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Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover the determination of the electrical conductivity of aviation and distillate fuels with and without a static dissipator additive. The test methods normally give a measurement of the conductivity when the fuel is uncharged, that is, electrically at rest (known as the rest conductivity).

1.2 Two test methods are available for field tests of fuel conductivity. These are: (a) portable meters for the direct measurement in tanks or the field or laboratory measurement of fuel samples, and (b) in-line meters for the continuous measurement of fuel conductivities in a fuel distribution system. In using either type of instrument, care must be taken in allowing the relaxation of residual electrical charges before measurement and in preventing fuel contamination. For specification purposes, conductivity measurements should be made with the portable meters.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 7.1, 7.1.1, and 11.2.1.

2. Referenced Documents

2.1 ASTM Standards:

D 4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination²

D 4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter²

¹ These test methods are under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and are the direct responsibility of Subcommittee D02.J on Aviation Fuels.

In the IP, these test methods are under the jurisdiction of the Standardization Committee.

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² *Annual Book of ASTM Standards*, Vol 05.02.

3. Terminology

3.1 Definitions:

3.1.1 *picosiemens per metre, n*—the unit of electrical conductivity is also called a conductivity unit (CU). A siemen is the SI definition of reciprocal ohm sometimes called mho.

$$1 \text{ pS/m} = 1 \times 10^{-12} \Omega^{-1} \text{ m}^{-1} = 1 \text{ cu} = 1 \text{ picomho/m} \quad (1)$$

3.1.2 *rest conductivity, n*—the reciprocal of the resistivity of uncharged fuel in the absence of ionic depletion or polarization.

3.1.2.1 *Discussion*— It is the electrical conductivity at the initial instant of current measurement after a d-c voltage is impressed between electrodes.

4. Summary of Test Methods

4.1 A voltage is applied across two electrodes in the fuel and the resulting current expressed as a conductivity value. With portable meters, the current measurement is made almost instantaneously upon application of the voltage to avoid errors due to ion depletion. Ion depletion or polarisation is eliminated in dynamic monitoring systems by continuous replacement of the sample in the measuring cell. The procedure, with the correct selection of electrode size and current measurement apparatus, can be used to measure conductivities from 1 pS/m or greater. The commercially available equipment referred to in these methods covers a conductivity range up to 2000 pS/m with good precision (see Section 12), although some meters can only read to 500 or 1000 pS/m.

4.1.1 The EMCEE Model 1152 Meter is available with expanded ranges but the precision of the extended range meters has not been determined. If it is necessary to measure conductivities below 1 pS/m, for example in the case of clay treated fuels or refined hydrocarbon solvents, Test Method D 4308 should be used.

5. Significance and Use

5.1 The ability of a fuel to dissipate charge that has been generated during pumping and filtering operations is controlled by its electrical conductivity, which depends upon its content of ion species. If the conductivity is sufficiently high, charges

dissipate fast enough to prevent their accumulation and dangerously high potentials in a receiving tank are avoided.

PORTABLE METER METHOD

6. Apparatus

6.1 *Conductivity Cell and Current-Measuring Apparatus*—Because hydrocarbon conductivities are extremely low compared to aqueous solutions, special equipment that is capable of giving an almost instantaneous response with application of voltage is needed.^{3,4}

6.2 *Thermometer*, having a suitable range for measuring fuel temperature in the field. A thermometer holder should be available so that the temperature can be directly determined for fuel in bulk storage, rail tank cars, and trucks.

6.3 *Measuring Vessel*—Any suitable cylindrical vessel capable of holding sufficient fuel to cover the electrodes of the conductivity cell. For the equipment referred to in Footnote 3, a minimum volume of 1 L is required.

7. Reagents and Materials

7.1 *Cleaning Solvents*—Use isopropyl alcohol if water is suspected (**Warning**—Flammable.) followed by analytical grade toluene. (**Warning**—Flammable. Vapor harmful.)

7.1.1 A mixture of 50 % volume analytical grade isopropanol and 50 % volume analytical grade heptane (**Warning**—Flammable. Vapor harmful.) is a satisfactory substitute for toluene.

