)621 772353
   Email: sales@easternsupplies.co.uk
   Website: www.easternsupplies.co.uk
   For Global Sales Inquiries Contact: Eastern Petroleum Supplies, Ltd.
2. Product: MicrobMonitor2® (ASTM D7978)
   Manufacturer: ECHA Microbiology Ltd., UK
   Distributors: Santex Corp.
   Tel: +772-360-4117 Fax: +772-882-3057
   Email: info@santexdirect.com
   Website: www.santexdirect.com
   Fuel Quality Services, Inc.
   Tel USA: 800-827-9790
   Fax USA: 770-967-9982
   Email: sales@fqsinc.com
   Website: www.fqsinc.com
   For Global Sales Inquiries Contact: ECHA Microbiology Ltd.
   Tel UK: +44(0)2920 365930
   Fax UK: +44(0)2920361195
   Website: www.echamicrobiology.com
3. Product: EasiCult® TTC Dip Slide (Bacterial) and M Dip Slide (Fungi)
   Manufacturer: Orion Diagnostica Finland
   Distributor: Life Sign, LLC
   Tel USA: 800-526-2125
   Fax USA: 732-246-0570
   Email: info@lifesignmed.com
   Website: www.lifesignmed.com
   For Global Sales Inquiries Contact: Orion Diagnostica Oy
   Tel: +358-10-4262390
   Fax: +358-10-426 2794
   Email: orion.diagnostica@oriondiagnostica.fi
   Website: www.oriondiagnostica.fi
4. Product: FuelStat® Resinae Plus
   Manufacturer: Conidia Bioscience, Ltd.
   Distributor: SATAIRUSA, Inc.
   Tel USA: 404-675-6333
   Fax USA: 404-675-6311
   Email: satairinq@satair.com

Website: www.conidia.com
For Global Sales Inquiries Contact:
Conidia Bioscience, Ltd.
Tel UK: +44(0)1491 829102
Fax UK: +44(0)2076 919523
Website: www.conidia.com

5. Product: HY-LiTE® Jet A-1
   Manufacturer: Merck KGaA, 64271 Darmstadt, Germany (Bitte Darmstadt und PLZ hinzufügen)
   Distributor: Fuel Quality Services, Inc.
   Tel USA: 800-827-9790
   Fax USA: 770-967-9982
   Email: sales@fqsinc.com
   Website: www.fqsinc.com
   For Global Sales Inquiries Contact:
   Merck KGaA, 64271 Darmstadt, Germany
   Fax: +49(0)615172 60 80
   Email: mibio@merckgroup.com
   Website: www.merckmillipore.com/microbiology
6. Product: Hum Bug Detector® Kit
   Hammonds Technical Services, Inc.
   Tel USA: 281-999-2900
   Fax USA: 281-847-1857
   Email: mbeldin@hammondscos.com
   Website: www.hammondscos.com
   For Global Sales Inquiries Contact:
   Hammonds Technical Services, Inc.
   Tel: USA: 281-999-2900,
   Fax USA: 281-847-1857
   Email: mbeldin@hammondscos.com
   Website: www.hammondscos.com

