Standard Test Method for Durability Wear Testing of Separable Electrical Connector Systems Using Electrical Resistance Measurements[1]

This standard is issued under the fixed designation B794; 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 effects of repeated insertion and withdrawal of separable electrical connectors which are harmful to the electrical performance of the connector.

1.2 This test method is limited to electrical connectors designed for use in applications where the current through any one connection in the connector does not exceed 5 A, and where the connector may be separated a number of times during the life of the connector.

1.3 This test method is limited to electrical connectors intended for use in air ambients where the operating temperature is less than 65°C.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B539 Test Methods for Measuring Resistance of Electrical Connections (Static Contacts)

2.2 *Military Standard:*[3]

MIL-STD-1344A Test Methods for Electrical Connectors

[1] This test method is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.11 on Electrical Contact Test Methods.

Current edition approved May 1, 2015. Published May 2015. Originally approved in 1988. Last previous edition approved in 2009 as B794 – 97 (2009). DOI: 10.1520/B0794-97R15.

[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.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

3. Summary of Test Method

3.1 Sample connectors are wired for precision resistance measurements of each test contact. The samples are divided into two groups; then resistance measurements are made of each test contact. The connectors in one group undergo a number of insertion/withdrawal cycles appropriate for the particular connector under test, and the resistances of these connectors are measured again. The connectors in the other group are not disturbed. All samples are subjected to an accelerated aging test; then the resistances are measured again. All samples are separated (withdrawn), exposed to an accelerated aging test in the uninserted condition, removed from the test, reinserted, and resistances measured again. The various resistance measurements are compared to detect effects of the wear and aging on electrical performance.

4. Significance and Use

4.1 Materials for electrical connector contacts must satisfy a number of requirements in the areas of electrical, mechanical, and economic characteristics. The stability of electrical properties is one of the most important of these characteristics. Wear of contact surfaces may adversely affect these electrical properties, especially in designs where the contact surfaces are relatively thin coatings. This test method provides a means to compare various material systems on a basis relevant to their application in electrical connector contacts.

4.2 Repeated insertion and withdrawal of a connector may cause wear or other mechanical damage to the electrical contact surfaces, rendering those surfaces more susceptible to environmental degradation. This test method is intended to detect degradation of the electrical properties of the connector by such processes.

4.3 This test method describes procedures for conducting wear and durability testing of electrical connectors; the procedures produce quantitative results. These results may be used to compare the performance of different connector designs so that meaningful design choices can be made. Such results may also be used to compare the performance of a connector to a previously established standard to evaluate the quality of the samples under test.

4.4 The test results obtained from this test method are limited in their applicability to connector combinations that are equivalent in design and manufacture to those actually tested.

4.5 The user is cautioned that the conditions in this test should be compared to the conditions that the connector will experience in the intended application in order to determine the relevance of this test method to the particular needs of the user. For example, the environmental stress in this test method is less severe than certain industrial and marine environments and therefore test results are not directly applicable to predict the performance of product intended for use in such areas.

4.6 It is recommended that this test method be used in one of two ways. First, it may be used to evaluate and report the performance of a particular connector system. In such a case, it is appropriate to report the results in a table in the format shown in Fig. 1 and to state "The results shown in the table were obtained for (insert connector designation or description) when tested in accordance with ASTM Standard B794, Method __ , Procedure __ ." Second, it may be used to impose requirements for acceptance of product. In this case, limits for the values shown in Fig. 1 must be established prior to product acceptance testing. Such limits may be established by various methods such as by evaluation of product which is known to be acceptable or by application of appropriate experience. These limits must be documented in a manner that the entity performing the product test can refer to the limits to determine if the test product conforms to such limits. A purchaser may wish to supply a table of limits and include on the purchase order a statement similar to: "The product, when tested in accordance with ASTM Standard B794, Method __ , Procedure __ , shall meet the limits in the supplied table." This table supplied by the purchaser may set limits on all of the values in Fig. 1, or only on a subset of those values that the purchaser deems adequate to ensure the performance of the product.