8. Sampling

8.1 Fuel conductivity measurements should be made in situ or at the point of sampling to avoid changes during sample shipment. If it is necessary to take samples for subsequent analysis, the following precautions should be taken:

8.1.1 If the cell is in contact with water and the instrument is switched on, an immediate offscale reading will be obtained. If the cell has been in contact with water, it shall be thoroughly rinsed with cleaning solvent, preferably isopropyl alcohol, and dried with a stream of air. In hot, humid conditions, condensation on the cell can occur, which can cause abnormally high zero, calibration and sample readings. This can be avoided by storing the cell at a temperature 2 to 5°C in excess of the maximum ambient temperature where this is practicable.

8.2 The sample size should be as large as practicable, and not less than 1 L.

8.3 The conductivity of fuels containing static dissipator additives is affected by sunlight and other strong light sources. Samples in clear glass containers may experience significant conductivity loss within 5 min of sunlight exposure. See Test Method D 4306 for further discussion.

NOTE 1—Test method results are known to be sensitive to trace contamination from sampling containers. For recommended sampling

³ The following equipment, as listed in RR:D02-1161 and RR:D02-1476, was used to develop the precision statements. Models 1150, 1151, and 1152 from Emcee Electronics, Inc., 520 Cypress Ave., Venice FL 3429; Maihak Conductivity Indicator and MLA 900 from Maihak AG, Poppenbueteler Bogen 9b, D-22399 Hamburg Germany. This is not an endorsement or certification by ASTM.

⁴ The older style Maihak Conductivity Indicator (Annex A1) and the Emcee Model 1151 are no longer in production.

containers refer to Practice D 4306.

8.4 All sample containers should be thoroughly cleaned with cleaning solvent and dried with a stream of air. Prior to taking the samples, all containers, including caps, should be rinsed at least three times with the fuel under test.

8.5 Conductivity measurements should be made as soon as possible after sampling and preferably within 24 h.

9. Cleaning Procedures

9.1 If the cell is in contact with water and the instrument is switched on, an immediate offscale reading will be obtained. If the cell has been in contact with water, it shall be thoroughly rinsed with cleaning solvent, preferably isopropyl alcohol, and dried with a stream of air. The meter may display a non-zero reading caused by condensation forming on the cell when the meter is taken from a cool, dry environment and subjected to hot, humid conditions. This condition can be avoided by storing the cell at a temperature 2 to 5°C in excess of the ambient temperature, when practicable.

9.2 In normal use, the probe on hand-held instruments should be cleaned with toluene or a mixture of heptane and isopropanol and air-dried after use, to ensure that ionic materials absorbed on the probe during previous tests will not contaminate the sample and give an erroneous result.

10. Calibration

10.1 The calibration procedure will be dependent upon the equipment used. The procedures for the instruments listed in Footnote 3 are described in Annex A1, Annex A2, Annex A3, and Annex A4.

11. Procedure

11.1 The specific instrument calibration procedures detailed in Annex A1, Annex A2, Annex A3, and Annex A4 are an essential part of the following generalized procedures. The appropriate calibration steps for the instrument used should be followed prior to commencing the subsequent procedures.

11.2 *In Situ Field Measurement on Tanks, Tank Cars, Tank Trucks, etc.*—For field measurements the conductivity meters referred to in Footnote 3 are considered suitable. The use of these meters in hazardous locations may be restricted by the regulatory agency having jurisdiction. Each has an extension cable or can be equipped with one to lower the cell into the tank. High impedance hand held meters are susceptible to electrical transients caused by extension cable flexing during measurements. Failure to hold the apparatus steady during measurement can result in significantly poorer precision than shown in Table 1. The following instructions apply to the meters referenced in Footnote 3.

11.2.1 Check meter calibration as detailed in Annex A1, Annex A2, or Annex A4, depending on the meter used. Bond the meter to the tank and lower the conductivity cell into the tank to the desired level taking care to avoid partial immersion or contact with tank water bottoms, if present. Move the conductivity cell in an up-and-down motion to remove previous fuel residues. (**Warning**—To prevent static discharge between a charged fuel and a conductive probe inserted into a tank, the appropriate safety precautions of bonding and waiting for charge dissipation should be observed. For example, the

TABLE 1 Precision^A

Conductivity, pS/m	Repeatability	Reproducibility
1	1	1
15	1	3
20	1	4
30	2	6
50	3	10
70	4	13
100	5	17
200	10	32
300	14	45
500	21	69
700	29	92
1000	39	125
1500	55	177

^A The precision limits in Table 1 are applicable at room temperature; significantly higher precision ($\times 2$) may be applicable at temperatures near -20°C .