E.1.4.2.2 Discussion

1. The Microbe Lab is a portable microbial testing laboratory that contains a series of four tests, sterile sample bottles, training information, and literature to test fuel and water samples in the field. Contact the manufacturer or your local sale representative for more detailed product information. Following are the tests included in the Microbe Lab:
   a. The MicrobMonitor2®, which can be used to test fuels and water associated with fuel. A description of the product is provided in number 2 of this section.
   b. The dip slide is a semiquantitative test used only with water samples to determine the level of microbial contamination from aerobic bacteria and fungi. The test consists of a rectangular plastic slide that has a nutrient agar affixed to each side specific to the growth of bacteria and fungi. The test is performed by inoculating the dip slide with a water sample, incubating the dip slide in the clear sterile tube provided, and examining regularly during the recommended incubation period for microbial colonies. The numbers of colonies are estimated by comparing the dip slide to a chart.
   c. The Sig® Sulphide is a semiquantitative test used to detect anaerobic microorganisms, such as sulfate-reducing bacteria (SRB), which can cause sulfide corrosion or sulfide spoilage of fuel. The test method consists of a glass tube containing a measured volume of nutrient growth gel selective for specific anaerobic microorganisms. The test is performed by adding a measured volume of a sample to the glass tube and incubating the glass tube. The speed and extent of the gel turning black indicates the severity of SRB contamination.
   d. The Sig® Rapid WB is a semiquantitative test used to detect the presence of moderate to heavy microbial contamination from aerobic and anaerobic bacteria, yeast, and mold in fuel tank water bottoms. The test method consists of a glass tube containing a reagent tablet specific for a microbial enzyme. The test is performed by adding a known volume of sample to the glass tube and incubating the tube for 1 h. At the end of the 1-h incubation period, a color developer is added to the glass tube and a color reading is obtained by comparison to a calibration chart.
2. The MicrobMonitor2® is recommended by IATA and enables testing in accordance with standard test methods ASTM D7978 and IP 613. It is a quantitative test used to detect aerobic microorganisms in fuel and water associated with fuel. The test consists of a clear nutrient gel in a rectangular glass bottle that contains an indicator that enhances the development of microbial colonies and makes them easier to count. The test is performed by adding a known volume of sample to the test bottle, shaking the bottle to liquefy the gel, and incubating the sample. The test bottle is then examined regularly during the recommended incubation period for microbial colonies. The number of colonies are counted or estimated by comparison to a chart. Contact the manufacturer or your local sales representative for more detailed product information.
3. The EasiCult® TTC and EasiCult® M dip slides are two types of semiquantitative tests used only for water samples to determine the level of microbial contamination from aerobic bacteria and fungi, respectively. Any fuel that comes in contact with the growth media will invalidate the test. The test consists of a rectangular plastic slide that has a nutrient agar affixed on each side specific to the growth of bacteria (the TTC dip slide) and fungi (the M dip slide). Both the M and TTC slides should be used to test each sample. The test is performed by inoculating the dip slide with a water sample, incubating the dip slide in the clear sterile tube provided, and examining the sample regularly during the recommended incubation period for microbial colonies. The numbers of colonies are determined by comparing the growth on the agar to a colony density chart provided. Contact the manufacturer or your local sale representative for more detailed product information.
4. The FuelStat® resinae PLUS is a semiquantitative immunoassay test that is specifically designed to detect the presence of *Hormoconis resinae* (*H. resinae*), bacteria, and other fungi that commonly contaminate aviation fuel and water associated with aviation fuel. The test is recommended by IATA. The test consists of a paddle with three pairs of lateral

flow devices (LFD), which together produce a combination of lines when in contact with cell material and metabolites from *H. resinae*, bacteria, and other fungi. The test is performed by preparing the fuel or water sample as directed, introducing the prepared sample onto the "low" and "high" LFDs, allowing the test to undergo a reaction for 10 min and then reading the results within 30 min. The combination of lines indicates a negligible, moderate, or high positive result. Contact the manufacturer or your local sales representative for more detailed product information.

5. The HY-LiTE® Jet A-1 Fuel Test is recommended by IATA and enables testing in accordance with standard test method ASTM D7463, *Standard Test Method for Adenosine Triphosphate (ATP) Content of Microorganisms in Fuel, Fuel/Water Mixtures, and Fuel Associated Water*. It is a quantitative rapid ATP bioluminescence assay that determines the presence and intensity of metabolically active microorganisms present in fuel system samples by the number of relative light units (RLU) produced by the amount of ATP in the sample. ATP is a unique biochemical that is responsible for energy metabolism and is present in all living organisms. The test is performed by preparing the sample as directed and then transferring a small volume of the sample to a test pen that combines the microbial ATP with other chemicals associated with the pen to activate the test pen to produce light. The activated test pen is then inserted into an analyzer that quantifies and reports the light produced by the sample. The test is completed in less than 10 min and the results are directly proportional to the quantity of microbial ATP present in the sample. Contact the manufacturer or your local sales representative for more detailed product information.
6. The Hum Bug Detector® Kit is a qualitative test designed to indicate the presence or absence of microorganisms that directly utilize hydrocarbons in fuels. The test consists of a sterile sampling syringe and bottle containing a hydrocarbon phase, growth nutrient, and an indicator dye. The test is performed by injecting a sample by sterile hypodermic syringe through the rubber septum into the test bottle. The test bottle is incubated and monitored for a recommended period. If microorganisms are present, the indicator dye will turn the solution in the test bottle pink. If microorganisms are absent, the solution in the test bottle will remain clear. Contact the manufacturer or your local sale representative for more detailed product information.

