Standard Guide for Specification and Quality Assurance for the Electrical Contact Performance of Crimped Wire Terminations[1]

This standard is issued under the fixed designation B942; 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 guide contains practices for specifying and evaluating the electrical contact performance of crimped-type terminations with solid or stranded conductors.

1.2 This guide provides information relevant to the electrical contact performance of a crimped wire termination. It does not cover other aspects of selection and use of crimped terminals.

1.3 The methods discussed in this guide apply only to the wire termination, which is the electrical contact interface between the conductor(s) and the terminal. Other aspects important to terminal evaluation, such as the properties and performance of electrical insulation, the effectiveness of strain relief features, and the quality of contact between the terminal and other electrical circuit elements, are not included.

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 Safety Data Sheet (SDS) 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)

B542 Terminology Relating to Electrical Contacts and Their Use

B827 Practice for Conducting Mixed Flowing Gas (MFG) Environmental Tests

B845 Guide for Mixed Flowing Gas (MFG) Tests for Electrical Contacts

B868 Practice for Contact Performance Classification of Electrical Connection Systems

B913 Test Method for Evaluation of Crimped Electrical Connections to 16-Gauge and Smaller Diameter Stranded and Solid Conductors

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

2.2 *Other References:*[3]

UL 486-A Wire connectors and Soldering Lugs for Use With Copper Conductors

UL-310 Electrical Quick-Connect Terminals

3. Terminology

3.1 Many terms related to electrical contacts used in this guide are defined in Terminology B542.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *connection resistance, n*—the electrical resistance attributable to a wire termination over and above that of an identical solid metallic structure without pressure contact interfaces. For crimped terminations that are the subject of this guide, the connection resistance results from the resistance of a multitude of contact regions having both film and constriction resistance, plus, where stranded wire is involved, an additional amount due to unequal current distribution among the wire strands at the termination.

3.2.2 *crimp, v*—to establish an electrical and mechanical attachment between the two members by mechanically deforming one contact member around another. In most cases, one member is a stranded or solid wire, or a group of wires, the other is a hollow cylinder or partial cylinder that is deformed around the wire(s).

3.2.3 *crimp barrel, crimp tab, n*—the portion of the crimp terminal that is deformed in the crimping operation.

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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.

[3] Available from Underwriters Laboratories Inc. (UL), http://www.ul.com.

3.2.4 *crimped termination, n*—a mechanical and electrical connection between a conductor, generally a wire, and a component, typically a terminal specifically made for the purpose. The crimped termination is made by compressing (crimping) the component (crimp barrel) or tab(s) of the component around the conductor using a tool specifically designed for the purpose.

3.2.5 *crimp terminal, n*—a metal component designed to be electrically and mechanically attached to a wire by deforming a portion of the component in a crimping operation to form an attachment to the wire. The other end of the terminal usually has a ring, fork, spade, tab, or related configuration designed to attach to another circuit element. Some crimp terminals terminate multiple wires within the same crimp barrel.

4. Significance and Use

4.1 The purpose of this guide is to provide end-product manufacturers and other users with technical information and methods recommended towards the achievement of successful application of crimped wire terminals.

4.2 For any given use, there is generally a choice of terminal types available, employing different mechanical design, materials, and installation tooling. Although terminals available to choose from may be similarly rated, typically according to wire sizes and combinations, their electrical contact performance in the end product may vary substantially. For many applications, the end-product reliability and user safety is substantially influenced by the choice of terminal and the quality of the completed termination. This guidance document contains specialized information on selection, assembly, and quality control of crimped wire terminals, covering aspects considered to be necessary to achieve reliable long-term operation in the intended application. This information is not generally found in commercial literature or textbooks. The methods discussed utilize connection resistance as the primary measure of termination quality, and change of connection resistance with time as the measure of termination deterioration. The methods are based on a foundation of modern electrical contact theory and practice.

5. Connection Resistance Considerations

5.1 The required performance of a crimped wire termination depends on the application, and it must be determined by the user or end-product manufacturer based on the effect that connection resistance may have on the reliability or safety, or both, of the end product. To satisfy the more demanding application requirements, it is necessary to establish adequate initial metallic contact at the wire-to-connector interface and maintain that contact over many decades of service without maintenance or inspections.

