IPC/WHMA-A-620D

2020–January

Requirements and Acceptance for Cable and Wire Harness Assemblies

Supersedes IPC/WHMA-A-620C
January 2017

An international standard developed by IPC

participants from 15 countries contributed to this standard

Association Connecting Electronics Industries

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WHMA
Wiring Harness Manufacturer's Association

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- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

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- Increase time-to-market
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IPC/WHMA-A-620D

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If a conflict occurs between the English and translated versions of this document, the English version will take precedence.

Developed by the IPC Task Group (7-31f) of the Product Assurance Subcommittee (7-30) and the WHMA Industry Technical Guidelines Committee (ITGC)

Supersedes:

IPC/WHMA-A-620C - January 2017
IPC/WHMA-A-620B with Amendment 1 - August 2013
IPC/WHMA-A-620B - October 2012
IPC/WHMA-A-620A - July 2006
IPC/WHMA-A-620 - January 2002

Users of this publication are encouraged to participate in the development of future revisions.

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Acknowledgment

Any document involving a complex technology draws material from a vast number of sources across many continents. While the principal members of the IPC/WHMA-A-620 joint working group comprised of IPC Task Group (7-31f) of the Product Assurance Subcommittee (7-30) and the WHMA Industry Technical Guidelines Committee (ITGC) are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC and WHMA extend their gratitude.

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Vesna Delic, Carlisle Interconnect Technologies
Samnang Doeun, Carlisle Interconnect Technologies
Matthew Nelson, Carlisle Interconnect Technologies
Brandy Tharp, Carlisle Interconnect Technologies
Fernando Moreno, Cesar-Scott, Inc

Acknowledgment (cont.)

Steven Perng, Cisco Systems Inc.
YC Yeung, CML EurAsia
Richard Smith, Cobham Mission Equipment
Caroline Ehlinger, Collins Aerospace
David Hillman, Collins Aerospace
Scott Meyer, Collins Aerospace
Miguel Dominguez, Continental Temic SA de CV
Jose Servin Olivares, Continental Temic SA de CV
Michael Meigh, Copper and Optic Terminations
Wen Danqing, CSIC Xi'an Dongyi Science Technology & Industry Group Co Ltd
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Francisco Fourcade, Fourcad, Inc
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Garry McGuire, NASA Marshall Space Flight Center

Acknowledgment (cont.)

Zackary Fava, NAVAIR
Joseph Sherfick, Naval Surface Warfare Ctr
Nicholas Walton, Naval Surface Warfare Ctr
Ron Folkeringa, Nortech Systems Inc.
Blanca Janet Canales, Northrop Grumman
Mahendra Gandhi, Northrop Grumman Aerospace Systems
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Michael Lau, Stryker Medical
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Rick Hawthorne, Technical Training Center
Xiao He, The 5th Electronic Institute of MII
Doug Wilson, The Electronics Group Ltd.
Geza Batiz, Toro Co.
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Acknowledgment (cont.)

A special note of thanks goes to the 7-31F-AT IPC-A-620 A-Team for making major contributions to the development of this standard.

Debbie Wade, Advanced Rework Technology-A.R.T
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Robert Cooke, NASA Johnson Space Center
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A special note of thanks goes to the 7-31F-GR IPC-A-620 Graphics Group for making major contributions to the development of the graphics in this standard.

Kevin Schuld
Sean Keating, Amphenol Limited (UK)
Joseph Kane, BAE Systems
Scott Meyer, Collins Aerospace
Richard Rumas, Honeywell Canada
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1 General

1.1 Scope This standard prescribes practices and requirements for the manufacture of cable, wire and harness assemblies. This standard does not provide criteria for cross-section or X-ray evaluation.

If a conflict occurs between the English and translated versions of this document, the English version will take precedence.

The illustrations in this document portray specific points noted in the title of each section. A brief description follows each illustration. The development committee recognizes that different parts of the industry have different definitions for some terms used herein. For the purposes of this document, the terms cable and wire harness are used interchangeably.

IPC/WHMA-A-620 can be used as a stand-alone document for purchasing products, however it does not specify frequency of in-process inspection or frequency of end product inspection. No limit is placed on the number of process indicators or the number of allowable repair/rework of defects. Such information should be developed with a statistical process control plan (see IPC-9191).

1.2 Purpose This standard describes materials, methods, tests and acceptability criteria for producing crimped, mechanically secured, or soldered interconnections and the related assembly activities associated with cable and harness assemblies.

The intent of this document is to rely on process control methodology to ensure consistent quality levels during the manufacture of products.

Any method that produces an assembly conforming to the acceptability requirements described in this standard may be used.

Standards may be updated at any time, including with the use of amendments. The use of an amendment or newer revision is not automatically required. The revision in effect **shall [D1D2D3]** be as specified by the User.

1.3 Classification Use of this standard requires agreement on the Class to which the product belongs. The User has the ultimate responsibility for identifying the Class to which the assembly is evaluated. If the User does not establish and document the acceptance Class, the Manufacturer may do so. Criteria defined in this standard reflect three Product Classes, which are as follows:

Class 1 General Electronic Products
Includes products suitable for applications where the major requirement is the function of the completed assembly.

Class 2 Dedicated Service Electronic Products
Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures.

Class 3 High Performance/Harsh Environment Electronic Products
Includes products where continued performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support systems and other critical systems.

1.4 Measurement Units and Applications This document uses the International System of Units (SI) in accordance with ASTM SI10-10, IEEE/ASTM SI 10, American National Standard for Metric Practice (Section 3). Imperial English equivalent units follow in brackets. The derived SI units used in this document are millimeters (mm) [in] for dimensions and dimensional tolerances, Celsius (°C) [°F] for temperature and temperature tolerances, grams (g) [oz] for weight, and lux (lx) [footcandles] for illuminance.

1.4.1 Verification of Dimensions Where not specifically invoked by this standard, actual measurements, e.g., of specific solder fillet dimensions, determination of damage and wrap percentages, are not required except for referee purposes.

1.5 Definition of Requirements The word ‘‘**shall**’’ is used in the text of this document wherever there is a requirement for materials, process or acceptance of cable, wire and harness assemblies.

Where the word **shall** indicates a requirement for at least one Class, the requirements for each Class are in brackets next to the **shall** requirement.

1 General (cont.)

N = No requirement has been established for this Class
A = Acceptable
P = Process Indicator
D = Defect

Examples:

[A1P2D3] is Acceptable Class 1, Process Indicator Class 2 and Defect Class 3
[N1D2D3] is Requirement Not Established Class 1, Defect Classes 2 and 3
[A1A2D3] is Acceptable Classes 1 and 2, Defect Class 3
[D1D2D3] is Defect for all Classes.

A defect for a Class 1 product means that the characteristic is also a defect for Class 2 and 3. A defect for a Class 2 product means that the characteristic is also a defect for a Class 3 product, but may not be a defect for a Class 1 product where less demanding criteria may apply.

The word ''should'' reflects recommendations and is used to reflect general industry practices and procedures for guidance only.

Many of the examples (figures) shown are grossly exaggerated to clearly depict the condition being described.

When sections of this standard are referenced in other parts of the document, then the criteria of that referenced section apply.

In the case of a discrepancy, the written description or written criteria always takes precedence over the illustrations.

1.5.1 Inspection Conditions The inspector **shall not [D1D2D3]** select the Product Class for the assembly under inspection. Documentation that specifies the applicable Class for the assembly under inspection **shall [D1D2D3]** be provided to the inspector. Criteria are given for each Product Class in three conditions: Acceptable, Defect or Process Indicator. The descriptions of these conditions follow.

1.5.1.1 Acceptable This characteristic indicates a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment.

1.5.1.2 Defect A defect is a condition that fails to meet the acceptance criteria of this document or negatively affects the form, fit or function of the assembly in its end use environment. The Manufacturer **shall [N1D2D3]** document and disposition each defect.

It is the responsibility of the Manufacturer to identify defects that are unique to the assembly process. It is the responsibility of the User to define unique defect categories applicable to the product.

1.5.1.2.1 Disposition Disposition is the determination of how defects should be treated. Dispositions include, but are not limited to, rework, use as is, scrap or repair.

User concurrence **shall [N1D2D3]** be required for ''use as is'' and **shall [N1N2D3]** be required for ''repair'' dispositions.

1.5.1.3 Process Indicator A process indicator is a condition (not a defect) that identifies a characteristic that does not affect the ''form, fit, function or reliability'' of a product.

- Such condition is a result of material, design and/or operator/machine related causes that create a condition that neither fully meets the acceptance criteria nor is a defect.
- Process indicators should be monitored as part of the process control system. If the number of process indicators indicates an abnormal variation in the process, identifies an undesirable trend, or displays other conditions that indicate the process is (or is approaching) out of control, the process should be analyzed. This may result in action to reduce the variation and improve yields.
- Disposition of individual process indicators is not required and affected product should be used as is.
- Not all process indicators are specified by this standard.
- It is the responsibility of the Manufacturer to identify process indicators that are unique to the assembly process.

1 General (cont.)

1.5.1.4 Combined Condition Cumulative conditions **shall [D1D2D3]** be considered in addition to the individual characteristics for product acceptability even though they are not individually considered defective. The significant number of combinations that could occur does not allow full definition in the content and scope of this specification but manufacturers should be vigilant for the possibility of combined and cumulative conditions and their impact upon product performance. Conditions of acceptability provided in this specification are individually defined and created with separate consideration for their impact upon reliable operation for the defined product classification. Where related conditions can be combined, the cumulative performance impact for the product may be significant, e.g., allowable strand damage per Table 3-1 (nicks, scrapes, severed strands) when combined with non-optimized crimping, such as overcrimped connection that otherwise passes pull testing and is otherwise acceptable, may cause significant degradation of the mechanical attachment integrity. The manufacturer is responsible for identification of such conditions.

1.5.1.5 Conditions Not Specified Conditions that are not specified as defective or as a process indicator are considered acceptable unless it can be established that the condition affects end user defined form, fit, function or reliability.

1.5.1.6 Uncommon or Specialized Designs IPC/WHMA-A-620, as an industry consensus document, cannot address all of the possible product design combinations. However, the standard does provide criteria for commonly used technologies. Where uncommon or specialized technologies are used, it may be necessary to develop unique acceptance criteria. The development should include User involvement. The acceptance criteria **shall [N1N2D3]** have User agreement. Requirements for specialized processes and/or technologies not specified herein **shall [N1D2D3]** be performed in accordance with documented procedures which are available for review.

Whenever possible, new criteria or criteria on specialized products should be submitted, using the Standard Improvement Form included in this standard, to the IPC Technical Committee to be considered for inclusion in upcoming revisions of this standard.

1.5.2 Material and Process Nonconformance Material and process nonconformance differs from hardware defects or hardware process indicators in that the material/process nonconformance often does not result in an obvious change in the hardware's appearance but can impact the hardware's performance, e.g., contaminated solder, incorrect solder alloy (per engineering documentation/procedure), chemical stripping of stranded wire.

Hardware found to be produced using either materials or processes that do not conform to the requirements of this standard **shall [D1D2D3]** be classified as defects and dispositioned. This disposition **shall [D1D2D3]** address the potential effect of the nonconformance on functional capability of the hardware such as reliability and design life (longevity).

1.6 Process Control The primary goal of process control is to continually reduce variation in the processes, products, or services to provide products or processes meeting or exceeding customer requirements. Process control tools such as IPC-9191, EIA-557-1 or other user-approved system may be used as guidelines for implementing process control.

Class 3 **shall [N1N2D3]** develop and implement a documented process control system. A documented process control system, if established, **shall [N1D2D3]** define process control and corrective action limits. This may or may not be a ''statistical process control'' system (see 1.6.1). The use of ''statistical process control'' (SPC) is optional and should be based on factors such as design stability, lot size, production quantities, and the needs of the company. Manufacturers **shall [N1D2D3]** perform 100% inspection unless a sampling inspection plan is defined as part of a documented process plan.

Process control methodologies **shall [N1D2D3]** be used in the planning, implementation and evaluation of the manufacturing processes used to produce cables and wire harness assemblies. The philosophy, implementation strategies, tools and techniques may be applied in different sequences depending on the specific company, operation, or variable under consideration to relate process control and capability to end product requirements.

When a decision or requirement is to use a documented process control system, failure to implement process corrective action and/or the use of continually ineffective corrective actions **shall [N1D2D3]** be grounds for disapproval of the process and associated documentation.

1.6.1 Statistical Process Control When a statistical process control system is used, it **shall [D1D2D3]** include the following elements as a minimum:

1 General (cont.)

a. Training is provided to personnel with assigned responsibilities in the development, implementation, and utilization of process control and statistical methods that are commensurate with their responsibilities.
b. Quantitative methodologies and evidence is maintained to demonstrate that the process is capable and in control. Improvement strategies define initial process control limits and methodologies leading to a reduction in the occurrence of process indicators in order to achieve continuous process improvement.
c. Criteria for switching to sample based inspection is defined. When processes exceed control limits, or demonstrate an adverse trend or run, the criteria for reversion to higher levels of inspection (up to 100%) is also defined.
d. When defect(s) are identified in the lot sample, and the number exceeds the limit allowed by the sampling plan, the entire lot is 100% inspected for the occurrence(s) to the defect(s).
e. A system is in place to initiate corrective action for the occurrence of process indicators, out-of-control process(es), and/or discrepant assemblies.
f. A documented audit plan is defined to monitor process characteristics and/or output at a prescribed frequency.
g. Objective evidence of process control may be in the form of control charts or other tools and techniques of statistical process control derived from application of process parameter and/or product parameter data.

1.7 Order of Precedence In the event of conflict, the following order of precedence applies:

1. Procurement as agreed between User and Manufacturer.
2. Engineering documentation reflecting the User's detailed requirements.
3. When invoked by the User or per contractual agreement, IPC/WHMA-A-620.

The developing committee recognizes that some requirements in IPC/WHMA-A-620 differ from those in other industry standards such as IPC-A-610 and J-STD-001. When IPC/WHMA-A-620 is cited or required by contract as a stand-alone document for inspection and/or acceptance, the requirements of J-STD-001 or IPC-A-610 do not apply unless separately and specifically required. When IPC/WHMA-A-620, J-STD-001, IPC-A-610 and/or other related documents are cited, the order of precedence should be defined in the procurement documents. If not defined in the procurement documents, the manufacturer should negotiate order of precedence with the User.

The User has the opportunity to specify alternate acceptance criteria.

1.7.1 Clause References When a clause in this standard is referenced, its subordinate clauses also apply.

1.7.2 Appendices Appendix A applies, see also 1.8. Other appendices to this standard are not binding requirements unless separately and specifically required by the applicable contracts, engineering documentation, or purchase orders.

1.8 Terms and Definitions Terms are consistent with the definitions provided by IPC-T-50. For the understanding of this document, selected definitions pertaining specifically to cable and wire harness manufacturing are listed below and in Appendix A.

1.8.1 FOD (Foreign Object Debris) A generic term for a substance, debris, particulate matter or article alien to the assembly or system.

1.8.2 Inspection An evaluation of quality characteristics relating to a standard or engineering documentation.

1.8.3 Manufacturer (Assembler) The individual, organization, or company responsible for the assembly process and verification operations necessary to ensure full compliance of assemblies to this standard.

1.8.4 Objective Evidence Documentation in the form of hard copy, computer data, video, or other media.

1.8.5 Process Control A system or method to continually steer an operation in reducing variation in the processes or products to meet or exceed the goal in quality and performance.

1.8.6 Supplier The individual, organization or company which provides to the Manufacturer (assembler) components (cables, wire harnesses, electronic, electromechanical, mechanical, printed boards, etc.) and/or materials (solder, flux, cleaning agents, etc.).

1 General (cont.)

1.8.7 User The individual, organization, company, contractually designated authority or agency responsible for the procurement of electrical/electronic hardware, cables and wire harnesses, etc., and having the authority to define the Product Class and any variation or restrictions to the requirements of this standard, i.e., the originator/custodian of the contract detailing these requirements.

1.8.8 Wire Diameter (D) In this document, the outside diameter of the wire, either stranded or solid, including insulation if present.

1.8.9 Engineering Documentation Drawings, specifications, technical illustrations, and other documents, prepared and released by the design activity in any form of media, that establish the design and design requirements.

1.9 Requirements Flowdown When this standard is contractually required, the applicable requirements of this standard (including Product Class – see 1.3) **shall [D1D2D3]** be imposed on all applicable subcontracts, engineering documentation, and purchase orders. Unless otherwise specified the requirements of this standard are not imposed on the procurement of commercial-off-the-shelf (COTS) assemblies or subassemblies.

When a part is adequately defined by a specification, the requirements of this standard should be imposed on the manufacture of that part only when necessary to meet end-item requirements. When it is unclear where flowdown should stop, it is the responsibility of the Manufacturer to establish that determination with the User. When an assembly is procured, that assembly should meet the requirements of this standard. If the assembly is manufactured by the same Manufacturer, the requirements are as stated in the contract for the entire assembly.

1.10 Personnel Proficiency All instructors, operators, and inspection personnel **shall [D1D2D3]** be proficient in the tasks to be performed. Objective evidence of that proficiency **shall [D1D2D3]** be maintained and available for review. Objective evidence should include records of training to the applicable job functions being performed, work experience, testing to the requirements of this standard, and/or results of periodic reviews of proficiency. Supervised on-the-job training is acceptable until proficiency is demonstrated.

1.11 Acceptance Requirements All products **shall [D1D2D3]** meet the requirements of the contracts, engineering documentation, applicable standards, and the requirements for the applicable Product Class specified herein.

1.12 Inspection Methodology

1.12.1 Process Verification Inspection Process verification inspection **shall [N1N2D3]** consist of the following:

- Surveillance of the operation to determine that practices, methods, procedures and a written inspection plan are being properly applied.
- Inspection to measure the quality of the product.

1.12.2 Visual Inspection The assembly **shall [N1D2D3]** be evaluated in accordance with the established process control system, see 1.6, or by 100% visual inspection, see 1.6.1.c. and 1.11.

1.12.2.1 Lighting Illumination at the surface of workstations should be at least 1000 lux (approximately 93 foot candles). Supplemental lighting may be necessary to assist in visual inspection. Light sources should be selected to prevent shadows on the item being inspected except those caused by the item being inspected.

Note: In selecting a light source, the color temperature of the light is an important consideration. Light ranges from 3000-5000 K enable Users to distinguish various metal and plating features and contaminants with increased clarity.

1.12.2.2 Magnification Aids Magnification power for assembly inspection **shall [A1P2D3]** be at least the minimum inspection power specified in Table 1-1 and Table 1-2. Other magnification powers within the inspection range may be used. The magnification power requirement is based on the gauge of the wire being inspected. For assemblies with mixed wire sizes, the greater

1 General (cont.)

magnification may be used for the entire assembly. If the presence of a defect cannot be determined at the inspection power, the item is acceptable. The referee magnification power is intended for use only after a defect has been determined but is not completely identifiable at the inspection power.

The tolerance for magnification aids is ± 15% of the selected magnification power. Magnification aids should be maintained and calibrated as appropriate (see IPC-OI-645).

Table_1-1 Magnification Aid Applications – Wire and Wire Connections[1]

Wire Size AWG Diameter mm [inch]	Magnification Power	
	Inspection Range	Maximum Referee
Larger than 14 AWG >1.63 mm [0.064 in]	N/A	1.75X
14 to 22 AWG 1.63 - 0.64 mm [0.064 to 0.025 in]	1.5X - 3X	4X
<22 to 28 AWG <0.64 mm - 0.32 mm [<0.025 - 0.013 in]	3 - 7.5X	10X
Smaller than 28 AWG <0.32 mm [<0.013 in]	10X	20X

Note 1: Referee magnification power is intended to be used only to verify a product rejected at the inspection magnification. For assemblies with mixed wire size, the greater magnification may be (but is not required to be) used for the entire assembly.

Table 1-2 Magnification Aid Applications – Other

Cleanliness (with or without cleaning processes)	Magnification not required, Note 1
Cleanliness (no-clean processes)	Magnification not required, Note 1
Encapsulation, Staking	Magnification not required, Notes 1, 2
Component	Magnification not required, Notes 1, 2
Marking	Magnification not required, Note 2

Note 1: Visual inspection may require the use of magnification, e.g., for very small features, to determine if the contamination or anomaly affects form, fit or function.
Note 2: If magnification is used it is limited to 4X maximum.

1.13 Facilities Work areas **shall [D1D2D3]** be maintained at levels that prevent contamination or deterioration of tools, materials, and work surfaces. Eating, drinking, smoking, including use of e-cigarettes, and/or use of tobacco products **shall [D1D2D3]** be prohibited in the work area.

For operator comfort and solderability maintenance, the temperature should be maintained between 18 °C [64.4 °F] and 30 °C [86 °F] and the relative humidity should not exceed 70%. For process control, more restrictive temperature and humidity limits may be required.

1.13.1 Field Assembly Operations In field assembly operations where the controlled environmental conditions required by this standard cannot be effectively achieved, precautions **shall [N1D2D3]** be taken to minimize the effects of the uncontrolled environment on the operation being performed on the hardware.

1.13.2 Health and Safety The use of some materials and processes used to meet the requirements of this standard may be hazardous or may cause injury. To provide for personnel and environmental safety, follow the applicable plant requirements and government regulations.

1.14 Electrostatic Discharge (ESD) Protection If there are any assemblies that contain components or parts sensitive to ESD, the Manufacturer **shall [D1D2D3]** implement a documented ESD control program in accordance with ANSI/ESD-S20.20, IEC-61340-5, MIL-STD-1686 or as otherwise specified. Documentation necessary for an effective program **shall [D1D2D3]** be available for review.

1 General (cont.)

When processing ESD sensitive assemblies, the Manufacturer **shall [N1D2D3]** verify that electrostatic discharge control is adequate when humidity decreases to a level of 30% or lower.

Note: This includes selection and use of devices such as connector covers, etc.

1.15 Tools and Equipment

1.15.1 Control Each Manufacturer **shall [D1D2D3]**:

a. Select tools to be used for crimping, cabling, wiring, measuring, soldering, inspecting and in work preparation areas appropriate to the intended function.
b. Clean and properly maintain all tools and equipment.
c. Examine all elements of tools for physical damage.
d. Prohibit unauthorized, defective, or uncalibrated tools in the work area.
e. Document detailed operating procedures and maintenance schedules for tools and equipment requiring calibration or set-ups.
f. Maintain records of tool and equipment calibration and functional testing.
g. Assure test fixtures, test adapters, and test equipment are maintained to assure the integrity of the test.
h. Assure process tooling and process equipment are maintained to assure acceptability of the product.
i. Assure lead/wire cutting tools do not impart shock that causes damage.

Soldering irons, equipment, and systems **shall [D1D2D3]** be chosen and employed to provide temperature control and isolation from electrical overstress or ESD when ESD sensitive parts or assemblies are involved.

See Appendix C for guidelines on tool selection and maintenance.

1.15.2 Calibration Torque tools, measuring equipment, and mechanical and electrical test equipment (including contact retention testers) **shall [N1D2D3]** be calibrated.

Crimping tools **shall [N1D2D3]** be calibrated or validated using a documented process.

The Manufacturer **shall [N1D2D3]** have a documented calibration system in accordance with ANSI/NCSL Z540-1 or other National or International standard. The minimum standard **shall [N1D2D3]** assure:

a. Measurement standards used for calibrating tools are traceable to National Institute of Standards and Technology (NIST) or other National or International standard. Calibration of tools is performed in an environment compatible with the environmental requirements of the tools.
b. Calibration intervals are based on the type of tool and records of the tool's calibration. Intervals may be lengthened or shortened on the basis of stability demonstrated over previous calibration periods.
c. Procedures are generated and utilized for the calibration of all tooling stated herein. Procedures include, as a minimum, standards to be used, parameters to be measured, accuracy, tolerances, environmental factors, and steps in the calibration process. The procedures may be the Supplier's specifications if judged adequate, and need not therefore be rewritten, but are documented.
d. Records are maintained that document calibration.
e. Tools are labeled to indicate, as a minimum:
   (1) Date of calibration.
   (2) Calibration due date.
   (3) Any limitation of use. If not practical to place the label directly on the tool, then the label is affixed to the tool container or other location as documented in the procedures.
   (4) Tool identification.

1.16 Materials and Processes The materials and processes used to assemble/manufacture cable and wire harness assemblies **shall [D1D2D3]** be selected such that their combinations produce products acceptable to this standard. When major elements of the proven processes are changed, e.g., flux, cleaning media or system, soldering system, tooling, marking, etc., validation of the acceptability of the change(s) **shall [N1N2D3]** be performed and documented.

1 General (cont.)

Limited shelf life items **shall [D1D2D3]** be stored and controlled in accordance with material suppliers' recommendations, or in accordance with the Manufacturer's documented procedures for controlling shelf life and shelf life extensions. The material manufacturer's instructions or other documented procedure **shall [N1D2D3]** be followed for mixing and curing. Material **shall [D1D2D3]** be used within the pot life (working time) specified by the material supplier or used within the time period indicated by a documented system. When curing conditions (temperature, time, infrared (IR) intensity, etc.) vary from the material supplier's recommended instructions, they **shall [D1D2D3]** be documented and available for review.

Equipment used for measuring viscosity, mixing, applying and curing silicone material **shall not [D1D2D3]** be used for processing other material.

The electrical and mechanical integrity of components and assemblies **shall [D1D2D3]** be retained after exposure to processes employed during manufacture and assembly, e.g., handling, baking, fluxing, soldering, and cleaning.

1.17 Electrical Clearance Violation of minimum electrical clearance **shall [D1D2D3]** be a defect. For the definition of Electrical Clearance, see Appendix A.

1.18 Contamination Assemblies produced in accordance with this standard **shall [D1D2D3]** be free of FOD/contamination (including but not limited to, wire clippings, insulation slugs, strands of shielding braid, green residue or any other item not required to be present). See 4.2 for cleanliness criteria specific to soldered assemblies.

Note: The four common sources for green residue on electronics are Copper Abietate, Copper (II) Chloride, Copper Fluoride, and Copper Phthalate. The appearance of green residue is a possible indicator of material breakdown, contamination, or corrosion, and the effect on performance and reliability may be benign or serious, depending on the chemical make-up and hardware service environment.

Handling of cleaned assemblies **shall [N1N2D3]** preclude recontamination.

FOD control program documents such as IPC-WP-116, NAS 412, or other User approved documents may be used as guidelines for implementing FOD control.

1.19 Rework/Repair In the event a rework or repair action takes place, any tests/inspections that were previously performed **shall [D1D2D3]** be repeated in their entirety for the portion of the product that was affected by the rework or repair.

1.19.1 Rework Rework is the act of reprocessing in a manner that assures full compliance to applicable engineering documentation. Rework **shall [N1N2D3]** be documented. Rework **shall [D1D2D3]** meet all applicable requirements of this standard. Rework does not include a second application of a soldering iron during a hand soldering operation on a single connection.

Proper soldering technique, including limiting the time on the connection and the amount of heat applied, is critical in preventing damage to the assembly. Control of hand soldering **shall [N1N2D3]** include operator training and process controls. See 1.10.

1.19.2 Repair Repair is the act of restoring the functional capability of a defective article in a manner that does not assure compliance of the article with applicable engineering documentation. Repairs **shall [N1D2D3]** be conducted in accordance with a documented procedure. The repair method **shall [N1D2D3]** be determined by agreement between the Manufacturer and the User.

1.19.3 Post Rework/Repair Cleaning After rework or repair, assemblies **shall [N1N2D3]** be cleaned as necessary. A process **shall [N1N2D3]** be established for post rework/repair cleanliness validation.

2 Applicable Documents

The following documents, of the issue in effect on the invitation for bid, form a part of this specification to the extent specified herein.

2.1 IPC[1]

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-CH-65 Guidelines for Cleaning of Printed Boards and Assemblies

IPC-A-610 Acceptability of Electronic Assemblies

IPC-OI-645 Standard for Visual Optical Inspection Aids

IPC-SM-817 General Requirements for Dielectric Surface Mounting Adhesives

IPC-AJ-820 Assembly and Joining Handbook

IPC-9191 General Guidelines for Implementation of Statistical Process Control (SPC)

IPC-WP-116 Guidance for the Development and Implementation of a Foreign Object Debris (FOD) Control Plan

2.2 Joint Industry Standards[2]

J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

J-STD-002 Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires

J-STD-004 Requirements for Soldering Fluxes

J-STD-006 Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications

2.3 Society of Automotive Engineers (SAE)[3]

SAE ARP 914A Glossary of Electrical Connection Terms

SAE ARP 1931A Glossary of Terms with Specific Reference to Electrical Wire and Cable

SAE AS50881 Wiring Aerospace Vehicle

SAE AS567 Safety Cable, Safety Wire, Key Washers, and Cotter Pins for Propulsion Systems, General Practices for Use of

AS22759 Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy

2.4 American National Standards Institute (ANSI)[4]

ANSI/NCSL Z540-1-1994 General Requirements for Calibration Laboratories and Measuring and Test Equipment, 1994

2.5 International Organization for Standardization (ISO)[5]

ISO 8815 Aircraft Electrical Cables and Cable Harnesses - Vocabulary

1. www.ipc.org
2. www.ipc.org
3. www.sae.org
4. www.ansi.org
5. www.iso.org

2.6 ESD Association (ESDA)[6]

ANSI/ESD-S20.20 ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment

2.7 United States Department of Defense (DoD)[7]

MIL-DTL-17 General Specification for Cables, Radio Frequency, Flexible and Semirigid

MIL-STD-1130 Department of Defense Standard Practice: Connections, Electrical, Solderless, Wrapped

MIL-STD-1686 Electrostatic Discharge Control Program For Protection Of Electrical And Electronic Parts, Assemblies And Equipment (Excluding Electrically Initiated Explosive Devices)

2.8 International Electrotechnical Commission (IEC)[8]

IEC 61340-5 Electrostatics - Part 5-1: Protection of electronic devices from electrostatic phenomena - General requirements

2.9 Aerospace Industries Association (AIA/NAS)[9]

NASM33540 Safety Wiring, Safety Cabling, Cotter Pinning, General Practices For

NAS412 Foreign Object Damage/Foreign Object Debris (FOD) Prevention

2.10 Electronics Industries Alliance[10]

EIA-557-1 Guidance for the Selection of Critical Manufacturing Operations for Use in Implementing an SPC System for Passive Components

2.11 ASTM International[11]

ASTM SI10-10 American National Standard for Metric Practice

2.12 Institute of Electrical and Electronics Engineers[12]

IEEE/ASTM SI 10 American National Standard for Metric Practice

6. www.esda.org
7. https://assist.daps.dla.mil/quicksearch
8. www.iec.ch
9. www.aia-aerospace.org
10. www.eia.org
11. www.astm.org
12. www.ieee.org

3 Preparation

This section provides requirements and acceptance criteria for preparation of wires that will be used in the cable/wire harness fabrication process.

The following topics are addressed in this section.

3.1 Stripping

Wire insulation may be removed using chemical, thermal (including laser) or mechanical strippers using a manual, semi or fully automated process.

Chemical insulation stripping agents **shall [D1D2D3]**:

- Be used only for solid wires.
- Be neutralized or removed prior to tinning or soldering.

Note: To prevent continuing degradation of the wire surface, the residue of chemical insulation stripping products should be removed within three hours of the completion of chemical stripping.

3.2 Strand Damage and End Cuts

Strand damage can lead to degraded performance. The number of damaged (scraped, nicked or severed) strands in a single wire **shall not [D1D2D3]** exceed the limits of Table 3-1.

As an exception to Table 3-1:

- Partial or incomplete cuts of strand groups **shall not [A1A2D3]** be in the crimp contact area.
- Partial cuts of a strand group **shall not [A1A2D3]** prevent contact of the strand group for the full length of a required wrap.

Conductors **shall not [N1D2D3]** be cut or modified in any manner to reduce circular mil area (CMA) to fit a termination.

Damaged wires that do not exceed the limits specified in Table 3-1 are considered process indicators for Classes 2 & 3.

Note: See 13.1 and 15.1 for shield strand damage criteria.

3.2 Strand Damage and End Cuts (cont.)

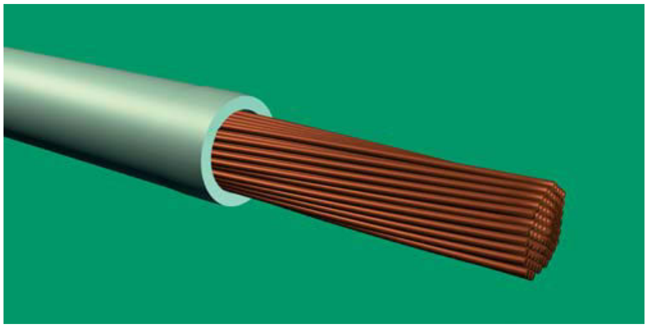

Figure 3-1

Acceptable – Class 1,2,3

- Attached burrs that will not be dislodged during process or operation.

Acceptable – Class 1
Process Indicator – Class 2,3

- Strands cut, broken, scraped or severed if the number of damaged or broken strands in a single wire does not exceed the limits in Table 3-1.

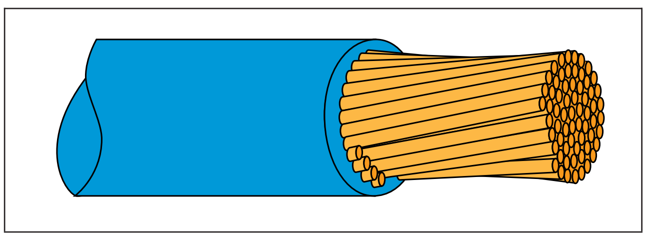

Figure 3-2

3.2 Strand Damage and End Cuts (cont.)

Table 3-1 Allowable Strand Damage[1,2,3]

Number of Strands	Maximum allowable strands scraped, nicked or severed for Class 1,2	Maximum allowable strands scraped, nicked or severed for Class 3 for wires that will not be tinned before installation	Maximum allowable strands scraped, nicked or severed for Class 3 for wires that will be tinned prior to installation
1 (solid conductor)	No damage in excess of 10% of conductor diameter		
2-6	0	0	0
7-15	1	0	1
16-25	3	0	2
26-40	4	3	3
41-60	5	4	4
61-120	6	5	5
121 or more	6%	5%	5%

Note 1: No damaged strands for wires used at a potential for 6 kV or greater.
Note 2: For plated wires, a visual anomaly that does not expose basis metal is not considered to be strand damage.
Note 3: Nicks or scrapes less than 10% of conductor diameter are not considered to be strand damage.

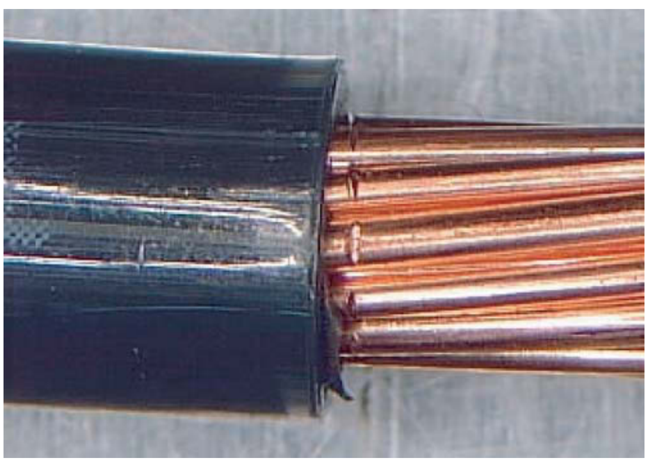

Figure 3-3

Defect – Class 1,2,3

- Attached burrs may be dislodged during process or operation.
- Variation in strand length within a strand group that prevents installation to the full depth of the crimp contact area or solder cup.
- Damaged strands exceed the limits specified in Table 3-1.

3.3 Conductor Deformation/Birdcaging

Disturbed wire strands should be restored to approximate their original lay. Strands are not flattened, untwisted, buckled, kinked or otherwise deformed.

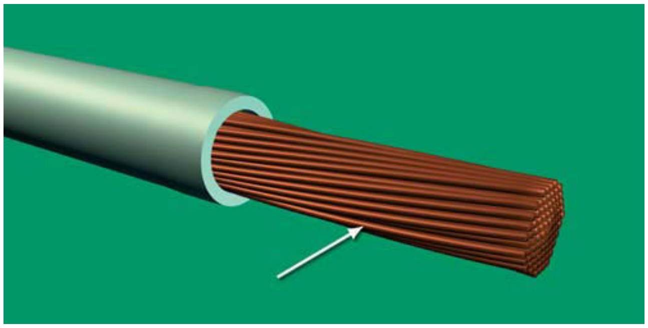

Figure 3-4

Acceptable – Class 1,2,3

- Wire strands have separation (birdcaging, shown by arrow in Figure 3-4) but:
  - do not exceed one strand diameter.
  - do not extend beyond wire insulation outside diameter.
- Where strands were straightened during the wire insulation removal, they have been restored to approximate the original spiral lay of the wire.
- Wire strands are not kinked.

3.3 Conductor Deformation/Birdcaging (cont.)

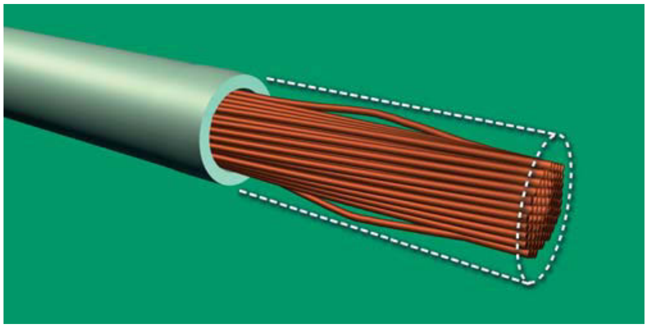

Figure 3-5

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire strands have separation exceeding one strand diameter but do not extend beyond wire insulation outside diameter.

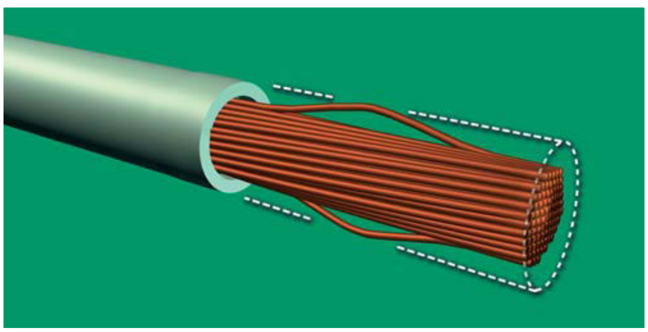

Figure 3-6

Acceptable – Class 1
Defect – Class 2,3

- The general spiral lay of the strands has not been maintained.
- Wire strands extend beyond wire insulation outside diameter.

Defect – Class 1,2,3

- Wire strands are kinked.

3.4 Twisting of Wires

When twisting is required, these criteria apply to all cable or harness bundles, whether they are twisted pairs of the same wire type and size, or cables incorporating various wire types and sizes. The length of lay (or ‘‘twist’’) as measured from the midpoint of wire’s crossover through a complete spiral to the next crossover midpoint of the same wire **shall [D1D2D3]** be 8 to 16 times the outer diameter of the bundle (see Figure 3-7).

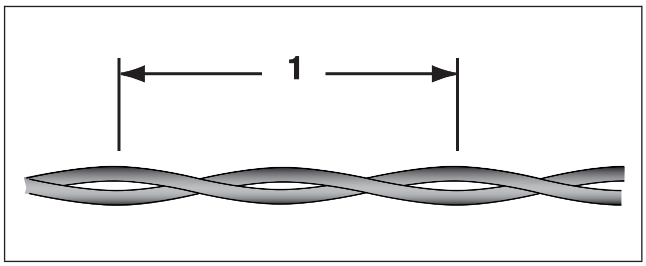

Figure 3-7

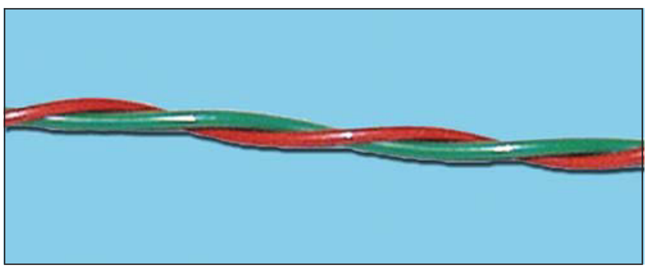

Figure 3-8

Acceptable – Class 1,2,3

- The length of lay for each twist is 8 to 16 times the outer diameter of the bundle.

Figure 3-9

Defect – Class 1,2,3

- The length of lay for each twist is less than 8 or more than 16 times the outer diameter of the bundle.
- There is residual twist (over-twist, kinking) in individual wires (see Figure 3-9).

3.5 Insulation Damage – Stripping

Coatings added over insulation base material such as resin coatings over polyimide are not considered to be part of the insulation and these criteria are not intended to be applicable to those coatings.

The cut ends of some insulation materials, particularly those with a fiberglass barrier, may show fraying. Acceptability of this fraying should be agreed upon between the User and Manufacturer.

These criteria are also applicable to post-assembly acceptance. Additional criteria for insulation damage as a result of soldering operations are provided in 4.5.2.

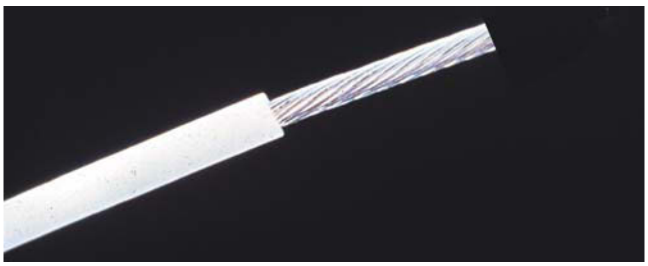

Figure 3-10

Acceptable – Class 1,2,3

- A slight, uniform impression in the insulation from the gripping of mechanical strippers.
- Chemical solutions, paste, and creams used to strip solid wires do not cause degradation to the wire.
- Slight discoloration of insulation resulting from thermal processing is permissible, provided it is not charred, cracked or split.

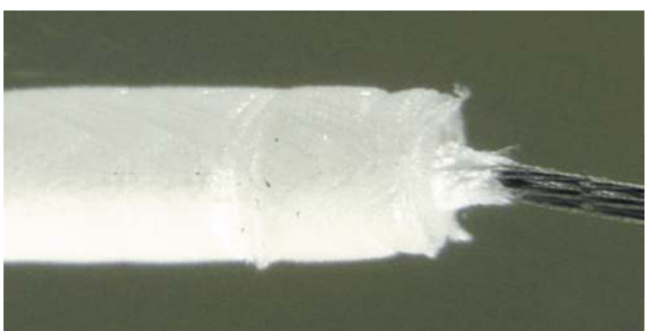

Figure 3-11

3.5 Insulation Damage – Stripping (cont.)

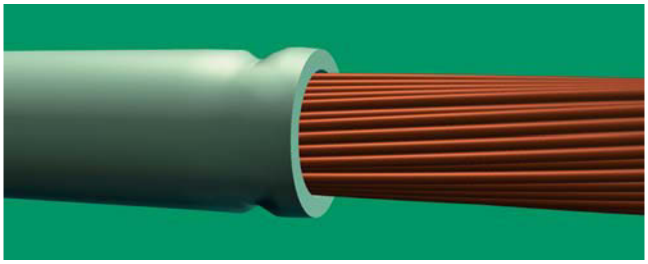

Figure 3-12

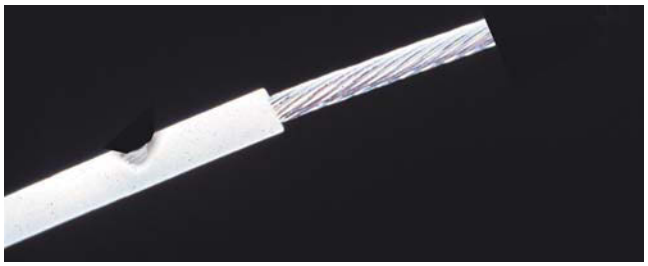

Figure 3-13

Defect – Class 1,2,3

- Insulation thickness is reduced by more than 20% (see Figures 3-12, 13).
- Uneven or ragged pieces of insulation (frays, tails, and tags) are greater than 50% of the wire diameter or 1 mm [0.039 in], whichever is more (see Figure 3-14).
- Insulation is charred (see Figure 3-15).
- Insulation is melted into the wire strands (see Figure 3-16).
- Any cuts, breaks, cracks or splits in insulation (see Figure 3-17).

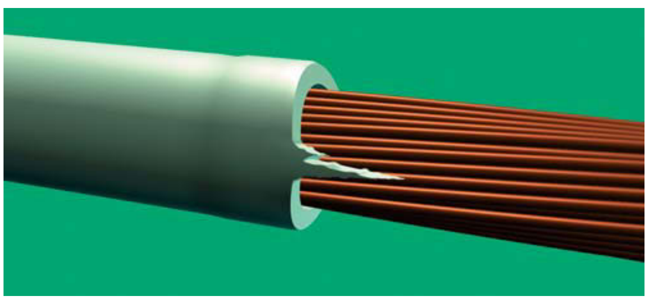

Figure 3-14

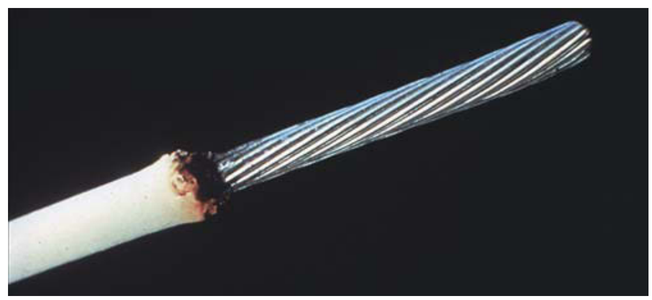

Figure 3-15

Figure 3-16

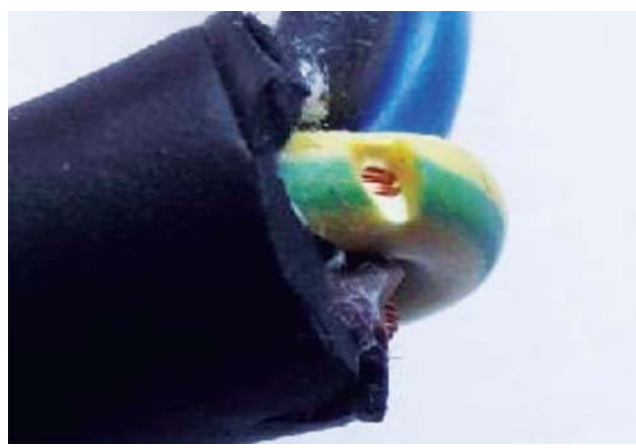

Figure 3-17

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4 Soldered Terminations

Soldered terminations can be used in cable/harness assembly and for that reason may merit special consideration.

Criteria for forming soldered splices are provided in 8 (Splices).

Criteria for heat shrinkable solder devices are provided in 8 (Splices) and 15 (Harness/Cable Electrical Shielding).

The following topics are addressed in this section.

4.1 Material, Components and Equipment

4.1.1 Material, Components and Equipment – Materials

See 1.16.

4.1.1.1 Material, Components and Equipment – Materials – Solder

Solder alloys **shall [D1D2D3]** be in accordance with J-STD-006 or equivalent. Solder alloys other than Sn60Pb40, Sn62Pb36Ag2, and Sn63Pb37 that provide the required electrical and mechanical attributes may be used if all other conditions of this standard are met and objective evidence of such is available for review. Flux that is part of flux-cored solder wire **shall [D1D2D3]** meet the requirements of 4.1.1.2. Flux percentage is optional.

Solder alloys less than 0.1% Pb by weight not listed by J-STD-006 may be used when such use is agreed upon by the User and Manufacturer.

4.1.1.1.1 Material, Components and Equipment – Materials – Solder – Solder Purity Maintenance

Solder used for preconditioning, gold removal, tinning of parts, and machine soldering **shall [N1D2D3]** be analyzed, replaced or replenished at a frequency to ensure compliance with the limits specified in Table 4-1.

SnPb solder alloys other than Sn60Pb40, Sn62Pb36Ag2, or Sn63Pb37 **shall [N1D2D3]** be in compliance with equivalent documented limits.

If contamination exceeds the limits, intervals between the analyses, replacement or replenishment **shall [N1D2D3]** be shortened. The frequency of analysis should be determined on the basis of historical data or monthly analyses. Records containing the results of all analyses and solder bath usage, e.g., total time in use, amount of replacement solder, or area throughput, **shall [N1D2D3]** be maintained for a minimum of one year for each process/system.

SnPb alloys used for preconditioning or assembly **shall [N1D2D3]** have a tin content maintained within ± 1.5% of the nominal alloy being used. Tin content for SnPb alloys **shall [N1D2D3]** be tested at the same frequency as testing for copper/gold contamination. The balance of the SnPb bath **shall [N1D2D3]** be Pb and/or the items listed in Table 4-1.

Pb-free alloys used for preconditioning or assembly **shall [N1D2D3]** have a tin content maintained within ± 1% of the nominal alloy being used. Tin content for Pb-free alloys **shall [N1D2D3]** be tested at the same frequency as testing for copper/silver contamination. The balance of a SAC305 Pb-free bath **shall [N1D2D3]** be the items listed in Table 4-1. Use of other lead-free solder alloy contamination limits **shall [N1D2D3]** be as agreed between Manufacturer and User.

Table 4-1 Maximum Limits of Solder Bath Contaminant

Contaminant	Preconditioning Maximum Contaminant Weight Percentage Limit SnPb Alloys	Assembly Maximum Contaminant Weight Percentage Limit SnPb Alloys	Preconditioning and Assembly Maximum Contaminant Weight Percentage Limit SAC305 Pb-Free Alloys
Copper	0.75	0.3	1.1, Note 2
Gold	0.5	0.2	0.2
Cadmium	0.01	0.005	0.005
Zinc	0.008	0.005	0.005
Aluminum	0.008	0.006	0.006
Antimony	0.5	0.5	0.2
Iron	0.02	0.02	0.02
Arsenic	0.03	0.03	0.03
Bismuth	0.25	0.25	0.25
Silver, Note 1	0.75	0.1	4.0
Nickel	0.025	0.01	0.05
Pb	N/A	N/A	0.1
Total of Copper, Gold, Cadmium, Zinc, Aluminum Contaminants	N/A	0.4	N/A

Note 1: Not applicable for Sn62Pb36Ag2; limits to be 1.75% to 2.25%.
Note 2: A maximum copper limit of 1.0% may be specified as agreed between Manufacturer and User.

4.1.1.2 Material, Components and Equipment – Materials – Flux

Flux **shall [D1D2D3]** be in accordance with J-STD-004 or equivalent. Flux **shall [N1N2D3]** conform to flux activity levels L0 and L1 of flux materials rosin (RO), resin (RE), or organic (OR), except organic flux activity level L1 **shall not [N1N2D3]** be used for no-clean soldering. When other activity levels or flux materials are used, data demonstrating compatibility **shall [N1N2D3]** be available for review.

Note: Flux or soldering process combinations previously tested or qualified in accordance with other specifications do not require additional testing.

Type H or M fluxes **shall not [D1D2D3]** be used for tinning of stranded wires.

When an external flux is used in conjunction with flux cored solders, the fluxes **shall [D1D2D3]** be compatible.

4.1.1.3 Material, Components and Equipment – Materials – Adhesives

Electrically nonconductive adhesive materials used for attachment of components should conform to an acceptable document or standard, e.g., IPC-SM-817, or as otherwise specified. The adhesives selected **shall not [D1D2D3]** be detrimental to the component or assembly they are used on. The material **shall [D1D2D3]** be cured, free of contamination, not negate stress relief, and show no visible gap or separation between the adhesive and the surface to which it is bonded.

4.1.1.4 Material, Components and Equipment – Materials – Solderability

Electronic/mechanical components (including terminals) and wires to be soldered **shall [D1D2D3]** meet the solderability requirements of J-STD-002 or equivalent. When a solderability inspection operation or pretinning and inspection operation is performed as part of the documented assembly process, that operation may be used in lieu of solderability testing.

The Manufacturer should establish procedures to minimize part solderability degradation.

A wire or terminal not conforming to the solderability requirements may be reworked, e.g., by dipping in hot solder, before soldering.

4.1.1.5 Material, Components and Equipment – Materials – Tools and Equipment

Tools and equipment used **shall [D1D2D3]** be selected and maintained such that no damage or degradation that would be detrimental to the designed function of parts or assemblies results from their use.

Soldering irons, equipment, and systems **shall [D1D2D3]** be chosen and employed to provide temperature control and isolation from electrical overstress or ESD when ESD sensitive parts or assemblies are involved.

See Appendix C for guidelines on tool selection and maintenance.

4.1.2 Material, Components and Equipment – Gold Removal

Gold **shall [N1D2D3]** be removed from the surfaces to be soldered of solder terminals plated with greater than 2.54 µm [100 µin] gold thickness. Gold **shall [N1N2D3]** be removed from all solder cup terminals, regardless of gold thickness.

A double tinning process or dynamic solder wave may be used for gold removal prior to mounting the component on the assembly.

These requirements may be eliminated if there is documented objective evidence available for review that there are no gold related solder embrittlement problems associated with the soldering process being used.

4.2 Cleanliness

IPC-CH-65 and IPC-AJ-820 provide additional information about cleaning processes and materials.

4.2.1 Cleanliness – Presoldering

The assembly should be clean of any matter that will inhibit compliance to the requirements of this standard.

4.2.2 Cleanliness – Postsoldering

Solder connections required to be cleaned, e.g., rosin/resin fluxes, **shall [D1D2D3]** be cleaned in a manner that assures removal of residual flux and activators. Flux residue can degrade product performance over time based upon environmental conditions.

Methods and materials that are used to clean soldered assemblies **shall [D1D2D3]** be compatible with the product and assembly materials so that the cleaning process does not adversely affect performance characteristics.

Solder connections produced using ''no-clean'' processes need only be cleaned when required.

4.2.2.1 Cleanliness – Postsoldering – Foreign Object Debris (FOD)

Defect – Class 1,2,3

- Dirt and particulate matter on assembly, e.g., solder splatter, solder balls, dirt, lint, dross, metallic particles, etc.

4.2.2.2 Cleanliness – Postsoldering – Flux Residue

4.2.2.2.1 Cleanliness – Postsoldering – Flux Residue – Cleaning Required

Acceptable – Class 1,2,3

- No visible flux residue.

Defect – Class 1,2,3

- Visible flux residue.

4.2.2.2.2 Cleanliness – Postsoldering – Flux Residue – No-Clean Process

Flux residue may be present if it is flux residue that is not intended to be cleaned. (Not illustrated.)

Acceptable – Class 1,2,3

- Flux residue does not inhibit visual inspection.
- Flux residue does not inhibit access to test points of the assembly.

Defect – Class 1,2,3

- Wet, tacky, or excessive flux residues that may spread onto other surfaces.
- No-clean flux residue on any electrical mating surface.

4.3 Solder Connection

These connection criteria apply regardless of which methods of soldering have been utilized.

There are specialized soldering finishes, e.g., immersion tin, palladium, gold, etc., that require the creation of special acceptance criteria other than as stated in this document. The criteria should be based on design, process capability and performance requirements.

Wetting cannot always be judged by surface appearance. The wide range of solder alloys in use may exhibit from low or near zero degree contact angles to nearly 90° contact angles. The acceptable solder connection **shall [D1D2D3]** indicate evidence of wetting and adherence where the solder blends to the soldered surface.

The solder connection wetting angle (solder to lead and solder to terminal) **shall not [D1D2D3]** exceed 90° (see Figure 4-1-A, B). As an exception, the solder connection to a termination may exhibit a wetting angle exceeding 90° (see Figure 4-1-C) when it is created by the solder contour extending over the edge of the solderable termination area.

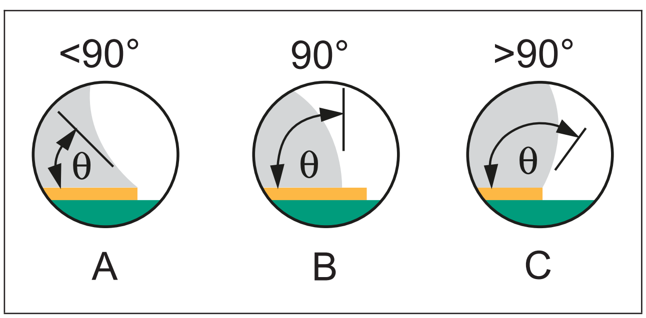

Figure 4-1

4.3 Solder Connection (cont.)

The primary difference between the solder connections created with processes using SnPb alloys and processes using Pb-free alloys is related to the visual appearance of the solder. This standard provides visual criteria for inspection of both SnPb and Pb-free connections. Figures specific to Pb-free connections will be identified with the symbol shown in Figure 4-2.

Figure 4-2

Acceptable Pb-free and SnPb connections may exhibit similar appearances but Pb-free alloys are more likely to have:

- Surface roughness (grainy or dull).
- Greater wetting contact angles.

All other solder fillet criteria are the same.

Typical SnPb connections have from a shiny to a satin luster, generally smooth appearance and exhibit wetting as exemplified by a concave meniscus between the objects being soldered. High temperature solders may have a dull appearance. Touch-up (rework) of soldered connections is performed with discretion to avoid causing additional problems and to produce results that exhibit the acceptability criteria of the applicable Product Class.

Undesirable wetting conditions are typically nonwetting and dewetting.

Nonwetting is characterized as partial adherence of solder to a surface that it has contacted and basis metal remains exposed. Dewetting is a condition where molten solder coats a surface and then recedes to leave irregularly shaped mounds of solder on the surface that are separated by areas covered with a thin film of solder and without leaving basis metal exposed.

Some solders may have a dull appearance, e.g., high temperature, some Pb-free alloys. These should not be considered defective based upon their surface appearance.

Rework (touch-up) of soldered connection defects should only be performed if required by disposition (see 1.5.1.2.1 and 1.19.1).

4.3.1 Solder Connection – General Requirements

The following general requirements are applicable to all terminals unless there is a specific requirement for a given terminal.

Solder connection anomaly criteria are shown in Table 4-2.

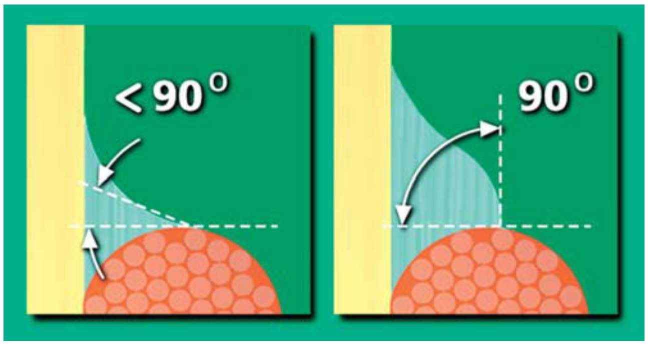

Figure 4-3

Acceptable – Class 1,2,3

- The acceptable solder connection indicates evidence of wetting and adherence when the solder blends to the soldered surface, forming a contact angle of 90° or less, except when the quantity of solder results in a contour which is limited by the edge of the attached surfaces.
- Solder wicking allows the wire to remain flexible in required areas.

4.3.1 Solder Connection – General Requirements (cont.)

Table 4-2 Solder Connection Anomalies

Criteria	Class 1	Class 2	Class 3
Insufficient Solder:			
Blowholes/pinholes/voids, etc., providing the solder connection meets minimum requirements.	Acceptable	Process Indicator	
Blowholes/pinholes/voids, etc., reduce the solder connection below minimum requirements.	Defect		
Solder coverage does not meet minimum requirements for the termination type.	Defect		
Excess Solder:			
Solder bridging except when the path is present by design.	Defect		
Solder violates minimum electrical clearance.	Defect		
Solder wicking under wire insulation inhibits flexibility where required.	Defect		
Loose solder balls, Note 1.	Defect		
Solder splash or webbing.	Defect		
Solder Wetting:			
Solder not wetted to the surface where required.	Defect		
Dewetting causes connection to not meet minimum solder fillet requirements.	Defect		
Solder Appearance:			
Fractured solder.	Defect		
Disturbed solder.	Defect		
Cold or rosin solder connection results in nonwetting or incomplete wetting.	Defect		
Probe mark or other damage degrades the integrity of the solder connection.	Defect		
Contaminated Solder:			
Flux residues, when cleaning is required.	Defect		
No-clean flux residues that are wet, tacky, or excessive.	Defect		

Note 1: ''Loose'' means it could be dislodged in the service environment of the product.

4.3.2 Solder Connection – Soldering Anomalies

4.3.2.1 Solder Connection – Soldering Anomalies – Exposed Basis Metal

Exposed basis metal is acceptable on wire ends or lead ends.

4.3.2.2 Solder Connection – Soldering Anomalies – Partially Visible or Hidden Solder Connections

Partially visible or hidden solder connections **shall [A1P2D3]** meet the following conditions:

a. The design does not restrict solder flow to any connection element.
b. The visible portion, if any, of the connection is acceptable.
c. Process controls are maintained in a manner assuring repeatability of assembly techniques.

4.4 Wire/Lead Preparation, Tinning

In this document, the term pretinning and tinning have the same meaning: The application of molten solder to a basis metal or surface finish.

When wires are tinned using alloys other than those listed in 4.1.1.1, the solder used for tinning **shall [D1D2D3]** be the same alloy used in the subsequent soldering process.

