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An American National Standard



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## Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels<sup>1</sup>

This standard is issued under the fixed designation D2624; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*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: (1) portable meters for the direct measurement in tanks or the field or laboratory measurement of fuel samples, and (2) in-line meters for the continuous measurement of fuel conductivities in a fuel distribution system. In using portable meters, care must be taken in allowing the relaxation of residual electrical charges before measurement and in preventing fuel contamination.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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:*<sup>2</sup>

D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination

D4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter

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

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 dc voltage is impressed between electrodes, or a measure of the average current when an alternating current (ac) voltage is impressed.

### 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 polarization is eliminated in dynamic monitoring systems by continuous replacement of the sample in the measuring cell, or by the use of an alternating voltage. 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

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and are the direct responsibility of Subcommittee D02.J0.04 on Additives and Electrical Properties.

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

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard.

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 and~~ D-2 Inc. Model JF-1A-HH are 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 D4308 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.<sup>3,4</sup>

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.

NOTE 1—The Emcee Model 1153 ~~and~~ D-2 Inc. Model JF-1A-HH measures and stores the sample temperature during the test cycle.

6.3 *Measuring Vessel*—Any suitable vessel capable of holding sufficient fuel to cover the electrodes of the conductivity cell.<sup>3</sup>

## 7. Reagents and Materials

7.1 *Cleaning Solvents*—Use isopropyl alcohol (**Warning**—Flammable) if water is suspected 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 (see 6.3).

8.3 The conductivity of fuels containing static dissipator additives is affected by sunlight and other strong light sources. Samples in clear glass containers can experience significant conductivity loss within 5 min of sunlight exposure. See Practice D4306 for further discussion.

NOTE 2—Test method results are known to be sensitive to trace contamination from sampling containers. For recommended sampling containers refer to Practice D4306.

~~8.4~~ **8.4** Prior to taking the samples, all sample containers, including caps, shall be rinsed at least three times with the fuel under test. Used containers should be thoroughly cleaned with cleaning solvent, if necessary, in accordance with D4306, paragraph 6.6, and air dried.

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

<sup>3</sup> The following equipment, as listed in RR:D02-1161, RR:D02-1476, RR:D02-1575, and ~~RR:D02-1575~~; RR:D02-1680 was used to develop the precision statements. Models 1150, 1151, 1152, and 1153 from Emcee Electronics, Inc., 520 Cypress Ave., Venice FL 3429; 34285; Maihak Conductivity Indicator and MLA 900 from ~~Maihak AG, Poppenbuetteleer Bogen 9b, D-22399 Hamburg Germany~~; MBA Instruments GmbH, Friedrich-List-Str 5, D-25451 Quickborn, Model JF-1A-HH from D-2 Incorporated, 19 Commerce Park Road, Pocasset, MA 02559. This is not an endorsement or certification by ASTM. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

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

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 handheld 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 A5~~ Annex A1-Annex A7.

## 11. Procedure

11.1 The specific instrument calibration procedures detailed in Annex A1-Annex A5 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~~ The EMCEE 1152 and Malik MLA 900 have 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, Annex A4, ~~or~~, Annex A5, or Annex A7, 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 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.

~~NOTE 3—The Emcee Model 1153 automatically measures and records the reading at 3 s. 3—The Emcee Model 1153 automatically measures and records the reading at 3 s. The D-2 Model JF-1A-HH Samples 10 times upon activation, allow the center bar indicator on the display to come to center which indicates the current reading has repeated, once repeated press the sample button again to display the conductivity, temperature data and store the data to the instruments memory.~~

### 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).

**TABLE 1 Precision<sup>A</sup> of Emcee Models 1150, 1151, 1152, and 1153 and Maihak Indicator**

Conductivity, pS/m	Repeatability <sup>B</sup>	Reproducibility <sup>C</sup>
1	1	1
15	6	3
20	7	4
30	9	6
50	13	10
70	15	13
100	19	17
200	29	32
300	37	45
500	51	69
700	62	92
1000	77	125
1500	98	177

<sup>A</sup> The precision limits in Table 1 are applicable at room temperatures; significantly higher precision (×2) may be applicable at temperatures near –20°C.

<sup>B</sup> The repeatability values were calculated from a November 2004 Round Robin program. The precision study reported in RR:D02-1575 was carried out with random, rather than sequential, testing of repeat testing of the same samples. This resulted in significant increases in repeatability.

<sup>C</sup> The data used to calculate reproducibility is given in RR:D02-1161.

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, Annex A2, ~~or~~, Annex A5, or Annex A7, 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 4—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 5—When using an analog meter, measurements exceeding the range of the meter are obvious. With the Emcee Model 1152 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. The D-2 Model JF-1A reports to the display the text, “Reading Out of Range.” 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 D4308. When using the Emcee Model 1153 Digital Meter, measurements exceeding the range of the meter “OVER” will be displayed.

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 6—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 Bias <sup>5</sup>

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. The precision data given in Table 1 are presented in Fig. 1 for ease of use.

NOTE 7—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.

<sup>5</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report 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 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. The data in RR:D02-1680 support the precision for the D-2 Model JF-1A-HH.

