


 Designation: D 2624 - 95


 Designation: 274/95

Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels¹

This standard is issued under the fixed designation D 2624; 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 (ϵ) indicates an editorial change since the last revision or reapproval. This is also a Standard of the Institute of Petroleum issued under the fixed designation IP 274. The final number indicates the year of last revision.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by 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 Notes 1, 2, and 5.*

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

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.

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 11), 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.

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.

Current edition approved Sept. 10, 1995. Published November 1995. Originally published as D 2624 - 67 T. Last previous edition D 2624 - 94.

² Annual Book of ASTM Standards, Vol 05.02.

PORTABLE METER METHOD

6. Apparatus

6.1 *Conductivity Cell and Current-Measuring Apparatus*—Any equipment capable of giving a conductivity reading almost instantaneously with the application of the voltage.³

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—See Note 1.) followed by analytical grade toluene. (Warning—See Note 2.)

NOTE 1: Warning—Flammable.

NOTE 2: Warning—Flammable. Vapor harmful.

7.1.1 A mixture of 50 % volume analytical grade isopropanol and 50 % volume analytical grade heptane (Warning—See Note 2) is a satisfactory substitute for toluene.

8. Calibration

8.1 The calibration procedure will be dependent upon the equipment used. The procedures for the instruments listed in Footnote 3 are described in Annexes A1 and A2.

9. Sampling

9.1 Fuel conductivity measurements should be made *in situ* to avoid changes during sample shipment. If it is necessary to take samples for subsequent analysis, the following precautions should be taken:

9.1.1 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.

³ The following portable equipment has been found satisfactory for this purpose:

(a) Maihak MLA Conductivity Indicator, manufactured by H. Maihak, 2000 Hamburg 60, Postfach 601709, W. Germany; the U. S. agent is Ampower Corp., 7700 Marene Rd., North Bergen, NJ 07047; the U. K. agent, Smail Sons & Co. Ltd., 129 Whitefield Road, Glasgow SW1, Scotland.

(b) Ethyl Distillate Conductivity Meter, Models 8150 and 8151 manufactured by Ethyl Corp., 19 Roszel Rd, Princeton, NJ 08540. These meters are no longer available. However, calibration procedures for the existing meters can be obtained from the manufacturer.

(c) Emcee Conductivity Meter, Models 1151A and 1152, manufactured by Emcee Electronics, Inc., 520 Cypress Ave., Venice, FL 34292. The Model 1151A is no longer available. However, calibration for the existing meters can be obtained from the manufacturer.

9.1.2 The sample size should be as large as practical and not less than 1 L.

NOTE 3—Test method results are known to be sensitive to contamination from sampling containers. For recommended sampling containers refer to Practice D 4306.

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

9.1.4 Conductivity measurements should be made as soon as possible after sampling and preferably within 24 hours.

10. Procedure

10.1 The specific instrument calibration procedures detailed in Annexes A1 and A2 are an essential part of the following generalized procedures. The appropriate calibration steps for the instrument used should be followed before commencing the subsequent procedures.

10.2 *In Situ Field Measurement on Tanks, Tank Trucks, etc.*—For field measurements the conductimeters referred to in Footnote 3 are considered suitable for use in hazardous locations only if approved by the regulatory agency having jurisdiction. Each meter should be equipped with one to two meters extension cable or can be equipped with one to two meters extension cable into the tank. High impedance hand held meters are susceptible to electrical transients caused by external electrical flexing during measurements. Failure to hold the meter steady during measurement can result in significant loss of precision than shown in Table 1. The following instructions apply to the meters referenced in Footnote 3.

10.2.1 Check meter calibration as detailed in Annexes A1 and A2, 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. Contact with tank water bottoms, if present, will cause a conductivity cell in an up-and-down motion to give erroneous previous fuel residues.

NOTE 4: Caution—To prevent static discharge between the fuel and a conductive probe inserted into a tank, the appropriate precautions of bonding and waiting for charge dissipation should be observed. For example, the American Petroleum Institute recommends that a 30-min interval be allowed after pump storage tank before an operator mounts a tank to insert a device. This will also ensure that the fuel is electrically at rest.

10.2.2 After flushing the cell, hold it steady.

TABLE 1 Precision^a

Conductivity, pS/m	Repeatability	Reproducibility
1	1	
15	1	
20	1	
30	2	
50	3	
70	4	
100	5	
200	10	
300	14	
500	21	
700	29	
1000	39	1
1500	55	1

^a The precision limits in Table 1 are applicable at room temperature. Slightly higher precision (x2) may be applicable at temperatures near room temperature.

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.

10.3 Laboratory and Field Measurements on Sampled Fuels:

10.3.1 *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 9).

10.3.2 *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 A2, depending on the meter used. Fully immerse the conductivity cell into the test fuel and measure the conductivity following the procedure in 10.2.2 and the appropriate Annex. Record the fuel temperature.