Stranded wires **shall [N1D2D3]** be tinned when:

- Wires will be formed for attachment to solder terminals.
- Wires will be formed into splices (other than mesh).

Stranded wires **shall not [D1D2D3]** be tinned when:

- Wires will be used in crimp terminations.
- Wires will be used in threaded fasteners.
- Wires will be used in forming mesh splices.

Tinning of stranded wires is optional when heat shrinkable solder devices are used.

Note: J-STD-002 provides additional information for assessing this requirement.

The following criteria are applicable if tinning is required.

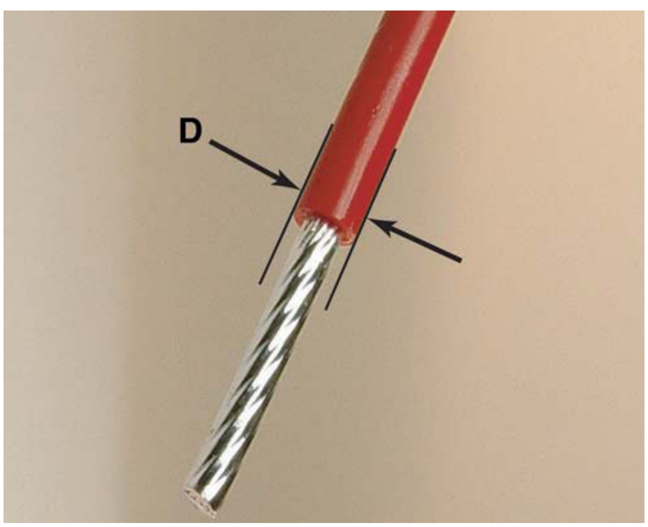

Figure 4-4

Acceptable – Class 1,2,3

- The solder wets the tinned portion of the wire and penetrates to the inner strands of stranded wire.
- Solder wicks up wire provided the solder does not extend to a portion of the wire that is required to remain flexible.
- The tinning leaves a smooth coating of solder and the outline of the strands are discernible.

Process Indicator – Class 2,3

- Strands are not discernible but excess solder does not affect form, fit or function.
- Solder does not penetrate to the inner strands of the wire.

4.4 Wire/Lead Preparation, Tinning (cont.)

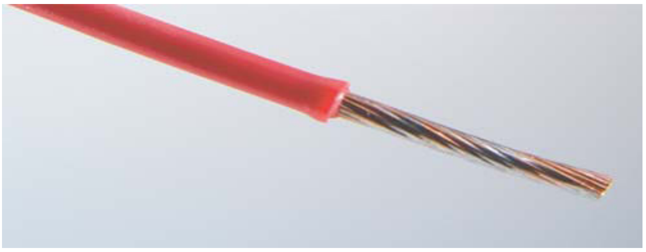

Figure 4-5

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Length of untinned strands from end of wire insulation is greater than one wire diameter (see Figure 4-4-D).

Defect – Class 2,3

- Tinned wire pinholes, voids, dewetting/nonwetting exceeding 5% of the area required to be tinned.
- Solder does not wet the tinned portion of the wire.

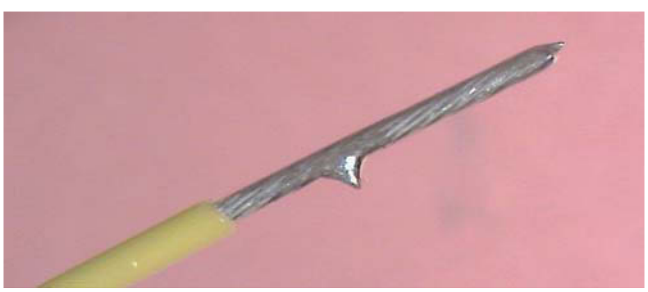

Figure 4-6

Defect – Class 1,2,3

- Solder build-up or icicles within the usable wire area that affect subsequent assembly steps.
- Solder wicking extends into the portion of wire that is required to remain flexible after soldering.

4.5 Wire Insulation

4.5.1 Wire Insulation – Clearance

Insulation clearance below is defined as the distance between the wire insulation and the solder fillet.

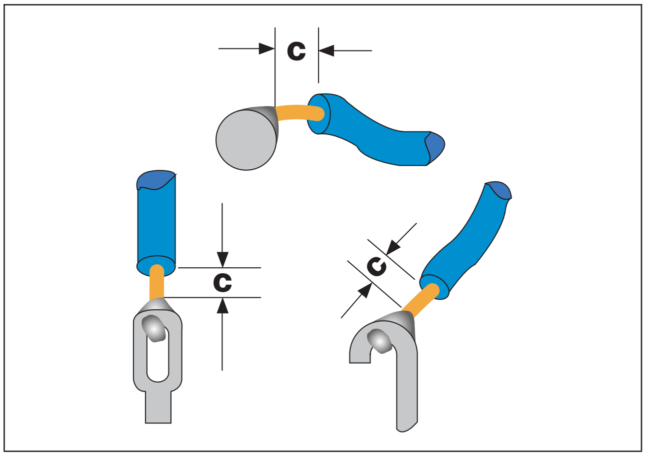

Figure 4-7

Figure 4-8

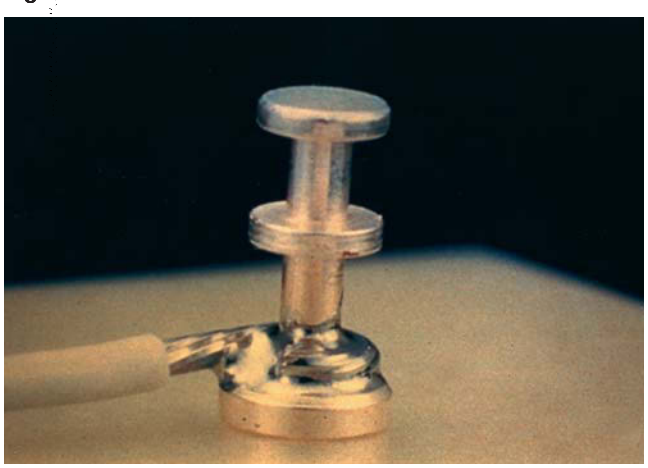

Figure 4-9

Acceptable – Class 1,2,3

- The insulation clearance (C) is two wire diameters (D) or less including insulation or 1.5 mm [0.060 in], whichever is greater.
- Insulation clearance (C) does not permit violation of minimum electrical clearance to adjacent conductors.
- The wire insulation is in contact with the solder but does not interfere with formation of an acceptable connection.

4.5.1 Wire Insulation – Clearance (cont.)

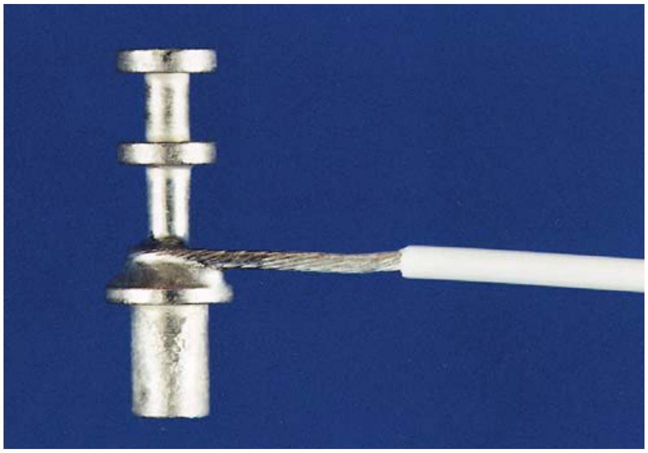

Figure 4-10

Acceptable – Class 1

- Exposed bare wire providing there is no danger of violating minimum electrical clearance to adjacent circuitry when the wire is moved.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- The insulation clearance is greater than two wire diameters or 1.5 mm [0.060 in], whichever is greater.

Defect – Class 2,3

- Insulation is embedded in or covered with solder.

Defect – Class 1,2,3

- The clearance between the end of the insulation and the connection violates minimum electrical clearance between noncommon conductors.
- Insulation interferes with formation of the solder connection.

4.5.2 Wire Insulation – Postsolder Damage

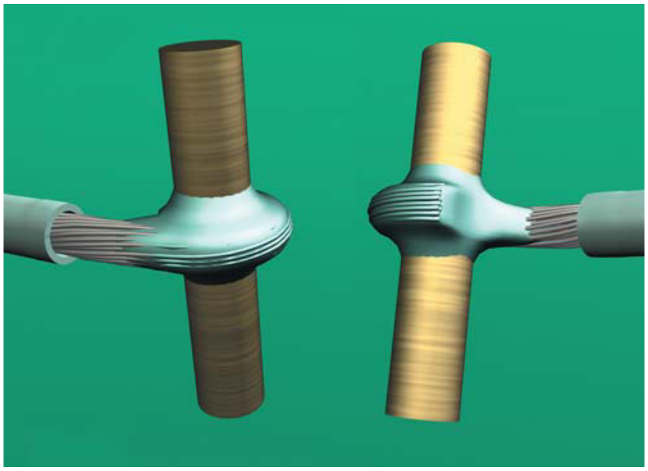

Figure 4-11

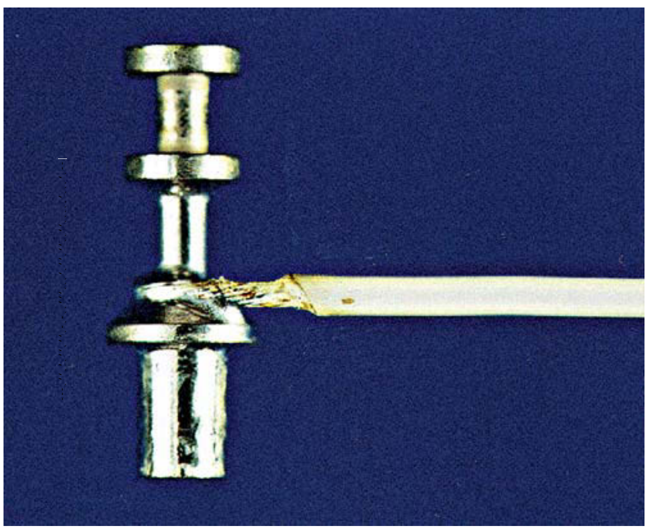

Figure 4-12

Acceptable – Class 1,2,3

- Insulation is not melted, charred or otherwise damaged from the soldering process (see Figure 4-11).
- Slight melting of insulation (see Figure 4-12).

Figure 4-13

Defect – Class 1,2,3

- Insulation charred.

4.6 Insulation Sleeving

The following criteria apply when insulation sleeving is required to be applied to any type of soldered terminal, i.e., not only soldered connector cups.

These criteria are intended for use with shrink sleeving. Criteria for other types of sleeving should be agreed upon between User and Manufacturer.

Cleaning, if required, **shall [D1D2D3]** be accomplished prior to shrinking of the sleeving.

Heating processes used to shrink sleeve insulation **shall not [D1D2D3]** damage the connector, wire, sleeving, or adjacent components, nor reflow the solder connection.

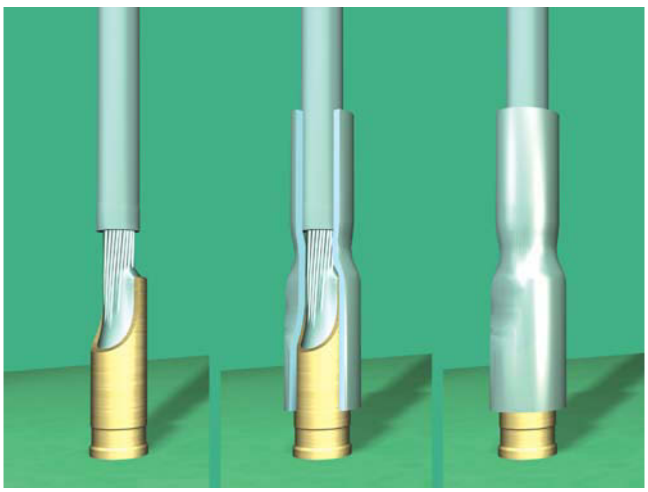

Figure 4-14

Acceptable – Class 1,2,3

- Insulation sleeving overlaps the connector terminal and the wire insulation by a minimum of two wire diameters.
- Insulation sleeving is more than 50% wire diameter and not more than two wire diameters from the point where the connector terminal enters the connector insert.
- Multiple pieces of sleeving overlap each other by at least three wire/cable diameters.

Acceptable – Class 1

- Sleeving/tubing is tight on terminal, but not tight on wire.

Acceptable – Class 2,3

- Sleeving/tubing is tight on terminal and wire.

4.6 Insulation Sleeving (cont.)

Defect – Class 2,3

- Multiple pieces of sleeving overlap less than three wire/cable diameters.
- Sleeving/tubing is not tight on wire/cable.

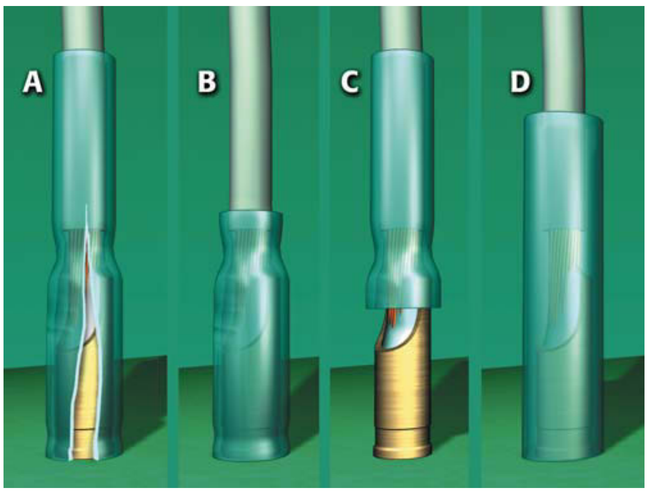

Figure 4-15

Defect – Class 1,2,3

- Insulation sleeving is damaged, e.g., split (see Figure 4-15-A), charred (not shown), pinholes (not shown).
- Insulation sleeving overlaps the wire insulation by less than two wire diameters (see Figure 4-15-B).
- Insulation sleeving is more than two wire diameters from the point where the connector terminal enters the connector insert (see Figure 4-15-C).
- Insulation sleeve is loose on the terminal (could slide or vibrate off, exposing more than the allowed amount of conductor or terminal) (see Figure 4-15-D).
- Insulation sleeving prevents movement of floating contact in the insert, when movement is required.

4.7 Soldered Strand Separation (Birdcaging)

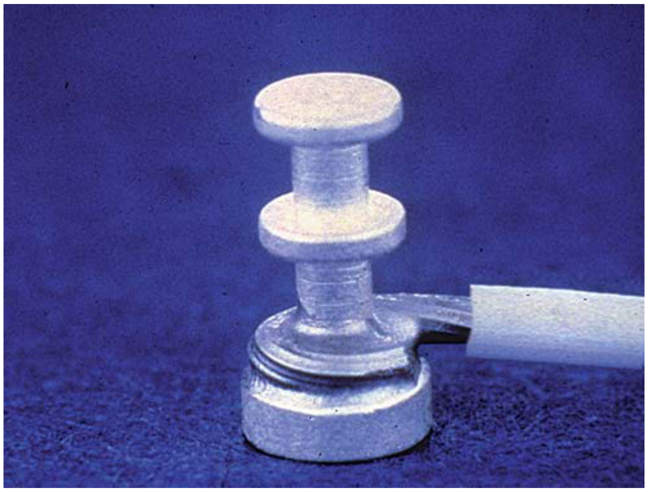

Figure 4-16

Acceptable – Class 1,2,3

- Wire strands have separation but:
  - Do not exceed one strand diameter.
  - Do not extend beyond wire insulation outside diameter.

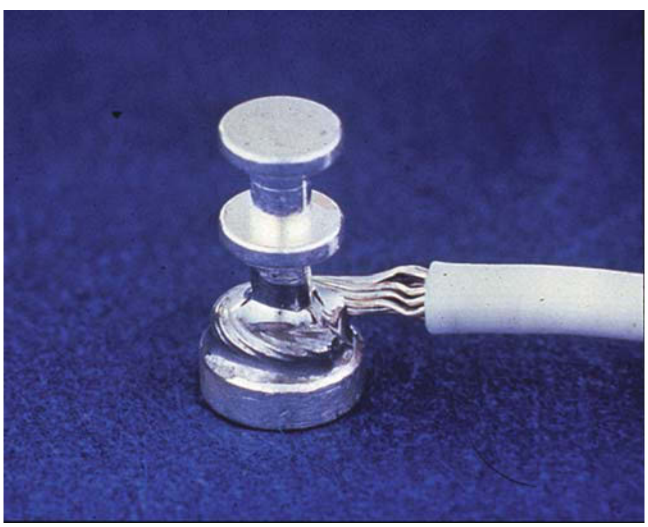

Figure 4-17

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire strands have separation exceeding one strand diameter but do not extend beyond wire insulation outside diameter.

Acceptable – Class 1
Defect – Class 2,3

- Wire strands extend beyond wire insulation outside diameter.

4.8 Terminals

The terminal wire wrap requirements apply equally to wires and component leads. The criteria associated with each terminal type or connection are in 4.8.1 through 4.8.8.

Wire Overwrap When a wire/lead that is wrapped more than 360° and remains in contact with the terminal post (see Figure 4-18-A).

Wire Overlap When a wire/lead that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post (see Figure 4-18-B).

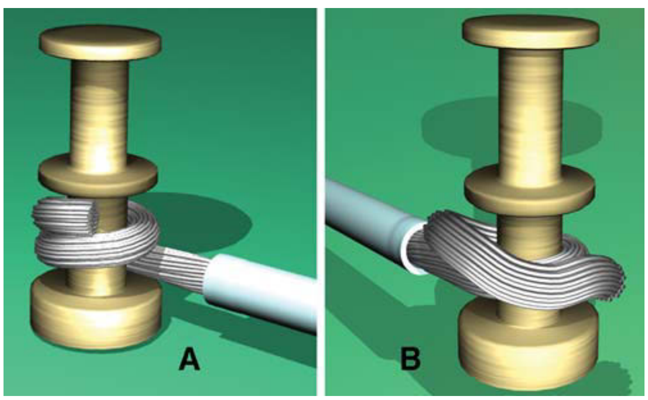

Figure 4-18

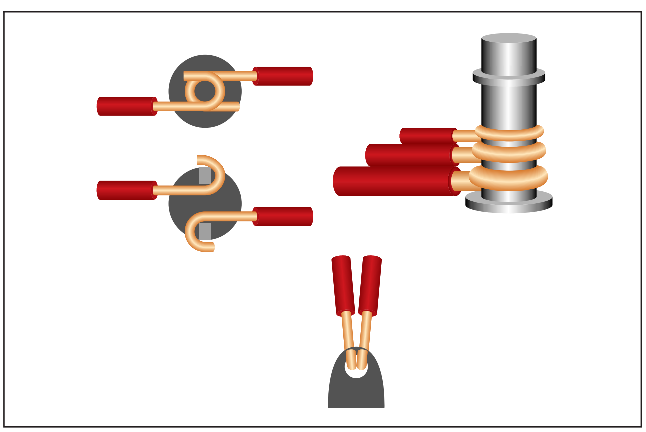

Figure 4-19

The preferred wrap conditions achieve a mechanical connection between the lead/wire and the terminal sufficient to assure that the lead/wire does not move during the soldering operation. Typically the mechanical connection includes a 180° mechanical wrap to effect mechanical connection.

The wire ends should not extend beyond the terminal greater than one lead diameter.

Attachments should be positioned on the base of the solder termination area or previous attachment consistent with the thickness of the wire insulation. When practical, wires should be placed in ascending order with the largest on the bottom. Connection wraps **shall [N1D2D3]** be in contact with the post termination area for the full curvature of the wrap. Wires should be parallel to the terminal base and each other.

As an exception to the wrap conditions described above, under certain circumstances, leads/wires attached to some terminal types may be routed straight through. See the specific terminal type for requirements.

4.8 Terminals (cont.)

Wires connected to terminals **shall [N1D2D3]** have stress relief. For additional stress relief criteria see 6.2.6, 6.2.8, 15.3.3, 17.3.1 and 17.3.2.

Terminals **shall not [A1D2D3]** be modified to accept oversized conductors. Wires **shall not [N1D2D3]** be modified to fit terminals.

Attachments to terminals that require a wrap may be wrapped clockwise or counterclockwise (consistent with the direction of potential stress application). Unless the wire/terminal connection is supported to prevent stress at the solder connection, the wire **shall [A1P2D3]** continue the curvature of the dress of the wire (see Figure 4-20). The conductor **shall not [A1D2D3]** interfere with the wrapping of other conductors on the terminal or overlap itself or each other (see 17.3.2).

The criteria in this section are grouped together in subsections. Not all combinations of wire/lead types and terminal types can possibly be covered explicitly, so criteria are typically stated in general terms to apply to all similar combinations. For example, a solid wire and a stranded wire connected to turret terminals have the same wrap and placement requirements, but only the stranded wire could be subject to birdcaging.

Unless otherwise stated for a specific terminal type, the following are general requirements for all terminals.

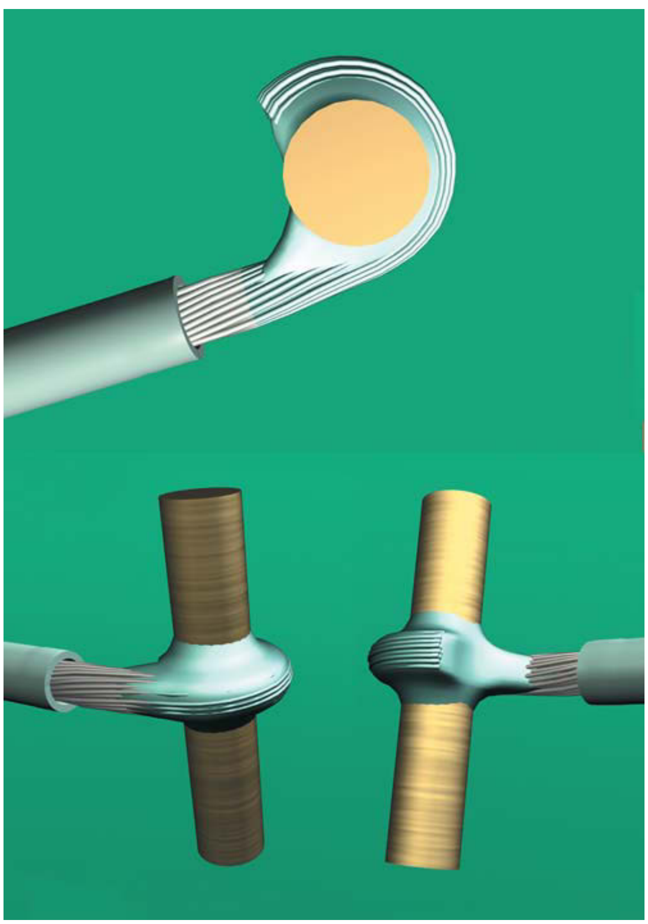

Figure 4-20

Acceptable – Class 1,2,3

- Solder fillet is at least 75% of the wire/lead and terminal interface.
- Wire/lead is discernible in solder.

4.8 Terminals (cont.)

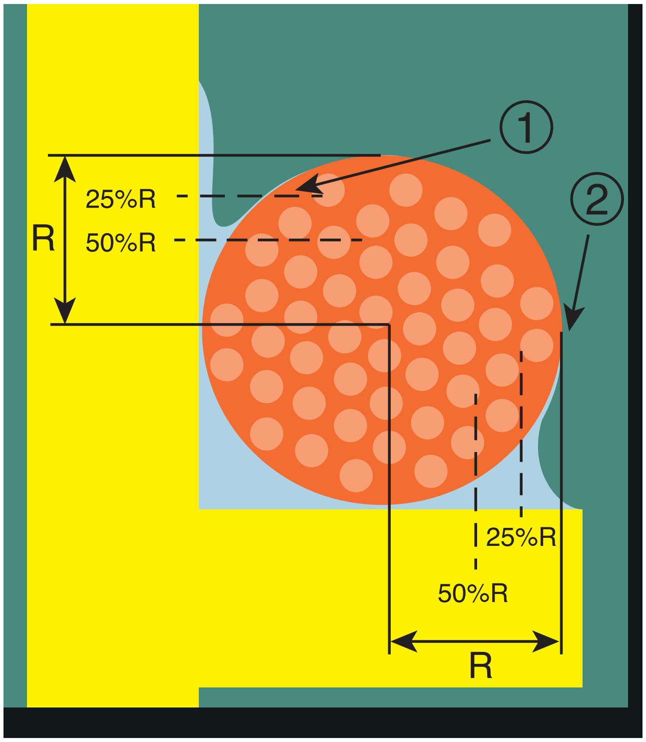

Figure 4-21

1. As shown, solder depression is a defect for Class 3.
2. As shown, solder depression is acceptable for all three Product Classes.

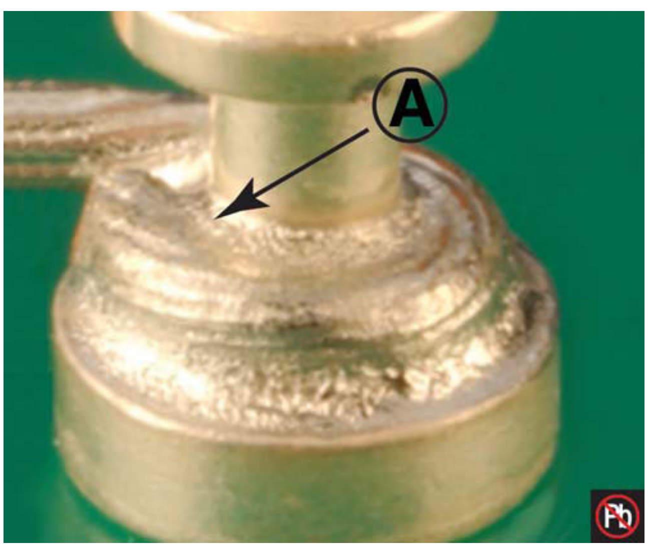

Figure 4-22

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire/lead not discernible in solder connection.

Defect – Class 1,2

- Depression of solder between the post and the wrap of the wire is deeper than 50% of wire radius (r) (see Figures 4-21-1 and 4-22-A).

Defect – Class 3

- Depression of solder between the post and the wrap of the wire is deeper than 25% of wire radius (r) (see Figures 4-21-1 and 4-22-A).

Defect – Class 1,2,3

- For terminals with a required minimum wrap of less than 180°, solder is wetted less than 100% of the required minimum wrap area.
- For terminals with a required minimum wrap of 180° or more, solder is wetted less than 75% of the required minimum wrap.

4.8.1 Terminals – Turrets and Straight Pins

4.8.1.1 Terminals – Turrets and Straight Pins – Lead/Wire Placement

Table 4-3 is applicable to leads and wires attached to turret and straight pin terminals.

Table 4-3 Turret or Straight Pin Terminal Lead/Wire Placement[2]

Criteria	Class 1	Class 2	Class 3
<90° contact between the lead/wire and terminal post	Defect		
90° to <180° contact between the lead/wire and terminal post	Acceptable	Process Indicator	Defect
≥180° contact between lead/wire and post	Acceptable		
>360° and overlaps itself.[1]	Acceptable	Defect	

Note 1: A wire that is wrapped more than 360° and remains in contact with the terminal post is considered an overwrap or spiral wrap (see Figure 4-18-A). A wire/lead that is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post, is considered an overlap (see Figure 4-18-B).

Note 2: See 4.8.8 for criteria for AWG 30 and smaller wires.

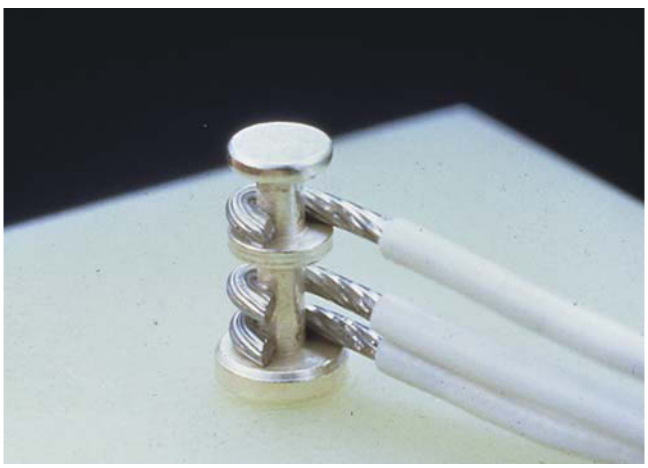

Figure 4-23

4.8.1.1 Terminals – Turrets and Straight Pins – Lead/Wire Placement (cont.)

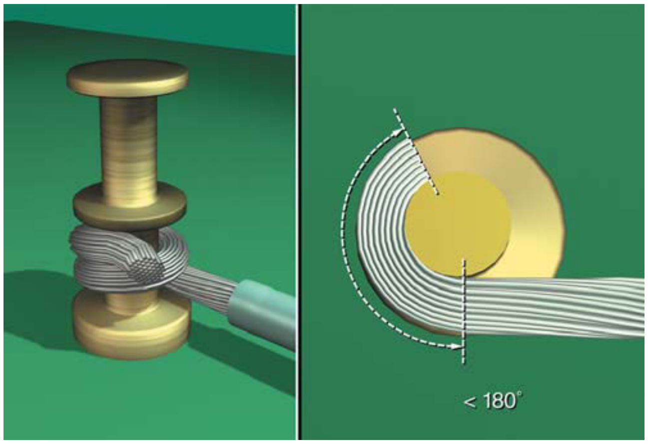

Figure 4-24

Acceptable – Class 1,2,3

- Wires and leads wrapped a minimum of 180° and do not overlap.
- Wire mounted against terminal base or previously installed wire.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- On straight pins, the top wire on terminal is less than one wire diameter below the top of the terminal.

Acceptable – Class 1
Defect – Class 2,3

- Wire overlaps itself.

Process Indicator – Class 2

- Wrap for round posts 90° to less than 180° of contact between the wires and the terminal.

Defect – Class 1,2

- Wrap for round posts has less than 90° of contact between the wires and the terminal.

Defect – Class 3

- Wrap for round posts has less than 180° of contact between the wires and the terminal.

Defect – Class 1,2,3

- Wire end violates minimum electrical clearance.

4.8.1.2 Terminals – Turrets and Straight Pins – Solder

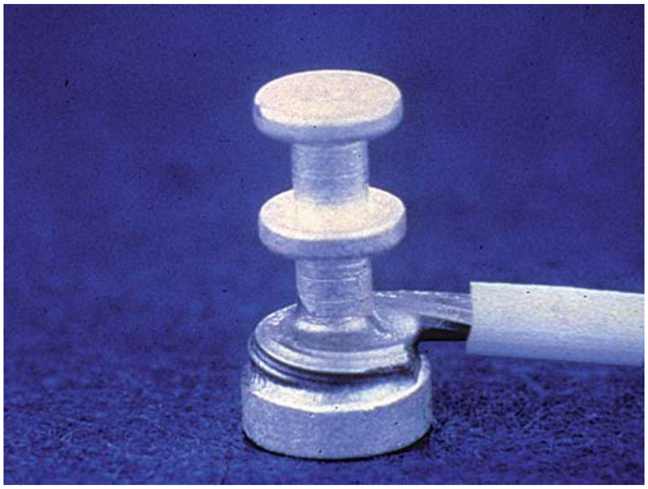

Figure 4-25

Figure 4-26

Acceptable – Class 1,2

- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.

Acceptable – Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped 180° or more.

4.8.1.2 Terminals – Turrets and Straight Pins – Solder (cont.)

Figure 4-27

Defect – Class 1,2,3

- Solder is wetted less than 100% of the lead to terminal contact area when the wrap is more than 90° and less than 180°.
- Depression of solder between the post and the wrap of the wire is deeper than 50% of wire radius.

Defect – Class 3

- Depression of solder between the post and the wrap of the wire is deeper than 25% of wire radius.

Defect – Class 1,2,3

- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more.

4.8.2 Terminals – Bifurcated

4.8.2.1 Terminals – Bifurcated – Lead/Wire Placement – Side Route

Table 4-4 is applicable to leads and wires attached to side route bifurcated terminals.

Table 4-4 Bifurcated Terminal Lead/Wire Placement – Side Route[1]

Criteria	Class 1	Class 2	Class 3
<90° wrap	Defect		
≥90° wrap	Acceptable		
>360° and wire overlaps itself	Acceptable	Defect	

Note 1: 4.8.2.1 provides exceptions to wrap requirements depending on wire size; 4.8.2.3 provides exceptions to wrap requirements when staking is used.

4.8.2.1 Terminals – Bifurcated – Lead/ Wire Placement – Side Route (cont.)

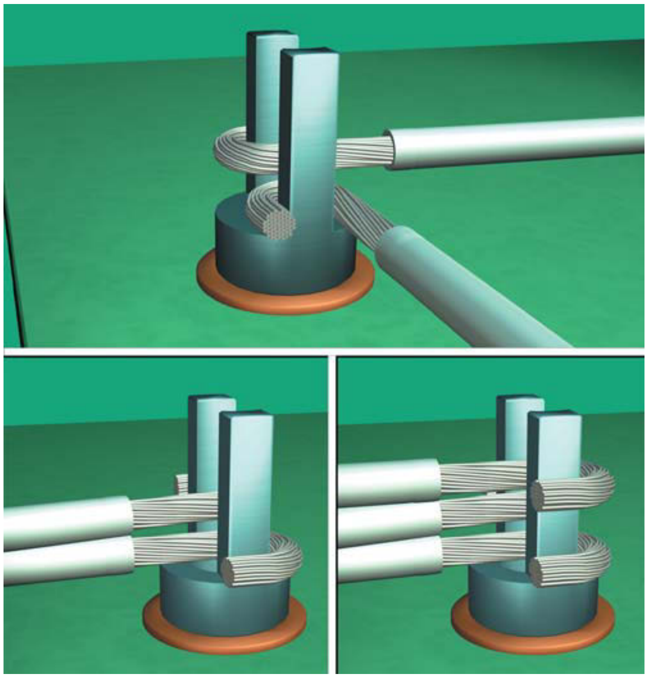

Figure 4-28

Acceptable – Class 1,2,3

- Wire end extends beyond the base of the terminal provided minimum electrical spacing is maintained.
- Wire passes through the slot.
- No portion of the wrap extends beyond the top of the terminal post.
- If required, wire wrap is at least 90°.

Acceptable – Class 1,2

- Wires/leads 0.75 mm [0.0295 in] or larger in diameter are routed straight through the posts.

Acceptable – Class 3

- Wires/leads 0.75 mm [0.0295 in] or larger in diameter are routed straight through the posts and staked (see 4.8.2.3).

4.8.2.1 Terminals – Bifurcated – Lead/ Wire Placement – Side Route (cont.)

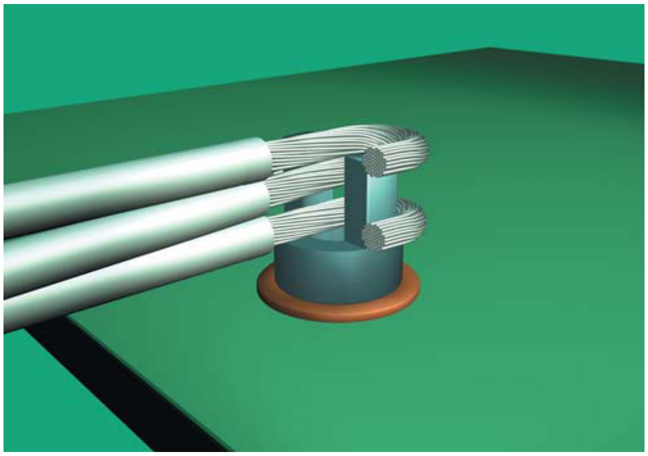

Figure 4-29

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Any portion of the wrap extends above the terminal post.
- Wire does not have positive contact with at least one corner of the post.

Acceptable – Class 1
Defect – Class 2,3

- Wire end overlaps itself.

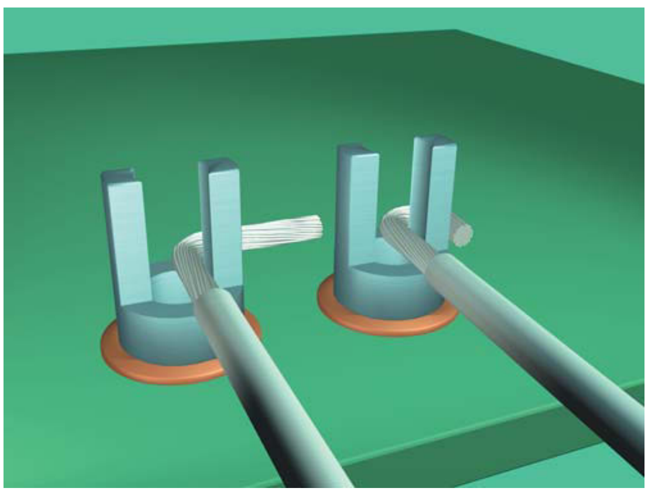

Figure 4-30

Defect – Class 3

- Wire/lead equal to or greater than 0.75 mm [0.0295 in] in diameter is wrapped less than 90° and is not staked (see 4.8.2.3).
- Straight through conductor is not in contact with the base of the terminal or the previously installed conductor, with allowance given for insulation thickness.

Defect – Class 1,2,3

- Wire does not pass through slot.
- Wire end violates minimum electrical clearance.
- Wire/lead less than 0.75 mm [0.0295 in] in diameter is wrapped around a post less than 90°. See 4.8.2.3 for exception.

4.8.2.2 Terminals – Bifurcated – Lead/ Wire Placement – Bottom and Top Route

Table 4-5 is applicable to leads and wires attached to bottom route bifurcated terminals. Top route wires do not have a wrap.

Table 4-5 Bifurcated Terminal Lead/Wire Placement – Bottom Route

Criteria	Class 1	Class 2	Class 3
<90° wrap	Acceptable	Process Indicator	Defect
90° to 180° wrap	Acceptable		

4.8.2.2 Terminals – Bifurcated – Lead/Wire Placement – Bottom and Top Route (cont.)

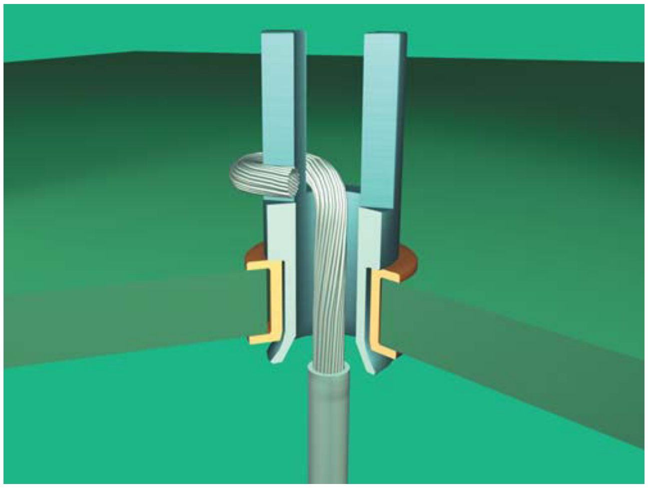

Figure 4-31

Acceptable – Class 1,2,3

- Wire insulation does not enter base or posts of terminal.
- Bottom route wire wraps post a minimum of 90°.
- Top route wire has space between posts filled by bending the wire double or using separate filler (see Figure 4-32-B, C).

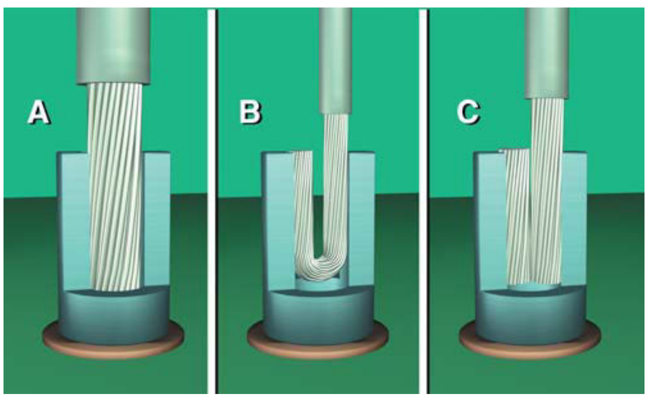

Figure 4-32

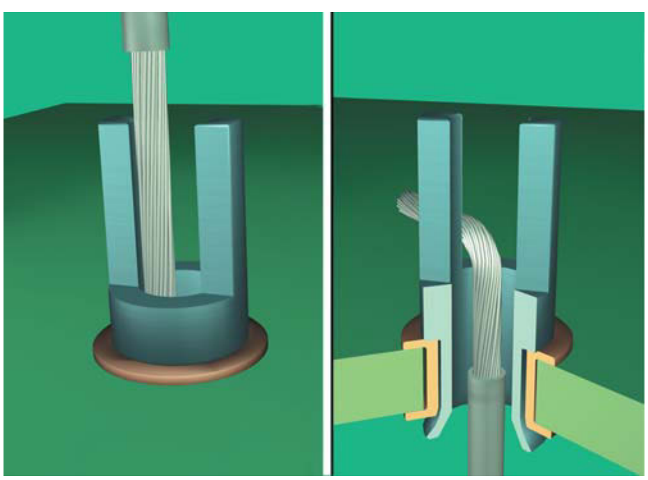

Figure 4-33

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire insulation enters base or posts of terminal.
- Top route wire is not supported with filler.
- Bottom route wire not wrapped to terminal base or post with a minimum 90° bend.

4.8.2.3 Terminals – Bifurcated – Lead/ Wire Placement – Staked/Constrained Wires

As an alternative to wrap requirements of 4.8.2.1, the following criteria (summarized in Table 4-6) apply to wires/leads that are staked, bonded or otherwise constrained to provide support for the solder connection.

Adhesive **shall not [A1D2D3]** overhang the board edge(s) or violate edge spacing requirements.

Table 4-6 Staking Requirements of Side Route Straight Through Connections – Bifurcated Terminals

Conductor Diameter	Class 1	Class 2	Class 3
<0.75 mm [0.03 in], Note 1	Defect if not staked		
≥0.75 mm [0.03 in], Note 2	Acceptable if not staked	Process Indicator if not staked	Defect if not staked

Note 1: 22 AWG and smaller
Note 2: 20 AWG and larger

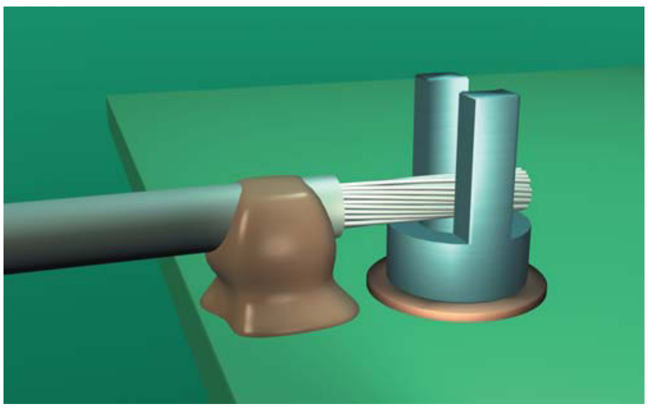

Figure 4-34

Acceptable – Class 1,2,3

- Wire is permanently staked or constrained by a permanent mounting device.
- Wire extends through posts of bifurcated terminal.

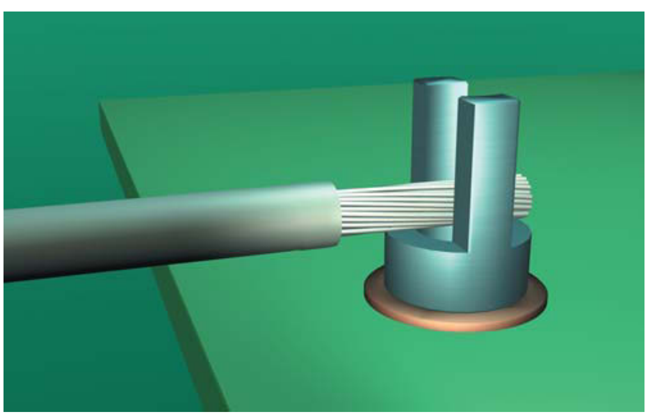

Figure 4-35

Acceptable – Class 1
Process Indicator – Class 2

- Wires or leads equal to or greater than 0.75 mm [0.03 in] and wrapped less than 90° are not staked.

Defect – Class 1,2

- Wires or leads less than 0.75 mm [0.03 in] and wrapped less than 90° are not staked.

Defect – Class 3

- Any straight through wire is not staked.

Defect – Class 1,2,3

- Wire does not extend through posts of bifurcated terminal.

4.8.2.4 Terminals – Bifurcated – Solder

Acceptable – Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped 180° or more.
- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.
- Solder is 75% of the height of the terminal post for top route wires.

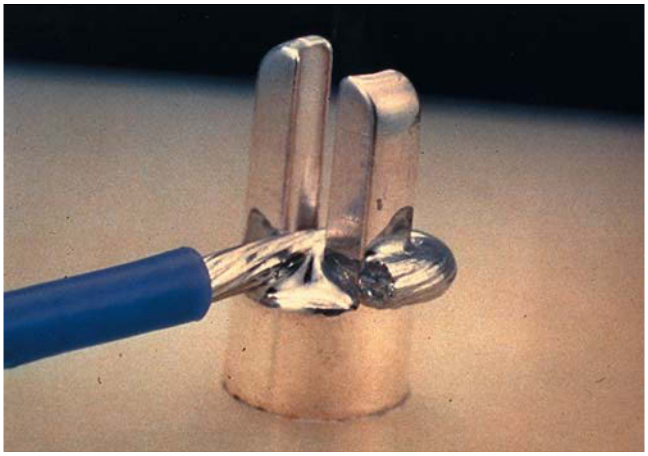

Figure 4-36

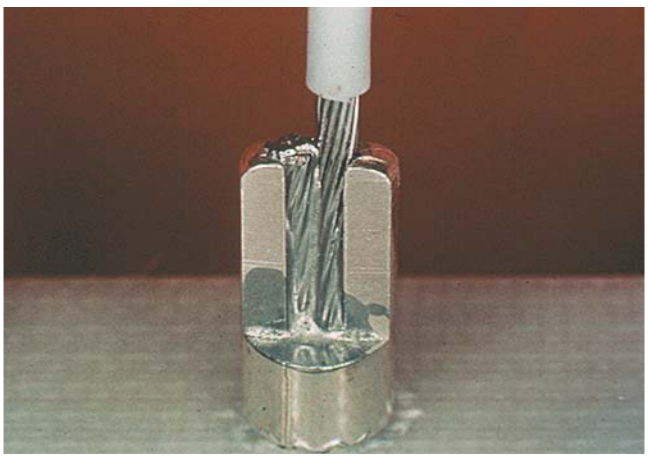

Figure 4-37

Figure 4-38

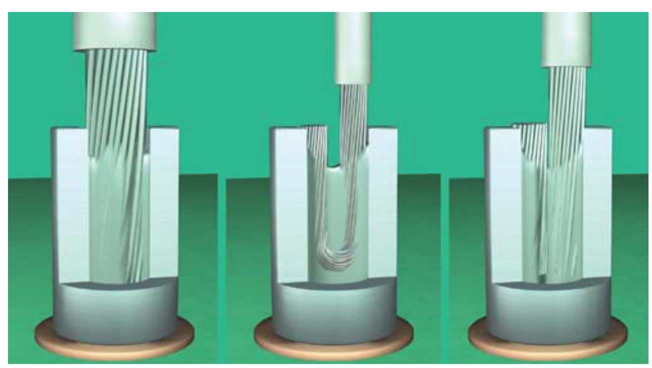

Figure 4-39

4.8.2.4 Terminals – Bifurcated – Solder (cont.)

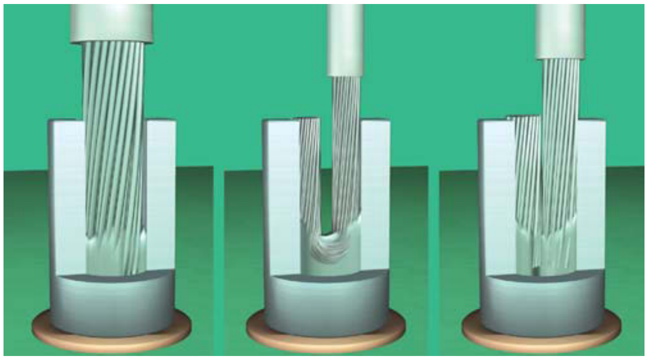

Figure 4-40

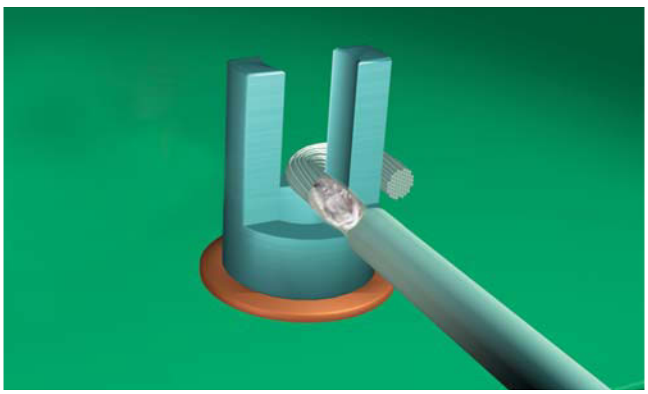

Figure 4-41

Defect – Class 1,2,3

- Solder is less than 75% of the height of the terminal post for top route wires (see Figure 4-40).
- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180° (not shown).
- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more (see Figure 4-41).

4.8.3 Terminals – Slotted

4.8.3.1 Terminals – Slotted – Lead/Wire Placement

Figure 4-42

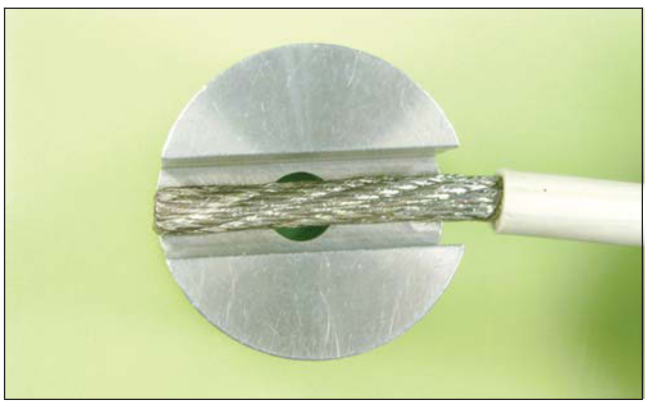

Figure 4-43

Acceptable – Class 1,2,3

- Lead or wire end is discernible on the exit side of terminal.
- No portion of the wire termination extends above the top of the terminal post.

Note: Wrap is not required on a slotted terminal.

Figure 4-44

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire termination extends above the top of the terminal post.

Defect – Class 1,2,3

- Lead or wire end is not flush or discernible on the exit side of terminal.
- Wire end violates minimum electrical clearance.

4.8.3.2 Terminals – Slotted – Solder

Solder should form a fillet with that portion of the lead or wire that is in contact with the terminal. Solder may completely fill the slot but should not be built up on top of the terminal. The lead or wire should be discernible in the terminal.

Figure 4-45

Acceptable – Class 1,2,3

- Fillet formed with 100% of the portion of the wire that is in contact with the terminal.
- Solder fills terminal slot.
- Lead or wire end is discernible in the solder on the exit side of terminal.

Note: Solder fill/height in the slot may be dependent upon the design.

Not Established – Class 1
Defect – Class 2,3

- Fillet not formed with 100% of the portion of the wire that is in contact with the terminal.

Figure 4-46

Defect – Class 1,2,3

- Lead or wire end not discernible on exit side of terminal.

4.8.4 Terminals – Pierced/Perforated/Punched

4.8.4.1 Terminals – Pierced/Perforated/ Punched – Lead/Wire Placement

Table 4-7 is applicable to leads and wires attached to pierced or perforated terminals.

Table 4-7 Pierced/Perforated/Punched Terminal Lead/Wire Placement

Criteria	Class 1	Class 2	Class 3
Wire overlaps itself.	Acceptable	Defect	
Wire does not pass through the eye.	Acceptable	Defect	
Wire does not contact at least two surfaces of the terminal.	Acceptable	Defect	
Conductor end violates minimum electrical clearance.	Defect		

4.8.4.1 Terminals – Pierced/Perforated/ Punched – Lead/Wire Placement (cont.)

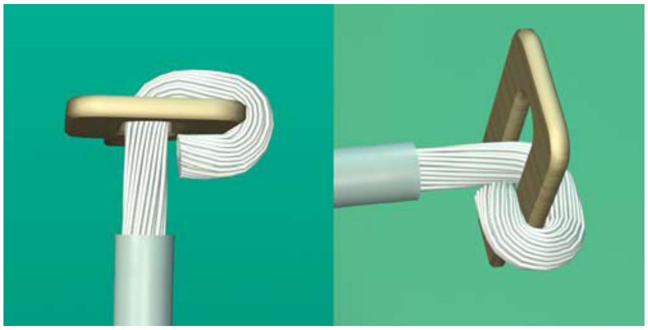

Figure 4-47

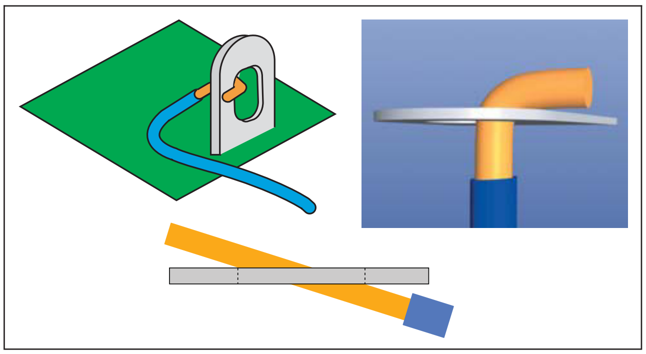

Figure 4-48

Acceptable – Class 1,2,3

- Wire contacts at least two surfaces of the terminal (see Figures 4-47 and 4-48, top right and bottom views).

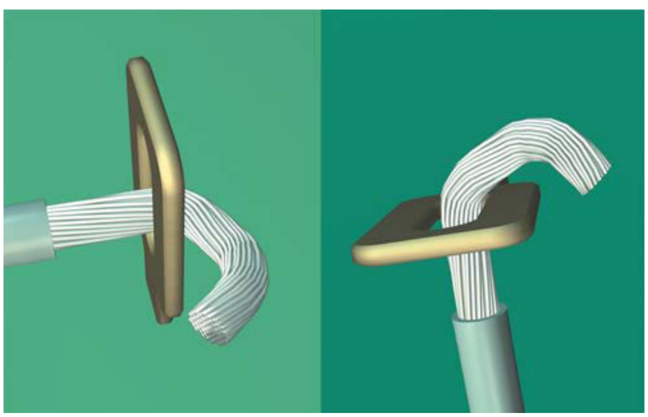

Figure 4-49

Acceptable – Class 1
Defect – Class 2,3

- Wire does not contact two surfaces of the terminal.
- Wire does not pass through the eye of the terminal (not shown).
- Wire overlaps itself (not shown).

Defect – Class 1,2,3

- Wire end violates minimum electrical clearance to noncommon conductor (not shown).

4.8.4.2 Terminals – Pierced/Perforated/Punched – Solder

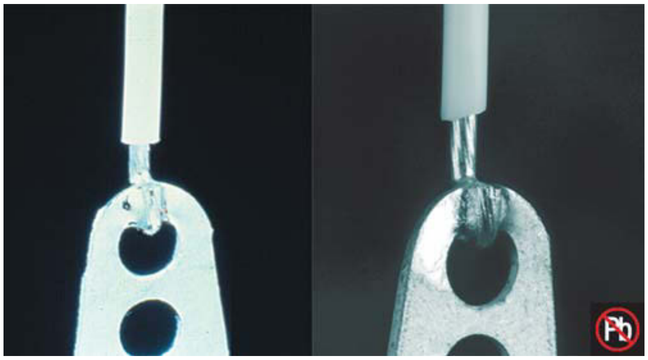

Figure 4-50

Acceptable – Class 1,2,3

- Solder fillet joins the wire to the terminal for at least 75% of the wire and terminal interface for wraps of 180° or more.
- Solder fillet joins the wire to the terminal for 100% of the wire and terminal interface for wraps less than 180°.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire/lead not discernible in solder connection.

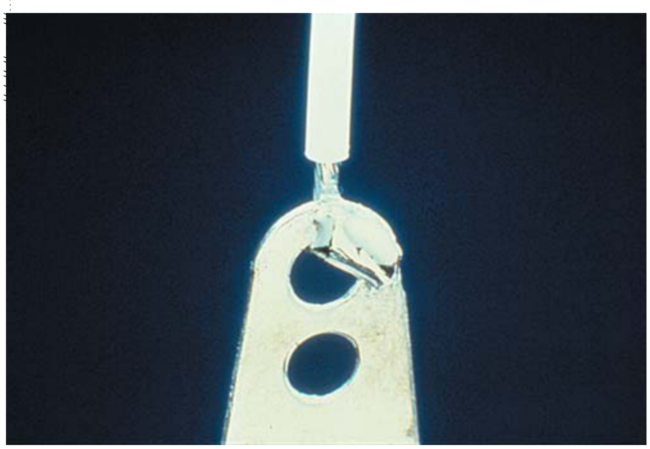

Figure 4-51

Defect – Class 1,2

- Depression of solder between the terminal and the wrap of the wire is deeper than 50% of wire radius.

Defect – Class 1,2,3

- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.
- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more.

Defect – Class 3

- Depression of solder between the terminal and the wrap of the wire is deeper than 25% of wire radius.

4.8.5 Terminals – Hook

4.8.5.1 Terminals – Hook – Lead/Wire Placement

Table 4-8 is applicable to leads and wires attached to hook terminals.

Table 4-8 Hook Terminal Lead/Wire Placement

<table>
<tr><th>Criteria</th><th>Class 1</th><th>Class 2</th><th>Class 3</th></tr>
<tr><td><90° contact between the lead/wire and terminal post.</td><td colspan="3">Defect</td></tr>
<tr><td>90° to <180° contact between the lead/wire and terminal post.</td><td>Acceptable</td><td>Process Indicator</td><td>Defect</td></tr>
<tr><td>≥180° contact between the lead/wire and terminal post.</td><td colspan="3">Acceptable</td></tr>
<tr><td>Wire overlaps itself.</td><td>Acceptable</td><td colspan="2">Defect</td></tr>
<tr><td>Distance less than one wire diameter from end of hook to closest wire.</td><td>Acceptable</td><td>Process Indicator</td><td>Defect</td></tr>
<tr><td>Wire attached outside the arc of the hook and less than two lead diameters or 1 mm [0.039 in], whichever is greater, from the terminal base.</td><td>Acceptable</td><td>Process Indicator</td><td>Defect</td></tr>
</table>

4.8.5.1 Terminals – Hook – Lead/Wire Placement (cont.)

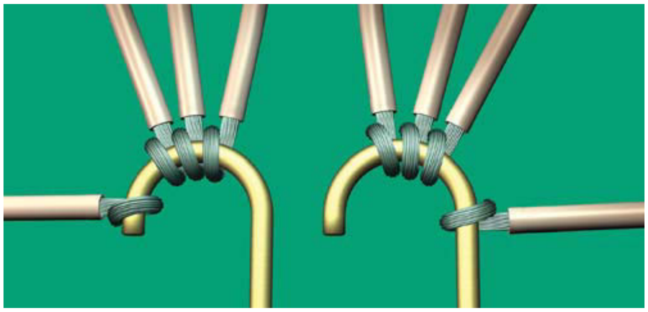

Figure 4-52

Acceptable – Class 1,2,3

- Wire contacts and wraps terminal at least 180°.
- Wires do not overlap.
- Minimum of one wire diameter space from end of hook to the closest wire.

Figure 4-53

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire is wrapped less than one wire diameter from end of hook.
- Wire wrap is less than 180°.
- Wire is attached outside the arc of the hook and is less than two lead diameters or 1.0 mm [0.039 in], whichever is greater, from the base of the terminal.

Acceptable – Class 1
Defect – Class 2,3

- Wire overlaps itself.

Defect – Class 1,2

- Wire wrap is less than 90°.

Defect – Class 1,2,3

- Wire end violates minimum electrical clearance to noncommon conductor.

4.8.5.2 Terminals – Hook – Solder

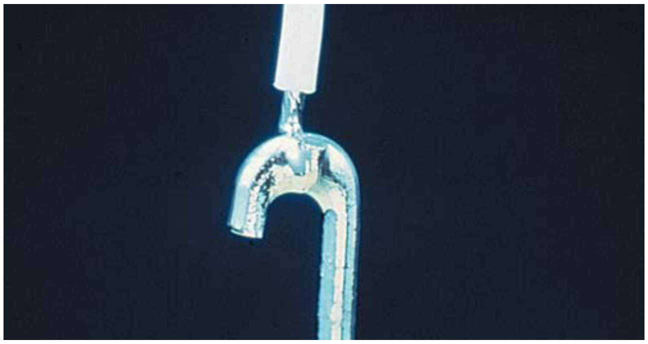

Figure 4-54

Figure 4-55

Acceptable – Class 1,2,3

- Solder is wetted to at least 75% of the contact area between the wire/lead and terminal interface for leads wrapped 180° or more.

Acceptable – Class 1,2

- Solder is wetted to 100% of the contact area between the wire/lead and terminal interface for leads wrapped less than 180°.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire/lead not discernible in solder connection.