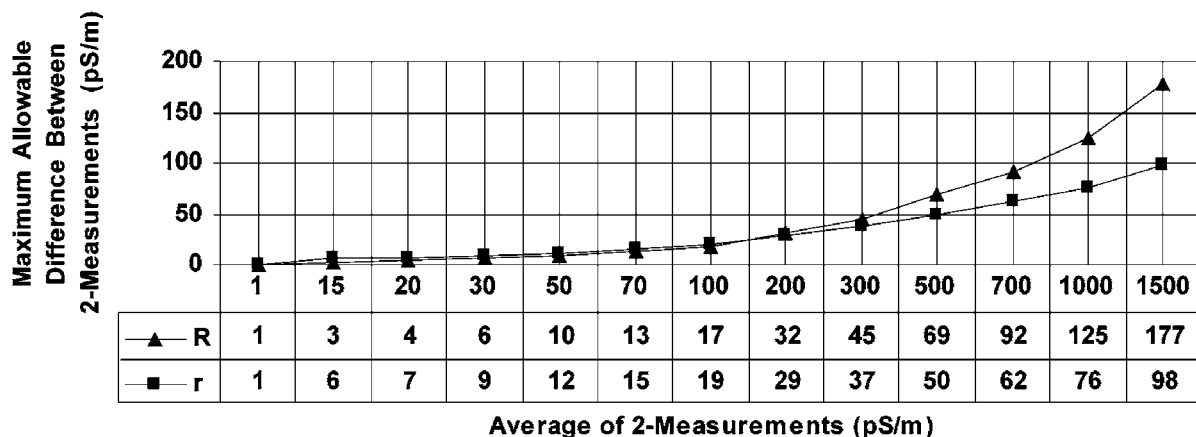


FIG. 1 Graphic Presentation of Table 1’s Precision

13.2 In 1987, a test program was carried out to investigate reproducibility of results when samples are shipped between laboratories. (See Appendix X1.)<sup>6</sup> 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.

~~13.3 The Maihak MLA 900 meter provides a sample temperature measurement. The precision of this temperature measurement has not been established. Precision of the Maihak MLA 900 is shown in~~

13.3 The Maihak MLA 900 Emcee Model 1153, and meters provide a sample temperature measurement. Precision of the Maihak MLA 900 is shown in Table 2. Precision of the D-2 Inc. Model JF-1A-HH is shown in Table 3.

13.4 *Bias*—Since there is no accepted reference material or test method for determining the bias of the procedure in Test Methods D2624 for measuring electrical conductivity, bias cannot be determined.

## CONTINUOUS IN-LINE CONDUCTIVITY

### 14. Apparatus <sup>7</sup>

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 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.

<sup>6</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1235.

<sup>7</sup> 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 34285. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

**TABLE 2 Precision<sup>A</sup> of Maihak MLA 900 Meter**

Conductivity, pS/m	Repeatability	Reproducibility
1	0	0
15	2	2
20	2	2
30	3	3
50	5	5
70	7	7
100	9	9
200	17	16
300	23	22
500	36	34
700	47	46
1000	64	61
1500	89	86

<sup>A</sup> The precision limits in Table 2 are applicable at room temperature; significantly higher precision ( $\times 2$ ) may be applicable at temperatures near  $-20^{\circ}\text{C}$ .



**TABLE 3 Precision A<sup>A</sup> of D-2 Incorporated JF-1A-HH**

Conductivity, pS/m	Repeatability	Reproducibility
1	1	1
15	6	6
20	7	7
30	8	8
50	10	10
70	12	12
100	15	15
200	21	21
300	26	26
500	33	33
700	39	39
1000	47	37
1500	57	57

<sup>A</sup> The precision limits in Table 2 are applicable at room temperature; significantly higher precision (×2) may be applicable at temperatures near –20°C.

## 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*—Repeatability of the continuous meter has been established to be within the range given for the portable instruments (see 13.1.1).<sup>5</sup>

20.2 *Reproducibility*—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. Apparatus<sup>8</sup>

21.1 Continuous measurements can be made using a sensor that utilized alternating current measurement technique. In this type of instrument, the constant rotation of the applied electric field prevents the formation of polarization impedances on the electrodes. The sensor then yields the equivalent of dc-type resting conductivity readings.

## 22. Installation

22.1 The JF-1A sensor should be used as specified in the “Installation and Safe Use Manual, Ref. A440–010” that is provided with the instrument. The JF-1A has an integral temperature measurement channel.

## 23. Calibration

23.1 The specific calibration procedure detailed in Annex A6 is an essential part of the general procedure and should be completed prior to initiating automatic monitoring and control of continuous fuel streams.

## 24. Procedure

24.1 Use instrument in accordance with the manufacturer’s procedures (see item 22).

## 25. Measurement

25.1 Model JF-1A provides means to read a 4 to 20 mA current loop output that is proportional to conductivity and a second loop output that is proportional to fuel temperature. Alternately, serial ASCII data is available for direct interface to a computer or other logging device.

NOTE 8—Current loop outputs are nominally scaled to 0 to 500 pS/m. The unit can be field programmed for other ranges up to 0 to 2000 pS/m.

## 26. Report

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

<sup>8</sup> The following continuous measuring equipment has been found to meet the stated precision for this test method: Model JF-1A Conductivity Sensor, manufactured by D-2 Incorporated, 21A Commerce Park Rd., Pocasset, MA 02559. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.