SUMMARY OF RESULTS FOR ALL CONTACTS						
Section 1: Wear Test Samples, Total Insertions = __						
Value Reported (data set)	Minimum	Mean	Median	Maximum	Stnd Dev.	N*
Initial Resistance (M1)	__	__	__	__	__	__
Resistance Change after added wear cycles (C1)	__	__	__	__	__	__
Resistance Change after 10 days in environmental test in the connected condition (C2)	__	__	__	__	__	__
Resistance Change after additional 10 days in environmental test in the unconnected condition (C3)	__	__	__	__	__	__
Section 2: Control Samples, Total Insertions = 2						
Value Reported (data set)	Minimum	Mean	Median	Maximum	Stnd Dev.	N*
Initial Resistance (M1)	__	__	__	__	__	__
Resistance Change after 10 days in environmental test in the connected condition (C2)	__	__	__	__	__	__
Resistance Change after additional 10 days in environmental test in the unconnected condition (C3)	__	__	__	__	__	__

* Number of contacts measured

Note: A value is to be entered in the table at each location indicated by "__"

FIG. 1 Sample Format for Reporting Results

5. Apparatus

5.1 *Environmental Test Chamber,* capable of controlling the test ambient in accordance with the sequence shown in Table 1. The test chamber shall be sufficiently large that each test sample shall be positioned with at least 100 mm separating it from the nearest wall of the test chamber. The test chamber design and operation procedure shall conform to the requirements contained in MIL-STD-1344A, Method 1002.2.

5.2 An instrument is required for measuring resistance by the four-wire method. This instrument shall operate within the limits on current and open-circuit voltage set forth in Test Methods B539, Test Method C. The instrument shall be capable of measuring a resistance less than 0.100 Ω with a resolution of 0.0001 Ω. For a resistance 0.100 Ω or larger, the instrument shall be capable of measuring it with a resolution of 0.1 % of the resistance value.

6. Sampling and Test Specimens

6.1 *Selection of Sample Connectors*—Obtain sufficient sample connectors so that the electrical resistance of at least 200 contacts contained in at least 20 separate connectors will be measured in the test. Obtain sample connectors that are representative of those that will be used in the intended application. Recognize that a connector consists of two halves and both halves must be representative of the product to be used. In some cases one half will be a conductive area or pad on a printed wiring-board surface, therefore printed wiring boards must be obtained that have representative conductive pads. Specifically, the conductive pads shall be manufactured to the same requirements as those that will be required of parts to be used in the system application. These requirements will normally cover the manufacturing process, thickness, composition, hardness, and roughness of both the finish coating and of any underplating or undercoating. Protective treatments, if used, shall also be specified. For the purpose of connector testing, such printed wiring boards are generally fabricated with appropriate circuitry to permit four-wire resistance measurements.

6.2 *Selection of Sample Contacts*—In the case where the samples are multicontact connectors and electrical measurements are performed only on a fraction of the total number of

TABLE 1 Environmental Test Sequence

NOTE 1—Tolerance on temperature control is ±2°.

Step	Elapsed Time, h	Temperature, °C	Relative Humidity, %
1	0–2.5	ascending, 25–65	92 ± 3
2	2.5–5.5	65	92 ± 3
3	5.5–8	descending, 65–25	87 ± 8
4	8–10.5	ascending, 25–65	92 ± 3
5	10.5–13.5	65	92 ± 3
6	13.5–16	descending, 65–25	87 ± 8
7	16–24	25	92 ± 3

contacts, the contacts measured shall be distributed throughout the field of contacts. Measure the corresponding contacts in each sample connector.

7. Conditioning

7.1 An electrical measurement laboratory is required in which the ambient temperature is controlled to 23 ± 5°C and the relative humidity is held below 60 %. This laboratory need not be dedicated to this test program to the exclusion of other uses so long as those other uses do not degrade the quality of data obtained on the connector test samples.

8. Procedure

8.1 *Selection of Test Method*—Select a test method from the following table which is appropriate for connector design and application.

Method	Number of Insertions
A	5
B	10
C	25
D	50
E	100
F	200
G	400
H	(number selected per agreement between producer and user)

8.2 *Sample Preparation:*

8.2.1 Assemble the connectors into mounting plates, guides, fixtures, racks, or similar apparatus if such apparatus is generally used in the actual application of the connector. Perform such assembly at the time in the sample wiring process that best simulates the typical manner in which the connectors are assembled into a system.

8.2.2 Wire samples for evaluation by this test method for electrical resistance measurements before the two connector halves are plugged together. The wiring and resistance measuring circuitry shall be of the four-wire type as described in Test Methods B539. Do the wiring in a manner that is typical of the way the connector would be wired in service, and especially in a manner that does not introduce unrealistic contaminants or mechanical stresses on the connector. Do not perform cleaning, lubrication, or other treatments of the connector unless such treatments are specified by the connector manufacturer or user as the required procedure for the application of the particular connector under test.