NOTE 5—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.

11. Report

11.1 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.

12. Precision and Bias⁴

12.1 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.

12.1.1 *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.

12.1.2 *Reproducibility*—The difference between two single and independent measurements of conductivity obtained by different operators working at the same location (12.2) 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.

12.2 In 1987, a test program was carried out to investigate reproducibility of results when samples are shipped between laboratories. (See Appendix X1.)⁵ 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.

12.3 *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

13. Apparatus⁶

13.1 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.

14. Installation

14.1 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.

15. Procedure

15.1 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

⁵ Refer to Appendix X1 for a summary of the data and conclusions from this program on file at ASTM Headquarters. Request RR:D02-1235.

⁶ The following continuous measuring equipment has been found satisfactory for this purpose: Staticon Conductivity Monitor. Manufactured by Emcee Electronics, 520 Cypress Avenue, Venice, FL 34292.

⁴ Supporting data can be obtained from ASTM Headquarters. Request RR:D02-1013 and RR:D02-1161. The second report is details of data by the IP which resulted in the data in Table 1.

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.

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. Measurement

17.1 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.

18. Report

18.1 Report the electrical conductivity of the fuel and fuel temperature at which measurement was made (see 7).

19. Precision and Bias

19.1 *Repeatability* of the continuous meter has established to be within the range given for the pointers instruments (see 12.1.1).⁴

19.2 *Reproducibility* has not been established.

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

20. Keywords

20.1 aviation fuels; conductivity meter; conductivity; distillate fuels; electrical conductivity; picosiemens; meter; rest conductivity; static dissipator additives; 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.

A1.3.1 To check the live zero reading, lift the conductivity cell slightly in the housing to break contact with the calibration resistor. Press the green READ button. Repeat

while pressing the red 2X button. For Series 3 instruments a reading of zero should be obtained. For Series 1 and 2 instruments a positive reading of about 10 pS/m should be obtained. This value must be subtracted from all measured conductivity readings. If readings at these limits are not obtained, the instrument requires servicing.

NOTE A1.1—If the pointer of the meter oscillates during measurement, it is likely that the battery needs replacing.

A1.4 *Verifying Performance of the Meter*—Fully immerse the conductivity cell into the test fuel, hold it steady, then press the green READ button and record the high reading after the needle has recovered from the overshoot caused by inertia. The initial recovery should exceed 20 pS/m and will be completed in less than 10 s. Conductivities in the range from 500 to 1000 pS/m the red 2X button should be pressed and kept pressed while the green READ button is pressed. Multiply the resultant scale reading by 2 to obtain the correct conductivity reading. This technique is also applicable for conductivities less than 500 pS/m (as a check on the direct reading.)

NOTE A1.2—It has been found that the early series instruments do not work properly at very low ambient temperatures. However, Series 1 and 4 instruments operate satisfactorily at temperatures down to -40°C provided that the exposure time is limited to 30 min maximum.

A2. CALIBRATION OF THE EMCEE CONDUCTIVITY METER (Digital Type)

Model 1152

A2.1 Connect the probe to the connector on the Emcee Digital Conductivity Meter and depress the MEASURE switch (M) with the probe out of the fuel sample. Zero reading should be 000 ± 001 (in approximately 3 s).

A2.2 If the instrument does not meet the specification, remove the probe and depress MEASURE switch (M). If the instrument meets the specification without the probe attached, the probe should be thoroughly rinsed with isopropyl alcohol and allowed to air dry before retesting for zero. If the instrument does not meet the specification without the probe attached, then the adjustment procedure of A3.4 should be performed.

A2.3 Note the calibration number stamped on the probe. Depress the CALIBRATION switch (C) with the probe out

of the fuel sample. The reading should be ten times the number stamped on the probe ± 0.005 (after approximately 3 s). For example: Probe number equals 40, meter reading must be 400 ± 005 (395 to 405). If instrument does not meet specification, proceed to A2.5.

A2.4 Zero adjustment is performed without the probe attached and the MEASURE switch (M) depressed. Insert a screwdriver in the hole marked "Zero" and adjust the control until the DISPLAY reads 000 ± 001 .

A2.5 Calibration is performed without the probe attached and with the CALIBRATION switch depressed. Insert a screwdriver in the hole marked "CALIBRATE" and adjust to within ± 002 of ten times the number stamped on the probe.

A3. CALIBRATION OF THE STATICON CONDUCTIVITY MONITOR

Model 1150 (In-Line)

A3.1 Before carrying out the calibration procedure, flush the installed conductivity cell and adjust the fuel flow to the recommended level.

A3.2 Before calibrating, turn the power switch to ON and adjust the meter to zero as directed. Turn the function switch to CALIBRATE. Press the meter button and read. The meter should indicate 100 pS/m on each of three scales. If not, adjust as instructed. Turn the function switch to LOW

ALARM, adjust the alarm level as required. The optional high-level alarm may be calibrated in a similar manner on monitors fitted with this equipment. Turn the function switch to OPERATE and lift the reset switch. (The alarm light will go out.) The recorder will then indicate the conductivity of the fuel stream. The alarm will be activated and the pumping circuits disabled if the conductivity drops below (or above) the preset level.

