Designation: D 5391 – 99

An American National Standard

Standard Test Method for Electrical Conductivity and Resistivity of a Flowing High Purity Water Sample[1]

This standard is issued under the fixed designation D 5391; 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.

1. Scope

1.1 This test method covers the determination of electrical conductivity and resistivity of high purity water samples below 10 µS/cm (above 0.1 Mohm-cm). It is applicable to both continuous and periodic measurements but in all cases, the water must be flowing in order to provide representative sampling. Static *grab* sampling cannot be used for such high purity water. Continuous measurements are made directly in pure water process lines, or in side stream sample lines to enable measurements on high temperature or high pressure samples, or both.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1066 Practice for Sampling Steam[2]

D 1125 Test Methods for Electrical Conductivity and Resistivity of Water[2]

D 1129 Terminology Relating to Water[2]

D 1192 Specification for Equipment for Sampling Water and Steam in Closed Conduits[2]

D 1193 Specification for Reagent Water[2]

D 2186 Test Methods for Deposit-Forming Impurities in Steam[3]

D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water[2]

D 3370 Practices for Sampling Water from Closed Conduits[2]

D 3864 Guide for Continual On-Line Monitoring Systems for Water Analysis[2]

D 4519 Test Method for On-Line Determination of Anions and Carbon Dioxide in High Purity Water by Cation Exchange and Degassed Cation Conductivity[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *electrical conductivity*—refer to Test Methods D 1125.

3.1.2 *electrical resistivity*—refer to Test Methods D 1125.

3.1.3 For definitions of other terms used in these test methods, refer to Terminology D 1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cell constant*—the ratio of the length of the path, L (cm) and the cross-sectional area of the solution, A (cm ^{2}), between the electrodes of a conductivity/resistivity cell, with units of cm $^{-1}$. In high purity water measurements, the cell constant is normally between 0.001 and 0.1 cm $^{-1}$ to prevent electrical interference. This is lower than the 1 cm $^{-1}$ of the standard centimetre cube and is taken into account by direct reading instrument ranges that are matched with specific cell constants.

4. Summary of Test Method

4.1 Conductivity or resistivity is measured with a cell and temperature sensor or compensator in a flowing, closed system to prevent trace contamination from wetted surfaces and from the atmosphere. Specialized temperature compensation corrects the measurement to 25°C, taking into account the temperature effects on the ionization of water, the contaminants, and interactions between the two. In the absence of specialized temperature compensation, the sample temperature is controlled to 25 ± 0.2°C.

4.2 To determine the cell constant of a high purity conductivity cell with an instrument capable of accurate measurement over the range of pure water to 150 µS/cm with a single cell constant, Test Methods D 1125 are used directly. Manufacturers' certification of cell constant traceability by this means is an acceptable alternative.

4.3 To determine the cell constant of a high purity conductivity cell with an instrument which does not accurately cover the range from pure water to 150 µS/cm with a single cell

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[1] This test method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.03 on Sampling of Water and Water-Formed Deposits, Surveillance of Water, and Flow Measurement of Water.

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 11.02.

constant, a secondary standard cell is used that has an intermediate cell constant with precise value determined by Test Methods D 1125. That secondary standard cell is then used in low conductivity water (not a standard) and readings are compared with those of the low constant cell under test. In this manner, the cell constant of the latter is determined. Manufacturers' certification of cell constant traceability by this means is an acceptable alternative.

5. Significance and Use

5.1 Conductivity measurements are typically made on samples of moderate to high ionic strength where contamination of open samples in routine laboratory handling is negligible. Under those conditions, standard temperature compensation using coefficients of 1 to 3 % of reading per degree Celsius over wide concentration ranges is appropriate. In contrast, this test method requires special considerations to reduce trace contamination and accommodates the high and variable temperature coefficients of pure water samples that can range as high as 7 % of reading per degree Celsius. In addition, measuring instrument design performance must be proven under high purity conditions.

5.2 This test method is applicable for detecting trace amounts of ionic contaminants in water. It is the primary means of monitoring the performance of demineralization and other high purity water treatment operations. It is also used to detect ionic contamination in boiler waters, microelectronics rinse waters, pharmaceutical process waters, etc., as well as to monitor and control the level of boiler and power plant cycle chemistry treatment chemicals. This test method supplements the basic measurement requirements for Test Methods D 1125, D 2186, and D 4519.