5.2 A crimped wire termination is intended to be a permanent electrical contact. Current passes through a multitude of contact interfaces among the wire strands and from some of the strands to the connector body.

5.3 In many applications, substantial connection deterioration can be tolerated because there are no harmful consequences of increasing connection resistance. Crimp termination failures in other applications have potentially severe consequences, however, which may be avoided by use of stringent acceptance criteria and quality control methods that assure high quality connections.

5.4 A crimp termination is conceptually visualized as compressed into a virtually solid mass of metal, with wire and terminal in intimate contact at the interfaces. Because of an effect generally called "spring-back," this is often incorrect. Spring-back is the elastic recovery of the distorted metal back towards its original shape. While the crimping dies are closed on the terminal, the surfaces are in contact. Spring-back then occurs when the crimping die is removed.

5.5 If the outer terminal springs back more than the wire strands, then the normal force and the real area of contact at the contact interfaces within the termination are substantially reduced. When this occurs, there may be little or no residual compressive force at the contact interfaces within the termination. This degrades the mechanical integrity of the termination and also makes it more susceptible to corrosive deterioration. Spring-back causes open spaces to develop where intimate surface-to-surface contact is expected, allowing ingress of moisture and atmospheric contaminants, thereby accelerating oxidation and corrosion related deterioration.

5.6 The selection and setup of the correct die set for the particular terminal are critical factors. For a given terminal and wire fill, there is a narrow range of compression within which satisfactory results will be obtained. Inadequate crimping generally results in shortened service life. Over-crimping may also be harmful, due to crack formation in the crimp barrel, severing of wire strands, or excessive deformation of the wire.

5.7 The typical connection resistance of crimped wire terminations when initially made will be low, about the same order of magnitude as the bulk resistance of the terminal. A newly-made termination of #16 AWG stranded copper wire, for example, is expected to have a connection resistance of less than 10^{-4} Ω (0.1 milliohm). Deterioration at the metallic contact interfaces within the crimped termination may occur after initial installation, causing increasing connection resistance with time in service. Termination deterioration may be due to oxidation, corrosion, mechanical and/or thermal effects, any of which may occur within the normal and expected conditions of use in a particular application.

5.8 Increasing connection resistance of terminations in a particular end-product may influence reliability or safety, or both, depending on the particular function and current for each crimped termination in the circuit. Within a given product, there may be crimp terminations having substantially different reliability and safety requirements.

5.8.1 An example is a portable heater intended for retail sale and residential use. There are eight crimped wire terminations in the unit's internal wiring that are in series with the heating element, which draws 12 A. There are also seven crimped wire terminations associated with neon indicator lights (less than 0.01 A), and another four in the heater's blower motor circuit (1.2 A). (Note: there may be more than one subcircuit terminated within a single crimp fitting.) The influence of connection resistance on reliability and safety for each of the crimped termination types in this example heater is outlined in Table 1. Adverse consequences of connection resistance increase are generally more severe with higher circuit current.

5.8.2 A second example is a temperature sensitive control or safety device, on which the effective operating set point may be substantially offset due to self heating (I^2R) at its wire terminals. For instance, a manually-reset thermal safety device may erroneously trip due to connection heating, causing malfunction of the product or system in which it is installed.

5.9 *Factors Influencing Connection Resistance:*

5.9.1 Acceptably low initial resistance of crimp terminations is very easily achieved. To assure that it will remain acceptably low in the intended application is the greater challenge, since the rate of deterioration (resistance increase) in service is sensitive to many variables of the terminal/wire/tooling system.

5.9.1.1 Terminal variables include the physical configuration, the materials of construction (including plating) and their properties, and the surface finish.

5.9.1.2 Conductor variables include the material, hardness, plating material and thickness, stranding, and surface cleanliness. If wire strands are to be pre-tinned, it is especially important to specify and control the thickness, since most tinning materials are self-annealing at room temperature. If the tinning is too thick, loss of contact force due to self-annealing (or creep/stress relaxation) may result in premature failure.

5.9.1.3 Tooling variables include selection of the tooling (dies and associated crimping tool or machine), its setup, its operation, and its wear and maintenance.