8.2.3 Wire at least one reference resistor for resistance measurements in such a manner that its resistance may be measured using the same instrumentation and procedures as are used for the test contacts. It is suggested that this reference resistor be a length of wire or a path on a printed wiring board with a resistance of the same order of magnitude as that of typical test contacts. Measure and record the resistance of this reference resistor each time that the test contacts are measured. Expose this reference resistor to the same test environments as the test contacts and generally treat the resistor in the same manner as the test contacts.

8.2.4 Label the connectors and individual contacts therein in such a manner that each test contact is uniquely identified. Randomly select one half of the connectors (10 connectors if 20 connectors is the total sample size) to undergo wear testing, and refer to these as the "wear test samples." Insert the other half of the connectors only once at the beginning of the test and refer to these as the "control samples."

8.3 *Methods and Procedures for Resistance Measurements:*

8.3.1 Prepare data sheets such that all information shown in the sample data sheet illustrated in Fig. 2 may be recorded for each test contact.

8.3.2 Perform all electrical measurements and wear tests in the electrical measurements laboratory discussed in Section 7. Test samples must be allowed to come to equilibrium in this ambient for a minimum of 1 h before electrical measurements or connector insertion/withdrawal operations begin. All connector insertion/withdrawal operations are done with the connector disconnected from any power source.

8.3.3 Perform all resistance measurements under dry-circuit conditions as specified in Test Methods B539, Test Method C. In addition, use a suitable method to cancel small potentials that may be present in the measurement circuit. Suitable methods are (1) measuring the resistance with the current flowing one direction through the test contact, reversing the current flow and remeasuring resistance, and averaging the two resistance measurements; (2) measuring voltage drop across the test contact with a constant d-c current flowing, measuring voltage across the contact with no impressed current, and subtracting the second voltage from the first and using the

DATA TO BE RECORDED FOR EACH CONTACT

Time of measurement	Designation for Measured value
Resistance, first measurement	**R1**
Resistance, second measurement	**R2**
Resistance, third measurement, made only if $\lvert \mathbf{R1}-\mathbf{R2} \rvert > 0.05\,(\mathbf{R1}+\mathbf{R2})$	**R3**
Resistance, after wear cycles, made only for contacts designated for wear testing	**R4**
Remeasure of above	**R5**
Resistance, after 10 days environmental test in the connected condition	**R6**
Remeasure of above	**R7**
Resistance, after additional 10 days in environmental test in the unconnected condition	**R8**
Remeasure of above	**R9**

FIG. 2 Sample Data Sheet

result to calculate resistance; or (3) measuring resistance using an a-c method. The user shall select one method and use it throughout the experiment.

8.3.4 Make all resistance measurements in such a manner that the value is recorded with the resolution meeting the following requirements: For contacts with a measured resistance less than 0.100 Ω, record the resistance with a resolution of 0.0001 Ω or better. For contacts with resistance of 0.100 Ω or greater, record the resistance measurement with a resolution of 0.1 % or better. If the resistance changes during the measurement such that after about 5 s a stable value of the required resolution cannot be determined, record an estimate and note that the resistance is unstable.

8.3.5 After each measurement of the reference resistor, compare the new measured value to the initial value. If the values differ by more than 2 %, check the calibration of the resistance measurement instrumentation. If repair or recalibration, or both, of the instrumentation is required, discard any measurements of test contacts made since the preceding measurement of the reference resistor and repeat the measurements. If new measurements are not feasible, mark the suspect measurements on the data sheets.

8.3.6 If the measured resistance of a contact appears unreasonable, appropriate investigation of possible causes is recommended so long as the investigation does not affect the experiment. If the resistance in question can be traced to a cause unrelated to the contact under test, the data for that contact may be deleted from the data set. If the cause is repairable without affecting the experiment, repair and remeasurement is permitted. Typical causes of this nature are wiring errors and failed connections in the measurement leads. Such investigations, repairs, and data-set adjustments are permitted at any time that the samples are accessible. Do not include contacts deleted from the data set in the sample size recorded in column "N" of Fig. 1. Deletion of more than 5 % of the contacts wired for measurement is not permitted.

8.4 *Initial Measurements and Wear Testing:*

8.4.1 Insert one connector half in its mating member such that the electrical circuit is completed in the manner that the connector is intended to function.

8.4.2 Measure and record (as R1) the resistance of each contact. After all test contacts on a connector have been measured, repeat the measurements recording the second value (as R2) measured for each contact. Compare the two measurements for each contact. If the absolute value of the difference between R1 and R2 exceeds 5 % of the sum of R1 and R2, then make and record a third measurement for that contact. Record the new value as R3.