5.3 At very low levels of alkaline contamination, for example, 0–1 µg/L NaOH, conductivity is suppressed, and can actually be slightly below the theoretical value for pure water. **(13,14)**[4] Alkaline materials suppress the highly conductive hydrogen ion concentration while replacing it with less conductive sodium and hydroxide ions. This phenomenon is not an interference with conductivity or resistivity measurement itself but could give misleading indications of inferred water purity in this range if it is not recognized.

6. Interferences

6.1 Exposure of the sample to the atmosphere may cause changes in conductivity/resistivity due to loss or gain of dissolved ionizable gases. Carbon dioxide, normally present in the air, can reach an equilibrium concentration in water of about 1 mg/L and add approximately 1 µS/cm to the conductivity due to formation of carbonic acid. Closed flow-through or sealed in-line cell installation is required for this reason.

6.2 Power plant installations utilizing long sample lines can experience significant sampling problems. New sample lines normally require longterm conditioning. Iron oxides and other deposits accumulate in slow flowing horizontal sample lines and can develop chromatograph-like retention of ionic species, resulting in very long delay times. Precautions are described in Section 9.

6.3 Cell and flow chamber surfaces will slowly leach trace ionic contaminants, evidenced by increasing conductivity readings with very low or zero flowrate. There must be sufficient flow to keep these contaminants from accumulating to the point that they affect the measurement. The high and convoluted surface area of platinized cells precludes their use for high purity measurements for this reason.

6.4 Capacitance of the cell and extension leadwire, especially in high purity ranges can add significant positive error to conductance readings (negative error to resistance readings). The measuring instrument must be designed to accommodate cell and leadwire characteristics in high purity water as described in 7.1.1 and Annex A1. In addition, the instrument manufacturers' recommendations on cell leadwire must be carefully followed.

6.5 Conductivity and resistivity measurements are referenced to 25°C. Either samples must be controlled to 25.0 ± 0.2°C or specialized temperature compensation must be employed that accounts for the characteristics of high purity water with specific contaminants, as described in 7.1.2.

6.6 Samples containing dissolved gases must have sufficient flow through the cell that bubbles cannot accumulate and occupy sample volume within the cell, causing low conductivity (high resistivity) readings. This problem is typical in makeup water treatment systems where water warms up, drops in pressure, and is acidified by cation exchange operations. This releases dissolved air and converts carbonates to carbon dioxide gas.

6.7 High purity conductivity measurement must not be made on a sample downstream of pH sensors since they invariably contaminate the sample with traces of reference electrolyte salts. Use a dedicated sample line or place the conductivity cell upstream from the pH sensors.

6.8 Conductivity cells mounted downstream from ion exchangers are vulnerable to catching resin particles between the cell electrodes. Resin particles are sufficiently conductive to short the cell and cause high off-scale conductivity or extremely low resistivity readings. Resin retainers must be effective and cells must be accessible for cleaning. Cell designs with electrode spacing greater than 0.06 in. (1.5 mm) have been found to be less likely to trap such particles.

6.9 Conductivity cells, if subjected to demineralizer regeneration reagents, would require excessive rinse time to obtain satisfactory results. Therefore, locate cells where they will be isolated during regeneration cycles.

7. Apparatus

7.1 *Measuring Instrument*:

7.1.1 The instrument shall be continuously reading in either conductivity or resistivity units. It shall be specifically designed to measure in high purity ranges, measuring with ac of appropriate voltage, frequency, wave shape, phase correction, and wave sampling technique to minimize errors due to parallel and series capacitance of cell and leadwire as well as minimizing electrode polarization errors and effects of small direct current (dc) potentials. A cell simulation technique to verify the

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[4] The boldface numbers in parentheses refer to the list of references at the end of this test method.

performance of an unproven measuring circuit design under high purity conditions is provided in Annex A1.

7.1.2 The measurement shall include algorithms to temperature compensate conductivity or resistivity values to 25.0°C. The algorithm shall compensate for changes in water ionization as well as for solute ion mobility for neutral salt contaminants. The conductivity of pure water has been documented with high accuracy **(15,1)**.