American Petroleum Institute in RP 2003 recommends that a 30-min interval be allowed after pumping into a storage tank before an operator mounts a tank to insert a sampling device. This will also ensure that the fuel is electrically at rest.)

11.2.2 After flushing the cell, hold it steady and after activating the instrument record the highest reading after initial stabilization. This should occur within 3 s. On instruments with more than one scale range, select the scale that gives the greatest sensitivity for the conductivity value being determined. Ensure that the appropriate scale multiplying factor (or scale range) is used. Record the fuel temperature.

11.3 *Laboratory and Field Measurements on Sampled Fuels:*

11.3.1 *Preparation of Containers (Metal or Glass)*—Prior to taking samples, take extreme care to ensure that all containers and measuring vessels have been thoroughly cleaned. It is preferable that containers are laboratory cleaned prior to shipment to the field for sampling (see Section 8).

11.3.2 *Measurement*—Rinse the conductivity cell thoroughly with the fuel under test to remove fuel residues remaining on the cell from previous tests. Transfer the fuel to the measuring vessel and record the conductivity of the fuel using the procedure applicable to the particular apparatus. If one of the conductivity meters referenced in Footnote 3 is used, follow these instructions: Rinse the cell concurrently with the rinsing of the measuring vessel. Then transfer the sample to be tested to the clean, rinsed measuring vessel. Check meter calibration as detailed in Annex A1 or Annex A2, depending on the meter used. Fully immerse the conductivity cell into the test fuel and measure the conductivity following the procedure in 11.2.2 and the appropriate Annex. Record the fuel temperature.

NOTE 2—In order to avoid erroneous readings, it is important to ensure that the bottom of the conductivity cell does not touch the sample container. This is applicable to all containers, whatever the material of construction.

NOTE 3—When using an analog meter, measurements exceeding the range of the meter are obvious. With the Emcee Digital Meter and the Maihak MLA 900 Meter, measurements exceeding the range of the meter are indicated by a single digit “1” in the left side of the display where 1000s are shown. A qualitative conductivity estimate (for which precision has not been established) can be made by inserting the probe in the sample to the first set of holes closest to the tip, which are at the mid point of the sensing portion of the probe. Since the displayed conductivity is inversely proportional to the depth of immersion, the value displayed, if any, should

be doubled. Conductivities less than 1 pS/m up to 20 000 pS/m can be determined using Test Method D 4308.

12. Report

12.1 Report the electrical conductivity of the fuel and the fuel temperature at which measurement was made. If the electrical conductivity reads zero on the meter, report less than 1 pS/M.

NOTE 4—It is recognized that the electrical conductivity of a fuel varies significantly with temperature and that the relationship differs for various types of aviation and distillate fuel. If it is necessary to correct conductivity readings to a particular temperature, each laboratory would have to establish this relationship for the fuels and temperature range of interest. Refer to Appendix X2 for additional information of the effect temperature has on the electrical conductivity of fuels.

13. Precision and Bias⁵

13.1 The precision of this test method as determined by statistical analysis of test results obtained by operator–instrument pairs at a common test site is as follows. The precision data generated for Table 1 did not include any gasolines or solvents.

NOTE 5—A precision program is being considered to develop a single precision statement for all portable meters.

13.1.1 *Repeatability*—The difference between successive measured conductivity values obtained by the same operator with the same apparatus under constant operating conditions on identical test material at the same fuel temperature would, in the long run, in the normal and correct operation of the test method, exceed the values in Table 1 only in one case in twenty.

13.1.2 *Reproducibility*—The difference between two single and independent measurements of conductivity obtained by different operators working at the same location (13.2) on identical test material at the same fuel temperature would, in the long run, in the normal and correct operation of the test method, exceed the values in Table 1 only in one case in twenty.

13.2 In 1987, a test program was carried out to investigate reproducibility of results when samples are shipped between laboratories. (See Appendix X1.)⁶ While repeatability values were similar to those in Table 1, it was concluded that adequate reproducibility values were not obtained due to changes in conductivity of samples during shipment and storage. In the event of dispute or concern regarding shipped sample conductivity, it is recommended that operators come to the bulk fuel storage site to measure conductivity on bulk fuel or on freshly obtained samples according to cited procedures. This assures that a sample identical to the bulk supply is tested by either or both parties and the precision data shown in Table 1 shall apply.

