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Standard Test Methods for
Electrical Conductivity of Aviation and Distillate Fuels[1]

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

~~Note—Table 2 was included editorially and the year date changed on April 16, 2001.~~

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*~~*1*) portable meters for the direct measurement in tanks or the field or laboratory measurement of fuel samples, and (~~*b*~~*2*) 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:*

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[1] 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 on Aviation Fuels.

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

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D 4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination[2]
D 4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter[2]

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.

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

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~~ dc 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 polari~~s~~zation 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~~.~~) 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,

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

[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, Poppenbuetteler 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.

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 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~~ A1-Annex A4.

11. Procedure

11.1 The specific instrument calibration procedures detailed in Annex ~~A1, Annex A2, Annex A3, and Annex~~ A1-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 American Petroleum Institute in

TABLE 1 Precision[A] of Emcee Models 1150, 1151, and 1152, and Maihak Conductivity Indicator

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 (×2) may be applicable at temperatures near − 20°C.

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~~ (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 Bias [5]

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.~~

~~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 Table 2~~ 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 Table 2.

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[5] Supporting data ~~can~~ have been filed at ASTM International Headquarters and may be obtained ~~from ASTM Headquarters. Request RR:D02-1013,~~ 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.

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

TABLE 2 Precision[A] 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

[A] The precision limits in Table 2 are applicable at room temperature; significantly higher precision (×2) may be applicable at temperatures near − 20°C.

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 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]

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[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.

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).~~ (see Note 2).

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 2 *X* 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 2 *X* button. For Series 3 and 4 instruments a reading of zero should be obtained. For Series 1 and 2 instruments a positive reading of about 10 to 30 pS/m should be obtained. This value must be subtracted from all measured conductivity readings. If readings within 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, and then press the green READ button and record the highest reading after the needle has recovered from the initial overswing caused by inertia. The initial recovery should not exceed 20 pS/m and will be completed in less than 1 s. For conductivities in the range from 500 to 1000 pS/m the red 2*X* button should be pressed and kept pressed while the 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 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 3 and 4 instruments operate satisfactorily at temperatures down to −29°C provided that the exposure time is limited to 30 min maximum.

A2. CALIBRATION OF THE EMCEE CONDUCTIVITY METER ~~(Digital Type)~~ Model 1152 (Digital Type)

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 A2.4 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 ±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. Do not attempt to adjust the meter using the plugged hole between the Zero and Calibrate holes.

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.

A4. CALIBRATION OF THE MAIHAK MLA 900 CONDUCTIVITY METER

A4.1 The MLA 900 consists of four instrument components: measuring probe, display unit, ground terminal, and probe cables which conform to technical safety regulations only when used as an assembled unit. The probe cables are 2 m or 10 m. The display unit and the measuring probe are a matched pair for optimum performance and have the same serial number.

A4.2 The cable connections, the ground terminal, and an earthing or bonding connection should be firmly in place before commencing measurements in a hazardous location. Verify that the outside cylinder of the measuring probe is tightly screwed on, and that the measuring probe is clean and dry. If not, clean according to instructions in Section 9.

A4.3 The instrument is switched on by opening the cover flap of the display unit. Open the cover flap with the probe hanging freely in air. The conductivity value measured should be –2 to +2 pS/m. If a value greater than 2 pS/m is displayed, carefully clean the probe and re-measure. If a value below –2 pS/m is displayed, check the battery – a "BAT" message will be seen on the display.

A4.4 Hold the surface of the measuring probe with the MAIHAK symbol close to the red disc on the display unit. A value of 1000 ± 10 pS/m should be displayed.

A4.5 If the instrument fails the calibration check after following the above instructions, it must be returned to the manufacturer for re~~-~~calibration.

APPENDIXES

(Nonmandatory Information)

X1. DISCUSSION OF PRECISION STATEMENTS—TESTS CONDUCTED AT A COMMON SITE VERSUS DIFFERENT LOCATIONS (RR:D02-1235)[5]

X1.1 *Purpose of Test Program*—A round-robin test program[6] 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),[5] 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,[5] 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.[5]

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 inhibitor 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 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)[5] be referenced in Test Methods D 2624 and D 4308, with the recommendation that samples should not be shipped between laboratories for these tests. 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 band of conditions under which many samples could be transported to other laboratories and tested with acceptable reproducibility of data. However, one reason for change in sample conductivity is interaction of the conductivity additive with other trace materials in the fuel, unrelated to the container type or other conditions. Because type and amount of these materials vary, there is no way of predicting whether a specific fuel sample will or will not be affected. This problem 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

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

Conductivity, pS/m	Repeatability		Reproducibility	
	Common Site	Different Sites	Common Site	Different Sites
30	2	4	6	53
100	5	7	17	97
300	14	13	45	169
500	21	22	69	218

extensively,[8] 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 X2.1).

$$\text{Log}_{10}\ K_{t1} = n(t1 - t2) + \text{Log}_{10}\ K_{t\,2} \tag{X2.1}$$

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:

$$n = \frac{\text{Log}_{10}\ K_{t1} - \text{Log}_{10}\ K_{t2}}{t1 - t2} \tag{X2.2}$$

Thus after measuring the conductivity of a fuel at two different temperatures the value of n can be calculated and then, using (Eq~~ 1),~~ X2.2), 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 fuels[8] have shown that the temperature-conductivity coefficients grows larger at temperatures below about −10°C. In other words, the semilog relationship is not always linear over a broad range. If conductivity at very low or high temperatures is of interest a separate coefficient should be calculated based on actual 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 which strongly affect the behavior of conductivity as temperature varies. In exceptional circumstances fuels have shown higher conductivity at −20°C than at +25°C. Evaluations of static dissipator additives in clay-treated versus nontreated fuel have demonstrated that trace impurities play an important role.

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

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	n, Typical, °C^{-1}
Aviation Gasoline	0.006 to 0.014
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

X2.4.1 It can be seen from the data that for aviation gasoline, like other fuels, the coefficient is greater for very low temperatures (see Table X2.1).

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.

TABLE X2.1 Temperature-Conductivity Coefficients

Aviation Gasoline (Avgas)	Temperature-Conductivity Coefficient / (C°)$^{-1}$		Average of Two Coefficients
	–30°C to 0°C	0°C to +30°C	
Refinery A	0.014007	0.005973	0.009990
Refinery B	0.009653	0.008371	0.009012
Average	0.011830	0.007172	0.009501

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

X2.5.5 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.

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