7.1.3 In the case of samples containing acidic or basic solutes (such as power plant treatment using ammonia, morpholine, etc., or acidic *cation conductivity* samples or microelectronics acid etch rinse monitoring), special algorithms shall be employed that account for the interaction of acids and bases with the ionization of water **(2, 3, 4)**. The user is cautioned that accuracy of temperature compensation algorithms for these solutes may vary significantly. The user must determine the applicability and accuracy for a particular sample in the anticipated temperature range. Fig. 1 illustrates the variation in temperature effects on conductivity representative of neutral salts, ammonia, morpholine, and acids. Where specialized high purity temperature compensation algorithms are not provided to accurately compensate for these effects, sample temperature shall be controlled to 25.0± 0.2°C. (Note that conductivity temperature coefficients exceed 7 % of reading per degree Celsius in the temperature range of 0 to 10°C.)

7.1.4 Output signal(s) from the instrument, if provided, shall be electrically isolated from the cell and from the earth ground to prevent ground loop problems when the instrument is connected to grounded external devices.

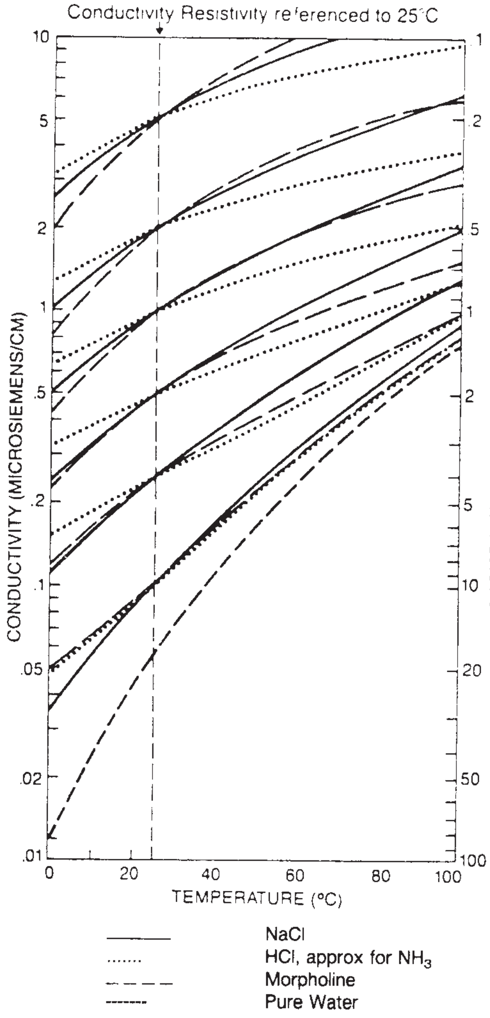
7.2 *Cell*:

7.2.1 Flow-through or in-line conductivity/resistivity cells shall be used to prevent contamination from the atmosphere and wetted surfaces as described in 6.1 and 6.3. Flowrates shall be maintained within the manufacturer's recommendations. The cell shall retain its constant calibration under the conditions of flowrate, temperature, and pressure of the installation. The cell shall incorporate an integral precision temperature sensor to ensure that it accurately senses the sample temperature where the conductivity/resistivity is being detected to ensure accurate temperature compensation.

7.2.2 The cell for high purity water measurements shall not be used for measuring higher ionic content samples (greater than 20 µS/cm, less than 0.05 Mohm-cm) since it would retain ionic contaminants and require excessive rinse-down time for valid measurements in high purity ranges. A high purity cell in a demineralizer system shall not be located where it can be exposed to regeneration reagents.

7.2.3 Electrodes of the cell shall not be platinized for pure water measurements since the microscopically rough, porous surface would retain ionic contaminants and produce excessive downscale response times. Only a trace or flash of platinum black is permissible on electrode surfaces. Electrodes of titanium, nickel, monel, stainless steel, or platinum are suitable for high purity measurement. However, extra care must be taken using platinum cells not to exceed manufacturers' recommended flowrate and not to permit rough handling that could bend the electrodes and change the cell constant.

7.2.4 If the cell constant as checked does not fall within acceptable limits of its nominal value, it is necessary to clean or replace the cell. Even in pure water samples, coatings such as iron oxide crud in power plant installations, resin fines, and other solids and films can develop. Insulating coatings over electrode surfaces can cause negative conductivity errors. Conductive accumulations between electrodes can short them and cause positive errors. Mechanical cleaning must not be attempted with platinum electrodes since this would change the cell constant. Cleaning must either follow manufacturer's



NOTE—Curves represent concentrations of impurities given in Table 1.