8.4.3 Disconnect the test contacts from any power source during the connector withdrawal/insertion operations.

8.4.4 Using any guides, handles, levers, or other mechanical aides provided by the connector and its housing, repeatedly withdraw and reinsert each of the wear-test connectors such that the total number of insertions on each connector equals the number of insertions indicated for the test method chosen. Withdrawal and insertion may be performed manually or with an appropriate actuating machine; however, the time for each complete withdrawal/insertion cycle shall not be less than 12 s. Provide a minimum dwell time of 5 s in both the connected and the unconnected position. Insertion and withdrawal velocity shall be reasonably typical of that seen by the particular connector in actual usage.

8.4.5 Remeasure the resistance of each contact in the wear-test group and record the result as R4. After a value of R4 has been recorded for all contacts on a connector, remeasure each contact on that connector and record the resistance of each as R5.

8.5 *Accelerated Aging Test:*

8.5.1 *Selection of Test Procedure*—Two alternative procedures are provided: the user must select one based on the test objectives and available facilities. The procedures differ only in their treatment of vibration during the test. Procedure A places no requirements on the measurement or control of vibration level experienced by the samples during the test. Procedure B requires that vibration exceed a minimum value and that the vibration level be measured and recorded at least once during the test.

8.5.1.1 *Procedure A*—Samples will be exposed to an accelerated aging test in accordance with the conditions shown in Table 1. This test is similar to that specified in MIL-STD-1344A, Method 1002.2, Type II. The test includes temperature and humidity cycling where the temperature is 65°C and the relative humidity is 92 ± 3 % at the high end of the cycle. The test duration is 10 days. The procedure is basically as described in MIL-STD-1344A except that the samples are not subjected to the low-temperature excursion (Step 7a). No bias or polarization voltage is to be applied to the samples during the test program.

NOTE 1—A convenient type of test chamber for this type of environmental exposure is a programmable temperature-humidity chamber. Such chambers normally show perceptible vibration which may be conducted to specimens exposed in the test volume. One survey of vibration levels showed that test samples in such chambers might experience vibration with a peak-to-peak amplitude in the range from 0.01 to 0.1 mm at a frequency of 350 cpm as measured on the fixture which holds the sample connectors. The significance of this variable is not known; therefore, information on the identity of the test chamber and any available information on the vibration levels is to be recorded in the test report described in Section 10.

8.5.1.2 *Procedure B*—The test conditions for this procedure are identical to those for Procedure A, except that the following additional requirement is imposed. During the exposure of samples to the accelerated aging test, also subject the samples to a vibration such that the peak-to-peak amplitude is greater than 0.01 mm at a frequency of 350 cpm as measured on the fixture that holds the sample connectors. This amplitude and frequency of vibration generally can be achieved by placing samples in a typical chamber of the type described in Note 1 if that test chamber has fans and motors for controlling the environment and no extra measures are taken to isolate the test samples from chamber vibration. Measure the amplitude of vibration once during the test period and report in the test report.

8.5.2 Subject the connector to the accelerated aging environment for 10 days with the two connector halves remaining connected together. Remove the test samples from the aging test and allow at least 1 h for them to come to equilibrium in the electrical measurement laboratory. Remeasure the resistance of each contact and record the result as R6. After a value of R6 has been recorded for all contacts on a connector, remeasure each contact on that connector and record the resistance of each as R7.

8.5.3 Separate all connector halves and subject all connectors to the accelerated aging ambient for an additional 10 days in the unconnected condition. Remove the test samples from the aging test and allow at least 1 h for them to come to equilibrium in the electrical measurement laboratory. Plug each pair of connector halves together again. Remeasure the resistance of each contact and record the result as R8. After a value of R8 has been recorded for all contacts on a connector, remeasure each contact on that connector and record the resistance of each as R9.

9. Calculation

9.1 Prepare a Summary of Results table in the format shown in Fig. 1 to report the results. For the wear-test samples, enter at the indicated location in the table the total number of insertions that each sample received.

9.2 For each contact, calculate the values shown in Table 2. Specifically, calculate the average initial value of resistance for each contact, M1, using the two or three initial values recorded. Calculate the average resistance for each contact at each step in the test program by averaging the two measurements made at that step, that is, R4 and R5, R6 and R7, R8 and R9. Subtract the average measured resistance of each contact after wear (but before the environmental test) from the average initial resistance for that contact to obtain the change in resistance, C1. (This data will be available only for the contacts which underwent wear testing.) Subtract the average measured resistance of each contact (after 10 days in the inserted condition in the environmental test) from the average initial resistance for that contact to obtain the change in resistance, C2. Subtract the average measured resistance of each contact (after the final 10 days in the unconnected condition in the environmental test) from the average initial resistance for that contact to obtain the change in resistance, C3.