Defect – Class 1,2

- Depression of solder between the post and the wrap of the wire is deeper than 50% of wire radius.
- Less than 100% fillet of the lead to terminal contact when the wrap is less than 180°.

Defect – Class 3

- Depression of solder between the post and the wrap of the wire is deeper than 25% of wire radius.

Defect – Class 1,2,3

- Less than 75% fillet of the lead to terminal contact when the wrap is 180° or more.

4.8.6 Terminals – Cup

4.8.6.1 Terminals – Cup – Lead/Wire Placement

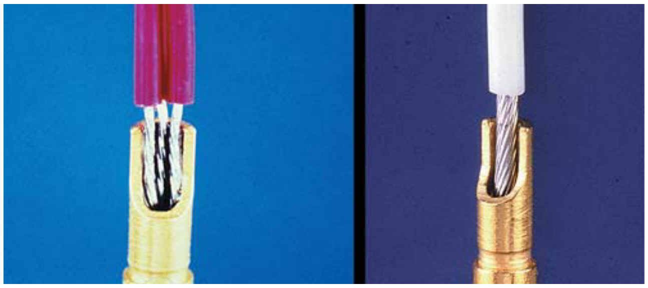
Figure 4-56

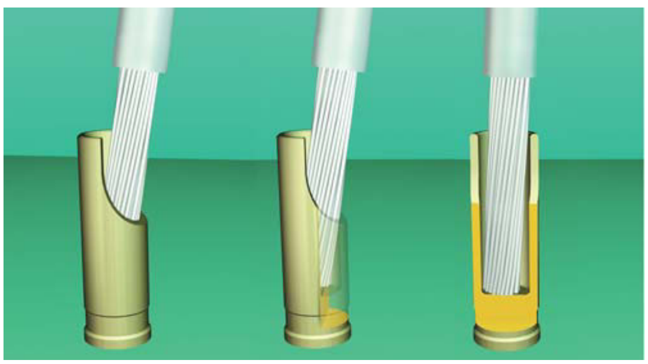
Figure 4-57

Acceptable – Class 1,2,3

- Wire(s) inserted for full depth of cup.
- Wire in contact with back wall.
- Wire does not interfere with subsequent assembly operations.
- Multiple conductors are not twisted together.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire does not contact the back wall or other wires.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wire(s) not inserted to the full depth of the cup. (Not visually inspectable; determined through process control.)

Defect – Class 1,2,3

- Wire strands outside of the cup.
- Wire placement interferes with subsequent assembly operations.
- Multiple conductors are twisted together.

4.8.6.2 Terminals – Cup – Solder

These criteria are applicable to either solid or stranded wire, single or multiple wires.

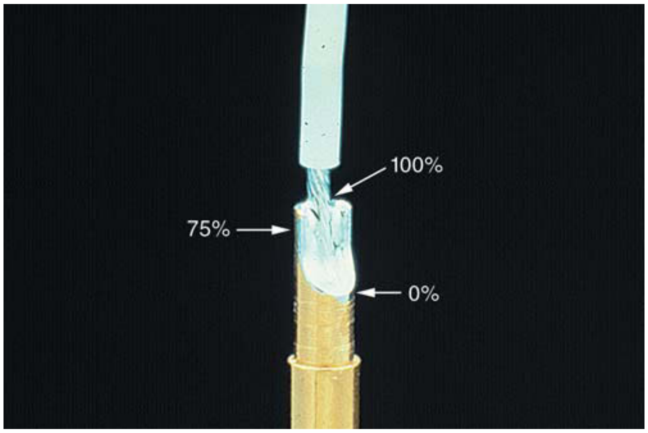

Figure 4-58

Acceptable – Class 1,2,3

- Thin film of solder on the outside of the cup.
- Solder fill of 75% or more.
- Solder buildup on the outside of the cup that does not affect form, fit, function or reliability.
- Solder visible in or slightly protrudes from the inspection hole (if one is provided) (see Figure 4-61).

Figure 4-59

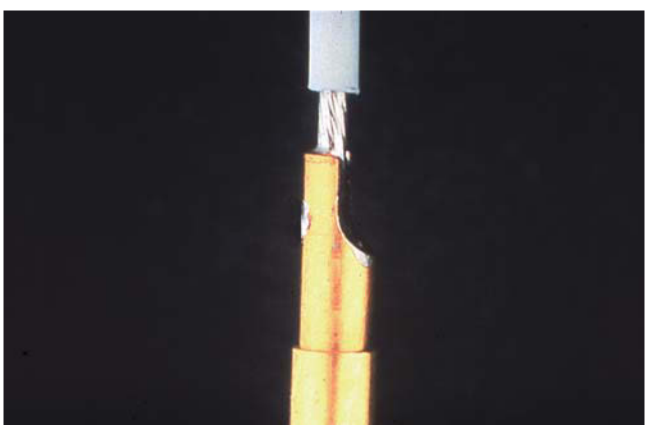

Figure 4-60

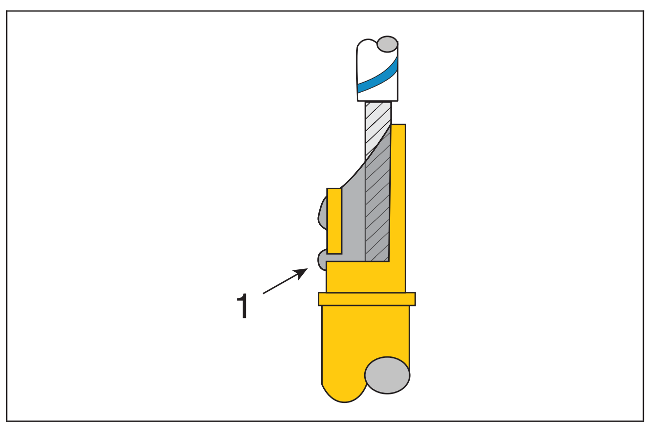

Figure 4-61
1. Inspection hole

4.8.6.2 Terminals – Cup – Solder (cont.)

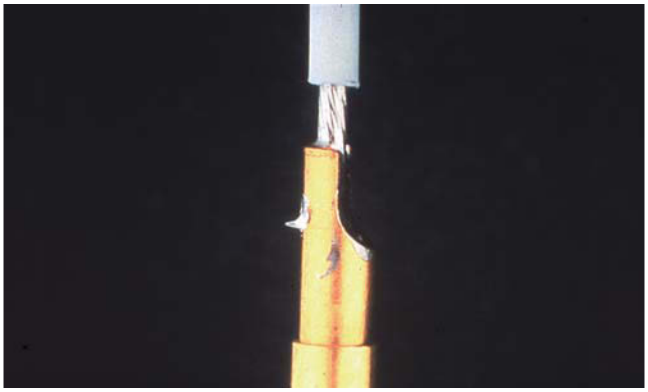

Figure 4-62

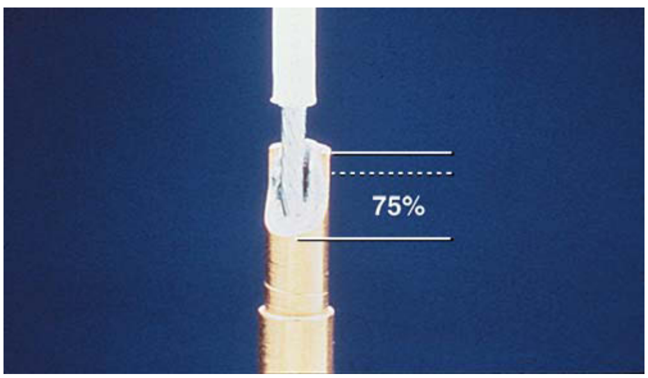

Figure 4-63

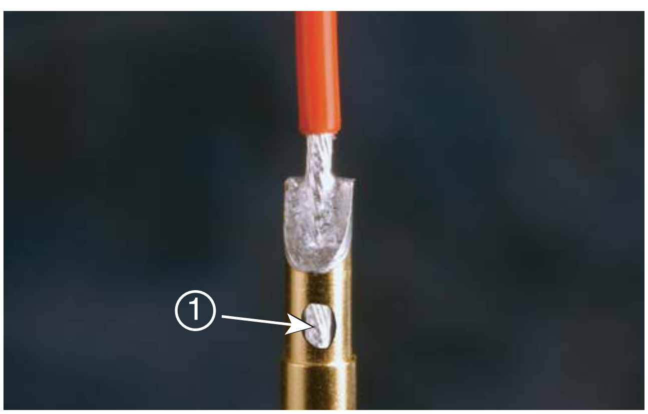

Figure 4-64
1. Solder not visible in the inspection hole.

Defect – Class 1,2,3

- Solder vertical fill less than 75% (see Figure 4-63).
- Solder buildup on outside of the cup negatively affects form, fit or function.
- Solder not visible in the inspection hole (if one is provided) (see Figure 4-64-1).

Defect – Class 1,2

- Depression of solder between the cup and the wire is deeper than 50% of wire radius.

Defect – Class 3

- Depression of solder between the cup and the wire is deeper than 25% of wire radius.

4.8.7 Terminals – Series Connected

These criteria apply when three or more terminals are connected by a common bus wire. Solder criteria are based on the individual terminal attachment.

Figure 4-65

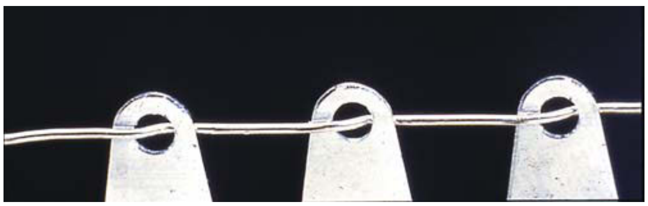

Figure 4-76

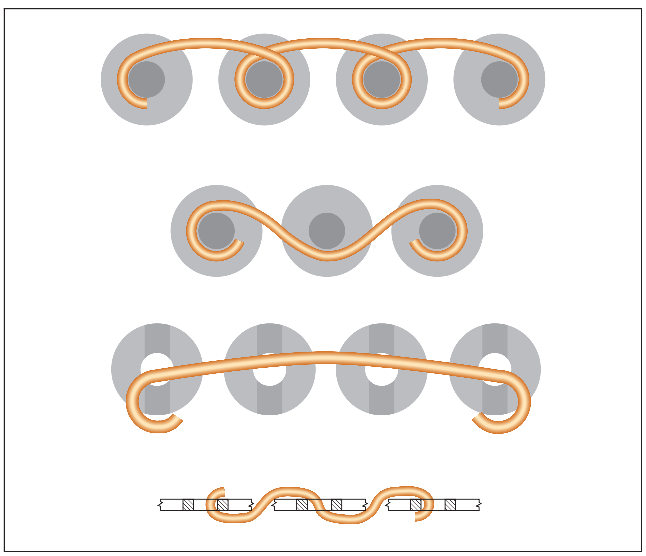

Figure 4-67

Acceptable – Class 1,2,3

- The connection to the first and last terminals meets the required wrap for individual terminals.
- *Turrets* – Wire contacts base of terminal or a previously installed wire, and wraps around or interweaves each terminal.
- *Hooks* – Wire wraps 360° around each intermediate terminal.
- *Bifurcated* – Wire passes between posts or wraps around posts and contacts base of terminal or previously installed wire.
- *Pierced/Perforated* – Wire contacts two nonadjacent sides of each terminal.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- *Turret Terminals* – Wire does not wrap 360° around each intermediate terminal or is not interwoven between terminals.
- *Hook Terminals* – Wire wraps less than 360° around intermediate terminal.
- *Bifurcated* – Wire does not pass between the posts or is not in contact with the terminal base or a previously installed wire.
- *Pierced/Perforated* – Wire does not contact two nonadjacent sides of each intermediate terminal.

Defect – Class 1,2,3

- The connection to the first and last terminals does not meet the required wrap for individual terminals.

4.8.8 Connection Requirements – Lead/Wire Placement – AWG 30 and Smaller Diameter Wires

Table 4-9 is applicable to AWG 30 and smaller diameter wires.

Table 4-9 AWG 30 and Smaller Wire Wrap Requirements

Criteria	Class 1	Class 2	Class 3
<90°	Defect		
90° to <180°	Acceptable	Defect	
180° to <360°	Acceptable	Process Indicator	Defect
≥360°	Acceptable		

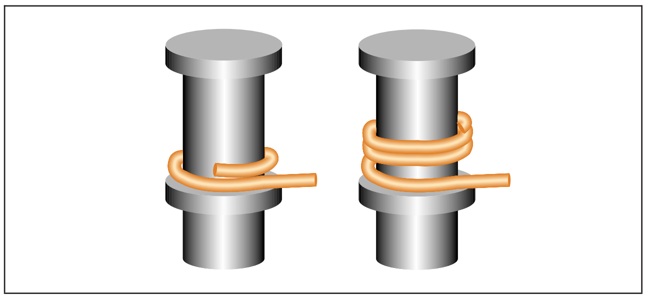

Figure 4-68

Acceptable – Class 1,2,3

- Wire has more than one wrap (360°).

Acceptable – Class 1
Defect – Class 2,3

- Wire has equal to or more than 90° wrap but less than 180° wrap.

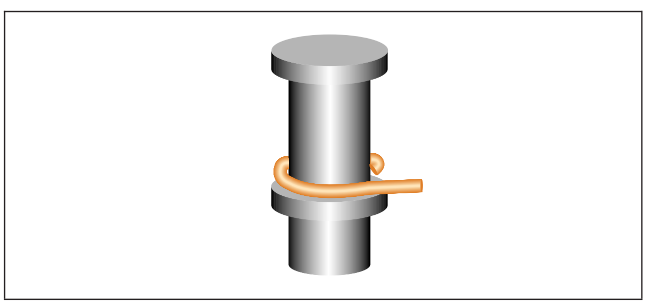

Figure 4-69

Acceptable – Class 1
Defect – Class 2

- Wire has less than 180° wrap.

Process Indicator – Class 2
Defect – Class 3

- Wire has less than one wrap (360°) around terminal.

Defect – Class 1,2,3

- Wire has less than 90° wrap.

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5 Crimp Terminations (Contacts and Lugs)

For the purposes of this section, the term ''terminal'' includes both lugs and contacts.

A critical element of any wire termination is the connection between the wire and the terminal. Crimping of terminals is one method of achieving this connection.

The importance of a good termination ensures mechanical integrity and meets electrical requirements for the application.

In addition to the basic requirements outlined in this section, there should also be no damage to plating or finish, no contact deformation that would cause friction or increase force to insert or load the contact into the connector body, and no contact deformation that does not allow all contact locking tabs or wings to fully engage and lock into the connector body. Contact deformation **shall not [D1D2D3]** interfere with form, fit or function of the connector.

Conductor strands **shall not [N1D2D3]** be cut or modified in any manner to reduce circular mil area (CMA) to fit a termination. Contacts **shall not [N1D2D3]** be altered to accept oversized wire or an excessive number of conductors. Conductors **shall not [D1D2D3]** be tinned prior to termination, unless otherwise specified. Solid wire **shall not [D1D2D3]** be crimped except as allowed in 13.2.1.

Terminals, electrical terminations or contacts **shall not [D1D2D3]** be re-crimped or double-crimped (see Appendix A), unless required as part of a documented process for the specific terminal.

Shrinkable sleeving **shall not [N1D2D3]** be applied as insulation diameter buildup unless required by the engineering drawing.

CMA build up is required when the wire gauge CMA is outside the CMA range of the contact. The CMA build up **shall [N1D2D3]** be determined by design engineering and documented in the engineering documentation or by manufacturing engineering and documented in the process. Any material used for CMA buildup **shall [N1D2D3]** be specified on the engineering drawing.

When attaching multiple wires to a single terminal, each wire **shall [D1D2D3]** meet the same acceptability criteria as a single wire termination. When attaching single or multiple wires to a terminal the combined CMA of the wires **shall [D1D2D3]** comply with the CMA range for the terminal. Conductors **shall not [D1D2D3]** be twisted together before insertion into the terminal.

All crimping needs to comply with the terminal manufacturer's published requirements, e.g., crimp height, pull test, etc., without regard to the specific tooling used. For a complete understanding, refer to applicable connector or terminal manufacturer's requirements and instructions. The quality requirements of the manufacturer of the terminals supersede this document. All crimped terminations need to meet applicable industry requirements, such as EIA, IEC, NEMA, UL or other as designated.

The tooling identified on a terminal manufacturer's documentation **shall [D1D2D3]** be used.

If alternate tooling is used, there **shall [D1D2D3]** be objective evidence available to show validity of the alternate process.

As an exception, if a terminal is manufactured in accordance with an industry specification, e.g., military, medical, automotive, the tool called out in that specification **shall [N1N2D3]** be used to crimp the terminal.

Crimp tools may be either manually (hand) or automatically operated. All hand tools should employ some form of an integral mechanism to control the crimping operation to the extent that, once the crimping operation has been started, the crimp tool cannot be opened until the crimping cycle has been completed (full-cycle/ratcheting tools). Full-cycle tools **shall [N1N2D3]** be used for Class 3 crimping.

This standard has not established criteria for crimping to wire braid. Crimping to wire braid **shall [D1D2D3]** be as agreed between User and Manufacturer.

5 Crimp Terminations (Contacts and Lugs) (cont.)

The following topics are addressed in this section.

5.1 Stamped and Formed – Open Barrel

Circular mil area (CMA) **shall not [D1D2D3]** be built up unless specified on design engineering documentation.

There are different configurations for insulation support and conductor crimps. When designed for a specific terminal configuration, insulation support tabs may overlap or bypass.

Figure 5-1 identifies the component parts of a typical stamped and formed open barrel terminal.

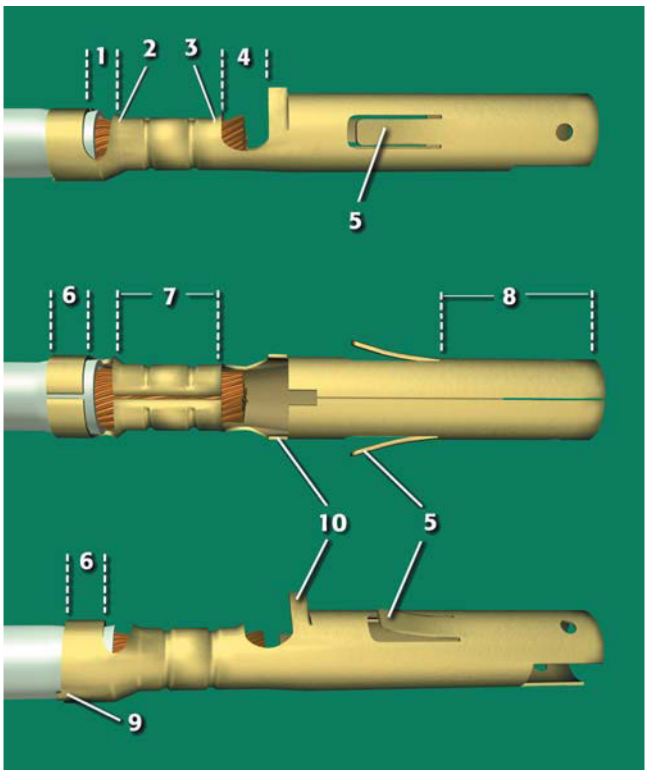

Figure 5-1

1. **Insulation inspection window**
2. **Entry bellmouth**
3. **Brush end bellmouth**
4. **Brush inspection window**
5. **Locking tab/tang**
6. **Insulation crimp area**
7. **Conductor crimp area**
8. **Terminal mating area**
9. **Cut off tab (may be at either end of terminal)**
10. **Terminal stop ear**

5.1.1 Stamped and Formed – Open Barrel – Insulation Support

5.1.1.1 Stamped and Formed – Open Barrel – Insulation Support – Inspection Window

Figure 5-2 identifies the insulation inspection window.

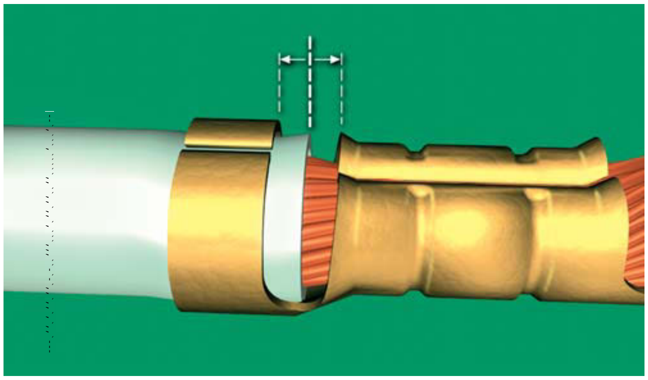

Figure 5-2

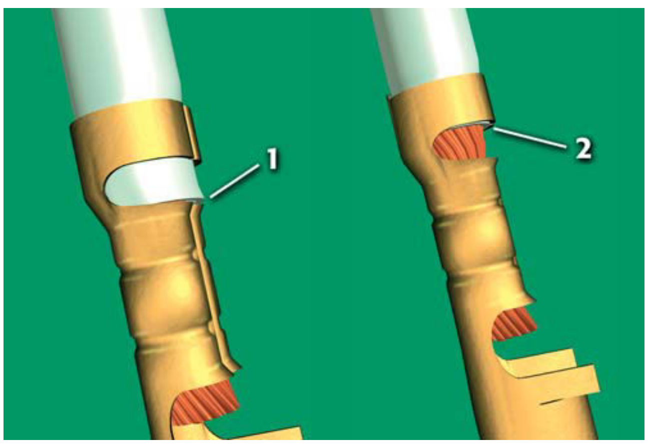

Figure 5-3

Acceptable – Class 1,2,3

- Insulation is flush with but does not extend into the conductor crimp area (see Figure 5-3-1).
- Insulation is flush with the end of the insulation crimp tabs and does not enter the inspection window area (see Figure 5-3-2).
- Both insulation and conductor are visible within the inspection window (see Figure 5-4).

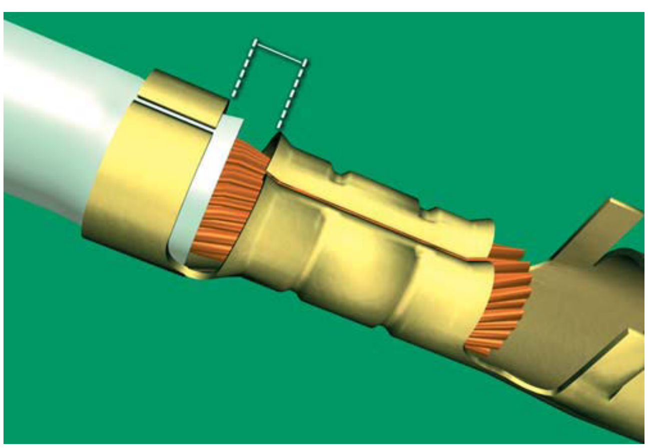

Figure 5-4

5.1.1.1 Stamped and Formed – Open Barrel – Insulation Support – Inspection Window (cont.)

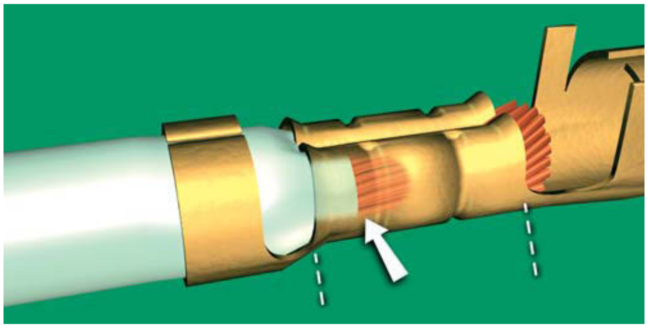

Figure 5-5

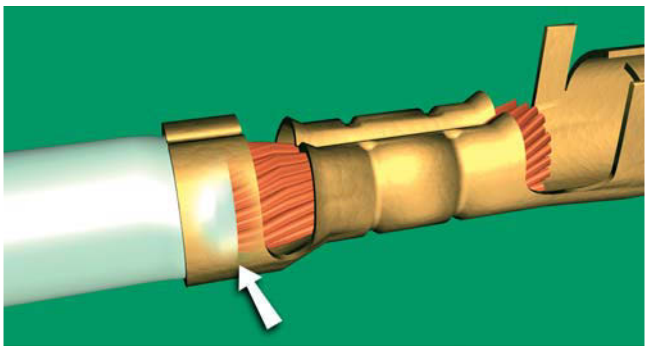

Figure 5-6

Defect – Class 1,2,3

- Insulation extends into conductor crimp area (see Figure 5-5, arrow points to end of insulation within the crimp area).
- Insulation and conductor transition line is not visible within insulation inspection window (see Figure 5-6, arrow points to end of insulation within the crimp area).

5.1.1.2 Stamped and Formed – Open Barrel – Insulation Support – Crimp

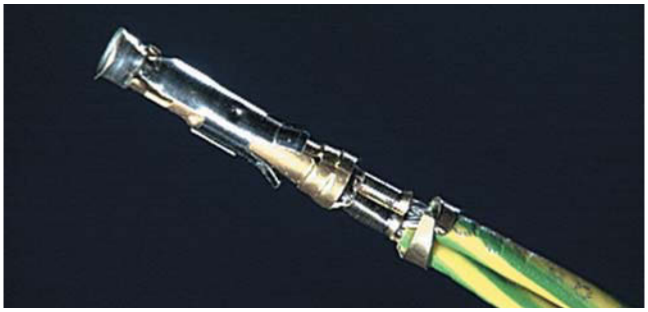

Figure 5-7

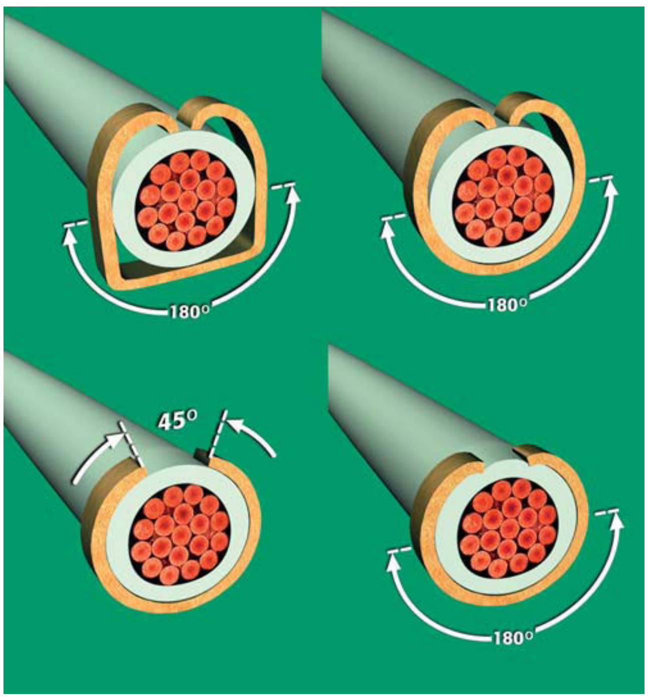

Figure 5-8

Acceptable – Class 1,2,3

- Minor deformation of the insulation surface as long as the insulation crimp tabs do not cut, break, penetrate or puncture the surface of the wire insulation.
- Insulation crimp tabs provide a minimum side support of 180° to the wire insulation and at least one tab contacts the top of the wire insulation. The second tab either contacts the top of the wire insulation or is within one material thickness of contacting the top of the wire insulation.
- Insulation crimp tabs do not meet at the top, but encircle the wire leaving an opening of 45° or less at the top.

5.1.1.2 Stamped and Formed – Open Barrel – Insulation Support – Crimp (cont.)

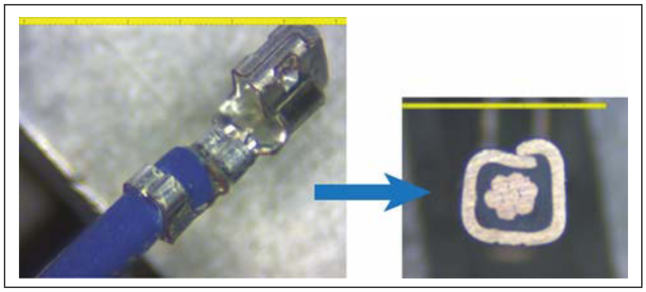

Figure 5-9

Figure 5-10

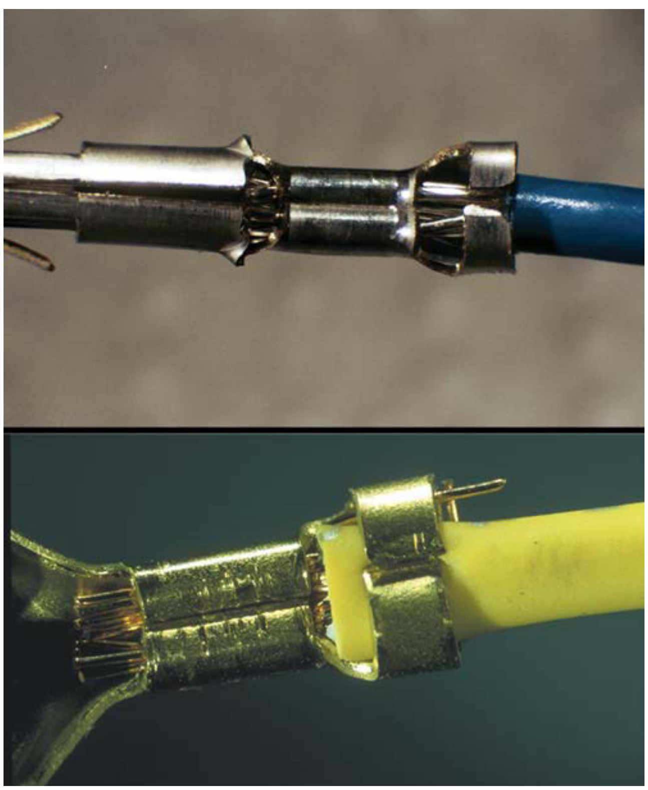

Figure 5-12

Defect – Class 1,2,3

- The insulation crimp tabs pierce the insulation (see Figures 5-9, 10).
- The insulation crimp tabs do not provide support at least 180° around the insulation (see Figure 5-11).
- At least one tab does not contact the top of the wire insulation. The second tab does not contact the top of the wire insulation or is greater than one material thickness of contacting the top of the wire insulation.
- Conductors are in insulation crimp area of the contact (see Figure 5-12).
- Insulation crimp tabs encircle the wire, but leave an opening of more than 45° at the top (see Figure 5-13).

Figure 5-11

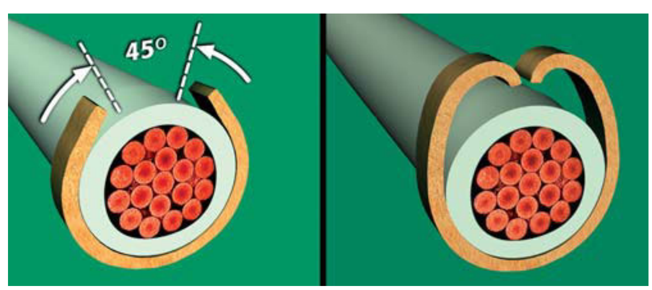

Figure 5-13

5.1.2 Stamped and Formed – Open Barrel – Insulation Clearance if No Support Crimp

Figure 5-14

Acceptable – Class 1,2,3

- Insulation is flush with but does not extend into the conductor crimp area.
- Conductor is visible between the insulation and contact barrel but not greater than one wire diameter.

Acceptable – Class 1
Process Indicator – Class 2,3

- Insulation is greater than one but less than two wire diameters from the end of the contact barrel.

Defect – Class 1,2,3

- Insulation is greater than two wire diameters from the end of the contact barrel.
- Insulation extends into the conductor crimp area.

5.1.3 Stamped and Formed – Open Barrel – Conductor Crimp

These criteria apply to stamped and formed contacts with insulation support (see Figure 5-15) or without (see Figure 5-16).

Figure 5-15 identifies the conductor crimp area.

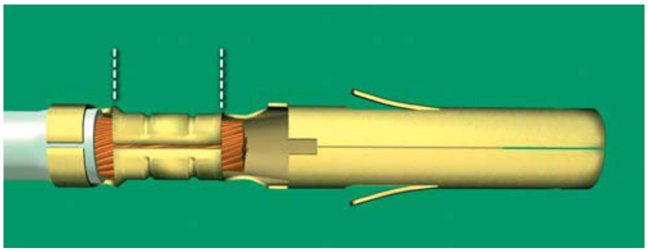

Figure 5-15

Acceptable – Class 1,2,3

- No insulation extends into the conductor crimp area.

Acceptable – Class 1,2
Process Indicator – Class 3

- Minor deforming of the contact does not alter its form, fit, function or reliability.

Note: A trial mating may be required for final acceptance.

Figure 5-16

Acceptable – Class 1
Process Indicator – Class 2,3

- Crimp indentations not uniform but do not affect form, fit, function or reliability.

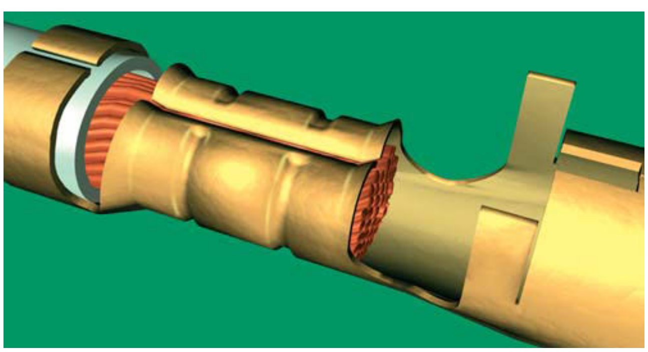

Figure 5-17

5.1.3 Stamped and Formed – Open Barrel – Conductor Crimp (cont.)

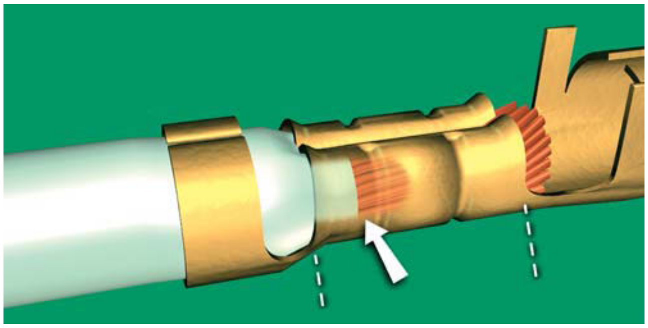

Figure 5-18

Figure 5-19

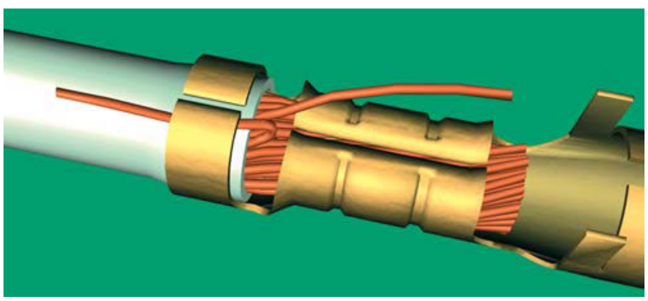

Figure 5-20

Defect – Class 1,2,3

- Insulation extends into conductor crimp area (see Figure 5-18, arrow points to end of insulation within the crimp area).
- Deformation (banana) of the contact/terminal that affects form, fit, function or reliability (see Figure 5-19).
- Any loose conductor strands that are outside the crimp area, trapped strands, folded back strands (see Figure 5-20).

5.1.4 Stamped and Formed – Open Barrel – Crimp Bellmouth

The bellmouth areas identified in Figure 5-21 are considered to be part of the conductor crimp area.

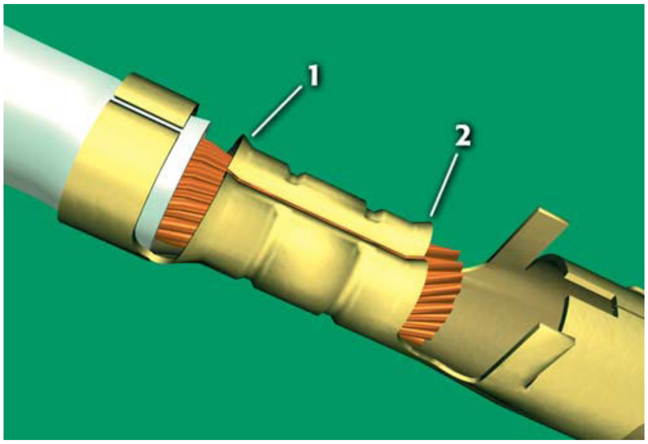

Figure 5-21
1. Entry bellmouth
2. Brush-end bellmouth

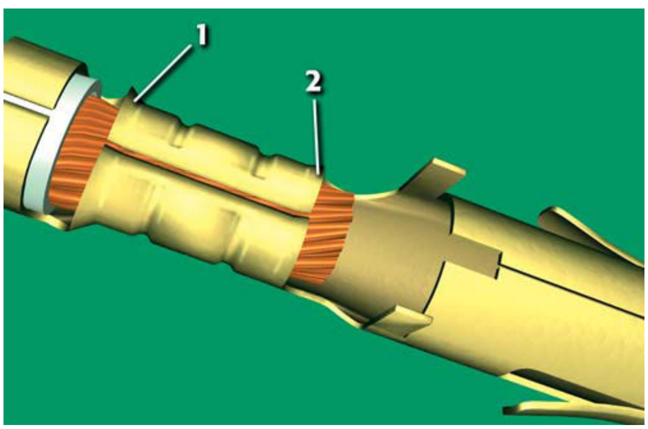

Figure 5-22

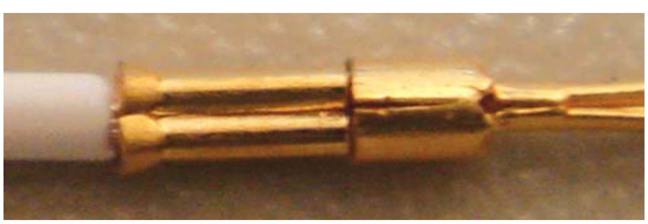

Figure 5-23

Acceptable – Class 1,2,3

- Bellmouth only at the conductor entry end (see Figure 5-22-1) and not at the conductor brush end of the crimp (see Figure 5-22-2).
- Bellmouth at conductor entry is visible but less than 2X the thickness of the contact/terminal metal.

5.1.4 Stamped and Formed – Open Barrel – Crimp Bellmouth (cont.)

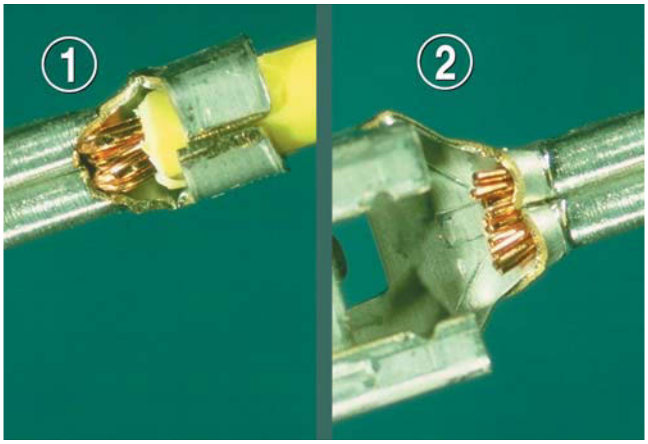

Figure 5-24

Defect – Class 1,2,3

- No visible bellmouth at the conductor entry end of the crimp (see Figure 5-24-1).

5.1.5 Stamped and Formed – Open Barrel – Conductor Brush

Figure 5-25 identifies the conductor brush area.

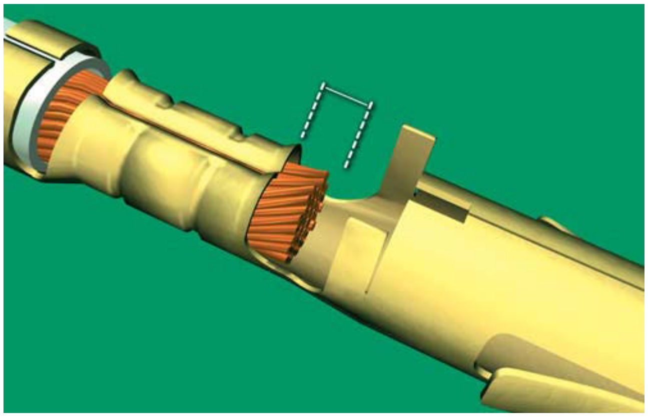

Figure 5-25

Acceptable – Class 1,2,3

- The conductor end is flush to the end of the conductor crimp area (see Figure 5-26-1).
- Conductor strands do not extend into the mating area of the terminal.
- Conductor strands are flared but do not extend beyond the outer perimeter of the crimp barrel (see Figure 5-26-2).

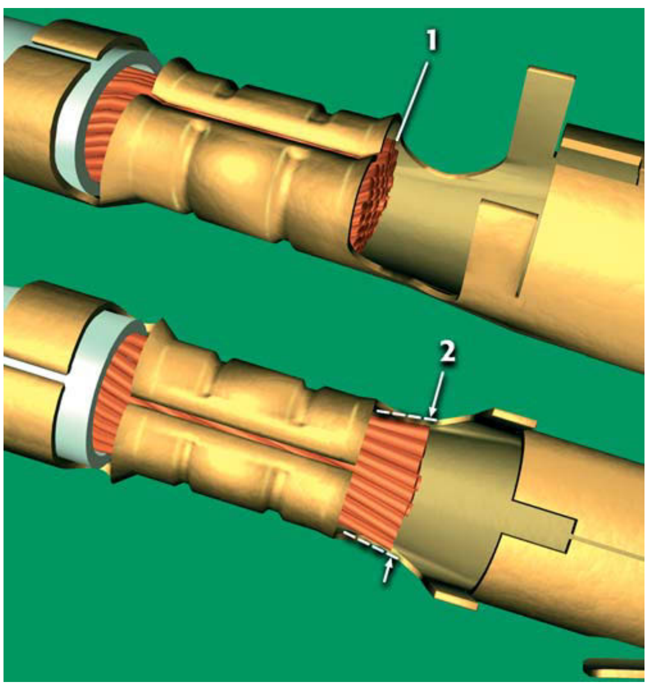

Figure 5-26

5.1.5 Stamped and Formed – Open Barrel – Conductor Brush (cont.)

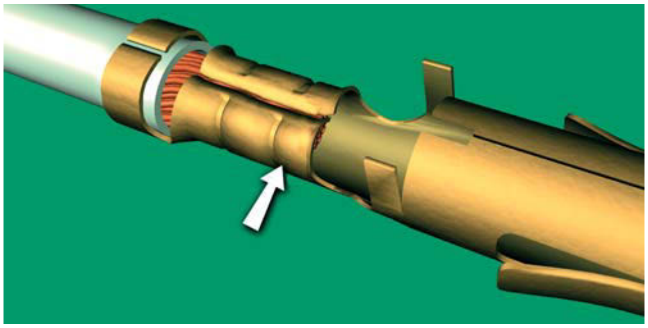

Figure 5-27

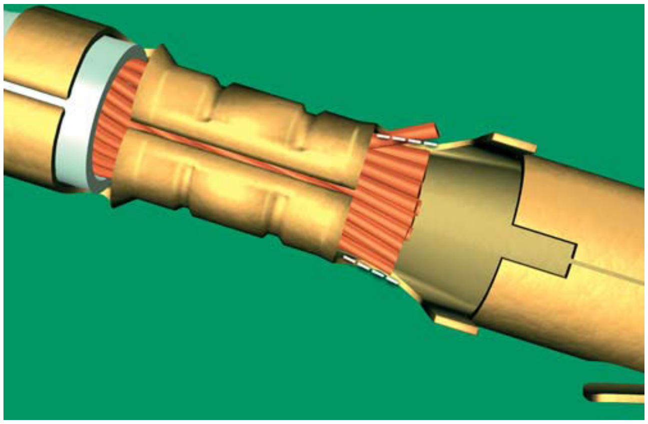

Figure 5-28

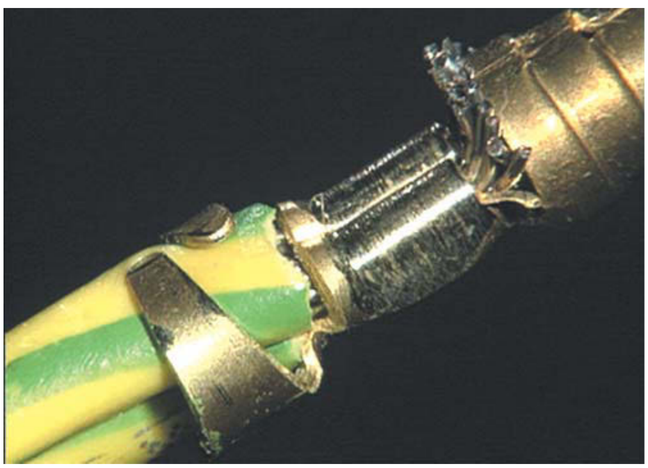

Figure 5-29

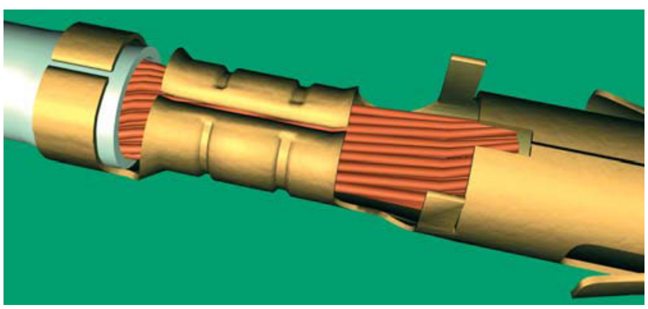

Figure 5-30

Defect – Class 1,2,3

- Wire end is less than flush to the end of the conductor crimp area (see Figure 5-27).
- Any conductor strands extending beyond the outer perimeter of the crimp barrel (see Figures 5-28, 29).
- The conductor strands extend into the mating area of the contact (see Figure 5-30).

5.1.6 Stamped and Formed – Open Barrel – Carrier Cutoff Tab

Figure 5-31 identifies a carrier cutoff tab (1) at the wire entry end. It is located at the mating end of some terminal types.

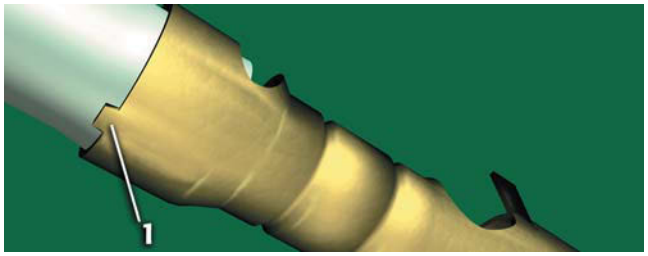

Figure 5-31

Acceptable – Class 1,2,3

- No damage to contact or terminal.
- Cutoff does not prevent complete mating of the contact/terminal.

Process Indicator – Class 2,3

- Cutoff tab length at mating end is greater than 2X its thickness but does not impede mating.
- Cutoff tab length at wire entry end is greater than 2X its thickness but does not protrude when inserted into connector body.

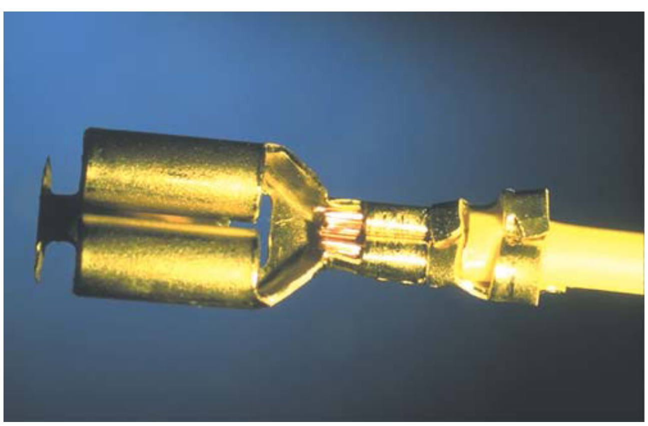

Figure 5-32

Defect – Class 1,2,3

- Removal of cutoff tab has damaged contact or terminal.
- Cutoff tab protrudes from connector body when contact has been inserted.
- Mating end cutoff tab interferes with complete mating.

Note: Contact/terminal needs to meet form, fit, function and reliability requirements. A trial mating may be required for final acceptance.

5.1.7 Stamped and Formed – Open Barrel – Individual Wire Seal

The seal **shall [D1D2D3]** remain in the correct position when the crimped contact is inserted into the required connector housing cavity.

The correct combination of seal, wire, and terminal is important to ensure the criteria in this section can be met.

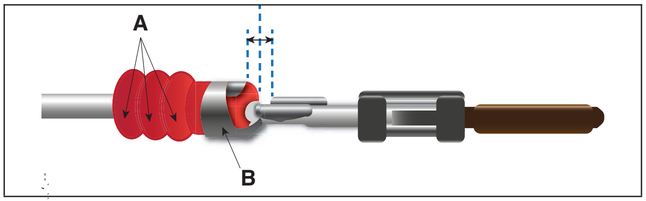

Figure 5-33
A. Sealing Ribs B. Seal Retention Crimp

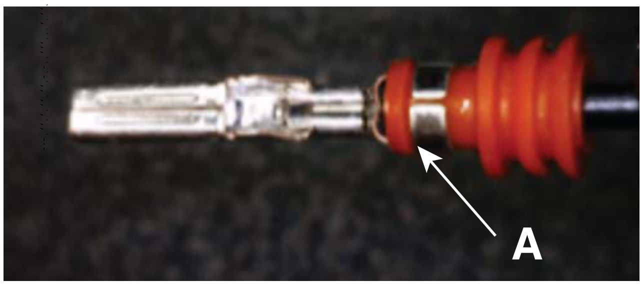

Figure 5-34
A. Sealing retention ring (optional)

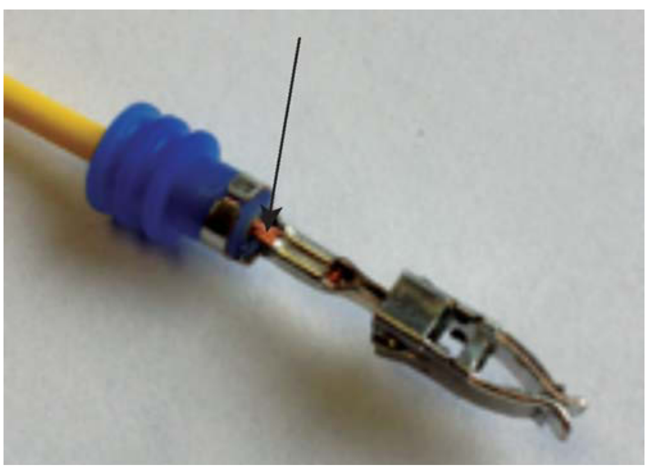

Figure 5-35

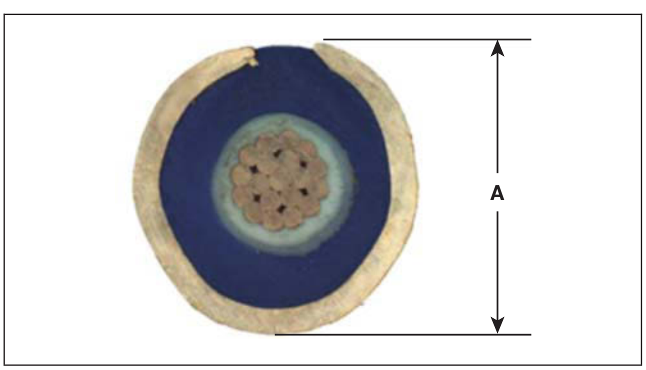

Figure 5-36

Acceptable – Class 1, 2, 3

- The seal is firmly secured by the insulation support crimp.
- The end of the seal is visible in the insulation inspection window.
- The wire insulation does not protrude from under the seal, but is visible under the seal (see Figure 5-35).
- Insulation crimp height is within the manufacturer's specified tolerances (see Figure 5-36).
- For seals that include a retention ring, the retention ring is not crimped and extends fully into the insulation inspection window (see Figure 5-34).

5.1.7 Stamped and Formed – Open Barrel – Individual Wire Seal (cont.)

Acceptable – Class 1
Process Indicator – Class 2, 3

- Wire insulation is flush with, but does not extend into the conductor crimp area.
- Wire insulation is flush with the end of the wire seal and insulation support crimp tabs, and does not enter into the insulation inspection window.

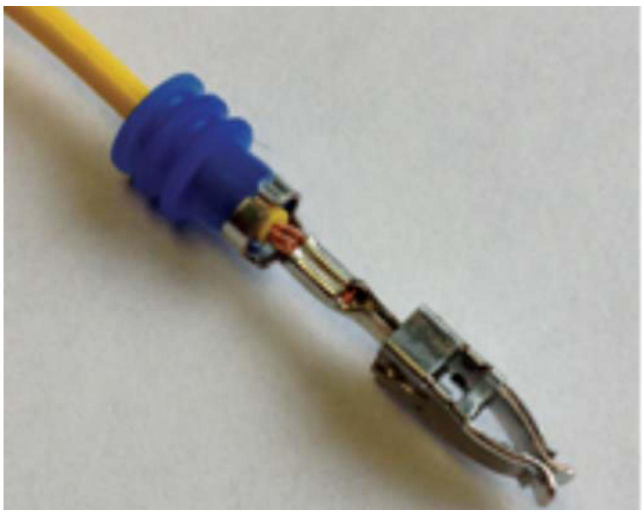

Figure 5-37

Figure 5-38

Figure 5-39

Defect – Class 1, 2, 3

- The seal is not firmly secured by the insulation crimp (see Figure 5-37).
- The end of the seal is not visible in the insulation inspection window (see Figure 5-37).
- Wire insulation is not visible under the seal.
- Seal retention ring (when present) does not extend fully into the insulation inspection window.
- Seal or wire insulation extends into the conductor crimp area (see Figure 5-38).
- The seal or sealing ribs show signs of damage (see Figures 5-38, 39).
- Insulation crimp tabs penetrate the seal (see Figure 5-39).
- Insulation crimp height does not meet the manufacturer's specified tolerances.

5.2 Stamped and Formed – Closed Barrel

These criteria are applicable to insulated and uninsulated closed barrel stamped terminals.

There are different configurations for insulation support and crimp areas and for the conductor crimp.

Figure 5-40 identifies the component parts of a typical insulated terminal.

Soldering crimp connections is normally not an approved method. However, soldering may be required when a lower resistance connection needs to be made to assure proper operation of electrical circuitry. Soldering a crimp connection **shall [D1D2D3]** be done only when specified by engineering documentation. When the crimped connection is required to be soldered, the stranded wire **shall not [D1D2D3]** be tinned prior to the crimping process.

When CMA buildup is required, the conductor foldback or filler **shall [D1D2D3]** be visible in the brush inspection area and the cut end **shall [D1D2D3]** be visible in the entry bellmouth.

Terminals **shall not [N1D2D3]** have visible fractures or cracks.

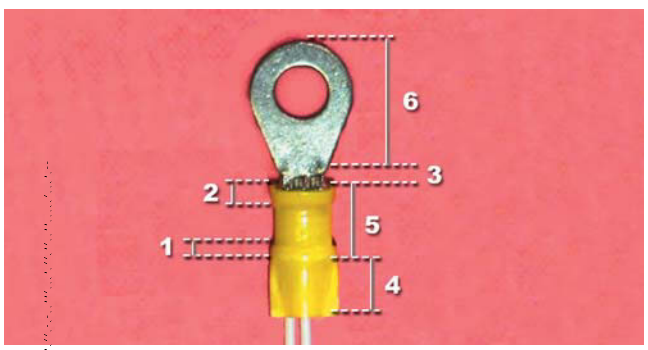

Figure 5-40
1. **Entry bellmouth (not visible)**
2. **Brush end bellmouth**
3. **Brush inspection window**
4. **Insulation crimp area**
5. **Conductor crimp area**
6. **Terminal mating area**

5.2.1 Stamped and Formed – Closed Barrel – Insulation Clearance

The following criteria are applicable to uninsulated closed barrel contacts.

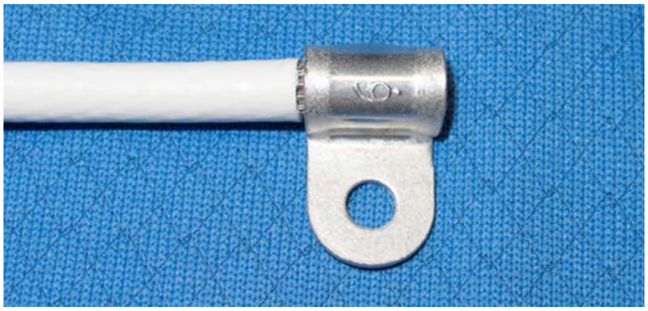

Figure 5-41

Acceptable – Class 1,2,3

- Insulation is flush to less than one wire diameter from the entry bellmouth.

Process Indicator – Class 2,3

- Insulation is greater than one but less than two wire diameters from the entry bellmouth.

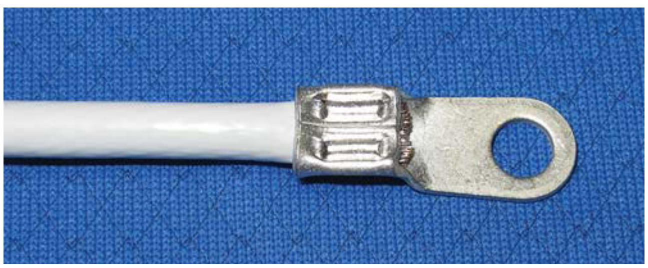

Figure 5-42

Defect – Class 1,2,3

- Insulation is greater than two wire diameters from the entry bellmouth.
- Insulation extends into the barrel of terminal.

5.2.2 Stamped and Formed – Closed Barrel – Insulation Support Crimp

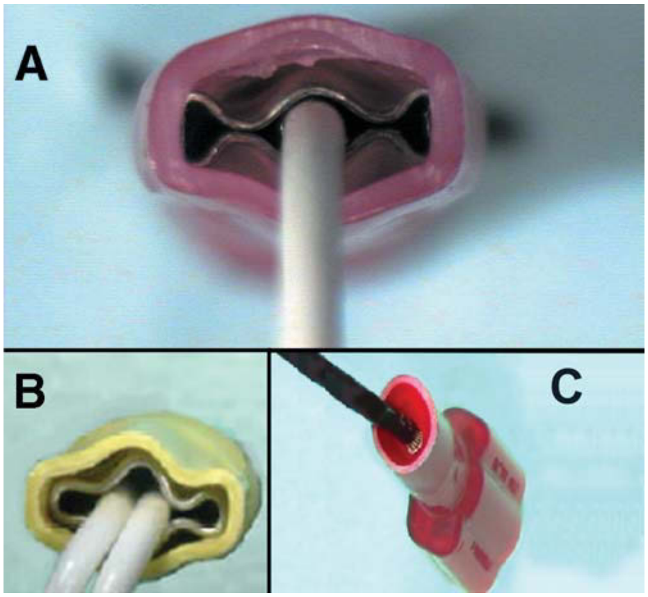

Figure 5-43

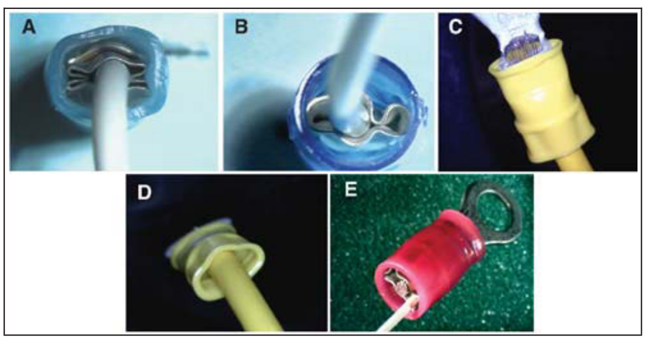

Figure 5-44

Acceptable – Class 1,2,3

- Irregular shaped insulation crimp contacts the wire insulation providing support (see Figure 5-44-A, B, C, D).
- Wire insulation crimp (see Figure 5-44-D) has been deformed by the crimping tool (and may not contact/grip the wire insulation).
- No damage to wire insulation.
- No damage to terminal insulation.
- Terminal insulation is secure to the terminal.
- Filler wire (see Figure 5-44-E) is within the insulation crimp and does not extend beyond the outer lug insulation.

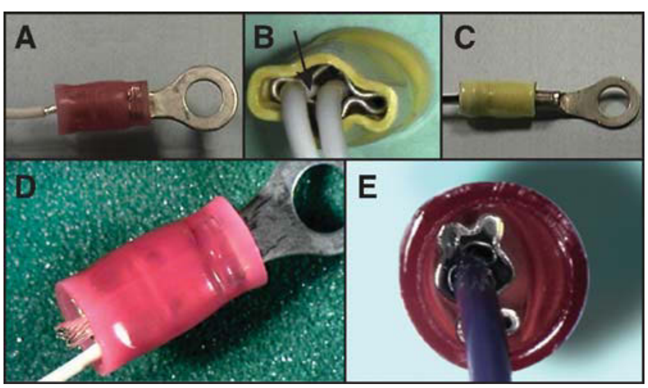

Figure 5-45

Defect – Class 1,2,3

- The wire insulation is not within the insulation crimp area (see Figure 5-45-A).
- Wire insulation damage exceeds the criteria of 3.5 (see Figure 5-45-B).
- Outer insulation of terminal is not secure on the terminal (see Figure 5-45-C).
- Filler wire extends beyond the terminal insulation (see Figure 5-45-D).
- No evidence of deformation of the insulation support crimp.
- Wire strands folded back or visible in the insulation crimp (see Figure 5-45-E).