FIG. 1 Temperature Effects on the Conductivity of High Purity Water

TABLE 1 Concentrations of Trace Contaminants Plotted in Fig. 1

Conductivity µS/cm at 25°C	Concentration (µg/L)			
	NaCl	HCl	NH$_3$	Morpholine
5.00	2295	430	638	13 755
2.00	903	172	177	2632
1.00	439	86	76	837
0.500	207	42.6	34.4	298
0.250	91	20.7	16.1	117
0.100	21.0	6.5	5.4	34.6
0.055	0.0	0.0	0.0	0.0

recommendations or that given in Test Methods D 1125. Ultrasonic cleaners have also been found effective in some cases.

7.3 Extension leadwire type, size, and length shall be according to manufacturers' recommendations, primarily to prevent parallel leadwire capacitance errors with this high resistance ac measurement. In particular, the length shall not exceed the measuring instrument's ability to minimize capacitance errors.

8. Reagents

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society.[5] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

8.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type I of Specification D 1193. In making up the potassium chloride comparison solution for cell constant determinations, use water of conductivity not greater than 1 µS/cm. If necessary, stabilize to the laboratory atmosphere by aspirating air through the water from a fritted glass or stainless steel gas dispersion tube. The equilibrium point is reached when the conductivity remains constant but not greater than 1.5 µS/cm.

8.3 *Conductivity Standard Reference Solutions*—See Test Methods D 1125.

9. Sampling

9.1 Direct measurements in the process shall have the cell located in an active flowing part of the piping. Stagnant areas or *dead legs* must be avoided to ensure a representative sample and prevent any bubbles from adhering to cell surfaces.

9.2 Design and operate side stream sample lines to maintain sample integrity.

9.2.1 Do not expose the sample to the atmosphere to prevent absorption or loss of gases, particularly carbon dioxide, that affect conductivity.

9.2.2 The sample line shall not have pH electrodes upstream of the conductivity cell as noted in 6.7.

9.2.3 In power plant installations where iron oxide and other solids occur in pure water samples, flowrates must be controlled to minimize accumulation of deposits that could greatly delay transport of ionic materials. A sample flow velocity of 2 m/s in horizontal sample lines has been found optimum. Additional sample line design criteria have been documented **(5, 6, 7)**.

9.2.4 The sample shall be continuously flowing at a stable flowrate to enable sample line wetted surfaces to reach equilibrium with sample conditions. Do not make measurements following changes to the sample flowrate for the period of time required to recover from transient effects on the particular sampling system.

9.2.5 Control the sample temperature within the capabilities of the temperature compensation algorithms used in the measuring instrument. The sample temperature shall be sufficiently stable to maintain reasonable equilibrium with the sample line wetted surfaces.

9.2.6 Do not locate the cell where it would be exposed to demineralizer reagents as noted in 6.9.

9.2.7 Additional sampling precautions are provided in Practices D 1066, D 3370, Specification D 1192, and Practice D 3864.

10. Calibration

10.1 *Measuring Instrument*—Evaluate instrumentation of unproven performance in high purity samples using the procedure in Annex A1. Thereafter, use calibrating resistors with ±0.1 % tolerance in place of the measuring cell and temperature compensator. The conductivity check resistance in ohms equals the cell constant (cm $^{-1}$) divided by the conductivity to be indicated (S/cm). Resistivity check resistance equals the cell constant (cm $^{-1}$) times the resistivity to be indicated (ohm-cm). The temperature compensator resistance as defined by the manufacturer must simulate a sample temperature of 25.0°C, the reference temperature, that eliminates any compensation in order to follow the relationships given above.

NOTE 1—It should be understood that the use of a precision resistor in place of the cell checks only the ability of the instrument to measure a pure resistance, whereas the cell and leadwire characteristics include parallel and series capacitance. The manufacturer's circuit design must have the capability to measure with installed cell and leadwire characteristics, verified by the test in Annex A1.