9.3 Combine the values of average initial resistance (M1) for the wear-test samples into a single data set; determine the minimum, mean, median, maximum, standard deviation, and number of contacts for this data set. Enter these values on the first line of Section 1 of the Summary of Results table shown in Fig. 1. Similarly, combine the M1 values for the control samples into a data set, determine the values requested, and enter on the first line of Section 2 of Fig. 1.

9.4 Using the values calculated for the average resistance change after wear for the wear sample group (C1), determine the number of test contacts and the minimum, mean, median, maximum, and standard deviation of the average resistance change values. Enter the values on the second line of Section 1 in the table shown in Fig. 1.

9.5 Using the values calculated for the average resistance change after exposure for 10 days in the connected condition (C2), determine for both sample groups the number of test contacts and the minimum, mean, median, maximum, and standard deviation of the average resistance-change values for each sample group. Enter the values on the appropriate lines in the table shown in Fig. 1.

9.6 Using the values calculated for the average resistance change after exposure for 10 days in the unconnected condition (C3), determine for both sample groups the number of test contacts and the minimum, mean, median, maximum, and standard deviation of the average resistance change values for each sample group. Enter the values on the appropriate lines in the table shown in Fig. 1.

TABLE 2 Values to be Calculated for Each Contact

Value to be Calculated, avg	Calculation	Designation
Initial resistance,	$(R1 + R2)/2$ or $(R1 + R2 + R3)/3$	*M1*
Resistance after added wear cycles, (available only for contacts designated for wear testing)	$(R4 + R5)/2$	*M2*
Resistance after 10 days environmental test in the connected condition	$(R6 + R7)/2$	*M3*
Resistance after 10 days environmental test in the unconnected condition	$(R8 + R9)/2$	*M4*
Resistance change after added wear cycles, (available only for contacts designated for wear testing)	$M2-M1$	*C1*
Resistance change, after 10 days environmental test in the connected condition	$M3-M1$	*C2*
Resistance change, after 10 days environmental test in the unconnected condition	$M4-M1$	*C3*

10. Report

10.1 Report the following information:

10.1.1 Date the test was started and completed,

10.1.2 Test method used (Method A to H). If Method H is used, list the number of insertions used,

10.1.3 Test procedure used (Procedure A or B),

10.1.4 Identify the test chamber(s) used to achieve the temperature-humidity cycle for the environmental exposure. Include a statement on what is known about the vibration level that samples experienced in the chamber. If Procedure B is used, state the measured vibration level in the chamber,

10.1.5 Provide a description of the connector samples used in this test method. This description will normally include the manufacturer and the designation (catalog number, code number, etc.) for the connector tested. Both halves of the connector must be described. If one half is a printed wiring board, provide a description of the contact area (coating thickness, composition, other requirements, etc.),

10.1.6 Include the Summary of Results table prepared in Section 9,

10.1.7 Note any deviations from the procedure outlined in this test method, and

10.1.8 Include notes on any observations of unusual or unexpected events, or any analysis that may help to explain the results.

11. Precision and Bias[4]

11.1 *Precision*—An interlaboratory round robin conducted with 4 separate laboratories using a single manufacturing lot of connectors produced the following results:

11.1.1 The ratio of the median of the C3 values for the 200 wear cycle group to the 2 wear cycle group ranged from 2 to 23.

11.1.2 Comparing the median of the C3 values for the 4 laboratories for the 2 wear cycle group, the ratio of the maximum to the minimum is 4.0. Comparing the median of the C3 values for the 4 laboratories for the 200 wear cycle group, the ratio of the maximum to the minimum is less than 5.

[4] Supporting data and results of the interlaboratory round robin that provides the basis for the precision statements are available from ASTM International Headquarters. Request Research Report RR:B04-1004. Contact ASTM Customer Service at service@astm.org.

11.1.3 The same round robin disclosed that mean of the C3 values is strongly influenced by outliers, and a precision statement based on the sample mean is not meaningful.

NOTE 2—Based on the round robin results, it is recommended that experimental controls be run with each experiment. Such controls may be examples of connectors known to be acceptable, or connectors of a known quality. It is also recommended that if the mean is used in the data analysis, that careful attention is given to the influence of outliers in the population.

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in Test Method B794 for measuring wear in electrical connectors using electrical resistance measurements, no statement on bias is being made.

12. Keywords

12.1 contact resistance; electrical connectors; electrical contacts; temperature and humidity cycling test; wear; wear tracks