E.1.5 CAUTIONS

1. Sec. A.1.1 should be consulted to ensure that representative samples are obtained. Water drain samples may give an indication of microbial growth. However, sump samples that do not contain free water may not show contamination because microorganisms live in the water layer. Samples taken from the fuel-water interface should contain the highest level of microbes.
2. Accidental contamination from outside sources during sampling and testing may give a false positive indication for the presence of microbial contamination. To protect against accidental contamination, sampling and testing conditions should be as close to sterile as possible and sample containers should be new and preferably sterile. Glass or high-density polyethylene containers are satisfactory for this purpose. For further information, please refer to ASTM D6469 or ASTM Manual 47.
3. Each of the test methods discussed in Sec. E.1.4 has performance advantages and limitations that should be taken into consideration during discussion with the test manufacturer, review of product technical literature, or discussion with a qualified microbiologist. Results obtained using different test methods are not directly comparable. For example, a rapid assay method may not correlate directly with a colony forming unit test.

E.1.6 INTERPRETATION OF TEST RESULTS

1. The test methods and the field test kits listed in Sec. E.1.4 use different technologies to detect microbial contamination. Always refer to the test instructions to interpret the results. A positive result does not necessarily indicate that microbial contamination will cause operational problems. A single positive test result always should be confirmed by a second test before any corrective actions are initiated. A second test will validate the test results and will indicate the risk of microbial contamination to equipment and downstream users.
2. Microorganisms are always present in an aviation fuel system. This generally does not pose an operational problem unless gross contamination is present. Many tests will indicate the presence of microorganisms at levels that can be considered normal. It is important to establish a baseline and track the changes in microbial contamination. The value of detecting early stages of growth is that remedial measures can be taken before an operational problem occurs. A sudden increase in microbial contamination can indicate a problem and a risk to the downstream users.
3. Trend monitoring of test data always provides more useful information than occasional spot-checks. By regularly monitoring fuel systems and trending the test results, the user can proactively observe an increase in contamination that deviates from normal baseline data, indicating the potential for increasing operational problems. A trend-monitoring program can provide valuable information regarding storage tanks and hydrant fuel systems.

Abstract

Manual 5, *Aviation Fuel Quality Control Procedures: 5th Edition* is an educational publication for entry-level fuel handling personnel. Fuel-handling jobs are not considered skilled labor, require no college, and there are no educational programs available. Some seminars address aspects of aviation fuel handling, but it is not a true "trade." The book is also meant to educate more advanced readers, who are, for example, skilled laboratory workers, but who have no knowledge of aviation fuel handling. Section A is dedicated to field tests and field sampling techniques. Section B addresses the determination of solid particulate contamination. Section C is dedicated to water detection in fuel. Section D covers aviation fuel filtration, including the correct choice of filters, and the use, inspection, and maintenance of vessels and controls. Section E is dedicated to the problem of microbes that grow in fuel systems, which feed on fuel or one another.

Keywords

density, gravity, sump, sampling, testing, jar, bucket, hydrometer, thermohydrometer, flash point, conductivity, visual, appearance, API, IP, EI, electrostatic, Microsep, WSIM, Msep, contamination, cans, shipment, surfactants, FSII, Prist, microseparometer, CI/LI, CI, refueling, membrane, gravimeteric, colormetric, Millipore, weight, solids, particulate, rust, Aqua-Dis, Aquadis, shell, hydrokit, Velcon, Aquaglo, Aqua-Glo, Casri, POZ-T, IKT, YPF, hydro-light, Gammon, D2, TCS, synthetic, teflow separator, coalescer, separator, clay treater, prefilter, slug valve, DP, delta P, Gammon Gauge, differential, differential pressure, pressure relief, air eliminator, synthetic, disarm, microbe, microbial, fungus, microbiology, fqs, echa, microbMonitor2, easiculy, fuelstat, biobor, kathon, hy-lite, srb, sulphide, atp, resinae, biocontamination

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