APPENDIXES

(Nonmandatory Information)

X1. DISCUSSION OF PRECISION STATEMENTS—TESTS CONDUCTED AT A COMMON SITE VERSUS DIFFERENT LOCATIONS (RR:D02-1235)

X1.1 *Purpose of Test Program*—A round-robin test program⁵ was conducted to determine if the precision of the test method is affected when samples are shipped to different laboratories for testing.

X1.2 *Background:*

X1.2.1 From past test programs such as the one documented in RR:D02-1013 (9/11/75), it was determined samples may change as a function of time. Therefore, the precision statement in Test Methods D 2624 - 89 was calculated from data obtained at a common test site. The basis for the precision data was developed in a cooperative test program carried out on October 28, 1981, at the Mobil Paulsboro laboratory. These data are reported in RR:D02-1161, dated June 1982, and were further analyzed by the IP to result in the precision statement data for repeatability and

reproducibility shown in Test Methods D 2624 - 89.

X1.2.2 The question still remained, however, of whether the judgment that samples shipped to various laboratories would not be "identical" was substantially correct. A cooperative test program was therefore organized to evaluate the precision of Test Methods D 2624 when samples were shipped between laboratories. The test program was conducted in 1987, and documented in RR:D02-1235.

X1.3 *Test Program:*

X1.3.1 In the 1987 program, ten fuels of various types were prepared with a planned conductivity range of 0 to 1000 pS/m. Details of the fuel types and additives are given in Appendix I of the research report. Samples included Jet A, Jet A-1, Diesel, JP-4, JP-8, and Jet-B fuels (the military specification fuels contained the fuel FSII/corrosion inhib-

itor package). Conductivity additives included Stadis 450 and ASA-3 in aviation fuels and Petrolite T-511 and Mobil Conductivity Improver in the nonaviation fuels.

X1.3.2 The protocol for testing as provided to participants is given in Appendix II of the research report. Tests were carried out with Emcee Model 1152 Digital Conductivity Meter only; participants were asked to measure conductivity directly in the containers.

X1.4 Data:

X1.4.1 Data were obtained at typical laboratory (20°C) and reduced temperatures. Data obtained at typical laboratory temperatures outside 19 to 21°C were temperature-compensated to 20°C.

X1.4.2 The data obtained from the test program as well as the temperature-compensated data are in Appendix III, Tables 1, 2, and 3 of the research report.

X1.5 Statistical Analyses—The reduced temperature data were not used to calculate precision. Details of the statistical analysis are in Appendix IV of the research report. The results from Appendix III, Table 3, temperature-compensated data, are given in Table X1.1. Information for the table was extracted from the April 7, 1988, minutes of the Test Methods D 2624 Conductivity Round Robin Task Force of Section J-11 on Electrical Characteristics.

X1.6 Conclusions:

X1.6.1 The task force recommended that results of this program (RR:D02-1235) be referenced in Test Methods D 2624 and D 4308, with the recommendation that samples

TABLE X1.1 Comparison of Precision Data from Common Different Sites

Conductivity, pS/m	Repeatability		Reproducibility	
	Common Site	Different Sites	Common Site	Different Sites
30	2	4	6	
100	5	7	17	
300	14	13	45	
500	21	22	69	

should not be shipped between laboratories for the test. The basis for this recommendation is that adequate reproducibility is not obtained for shipped samples.

X1.6.2 It is not possible to decide on the basis of this study that any one fuel or additive type presents a particular problem with respect to shipment of samples between laboratories, or that any one fuel type is less vulnerable to change in transit/storage.

X1.6.3 It might be possible to define a narrow set of conditions under which many samples could be transferred to other laboratories and tested with acceptable reproducibility of data. However, one reason for change in conductivity is interaction of the conductivity additive with other trace materials in the fuel, unrelated to the conductivity type or other conditions. Because type and amount of trace materials vary, there is no way of predicting which specific fuel sample will or will not be affected. This has been observed with all fuel and additive types.

X2. TEMPERATURE-CONDUCTIVITY RELATIONSHIPS

X2.1 Introduction:

X2.1.1 The conductivity of hydrocarbon fuels and solvents generally changes with temperature, primarily due to changes in the mobility of the conducting species related to fuel viscosity effects. The possibility of dramatic temperature changes during the handling of hydrocarbons should especially be considered when the fuel or solvent is treated with static dissipator (conductivity improving) additives. The temperature-conductivity relationship of jet fuels and No. 2 heating and diesel fuels has been studied extensively,⁷ although much data are not in the open literature. Extensive data are not available for other hydrocarbons.