5.10 The rate of deterioration is also influenced by the environmental and mechanical conditions of the application.

5.10.1 Deterioration due to corrosion and oxidation can occur in ordinary environment, and is generally accelerated by high temperature and high humidity. Corrosive agents are present in the normal atmosphere as well as in special industrial and household situations.

5.10.2 Temperature variations in service may cause deterioration due to differential thermal expansion effects (causing fretting and thermal ratcheting), while extreme high temperature can result in metallurgical changes (dezincification of brass, annealing) and loss of contact force (creep, stress relaxation). The specific operating conditions in many common applications impose harsh thermal conditions, such as in the engine wiring harness of an automobile, or at the terminal of a heating element.

5.10.3 Deterioration may also occur due to mechanical vibrations (causing fretting) and due to mechanical motions and stresses that cause conductor strand breakage.

6. Specification of Required Crimp Termination Performance

6.1 The sensitivity of each particular circuit to connection resistance of its crimp terminations must be assessed, and a maximum allowable connection resistance must be specified. Connection resistance is a series resistance, and, in a newly-made wire termination, is generally negligible, of the order of less than 0.001 Ω. With time in service, however, or if poorly made, connection resistance may exceed 1 Ω.

6.1.1 Relatively high series resistance of one or more crimp terminations in a circuit may have an adverse effect on the circuit's functionality. For example, some battery chargers will malfunction (improperly regulate the charging cycle) if a series resistance of the order of 0.1 Ω or more is introduced in the output circuit.

6.1.2 Resistive heating (I^2R) at a high resistance termination may have an adverse effect on both the functionality and also on the safety of the product.

6.1.2.1 An example of thermally-induced malfunction due to excessive crimp termination resistance is at a manually reset over-temperature cutout device in a portable electric heater. Normally, with connection resistance of the order of 0.0001 Ω, at 12 amps, the I^2R heating from the two crimp terminations on the device (0.03 W) results in a negligible temperature increase at its temperature sensing element. If the connection resistance increases to 0.01 Ω at one of the terminations, the resulting heat generation (1.4 W) causes sufficient temperature rise at the over-temperature device to activate it, incorrectly shutting off the heater.

6.1.2.2 A safety problem arises if self-heating at a termination causes damage to the electrical insulation or is extreme enough to pose a direct fire hazard. For example, if the connection resistance of a crimp termination carrying 12 A increases to 0.1 Ω, (14 W heat generation), the temperature on the wire would become high enough to destroy the insulation on the adjacent section of wire and present a fire ignition hazard if any combustible materials are in contact with it.

6.2 The minimum life requirement must be determined and specified. This is the time that must pass before a termination can deteriorate to its allowable maximum connection resistance.

6.2.1 When there is no safety consequence of failure, the specified crimp termination minimum life may be set as low as the expected (or guaranteed) life of the system of which it is a part.

6.2.2 When there may be safety consequences of failure, it is recommended that the required life be considered as indefinite. In terms of connection resistance, that requires that there

TABLE 1 Example—Crimp Terminations within a Portable Electric Heater

Circuit Application within Heater Assembly	Maximum Current, Amps	No. of Terminals/ No. of Different Types	Maximum Allowable Connection Resistance, Ohms	Consequence(s) of Exceeding Maximum Allowable Resistance
Main power	13.2	2/1	0.005	damage to wire insulation
Heater element power, general	12	4/2	0.005	damage to wire insulation
Temperature limit switch (heater element power)	12	2/1	0.001	offset of trip point, product malfunction
Blower Motor	1.2	2/1	2.0	motor may fail to start
Indicator Lights	nil	7/3	>10 000	indicator light malfunction

be no reasonable possibility that the resistance will increase to its allowable maximum no matter how long it remains in service. This is achievable, in that crimp terminations can be reliably manufactured that will demonstrate essentially zero resistance increase under most service conditions. If it cannot be done with a crimp termination, due to the specific challenges of the particular application, then it is recommended that a more suitable termination type should be utilized.

7. Crimp Termination Evaluation for Initial Selection

7.1 Potential suitability for the application, for commercially-available terminals, may be determined by the manufacturer's information together with listing or certification by a recognized testing laboratory based on an existing standard (UL 486-A, for example). It must be understood that listing or certification by a testing laboratory does not guarantee or imply suitability for any particular application. For non-critical (no safety risk on failure) and non-demanding (large tolerance for connection resistance increase) applications, however, this level of assurance of performance may suffice.