10.2 *Leadwire Effects*— When leadwire length between the instrument and cell is greater than 7 m, check calibration of the instrument a second time by connecting the calibrating resistors at the far end of the leadwire and noting the difference, if any, in readings with the long leadwire in the circuit. Check both temperature and conductivity/resistivity readings. Leadwire-induced errors in high purity measurements are typically caused by parallel capacitance of the cell leads and resistance of the temperature compensator leads. Leadwire capacitance is minimized on some instruments by isolating one cell lead within a driven shield. With other instruments, the use of fluorocarbon insulated or shortened leadwire, or both, may be necessary. (Fluorocarbon provides the best available dielectric properties and can reduce capacitance to about half that of cable using other insulating material.) Do not use long shielded leadwire unless the instrument is specifically designed for it since the shield can increase capacitance and associated errors with conventional measuring circuits. Follow manufacturer's wiring recommendations closely.

10.3 *Temperature Measurement Circuit*—Some temperature measurement circuits require precise temperature calibration after installation to compensate for leadwire resistance and ensure accurate temperature compensation. Where necessary, perform this according to manufacturer's recommendations.

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[5] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Analar Standards for Laboratory Chemicals," BDH Ltd., Poole, Dorset, U.K., and the "United States Pharmacopeia."

10.4 *Conductivity Cells*—The cell constant calibration of conductivity/resistivity cells is ultimately referenced to standard solutions of potassium chloride of known conductivity from Test Methods D 1125 or NIST standards **(8)**. However, due to the high uncertainties of atmospheric and container surface contamination, direct cell calibration with standard solutions below 100 µS/cm is not recommended. Although these solutions are available, their successful use for calibration is beyond the scope of this test method. See Note 2 and Note 3.

10.4.1 To determine the cell constant of a high purity conductivity cell with an instrument capable of accurate measurement over the range of pure water to 150 µS/cm with a single cell constant, use Test Methods D 1125, Solution D, 146.93 µS/cm or NIST Standard Reference Material 3191, nominal value 100 µS/cm directly. This calibration with documented certification can be provided by some cell manufacturers.

10.4.2 To determine the cell constant of a high purity conductivity cell with an instrument which does not accurately cover the range from pure water to 150 µS/cm with a single cell constant, accomplish calibration using an intermediate higher constant cell as a secondary standard. Calibrate in a higher conductivity standard solution from Test Methods D 1125, Reference Solution C, 1408.8 µS/cm, or Reference Solution D, 146.93 µS/cm or NIST Standard Reference Materials 3192, nominal value 500.0 µS/cm or 3193, nominal value 1000.0 µS/cm **(8)**. This cell then becomes the secondary standard for comparison with low constant cells in lower conductivity solutions that need not be standards **(9, 10)**. This calibration with documented certification can be provided by cell manufacturers. Refer to Annex A2 for details of cell constant calibration.

NOTE 2—Direct cell calibration in a low conductivity standard near 15 µS/cm has been proposed under highly controlled conditions. However, determination of the contribution of the background water conductivity, which represents about 7 % of the total measurement if performed in open air, was not addressed **(11)**.

NOTE 3—The lowest conductivity NIST Standard Reference Material has a nominal conductivity of 5 µS/cm at 25.0°C. However, the typical uncertainty is greater than that expected by other methods.

11. Procedure

11.1 Set up the flow type conductivity/resistivity cell, leadwire and instrument with calibration verified as in Section 10. Where severe fouling is anticipated at startup, divert the sample initially to prevent an accumulation of contaminants in the cell. If using a sample line, establish a flowrate through the cell of 200 cc/min or according to manufacturer's recommendations and allow several hours of rinse time if using new sample components, flow chamber, or cell to ensure complete removal of air and trace contaminants.

11.2 If specialized temperature compensation is not available, verify that the sample temperature is stabilized at 25.0 ± 0.2°C.

11.3 Read the conductivity or resistivity.

12. Precision and Bias

12.1 Neither precision nor bias data can be obtained for this test method from a collaborative study designed in accordance with the requirements of Practice D 2777 since this test method is a continuous determination. This inability of Practice D 2777 procedures to obtain precision and bias data for continuous determinations is recognized and stated in the scope of Practice D 2777. (Some experience approximating single-operator precision on high purity specific and cation conductivity measurements in power plants has been reported as a part of EPRI project RP2712-3 **(12).**)

13. Keywords

13.1 cation; conductivity; high purity water measurements; resistivity; specific conductance; specific resistance