X2.1.2 This appendix provides some guidance on how to evaluate low temperature needs and on the examination of fuel or solvent behavior.

X2.2 Fundamental Relationships:

X2.2.1 Conductivity has a semi-log relationship to temperature, but with some restrictions, as shown in Eq (1).

$$\text{Log}_{10} K_{t1} = n(t1 - t2) + \text{Log}_{10} K_{t2} \quad (1)$$

where K_{t1} and K_{t2} are the conductivities at temperatures $t1$ and $t2$, and n is the temperature-conductivity coefficient and has units of °F⁻¹ or °C⁻¹. It is important to show these units to avoid confusion. This equation can be rearranged to give the following:

$$n = \frac{\text{Log}_{10} K_{t1} - \text{Log}_{10} K_{t2}}{t1 - t2}$$

Thus after measuring the conductivity of a fuel at two different temperatures the value of n can be calculated. Then, using Eq (1), the conductivity of that fuel can be estimated at other temperatures.

X2.2.2 There are, however, some limitations to this approach. Studies with jet fuels⁷ have shown that the temperature-conductivity coefficient grows larger at temperatures below about -10°C. In other words, the relationship is not always linear over a broad range. Conductivity at very low or high temperatures is of a different order of magnitude and a separate coefficient should be calculated based on measurements at the lowest temperatures likely to be encountered.

X2.3 Practical Considerations:

X2.3.1 Unfortunately, only very clean hydrocarbons show reproducible conductivity-temperature relationships. Most fuels contain trace contaminants or co-additives that strongly affect the behavior of conductivity as temperature varies. In exceptional circumstances fuels have shown higher conductivity at -20°C than at +25°C. Evaluation of static dissipator additives in clay-treated versus nontreated fuels have demonstrated that trace impurities play an important role.

X2.3.2 Either the temperature-conductivity relationship can be assumed to vary over a wide range, or selected from a specific source can be evaluated to see if a range applies.

⁷Gardner, L., and Moon, F. G., "The Relationship Between Electrical Conductivity and Temperature of Aviation Fuels Containing Static Dissipator Additives," NRC Report No. 22648, 1983.

X2.3.3 Temperatures likely to be encountered can be determined based on expected ambient temperatures during the lifetime of the hydrocarbon, bulk storage temperatures, and line-fill volume and temperatures.

X2.4 *Typical Temperature-Conductivity Coefficients*—Temperature-conductivity coefficients likely to be encountered are cited in the following table. These data are not represented, or expected, to include the extremes of behavior which can be encountered and are only for guidance purposes.

Fuel Type	α , Typical, °C ⁻¹
Jet B (JP-4)	0.007 to 0.015
Jet A-1 (Jet A)	0.013 to 0.018
No. 2, 2D	0.015 to 0.022

X2.5 *Determination of Temperature-Conductivity Coefficients*:

X2.5.1 Measurements to determine coefficients are easily carried out and require only a few simple precautions. In general, these simply assure that other variables are controlled so that temperature effects only are measured.

X2.5.2 Test containers should be as specified in Practice D 4306.

X2.5.3 Before varying temperature, fuel should be stored in the test container for a time until a stable conductivity value is obtained at room temperature; one or two weeks may be required.

X2.5.4 Conductivity should then be measured at room temperature, then after storage for 24 h at each test temperature. Temperatures should include the complete range of interest.

X2.5.5 The container should then be stored for 24 h at room temperature and conductivity remeasured; a value close to that obtained originally should be obtained.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.



Standard Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter¹

This standard is issued under the fixed designation D 4308; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 This test method applies to the determination of the "rest" electrical conductivity of aviation fuels and other similar low-conductivity hydrocarbon liquids in the range from 0.1 to 2000 pS/m (see 3.2). This test method can be used in the laboratory or in the field.

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

1.3 *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 hazard statements, see Notes 2 through 4.

2. Referenced Documents

2.1 ASTM Standards:

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials²

D 2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels³

D 4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination³

E 1 Specification for ASTM Thermometers⁴

3. Terminology

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

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

3.2 *rest conductivity*—the reciprocal of the resistance of uncharged fuel in the absence of ionic depletion or polarization. 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 Method

4.1 A sample of liquid hydrocarbon is introduced into a

clean conductivity cell which is connected in series to a battery voltage source and a sensitive dc ammeter. The conductivity, automatically calculated from the observed peak current reading dc voltage and cell constant using Ohm's law, appears as a digital value in either a manual or automatic mode of meter operation.

5. Significance and Use

5.1 The generation and dissipation of electrostatic charge in fuel due to handling depend largely on the ionic species present which may be characterized by the rest or equilibrium electrical conductivity. The time for static charge to dissipate is inversely related to conductivity. This test method can supplement Test Method D 2624 which is limited to fuels containing static dissipator additive.