7.2 For resistance-sensitive or critical applications, available life test data pertinent to the intended application should be reviewed. Life test results may be available from the terminal manufacturer, from the listing or certifying laboratory, or from present or past users of the particular terminal(s) being considered. The information should be reviewed for relevance of the applied conditions to those of the intended application, for data quantifying the change of resistance resulting from the applied test conditions, and for statistical significance (sample size, see Practice E122).

7.3 When considering a specific candidate terminal for a resistance-sensitive or critical application, if the available test data does not provide a suitable basis on which to assure satisfactory performance in the intended application to a sufficient level of confidence, then additional testing is required. (See Section 10.) If additional testing cannot be undertaken, by either the supplier or potential user, then consideration of an alternate terminal (manufacturer or model) or alternate terminating means is recommended.

7.4 It is recommended that, for resistance-sensitive or critical applications, the final step in the selection process should include verification testing using the actual termination system (terminal, wire, tooling, and manufacturing procedure) that will be used in product manufacturing. Once the performance of this combination is confirmed by test results, no part of the system can be changed without risk of adversely changing the rate of deterioration in service.

8. Manufacturing Considerations

8.1 For non-critical applications, follow the terminal manufacturer's general recommendations.

8.2 For resistance-sensitive or critical applications, it is generally required to establish tight control of materials and manufacturing beyond the terminal manufacturer's general recommendations.

8.2.1 Assure that all materials, tooling, and procedures are specified and held constant. Seemingly harmless changes, such as wire stranding and hardness, cannot be made without risk of impact on service life.

8.2.2 Effective procedures for crimp tooling set up, maintenance, and verification must be established and adhered to.

8.2.3 Equipment operators must be trained and qualified for the specific operation.

8.2.3.1 Operators should be capable of identifying misoperation, such as incorrect insertion of the wire into the terminal or misaligned crimping, and taking appropriate corrective action. (Stop production, correct problem.)

8.2.3.2 Operators should be empowered and motivated to assure that, when crimp defects do occur, defective crimp terminations are not passed through for assembly into the final product.

9. Quality Control Considerations

9.1 *Visual Inspection:*

9.1.1 Visual inspection is necessary to determine the general quality of the termination, including the following factors:

9.1.1.1 Whether the crimp compression or indent is at the correct position on the terminal.

9.1.1.2 Whether all of the strands of the conductor are properly contained within the crimped portion of the terminal.

9.1.1.3 Whether the correct length of bare conductor is properly inserted into the terminal.

9.1.1.4 Whether any strain relief features are correctly positioned and applied.

9.1.1.5 Whether there is any insulation material or other foreign matter in the wire termination portion of the terminal assembly.

9.1.1.6 Whether there is any corrosion or abnormal coloration evident on the electrical contact surfaces of the conductor or terminal. The metal parts should appear bright and clean, without abnormal coloration.

9.1.2 Some crimp terminals are pre-insulated. It may be necessary to remove the terminal's insulation to perform an adequate visual inspection.

9.2 *Crimp Dimension and Pull Test:*

9.2.1 Periodic dimensional measurements and pull testing are generally specified by the crimp terminal manufacturer for setup and quality control purposes. These recommendations should be followed.

9.2.2 The dimension and pull test are primarily useful to check tooling operation, setup and wear.

9.2.3 For applications that are not critical or resistance sensitive, periodic dimensional and pull test measurements may be the only tests necessary, provided that the components (wire, terminal, and tooling) have not been changed.

9.2.4 For proper evaluation of the crimp termination, pull testing must be performed with any wire strain relief feature disabled (opened or removed).

9.3 For resistance-sensitive or critical applications, in addition to visual inspection, dimensional measurement, and pull testing, the following aspects should be incorporated into the quality control procedures.

9.3.1 Assure that all materials, tooling, and procedures are as specified. Changes, such as wire stranding and hardness, cannot be made without risk of adverse impact on the projected service life.

9.3.2 *Connection Resistance:*

9.3.2.1 Initial Connection Resistance (as manufactured) should be monitored for resistance-sensitive applications.

9.3.2.2 Life testing (connection resistance change after accelerated life test) should be performed periodically for resistance-sensitive and critical applications subject to abnormal or harsh environment.