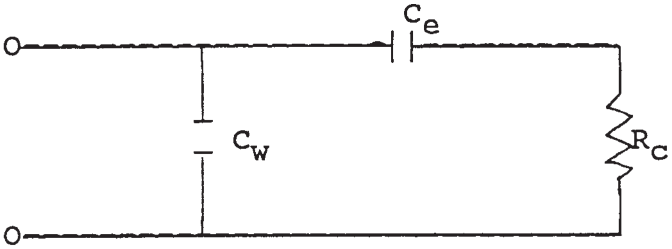
ANNEXES

(Mandatory Information)

A1. EVALUATION OF INSTRUMENT HIGH PURITY MEASUREMENT CAPABILITY

A1.1 The performance of a conductivity/resistivity measuring instrument design is evaluated using an electrical circuit model. This is necessary because measurement of a conductivity cell in high purity water is more complex than measuring a simple resistance. Not all instrument designs are capable of accurate measurements under these conditions. Fig. A1.1 shows the schematic of a simple network that electrically simulates a conductivity cell immersed in high purity water. The instrument must be able to measure the solution resistance, R_c, accurately in this network.

A1.2 From Table A1.1 select measurement conditions closest to those in which the equipment will be installed and find the appropriate circuit component values.



NOTE—C_w = parallel leadwire and cell capacitance,
C_e = series electrode capacitance,
R_c = solution resistance = cell constant/conductivity
= cell constant × resistivity,

FIG. A1.1 Circuit Model of Conductivity Cell in High Purity Water

TABLE A1.1 Conductivity Cell Model Component Nominal Values

Simulated Conditions	C_w (pF)	C_e (µF)	R_c (ohms)
0.055 µS/cm, 18.2 MΩ-cm 0.01 cm $^{-1}$ cell 2 m cable	330	1	182 k
0.055 µS/cm, 18.2 MΩ-cm 0.01 cm $^{-1}$ cell 50 m cable	8200	1	182 k
0.055 µS/cm, 18.2 MΩ-cm 0.1 cm $^{-1}$ cell 2 m cable	330	0.47	1.82 M
0.055 µS/cm, 18.2 MΩ-cm 0.1 cm $^{-1}$ cell 50 m cable	8200	0.47	1.82 M
0.1 µS/cm, 10 MΩ-cm 0.01 cm $^{-1}$ cell 2 m cable	330	5	100 k
0.1 µS/cm, 10 MΩ-cm 0.01 cm $^{-1}$ cell 50 m cable	8200	5	100 k
0.1 µS/cm, 10 MΩ-cm 0.1 cm $^{-1}$ cell 2 m cable	330	0.1	1 M
0.1 µS/cm, 10 MΩ-cm 0.1 cm $^{-1}$ cell 50 m cable	8200	0.1	1 M

A1.3 Connect the network to the cell input of the instrument. Connect a resistor to the temperature compensator input of the instrument with value to simulate 25.0 ± 0.1°C, as specified by the instrument manufacturer. Alternatively, read uncompensated conductivity, if available on the instrument.

A1.4 Remove any trims, cell calibrations, etc., from instrument memory that would prevent it from indicating absolute, uncorrected conductivity or resistivity.

A1.5 Take readings with the instrument measuring the network and again measuring only the resistor. The difference between these readings represents an approximation of the error that can be anticipated in actual cell measurements due to instrument signal handling limitations. (This does not include errors from temperature compensation or cell constant uncertainties.) This test will identify most signal handling deficiencies but is not intended to quantify errors. Also, note that more complex models are needed to represent higher ranges of conductivity measurement. This model is appropriate only for the ranges given.

A2. HIGH PURITY CONDUCTIVITY CELL CONSTANT CALIBRATION WITH LIMITED-RANGE INSTRUMENTS

A2.1 The conductivity cell constant is the greatest uncertainty in the measurement once the requirements for temperature compensation, measuring instrument capability, leadwire, sampling, etc., are satisfied. Therefore, it must be determined with precision, whether in the laboratory or by the cell manufacturer.

A2.2 Using Test Methods D 1125 prepare a Standard Reference Solution C, 1408.8 µS/cm, or Reference Solution D, 146.93 µS/cm. Alternatively, obtain NIST Standard Reference Material 3191, nominal value 100.0 µS/cm, 3192, nominal value 500.0 µS/cm or 3193,nominal value 1000.0 1µ S/cm, or from a traceable source **(8)**. Using one of the standard solutions above, determine the precise cell constant of a nominal 0.5 to 5 cm $^{-1}$ cell using Test Methods D 1125, with the standard solution temperature controlled and cell equilibrated to 25.0 ± 0.2°C. This cell is used as the secondary standard. The type of instrument used for this determination must meet the performance requirements of Annex A1, since the same instrument is used for the comparison in A2.4.