NOTE 1—For low-conductivity fluids below 1 pS/m in conductivity, an a-c measurement technique is preferable to a d-c test method for sensing the electrical conductivity of bulk fluid. This d-c test method can be used at conductivities from 0.1 to 1 pS/m if precautions are observed in cell cleaning and sample handling. A waiting period of 15 min is required after filling the cell before measuring d-c conductivities below 1 pS/m. A single-laboratory program was conducted comparing this test method with a-c Test Method D 150. The results are on file at ASTM Headquarters. Request RR: D02-1241.

6. Apparatus

6.1 *Conductivity Apparatus*—Components of the dc conductivity apparatus are shown in Fig. 1.⁵

6.1.1 The conductivity cell shown in Fig. 1 consists of an inner electrode and an outer electrode separated by an insulator. The outer electrode and cap provide a ground path and electrostatic (Faraday) shield.

6.1.2 The electrometer shown in Fig. 1 contains a battery which supplies a voltage to the cell and a bridge circuit which senses the flow of current and converts the output signal directly into conductivity units, that is, pS/m. A pushbutton selector allows selection of zero reading, calibration, and four range selections.

6.1.3 The cell and electrometer are connected by a triaxial cable as shown in Fig. 1.

6.2 *Thermometer*, calibrated to 0.5°C and conforming to Specification E 1.

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

Current edition approved Feb. 15, 1995. Published April 1995. Originally published as D 4308 - 83. Last previous edition D 4308 - 89.

² *Annual Book of ASTM Standards*, Vol 10.01.

³ *Annual Book of ASTM Standards*, Vol 05.02.

⁴ *Annual Book of ASTM Standards*, Vol 14.03.

⁵ The KSLA Cell and Precision Conductivity Meter System, Emcee Model #1154 are available from Emcee Electronics, Inc., 520 Cypress Ave., Venice, FL 34292.

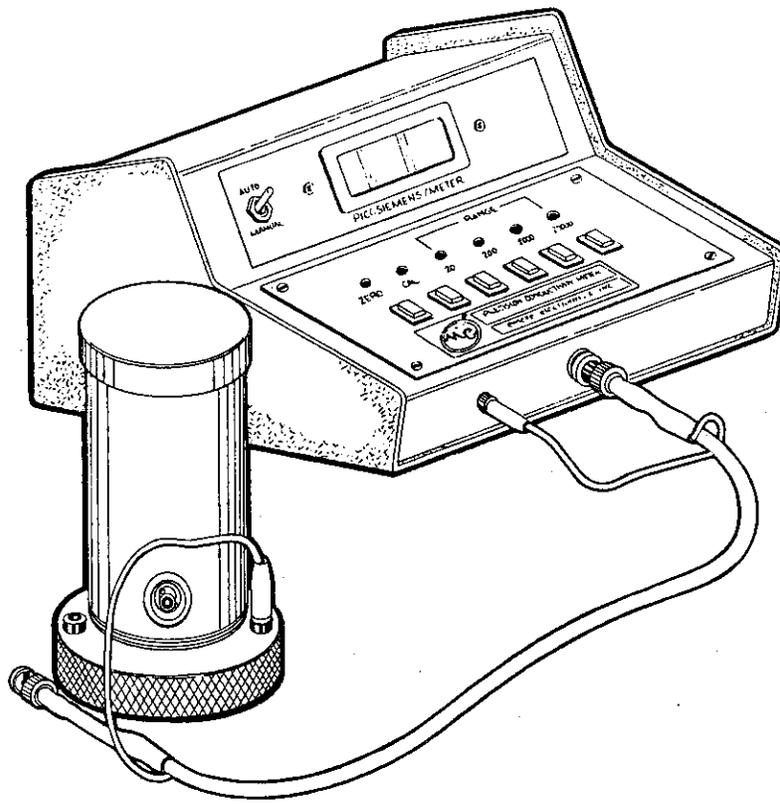


FIG. 1 Precision Conductivity Meter

7. Reagents

7.1 *Cleaning Solvent*—The following may be used:

7.1.1 *Toluene-Isopropyl Alcohol Mixture*—(Warning—See Note 2) Mix two volumes of toluene and three volumes of isopropyl alcohol both of reagent grade and distill. Discard the first 20 % and last 5 % fractions.

NOTE 2: Warning—Flammable. Vapor harmful. See Annex A1.1.

7.2 *n-Heptane*—(Warning—See Note 4) Prepare by percolating ASTM reference fuel grade *n*-heptane through silica gel⁶ as follows:

NOTE 3: Warning—Flammable. Harmful if inhaled. See Annex A1.3.

7.2.1 Activate approximately 2000 g of 100 to 200 mesh silica gel by heating at 180°C for 24 h. Allow it to cool in a desiccator under nitrogen or in vacuum. Soak approximately 0.5 g of glass wool⁷ for 24 h in clean *n*-heptane.