5.2.3 Stamped and Formed – Closed Barrel – Conductor Crimp and Bellmouth

The bellmouth area identified in Figure 5-40 is considered to be part of the conductor crimp barrel when tooling is intended to form a bellmouth.

Figure 5-46

Figure 5-47

Acceptable – Class 1,2,3

- The conductor (and filler if specified) is flush to the end of the bellmouth.
- Conductor strands do not extend into the mating area of the terminal.
- Bellmouth is evident at each end of the conductor crimp area.
- Multiple conductors extend past the bellmouth but may not be equal in length.

5.2.3 Stamped and Formed – Closed Barrel – Conductor Crimp and Bellmouth (cont.)

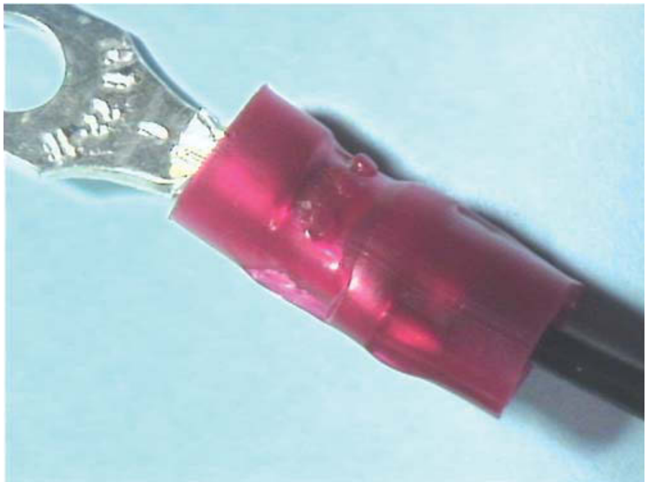

Figure 5-48

Acceptable – Class 1,2
Process Indicator – Class 3

- Terminal insulation damaged not exposing metal nor affecting its intended application.
- Minor deforming of the terminal does not alter its form, fit, function or reliability.
- Conductor crimp not centered but located on crimp barrel.
- Crimp indentations not uniform but do not affect form, fit, function or reliability.

Figure 5-49

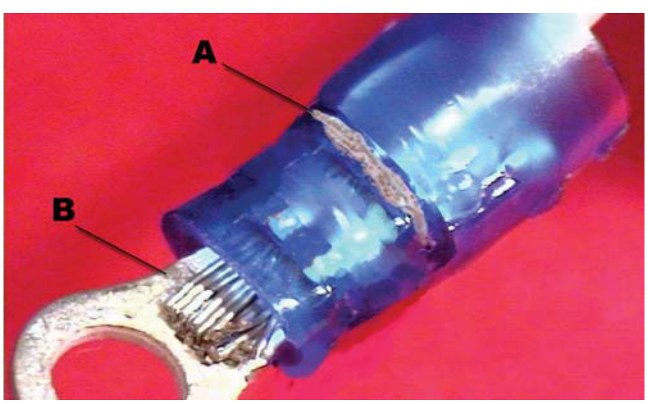

Figure 5-50

Defect – Class 1,2,3

- Wire end is less than flush to the end of the bellmouth (see Figure 5-49).
- Bellmouth not evident at each end of the conductor crimp area when tooling is intended to form a bellmouth (not shown).
- Terminal insulation damaged exposing metal (see Figure 5-50-A).
- Conductor extends into the mating area of the terminal (see Figure 5-50-B).

5.2.4 Stamped and Formed – Closed Barrel – Cutoff Tabs

Figure 5-51 identifies carrier cutoff tabs (arrows).

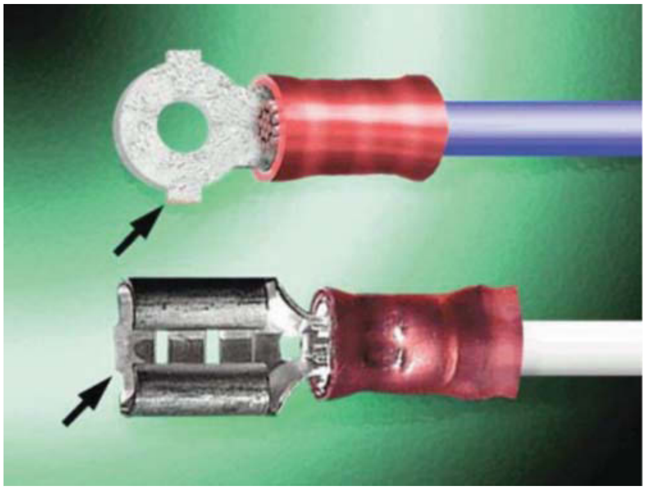
Figure 5-51

Acceptable – Class 1,2,3

- No damage to contact or terminal.
- Cutoff does not prevent complete mating of the contact/terminal.

Process Indicator – Class 2,3

- Cutoff tab length at mating end is greater than 2X its thickness but does not impede mating.
- Cutoff tab length at conductor entry end is greater than 2X its thickness but does not protrude when inserted into connector body.

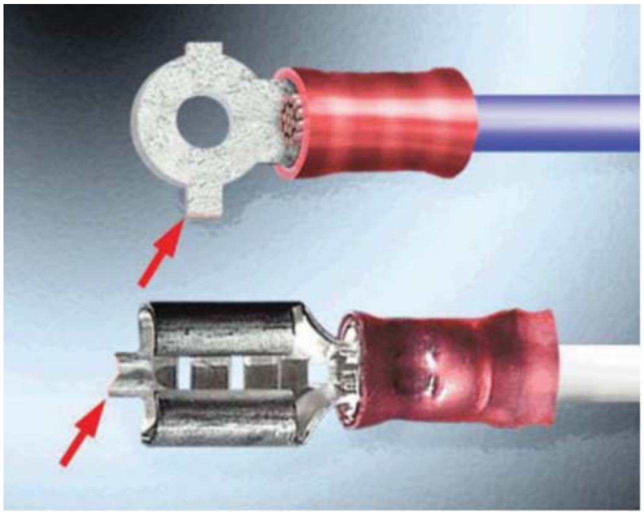
Figure 5-52

Defect – Class 1,2,3

- Removal of cutoff tab has damaged contact or terminal (not shown).
- Cutoff tab at conductor entry end protrudes from connector body when contact has been inserted (not shown).
- Mating end cutoff tab interferes with complete mating.

Note: Contact/terminal needs to meet form, fit, function and reliability requirements. A trial mating may be required for final acceptance.

5.3 Machined Contacts

Figure 5-53 defines the parts of a machined crimp contact. See 5.3.2 for machined crimp contacts – insulation support style criteria.

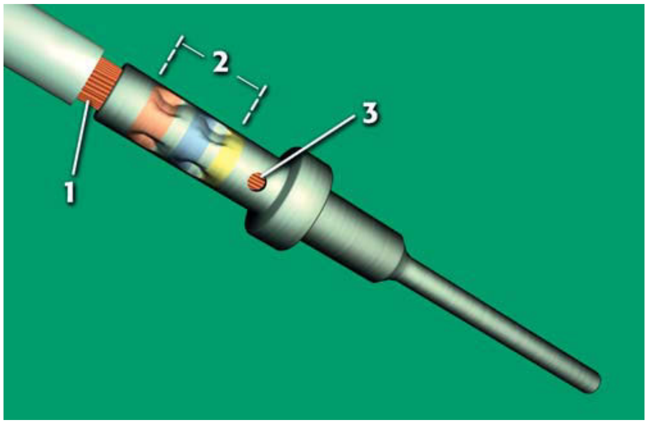

Figure 5-53
1. Insulation clearance
2. Conductor crimp
3. Inspection window

5.3.1 Machined Contacts – Insulation Clearance

Figure 5-54

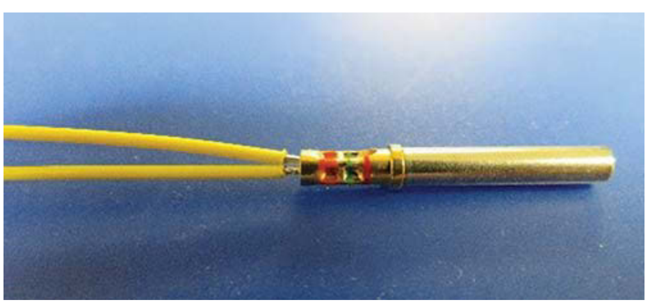

Figure 5-55

Acceptable – Class 1,2,3

- Insulation is flush to the end of the contact barrel.
- Conductor is visible between the insulation and contact barrel but not greater than one wire diameter.

5.3.1 Machined Contacts – Insulation Clearance (cont.)

Acceptable – Class 1
Process Indicator – Class 2,3

- Insulation is greater than one but less than two wire diameters from the end of the contact barrel.

Figure 5-56

Defect – Class 1,2,3

- Insulation is greater than two wire diameters from the end of the contact barrel.
- Insulation extends into the barrel of contact.
- Exposed conductor violates minimum electrical clearance.

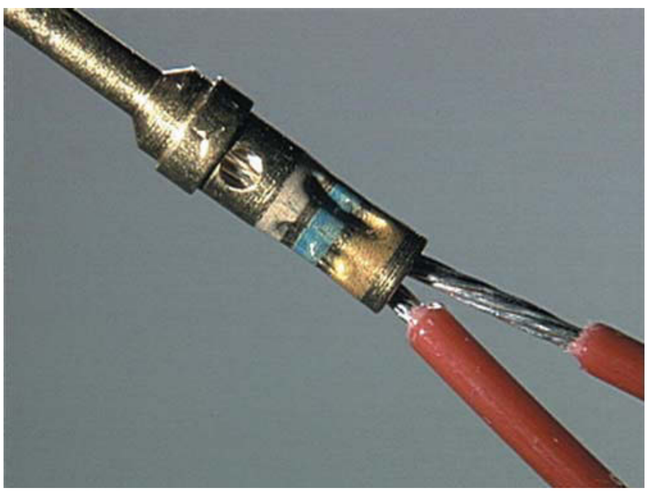

Figure 5-57

Figure 5-58

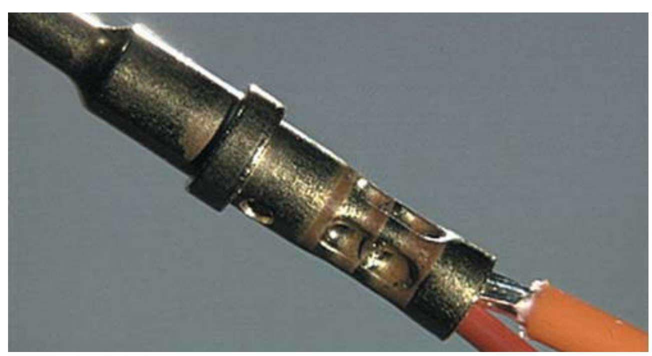

Figure 5-59

5.3.2 Machined Contacts – Insulation Support Style

Figure 5-60 defines the parts of an insulation support style machined crimp contact.

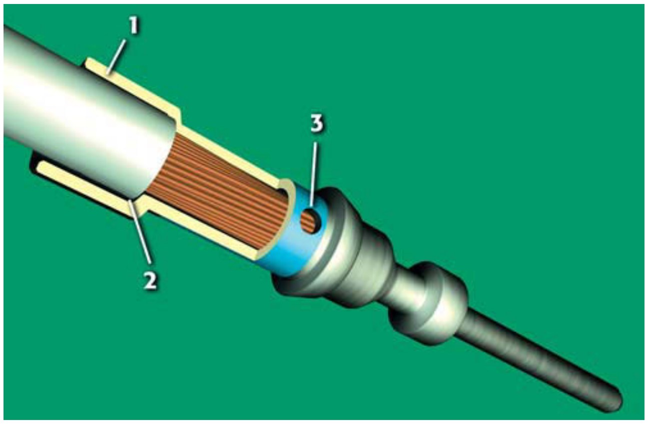

Figure 5-60
1. Insulation support barrel
2. Insulation funnel
3. Inspection window

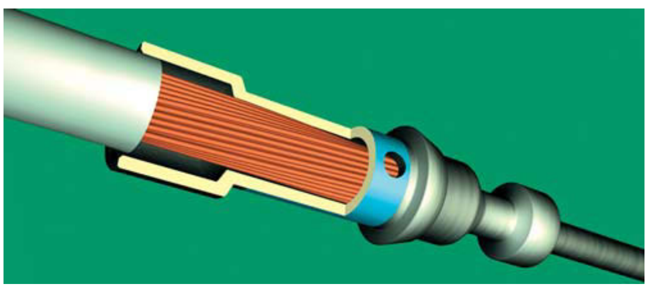

Figure 5-61

Acceptable – Class 1,2,3

- Wire insulation enters insulation support barrel.

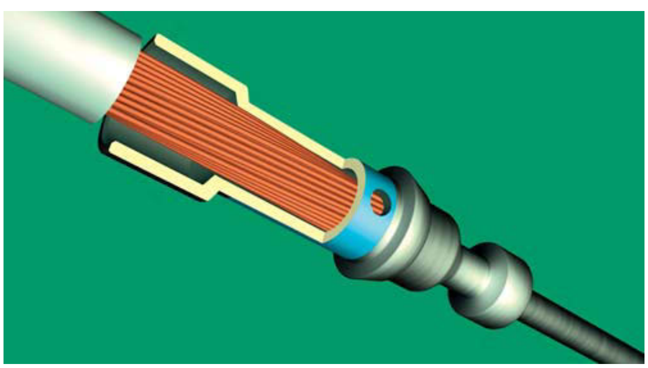

Figure 5-62

Defect – Class 1,2,3

- Wire insulation not inserted into the insulation support barrel of the contact.

5.3.3 Machined Contacts – Conductor

This section is applicable to all machined crimp contacts.

Acceptable – Class 1,2,3

- Conductor partially visible in the inspection window.
- No conductor strands outside of the contact.

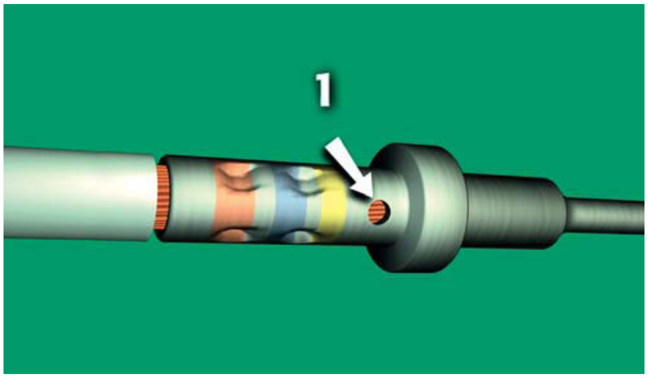

Figure 5-63
1. Inspection hole

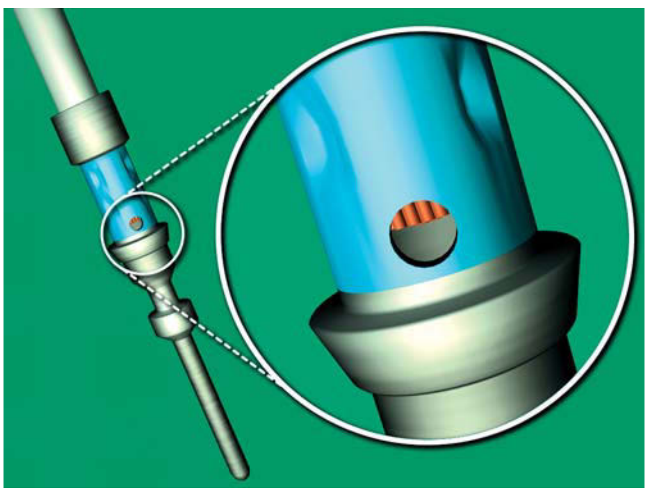

Figure 5-64

5.3.3 Machined Contacts – Conductor (cont.)

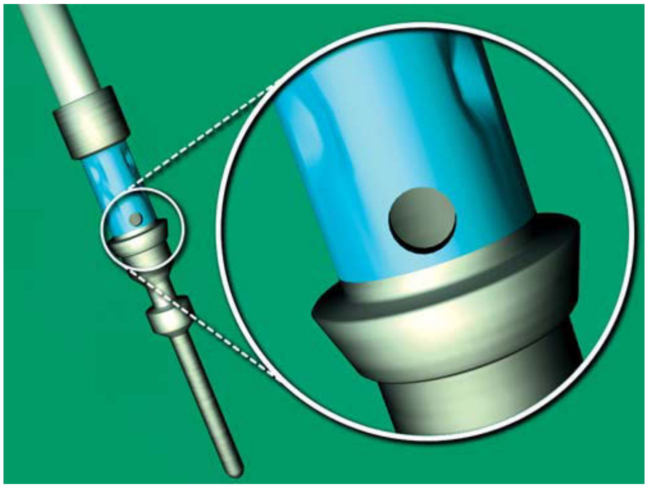

Figure 5-65

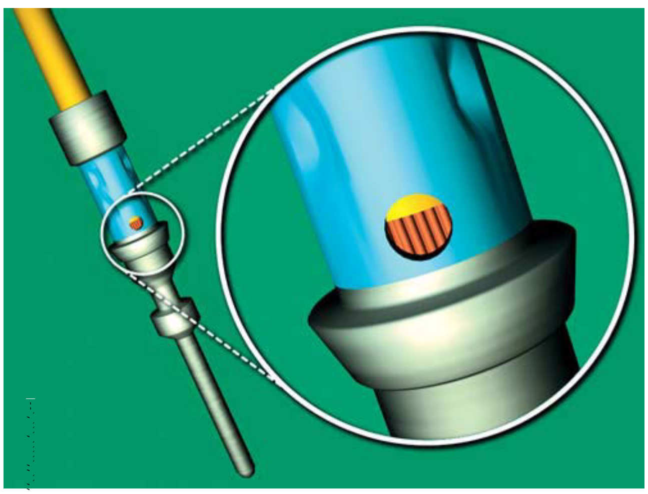

Figure 5-66

Defect – Class 1,2,3

- Conductor strands not visible in the inspection window of the contact (see Figure 5-65).
- Insulation visible in the inspection window of the contact (see Figure 5-66).
- Conductors twisted together before insertion into the contact (see Figure 5-67).
- Any conductor strands outside of the conductor crimp area (see Figure 5-68).

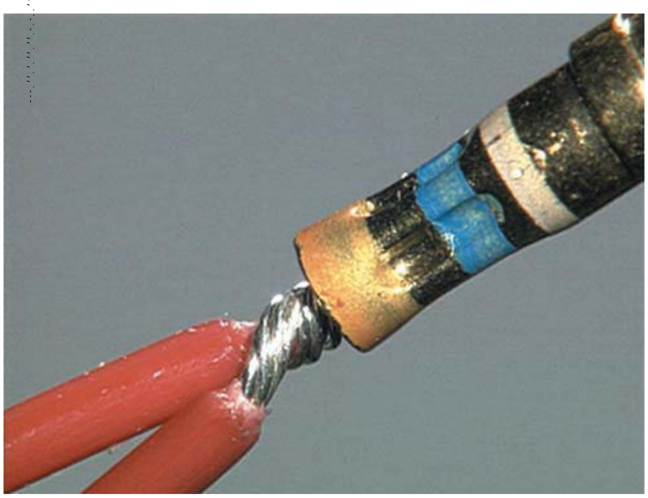

Figure 5-67

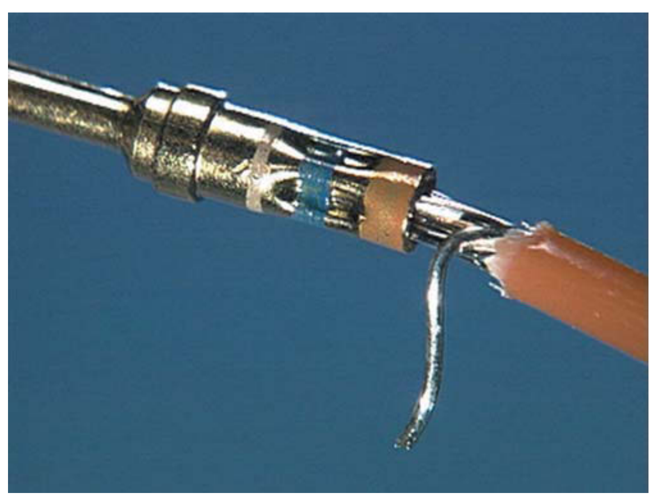

Figure 5-68

5.3.4 Machined Contacts – Crimping

The crimp area is defined as the area between the wire entry end of the contact and the closest edge of the inspection window as long as the following criteria are not violated.

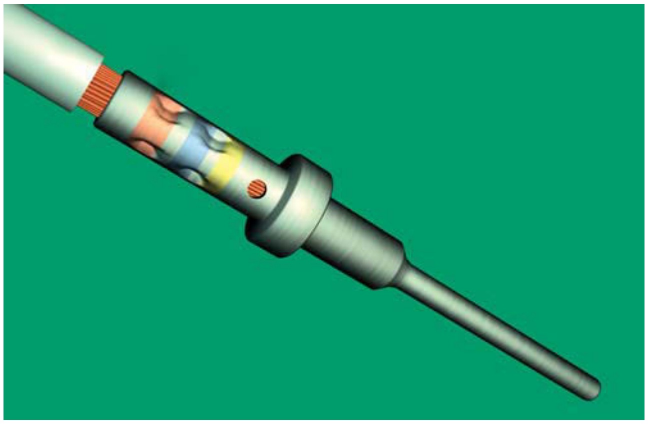

Figure 5-69

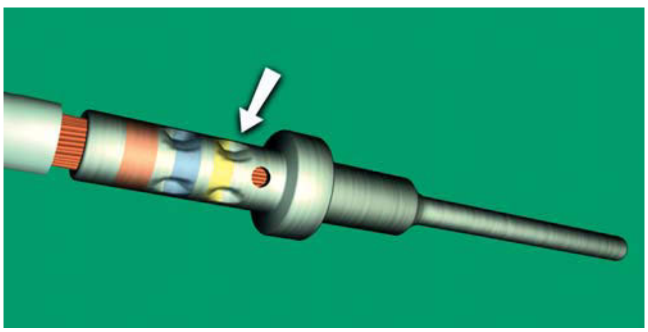

Figure 5-70

Acceptable – Class 2,3

- The crimp is not centered and the inspection window is not deformed.
- The wire entry end of the barrel is not deformed by the crimp.

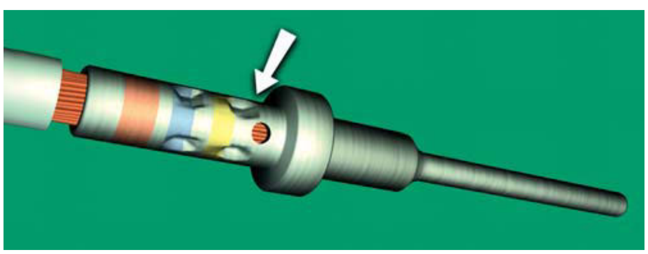

Figure 5-71

Figure 5-72

Acceptable – Class 1
Defect – Class 2,3

- The crimp indent is outside the crimp area (see Figure 5-71).
- Wire entry end of the barrel is deformed by the crimp (see Figure 5-72).

5.3.4 Machined Contacts – Crimping (cont.)

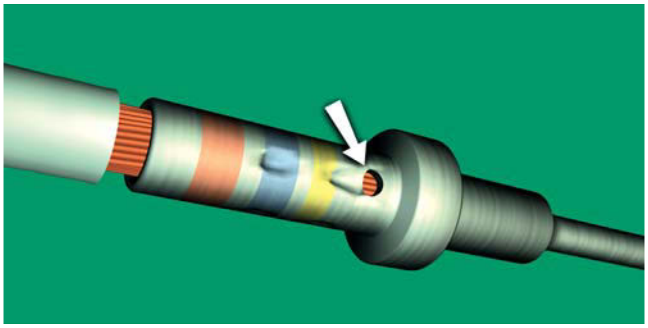

Figure 5-73

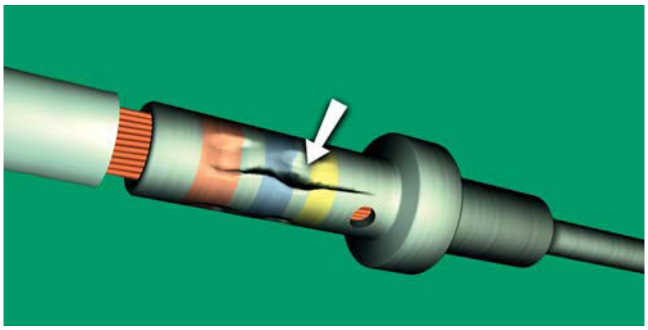

Figure 5-74

Defect – Class 2,3

- The crimp deforms the inspection window.
- Contact has exposed basis metal.
- Wire is not secured by crimp.
- Contact has visible fractures or cracks.
- Contact barrel is deformed or bent.

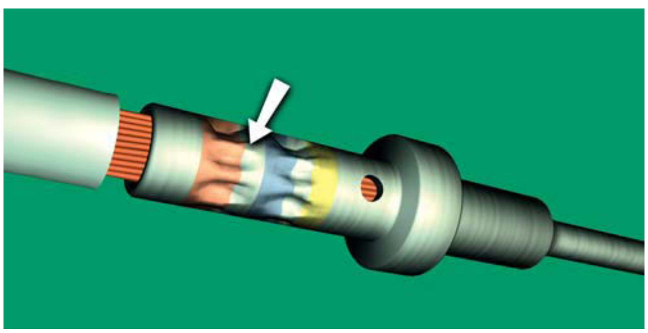

Figure 5-75

Defect – Class 1,2,3

- Contact is double-crimped.

5.3.5 Machined Contacts – CMA Buildup

These are four common methods for building up the CMA so it falls within the acceptable range of the contact:

– The conductor is folded or bent back to achieve the correct CMA buildup.

– The conductor area is increased by the use of bare (non-insulated) filler conductors as needed to achieve the correct CMA buildup.

– A combination of both the foldback and the filler method are used to achieve the correct CMA buildup.

– Special ''CMA Adapter Bushings'' are used when called out on the assembly documentation. (Use of these adapters will usually require special additional insulating coverage requirements.) (see Figure 5-77).

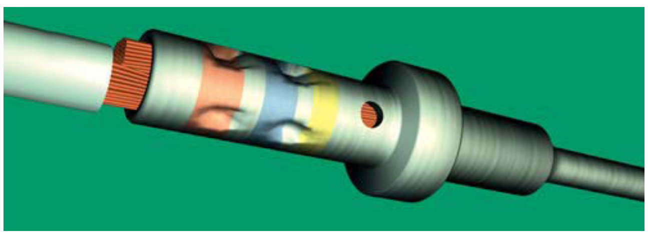

Figure 5-76

Figure 5-77
1. Adapter Bushing

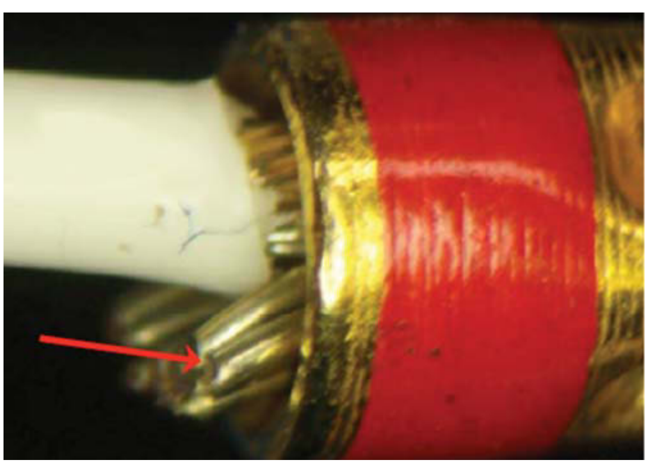

Figure 5-78

Acceptable – Class 1,2,3

- The filler conductors and/or the wire conductor are visible in the inspection window of the contact.
- The filler conductor is of the same type conductor as the wire being crimped into the contact. (Gauge can be different as needed but the basis metal and the plating, if any, needs to be the same.)
- Fill conductor extends beyond the contact a maximum of one wire diameter of the primary wire (see Figure 5-78, red arrow).
- The flair or splay of any fill conductor does not extend past or exceed the contact diameter.

5.3.5 Machined Contacts – CMA Buildup (cont.)

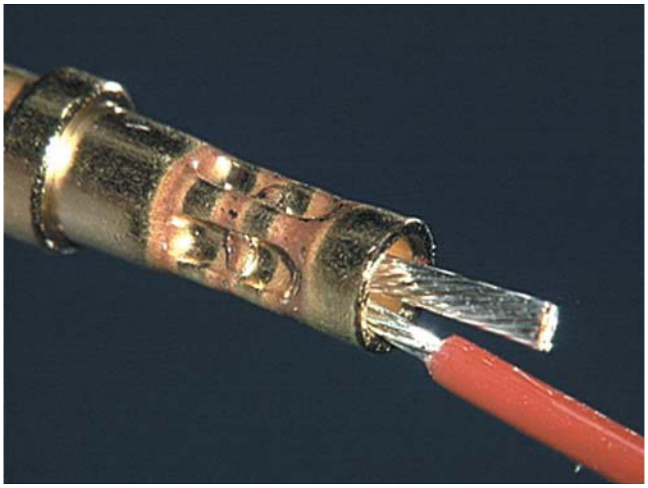

Figure 5-79

Defect – Class 1,2,3

- Fill conductor extends beyond the contact more than one wire diameter of the primary wire.
- Fill conductor or foldback are not visible at wire entry end.
- Fill conductor not the same type as primary conductor.

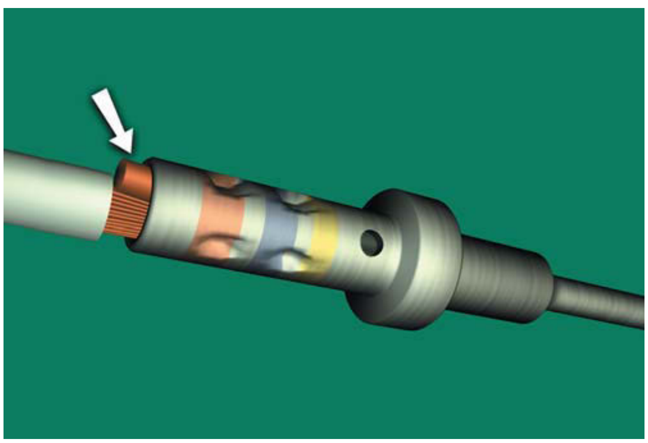

Figure 5-80

Defect – Class 1,2,3

- Solid conductors used to build up the CMA.
- The filler conductors and/or the wire conductor are not visible in the inspection window.
- The flair or splay of any filler conductor used extends past or exceeds the contact diameter.
- Exposed conductor violates minimum electrical clearance.

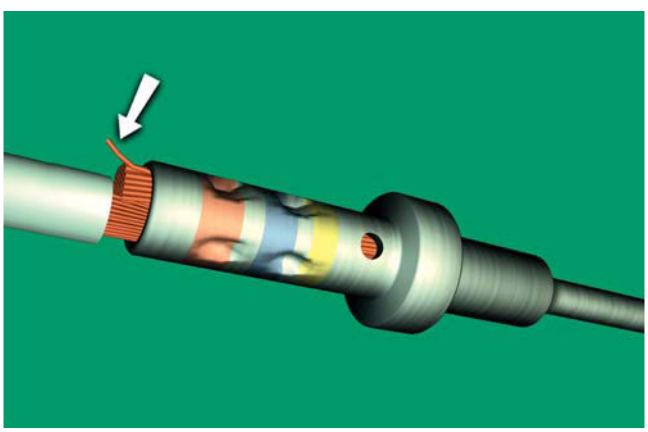

Figure 5-81

5.4 Termination Ferrule Crimp

Termination ferrules are typically used to terminate stranded wires into terminal blocks.

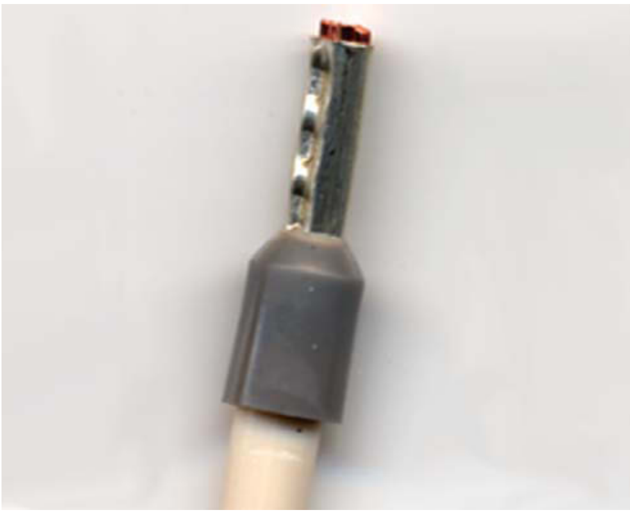

Figure 5-82

Acceptable – Class 1,2,3

- Ferrule cavity completely filled by the conductor.
- Crimp shape is symmetrical.

Figure 5-83

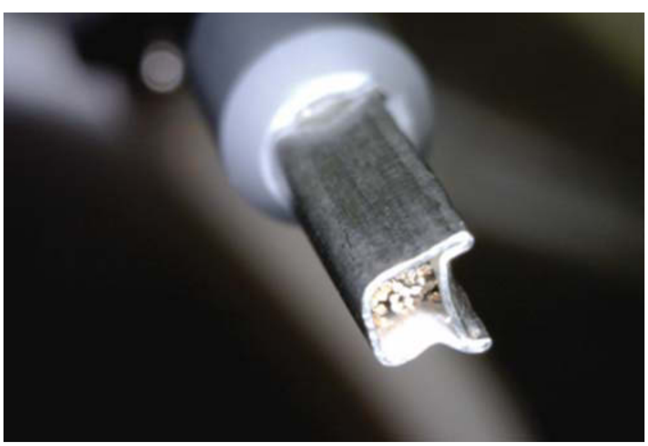

Figure 5-84

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Conductor recessed more than 0.5 mm [0.020 in].
- Conductor protruding more than 0.5 mm [0.020 in].
- Nonsymmetrical crimp shape.

5.4 Termination Ferrule Crimp (cont.)

Figure 5-85

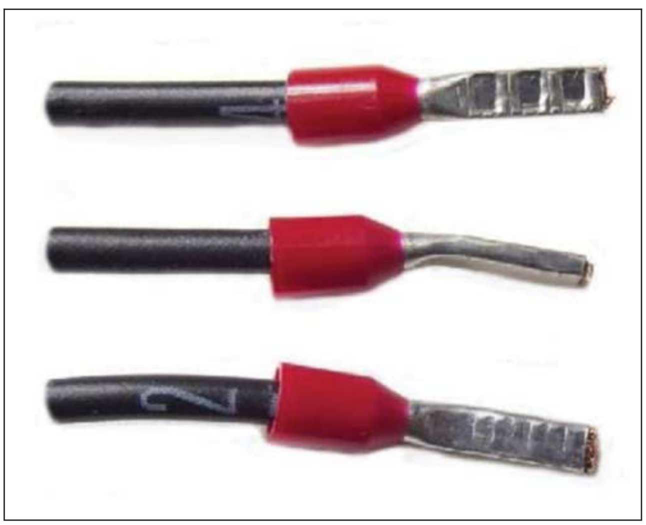

Figure 5-86

Defect – Class 1,2,3

- Cracks or splits in ferrule conductor.
- Individual wire(s) protrude from the insulation sleeve.
- Conductor insulation not in the insulation sleeve.
- Ferrule bent.
- Dog ear on the lateral edge of the crimp.

5.5 Shrink Sleeving – Wire Support – Crimped Terminals

This section applies to crimped terminals. Sleeving may be used to cover crimped termination for stress relief or electrical isolation. The heating processes used to shrink the sleeving insulation **shall not [D1D2D3]** damage the crimped device, wire, sleeving, or adjacent components.

Acceptable – Class 1

- Sleeving is tight on the crimped device, but not on the wire.

Acceptable – Class 2,3

- Sleeving is tight on the crimped device and the wire.

Acceptable – Class 1,2,3

- Sleeving is flush to the end of the brush or inspection window.
- Sleeving extends onto the wire insulation a minimum of two wire diameters.
- Multiple pieces of sleeving overlap each other by at least three wire/cable diameters.

Defect – Class 1

- Sleeving is not tight on the crimped device.

Defect – Class 2, 3

- Sleeving is not tight on the crimped device and the wire.

Defect – Class 1, 2, 3

- Sleeving extends into the mating area of the crimped device.
- Sleeving is less than flush to the end of the brush or inspection window.
- Sleeving is damaged, e.g., split, charred.
- Sleeving extends less than two wire diameters onto the wire insulation.
- Multiple pieces of sleeving overlap less than three wire/cable diameters.

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6 Insulation Displacement Connection (IDC)

Insulation displacement connection (IDC), sometimes referred to as insulation displacement termination (IDT) is a method for terminating an insulated wire to a connector or terminal without pre-stripping the insulation from the conductor. However, this method may be used for an uninsulated wire as well. It is recognized that this technology is utilized by a significant number of different connector types. This section attempts to define common acceptance criteria regardless of the connector type.

It is extremely important to assure that the wire, the connector, and the assembly process are compatible, as normally specified by the connector manufacturer. Variations in wire gauge, wire-to-wire spacing (for multiple conductor flat or ribbon cable), insulation thickness, insulation type, application tooling, or alignment of the cable to the connector may result in an unreliable connection or in an electrical open or short circuit.

For some IDC products, visual inspection of the wire/termination connection is not possible without destructive analysis.

The following topics are addressed in this section.

6.1 Mass Termination, Flat Cable

6.1.1 Mass Termination, Flat Cable – End Cutting

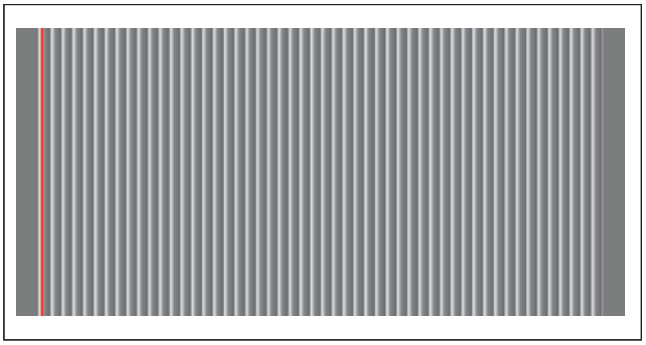

Figure 6-1

Acceptable – Class 1,2,3

- The cable end is cut so that it allows compliance to all other assembly requirements.

Process Indicator – Class 2,3

- Conductor strand protrusion from the end of the cable equal to or less than 50% cable thickness.

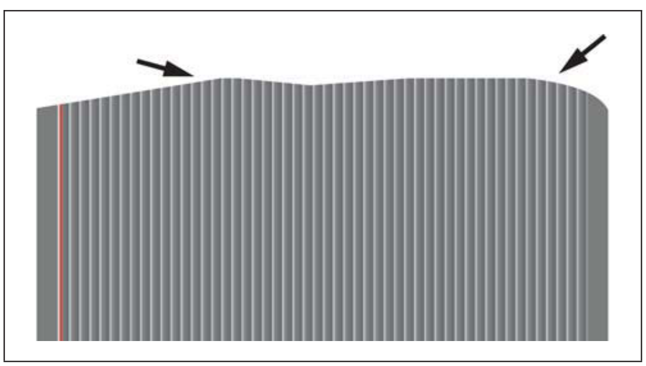

Figure 6-2

Defect – Class 1,2,3

- Uneven or wavy cutting of the cable end precludes compliance to any other assembly requirement.
- Conductor strand protrusion from the end of the cable greater than 50% cable thickness or violates minimum electrical clearance.

6.1.2 Mass Termination, Flat Cable – Notching

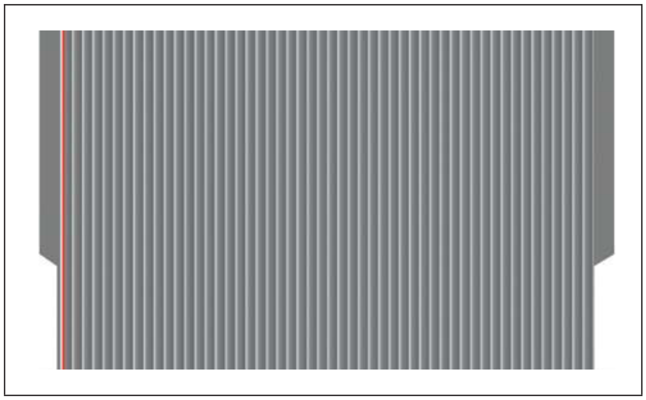

Figure 6-3

Acceptable – Class 1,2,3

- Variations in the notch cuts do not interfere with the mounting and crimping of the connector or reduce conductor insulation.
- Tooling marks do not break the surface of the insulation.

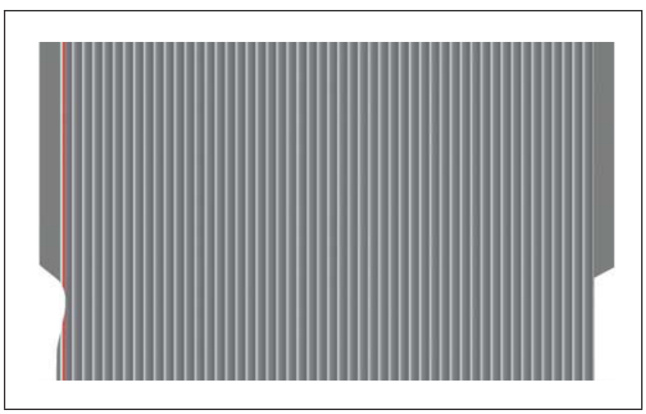

Figure 6-4

Defect – Class 1,2,3

- Notching that cuts, nicks or exposes the conductors.
- Variations in the notch cuts interfere with the mounting and crimping of the connector or reduce conductor insulation.
- Tooling marks break the surface of the insulation.

6.1.3 Mass Termination, Flat Cable – Planar Ground Plane Removal

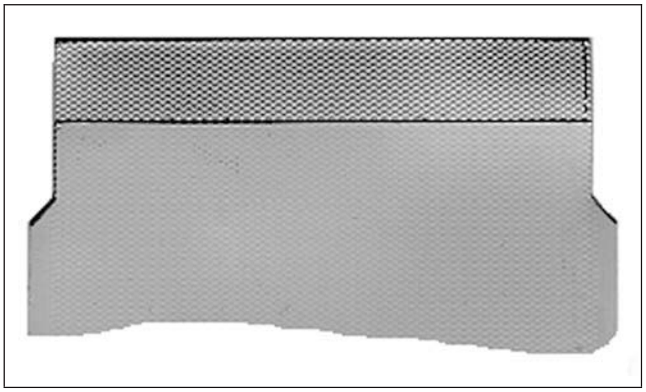

Figure 6-5

Acceptable – Class 1,2,3

- Minor tooling marks that do not break the surface of the insulation.
- Planar ground screen removed prior to installing and crimping an IDC connector to the cable.

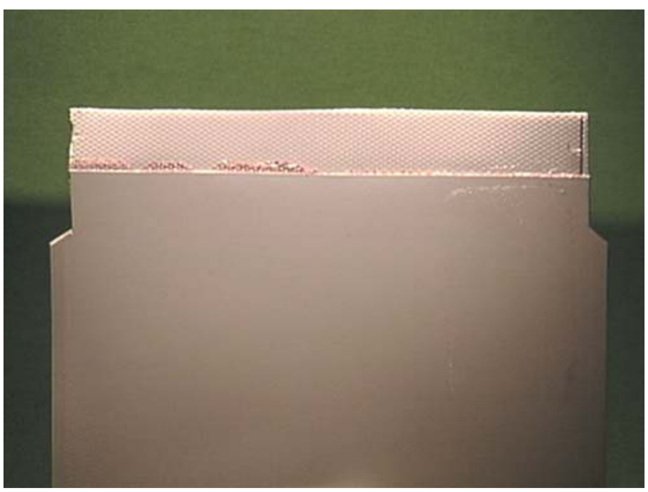

Figure 6-6

Defect – Class 1,2,3

- Planar ground screen not removed from connector crimp area.
- Nicked or cut insulation after removal of the planar ground screen layer.
- Connector crimped on any portion of the cable that does not have the planar ground screen removed.

6.1.4 Mass Termination, Flat Cable – Connector Position

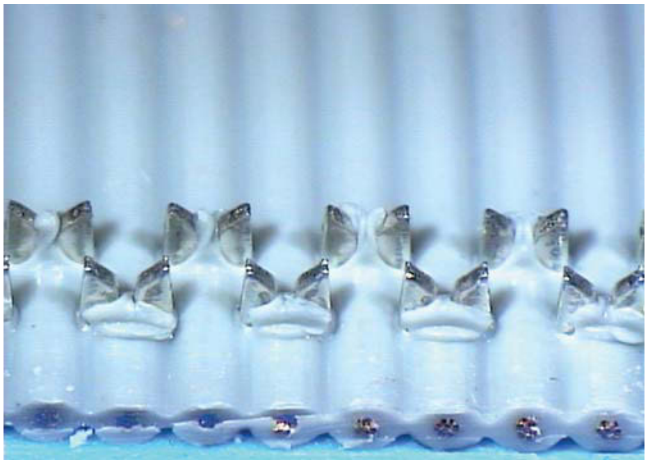

Figure 6-7
Note: Locking cap removed for clarity.

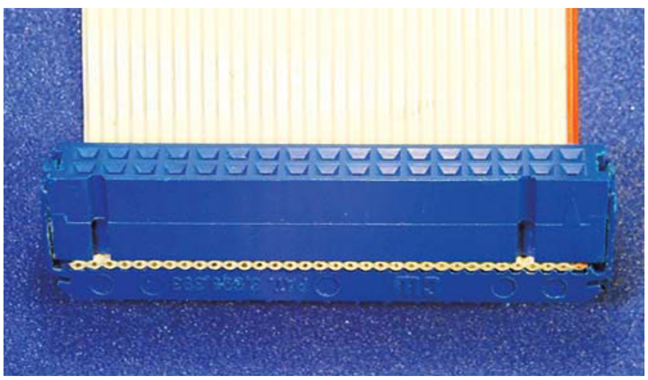

Figure 6-8

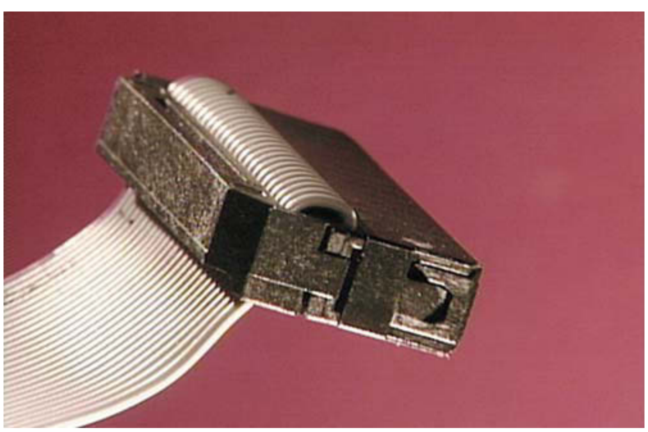

Figure 6-9

Acceptable – Class 1,2,3

- The cable end is flush or extends beyond the outside edge of the connector one cable thickness or less and does not violate minimum electrical clearance.
- Minor tooling marks that do not break the surface of the insulating material of the connector or cable.
- Cable foldback inside radius, if applicable, is flush with connector body and does not interfere with installation of the connector.
- Color reference stripe (or lowest number conductor) on ribbon cable aligned with pin 1 unless otherwise specified.

6.1.4 Mass Termination, Flat Cable – Connector Position (cont.)

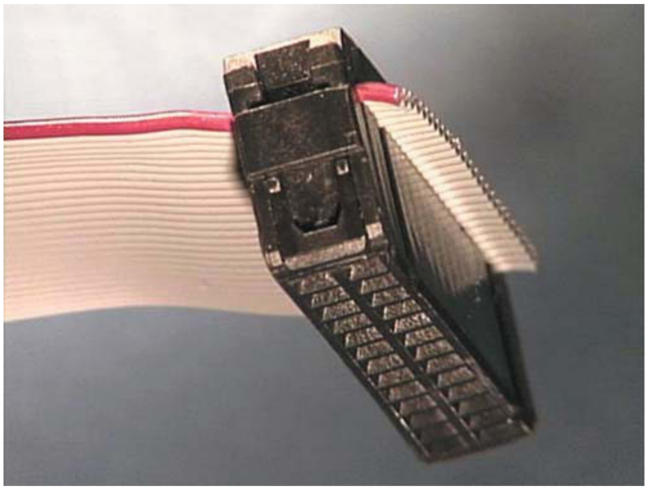

Figure 6-10

Acceptable – Class 1
Defect – Class 2,3

- Cable extends beyond the edge of the connector greater than one thickness of cable (see Figure 6-10).

6.1.4 Mass Termination, Flat Cable – Connector Position (cont.)

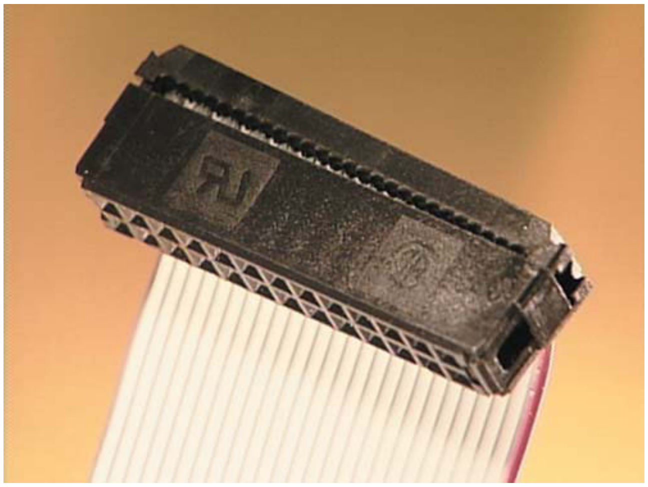

Figure 6-11

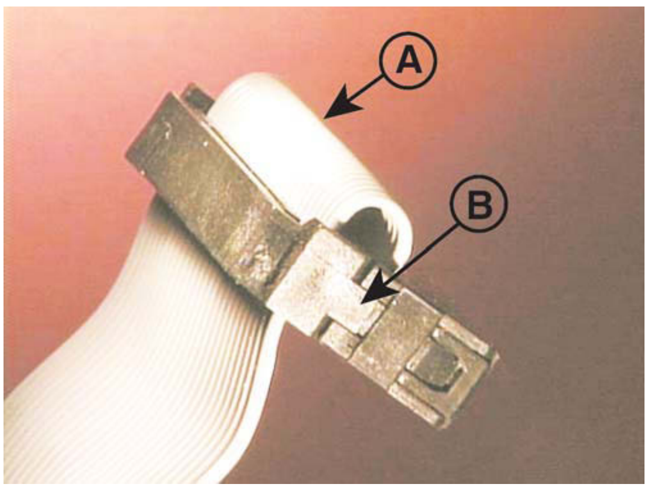

Figure 6-12

Figure 6-13

Defect – Class 1,2,3

- Cover hold down latches are not fully engaged and latched (see Figure 6-11).
- Any broken cover hold down latches or barbs (not shown).
- Cable does not extend into IDC contacts for all wires (not shown).
- Exposed wires violate minimum electrical clearance (not shown).
- Cable foldback, if applicable, interferes with mechanical fit of the connector (see Figure 6-12-A).
- Strain relief (cover) installed backwards (see Figure 6-12-B).
- Ribbon cable wires are misaligned with the piercing terminals (see Figure 6-13).
- Wires are shorted together via piercing terminals.
- Color reference stripe (or lowest number conductor) on ribbon cable not aligned with pin 1.

6.1.5 Mass Termination, Flat Cable – Connector Skew and Lateral Position

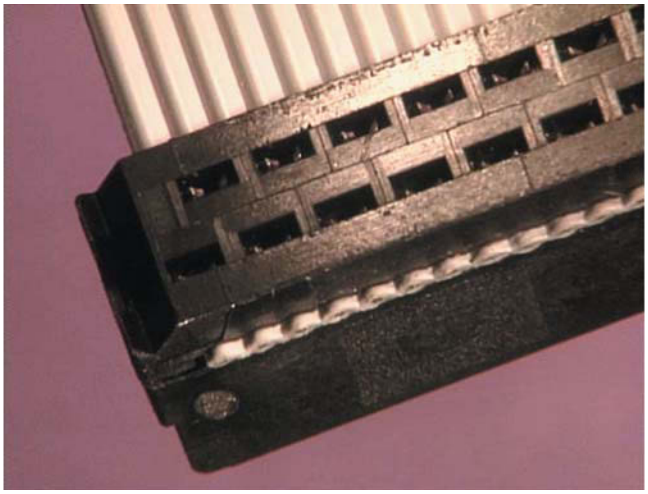

Figure 6-14

Acceptable – Class 1,2,3

- Connector is aligned so that all conductors are centered in their respective v-notches.

Figure 6-15

Figure 6-16

Defect – Class 1,2,3

- Connector misalignment precludes contact of all wires to the IDC contacts (see Figure 6-15, arrow).
- Connector misalignment permits shorting of conductors in the IDC contact area.
- Connector misalignment precludes assembly of connector cover.
- Connector misalignment causes wire damage during crimping.
- Face of the cable is not parallel to the face of the connector (see Figure 6-16).

6.1.6 Mass Termination, Flat Cable – Retention

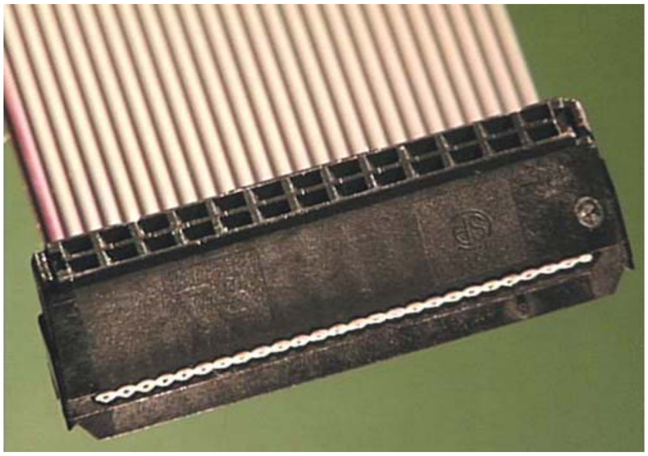

Figure 6-17

Acceptable – Class 1,2,3

- Wires are retained in the connector.
- Strain relief features of the connector, if applicable, are utilized.
- Where present, connector-locking tabs are properly engaged.

Figure 6-18

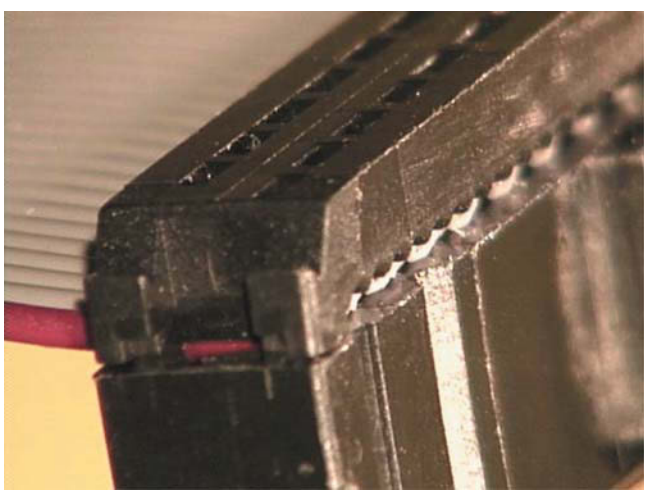

Figure 6-19

Defect – Class 1,2,3

- Wires are not retained in the connector (see Figure 6-18).
- Strain relief features of the connector, if applicable, are not utilized.
- Where present, connector-locking tabs are not engaged (see Figure 6-19).

6.2 Discrete Wire Termination

6.2.1 Discrete Wire Termination – General

Figure 6-20 shows the parts of an insulation displacement contact.

Only acceptable materials and appropriate equipment and methods **shall [D1D2D3]** be used in insulation displacement connections.

Insulation displacement connections **shall not [D1D2D3]** be mechanically stressed after making the connection, e.g., the connection **shall not [D1D2D3]** be reworked afterwards by moving the wire or the mechanics of the slot.

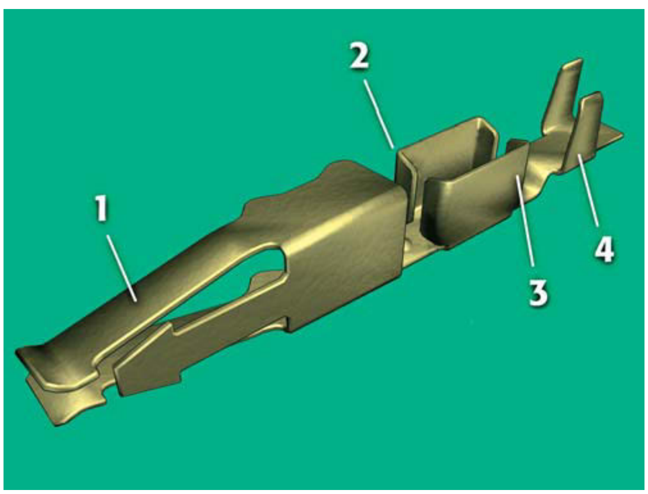

Figure 6-20
1. **Dual cantilever contact**
2. **Electrical slot**
3. **Mechanical slot**
4. **Insulation crimp tabs**

6.2.2 Discrete Wire Termination – Position of Wire

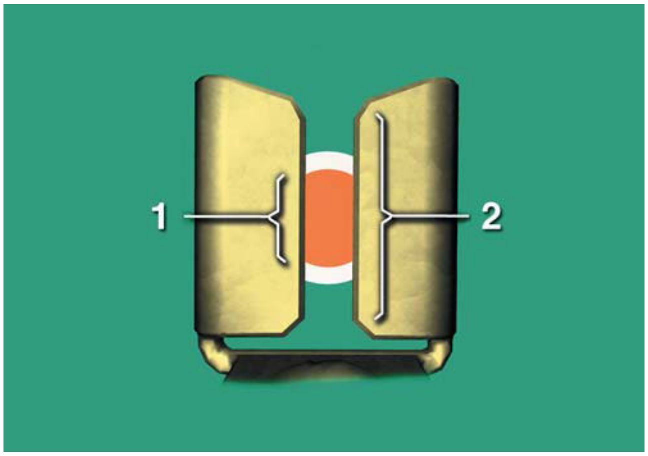

Figure 6-21
1. Wire connection area
2. Slot connection area

Acceptable – Class 1,2,3

- Connection area of the wire is completely in the connection area of the slot.

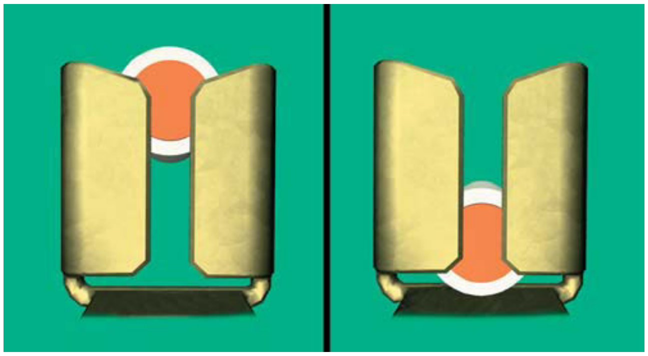

Figure 6-22

Defect – Class 1,2,3

- Connection area of the wire is not completely in the connection area of the slot in both the front and back wire slots of a dual slot contact.
- Conductor is not completely within the connection area of the slot.

6.2.3 Discrete Wire Termination – Overhang (Extension)

These criteria are not applicable to pass through IDC connectors (see 6.2.7).

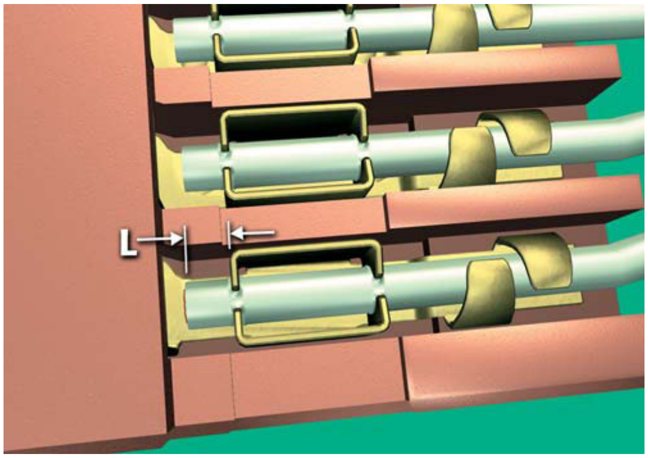

Figure 6-23

Acceptable – Class 1

- Wire end is flush with electrical (second) contact.

Acceptable – Class 2,3

- Length (L) of the wire past the electrical (second) contact is equal or greater than 50% wire diameter.