9.3.3 Metallurgical cross section inspection should be used periodically. Representative cross sections for crimp terminations, with interpretation, are provided in Appendix X1.

10. Applicable Test Methods

10.1 Information regarding dimensional and pull test methods and pass/fail criteria are generally provided by the terminal manufacturers.

10.2 *Measurement of Connection Resistance of Crimp Terminations:*

10.2.1 Test Method B539 provides information regarding general methods for measurement of contact (connection) resistance.

10.2.2 In general, connection resistance is calculated by Ohm's law (E = IR) from measurement of potential drop while passing a constant current. For practical termination configurations, it is often not possible to make these measurements without including some of the bulk resistance of the wire or terminal, or both. The following methods may be used for practical connection type acceptance and quality control connection resistance measurement.

10.2.3 Connection resistance may be determined by the difference between the resistance of a terminal and section of wire before and after soldering of the crimp termination. An example of use of soldering terminations to establish "zero connection resistance" is contained in the paper "Evaluation of Crimped Terminations and Splices in In-Wall Electric Heaters."[4] An example of the use of this method of determining connection resistance is provided in Appendix X2.

10.2.4 When multiple mechanically-identical samples of the same type of wire/terminal assembly are to be measured, a comparative method may be employed. This involves measuring the ratio of potential drop between the unknown sample and a reference sample, carrying the same current (in series) and at the same (ambient) temperature. The reference sample must be of known and stable connection resistance, or, if applicable, may be a "zero connection resistance" sample with soldered terminations as noted above. The comparative (ratio) method is suitable for quality control testing, in that it is easily accomplished, nondestructive of the sample, and it compensates for temperature and instrumentation variables.

10.2.5 Life testing generally consists of exposure of samples to conditions designed to accelerate deterioration that may occur in the intended use. Such conditions may be, for instance, environmental, such as temperature, humidity, and airborne contaminants, or mechanical, such as vibration. Life testing for the specific application is considered to be necessary for the selection of crimp terminations for resistance-sensitive or critical applications. Periodic confirmation of life test results is recommended as a quality control factor for critical applications. The papers "Contact Resistance Failure Criteria" [5] and "Stability and Contact Resistance Failure Criteria" [6] provide some guidance as to the general principles and selection of life test pass/fail criteria. Practice B827 and Guide B845 provide information related to conduct of Mixed Flowing Gas environmental testing. Test Method B913 provides basic tests for crimp terminations used in signal applications.

10.3 Metallurgical cross sectioning is used to reveal the extent of mechanical compression and spring-back in the crimp barrel or tab, and can reveal potentially harmful fractures. Periodic sampling and inspection of cross sections is considered to be necessary for control of the mechanical aspects of the crimp termination for resistance-sensitive and critical applications. (See Appendix X1 for examples.) Reference cross sections of acceptable and unacceptable terminals are useful for quality control inspection purposes.

11. Statistical Considerations

11.1 For any of the testing discussed in the previous sections, it is essential that the sample size be large enough to provide the required level of confidence in the result. Conventional statistical analysis methods are available by which to predict the range of results to be expected in a large population of terminations from a given sample size and performance distribution.

11.2 In general, a tight distribution of connection resistance measurement results is indicative of a sound and dependable crimp termination system. The tighter the distribution, the smaller the sample size required to predict satisfactory performance of the larger population.

11.3 Testing of the repeatability of the result is advised for critical applications.

12. Specification of Performance (for Resistance Sensitive or Critical Applications)

12.1 Practice B868 provides a means of specifying performance levels required or reporting test results achieved. An example of its use is provided in Appendix X3.

13. Keywords

13.1 crimp; terminal; termination; wire

[4] Aronstein, J., and Butterini, R., "Evaluation of Crimped Terminations and Splices in In-Wall Electric Heaters," 48th IEEE Holm Conference on Electrical Contacts, Orlando, FL, 2002.

[5] Whitley, J. H., and Malucci, R. D., "Contact Resistance Failure Criteria," Electrical Contacts–1978, Proceedings of the Ninth International Conference on Electric Contact Phenomena and the Twenty Fourth Annual Holm Conference on Electrical Contacts, Illinois Institute of Technology, Chicago, 1978, pp. 111-116.