7.2.2 Take a tube of borosilicate glass having an inside diameter of 60 to 70 mm, a length 1500 mm, with a conically shaped lower end provided with a glass cock. Place a perforated porcelain disk (diameter 25 mm) in the lower end of the tube and put the soaked glass wool on top of the disk. Fill the tube with the activated silica gel while tapping to achieve homogeneous filling. The silica gel layer will be

approximately 1250 mm high. Wrap the column in black paper to exclude light.

7.2.3 Percolate *n*-heptane through the column at a rate of about 2 to 3 L/h. Discard the first 3 L. Never allow the column to run dry. The silica gel charge is sufficient for the percolation of 1000 L of *n*-heptane, provided the conductivity of the untreated *n*-heptane is below 1 pS/m.

NOTE 4—If the conductivity of the *n*-heptane after treatment, measured in accordance with Section 11 in a thoroughly cleaned cell, is higher than 0.1 pS/m, the treatment should be repeated.

7.3 *Hydrocarbon*, for calibration. The dielectric constant must be known to ±5 % at the temperature of calibration.⁸

8. Sampling

8.1 The sample volume should be at least 0.7 L.

8.2 Use a clean epoxy-lined can, or a new glass bottle that has been rinsed successively with hot water, distilled water, acetone, and cleaning solvent then flush with dry nitrogen. Use only non-contaminating caps.

NOTE 5—Test method results are known to be sensitive to trace contamination from sampling containers. For recommended sampling containers refer to Practice D 4306.

NOTE 6—Bottle samples should be tested immediately, since the glass surface tends to absorb from the fuel the conductive substances that the test method is intended to measure.

8.3 Rinse the container several times with portions of the aviation turbine fuel to be sampled (Jet A or A-1, (Warn-

⁶ A suitable grade is available from W. R. Grace & Co., Davison Chemical Division, Baltimore, MD 21202 by specifying Code 923.

⁷ A suitable product is filtering fiber Pyrex Wool. Catalogue No. 3950, supplied by Owens-Corning Fiber Glass Corp.

⁸ A standard, such as cyclohexane, with certified dielectric constant, may be obtained from the National Bureau of Standards, Washington, DC 20234.

ing—See Note 8), Jet B (Warning—See Note 9)). If possible fill the container, let stand, then empty and refill. Avoid taking the sample for test by pouring from the container; pipet instead. The sample should be clean and bright when tested.

NOTE 7: Warning—Combustible. Vapor harmful. See Annex A1.4.

NOTE 8: Warning—Extremely flammable. Harmful if inhaled. Vapors can cause flash fire. See Annex A1.5.

9. Preparation of Apparatus

9.1 *Cleaning the Cell*—The cleaning procedure to be used depends on the estimated conductivity of the sample to be tested.

9.1.1 For samples that are expected to exhibit conductivities below 1 pS/m, the KSLA cell should be completely disassembled, the parts cleaned and the cell reassembled using protective gloves.

9.1.1.1 Dismantle the cell by removing the loose battery cap, the outer electrode electrical connector and the bottom screw-on cap. Press the inner electrode towards the bottom of the outer electrode and remove the inner electrode TFE-fluorocarbon insulator assembly.

9.1.1.2 Each part of the cell should be rinsed thoroughly five times with cleaning solvent followed by rinsing with treated *n*-heptane. The parts should be dried with a stream of nitrogen gas.

9.1.1.3 After reassembly, the cell should be rinsed with treated *n*-heptane.

9.1.1.4 After cleaning, check the cleanliness of the cell by measuring the conductivity of treated *n*-heptane in accordance with Section 11. The corrected value should be lower than 0.05 pS/m.

9.1.2 For samples that are expected to exhibit conductivities above 1 pS/m, the KSLA cell still assembled should be rinsed five times with cleaning solvent, followed by rinsing with treated *n*-heptane. The cell should be dried with a stream of nitrogen gas.

9.1.2.1 After cleaning, check the cleanliness of the cell by measuring the conductivity of treated *n*-heptane in accordance with Section 11. The corrected value should be lower than 0.1 pS/m.

9.2 *Cleaning of Auxiliary Equipment*

9.2.1 Pipets used to transfer samples should be rinsed inside and outside with cleaning solvent using a non-contaminating squeeze bottle, then blown dry with clean, dry nitrogen. Thermometers should be similarly rinsed and maintained.

NOTE 9—If a cell has been used to test samples of high-conductivity, that is, more than 1000 pS/m, it should be disassembled for thorough cleaning. Very thorough cleaning may also be accomplished by placing the disassembled cell in a Soxhlet apparatus containing boiling toluene/isopropyl alcohol for several hours.

NOTE 10—If testing is to be done on both low-conductivity (<1 pS/m) and high-conductivity (>1000 pS/m) samples, separate cells are recommended.

10. Calibration and Standardization

10.1 *Checking the Test Equipment*

10.1.1 Remove cell and cable from the meter.

10.1.2 Depress the 20-pS/m switch. The digital reading should indicate 0.00 ± 0.01 pS/m after 3 s. If readings exceed

± 0.01 either adjust zero or record the zero error for calculating final report value.