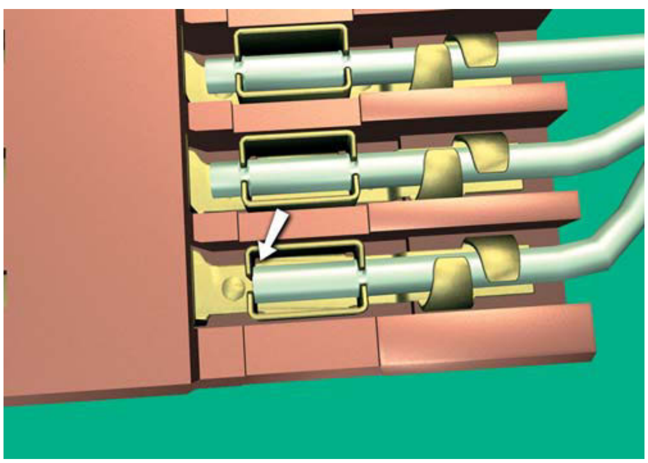
Figure 6-24


Figure 6-25

Defect – Class 1,2,3

- Wire does not pass through both IDC contacts (see Figures 6-24, arrow, and 25).
- Exposed conductors violate minimum electrical clearance (not shown).

6.2.3 Discrete Wire Termination – Overhang (Extension) (cont.)

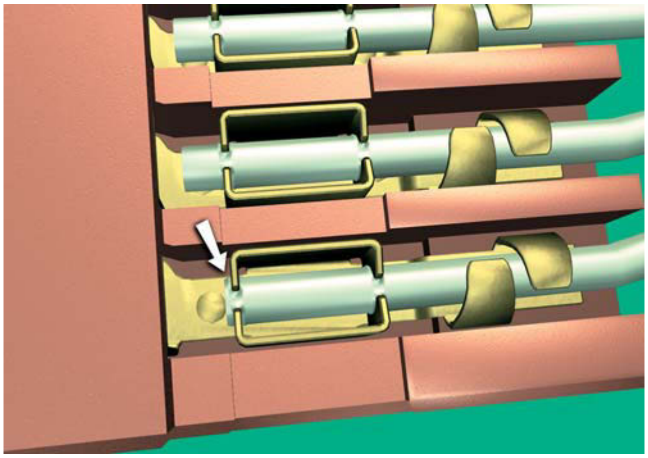

Figure 6-26

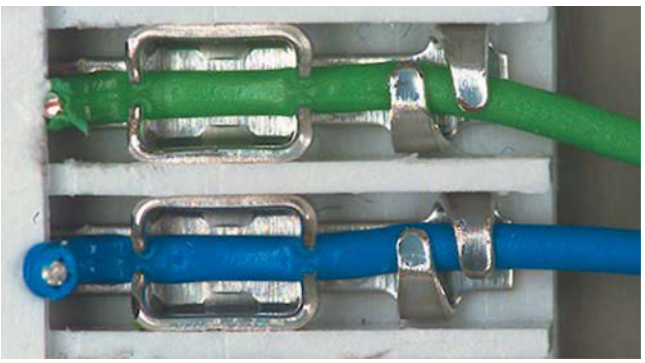

Figure 6-27

Defect – Class 2,3

- Length (L) of the wire past the electrical (second) contact is less than 50% overall wire diameter (see Figure 6-26, arrow).
- Wire is deformed and extends out of the connector (see Figure 6-27).

6.2.4 Discrete Wire Termination – Insulation Crimp

The requirements of 5.1.1.2 also apply.

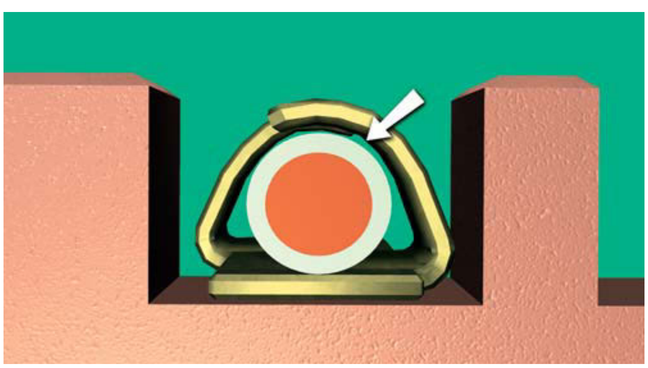

Figure 6-28

Acceptable – Class 1,2,3

- Wire is contained (space is permitted between insulation and holders).

6.2.4 Discrete Wire Termination – Insulation Crimp (cont.)

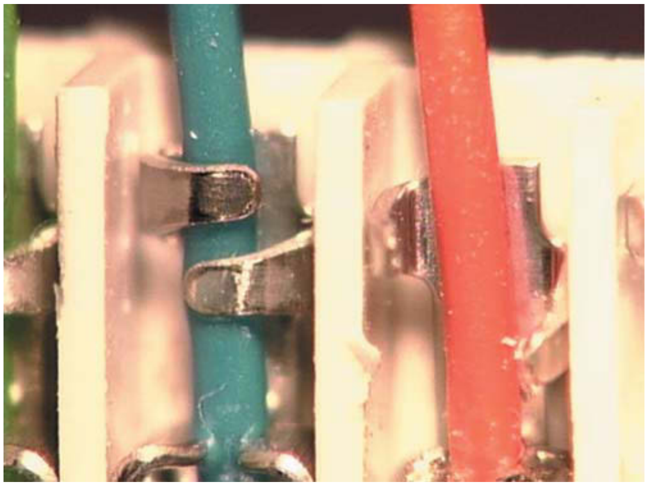

Figure 6-29

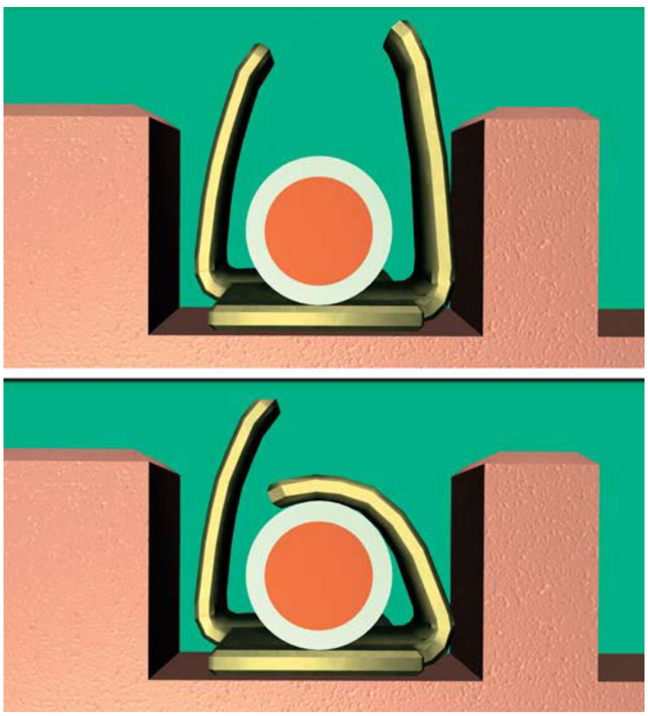

Figure 6-30

Defect – Class 2,3

- Both insulation crimp tabs are not crimped to prevent the wire escaping the holders.
- Insulation crimp tabs pierce insulation.

Defect – Class 1,2,3

- Insulation crimp tabs violate minimum electrical clearance.

6.2.5 Discrete Wire Termination – Damage in Connection Area

The circled area in Figure 6-31 defines the connection area.

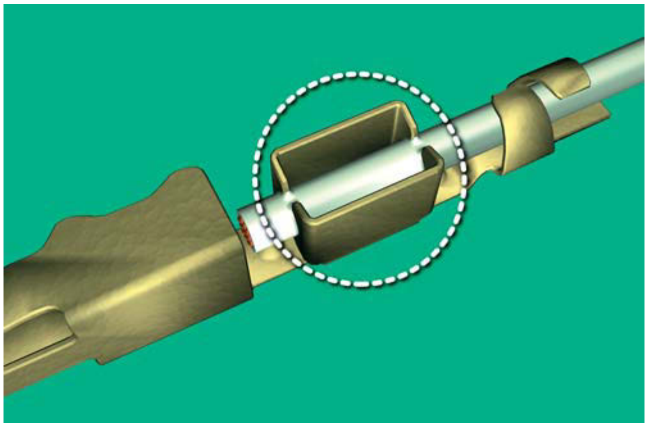

Figure 6-31

Figure 6-32

Acceptable – Class 1,2,3

- Minor deformation to the slot but pierces wire insulation on both sides of the slot.
- Minor damage in the slots does not affect functionality.

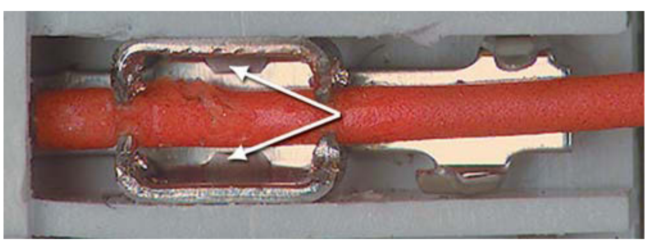

Figure 6-33

Defect – Class 2,3

- Corrosion damage or other detrimental impurities on the surface of the slot.
- Plating damage that exposes basis metal.
- Side beams (see Figure 6-33, arrows) of the wire slot are not parallel with each other.

Defect – Class 1,2,3

- Damage prevents slots from piercing both sides of the insulation.

6.2.6 Discrete Wire Termination – End Connectors

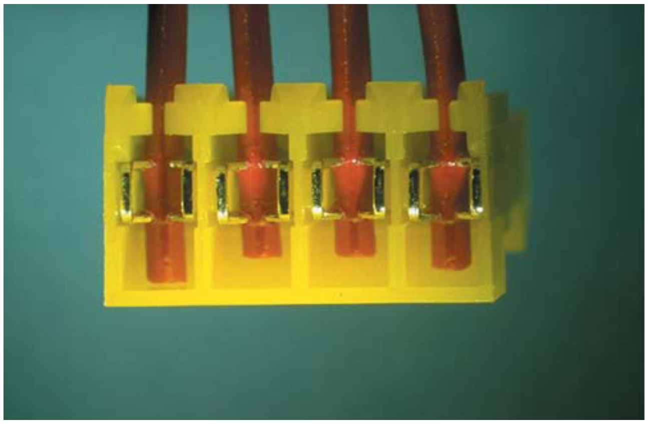

Figure 6-34

Acceptable – Class 1,2,3

- Wire touches back wall with slight deformation but the top of the wire does not rise above the back wall.
- Portions of bare conductor are visible but no bare conductor extends outside the connector body.
- Length of the wire past the electrical (second) contact is equal to or greater than 50% wire diameter.

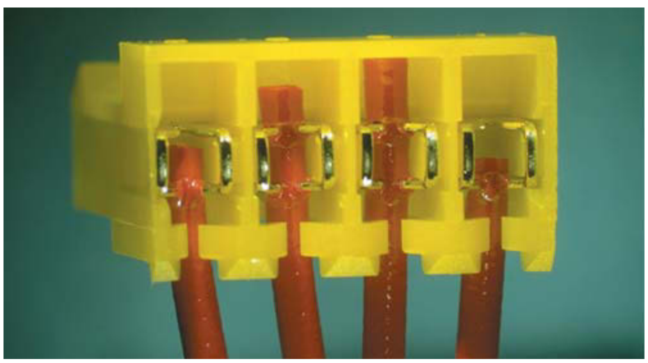

Figure 6-35

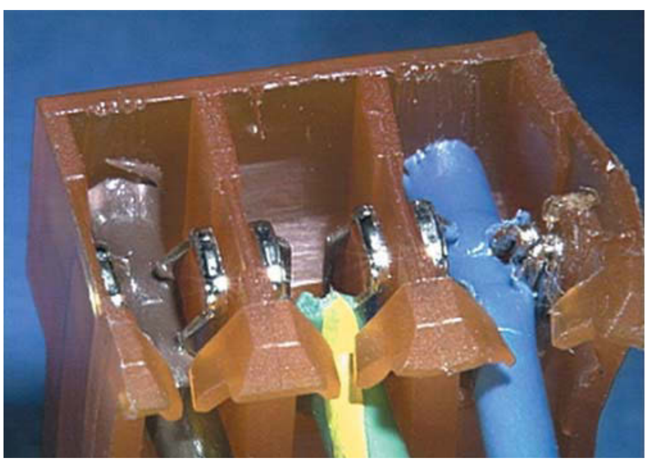

Figure 6-36

Defect – Class 1,2,3

- Wire stripped or partially stripped before being inserted into the connector.
- Wire not within retaining tabs.
- Two wires into a single contact unless the contact or connector specifications indicate that this is acceptable.
- Deformation of the connector body.
- Insufficient stress relief on wires entering connector.
- Wire size does not match connector size.
- Wire not fully seated in both sets of v-notches of the IDC contact.
- Length (L) of the wire past the electrical (second) contact is less than 50% overall wire diameter.
- Broken retaining tab(s) on the connector.

6.2.7 Discrete Wire Termination – Pass Through Connectors

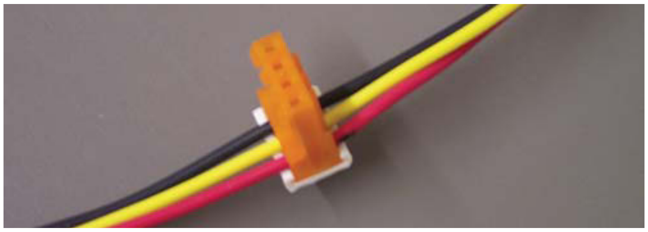

Figure 6-37

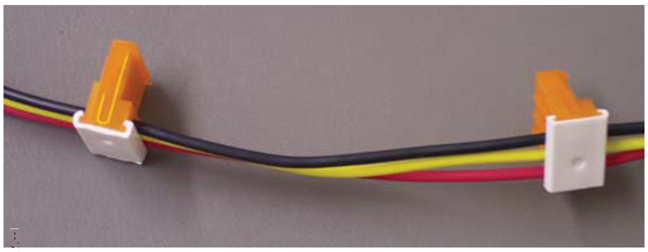

Figure 6-38

Acceptable – Class 1,2,3

- Portions of bare conductor are visible but no bare conductor extends beyond either side of the connector body.

Defect – Class 1,2,3

- Wire stripped or partially stripped before being inserted into the connector.
- Wire not within retaining tabs.
- Two wires into a single contact unless specified.
- Deformation of the connector body due to wires with over-size insulation.
- Wire size does not match connector.
- Wire not fully seated in both sets of v-notches of the IDC contact.
- Two wires spliced together mechanically by IDC contact.

6.2.8 Discrete Wire Termination – Wiremount Connectors

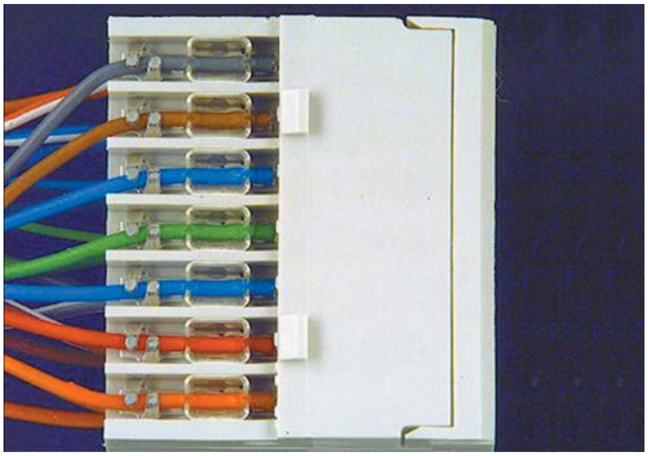

Figure 6-39

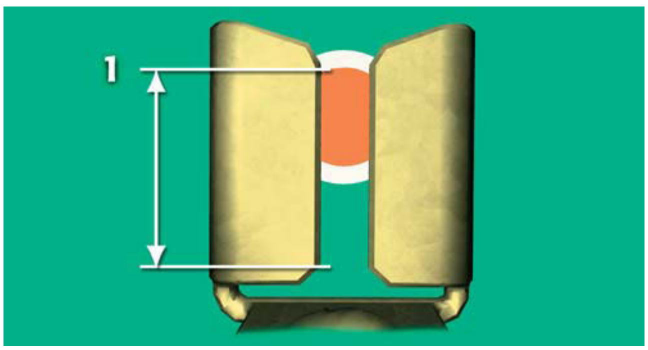

Figure 6-40
1. Wire connection area

Acceptable – Class 1,2,3

- Connector position does not cause any wire stress.
- Wire position is within the wire connection area (see 6.2.2).

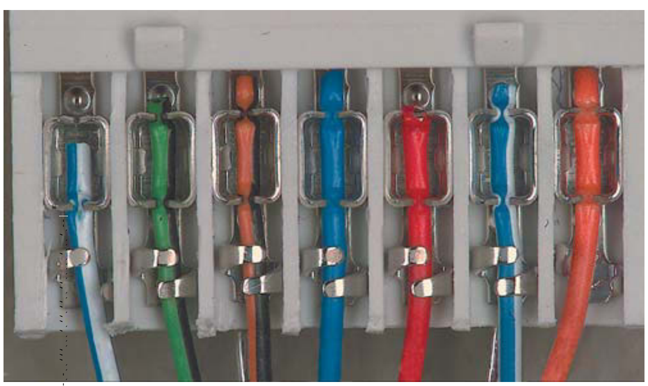

Figure 6-41

Defect – Class 1,2,3

- Wire stripped or partially stripped before being inserted into the connector (not shown).
- Wire not retained.
- Wire not fully seated in both sets of v-notches of the IDC contact.
- Wire size does not meet connector parameters (not shown).
- Two wires into a single contact unless the contact or connector specifications indicate that this is acceptable (not shown).
- Deformation of the connector body.
- Insufficient stress relief on wires entering connector (not shown).
- Broken retaining barbs on the connector.

6.2.9 Discrete Wire Termination – Subminiature D-Connector (Series Bus Connector)

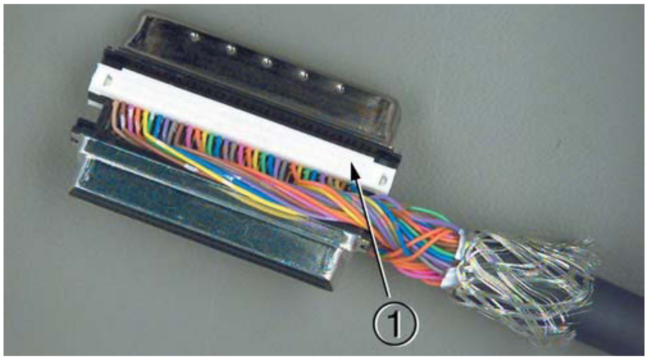

Figure 6-42
1. Termination cover plate

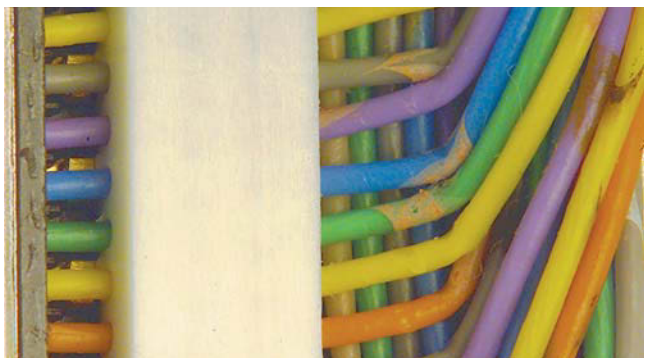

Figure 6-43

Acceptable – Class 1,2,3

- Wire may extend past the cover plate (see Figure 6-42-1) up to the end of free space (see Figure 6-43).

6.2.9 Discrete Wire Termination – Subminiature D-Connector (Series Bus Connector) (cont.)

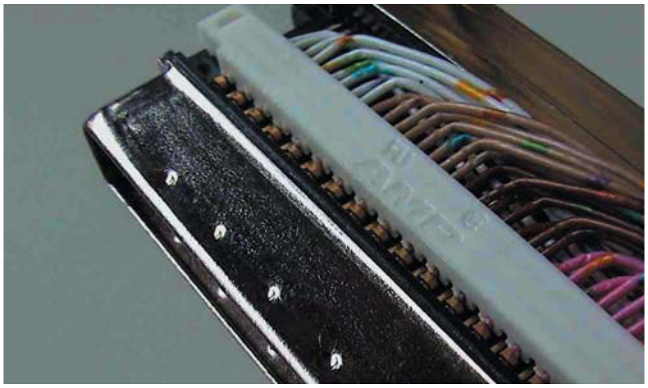

Figure 6-44

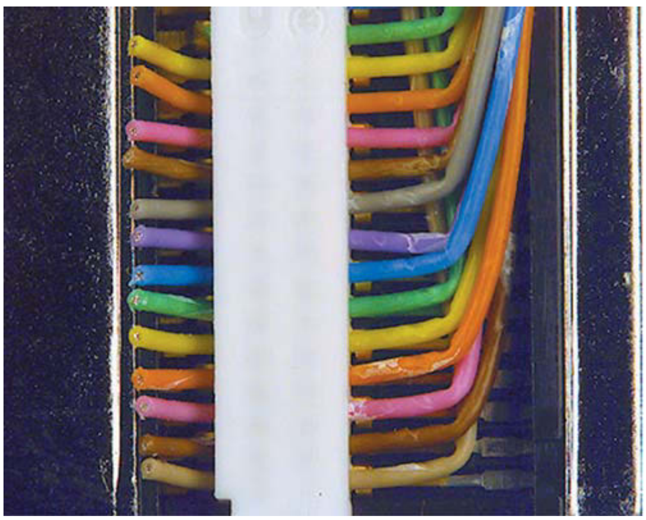

Figure 6-45

Defect – Class 1,2,3

- Wire is less than flush (not visible in the free space beyond the cover plate) (see Figure 6-44).
- Wire is bent upwards in the free space over the top of the connector body (see Figure 6-45).
- Termination cover plate is broken or deformed (see Figures 6-46, 47).
- Contact basis metal is exposed (not shown).
- Contact is bent after termination and does not fit within the termination cover slots (not shown).
- Covers are not fully seated against connector housing at cover ends or cover is clearly convex at the center (not shown).

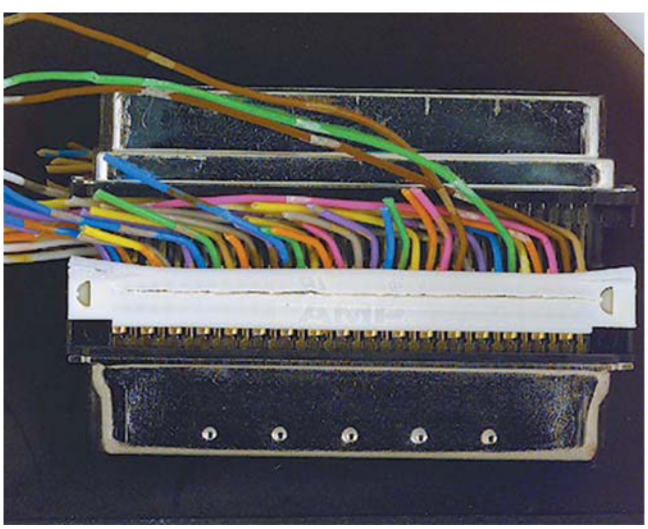

Figure 6-46

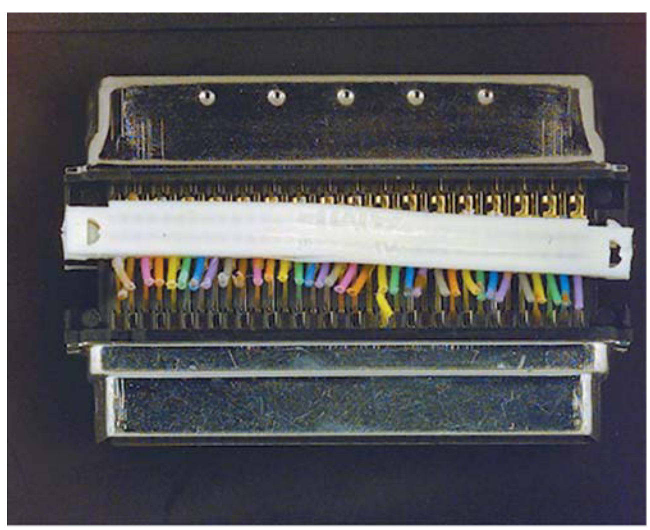

Figure 6-47

6.2.10 Discrete Wire Termination – Modular Connectors (RJ Type)

The following criteria apply to Type RJ telecommunications connectors with or without loading bar.

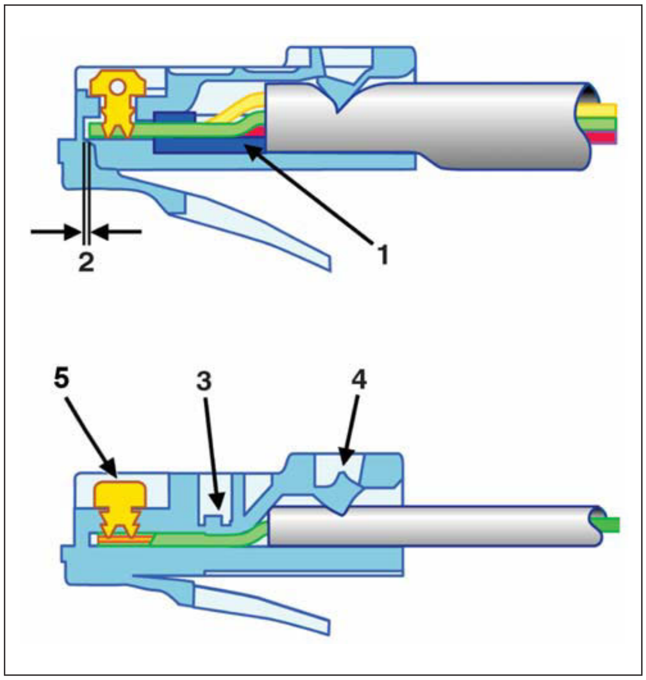

Figure 6-48

1. **Loading bar**
2. **Wire end clearance**
3. **Secondary strain relief**
4. **Primary strain relief**
5. **Terminal**

Acceptable – Class 1,2,3

- Wires are not bottomed but all are within 0.5 mm [0.02 in] or less of the end wall and all are inserted at least past the terminal.
- Terminals meet the connector manufacturer's crimp height specification.
- The primary strain relief is crimped tightly against the cable jacket (see Figure 6-48-4).
- The cable jacket extends past the point of the strain relief.
- For connector without a loading bar (see Figure 6-48-1), the secondary strain relief (see Figure 6-48-3) is crimped so that it is in contact with the insulation.

Defect – Class 1,2,3

- The primary strain relief is not in tight contact against the cable jacket or is not latched.
- The cable jacket does not extend past the primary strain relief.
- Wire ends (see Figure 6-48-2) are not within 0.5 mm [0.02 in] or less of the contact end wall or are not inserted past the terminal.
- All wire ends are not visible through the face of the connector.
- For connectors without loading bars, the secondary strain relief is not in contact with the wires or is not latched.
- The terminals are not crimped sufficiently and extend above the plane created by the top of the plastic dividers between the contacts.

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7 Ultrasonic Welding

In multiple wire applications, the operator should place smaller wires on the side of the bundle away from the welding horn.

The following topics are addressed in this section.

7.1 Insulation Clearance

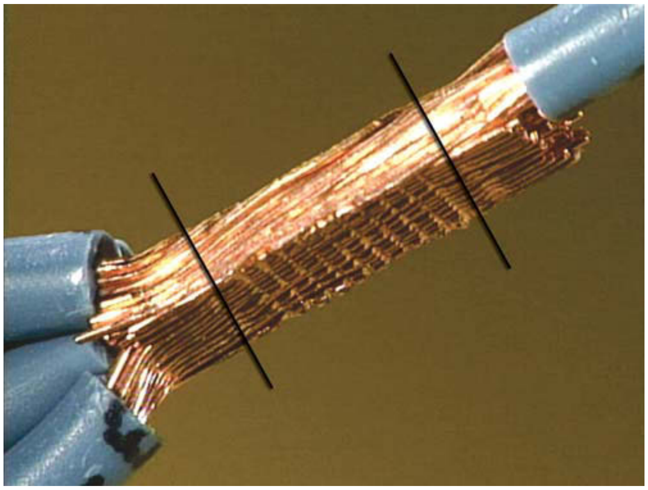

Figure 7-1

Acceptable – Class 1,2,3

- End of insulation is between one and two wire diameters from weld nugget.

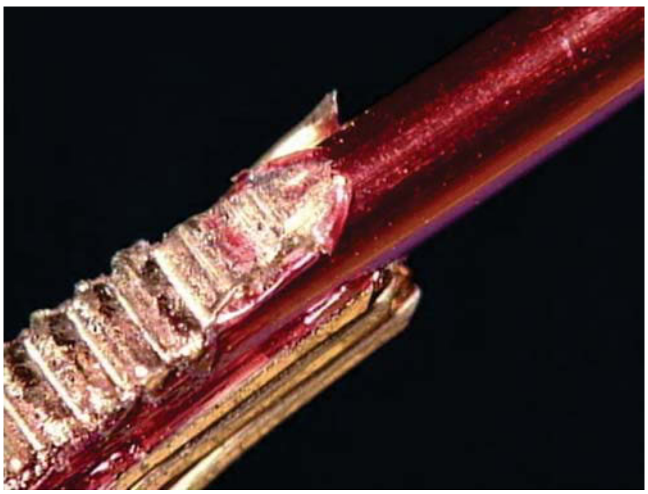

Figure 7-2

Defect – Class 1,2,3

- Insulation is embedded in weld nugget.
- Insulation gap is so large that it causes the conductor to violate minimum electrical spacing.

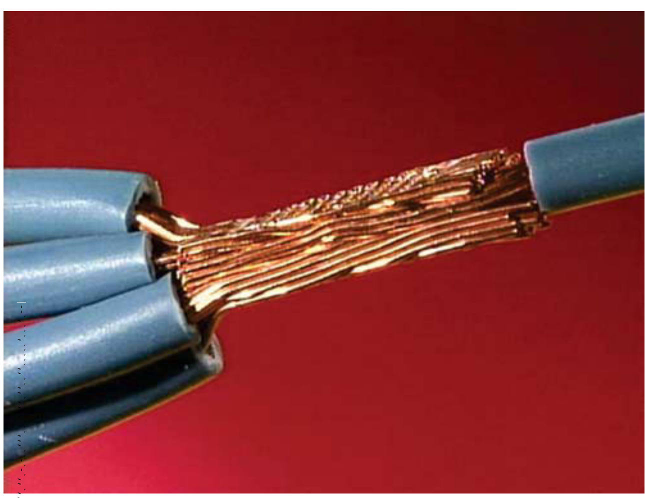

Figure 7-3

Defect – Class 2,3

- End of insulation is less than one wire diameter or more than two wire diameters from weld nugget.

7.2 Weld Nugget

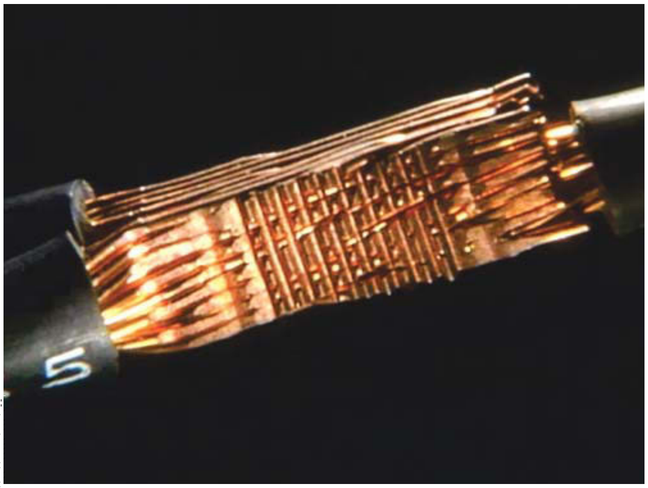

Figure 7-4

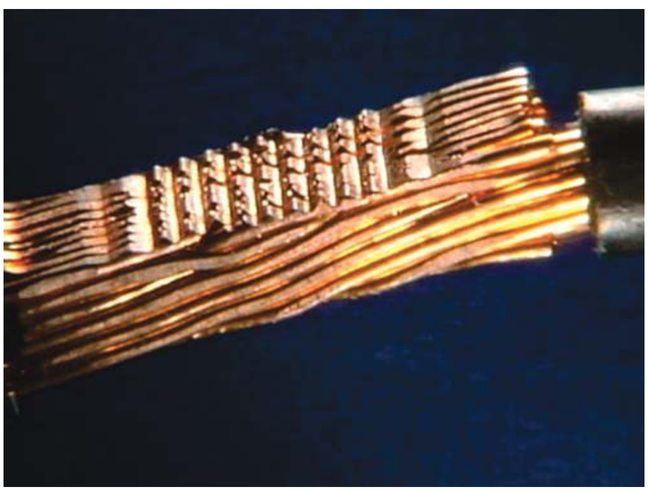

Figure 7-5

Acceptable – Class 1,2,3

- Nugget width to height ratio is at least 1 to 1 but does not exceed 2 to 1.
- Individual wire strands are not distinguishable on compression surfaces (top & bottom) of nugget.

7.2 Weld Nugget (cont.)

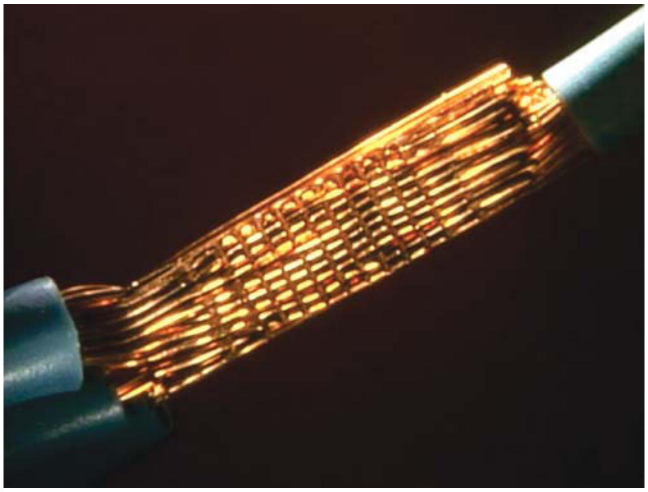

Figure 7-6

Acceptable – Class 1
Process Indicator – Class 2,3

- Individual wire strands are distinguishable on compression surfaces and there are no loose strands.

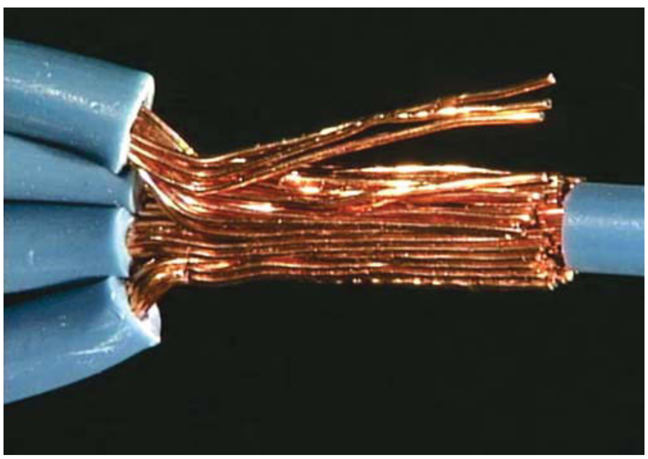

Figure 7-7

Defect – Class 1,2,3

- Any loose wire strands.
- Any discoloration of the conductors.
- Nugget width to height ratio is less than 1 to 1 or exceeds 2 to 1.

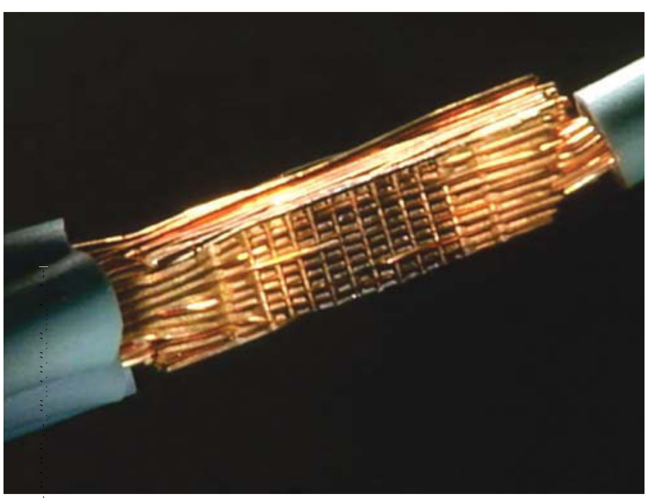

Figure 7-8

8 Splices

Splices **shall not [N1D2D3]** be used to repair broken or damaged conductors without end-user concurrence prior to the repair.

For the purposes of this section, the word ''sleeving'' is used to describe heat shrinkable tubing, tape, or any other insulation added to cover the spliced connection. Additional criteria for sleeving damage are provided in 16 (Cable/Wire Harness Protective Coverings).

Sleeving length should be sufficient to extend over the wire insulation on both sides of the spliced area as specified throughout this section. The recovered (shrunk) sleeve **shall [D1D2D3]** be snug (no lateral movement) to the wire splice and wire insulation maintaining sufficient sleeving thickness over the wire splice.

Position appropriate sleeving/tubing/wire designations over one end of the wires to be spliced for later use.

Wire splicing is used when replacing the entire length of a damaged wire is not feasible or when a self-lead component (inductor, transformer, choke, etc.) is installed (either during assembly or as a replacement for a failed component).

If possible, replace one end of the wire to limit the splice to just one splice. If necessary, replace one section of the wire, which may require two splices.

Splices **shall [N1N2D3]** be staggered within specified design limits.

There **shall [N1N2D3]** be no splices within two harness diameters of a breakout.

Splices **shall not [N1N2D3]** be placed where they may be exposed to tension, flexure or other stresses.

Heat shrinkable solder devices should not be used near optic or other sensor devices. Remaining flux residues can contaminate these devices, e.g., from outgassing.

If the splice has an insulation support the insulation support requirements of 5 (Crimp Terminations (Contacts and Lugs)) apply.

Users of this section should also refer to the following sections and clauses as applicable.

3 (Wire) Preparation

4.2 Cleanliness

4.3 Solder Connection

4.4 Wire/Lead Preparation, Tinning

4.5.2 Wire Insulation – Postsolder Damage

16.2 Sleeving/Shrink Tubing

8 Splices (cont.)

The following topics are addressed in this section.

8.1 Soldered Splices

Stranded wires **shall [N1D2D3]** be tinned when wires will be formed into splices (other than mesh) and optional (following device manufacturer's recommendations) when heat shrinkable solder devices are used.

Prior to sleeving, there **shall not [D1D2D3]** be any sharp points that could pierce the sleeving.

Sleeving **shall [D1D2D3]** conform to the splice contour and have a snug fit over the wire splice area and wire insulation. Sleeving **shall [D1D2D3]** cover wire insulation on both ends of the spliced area by a minimum of one diameter of the wire group.

When wires are tinned using alloys other than those listed in 4.1.1.1, the solder used for tinning **shall [N1N2D3]** be the same alloy that will be used in subsequent soldering processes (see 4.4).

Requirements in 3, 4.1 through 4.4, 4.5.2 and 16.2 are applicable to soldered wire splices.

The requirements in 8.1.4 and 8.1.5 also apply when soldering axial leaded components in-line into a harness or cable assembly.

8.1.1 Soldered Splices – Mesh

Mesh splices use the least amount of wire. Each wire should have insulation removed exposing from three to five wire diameters of the stranded wire. Splices **shall [D1D2D3]** be insulated with appropriate sleeving/tubing.

Wire strands **shall not [D1D2D3]** be pretinned. Wire strands **shall [D1D2D3]** be meshed together so the strands interlace evenly and are of equal length.

Figure 8-1

Acceptable – Class 1,2,3

- Interlocking of conductor strands into a smooth joined section for a minimum of three but not more than five wire diameters.
- Solder is wetted forming a visible solder fillet joining the wires for the length of the splice contact area.
- Individual wire strands are discernible.
- Conductor strands form a smooth joined section.
- Conductor strands are covered with sleeving.
- Sleeving is snug to the splice and wire insulation.
- No conductor strands piercing the sleeving.
- Sleeving covers wire insulation on both ends of the spliced area by a minimum of one wire diameter.
- Sleeve or wire insulation is slightly discolored but not charred.

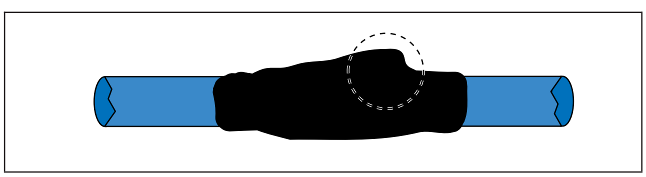

Figure 8-2

Process Indicator – Class 2,3

- Wire bulges the sleeving but does not pierce it.

8.1.1 Soldered Splices – Mesh (cont.)

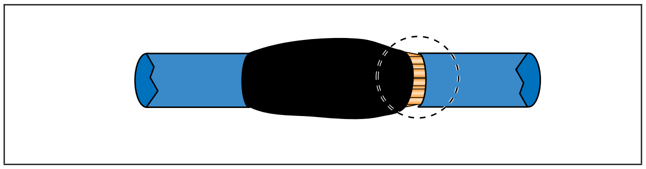

Figure 8-3

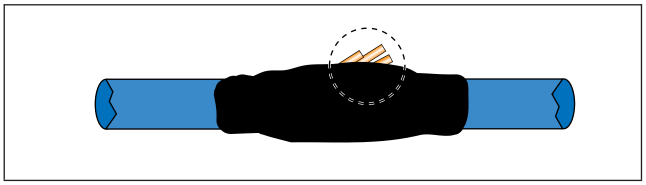

Figure 8-4

Defect – Class 1,2,3

- Conductor strands interlock less than three wire diameters.
- Insufficient solder fillet.
- Wire splice area is exposed.
- Sleeving is loose.
- Conductor strands or sharp points pierce the sleeving.
- Sleeving does not overlap wire insulation (on both ends) a minimum of one wire diameter.
- Sleeve or wire insulation is charred.
- Sleeving is split or damaged.

8.1.2 Soldered Splices – Wrap

Wrapped splices require a longer amount of wire to complete the splice. Strip wire to allow a minimum of three wraps (not twists) of each wire around the other.

Figure 8-5

Figure 8-6

Figure 8-7

Acceptable – Class 1,2,3

- Interlocking of two wires into a smooth joined section for a minimum of three wraps of each conductor.
- Solder is wetted forming a visible solder fillet joining the wires for the length of the splice contact area.
- Individual wire strands are discernible.
- Conductor strands form a smooth joined section.
- Conductor strands are covered with sleeving.
- Sleeving is snug to the splice and wire insulation.
- No conductor strands piercing the sleeving.
- Sleeving is not split or damaged.
- Sleeving covers wire insulation on both ends of the spliced area by a minimum of one wire diameter.
- Sleeve or wire insulation is slightly discolored but not charred.

8.1.2 Soldered Splices – Wrap (cont.)

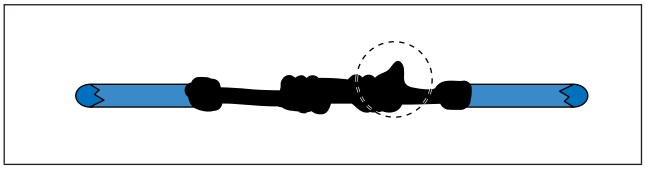

Figure 8-8

Process Indicator – Class 2,3

- Wire bulge in the sleeving does not pierce it.

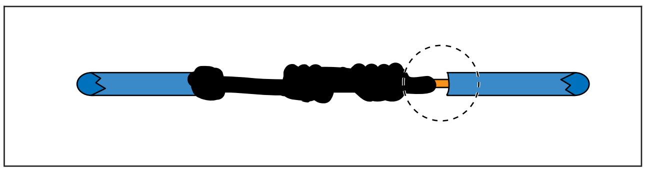

Figure 8-9

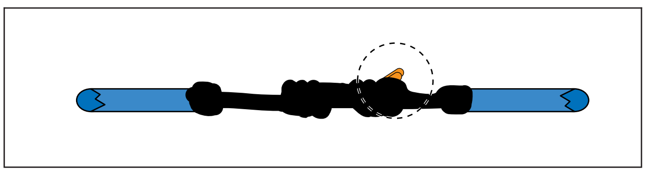

Figure 8-10

Defect – Class 1,2,3

- Less than three wraps of each conductor.
- Insufficient solder fillet.
- Wire splice area is exposed.
- Sleeving is loose.
- Conductor strands or sharp points pierce the sleeving.
- Sleeving does not overlap wire insulation (on both ends) a minimum of one wire diameter.
- Sleeve or wire insulation is charred.
- Sleeving is split or damaged.

8.1.3 Soldered Splices – Hook

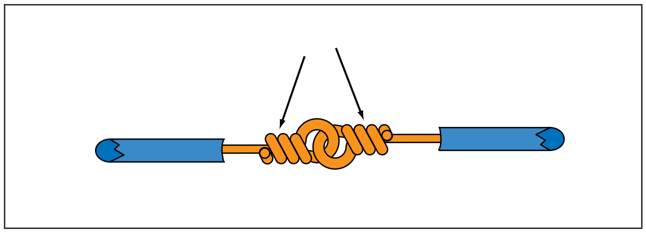

Figure 8-11

Acceptable – Class 1,2,3

- Interlocking of two conductors into a smooth joined section for a minimum of three wraps (see Figure 8-11, arrows).
- Solder is wetted forming a visible solder fillet joining the wires for the length of the splice contact area.
- Individual wire strands are discernible.
- Conductor strands form a smooth joined section.
- Conductor strands are covered with sleeving.
- Sleeving is snug to the splice and wire insulation.
- No conductor strands piercing the sleeving.
- Sleeving is not split or damaged.
- Sleeving covers wire insulation on both ends of the spliced area by a minimum of one wire diameter.
- Sleeve or wire insulation is slightly discolored but not charred.

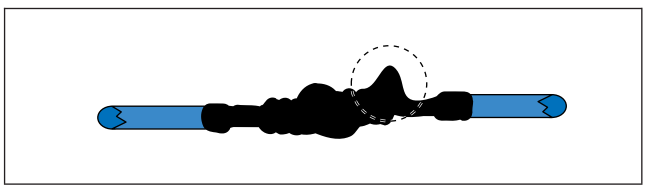

Figure 8-12

Process Indicator – Class 2,3

- Wire bulges the sleeving but does not pierce it.

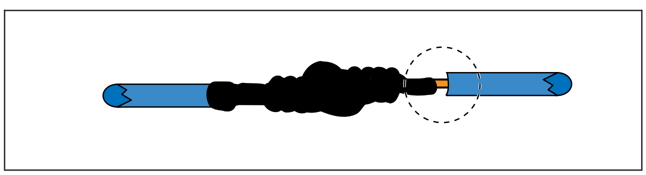

Figure 8-13

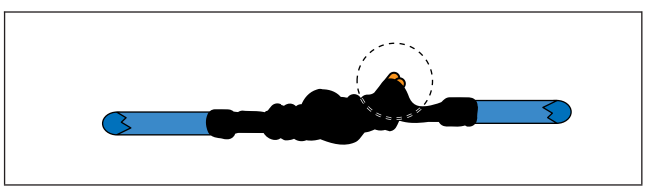

Figure 8-14

Defect – Class 1,2,3

- Less than three wraps of each conductor.
- Insufficient solder fillet.
- Wire splice area is exposed.
- Sleeving is loose.
- Conductor strands or sharp points pierce the sleeving.
- Sleeving does not overlap wire insulation (on both ends) a minimum of one wire diameter.
- Sleeve or wire insulation is charred.
- Sleeving is split or damaged.

8.1.4 Soldered Splices – Lap

The criteria in this section are applicable to hand soldered in-line lap splices, where two or more conductors overlap, are parallel and soldered. These criteria apply to in-line wire lap splices (see Figure 8-15) or end lap splices (see Figure 8-17) showing optional lash splice. Requirements are the same for either type of lap splice except as noted.

See 8.1.5 for lap splices formed with heat shrinkable solder devices.

This type of splice requires a minimal amount of wire. Wire ends **shall [D1D2D3]** be stripped so the wires overlap a minimum of three conductor diameters of the largest wire (see Figure 8-15). Conductors **shall not [N1D2D3]** overlap the insulation of the other wire.

While overwrapping of a lap splice with a smaller diameter wire (see Figure 8-16), referred to as a lash splice, does not provide a significant increase in strength to the connection, it may facilitate forming the splice. The number and spacing of turns used to hold the lapped wires in place during soldering is optional. For Class 3 products, the option to wrap a lap splice or not is at the design level. Lash splices **shall [N1N2D3]** be performed only as required on the engineering drawing.

Solder **shall [D1D2D3]** wet all elements of the required termination fillet. Individual wire strands should remain discernible.

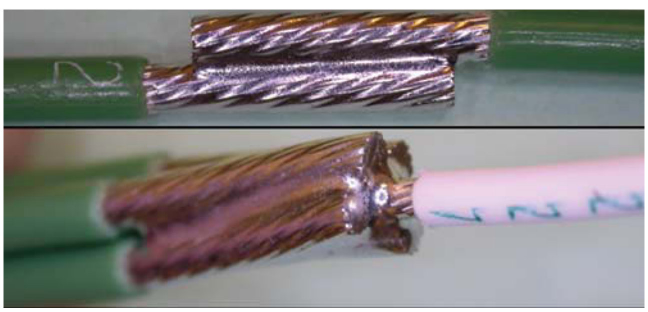

Figure 8-15

8.1.4.1 Soldered Splices – Lap – Two or More Conductors

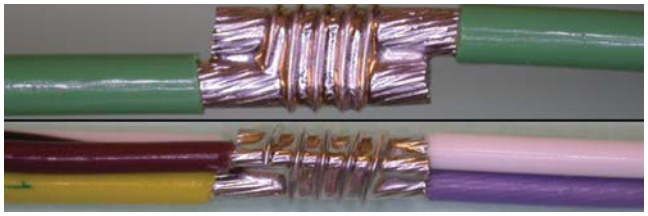

Figure 8-16

Figure 8-17

Figure 8-18

Figure 8-19

Figure 8-20

Figure 8-21

Acceptable – Class 1,2,3

- Wires overlap at least three conductor diameters of the largest wire.
- If required, splice is overwrapped with smaller diameter wire (see Figures 8-16, 17).
- Conductor strands form a smooth joined section.
- Solder is wetted forming a visible solder fillet joining the conductors for the length of the splice contact area.
- Individual conductor strands are discernible.
- Conductor strands are covered with sleeving.
- Sleeving is snug to the splice and wire insulation.
- No conductor strands piercing the sleeving.
- Sleeving is not split or damaged.
- Sleeving overlaps the wire insulation on both ends of the spliced area by a minimum of one wire group (largest group) diameter (see Figures 8-18, 20).
- The sleeving or insulation may be discolored but not charred.
- End splice insulating shrink sleeving is less than two wire group diameters beyond the cut end and is sealed (see Figure 8-19).
- End splice insulating shrink sleeving is greater than two wire group diameters beyond the cut end (see Figure 8-21).

8.1.4.1 Soldered Splices – Lap – Two or More Conductors (cont.)

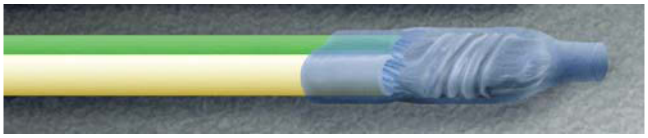

Figure 8-22

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- End splice insulating shrink sleeving is not sealed when it is less than two wire group diameters beyond the cut end (see Figure 8-22).

Figure 8-23

Process Indicator – Class 2,3

- Wire bulges the sleeving but does not pierce it.

Figure 8-24

Process Indicator – Class 2
Defect – Class 3

- Conductors are not in full contact or are not parallel.

Defect – Class 1

- No evidence of solder wetting.

Defect – Class 2

- Solder fillet less than 75% of the length of the overlap interface.

Figure 8-25

Defect – Class 3

- Solder fillet less than 75% of the length of the overlap interface or three conductor diameters of the largest wire, whichever is greater.

8.1.4.1 Soldered Splices – Lap – Two or More Conductors (cont.)

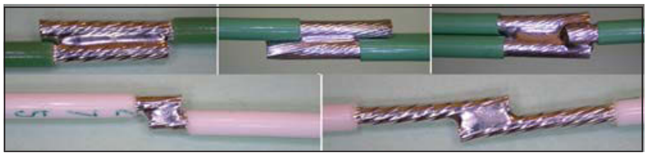

Figure 8-26

Figure 8-27

Figure 8-28

Defect – Class 1,2,3

- End splice insulating shrink sleeving overlaps the wire insulation less than one diameter of wire group (not shown).
- Wires do not overlap a minimum of three conductor diameters of the largest wire.
- Conductor overlaps insulation of the other wire.
- Insufficient solder fillet.
- Wire splice area is exposed (see Figure 8-28).
- Sleeving is loose (not shown).
- Conductor strands or sharp points pierce the sleeving.
- Sleeving does not overlap the wire insulation on both ends of the spliced area by a minimum of one wire group (largest group) diameter.
- Sleeve or wire insulation is charred.
- Sleeving is split or damaged (see Figure 8-27).

8.1.4.2 Soldered Splices – Lap – Insulation Opening (Window)

This splice is accomplished by removing a section of wire insulation creating an opening (window) in the insulation.

Figure 8-29

Acceptable – Class 1,2,3

- The wire opening (window) is slightly larger than the stripped portion of the pickoff wire.
- Conductor is not damaged beyond the limits of 3.2.
- Insulation is not damaged beyond the limits of 3.5.

Defect – Class 1,2,3

- The wire opening (window) is shorter in length than the stripped portion of the pickoff wire.
- Conductor is damaged beyond the limits of 3.2.
- Insulation is damaged beyond the limits of 3.5.

8.1.5 Soldered Splices – Heat Shrinkable Solder Devices

When heat shrinkable soldering devices are used the solder preform (ring) **shall [D1D2D3]** be completely melted and a solder fillet **shall [D1D2D3]** wet to the wires in the connection. Wire contour should be visible in the solder fillet.

When heat shrinkable soldering devices are used, the solder preform (ring) and pickoff wire should be centered in the wire insulation opening (window) then shrunk in place. Self sealing heat shrinkable solder devices are exempt from cleaning requirements.

A thermal indicator (if provided) is an aid for deciding when to stop heating. Its presence or absence in the installed part is not reason for rejection of the installation.

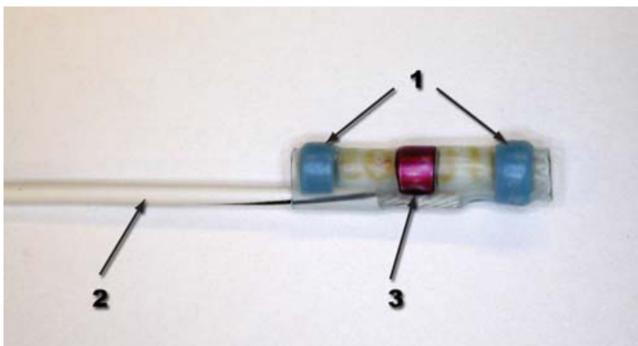

Figure 8-30
1. **Meltable Sealing Ring(s)**
2. **Pickoff Wire**
3. **Solder Preform (solder ring) with thermal indicator (red)**

Figure 8-31

Figure 8-32

Acceptable – Class 1,2,3

- Wires overlap for at least three conductor diameters and are approximately parallel.
- The solder preform (ring) is centered over the splice.
- Solder preform has fully melted and forms a fillet joining both wires.
- Conductor contour is discernible.
- Sleeving covers wire insulation on both ends of the spliced area by a minimum of one wire diameter.
- No conductor strands piercing the sleeving.
- Sleeve is discolored but not charred.
- Meltable sealing ring does not interfere with formation of required solder connection.
- Meltable sealing ring provides 360° of seal at both ends.
- No wire strands are exposed.
- Sleeve is not split or damaged.
- Sleeve conforms to the contour of the lead and the cable.

Process Indicator – Class 2,3

- Wire bulges the sleeving but does not pierce it.

8.1.5 Soldered Splices – Heat Shrinkable Solder Devices (cont.)

Figure 8-33

Figure 8-34

Figure 8-35

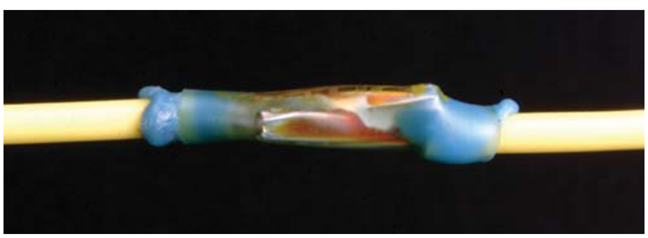

Figure 8-36

Defect – Class 1,2,3

- Solder fillet not wetted to both wires (see Figure 8-34).
- The solder preform ring is not fully melted (see Figures 8-33, 34).
- There are sharp points or projections (not shown).
- Conductor strands pierce the sleeving (not shown).
- Wires do not overlap at least three conductor diameters (not shown).
- Sleeving does not cover wire insulation on both ends at least one wire diameter (see Figure 8-35).
- Meltable sealing ring interferes with formation of required solder connection (not shown).
- Meltable sealing ring does not provide 360° of seal at either end (not shown).
- Sleeving or wire insulation is charred (not shown).
- Conductor overlaps insulation of the other wire (see Figure 8-36).
- No visible fillet between the wire and pickoff lead (not shown).
- Conductor contour is not discernible (not shown).
- Wire strands are exposed (not shown).
- Solder has flowed beyond the meltable sealing rings or has extruded beyond the end of the heat shrinkable sleeving (not shown).
- Sleeve does not conform to the contour of the lead and the cable (not shown).

8.2 Crimped Splices

General crimping requirements in 5 ((Crimp Terminations (Contacts and Lugs)) **shall [D1D2D3]** apply when using crimp splices. When attaching multiple wires to a single terminal, each wire **shall [D1D2D3]** meet the same acceptability criteria as a single wire termination. When attaching single or multiple wires to a terminal, the combined circular mil area (CMA) of the wires **shall [D1D2D3]** comply with the CMA range for the terminal.

8.2.1 Crimped Splices – Barrel

The criteria in this section are applicable to crimped in-line splices, where two or more conductors overlap, are parallel and crimped inside a sleeve. These criteria apply to in-line splices (see Figure 8-37) or end lap splices (see Figure 8-38). Requirements are the same for either type of lap splice except as noted.

This type of splice requires a minimal amount of wire. Wire ends **shall [D1D2D3]** be stripped so the wires overlap a minimum of three conductor diameters. Conductors should be in full contact and parallel (no twisting of the conductors). Conductors **shall not [N1D2D3]** overlap the insulation of the other wire.

16.2 provides criteria for shrink sleeving.

8.2.1 Crimped Splices – Barrel (cont.)

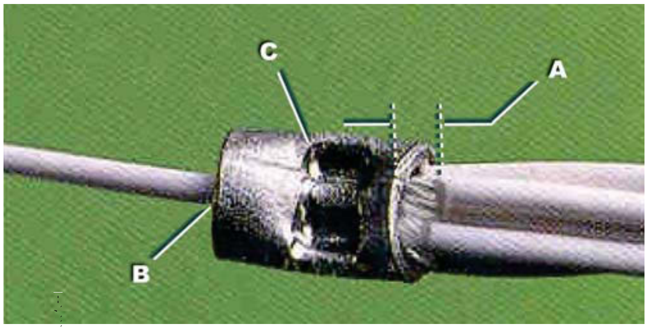

Figure 8-37

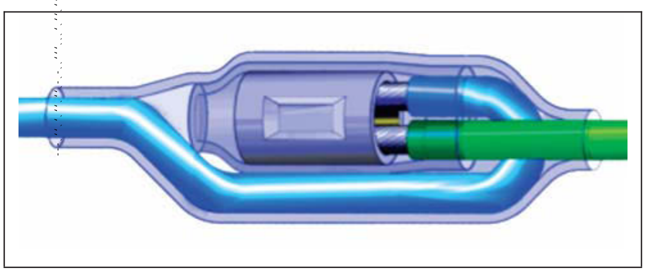

Figure 8-38

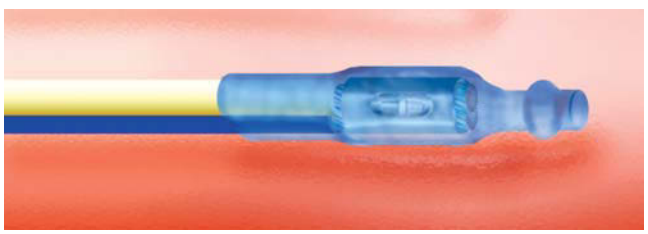

Figure 8-39

Acceptable – Class 1,2,3

- Bare wire end is less than flush, but is visible and included in crimp indentation (see Figure 8-37-B).
- Crimp not centered but bellmouth is evident at each end and ends of all conductors are visible (see Figure 8-37-C).
- Barrel splice is not cracked.
- When required, sleeving overlaps the wire insulation at least one wire group diameter on both sides of the barrel splice.
- End splice insulating shrink sleeving is less than two wire group diameters beyond the cut end and is sealed (see Figure 8-39).
- End splice insulating shrink sleeving is greater than two wire group diameters beyond the cut end (not shown).
- Does not violate minimum electrical clearance.