⁵ Supporting data can be obtained from ASTM Headquarters. Request RR:D02-1013, RR:D02-1476, and RR:D02-1161. RR:D02-1161 gives details of data by the IP which resulted in the data in Table 1 for the Maihak Conductivity Indicator and the Emcee Digital Conductivity Meter. The data in RR:D02-1476 support the precision for the Maihak MLA-900.

⁶ Refer to Appendix X1 for a summary of the data and conclusions from this program on file at ASTM Headquarters. Request RR:D02-1235.

13.3 The Maihak MLA 900 meter provides a sample temperature measurement. The precision of this temperature measurement has not been established.

13.4 *Bias*—Since there is no accepted reference material or test method for determining the bias of the procedure in Test Methods D 2624 for measuring electrical conductivity, bias cannot be determined.

CONTINUOUS IN-LINE CONDUCTIVITY MONITOR METHOD

14. Apparatus ⁷

14.1 Continuous measurements can be made where suitable precautions have been taken to remove static charges before the representative fuel stream is passed through the in-line measuring cell. A controlled, continuous flow through the cell prevents ion depletion, thereby providing the equivalent of rest conductivity as a continuous measurement.

15. Installation

15.1 In general, the equipment is designed for permanent installation in the fuel distribution system. Follow the manufacturer's recommendations concerning installation and flow control, particularly with respect to the provision of adequate relaxation time. Install the sample tapping point at least 30 m downstream of any additive injection system, unless a mixing device is used which has been shown to give adequate mixing of the additive concerned prior to sampling. A thermometer having a suitable range for measuring fuel temperature in the field should be installed downstream of the test cell.

16. Calibration

16.1 The specific calibration procedure detailed in Annex

⁷ The following continuous measuring equipment has been found to meet the stated precision for this test method: Model 1150 Staticon Conductivity Monitor and injection system, manufactured by Emcee Electronics, 520 Cypress Ave., Venice, FL 34292.

A4 is an essential part of the general procedure and should be completed prior to initiating automatic monitoring and control of continuous fuel streams. If fitted, the high- and low-level alarm circuits should be calibrated as recommended by the manufacturer.

17. Procedure

17.1 Flush the cell thoroughly by initiating a controlled flow of the fuel to be measured. Purging of air from the cell and adequate flushing is normally achieved in a few minutes but a longer flush is recommended when calibrating the instrument. The controlled flow must conform to the manufacturer's recommendation. Too fast or too slow a flow will result in inaccuracies in the conductivity measurement.

18. Measurement

18.1 After calibration, select the instrument scale of the approximate range anticipated for the fuel stream and initiate continuous measurements of fuel conductivity. Make measurements at the test cell temperature (indicated by the installed thermometer), which should approximate the temperature of the fuel in the system.

19. Report

19.1 Report the electrical conductivity of the fuel and the fuel temperature at which measurement was made (see Note A1.1).

20. Precision and Bias

20.1 *Repeatability* of the continuous meter has been established to be within the range given for the portable instruments (see 13.1.1).⁵

20.2 *Reproducibility* has not been established.

20.3 *Bias*—Since there is no accepted reference material or test method for determining the bias of the procedure in this test method, bias cannot be determined.

21. Keywords

21.1 aviation fuels; conductivity meter; conductivity unit; distillate fuels; electrical conductivity; picosiemens per meter; rest conductivity; static dissipator additives; static electricity

ANNEXES

(Mandatory Information)

A1. CALIBRATION OF THE MAIHAK METER (Analog Type)

A1.1 Before carrying out the calibration procedure the conductivity cell must be clean and dry (Note 4 in Test Method D 2624).

A1.2 The Maihak meter has been built in four models or series with different characteristics. The corresponding instrument numbers are as follows:

Series	Instrument Number
1	64001 to 64068, 64070
2	64069, 64071 to 64171
3	Prefix 2-
4	Prefix 3-

Series 2 and 3 instruments should have been subsequently modified with parts supplied by the manufacturer; in this case, the instrument numbers bear the suffix "M."

A1.3 *Checking the Calibration*—To check the calibration reading, press the green READ button with the conductivity cell in the rest position against the calibration resistor in the housing. A meter reading of 465 ± 10 pS/m should be obtained. For confirmation press the red 2X button and then also the green READ button, as above. The meter should read 232 ± 10 pS/m.