10.1.3 Depress the calibrate switch. The digital reading should indicate 1000 ± 3 pS/m.

10.1.4 If low battery indicator is displayed during measure or calibration, the internal batteries should be replaced.

10.2 *Checking the Cell Constant*

10.2.1 A check on the cell constant is necessary only if the cell has been damaged. Two capacitance measurements are required with a precision a-c bridge. Make a rigid two-terminal connection between the cell assembly and the bridge. Measure the total capacitance, C_E (picofarad) of the empty assembly. Without disturbing the connection, add 100 mL of a hydrocarbon standard and measure the new total capacitance, C_S (picofarad) and the temperature in the cell. Alternatively, the cell can be sent to the manufacturer for recalibration.

10.2.2 Calculate the actual capacitance, C_A , of the empty cell as follows:

$$C_A = (C_S - C_E)/(k-1) \quad (2)$$

where:

k = dielectric constant of the hydrocarbon at test temperatures.

10.2.3 Calculate the cell constant as follows:

$$K = 8.854/C_A \quad (3)$$

10.2.4 The cell constant of a new KSLA cell is 1.0. Because of its configuration, the cell constant cannot change significantly unless there is gross damage.

11. Procedure

11.1 Attach the cleaned cell to the meter as shown in Fig. 3.

11.1.1 Depress the ZERO switch, the digital reading should indicate the same value recorded in 10.1.2.

11.1.2 Depress the CAL switch, the digital reading should indicate 1000 ± 5 .

11.1.3 Rinse the cleaned cell three times with the sample, empty completely, then fill the outer chamber until sample overflows into the center receptacle. (Alternatively, the outer chamber can be filled by pipet with 100 mL of sample).

NOTE 11—Static charges generated by handling the sample must be allowed to dissipate. If the sample is expected to have a conductivity below 1 pS/m, 15-min waiting time must be allowed before reading.

11.1.4 If the sample conductivity is known, select the corresponding range position. When the conductivity is unknown, first check the fuel on a 2000 pS/m range position, then read in a lower scale if appropriate.

11.1.5 Using the AUTO mode, depress the appropriate RANGE switch. In the AUTO mode, the reading is stabilized after 3 s and held on display for 9 s. Record the pS/m value.

11.1.6 Repeat readings can be taken after a 1-min delay.

11.1.7 Remove the cell cover and measure the temperature of the test samples to the nearest 1°C with a clean thermometer.