Acceptable – Class 1
Process Indicator – Class 2,3

- Heat shrinkable sleeve is not centered yet sleeve ends fit snugly to the wire insulation.

Acceptable – Class 1,2

- Wire insulation gap is within two wire diameters.
- Conductor ends extend no more than two wire diameters beyond crimp barrel.

Process Indicator – Class 3

- Wire insulation gap is more than one but less than two wire diameters (see Figure 8-37-A).
- Conductor ends extend more than one but less than two wire diameters beyond crimp barrel.

8.2.1 Crimped Splices – Barrel (cont.)

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- End splice insulating shrink sleeving is not sealed when it is less than two wire group diameters beyond the cut end.

Figure 8-40

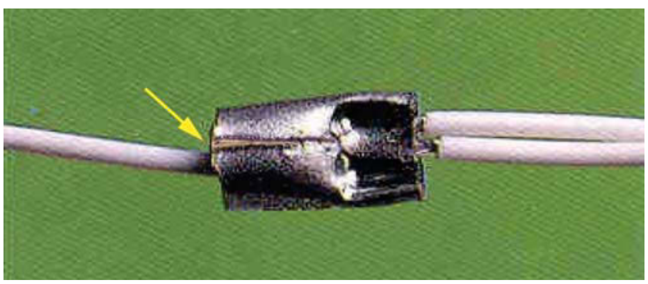

Figure 8-41

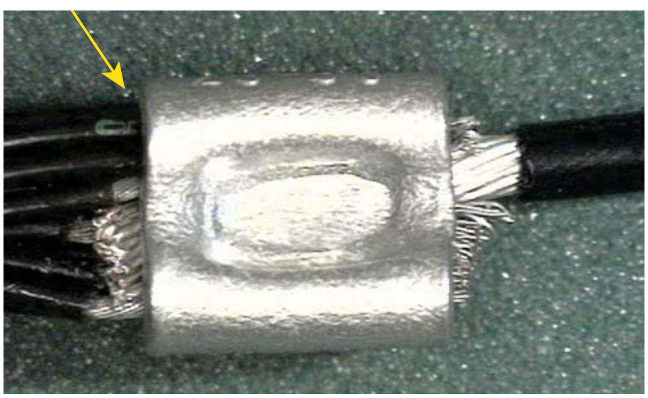

Figure 8-42

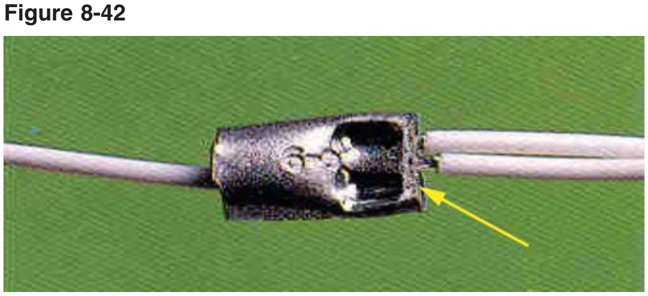

Figure 8-43

Defect – Class 1,2,3

- End splice insulating shrink sleeving overlaps the wire insulation less than one diameter of the wire group.
- Insulation gap exceeds two wire diameters (see Figure 8-40).
- Conductors extend greater than two wire diameters beyond crimp barrel.
- Wire insulation extends into barrel splice crimp (see Figure 8-42, arrow).
- Barrel splice is cracked (see Figure 8-41, arrow).
- Crimp indentation is off the end of the barrel splice, bell mouth is not evident (see Figure 8-43, arrow).
- Wires are not contained in the crimp.
- Conductors twisted together before insertion into the contact.
- Ends of all conductors are not visible.
- When required, sleeving does not overlap the wire insulation at least one wire/bundle diameter on both sides of the barrel splice.
- When required, sleeving is missing.

8.2.2 Crimped Splices – Double Sided

Figure 8-44 identifies the inspection windows (A) and bellmouths (B).

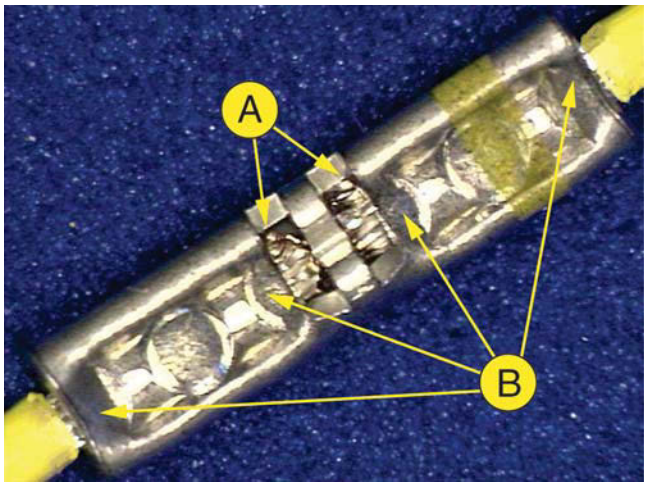

Figure 8-44

8.2.2 Crimped Splices – Double Sided (cont.)

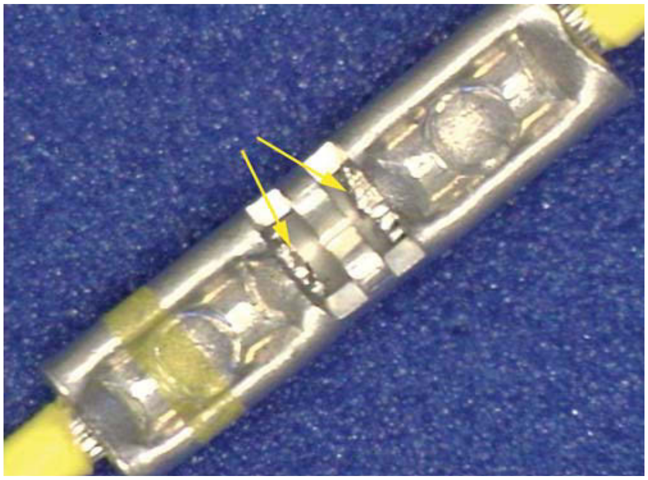

Figure 8-45

Figure 8-46

Figure 8-47

Acceptable – Class 1,2

- Wire insulation gap is less than two wire diameters at both ends.

Acceptable – Class 1,2,3

- Ends of wires are visible through the inspection window (see Figure 8-45, arrows).
- Bellmouth is evident.
- Heat shrinkable sleeve ends are sealed to the wire insulation (no wire strands are exposed) when heat shrinkable sleeving has sealing rings.
- For seamless splices, crimp indents are rotated (see Figure 8-47).
- Crimps are approximately centered and properly formed to retain wires.

8.2.2 Crimped Splices – Double Sided (cont.)

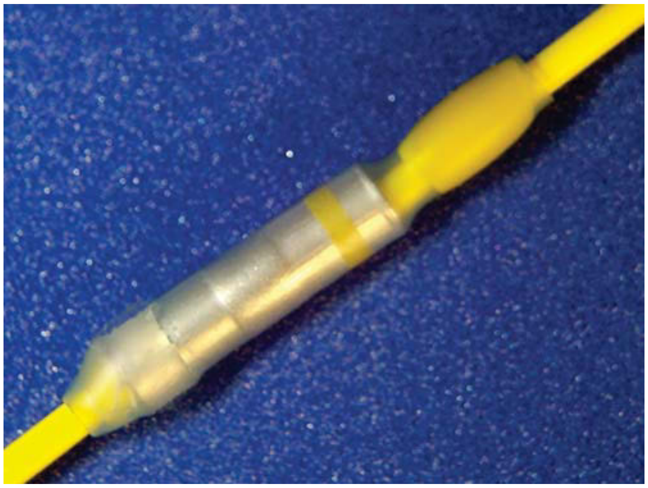

Figure 8-48

Acceptable – Class 1
Process Indicator – Class 2,3

- Heat shrinkable sleeve with sealing rings is not centered yet sleeve ends are sealed to the wire insulation (see Figure 8-48).

Process Indicator – Class 3

- Wire insulation gap is greater than one but less than two wire diameters at either end.

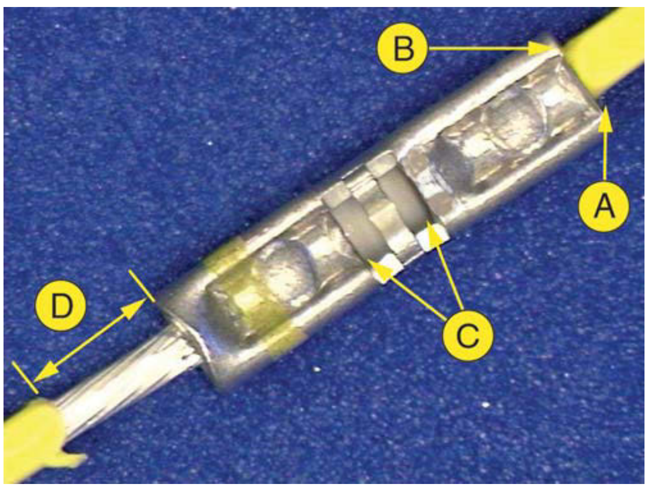

Figure 8-49

Figure 8-50

Figure 8-51

Defect – Class 1,2,3

- Double sided crimp splice is cracked (not shown).
- Wire insulation extends into the wire crimp barrel (see Figure 8-49-A).
- Crimp indent is off the end of the splice (see Figure 8-49-B).
- Wire end(s) are not visible through the inspection window(s) (see Figure 8-49-C).
- Wire insulation gap is greater than two wire diameters including insulation (see Figure 8-49-D).
- Sleeving, if required, does not overlap wire insulation at least one wire diameter on both ends (not shown).
- Wire strands extend out of inspection window (see Figure 8-50).
- Wire strands have pierced the heat shrinkable sleeve (see Figure 8-51).
- Multiple conductors twisted together before insertion into the crimp barrel (not shown).
- Heat shrinkable sleeves with meltable sealing rings do not provide 360° of seal at both ends (not shown).

8.2.3 Crimped Splices – Contact

These criteria apply to crimped end lap splices formed in a machined contact (see Figure 8-52). When attaching multiple wires to a terminal, the combined CMA of the wires **shall [D1D2D3]** comply with the CMA range for the terminal.

5.3 provides criteria for wire barrel crimp and CMA buildup.

16.2 provides criteria for shrink sleeving.

Figure 8-52

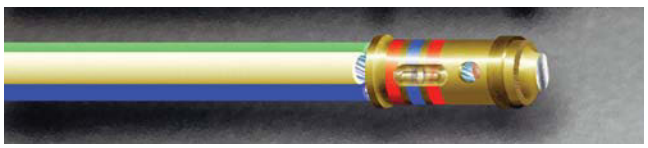

Figure 8-53

Acceptable – Class 1,2,3

- End splice insulating shrink sleeving is less than two wire group diameters beyond the cut end and is sealed.
- End splice insulating shrink sleeving is greater than two wire group diameters beyond the cut end.
- Machined contact pin cut end is insulated with shrink sleeving or cap.
- Machined contact is not cracked after cutting off pin.
- Wire insulation is flush to the end of the contact barrel.
- Conductors visible between the insulation and contact barrel but no greater than one wire diameter.
- The crimp is not centered and the inspection window is not deformed.
- The wire entry end of the barrel is not deformed by the crimp.

8.2.3 Crimped Splices – Contact (cont.)

Figure 8-54

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- End splice insulating shrink sleeving or cap is not sealed when it is less than two wire group diameters beyond the cut end.

Acceptable – Class 1
Process Indicator – Class 2,3

- Wire insulation is greater than one but less than two wire diameters from the end of the contact barrel.

Defect – Class 2,3

- Contact has visible fractures, cracks, or exposed basis metal in the crimp barrel area.

Defect – Class 1,2,3

- Machine contact pin is not cut.
- Machine contact is cracked after cutting off pin.
- Wire insulation is greater than two wire diameters from the end of the contact barrel.
- End splice insulating shrink sleeving or cap overlaps the wire insulation less than one diameter of the wire group.

8.2.4 Crimped Splices – Wire In-Line Junction Devices (Jiffy Junctions)

Wire in-line junction devices, sometime referred to as ''Jiffy Junctions,'' are essentially feed through environmentally resistant disconnect components for joining wires. Crimp contacts are terminated onto conductors (see Figure 8-55) and then inserted into the in-line junction device as it would be with a rear-entry machined contact connector (see Figure 8-56) shown in cross-section).

The tooling, tooling verification, crimping processes, and completed terminations **shall [D1D2D3]** comply with the requirements for tool control and machined contact crimped terminations in 1 (General), 5 (Crimp Terminations (Contacts and Lugs)) and 19 (Testing).

When the CMA of the conductor needs to be built up so that it falls within the minimum and maximum CMA range of the contact, CMA buildup **shall [D1D2D3]** be in accordance with 5.3.5.

As an exception to 9.5.2, when a sealing plug is required it **shall [D1D2D3]** be inserted shaft first.

Figure 8-55

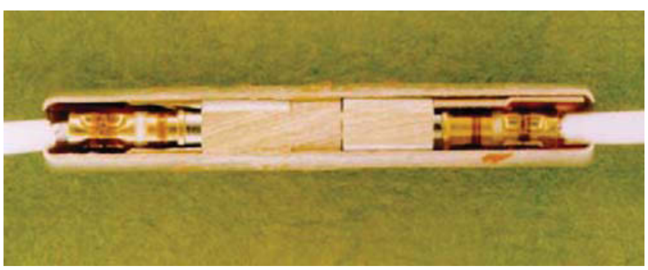

Figure 8-56

8.2.4 Crimped Splices – Wire In-Line Junction Devices (Jiffy Junctions) (cont.)

Defect – Class 1,2,3

- Multiple wire attachments, when used, do not meet the requirements of 5.3.
- Insulation clearance does not meet the requirements of 5.3.1.
- The conductor location does not meet the requirements of 5.3.3.
- Crimping does not meet the requirements of 5.3.4.
- CMA buildup, when used, does not meet the requirements of 5.3.5.
- Contact installation does not meet the requirements of 9.5.
- Qualification of crimped connection fails Pull Force/Tensile Test per 19.7.2.
- Mated assembly fails Pull Test Contact Retention Verification Test per 19.7.5.

8.3 Ultrasonic Weld Splices

Refer to 7 (Ultrasonic Welding) for ultrasonic splice requirements.

9 Connectorization

When torque requirements are established, see 17.2.

The following topics are addressed in this section.

9.1 Hardware Mounting

9.1.1 Hardware Mounting – Jackpost – Height

This section covers the height relationship of the face of the jackpost to the associated connector face. This is critical to obtain maximum connector pin contact.

Assembly **shall [D1D2D3]** meet the connector manufacturer's instructions.

Note: ''C'' style retaining clips will add the thickness of the clip to the jackpost height.

Note: A trial mating of connector to connector or to assembly may be required to assure the connectors meet form, fit and function requirement.

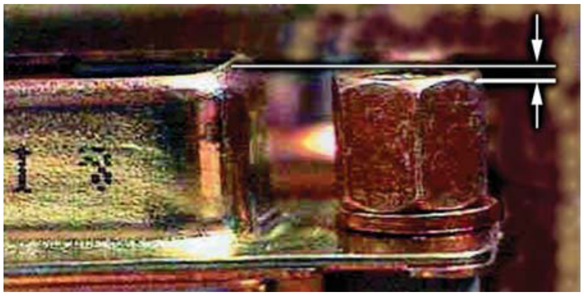

Figure 9-1

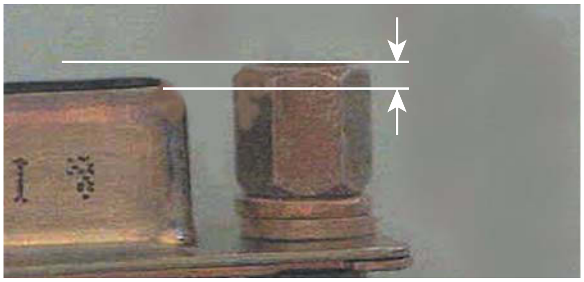

Figure 9-2

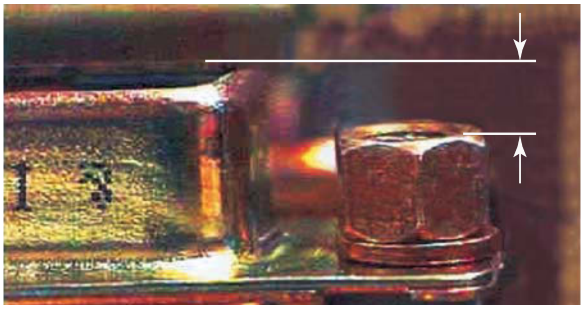

Figure 9-3

Acceptable – Class 1,2,3

- The jackpost can be above or below the face of the connector, depending on the design, providing the connector and jackposts mate correctly.
- Height is obtained by adding or removing washers in accordance with manufacturer's instructions.

Defect – Class 1,2,3

- The jackposts are above or below the face of the connector, depending on the design, and the connector and jackposts do not mate correctly (not shown).

9.1.2 Hardware Mounting – Jackscrews – Protrusion

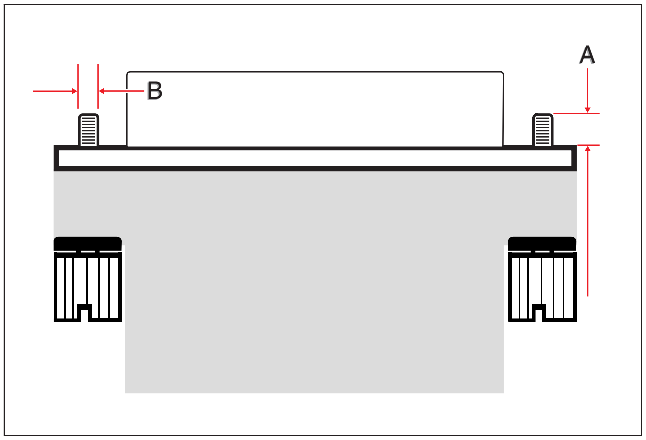

Figure 9-4

Acceptable – Class 1,2,3

- On jackscrew hardware the minimum thread protrusion (see Figure 9-4-A) is one and one-half (1.5) screw diameters (see Figure 9-4-B) but does not extend beyond the face of the connector.

Defect – Class 1,2,3

- On jackscrew hardware the minimum thread protrusion (see Figure 9-4-A) is less than one and one-half (1.5) screw diameters (see Figure 9-4-B) or extends beyond the face of the connector.

9.1.3 Hardware Mounting – Retaining Clips

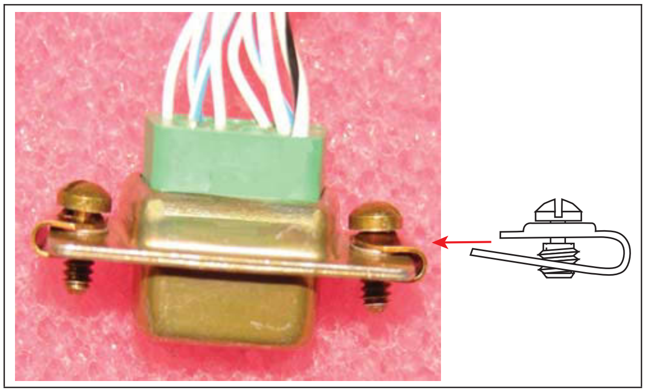

Figure 9-5

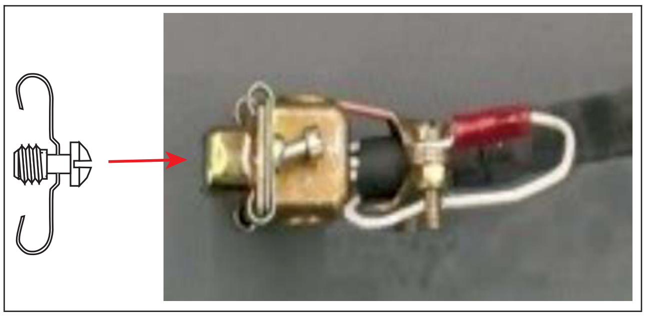

Figure 9-6

Acceptable – Class 1,2,3

- Retaining clip is properly oriented.
- Screw is completely through threaded portion of the clip.

Figure 9-7

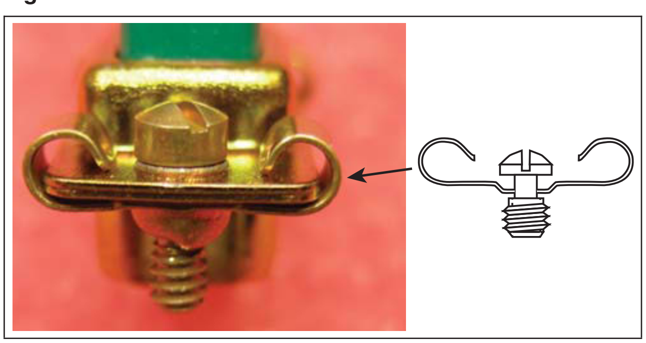

Figure 9-8

Defect – Class 1,2,3

- Retaining clip is improperly oriented (threaded side of clip is on the mating side of connector flange).
- Screw is not completely through the threaded device.

9.1.4 Hardware Mounting – Connector Alignment

When torque requirements are established, see 17.2.

When the connector/backshell/accessory uses teeth to interlock the mating surfaces, the connector assembly procedures **shall [D1D2D3]** include a process that ensures the teeth are fully engaged prior to tightening. Figure 9-9 shows an acceptable mating where the alignment teeth are fully engaged. Figure 9-10 shows two examples of teeth that are not fully engaged. The locking ring is removed in these illustrations to show the condition; the interlocking teeth are not visually inspectable.

Figure 9-9

Figure 9-10

9.2 Strain Relief

9.2.1 Strain Relief – Clamp Fit

Clamps, as specified on the engineering drawing, **shall [D1D2D3]** support cables, harnesses or individual wires to prevent wire movement that may place strain on the wire/connector terminations. Split lock washers incorporated as part of the backshell or strain relief clamp **shall [D1D2D3]** be fully compressed.

If the number of wires terminating into the connector is insufficient to allow the strain relief clamp to grip the wires properly, then insulating tape, sleeving or a grommet of an approved material **shall [D1D2D3]** be used to ''build-up'' the bundle diameter to provide contact and support between the cable and the strain relief clamp. The build-up material may also be required to provide protection of the insulated wires from damage caused by the connector clamp.

Build up material is referred to as ''sleeving'' in the following criteria. The sleeving criteria apply only when such material is applied to the wire bundle. Build-up material, when used, **shall [D1D2D3]** be as specified on engineering documentation.

Spacers, when used, **shall [N1D2D3]** be as specified on engineering documentation.

Clamps **shall [D1D2D3]** be tightened to secure the jacket, wires, or bundle but do not need to be fully closed (touching the tangs/ears of the backshell).

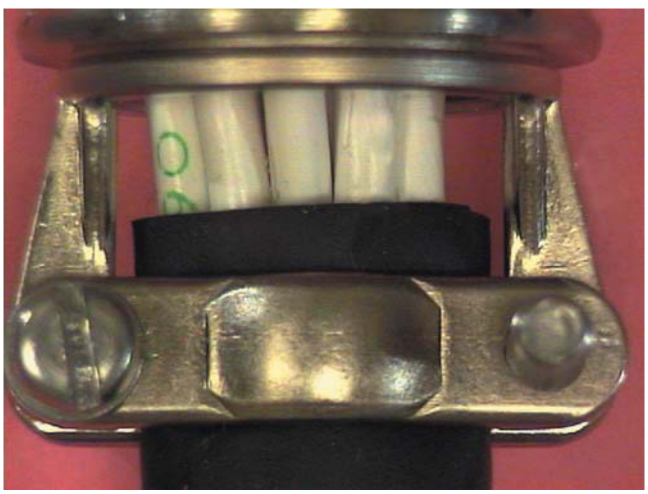

Figure 9-11

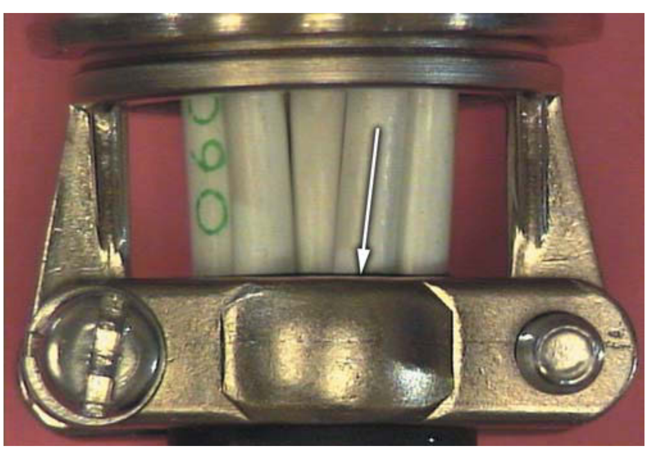

Figure 9-12

Acceptable – Class 1,2,3

- Sleeving is at minimum flush with the end of clamp (see Figure 9-12, arrow).
- Spacers, if present, are mounted under the same adapter on both sides of the cable.
- Space between the inner surfaces of the clamps and the connector backshell ears is approximately equal.

9.2.1 Strain Relief – Clamp Fit (cont.)

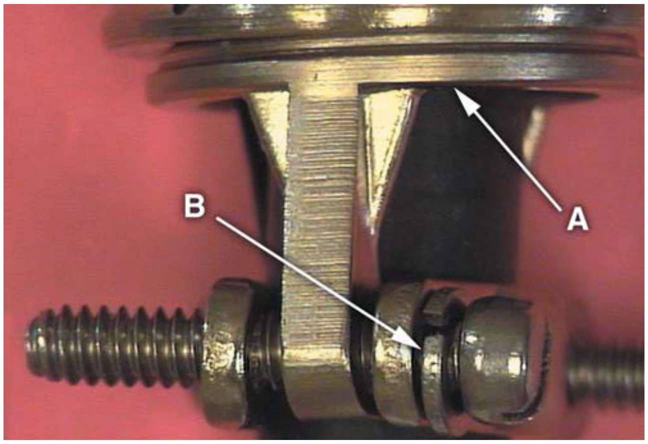

Figure 9-13

Figure 9-14

Defect – Class 1,2,3

- Sleeving does not extend through the clamp to be at minimum flush with the inside edge of the clamp.
- Sleeving extension beyond clamp causes stress on the wires (see Figure 9-13-A).
- The split lock washers are not collapsed (see Figure 9-13-B).
- Clamps do not captivate and support the cable.
- Clamps do not prevent movement of the cable.
- Damage to sleeving that exposes the harness or other protected material (see Figure 9-14).
- Spacers, if required, are not present or are not mounted under the same adapter clamp on both sides of the cable.
- Splice or ferrule located under the backshell clamp.

Note: Some end-use environments, e.g., high vibration, may require the use of buildup spacers to eliminate any gaps. Such requirements will be noted on the documentation.

9.2.2 Strain Relief – Wire Dress

Wire dress depends on the connector design, direction that wires are required to exit, and the amount of movement that may be required in the connector.

9.2.2.1 Strain Relief – Wire Dress – Straight Approach

Figure 9-15

Acceptable – Class 1,2,3

- Wires exit approximately perpendicular to connector.
- Wires are not stressed.

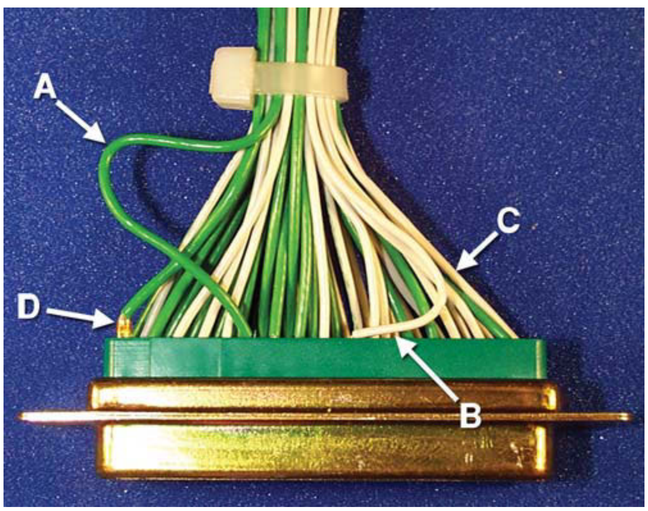

Figure 9-16

Process Indicator – Class 2
Defect – Class 3

- Wire length is outside the contour of the wire bundle (see Figure 9-16-A).

Defect – Class 2,3

- Wire exits connector at a sharp angle (see Figure 9-16-B).

Defect – Class 1,2,3

- Wire is stressed (no freedom of movement) (see Figure 9-16-C).

Note: See 9.5.1 for criteria related to contact not seated (see Figure 9-16-D).

9.2.2.2 Strain Relief – Wire Dress – Side Approach

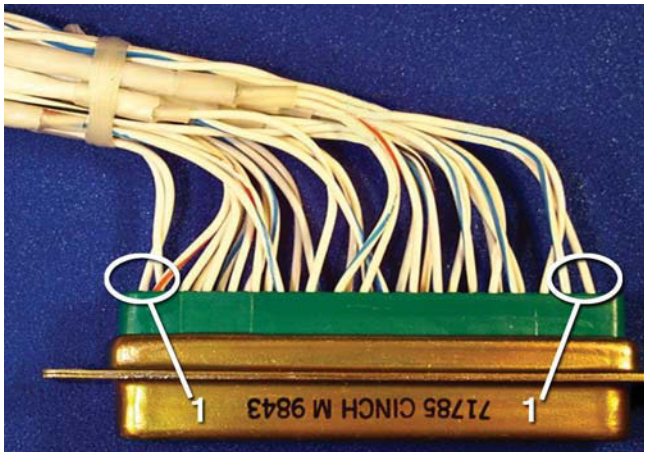

Figure 9-17
1. High stress areas

Acceptable – Class 1,2,3

- Wires exit approximately perpendicular to connector.
- Wires are not stressed.
- Ties do not stress wires.

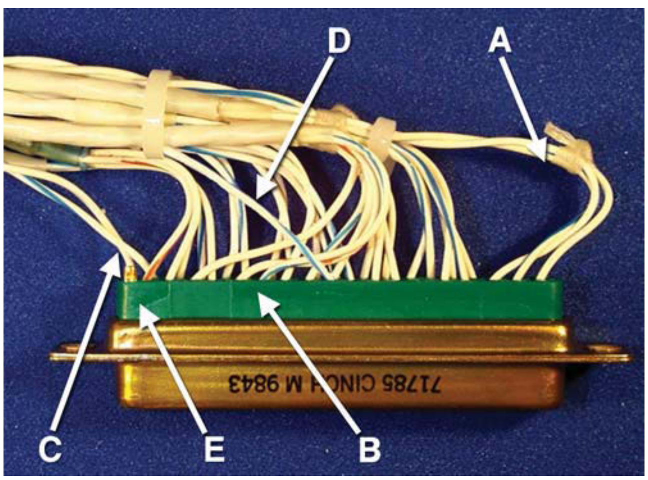

Figure 9-18

Process Indicator – Class 2
Defect – Class 3

- Wire length is outside the contour of the wire bundle (see Figure 9-18-A).

Defect – Class 2,3

- Wire exits connector at a sharp angle (see Figure 9-18-B).

Defect – Class 1,2,3

- Wire is stressed (no freedom of movement) (see Figure 9-18-C, D).

Note: See 9.5.1 for criteria related to contact not seated (see Figure 9-18-E).

9.3 Sleeving and Boots

9.3.1 Sleeving and Boots – Position

Criteria apply to both adhesive and nonadhesive lined boots.

Figure 9-19

Figure 9-20

Acceptable – Class 1,2,3

- Boot is shrunk over threaded adapter ring.
- Boot does not interfere with locking ring.

Not Established – Class 1
Process Indicator – Class 2
Defect – Class 3

- Boot does not extend to the end of the first accessory attachment area.

Figure 9-21

Defect – Class 2,3

- Boot overlap of cable sleeving or jacket is insufficient to prevent exposure of wires or braid when flexed.

Defect – Class 1,2,3

- Boot interferes with locking ring.

9.3.2 Sleeving and Boots – Bonding

When conductive adhesive is required in the assembly process, separate testing **shall [D1D2D3]** be accomplished to assure that the resultant conductive path is acceptable.

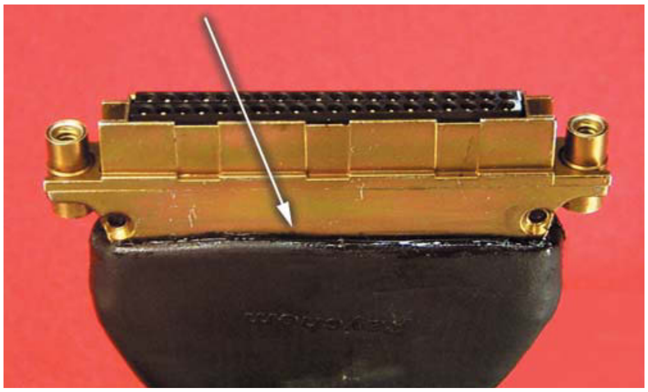

Figure 9-22

Figure 9-23

9.3.2 Sleeving and Boots – Bonding (cont.)

Figure 9-24

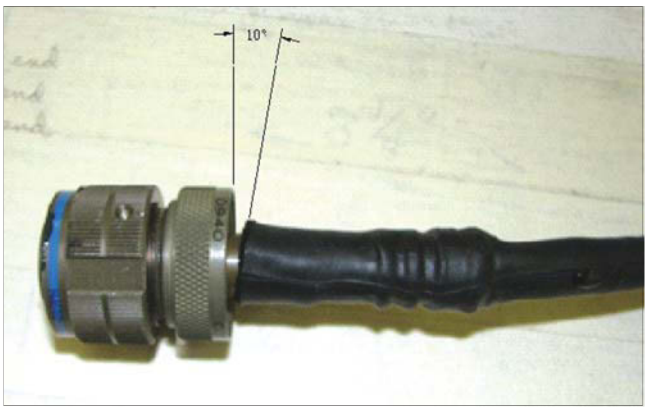

Figure 9-25

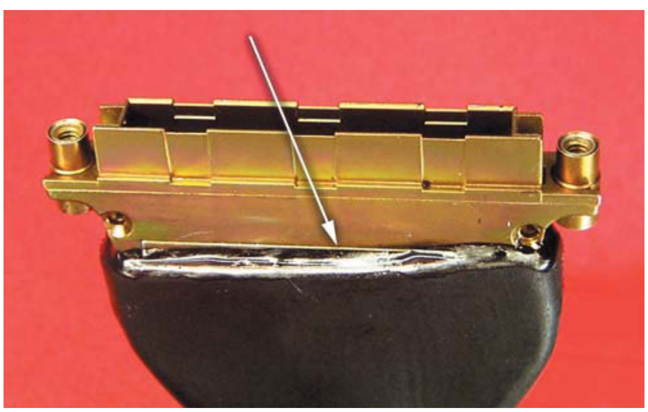
Figure 9-26


Figure 9-27

Acceptable – Class 1,2,3

- The boot is within 10° of parellel to the connector face in both axes (see Figures 9-24, 25).
- The boot is bonded to the connector on all sides, and the structural adhesive is visible; pin-holes with a visible bottom are acceptable.
- There is conductive adhesive, if used, outside the boot within the structural adhesive.
- Boot and adhesive buildup does not exceed 3 mm [0.12 in] from connector surface (see Figure 9-26).
- Sleeving/boot is bonded to the sleeving; voids or separations are not evident (see Figure 9-27).

9.3.2 Sleeving and Boots – Bonding (cont.)

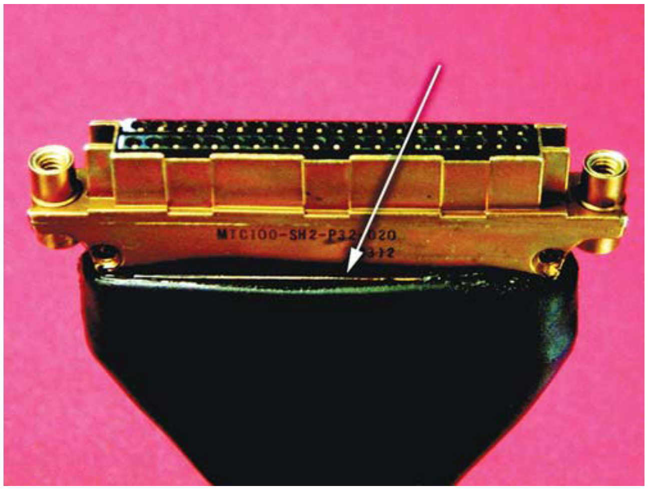

Figure 9-28

Acceptable – Class 1
Defect – Class 2,3

- Void or separation between the boot and connector.
- Nonparallelism of boot and connector face exceeds 10° in either axis.

9.3.2 Sleeving and Boots – Bonding (cont.)

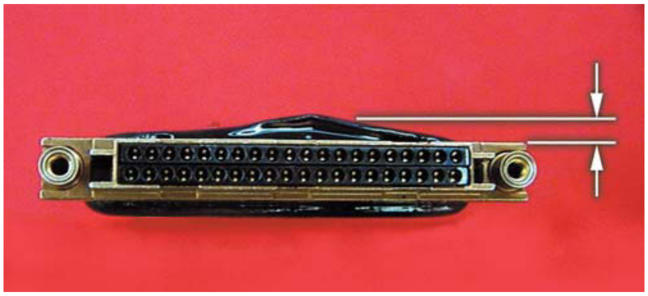

Figure 9-29

Figure 9-30

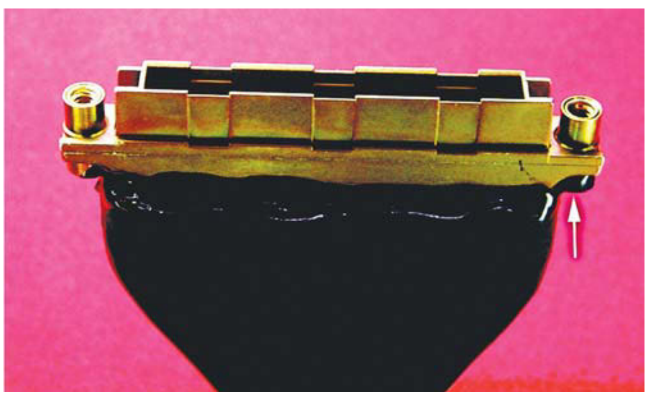

Figure 9-31

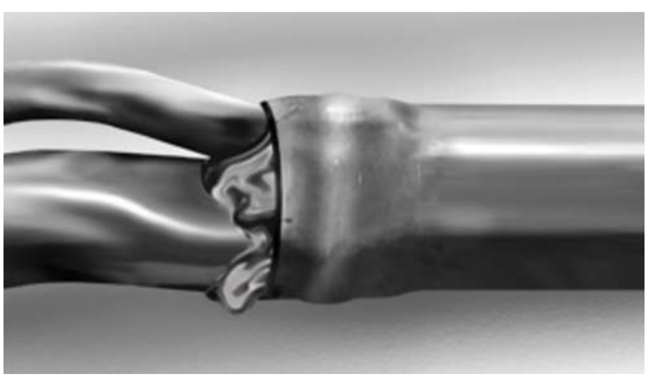

Figure 9-32

Defect – Class 1,2,3

- Boot and adhesive buildup exceeds 3 mm [0.12 in] from the connector surface (see Figure 9-29).
- Voids or separation in the adhesive between the boot and sleeving (see Figure 9-30).
- Adhesive interferes with subsequent assembly steps (see Figure 9-31).
- Adhesive is not fully cured.
- When required, conductive adhesive does not provide the specified conductive path or conductivity.
- Adhesive is excessive and flowed beyond the boundaries of the joint (see Figure 9-32).
- Adhesive has not adhered to sleeving or boot (see Figure 9-33).

Figure 9-33

9.4 Connector Damage

9.4.1 Connector Damage – Criteria

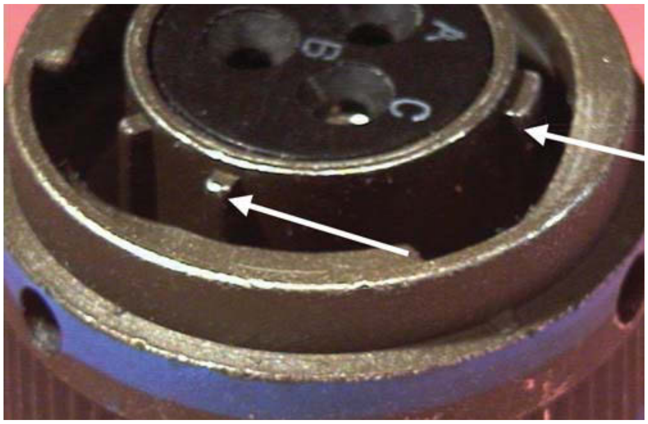
Figure 9-34

Acceptable – Class 1,2,3

- Scuff marks that do not expose basis metal.
- Key or keyways are not distorted but do show signs of normal wear.

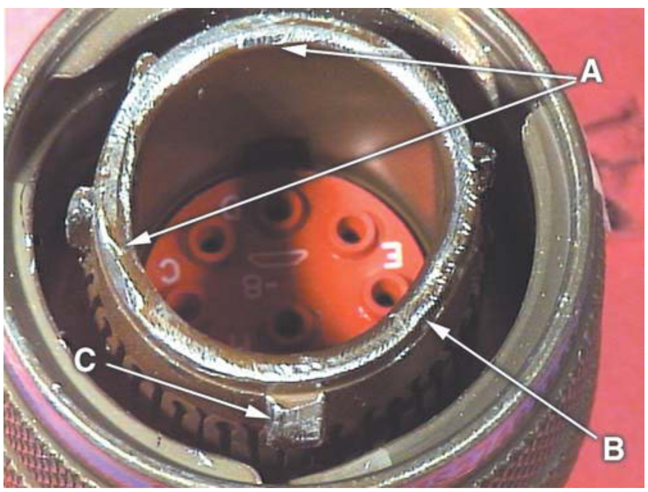

Figure 9-35

Defect – Class 2,3

- Damage such as scratches or burrs (see Figure 9-35-A) that exposes basis metal.

Defect – Class 1,2,3

- Deformed or distorted inner or outer ring (out-of-round condition) (see Figure 9-35-B).
- Key width or height has been reduced (see Figure 9-35-C).
- Key is mispositioned (not shown).
- Connector shell or body is cracked, fractured or otherwise damaged.

9.4.2 Connector Damage – Limits – Hard Face – Mating Surface

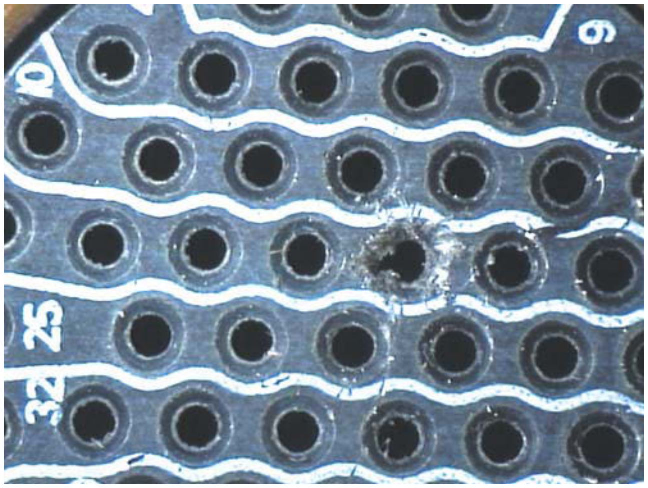

Figure 9-36

Acceptable – Class 1
Process Indicator – Class 2

- Connector face has been chipped but dielectric between seals is intact.
- Chipping does not extend from one cavity to the outer diameter of any adjacent cavity.

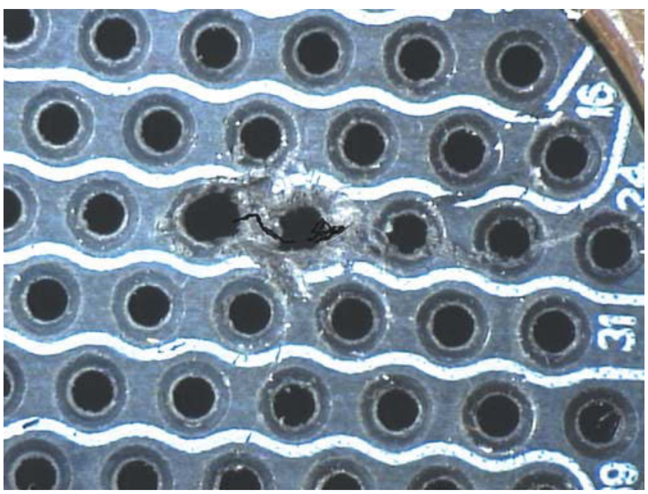

Figure 9-37

Defect – Class 1,2

- Chipping of the dielectric extends from cavity to the outside diameter of any adjacent cavity.
- Crack extends from one cavity to another.

Defect – Class 3

- Any evidence of chipping or cracks in any contact cavity.

9.4.3 Connector Damage – Limits – Soft Face – Mating Surface or Rear Seal Area

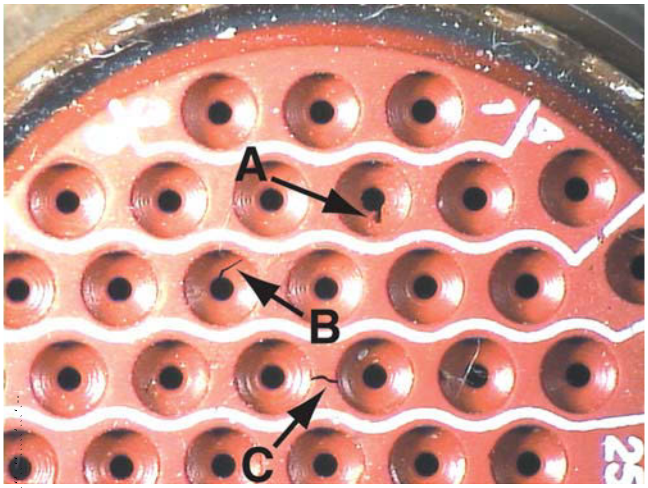

Figure 9-38

Acceptable – Class 1
Process Indicator – Class 2,3

- Material is missing with no damage to dielectric between cups (see Figure 9-38-A).
- Cut, fracture or tear that does not extend beyond cup diameter (see Figure 9-38-B).
- Cut, fracture or tear in dielectric face does not extend into the cup area (see Figure 9-38-C).

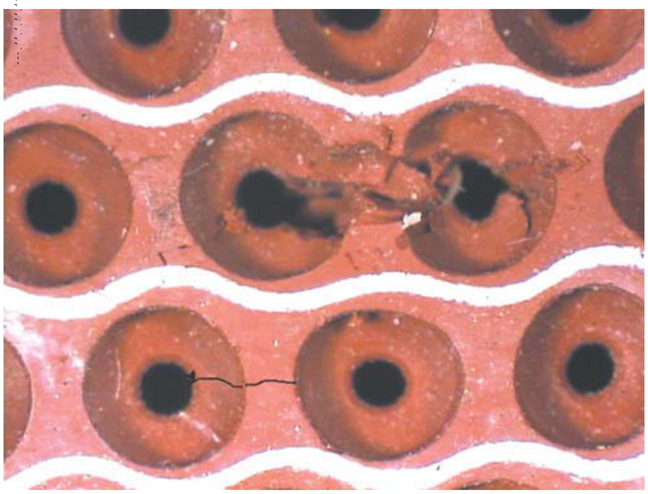
Figure 9-39

Defect – Class 1,2,3

- Cut, fracture or tear is in both the dielectric face and the cup diameter.

9.4.4 Connector Damage – Contacts

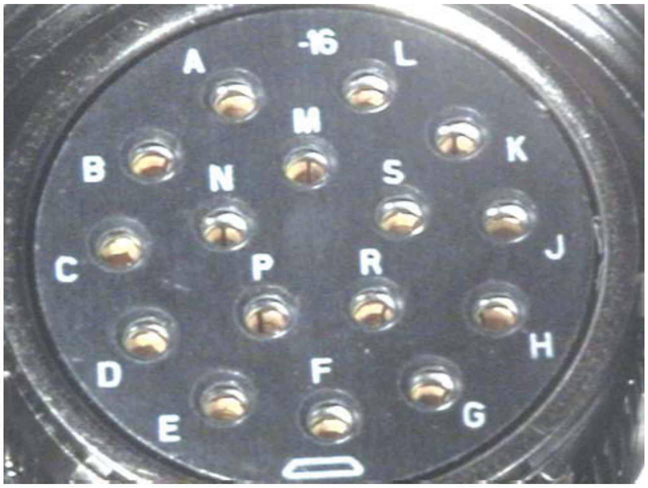

Figure 9-40

Acceptable – Class 1,2,3

- Contact plating damage does not expose basis metal.
- Pin contact is bent less than one pin diameter (not shown) and does not affect form, fit or function.

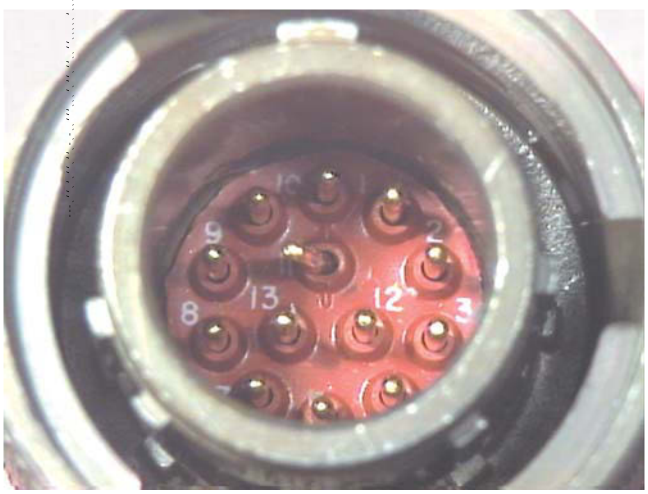
Figure 9-41

Defect – Class 1,2,3

- Damaged contact.
- Contact is bent more than one pin diameter.
- Basis metal exposed.

9.5 Installation of Contacts and Sealing Plugs into Connectors

Contacts should be installed with the connector manufacturer's recommended tooling.

Contact retention (seating/locking) **shall [D1D2D3]** be verified on all contacts with a nondestructive process appropriate to the connector in use, such as visually through an inspection window (see also 19.7.5). Verification **shall [D1D2D3]** be accomplished prior to addition of any restraining devices, including potting or molding.

Unused contact locations **shall [D1D2D3]** be filled with contacts and/or plugs if specified on the documentation. The contacts are not crimped unless required for insertion.

Exceptions to retention verification include:

- Connectors where contacts are retained by potting or molding.
- Potted or molded connectors after molding/potting.
- Solder cup connectors.
- Connector contact lead ends that are soldered into position.
- Connector contact locking device that is visible through an inspection window.

9.5.1 Installation of Contacts and Sealing Plugs into Connectors – Installation of Contacts

Figure 9-42

Acceptable – Class 1,2,3

- All connector contacts are seated and locked into position.
- All locations in connector have been filled (if required).

9.5.1 Installation of Contacts and Sealing Plugs into Connectors – Installation of Contacts (cont.)

Figure 9-43

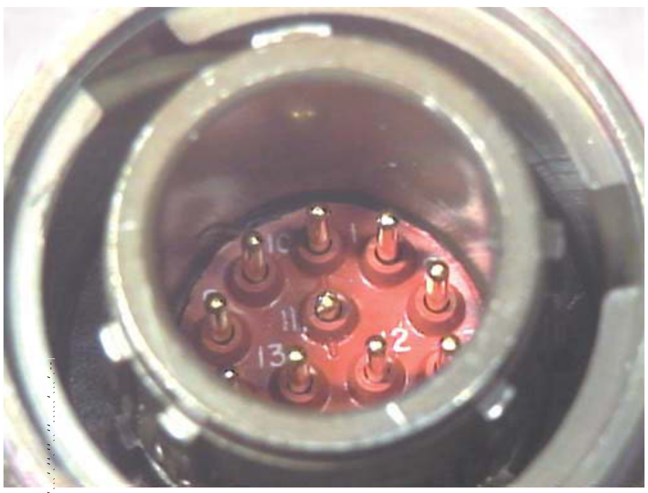

Figure 9-44

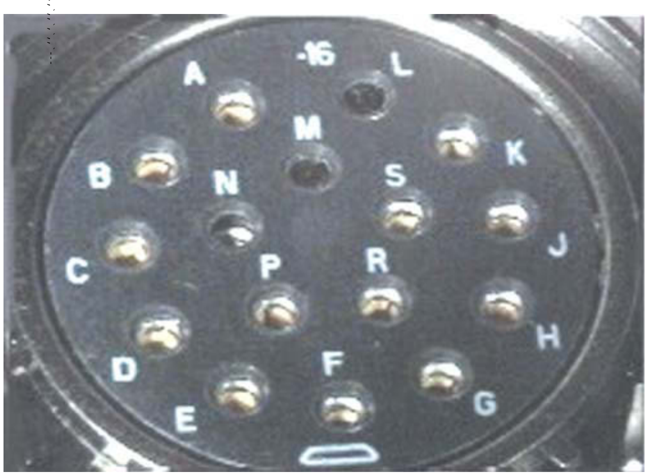

Figure 9-45

Defect – Class 1,2,3

- Contact is not seated as visible through inspection window (see Figure 9-43).
- Pin or socket is not seated and locked (see Figure 9-44).
- Contact(s) missing when unused positions are required to be filled (see Figure 9-45).

9.5.2 Installation of Contacts and Sealing Plugs into Connectors – Installation of Sealing Plugs

These criteria apply only to a connector cavity with a contact. If the cavity has no contact, any required sealing plug **shall [D1D2D3]** be installed in accordance with the connector manufacturer's instructions.

Sealing plugs featuring a head are installed with the head end first (see Figure 9-46).

Figure 9-46
1. Shaft
2. Head

Acceptable – Class 1,2,3

- Sealing plug head is captured by the wire seal (head is not visible).

Figure 9-46

9.5.2 Installation of Contacts and Sealing Plugs into Connectors – Installation of Sealing Plugs (cont.)

Figure 9-48

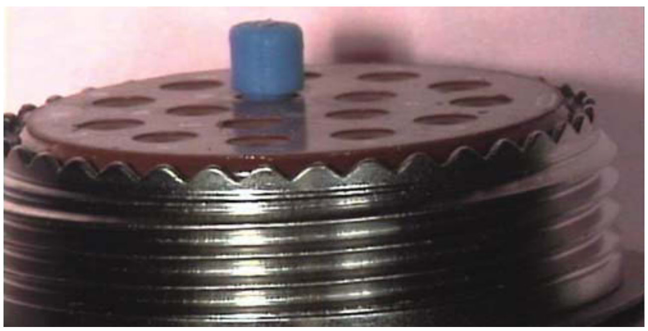

Figure 9-49

Defect – Class 1,2,3

- Missing sealing plug(s) where required.
- Sealing plug head is not captured (head is visible).

10 Over-Molding/Potting

The requirements in this section are imposed primarily to give confidence in the reliability of the wire, cable or harness assembly.

This section addresses two distinct types of component encapsulation: over-molding (injection molding) and potting with either using thermoplastic, thermoset, or elastomeric materials.

Over-molding is a single or multi-step process in which a component is introduced into a mold die and injected with an encapsulating material. Over-molding typically uses thermoplasic material but can also use a thermoset or elastomeric material. Injection molding equipment provides the necessary high temperatures and pressures required to soften and subsequently inject the thermoplastic materials into the die cavities.

Thermoplastic over-molding is a common solution in benign medical, industrial, commercial, communications, IT infrastructure and other electronics environments where flexibility, strain relief and environmental stability are important.

Potting is typically a single step, relatively low pressure and low temperature process in which the component is introduced into a mold die and is selectively encapsulated. Potting typically uses thermoset materials that are applied by hand or by injecting into a mold using low pressure application. The cure may be done by heat, through a chemical reaction, e.g., two-part epoxy, or irradiation.

When used, masking material **shall [D1D2D3]** have no deleterious effect on the assembly and **shall [D1D2D3]** be removable without contaminant residue.

Opaque materials preclude visual inspection for internal anomalies. Use of any other inspection technologies **shall [D1D2D3]** be specified by the User.

See 1.16 for additional material requirements.

The following topics are addressed in this section.

10 Over-Molding/Potting (cont.)

Table 10-1 is a partial listing of common definitions for molded and potted visual characteristics. This section includes criteria to determine acceptability of these visual anomalies.

Table 10-1 Definitions of Molding/Potting Visual Anomalies

Air Burn	A patch or streak of brown or black material on the component caused by air or gases that have not been properly vented from the mold and have caused the material to overheat and burn.
Black Specks	A specific kind of inclusion/contamination often associated with heat-degraded materials.
Blister	An imperfection on the surface of a plastic article caused by a pocket of air or gas beneath the surface.
Bloom (also known as Migration)	An undesirable cloudy effect or whitish powdery deposit on the surface of a plastic article or to the surrounding environment caused by the exudation of an ingredient such as a lubricant, stabilizer pigment, plasticizer, or other non-bonded component.
Blushing	The tendency of a plastic article to turn white or chalky in areas that are highly stressed.
Bubbles	Air or gas pockets that have formed in the material of the component. Bubbles may vary in size.
Burned	Showing evidence of excessive heating during processing or use of a plastic, as evidenced by blistering, discoloration, distortion or destruction of the surface.
Cold Flow Lines	Imperfections within the part wall due to thickening or solidification of resin prior to full cavity fill.
Crack/Splits/Chips	A physical separation or tearing of the part.
Crazing	Defect in plastics articles characterized by distinct surface cracks or minute frost-like internal cracks, resulting from stresses within the article which exceed the tensile strength of the plastic.
Creep	Due to its viscoelastic nature, a plastic subjected to a load for a period of time tends to deform more than it would from the same load released immediately after application, and the degree of this deformation is dependent of the load duration.
Degradation	A deleterious change in the chemical structure, physical properties or appearance of a plastic caused by exposure to heat, light, oxygen, weathering or other external influence.
Delamination	When the surface of a finished part separates. Strata or fish-scale-type appearance may be visible where the layers may be separated.
Discoloration	Any change from the designated color of the material or component.
Drag Marks	A form of deep scratch or scratches on the surface of the component usually caused by the ejection of the part.
Ejection Pin Marks	A residual mark on the part caused by the profile of the ejection pin.
Flash	Seepage of mold material along parting lines, and/or mating surfaces, i.e., thin surplus of material, which is forced between mating mold surfaces during molding operation.
Flow Marks	Wavy surface appearances on a molded part caused by improper flow of the melt into the mold.
Fracture	The separation of a body, usually characterized as either brittle or ductile.
Gate Blush	A blemish or disturbance in the gate area of an injection molded article.
Haze	The cloudy appearance of a material caused by light scattered from within the specimen or from its surfaces.
Jetting	A turbulent flow in the melt caused by an undersized gate or where a thin section rapidly becomes thicker.
Knit Lines	Where melted material flows together to form a line or lines that may cause weakening or breaking of the component.
Mold Release Problems	Excess use of mold release may leave parts oily and weaken the material.
Orange Peel	A surface finish on a molded part that is rough and splotchy. Usually caused by moisture in the mold cavity or poor heat transfer properties.
Parting line	Mark on the part indicating where the two halves of the mold met in closing.
Peeling	An open blister.
Pit	An imperfection, a small crater in the surface of the plastic.
Pulled Gate	Area where the part was connected to the sprue or runner that has been drawn out or stretched from the surface.
Short Shot (also known as Non-Fill)	Failure to completely fill the mold or cavities of the mold. Edges may appear melted.
Sink Mark	An indentation on the surface of the part as a result of significant local change in wall section. The mark will occur in the thicker area.

10 Over-Molding/Potting (cont.)

Splay Marks	Scan or surface defects on molded part caused by abnormal racing of the melt in the mold.
Stress Cracking	There are three types of stress cracking; all of these result in splitting or fracturing of the molding: 1. Thermal stress cracking is caused by prolonged exposure of the part to elevated temperatures or sunlight. 2. Physical stress cracking occurs between crystalline and amorphous portions of the part when the part is under an internally or externally induced strain. 3. Chemical stress cracking occurs when a liquid or gas permeates the parts surface.
Striations	Marks evident on the molded-part surfaces that indicate melt flow directions or impingement.
Thermal Degradation	Deterioration of the material by heat, characterized by molecular scission.
Underflow	The dominant flow of two confronting flows, over the other. The lesser flow reverses direction giving poor surface appearance and structural strength. Underflow should be avoided by positioning gates so that the flow fronts meet at the end of filling.
Void	An unfilled space within a solid material.
Warpage	Distortion caused by nonuniform internal stresses.
Weld Line	Where melted material flows together during molding to form a visible line or lines on a finished part that may cause weakening or breaking of the component.

10.1 Over-Molding

10.1.1 Over-Molding – Mold Fill

10.1.1.1 Over-Molding – Mold Fill – Inner

This is step one of a multistep molding process.