[6] Malucci, R. D., "Stability and Contact Resistance Failure Criteria," Electrical Contacts–2004, Proceedings of the 50th IEEE Holm Conference on Electrical Contacts and the 22nd International Conference on Electrical Contacts, IEEE, 2004, pp. 1206-213.

APPENDIXES

(Nonmandatory Information)

X1. METALLURGICAL CROSS SECTIONS

X1.1 The cross sections below illustrate varying levels of compaction of the conductor strands within the body of the terminal. They were taken from terminations expected to carry 12 A in wiring harnesses of off-the-shelf residential portable electric heaters. Each cross section was taken at the smallest (most compressed) position along the length of the terminal body.

NOTE X1.1—The material that appears white in Fig. X1.1, Fig. X1.3, and Fig. X1.4 is solder. These terminations were soldered for the purpose of determining connection resistance (see 10.2.3 and Appendix X2), and the solder also serves to maintain the initial position of the strands during the sectioning and polishing process.

X1.1.1 The cross section in Fig. X1.1 demonstrates extensive compaction of the conductor strands, but some spring-back (see 5.5) has occurred, resulting in some gaps between conductor strands and between conductor strands and the connector body. There is adequate strand to strand and strand to terminal metallic contact to yield low connection resistance. There are no cracks in the connector body at points of severe deformation. For mass-produced terminations, this level of compaction, with some spring-back, would be considered normal and satisfactory for all but the most critical applications.

X1.1.2 The cross section in Fig. X1.2 demonstrates less compaction than the terminal previously depicted (Fig. X1.1). A larger portion of the cross section within the crimp barrel is air space. This level of compaction may nevertheless be adequate for many applications.

X1.1.3 The crimp termination in Fig. X1.3 shows virtually no compaction of the conductor strands. This level of compaction is not considered satisfactory for wire terminations carrying significant current in resistance sensitive or critical applications.

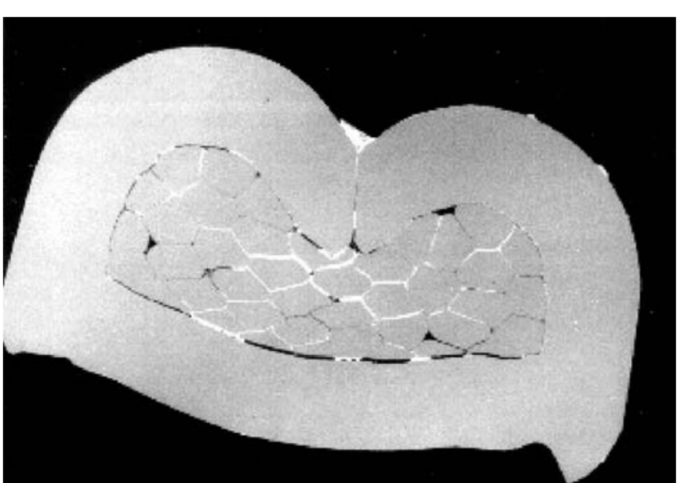

FIG. X1.1

FIG. X1.2

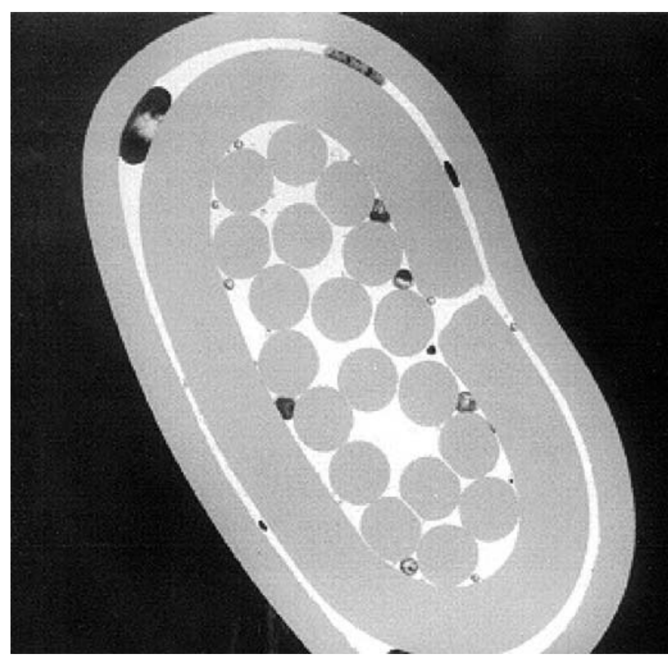

FIG. X1.3

X1.1.4 In addition to poor compaction, the cross section in Fig. X1.4 shows a crack in the crimp fitting (lower right). Cracks in the crimp barrel are potentially harmful, as they can cause a substantial reduction of compression forces within the termination.