12. Calculation

12.1 If the zero error in 10.1.2 was greater than ± 0.01 and the zero of the meter was not adjusted, the readings

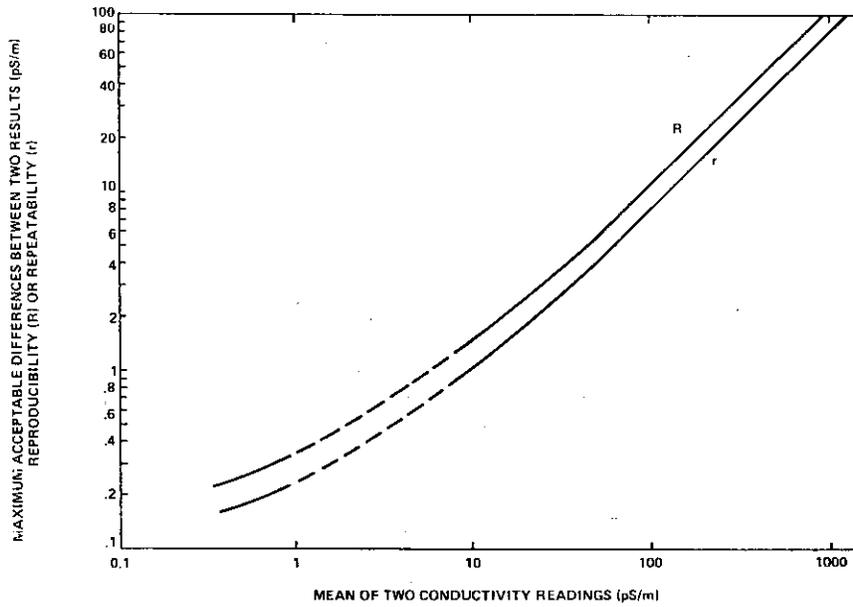


FIG. 2 Variation of Repeatability and Reproducibility with Conductivity Level

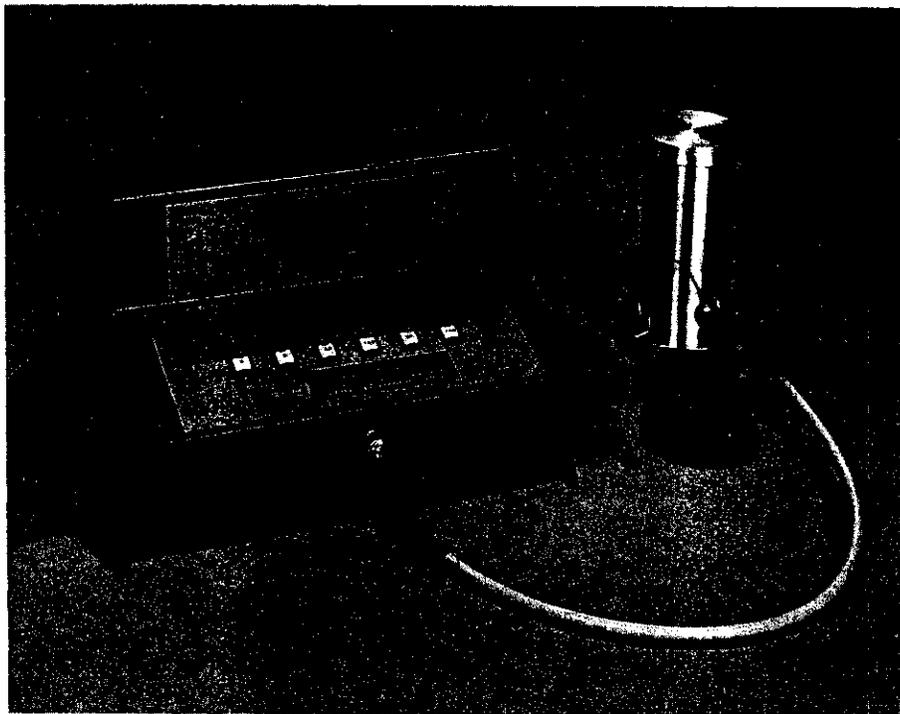


FIG. 3 Cleaned Cell Attached to Meter

should be corrected by subtracting any positive zero error or adding any negative zero error. For example;

Sample reading (11.1.5)	1.67
Uncorrected zero error (10.1.2)	+ 0.03
Calculated reading	<u>1.64</u>

13. Report

13.1 The report is to include the following:

13.1.1 The calculated conductivity of the sample in pS/m

after correcting for the zero reading. Note MANUAL or AUTO mode.

13.1.2 Temperature of sample.

NOTE 12—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.

14. Precision and Bias⁹

14.1 The precision of this test method obtained by statistical examination of test results in the range between 0.1 and 2000 pS/m by operator/instrument pairs at a common test site is described in 14.2 and 14.3.

NOTE 13—The data used to determine the precision of this test method were obtained using the auto mode.

14.2 *Repeatability*—The difference between successive test results obtained by the same operator with the same apparatus under constant operating conditions on identical test samples would, in the long run, in the normal and correct operation of the test method, exceed the values in Fig. 2 in only one case in twenty.

14.3 *Reproducibility*—The difference between two single and independent results obtained by different operators working at the same location on identical test materials would, in the long run, exceed the values in Fig. 2 only in

one case in twenty.

14.3.1 In the event of a dispute or concern regarding shipped sample conductivity, it is recommended that operators come to the bulk hydrocarbon storage site to measure conductivity on freshly obtained samples according to the cited procedure. This ensures that samples identical to bulk storage are tested by either or both parties and the precision data in Fig. 2 shall apply (Note 14).

NOTE 14—In 1987, a test program using Test Method D 2624 was carried out to investigate reproducibility of results when samples are shipped between laboratories.¹⁰ While repeatability values were similar to those from common site testing, it was concluded that adequate reproducibility values were not obtained due to changes in conductivity of samples during shipment and storage. The same possibility of conductivity change would occur for samples tested according to Test Method D 4308.

14.4 *Bias*—Since there is no accepted reference material suitable for determining the bias of the procedure in Test Method D 4308 for measuring conductivity, bias cannot be determined.

⁹ A report on statistical analysis of interlaboratory test results is on file in ASTM Headquarters as RR: D02-1170.

¹⁰ A report of data and conclusions from this program is on file at ASTM Headquarters; request RR:D02-1235.

ANNEX

(Mandatory Information)

A1. PRECAUTIONARY STATEMENTS

A1.1 Toluene

Keep away from heat, sparks, and open flame.
Keep container closed.
Use with adequate ventilation.
Avoid breathing of vapor or spray mist.
Avoid prolonged or repeated contact with skin.

A1.2 n-Heptane

Keep away from heat, sparks, and open flame.
Keep container closed.
Use with adequate ventilation.
Avoid prolonged breathing of vapor or spray mist.
Avoid prolonged or repeated skin contact.

A1.3 Aviation Turbine Fuel (Jet A or A-1)

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.

A1.4 Aviation Turbine Fuel (Jet B)

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 non-explosionproof electrical apparatus and heaters.
Avoid breathing vapor or spray mist.
Avoid prolonged or repeated contact with skin.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.