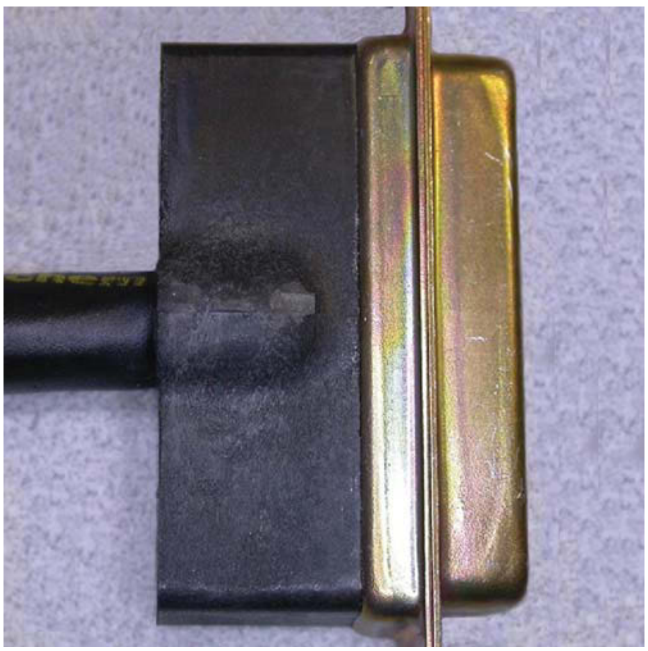

Figure 10-1

Figure 10-2

10.1.1.1 Over-Molding – Mold Fill – Inner (cont.)

Acceptable – Class 1,2,3

- Air marks (not shown).
- Exposed (float) insulation, sleeve, jacket, braid (see Figure 10-3-1), conductor (see Figures 10-4, 5), foil, ferrules, etc.
- Voids equal to or less than 3 mm [0.12 in] length or 2 mm [0.08 in] width or 1.5 mm [0.06 in] depth.
- Voids do not have sharp edges.
- Cracked inner-mold material.
- Surface roughness/markings (see Figure 10-6).

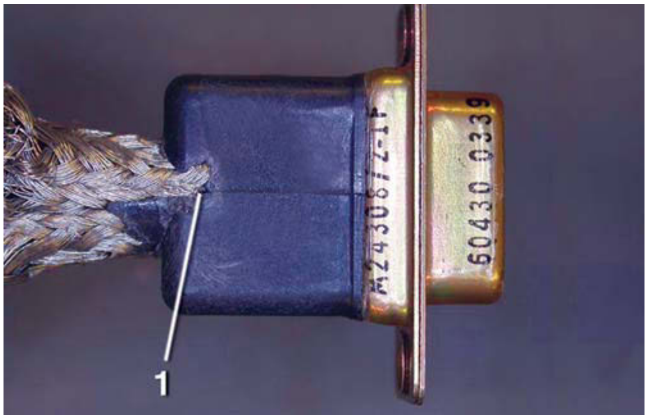

Figure 10-3
1. Braid float

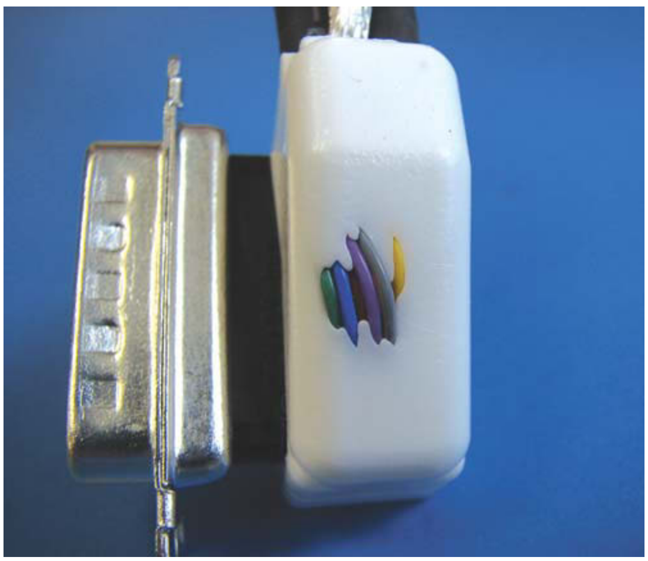

Figure 10-4

Figure 10-5

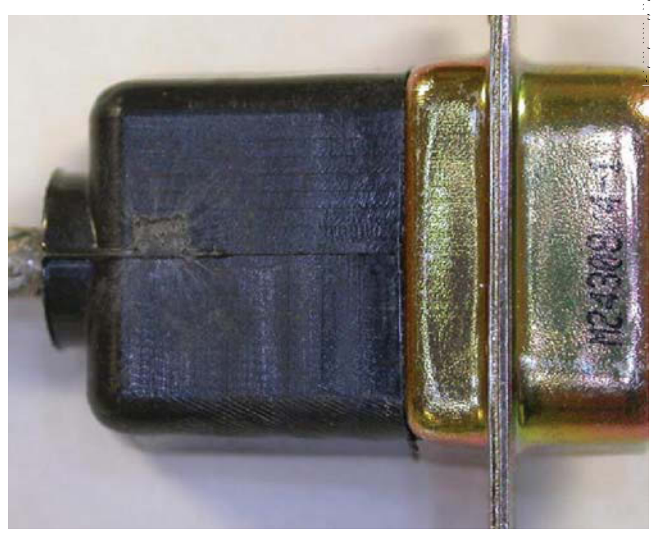

Figure 10-6

10.1.1.1 Over-Molding – Mold Fill – Inner (cont.)

Defect – Class 2,3

- Voids with sharp edges when shielding will be applied over the inner mold (not shown).

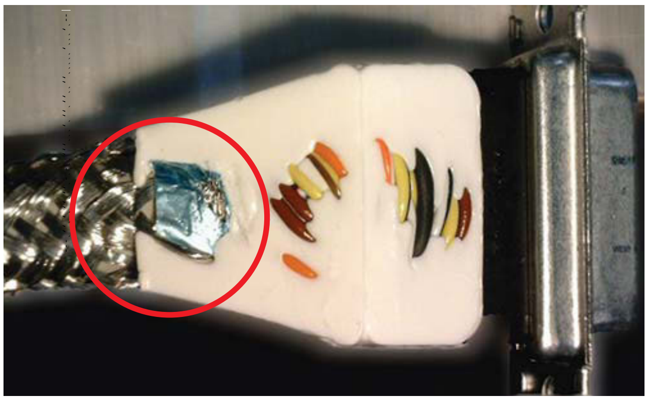

Figure 10-7

Figure 10-8

Defect – Class 1,2,3

- Incomplete material fill (see Figure 10-7).
- Voids greater than 3 mm [0.12 in] length or 2 mm [0.08 in] width or 1.5 mm [0.06] depth (see Figure 10-8).

10.1.1.2 Over-Molding – Mold Fill – Outer

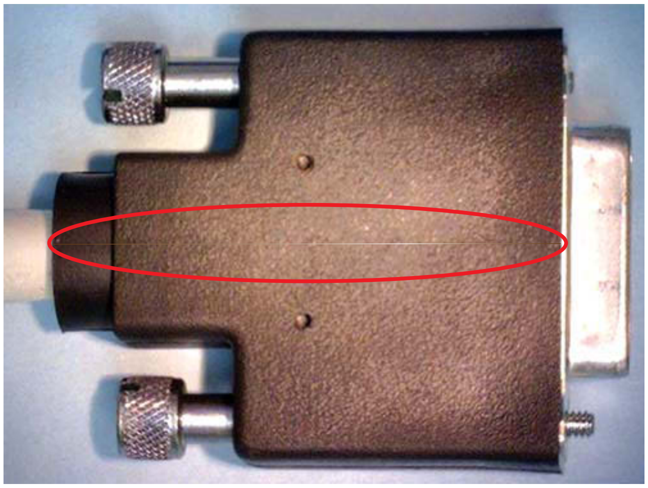

Figure 10-9

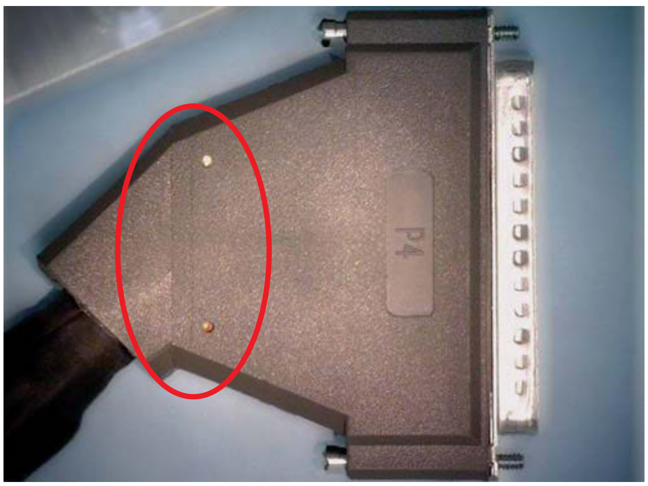

Figure 10-10

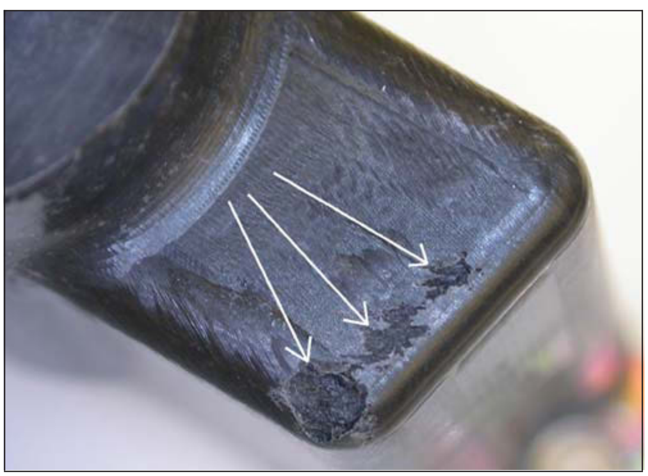

Figure 10-11

Acceptable – Class 1,2,3

- Part has all features required by the engineering documentation.
- All required marking is legible.
- Cosmetic anomalies do not affect form, fit or function (see Figures 10-9, 11, 12).
- Streaking (see Figure 10-13).
- Complete fill.
- Sink marks in material without cracks (see Figure 10-14).
- Part lines discernible but not raised (see Figure 10-10).

10.1.1.2 Over-Molding – Mold Fill – Outer (cont.)

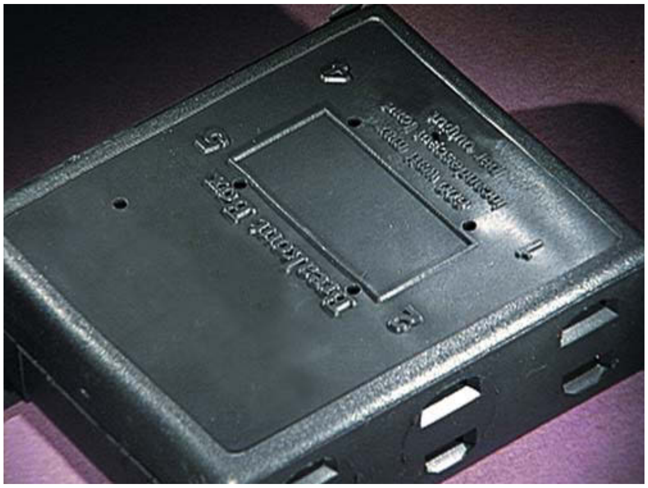

Figure 10-12

Figure 10-13

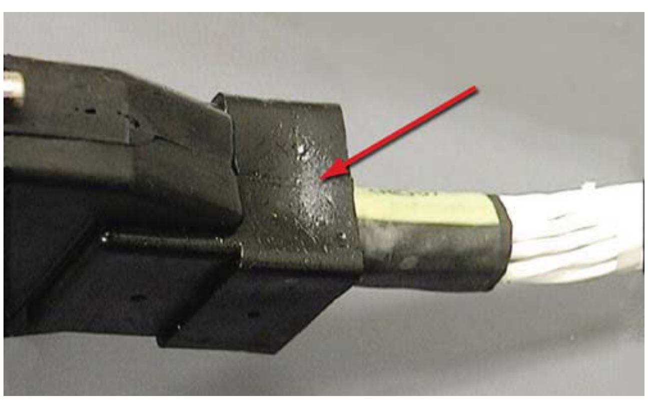

Figure 10-14

10.1.1.2 Over-Molding – Mold Fill – Outer (cont.)

Acceptable – Class 1,2
Process Indicator – Class 3

- Air marks (not shown).

Note: Air marks are created when gasses are trapped in the mold during outer-molding. Integrity is not compromised. This is not the same condition as incomplete fill.

Defect – Class 1,2,3

- Voids where outer-molding material should be present (see Figure 10-15).
- Marking is incomplete or not legible (see Figure 10-16).
- Incomplete material fill (see Figure 10-16).
- Sink marks in material with cracks (see Figure 10-17).
- Exposed insulation, sleeving, jacket, braid or foil (see Figure 10-18).

Figure 10-15

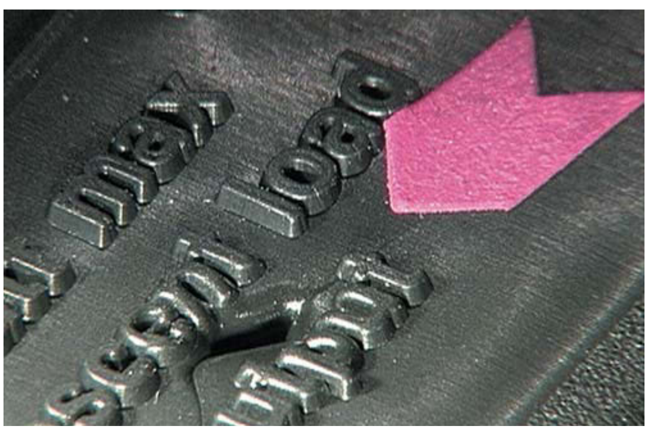

Figure 10-16

Figure 10-17

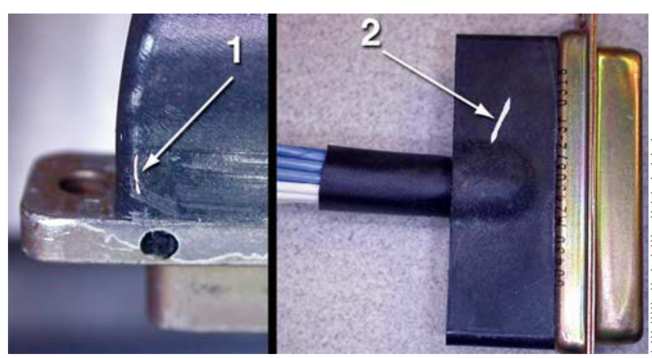

Figure 10-18
1. Foil float
2. Wire float

10.1.1.2.1 Over-Molding – Mold Fill – Outer – Mismatch

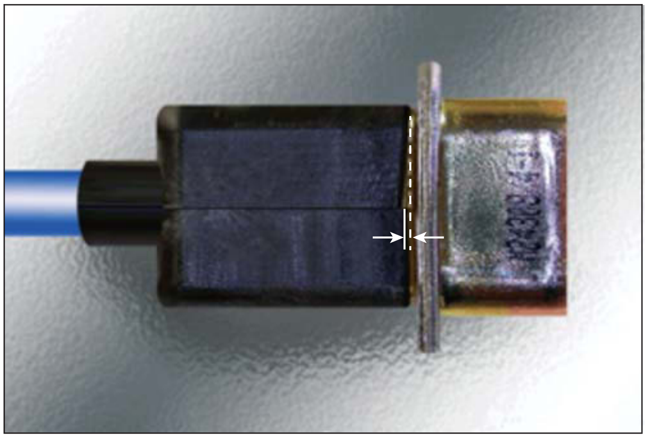

Figure 10-19

Acceptable – Class 1,2,3

- Mismatch part lines measuring 0.75 mm [0.030 in] or less.

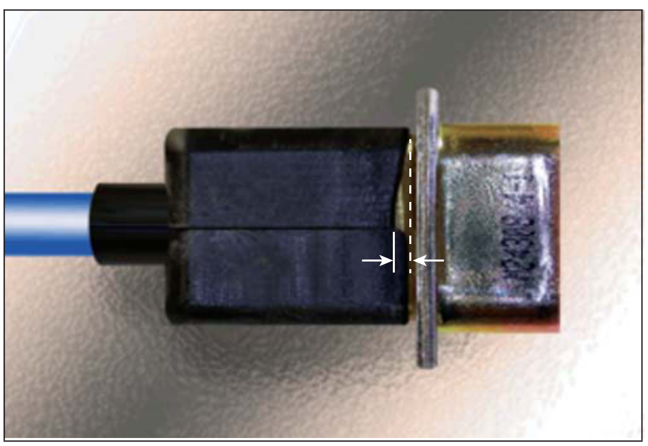

Figure 10-20

Defect – Class 1,2,3

- Mismatch part lines measuring greater than 0.75 mm [0.030 in].

10.1.1.2.2 Over-Molding – Mold Fill – Outer – Fit

Figure 10-21

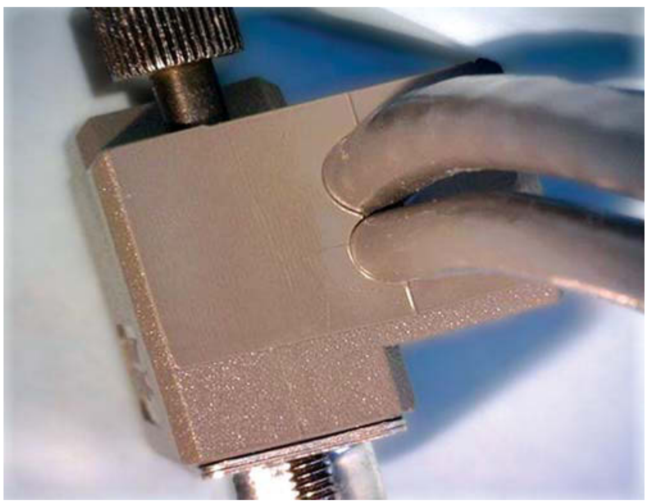

Figure 10-22

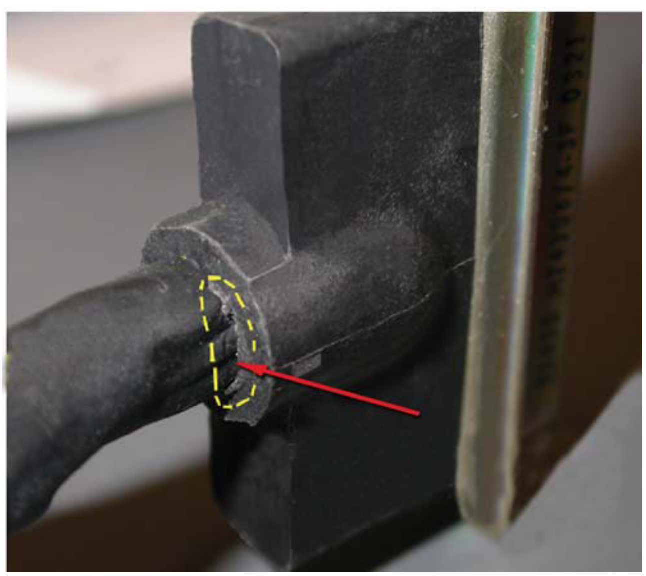

Figure 10-23

Acceptable – Class 1

- Outer-mold captures at least 75% of the circumference of the wire or cable jacket.

10.1.1.2.2 Over-Molding – Mold Fill – Outer – Fit (cont.)

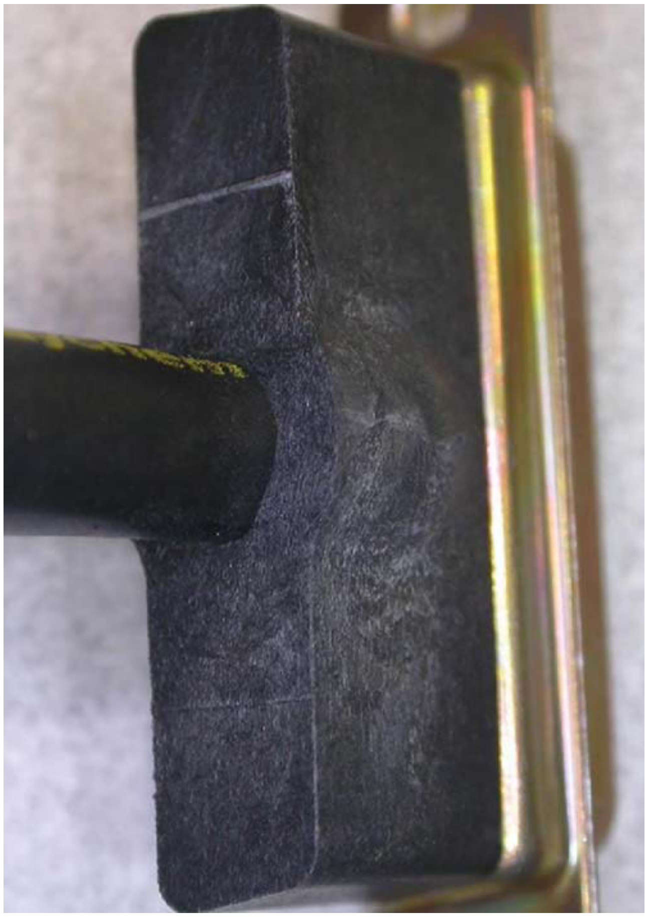

Figure 10-24

Acceptable – Class 2,3

- Outer-molding conforms to the entire contour of the cable jacket, insulation, sleeve or boot.
- When specified, outer-molded material adheres to the entire contour of the cable jacket.

Defect – Class 1

- Outer-molding conforms to less than 75% of the circumference of the wire or cable jacket.

Defect – Class 2,3

- Outer-molding captures less than the entire contour of the wire, cable jacket or connector.
- Any gaps between outer-molded material and cable jacket, insulation, sleeve, boot or connector that expose any material or components that are required to be fully encapsulated.

10.1.1.2.2 Over-Molding – Mold Fill – Outer – Fit (cont.)

Figure 10-25

Figure 10-26

Defect – Class 1,2,3

- Wire, sleeving or cable jacket pulled out (pop-out) of outer-molding (see Figure 10-25).
- Outer-molded material does not adhere to the circumference of the wire, cable jacket or connector body when required by engineering documentation (see Figure 10-26).

10.1.1.2.3 Over-Molding – Mold Fill – Outer – Cracks, Flow Lines, Chill Marks (Knit Lines) or Weld Lines

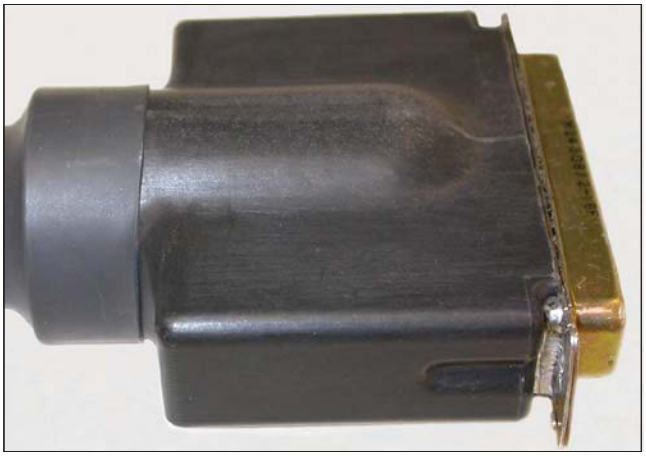

Figure 10-27

Figure 10-28

Figure 10-29

Acceptable – Class 1,2,3

- Surface chill mark (knit line) is visible but does not penetrate greater than 20% of outer-molding material thickness (see Figure 10-28).
- Flow lines at injection gate (see Figure 10-29).

10.1.1.2.3 Over-Molding – Mold Fill – Outer – Cracks, Flow Lines, Chill Marks (Knit Lines) or Weld Lines (cont.)

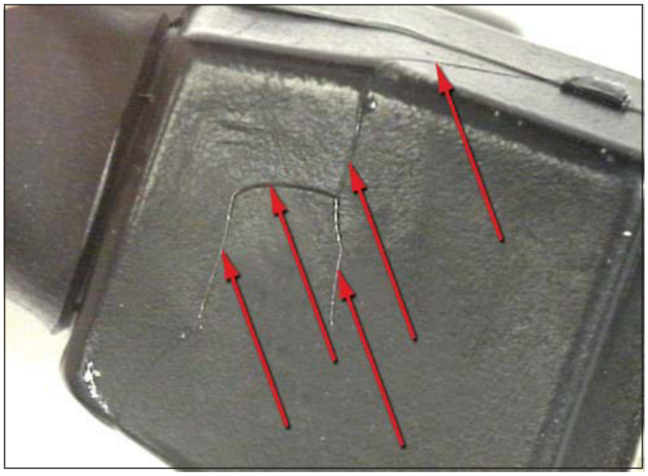

Figure 10-30

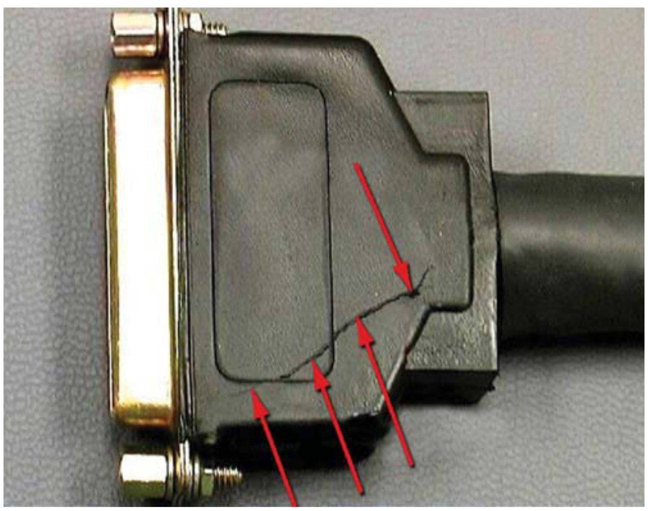

Figure 10-31

Figure 10-32

Defect – Class 1,2,3

- Chill marks/knit lines (flow front) if the depth exceeds 20% of the outer-mold material thickness (see Figure 10-30).
- Cracks (see Figures 10-31, 32).

10.1.1.2.4 Over-Molding – Mold Fill – Outer – Color

(Not illustrated.)

Acceptable – Class 1,2,3

- Color is uniform and in accordance with engineering documentation.

Defect – Class 2,3

- Color across the surface(s) is not uniform or is not in accordance with engineering documentation.

10.1.2 Over-Molding – Blow Through

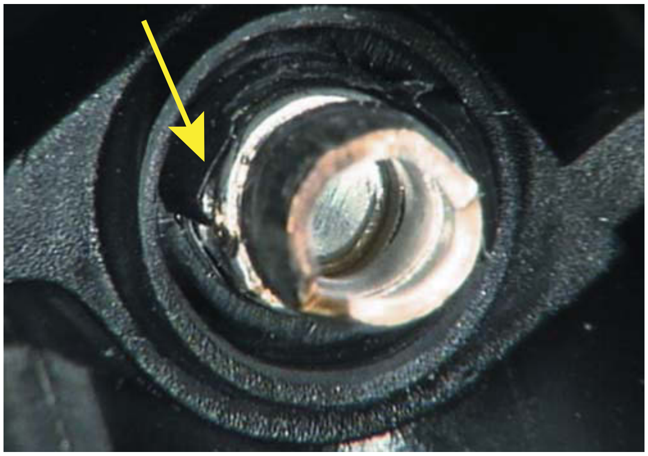

Figure 10-33

Acceptable – Class 1
Process Indicator – Class 2,3

- Blow through that is not on an electrical mating surface or does not prevent proper mating or function of the connector.

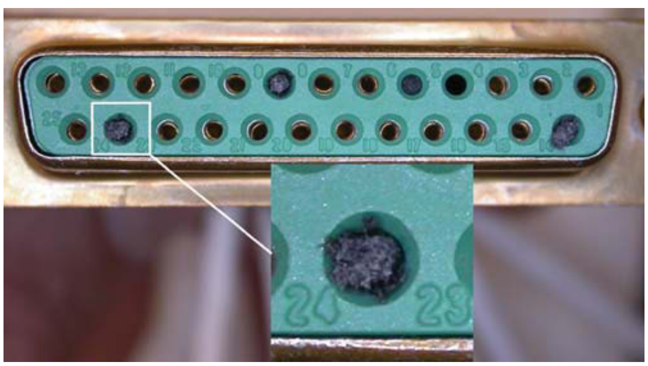

Figure 10-34

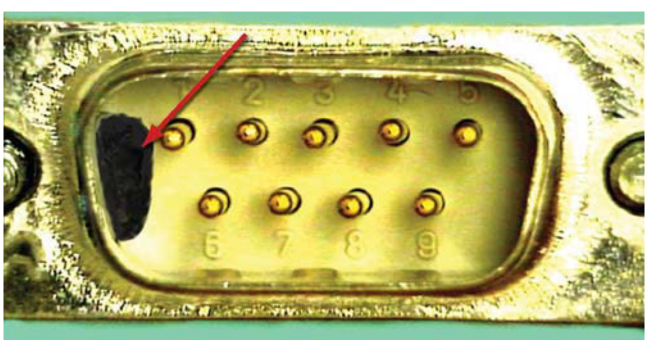

Figure 10-35

Defect – Class 1,2,3

- Blow through present on an electrical mating surface (see Figure 10-34) or prevents proper mating or function of the connector (see Figure 10-35).

10.1.3 Over-Molding – Position

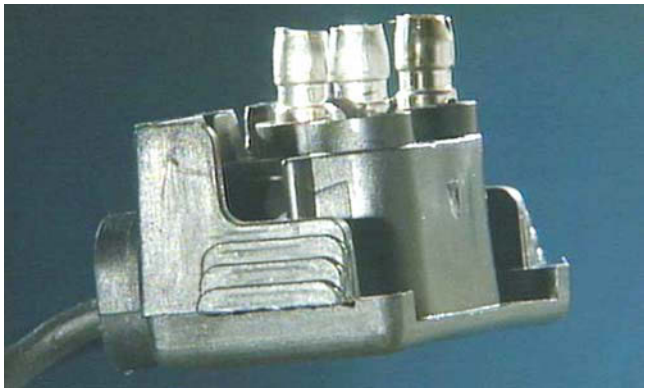

Figure 10-36

Figure 10-37

Figure 10-38

Acceptable – Class 1,2,3

- Any variation in contact height or alignment that meets requirements of engineering documentation.
- Unless otherwise specified, the connector or terminal(s) within 10° of perpendicular with molding material.
- No impact on intended form, fit or function.

10.1.3 Over-Molding – Position (cont.)

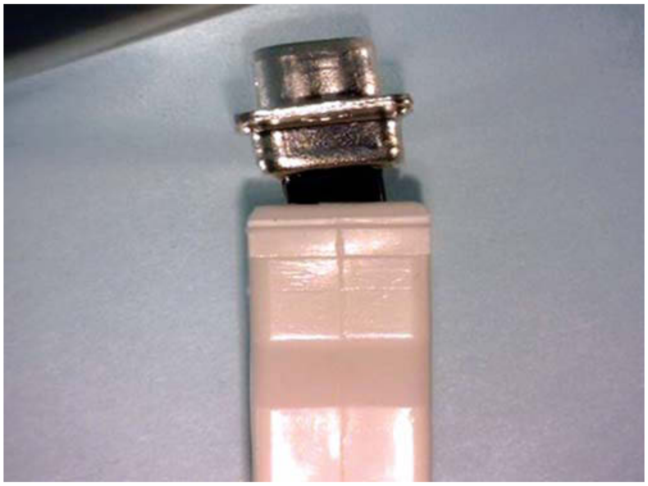

Figure 10-39

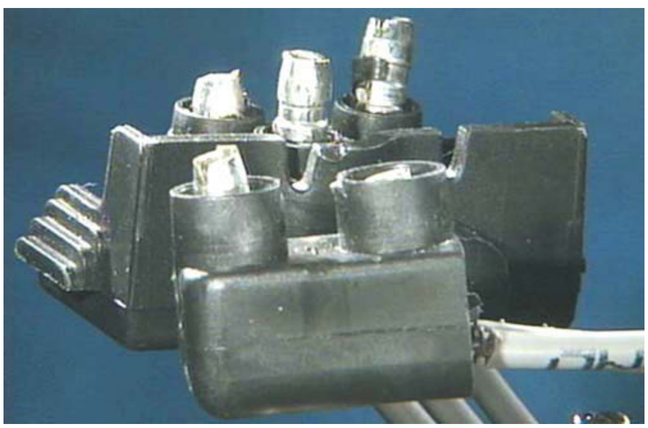

Figure 10-40

Defect – Class 1,2,3

- If not otherwise specified, the connector or terminal misalignment is greater than 10° from perpendicular (see Figure 10-39).
- Terminals not fully seated or aligned as required by engineering documentation (see Figure 10-40).
- Any variation in contact height or alignment that does not meet requirements of engineering documentation (see Figures 10-41, 42).
- Impacts form, fit or function.

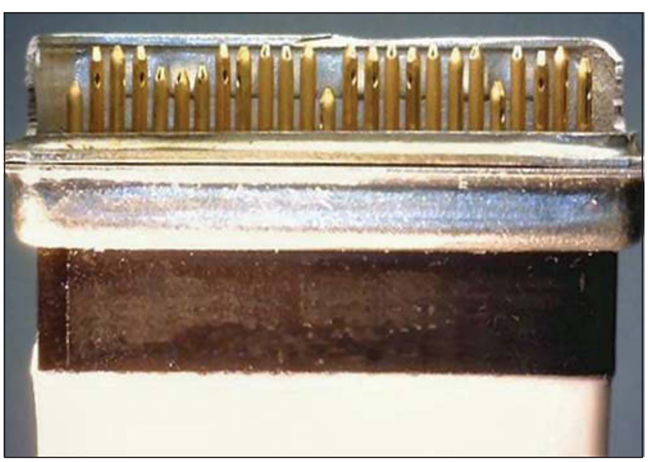

Figure 10-41

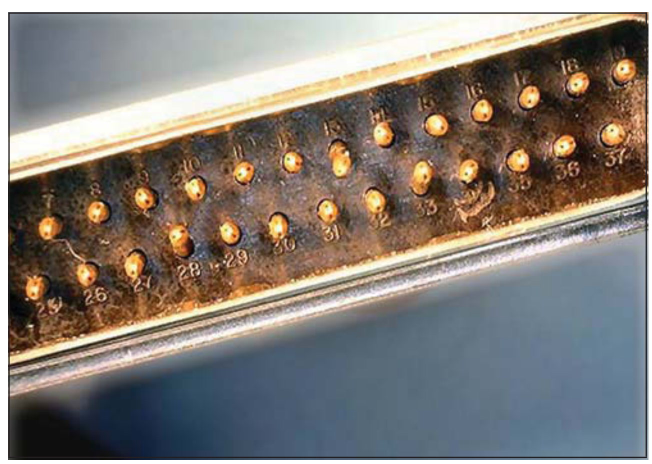

Figure 10-42

10.1.3 Over-Molding – Position (cont.)

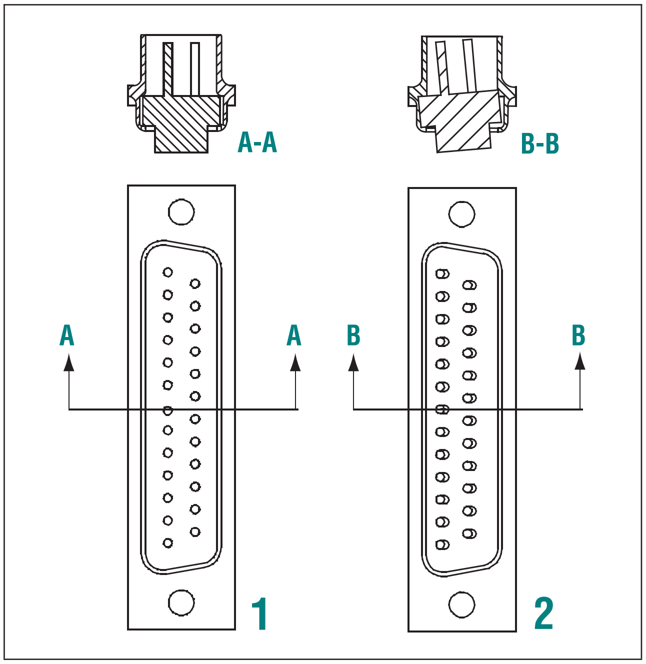

Figure 10-43
1. Insert properly aligned
2. Insert is misaligned (pins angled)

Defect – Class 1,2,3

- Connector insert misaligned.

10.1.4 Over-Molding – Flashing

The Manufacturer **shall [N1D2D3]** establish a process to determine if flash will break loose in the normal service environment. If there is flash at the connector/over-mold interface, it **shall not [D1D2D3]** interfere with the mechanical or electrical function. Surface anomalies that result from removal of flash are typically acceptable.

Figure 10-44

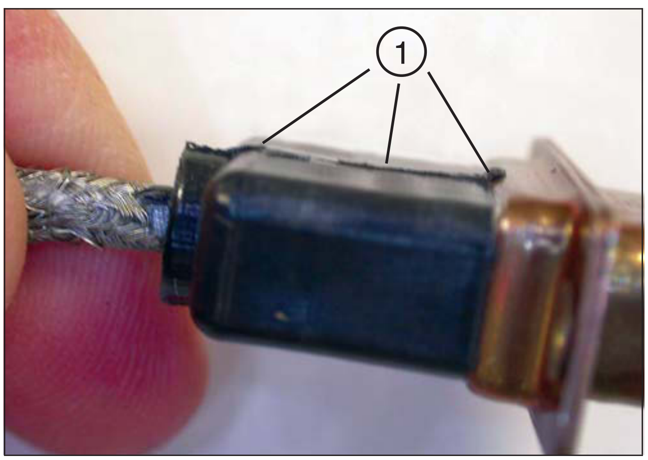

Figure 10-45
1. Part line

Acceptable – Class 1,2,3

- Flashing is not present on electrical mating surfaces.
- No sharp edges (see Figure 10-44).
- Part line (flash) raised no greater than 0.75 mm [0.03 in] (see Figure 10-45).

10.1.4 Over-Molding – Flashing (cont.)

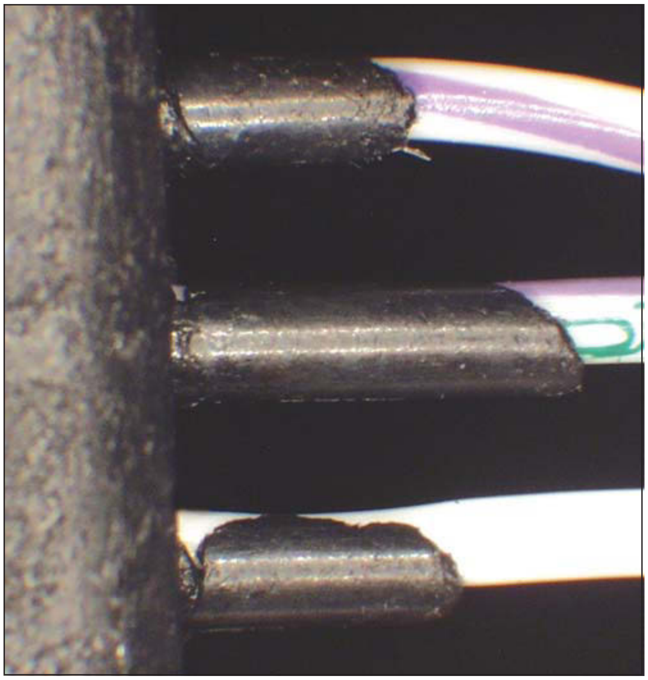

Figure 10-46

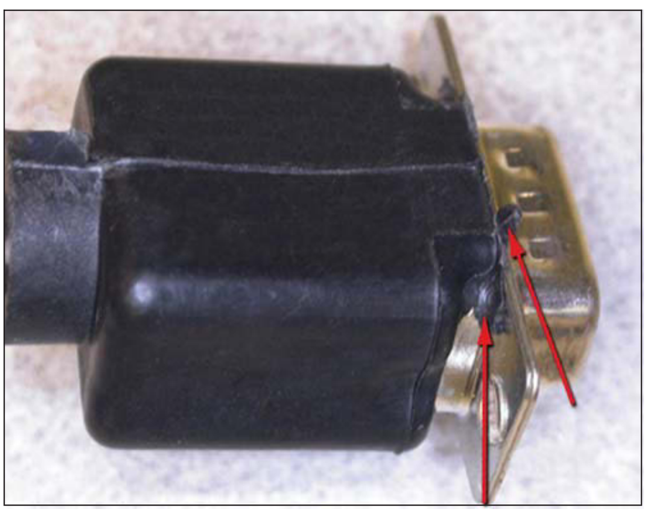

Figure 10-47

Defect – Class 1,2,3

- Flash present at the connector, cable/wire over-mold interface that interferes with the mechanical or electrical function (see Figure 10-46).
- Flashing that may break loose (see Figure 10-47, left arrow).
- Flashing present on electrical mating surfaces (see Figure 10-47, right arrow).
- Sharp edges.

10.1.5 Over-Molding – Wire Insulation, Jacket or Sleeving Damage

Figure 10-48

Acceptable – Class 1,2,3

- The outer-molding process has not damaged the wire insulation beyond criteria listed in 3.5.

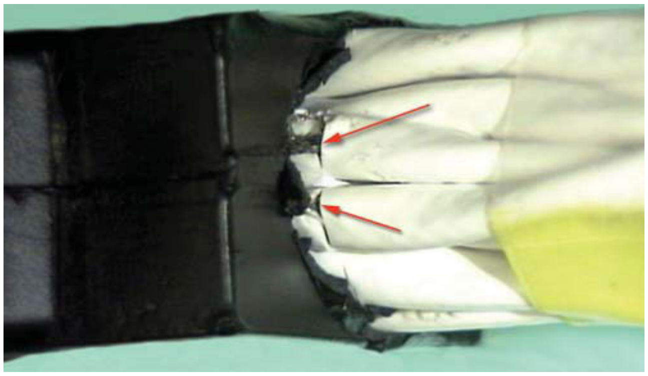

Figure 10-49

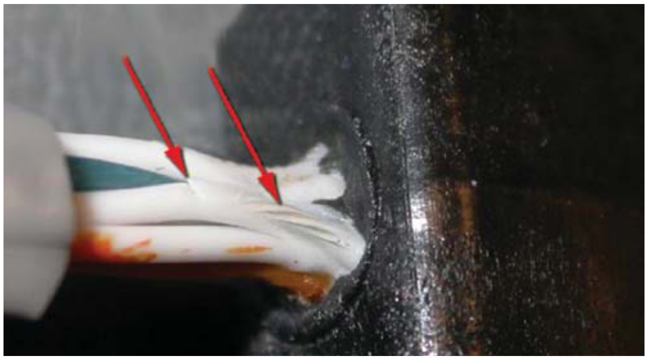

Figure 10-50

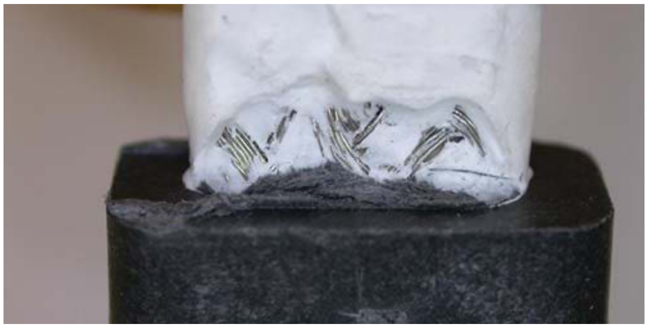

Figure 10-51

Defect – Class 1,2,3

- Wire insulation is damaged beyond the insulation damage criteria listed in 3.5 (see Figures 10-49, 50, 51).
- Cable jacket, sleeve or boot damaged exposing wire, braid, insulation or conductor (see Figures 10-51, 52).
- Solder wicking exceeds maximum criteria (see Figure 10-53).

10.1.5 Over-Molding – Wire Insulation, Jacket or Sleeving Damage (cont.)

Figure 10-52

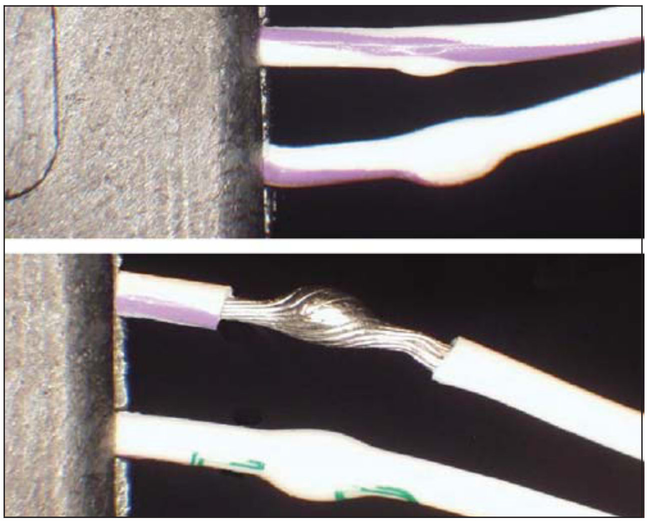

Figure 10-53
Note: The top view shows solder wicked up the wire. The bottom view shows one wire with the insulation removed.

10.1.6 Over-Molding – Curing

(Not illustrated.)

Acceptable – Class 1,2,3

- Molding material has hardened and is tack free to the touch after curing.
- Molding material is within the specified hardness range after curing.

Defect – Class 1,2,3

- Molding material is tacky after curing.
- Molding material is not within the specified hardness range after curing.

10.2 Potting (Thermoset Molding)

10.2.1 Potting (Thermoset Molding) – Filling

Figure 10-54

Figure 10-55

10.2.1 Potting (Thermoset Molding) – Filling (cont.)

Figure 10-56

Figure 10-57

Acceptable – Class 1,2,3

- No bubbles or cavities that bridge between conductors (see Figure 10-56).
- No spillage or potting material that interferes with the physical function of the connector.
- No potting material on the mating surfaces of the connector.
- All required marking is legible.
- Part line raised no greater than 0.75 mm [0.03 in] (see Figure 10-57).

10.2.1 Potting (Thermoset Molding) – Filling (cont.)

Figure 10-58

Acceptable – Class 1
Process Indicator – Class 2,3

- Cosmetic anomalies that do not affect form, fit or function, e.g., streaking, air marks, rough finish (see Figure 10-58), rough edges (see Figure 10-59), sink marks without cracks (see Figure 10-60).

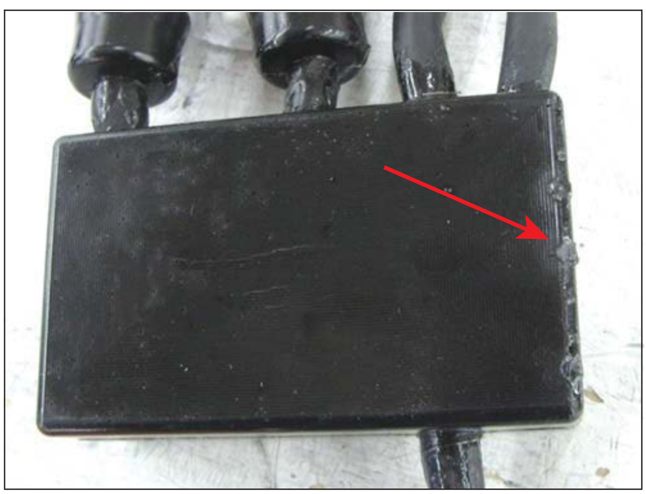

Figure 10-59

Figure 10-60

10.2.1 Potting (Thermoset Molding) – Filling (cont.)

Defect – Class 2,3

- Bubbles, voids or cavities that bridge conductors (not shown).

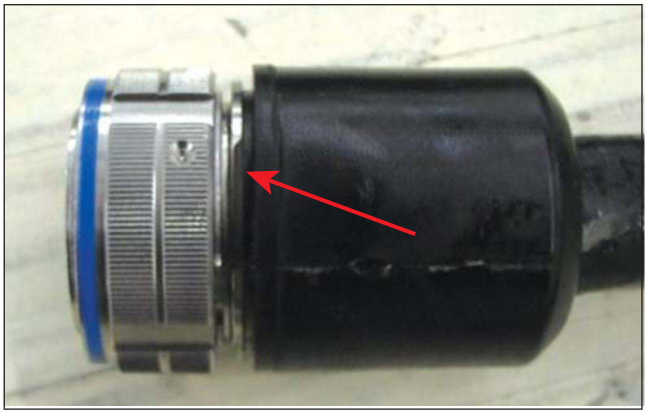

Figure 10-61

Figure 10-62

Figure 10-63

Defect – Class 1,2,3

- Potting material present on electrical mating surfaces of connector (not shown).
- Spillage or potting material that interferes with the physical function of the connector (see Figure 10-61).
- Exposed parts (insulation, sleeving, jacket, conductors, braid foil, tape, wire, ferrules, etc.) (see Figure 10-62).
- Sharp edges (not shown).
- Required marking is incomplete or not legible (not shown).
- Incomplete material fill (see Figure 10-63).

10.2.2 Potting (Thermoset Molding) – Fit to Wire or Cable


Figure 10-64


Figure 10-65

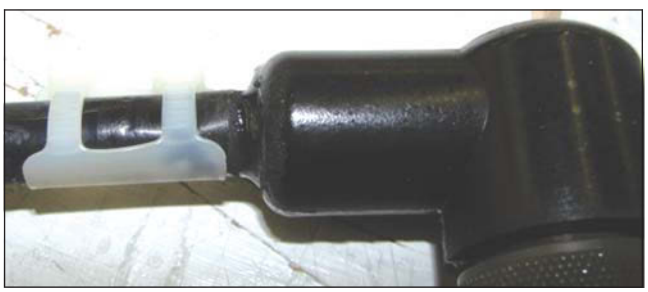
Figure 10-66

Acceptable – Class 1

- Potting material adheres to at least 75% of the circumference of the wire(s) or cable jacket.

Acceptable – Class 2,3

- No exposed inner wires for multiwire cables.
- No gaps between the cured potting material and wire(s) or cable jacket.
- Potting material adheres to the entire circumference of the wire(s) or cable jacket when the engineering documentation requires the potting material to bond to the wire(s) or cable jacket.

10.2.2 Potting (Thermoset Molding) – Fit to Wire or Cable (cont.)

Figure 10-67

Defect – Class 1

- Potting material does not adhere to at least 75% of the circumference of the wire or cable jacket (see Figure 10-67).

Defect – Class 2,3

- Any exposed inner wires for multiwire cables.
- Any gaps between the cured potting material and wire or cable jacket.
- Potting material that does not adhere to the entire circumference of the wire or cable jacket when the engineering documentaton requires the potting material to bond to the wire or cable jacket.

Defect – Class 1,2,3

- Any exposed conductors.

10.2.3 Potting (Thermoset Molding) – Curing

(Not illustrated.)

Acceptable – Class 1,2,3

- Potting material has hardened and is tack free to the touch after curing.
- Potting material is within the specified hardness range after curing.

Defect – Class 1,2,3

- Potting material is tacky after curing.
- Potting material is not within the specified hardness range after curing.

10.3 Over-Molding of Flexible Flat Ribbon

These criteria apply to wires or conductors molded together with polyurethane, silicone, or other flexible material.

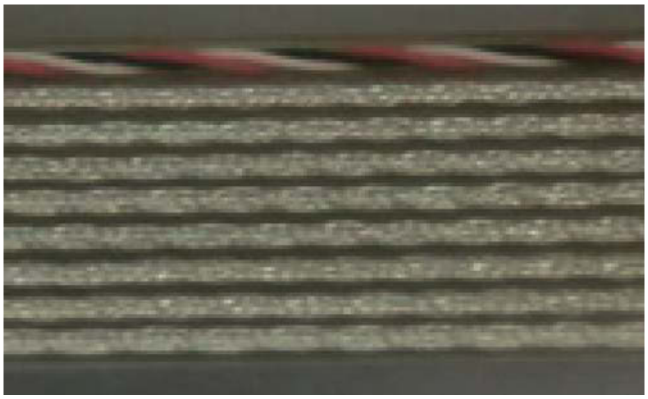

Figure 10-68

Figure 10-69

Acceptable – Class 1,2,3

- Parallel and uniform spacing between wires/cables (see Figure 10-68).
- Encapsulation of all wire/cable.
- No flashing.
- No shielding discoloration.
- No damage to wire/cable inside ribbon compound.
- Bubbles/voids within ribbon that do not expose conductive material to cable surface or between conductors (see Figures 10-69, 70).

10.3 Over-Molding of Flexible Flat Ribbon (cont.)

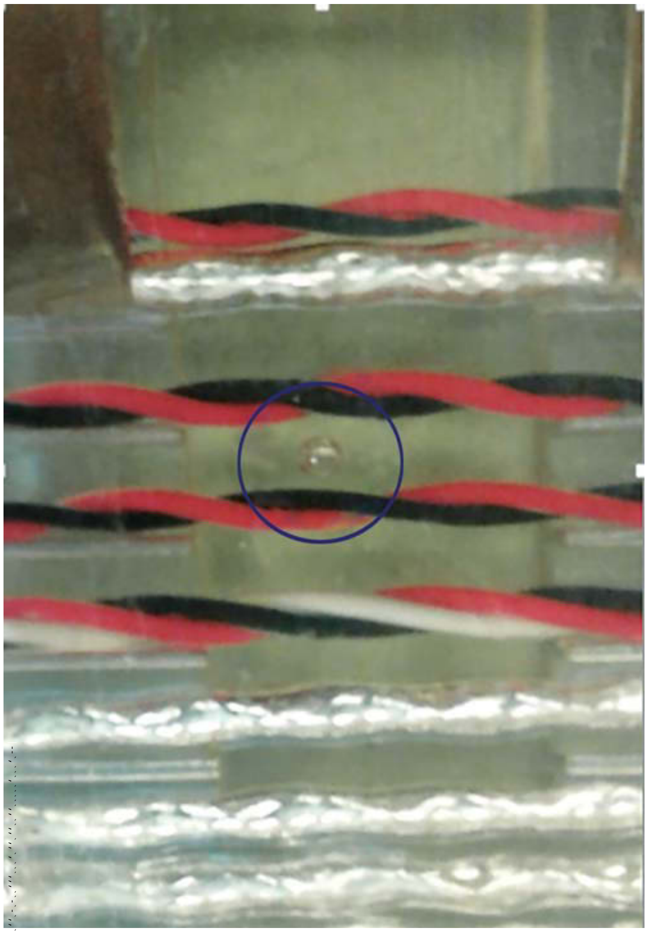

Figure 10-70

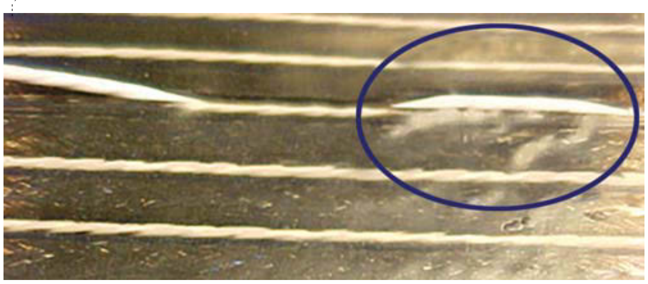

Figure 10-71

Figure 10-72

Defect – Class 1,2,3

- Conductors violate minimum electrical spacing.
- Wire/cable uneven routing within ribbon material.
- Wire/cable not encapsulated and outside of ribbon material (see Figure 10-71).
- Bubbles/voids/damage within ribbon that expose conductive material to cable surface (see Figure 10-72).
- Bubbles/voids within ribbon that bridge between conductors.
- Discolored shielding (see Figure 10-73).
- Flashing (see Figure 10-74).

10.3 Over-Molding of Flexible Flat Ribbon (cont.)

Figure 10-73

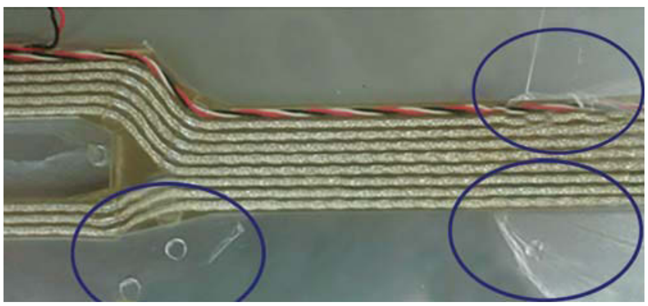

Figure 10-74

10.3.1 Over-Molding of Flexible Flat Ribbon – Mounting and Alignment Feature Adhesion

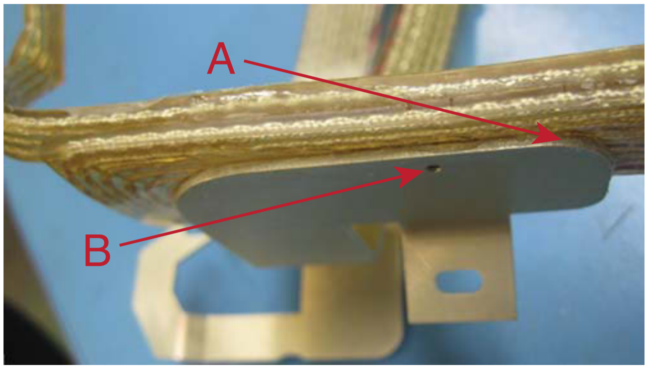

Figure 10-75

Acceptable – Class 1,2,3

- Proper adhesion between hardware and ribbon material, no gaps (see Figure 10-75-A).
- Adhesive does not interfere with mounting hardware (see Figure 10-75-B).

Defect – Class 1,2,3

- Gaps between hardware and ribbon material.
- Adhesive interferes with mounting hardware.

10.3.2 Over-Molding of Flexible Flat Ribbon – Adhesion Between Ribbon and Connector Potting

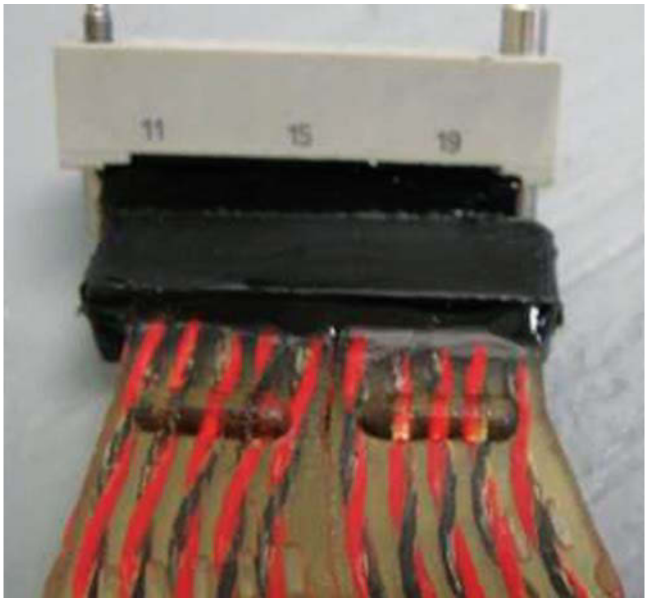

Figure 10-76

Acceptable – Class 1,2,3

- Adherence between ribbon material and potting material (see Figure 10-76).

Defect – Class 1,2,3

- Separation between ribbon material and potting material.

10.3.3 Over-Molding of Flexible Flat Ribbon – Mounting Hardware

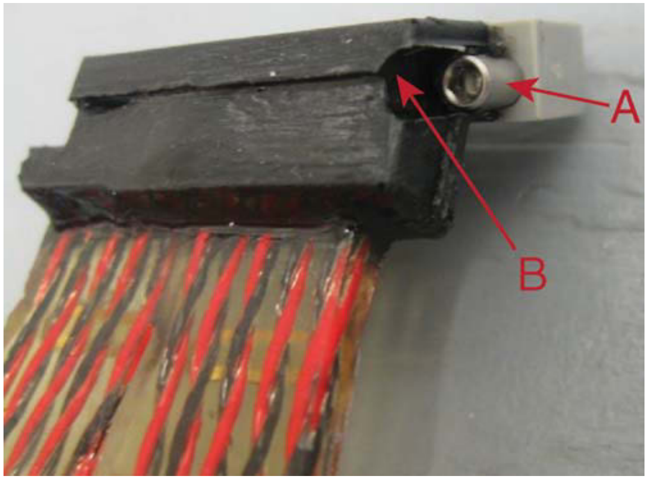

Figure 10-77

Acceptable – Class 1,2,3

- Mounting hardware free of potting material (see Figure 10-77-A).
- No exposed insulation, sleeving, jacket, braid or foil (see Figure 10-77-B).

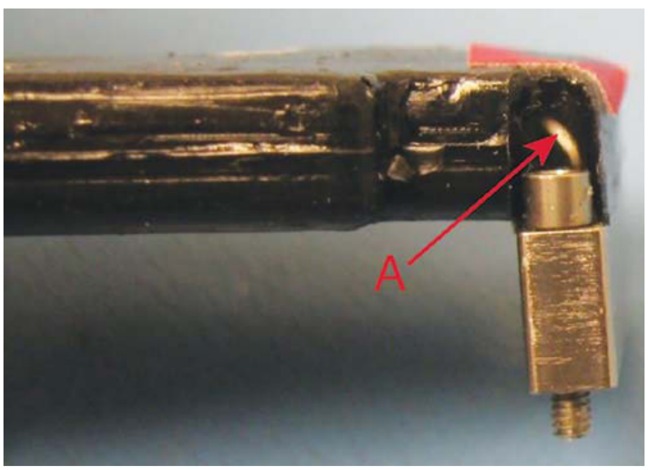

Figure 10-78

Defect – Class 1,2,3

- Potting material interferes with hardware mounting.
- Exposed insulation, sleeving, jacket, braid or foil (see Figure 10-78).