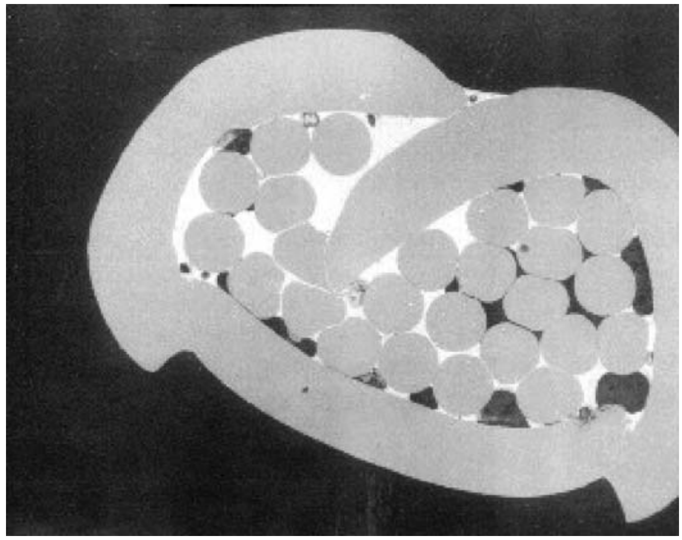

FIG. X1.4

X2. EXAMPLE OF USE, SOLDERING METHOD TO DETERMINE CRIMP TERMINATION CONNECTION RESISTANCE

X2.1 Connection resistance in a stranded wire termination is the excess resistance of the conductor-termination combination over and above what it would be if it were constructed of continuous metallic conductive material at the contact interfaces. This excess resistance is the additive result of three contributing factors: constriction resistance, film resistance, and strand equalization resistance.[4]

X2.1.1 The first two contributing factors are commonly considered as the components of "contact resistance."

X2.1.2 The third contributing factor is a reflection of the fact that the conductor strands do not necessarily conduct the same current in the immediate vicinity of the termination. For instance, many of the strands within the crimp termination shown in Fig. X1.3 do not carry any current by direct contact to the body of the termination. Going along the conductor for some distance away from the termination, the current eventually equalizes due to random contacts between strands.

X2.2 Two measurements at room temperature are made to determine the connection resistance by this method.

X2.2.1 The first measurement is the potential drop of the connector and a section of the terminated wire at a specific current. The measured potential drop includes that due to connection resistance and that due to bulk resistance. The total resistance is determined from the applied current and the measured potential drop using Ohm's law.

X2.2.2 The crimped termination is then soldered and allowed to cool to room temperature. A second potential drop reading is taken at the same current between the same measuring points. To a reasonable approximation, the soldering eliminates the connection resistance, leaving only the bulk resistance.

X2.3 The difference between the two measurements, expressed in ohms (or milliohms), is the connection resistance of

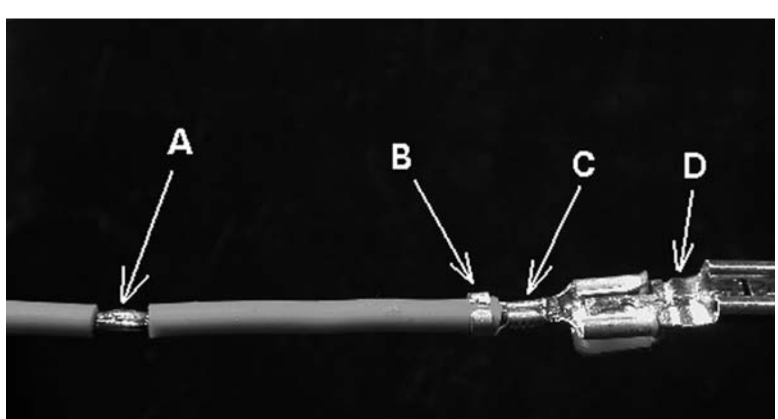

FIG. X2.1

the crimp termination.

