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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 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:²

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.J0.04 on Additives and Electrical Properties.

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

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² 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.

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

D 4308 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.

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

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

3.1.2.1 *Discussion*—It is the electrical conductivity at the initial instant of current measurement after a 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 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.

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

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.

NOTE 1—The Emcee Model 1153 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.³

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:

³ The following equipment, as listed in RR:D02-1161, RR:D02-1476, and RR:D02-1575, was used to develop the precision statements. Models 1150, 1151, 1152, and 1153 from Emcee Electronics, Inc., 520 Cypress Ave., Venice FL 3429; Maihak Conductivity Indicator and MLA 900 from Maihak AG, Poppenbueteler Bogen 9b, D-22399 Hamburg Germany. This is not an endorsement or certification by ASTM. 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,¹ which you may attend.

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

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 **D 4306** 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 **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 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**.

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

TABLE 1 Precision^A of Emcee Models 1150, 1151, 1152, and 1153 and Maihak Indicator

Conductivity, pS/m	Repeatability ^B	Reproducibility ^C
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

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

^B 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.

^C The data used to calculate reproducibility is given in RR:D02–1161.

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, Annex A4, or Annex A5, 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.

11.3 Laboratory and Field Measurements on Sampled Fuels:

11.3.1 *Preparation of Containers (Metal or Glass)*—Prior to taking samples, take extreme care to ensure that all containers and measuring vessels have been thoroughly cleaned. It is

preferable that containers are laboratory cleaned prior to shipment to the field for sampling (see Section 8).

11.3.2 *Measurement*—Rinse the conductivity cell thoroughly with the fuel under test to remove fuel residues remaining on the cell from previous tests. Transfer the fuel to the measuring vessel and record the conductivity of the fuel using the procedure applicable to the particular apparatus. If one of the conductivity meters referenced in Footnote 3 is used, follow these instructions: Rinse the cell concurrently with the rinsing of the measuring vessel. Then transfer the sample to be tested to the clean, rinsed measuring vessel. Check meter calibration as detailed in Annex A1, Annex A2, or Annex A5, 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. 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. 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 Bias⁵

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

⁵ 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.

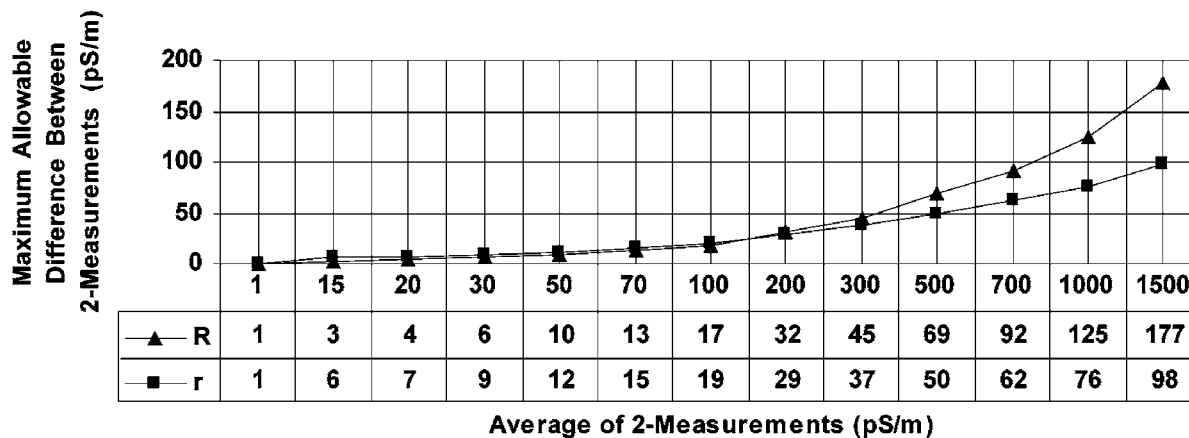


FIG. 1 Graphic Presentation of Table 1's Precision

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.

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.

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.

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.

CONTINUOUS IN-LINE CONDUCTIVITY

14. Apparatus⁷

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

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 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,¹ which you may attend.

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

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

20.2 *Reproducibility*—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. Apparatus⁸

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**).

27. Precision and Bias

27.1 *Repeatability*—Repeatability of the continuous meter has been established to be within the range given for the portable instruments (see **13.1.1**).⁹

27.2 *Reproducibility*—Reproducibility of the continuous meter has been established to be within the range given for the portable instruments.

27.3 *Bias*—Bias of the continuous meter has been established to be within the range given for the portable instruments.

28. Keywords

28.1 aviation fuels; conductivity meter; conductivity unit; distillate fuels; electrical conductivity; in-line; picosiemens per meter; rest conductivity; static dissipator additives; static electricity

⁸ 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,¹ which you may attend.

⁹ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1588.

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 (see **Note 4**).

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 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 2X 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 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.