A2.3 Rinse the secondary standard cell and the high purity cell to be tested for at least an hour with flowing Type I water prior to measurement to fully wet electrode surfaces and to wash away any residual contaminants accumulated in storage.

A2.4 Immerse the two cells in stirred Type I water to which dilute KCl solution has been added dropwise to raise the conductivity to 5 to 10µ S/cm. Allow time for the cells and solution to reach temperature equilibrium and tap the cells to remove any bubbles adhering to the cell surfaces. Using the same type of instrument as in A2.2, measure the conductivity/resistivity of each cell as quickly as possible.

A2.5 Calculate the cell constant of the low constant cell as follows:

$$\text{cell constant} = \text{nominal test cell constant} \times \frac{\text{standard cell conductivity}}{\text{test cell conductivity}}$$

REFERENCES

(**1**) Light, T. S., and Licht, S. L., "Conductivity and Resistivity of Water from the Melting to Critical Points," *Analytical Chemistry*, Vol 59, No. 19, Oct. 1987, pp. 2327–2330.

(**2**) Hunt, R. C., "Conductivity and pH Measurements in High Purity Water," *Ultrapure Water*, Vol 3, No. 4, March/April 1986, pp. 39–46.

(**3**) Hunt, R. C., "Combined Conductivity and pH Temperature Compensation in High Purity Water," *Ultrapure Water*, Vol 3, No. 2, July/August 1986, pp. 31–39.

(**4**) Gray, D., and Tenney, A., "Improved Conductivity/Resistivity Temperature Compensation for High Purity Water," *Ultrapure Water*, Vol 3, No. 2, July/August 1986, pp. 27–30.

(**5**) Davis, J., and Blair, C., "Guidelines for Design and Operation of Condensate and Feedwater Sampling Systems," *Ultrapure Water*, Vol 6, No. 3, April 1989, pp. 18–27.

(**6**) "Survey of Corrosion Product Generation, Transport, and Deposition in Light Water Reactors," Electric Power Research Institute Report NP-522, March 1979.

(**7**) Eater, L., "Make Sure Water-Chemistry Samples Are Representative," *Power*, July 1989, pp. 47–50.

(**8**) Certificate of Analysis, Aqueous Electrolytic Conductance Standard Reference Materials 3190–3195, National Institute of Standards and Technology, U.S. Department of Commerce, Gaithersburg, MD.

(**9**) Gray, D. M., "High Purity Conductivity Cell Standardization," *1990 International Conference on Measuring Waterborne Trace Substances, EPRI and NIST*, Baltimore, Aug. 1990.

(**10**) Scheerer, C. C., Cluzel, J., and Lane, R. W.," Monitoring Condensate Polisher Operation Using Conductivity (Specific, Cation, and Degassed Cation) and Sodium Analysis," *International Water Conference Proceedings*, 1989, pp. 321–334.

(**11**) Light, T. S., and Thornton, R. D., "Conductivity Cell Standard for Low Ionic Strength Solutions," *Ultrapure Water*, Vol 8, No. 3, April 1991, pp. 59–66.

(**12**) Rice, J. K., Sopocy, D. M., and Dooley, R. B.," Quantification of Continuous Instrument Error," 1990 International Conference on Measuring Waterborne Trace Substances, *EPRI and NIST*, Baltimore, Aug. 1990.

(**13**) Light, T.S., and Sawyer, P.B., "Resistivity of Very Pure Water and its Maximum Value,"*Power Plant Instrumentation for Measurement of High-Purity Water Quality*, ASTM STP 742, 1981, pp. 175–184.

(**14**) Pate, K.T., "DI Water Resistivity Versus Trace Ion Levels," *Ultrapure Water*, Vol 8, No. 1, January/February 1991, pp. 26–33.

(**15**) Thornton, R.D., Morash, K.R., Light, T.S., Saunders, C.H., and Bevilacqua, A.C., "Measurement of the Resistivity of High-Purity Water at Elevated Temperatures," *Ultrapure Water*, Vol 11, No. 9, December 1994, pp. 18–24.