X2.4 As an example, Fig. X2.1 shows a representative crimp termination. A conductor "equalizer" has been created at point "A" by soldering. The conductor is connected to a regulated current source at a point to the left of the equalizer. To complete the circuit, the terminal is connected to a mating connector tab " D." Potential drop is measured between the equalizer ("A") and "B," which is the wire restraint (non current carrying) section of the terminal. After taking an initial potential drop measurement, the crimp termination "C" is soldered, and the measurement is repeated (after cooling to room temperature).

X2.5 The basic method may be adapted to accommodate different wire and connector configurations. For pigtail crimp terminations (splices), for example, measurements would be made between an equalizer on one wire and the equalizer on the another wire. The calculated connection resistance is the wire-to-wire connection resistance of the splice. Provided that each pair of potential drop measurements (before and after soldering) are taken from exactly the same points and at the same (room) temperature, the result is a reasonably accurate value of the connection resistance that is relatively independent of the configuration variations.

X3. EXAMPLES OF USE OF PRACTICE B868 FOR SPECIFICATION OF REQUIRED PERFORMANCE FOR CRIMP TERMINATIONS

X3.1 Practice B868 provides a standard method of specifying performance requirements, or reporting test results, of connectors, including crimp terminations. It is based on the use of contact (connection) resistance as the indicator of connection performance.

X3.1.1 A standard statement format is prescribed that provides information on initial resistance, change in contact resistance at end of testing, the test performed, and the sample-to-sample variability. The same format is used for specifying required performance and for reporting test results.

X3.1.2 Refer to the latest revision of Practice B868 for complete details.

X3.2 *Example of Use*—Specifying a crimp termination for a resistance-sensitive application.

NOTE X3.1—The detailed process by which connection resistance requirements (or test results) are converted into the classification indices of Practice B868 is not provided in this example. Refer to Practice B868 for the complete procedure.

X3.2.1 The application is a crimp termination for a single #16 AWG stranded copper wire, carrying 12 A, at a temperature limit switch. Based on thermal analysis or testing, or both, for the particular application, it is determined that the allowable operating point tolerance requirement for the limit switch restricts self-heating of the wire termination to an allowable maximum of 0.15 W of self-heating from connection resistance. The corresponding allowable maximum connection resistance (initial connection resistance plus any increase over the life of the end product) calculates to be 0.00104 Ω.

X3.2.2 There are three components of the maximum connection resistance to be considered; initial resistance, increase during life of the product (as indicated by appropriate life testing), and sample-to-sample variation. The end-product maximum resistance requirement may be met by any combination of the three factors.

X3.2.3 A reasonably achievable maximum initial resistance for crimp terminations in this size range is 0.0001 Ω. Applying a safety factor of two, that leaves approximately 0.0004 Ω for increase in service over time and sample-to-sample variation (worst case). For this example, this is divided approximately equally between the two remaining factors (increase during life and sample-to-sample variation), allowing about 0.0002 Ω for each. These values are then adjusted (rounded off) as appropriate to fit the classification groups of Practice B868. The resulting performance classification indicators (see Practice B868) are then as follows:

Initial Resistance Indicator: C
Resistance Change Indicator: C
Variability Index: 11

X3.2.3.1 The balance of the specification statement defines the applied life test conditions used to predict the resistance change in actual service. For this example, based on consideration of the actual conditions of use, two tests are employed; a "heat cycle" test (high current cycling) and an environmental test. The applied conditions for heat cycle testing are well defined and often specified for connector qualification testing. For the crimp termination, the UL-310 heat cycle test conditions are selected as being appropriate. The heat cycle test does not test for susceptibility to environmental deterioration (oxidation, corrosion), however, and a basic T-H exposure test is therefore added.

X3.2.4 A performance specification statement for the crimp connector for this application, per Practice B868, is then:

"Connections shall meet or exceed Practice B868 Class PCC with 11.0 variability index when tested according to the applied conditions of UL-310 and subsequently exposed to 85°C, 90 % RH for 100 h."

NOTE X3.2—The "P" before the initial resistance and resistance change indicators signifies that this is a power connector classification.