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11 Measuring Cable Assemblies and Wires

The following topics are addressed in this section.

11.1 Measuring – Cable and Wire Length Tolerance

Cable assembly and wire length measurement tolerance **shall [D1D2D3]** be as shown in Table 11-1 unless otherwise defined on the engineering documentation.

Table 11-1 Cable/Wire Length Measurement Tolerance

Metric		Imperial English	
≤0.3 m	+25 mm -0 mm	≤1 ft	+1 in -0 in
>0.3 m - 1.5 m	+50 mm -0 mm	>1 ft - 5 ft	+2 in -0 in
>1.5 m - 3 m	+100 mm -0 mm	>5 ft - 10 ft	+4 in -0 in
>3 m - 7.5 m	+150 mm -0 mm	>10 ft - 25 ft	+6 in -0 in
>7.5 m	+5% -0%	>25 ft	+5% -0%

11.2 Measuring – Cable

11.2.1 Measuring – Cable – Reference Surfaces – Straight/Axial Connectors

Figure 11-1 identifies the points on a cable that are to be used as the reference surfaces.

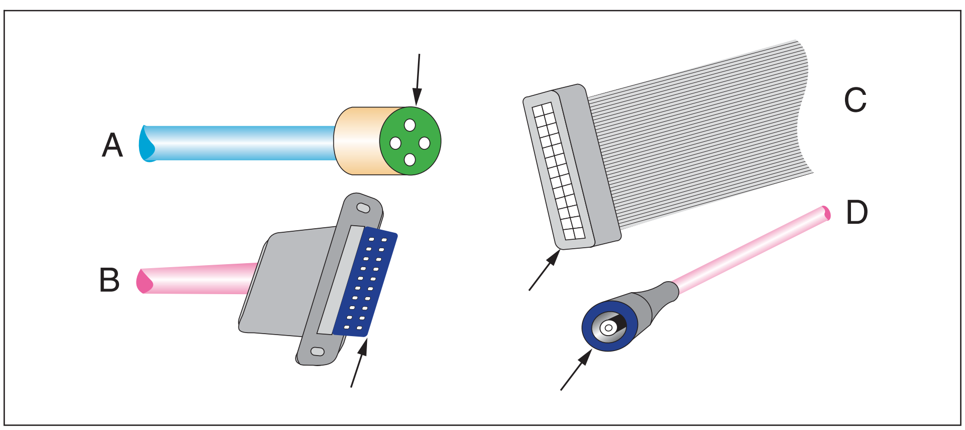

Figure 11-1

11.2.2 Measuring – Cable – Reference Surfaces – Right-Angle Connectors

Figure 11-2 identifies the points on a cable that are to be used as the reference surfaces.

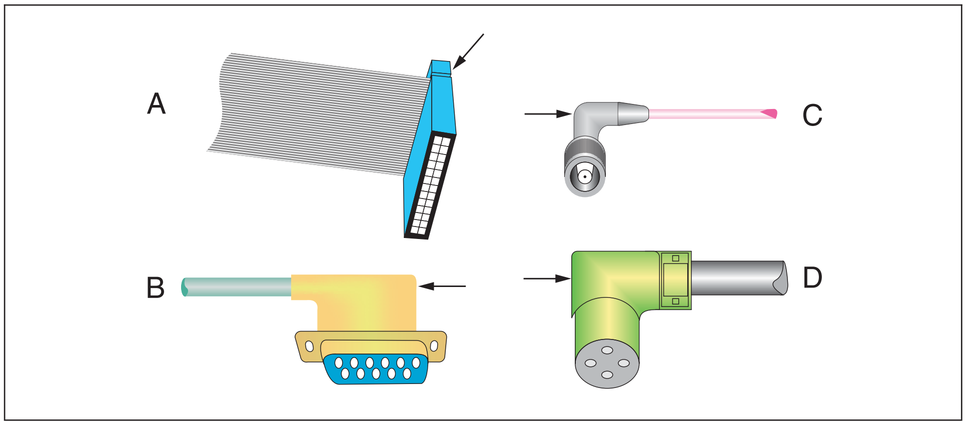

Figure 11-2

11.2.3 Measuring – Cable – Length

The length of a cable is measured from one end of the cable assembly to the other end. If reference surfaces are not specified on documentation, the reference surfaces are to be as specified in 11.2.1 and 11.2.2.

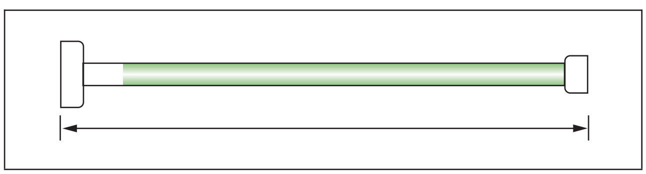

Figure 11-3

Acceptable – Class 1,2,3

- Cable length is within specified tolerances.

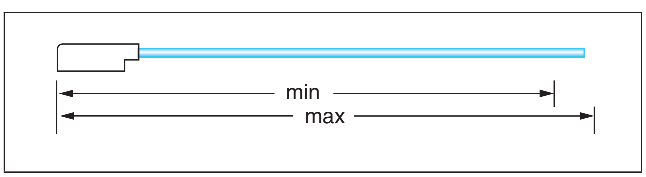

Figure 11-4

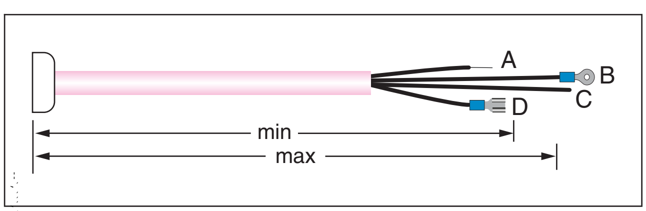

Figure 11-5

Defect – Class 1,2,3

- Cable length is not within specified tolerances.

11.2.4 Measuring – Cable – Breakout

11.2.4.1 Measuring – Cable – Breakout Measurement Points

The breakout measurement points are the centerlines of the cable bundle and the breakout bundle (see Figures 11-6, 7) and the ends of the breakout or bundle.

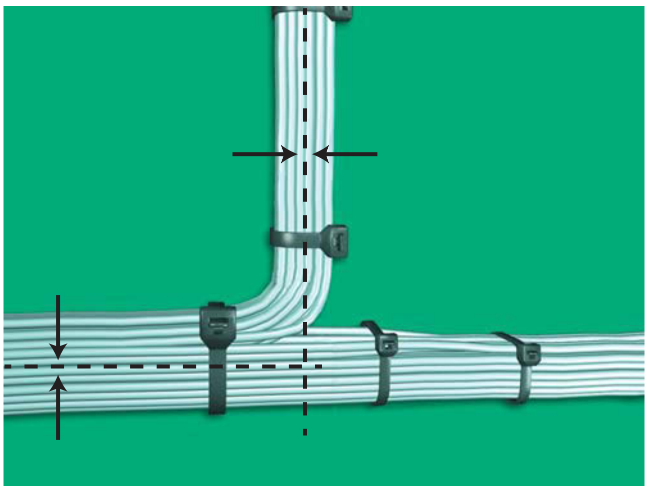

Figure 11-6

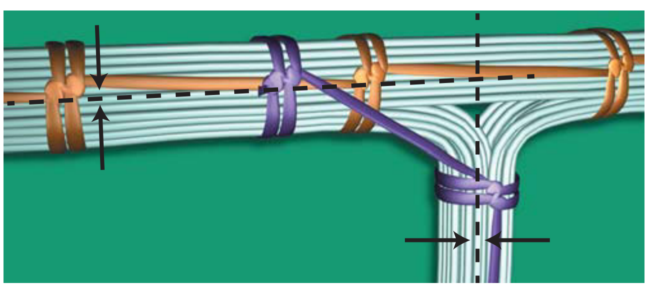

Figure 11-7

11.2.4.2 Measuring – Cable – Breakout Length

Breakout length is measured from the breakout point to the end of the breakout. If reference locations are not specified on documentation, use reference surfaces specified in 11.2.1 and 11.2.2. Cable length measurement tolerance is provided in Table 11-1.

Acceptable – Class 1,2,3

- Breakout length is within the specified tolerance of the engineering documentation nominal length or Table 11-1 if not specified.

Defect – Class 1,2,3

- Breakout length is not within the specified tolerance of the engineering documentation nominal length or Table 11-1 if not specified.

11.3 Measuring – Wire

Single wires used as a finished assembly or product generally consists of an insulated wire with one or both ends of the wire installed into electrical terminal(s).

If reference locations are not specified on documentation, use the reference surfaces specified in 11.3.1.

11.3.1 Measuring – Wire – Electrical Terminal Reference Location

Figure 11-8 illustrates the dimensional reference location (RL) or surface (RS) for several types of insulated and uninsulated electrical terminals. For ring (A), hook (B) and fork (C) terminals the fastener hole center is the reference location (RL). For quick-disconnect (D) and bullet (E) terminals the end of the terminal is the reference surface (RS).

Figures 11-9, 10 and 11 illustrate the dimensional reference location for wires and cables without terminations.

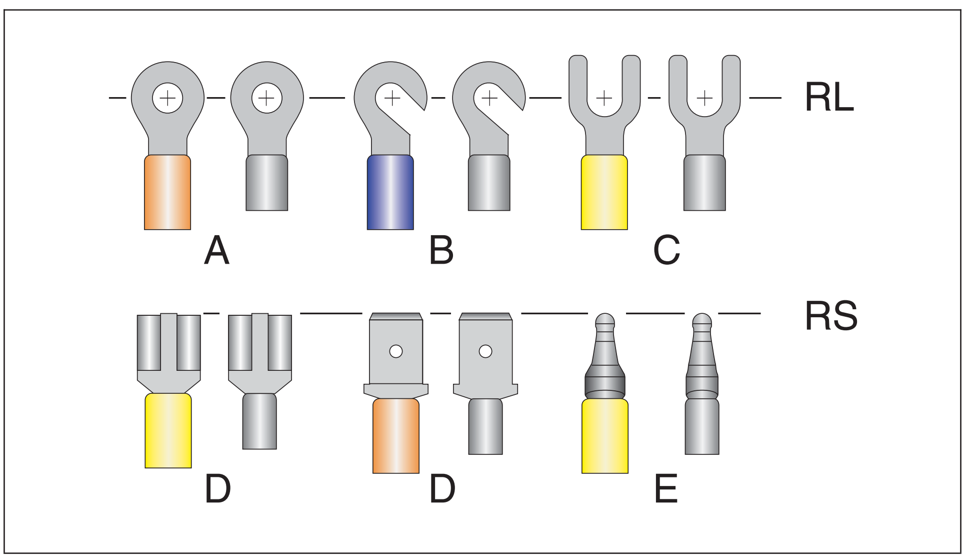

Figure 11-8

11.3.2 Measuring – Wire – Length

The overall wire length, as an assembly, of a wire includes all or a portion of the electrical terminal(s) from their reference location or reference surface.

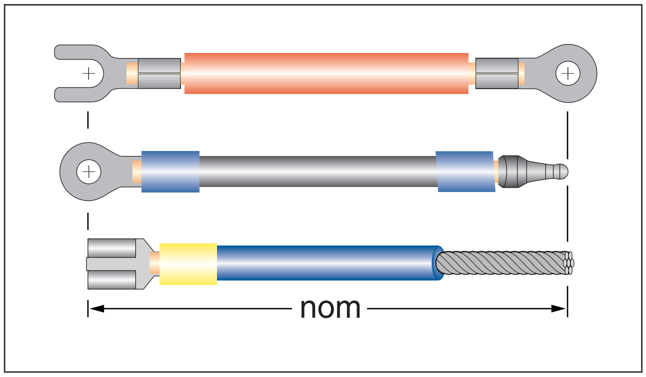

Figure 11-9

Acceptable – Class 1,2,3

- Wire length is within specified tolerances.

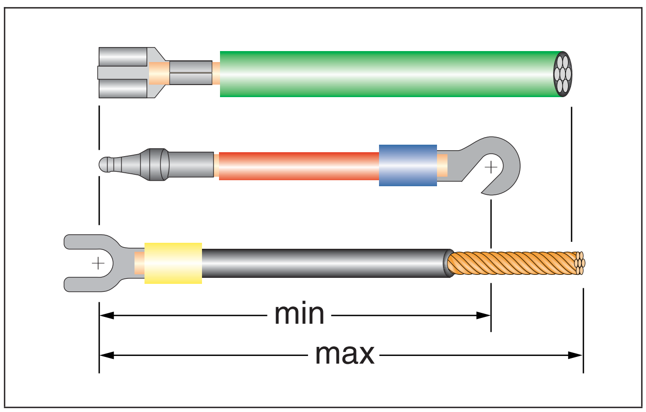

Figure 11-10

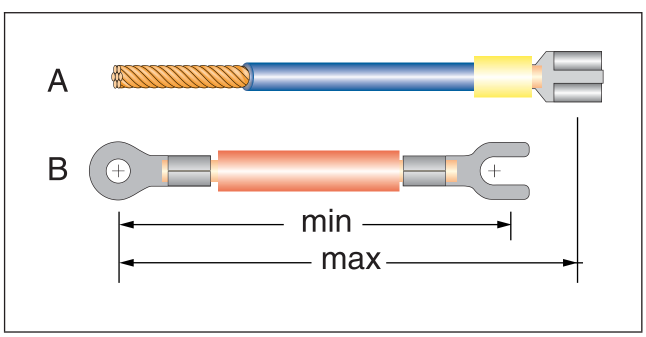

Figure 11-11

Defect – Class 1,2,3

- Wire length is not within specified tolerances.

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12 Marking/Labeling

Note: For the purposes of this section, marking and labeling are referred to as marking, as applied by the Manufacturer.

Marking is not required unless specified on the controlling document. If a marking method has not been specified by the controlling document, any marking method that meets the requirements of this section is acceptable.

Regardless of the marking method used, markings **shall [D1D2D3]** contain the required information, be legible, be permanent in the intended application, and **shall not [D1D2D3]** damage the product nor impair its function.

Marking inspection is to be performed without magnification.

Note: Additional (non-required) information may be marked onto the product for internal purposes. This marking is not subject to the provisions of this section, provided that:

- The marking does not conflict with, and is separated from, required information; and,
- Prior to delivery temporary markings **shall [N1N2D3]** be removed.

Criteria with obvious understanding may not have illustrations.

Tie wraps/lacing used to install markers **shall [D1D2D3]** meet the criteria of 14.1.

The following topics are addressed in this section.

12.1 Content

12.2 Legibility

12.3 Permanency

12.4 Location and Orientation

12.5 Functionality

12.6 Marker Sleeve

12.6.1 Wrap Around
12.6.2 Tubular

12.7 Flag Markers

12.7.1 Adhesive

12.8 Tie Wrap Markers

12.1 Content

Acceptable – Class 1,2,3

- Markings include the content specified by the controlling document.

Defect – Class 1,2,3

- Marking content incorrect.
- Marking missing.

12.2 Legibility

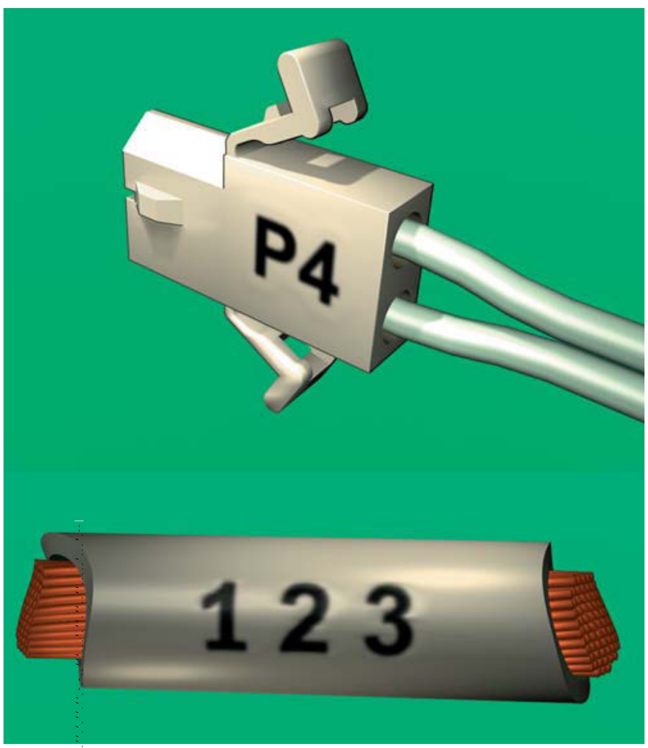


Figure 12-1

Acceptable – Class 1,2,3

- Marking legible but blurred (see Figure 12-2).
- Machine readable code can be successfully read within three attempts (see Figure 12-3).

12.2 Legibility (cont.)

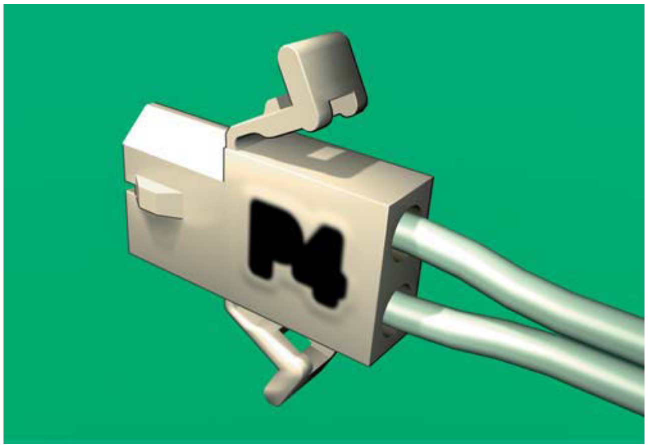


Figure 12-2

Figure 12-3

12.2 Legibility (cont.)

Figure 12-4

Figure 12-5

Defect – Class 1,2,3

- Marking not legible.
- Machine readable code cannot be successfully read within three attempts.

12.3 Permanency

Acceptable – Class 1,2,3

- Markings remain legible after exposure to handling, assembly and required environmental testing.

Defect – Class 1,2,3

- Markings not legible or present after exposure to handling, assembly and required environmental testing.

12.4 Location and Orientation

Figure 12-6

Figure 12-7

Acceptable – Class 1,2,3

- Marking present in location(s) designated by controlling document.
- If marking is required and the location is not specified, the marking is less than 300 mm [12 in] from the breakout, end of wire (where the end product is unterminated wire or wires), or the rearmost connector accessory, e.g., backshell, boot, ferrule, etc.
- The marker sleeve is positioned on the boot.
- Color coded marking (bands) read away from the connector (see Figure 12-7 reading ‘‘10549’’).
- Marker orientation meets requirements if specified.

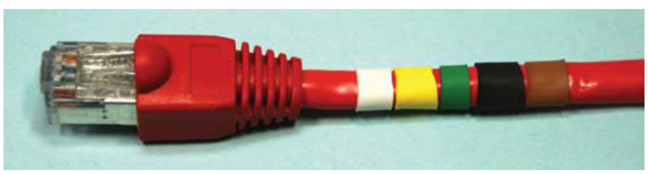


Figure 12-8

Acceptable – Class 1
Defect – Class 2,3

- Marking not in specified location(s).
- If marking is required and the location is not specified the marking is more than 300 mm [12 in] from the breakout, end of wire (where the end product is unterminated wire or wires), or the rearmost connector accessory, e.g., backshell, boot, ferrule, etc.
- Color coded marking (bands) does not read away from the connector (see Figure 12-8 reading ‘‘94501’’).

Defect – Class 3

- Marking is placed over spot ties/wraps.

Defect – Class 1,2,3

- Marker orientation does not meet specified requirements.

12.5 Functionality

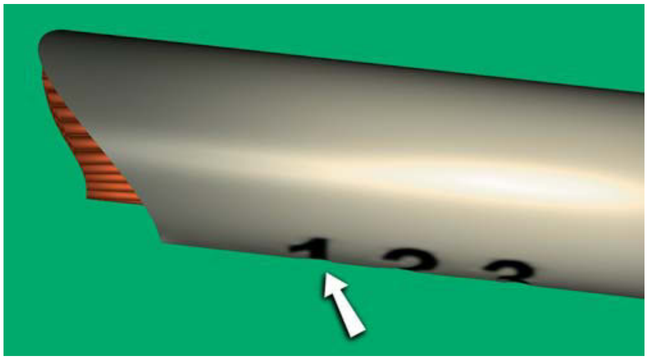


Figure 12-9

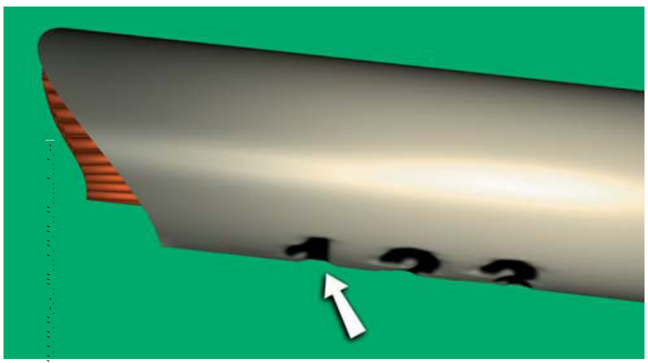


Figure 12-10

Acceptable – Class 1,2,3

- Insulation exhibits slight discoloration as a result of marking.
- Insulation deformation does not reduce insulating properties to less than the minimum dielectric requirements (see Figure 12-10).

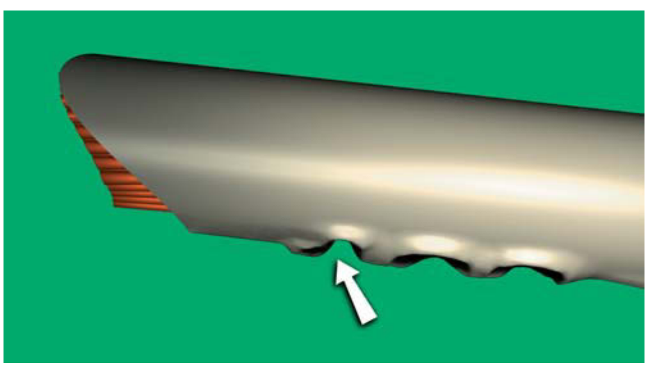


Figure 12-11

Defect – Class 1,2,3

- Insulation thickness reduced by more than 20%.
- Insulation scorched, charred, melted, or brittle as a result of the marking process.
- Marking present on exposed (uninsulated) conductor in region where conductor will connect to mating surface or hardware.

12.6 Marker Sleeve

12.6.1 Marker Sleeve – Wrap Around

Figure 12-12

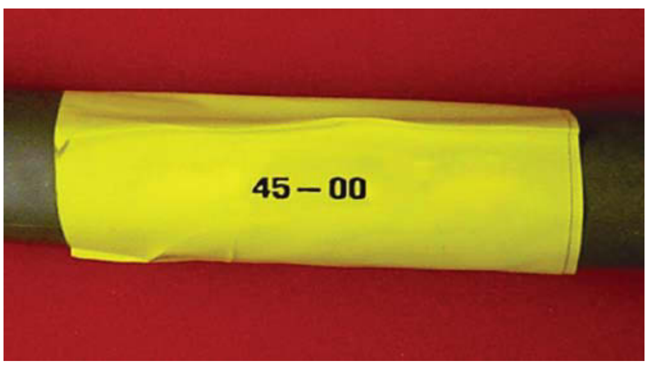


Figure 12-13

Acceptable – Class 1,2,3

- The marker sleeve wraps around the cable a minimum of 1.25 times and is secure and does not obscure any required marking.
- The marker sleeve is wrinkled or misaligned but remains legible and does not affect further assembly steps.

12.6.1 Marker Sleeve – Wrap Around (cont.)

Defect – Class 2,3

- For marker sleeves with a clear section, the clear section does not extend beyond the marking by at least 25% of the wire/wire bundle circumference.
- For marker sleeves with a clear section, the clear section renders the marking illegible.

Figure 12-14

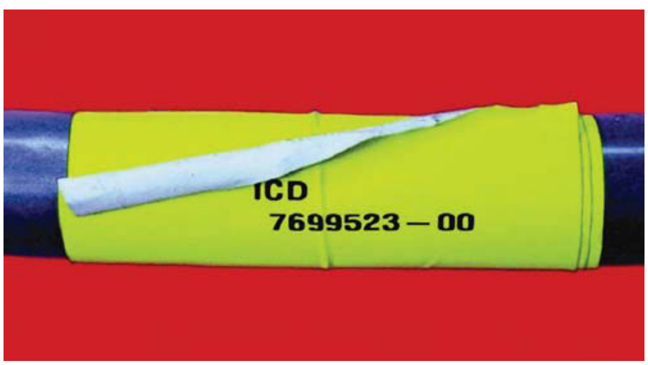


Figure 12-15

Figure 12-16

Defect – Class 1,2,3

- Any wrinkles or misalignment that affects legibility or further assembly steps (see Figure 12-14).
- The marker sleeve overlap is not secure (see Figure 12-15).
- The marker sleeve overlap is less than 1.25 times the cable circumference (see Figure 12-16).
- The wrap covers required marking.

12.6.2 Marker Sleeve – Tubular

Figure 12-17

Figure 12-18

Acceptable – Class 1,2,3

- The marker sleeve is sufficiently shrunk to remain secure (no sliding).

Figure 12-19

Defect – Class 2,3

- Any split.
- Any hole greater than 3 mm [0.12 in].

Defect – Class 1,2,3

- Any splits or holes that render marking illegible.
- The marker sleeve is not sufficiently shrunk to remain secure.

12.7 Flag Markers

12.7.1 Flag Markers – Adhesive

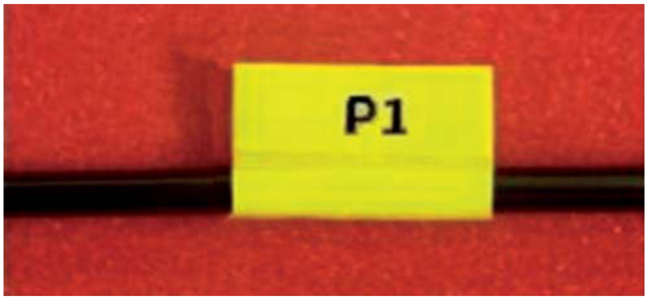


Figure 12-20

Figure 12-21

Acceptable – Class 2,3

- The flag marker side or end misregistration is less than 10% of the width of the marker (see Figure 12-21).

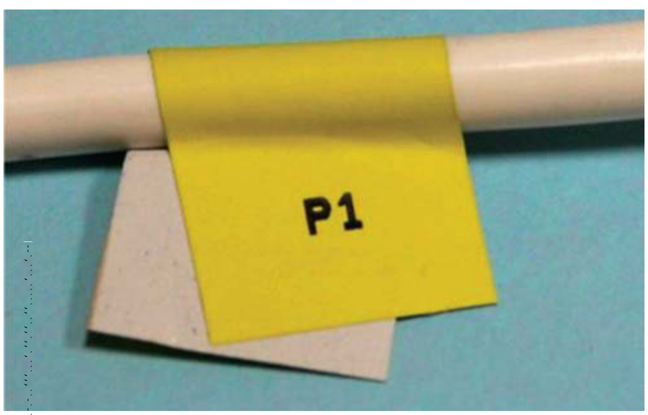


Figure 12-22

Defect – Class 2,3

- The flag marker side or end misregistration exceeds 10% of the width of the marker (see Figure 12-22).

12.8 Tie Wrap Markers

See 14.1 for tie wrap installation requirements.

13 Coaxial and Biaxial Cable Assemblies

Where coaxial and biaxial connectors are used with the recommended cable type, one should follow all assembly instructions provided by the connector manufacturer. For non-standard applications, process design verification should be performed. In general, the pieces of the connectors must remain as concentric as possible. The relationship of the outside diameter (OD) of the cable center conductor/connector contact, the thickness of the dielectric, and the inside diameter (ID) of the connector body and cable shielding are critical to electrical and mechanical function of the assembly. Insulation integrity is important to preclude shorting of shields to each other or shorting of shields to the center conductor.

Criteria for sleeving damage are provided in 16 (Cable/Wire Harness Protective Coverings).

The following topics are addressed in this section.

13.1 Stripping

Coaxial cable is manufactured using different shield configurations that give different percentage of coverage values. The majority of cable fits into just a few groups. Some cable is identified as double shield. When the double shield has a foil wrap rather than a second braid, the foil is not used during mechanical attachment and would be assembled as a single-braid cable.

Tolerance of a shield configuration to missing strands depends on the shield coverage percentage required. Table 13-1 provides the damaged or missing braid allowances.

Table 13-1 Coaxial and Biaxial Shield and Center Conductor Damage[1,2]

Number of Strands	Maximum Allowable Strands[1] Scraped, Nicked, Severed or Missing Classes 1,2,3		
	Shield Braid[3]	Center Conductor: Crimped Terminations	Center Conductor: Soldered Terminations
Less than 7	0	0	0
7-15	1	0	1
16-25	3	0	2
26-40	4	3	3
41-60	5	4	4
61-120	6	5	5
121 or more	6%	5%	5%

Note 1: For plated wires, a visual anomaly that does not expose basis metal is not considered to be strand damage.
Note 2: The effects of nicks or scrapes vary with the applied signal frequency and will require engineering determination for acceptability.
Note 3: No severed or missing shield braid strands allowed for Class 3.

Figure 13-1

Figure 13-2

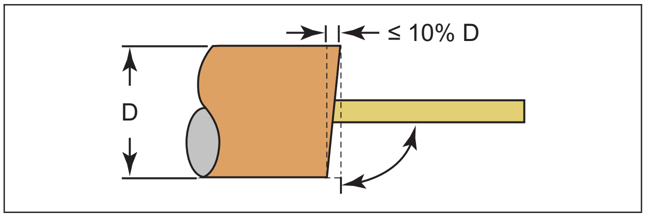


Figure 13-3

Acceptable – Class 1,2,3

- Slight marks on dielectric.
- Minor unraveling of braid (see Figure 13-2).
- Slight discoloration on dielectric from thermal stripping.
- Trim area offset does not exceed 10% of the cable diameter (D) beyond the perpendicular angle to the center conductor (see Figure 13-3).

Acceptable – Class 1
Process Indicator – Class 2,3

- Any damage that does not exceed the limits of Table 13-1.

13.1 Stripping (cont.)

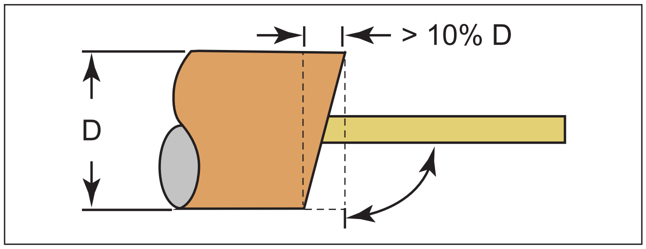


Figure 13-4

Not Established – Class 1
Defect – Class 2,3

- Trim area offset exceeds 10% of the cable diameter (D) beyond the perpendicular angle to the center conductor (see Figure 13-4).

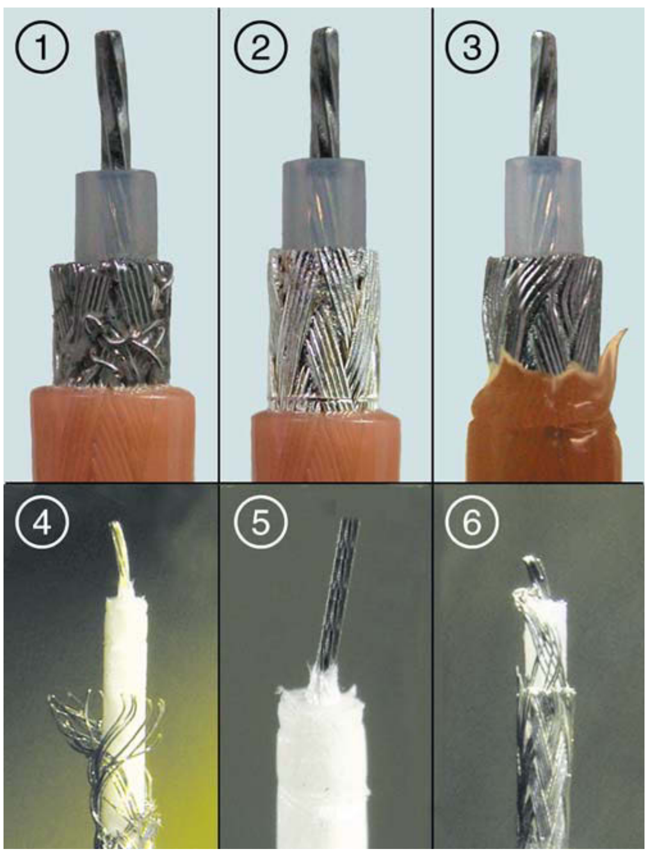


Figure 13-5
1. Braid twisted
2. Braid scored
3. Outer jacket frayed
4. Unwoven braid, missing strands
5. Ragged dielectric, tool marks
6. Incomplete removal of strands

Defect – Class 1,2

- Any damaged braid that exceeds the limits of Table 13-1 (see Figure 13-5-2, 4).

Defect – Class 3

- Scraped or nicked shield braid exceeds the allowance of Table 13-1.
- Any severed or missing shield strands.

Defect – Class 1,2,3

- Braid twisted/birdcaged (see Figure 13-5-1).
- Any cuts or breaks in outer jacket (not shown).
- Outer jacket thickness is reduced greater than 20% (see Figure 13-5-3).
- Uneven or ragged pieces (frays, tails, tags) of outer jacket are greater than 50% of the outer jacket thickness or 1 mm [0.040 in], whichever is more (see Figure 13-5-3).
- Uneven cut on braid; any long strands (see Figure 13-5-6).
- Discernible nicks or cuts in center conductor are greater than allowance of Table 13-1.
- Burns or melted areas on dielectric.
- Damage or indentation to center dielectric reducing insulation diameter by more than 10% (see Figure 13-5-5).

13.2 Center Conductor Termination

13.2.1 Center Conductor Termination – Crimp

As an exception to crimping criteria of 5 (Crimp Terminations (Controls and Lugs)) introduction, crimping of solid wire is acceptable when the connector is designed for solid wire and the connection is performed in accordance with the connector manufacturer's procedures and recommended tooling.

Figure 13-6

Acceptable – Class 1,2,3

- Crimp not centered on crimp area of terminal but does not cause damage to terminal.
- Dielectric does not enter barrel of terminal.
- Gap between dielectric and terminal meets manufacturer's requirements. In the absence of manufacturer's specifications, there is no gap.

13.2.1 Center Conductor Termination – Crimp (cont.)

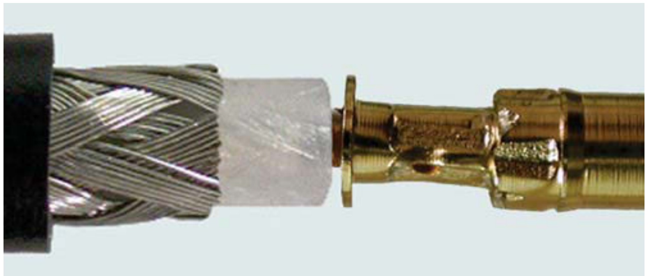


Figure 13-7

Figure 13-8

Figure 13-9

Figure 13-10

Defect – Class 1,2,3

- Crimp is not centered in crimp area of terminal and causes damage to terminal (see Figure 13-7).
- Conductor strand(s) not captured in terminal (see Figure 13-8).
- Terminal damaged by crimp (see Figures 13-7, 9 and 10).
- Pin shows ''dog ear'' of excess material (see Figure 13-9).
- Crimp loose – does not hold terminal (not shown).
- Braid strand(s) caught in terminal (not shown).
- Gap between terminal and dielectric exceeds manufacturer's requirements. In the absence of manufacturer's specifications, there is a gap between terminal and dielectric.

13.2.2 Center Conductor Termination – Solder

Figure 13-11

Figure 13-12

Acceptable – Class 1,2,3

- Solder slightly protrudes from inspection window, but will not interfere with assembly (see Figure 13-12).
- Minor flare of dielectric due to heat from solder does not interfere with assembly of connector.
- Gap between dielectric and terminal meets manufacturer's requirements. In the absence of manufacturer's specifications, there is no gap.
- During assembly center conductor is visible in the inspection window.
- The inspection window is filled with solder (see Figure 13-11).

13.2.2 Center Conductor Termination – Solder (cont.)

Figure 13-13

Figure 13-14

Defect – Class 1,2,3

- Braid extends into barrel of terminal (not shown).
- Strand(s) of center conductor not captured in terminal (not shown).
- Solder not visible in inspection window (see Figure 13-13).
- No discernible solder fillet or wetting between terminal and conductor (see Figure 13-13).
- Prior to soldering, center conductor not visible in inspection window (not shown).
- Excess solder prevents proper assembly of connector and electrical impedance of the connector (see Figure 13-14).
- Damage to dielectric due to heat from solder (see Figure 13-14).
- Residue remains when connection is required to be clean.
- Terminal embedded into dielectric.
- Gap between terminal and dielectric exceeds manufacturer's requirements. In the absence of manufacturer's specifications, there is a gap between terminal and dielectric.
- Solder on mating surface of contact.

13.3 Solder Ferrule Pins

13.3.1 Solder Ferrule Pins – General

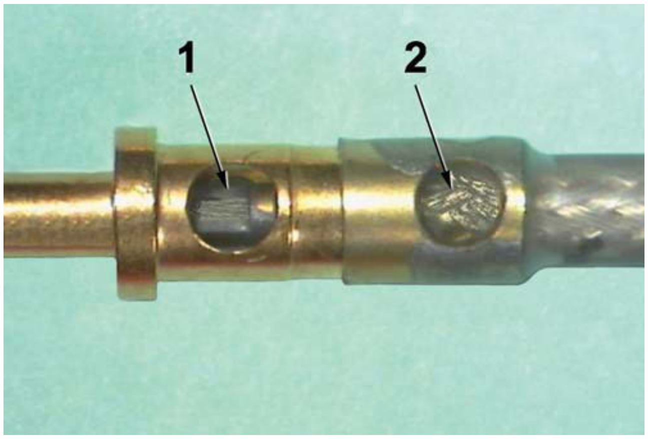


Figure 13-15
1. Wire inspection hole
2. Shield inspection hole

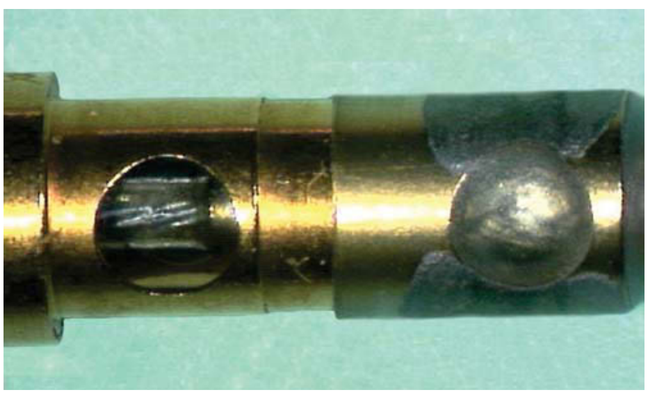


Figure 13-16

Acceptable – Class 1,2,3

- Twist of center conductor (see Figure 13-15-1) is disturbed.
- Solder fillet is evident in inspection holes.
- Film of solder on outside of terminal that does not interfere with subsequent assembly operations.

13.3.1 Solder Ferrule Pins – General (cont.)

Figure 13-17

Figure 13-18

Defect – Class 1,2,3

- Shield strand is protruding through sleeving or out of inspection hole.
- Solder ring is improperly flowed.
- Solder buildup on outside surface of contact.
- Film of solder on outside of terminal interferes with subsequent assembly operations.

13.3.2 Solder Ferrule Pins – Insulation

Figure 13-19

Acceptable – Class 1,2
Process Indicator – Class 3

- Pin tip insulation has melted flush to the surface of contact, and contact hole is free of insulation obstruction.
- Insulation in inspection hole is protruding beyond the pin surface. Does not prevent contact mating.

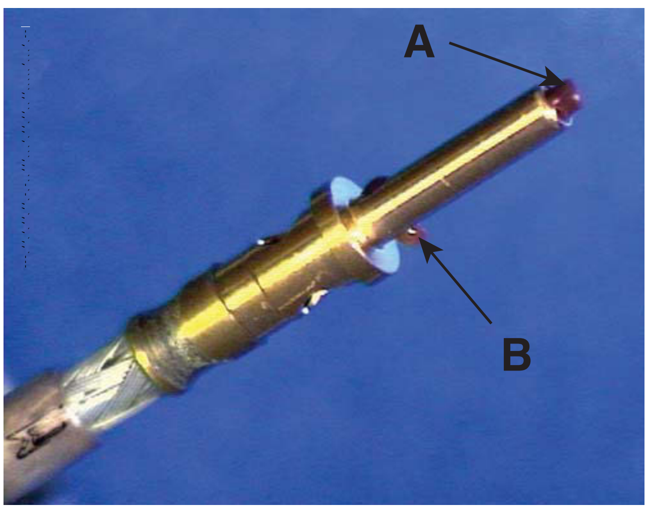


Figure 13-20

Defect – Class 1,2,3

- Insulation has melted beyond the outside surface of contact, and contact hole is obstructed (see Figure 13-20-A).
- Insulation in inspection hole is protruding beyond the pin surface, prevents contact mating (see Figure 13-20-B).

13.4 Coaxial Connector – Printed Wire Board Mount

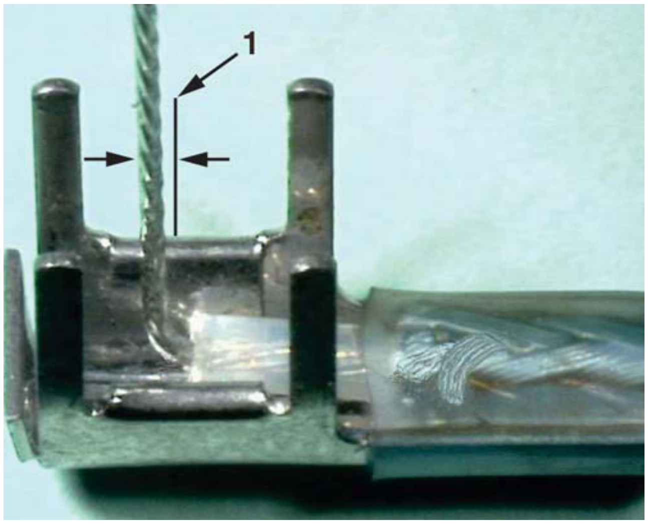


Figure 13-21

Acceptable – Class 1,2,3

- Wire is positioned 0.75 mm [0.03 in] or less from center (see Figure 13-21-1) of the four connector leads.
- Solder fillet is evident between shield and connector.
- Shield weave pattern is slightly disturbed.

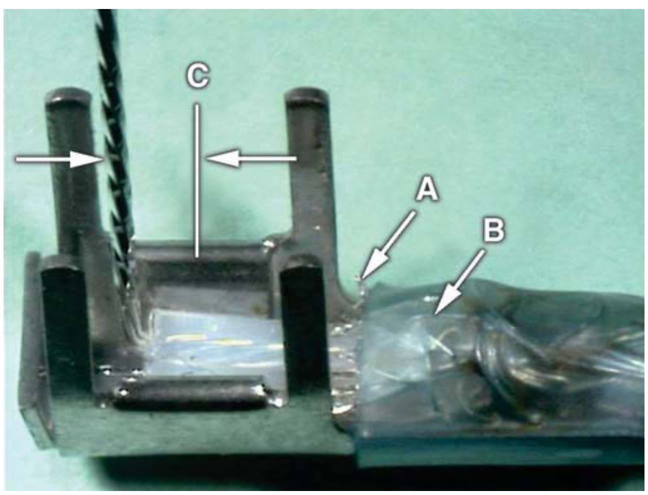


Figure 13-22

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Shield extends beyond sleeving (see Figure 13-22-A).

Defect – Class 1,2,3

- Shield is piercing sleeving (see Figure 13-22-B).
- Solder fillet is not evident between shield and connector.
- Wire is positioned greater than 0.75 mm [0.03 in] from the center (see Figure 13-22-C) of the four connector leads.

13.5 Coaxial Connector – Center Conductor Length – Right Angle Connector

Figure 13-23

Acceptable – Class 1,2,3

- Center conductor extends beyond the edge of the slotted terminal no greater than one center conductor diameter.
- Center conductor does not contact connector housing.
- Dielectric extends into connector cavity. Air gap is maintained between slotted terminal and dielectric.

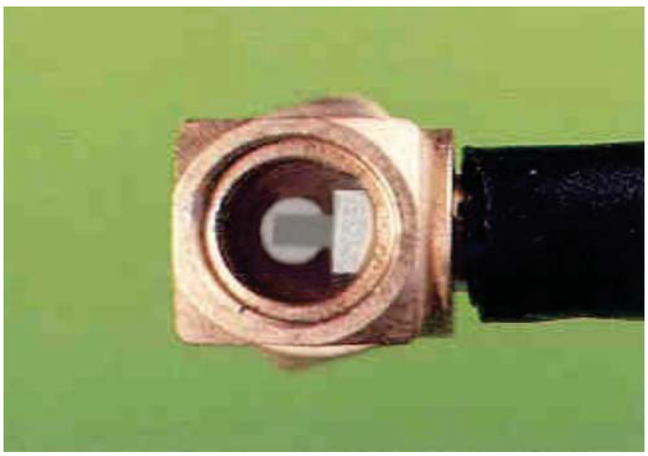


Figure 13-24

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Center conductor is not flush, or visible beyond the edge of the slotted terminal.

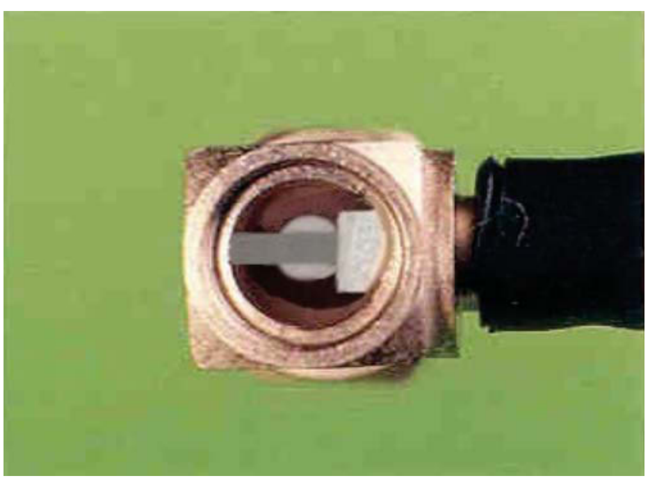


Figure 13-25

Acceptable – Class 1
Process Indicator – Class 2,3

- Dielectric extends into connector cavity and touches the slotted terminal.

Defect – Class 1,2,3

- Center conductor extends beyond the edge of the slotted terminal greater than one center conductor diameter.
- Center conductor contacts connector housing.

13.6 Coaxial Connector – Center Conductor Solder

Figure 13-26

Acceptable – Class 1,2,3

- Conductor end is discernible in the solder on the exit side of terminal.

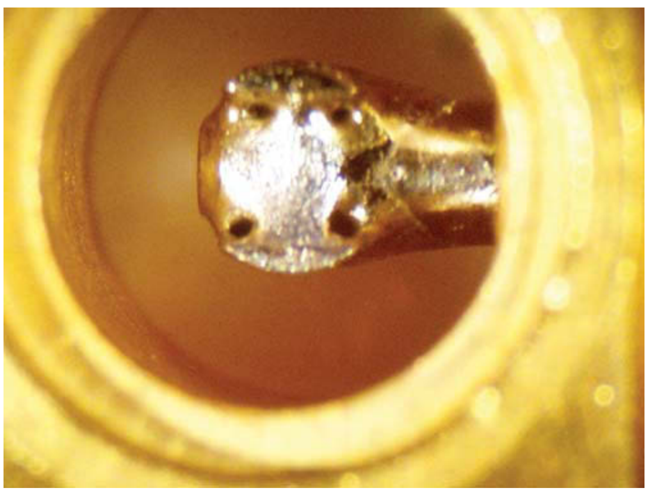


Figure 13-27

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Any pinholes/blowholes where all inner surfaces are not visible.

13.6 Coaxial Connector – Center Conductor Solder (cont.)

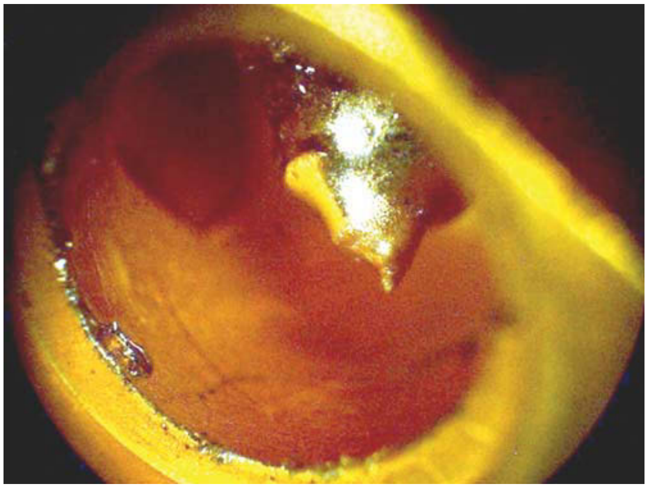


Figure 13-28

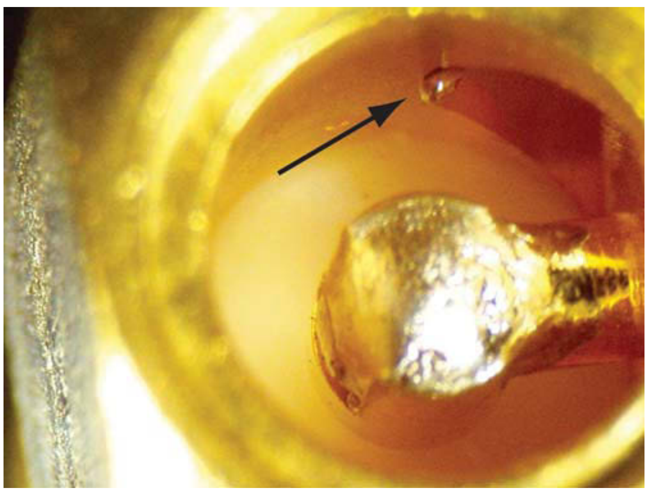


Figure 13-29

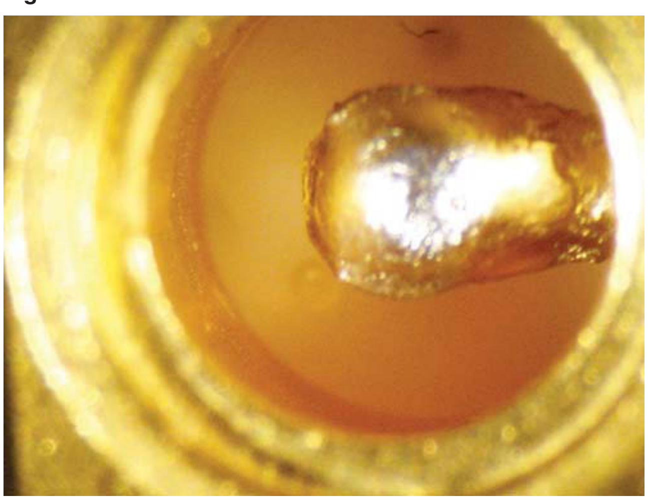


Figure 13-30

Defect – Class 1,2,3

- Solder splash or spillage on sides of contact, inside walls of cavity or the terminal cover area (see Figure 13-28).
- Any solder balls inside cavity (see Figure 13-29).
- Excess solder on top of contact (see Figures 13-29, 30) or solder peaks/icicles (see Figure 13-28).

13.7 Coaxial Connector – Terminal Cover

Terminal covers may be intended for either solder (13.7.1) or press fit (13.7.2) attachment.

13.7.1 Coaxial Connector – Terminal Cover – Soldering

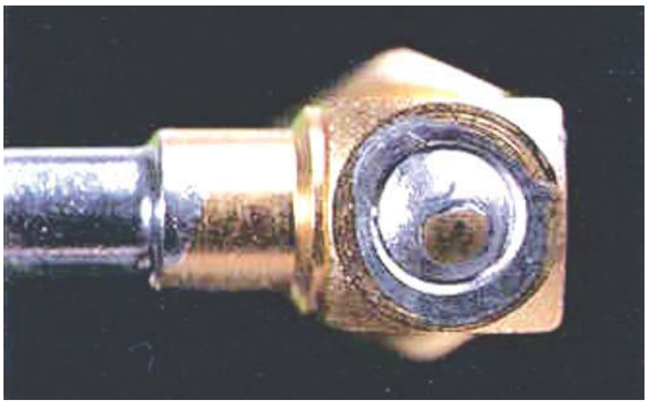


Figure 13-31

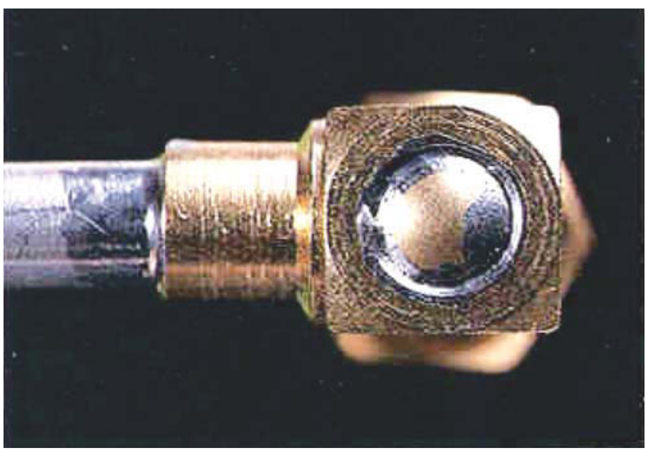


Figure 13-32

Acceptable – Class 1

- Cumulative solder fillet(s) greater than or equal to 330° around connector body and cover (see Figure 13-32).

Acceptable – Class 2,3

- 360° solder fillet between connector body and cover (see Figure 13-31).

Figure 13-33

Acceptable – Class 1,2,3

- Solder buildup over entire cover, but does not interfere with subsequent assembly steps.

13.7.1 Coaxial Connector – Terminal Cover – Soldering (cont.)

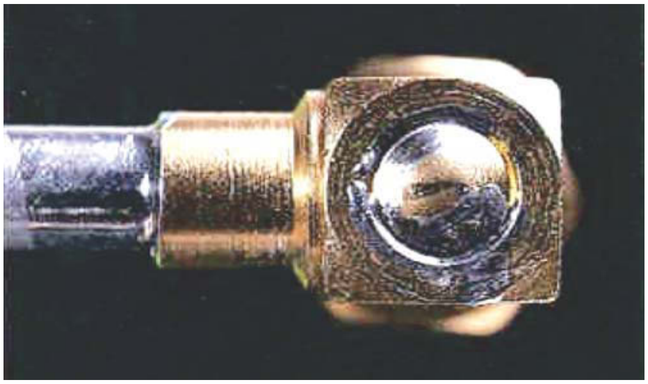


Figure 13-34

Defect – Class 1

- Solder fillet is less than 330° around connector body and cover.

Defect – Class 2,3

- Solder fillet is less than 360° around connector body and cover.

13.7.2 Coaxial Connector – Terminal Cover – Press Fit

The completed press fit connector cover **shall [D1D2D3]** comply with the connector manufacturer's published requirements and instructions.

13.8 Shield Termination

13.8.1 Shield Termination – Clamped Ground Rings

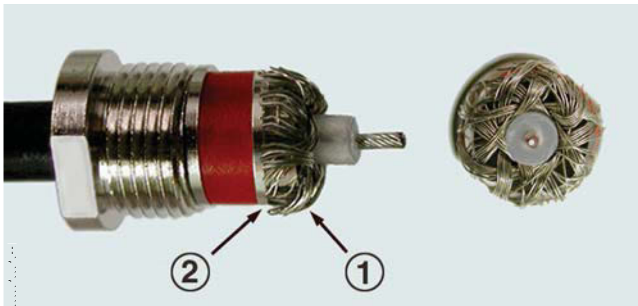


Figure 13-35
1. Braid
2. Ground ring (only base is visible)

Figure 13-36

Acceptable – Class 1,2,3

- Shield strands not uniformly distributed around the ground ring (see Figure 13-36).
- Shield strands contact outer shoulder flange of the shield ground ring but do not impede assembly of the connector.
- Shield ground strands hold the shield ground ring in tight contact with the cable outer jacket.

Defect – Class 1,2,3

- Shield strands do not hold the shield ground ring in tight contact with the cable outer jacket.

13.8.2 Shield Termination – Crimped Ferrule

Figure 13-37

Figure 13-38

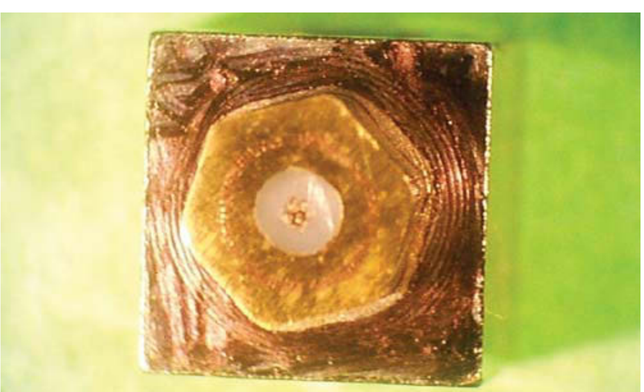


Figure 13-39

Acceptable – Class 1,2,3

- Gap between connector body and ferrule is less than 0.75 mm [0.030 in] (see Figure 13-37).
- Distance between connector body and start of crimp is less than 0.75 mm [0.030 in].
- No wire strands protrude from the gap between the connector body and ferrule.

Note: Figure 13-39 shows cross-section of a ferrule with uniform crimp.

13.8.2 Shield Termination – Crimped Ferrule (cont.)

Figure 13-40

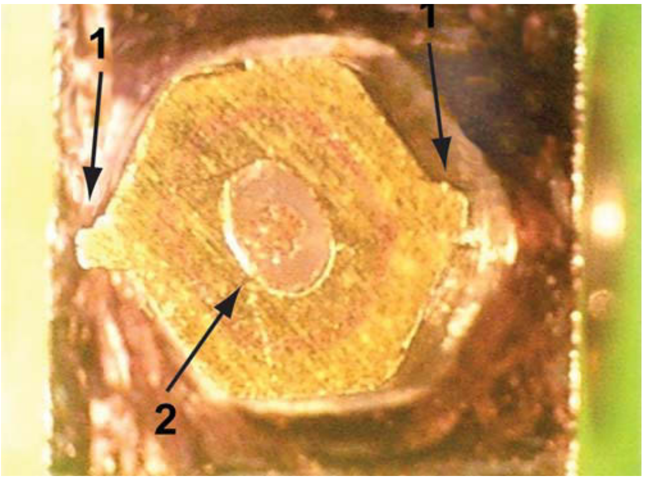


Figure 13-41
1. Dog ears
2. Dielectric deformation

Defect – Class 1,2,3

- Crimp extends over the cable jacket.
- Double crimps.
- Gap between ferrule and connector body is more than 0.75 mm [0.030 in].
- Distance between connector body and crimp is more than the maximum allowed.
- Ferrule shows ''dog ear'' of excess material; cross-section example of ''dog ear'' shown in Figure 13-41.
- Wire strand protrudes from the gap between the connector body and ferrule.
- Ferrule is loose.

13.9 Center Pin

13.9.1 Center Pin – Position

The location of the center conductor's connector contact is critical to meeting the electrical signal's integrity requirements. In the case of ‘‘fixed'' coaxial cable center conductor contacts, the position of the center contact is determined by the design of the connector, and the assembly process generally minimally affects the position of the center conductor's contact. The position of ‘‘floating'' center conductor contacts is greatly affected by the assembly, primarily due to shield termination and wire preparation cut/trim lengths. Refer to manufacturer's assembly specifications.

Figure 13-42

Acceptable – Class 1,2,3

- Center pin fully seated.

Figure 13-43

Defect – Class 1,2,3

- Center pin not fully seated.
- Center pin extends beyond proper height (not shown).

13.9.2 Center Pin – Damage

(Not illustrated.)

Acceptable – Class 1,2

- Cuts, nicks or scrapes less than 10% in the center pin diameter and/or surface area, and do not expose basis metal.

Note: The effects of nicks or scrapes vary with the applied signal frequency and will require engineering determination for acceptability.

Acceptable – Class 3

- No cuts, nicks or scrapes on the center pin.

Defect – Class 1,2

- Damage greater than 10% diameter of the center pin.
- Exposed basis metal.

Defect – Class 1,2,3

- Center pin is bent (not shown).
- Discernible cuts, nicks or scrapes on the center pin that expose basis metal.

13.10 Semirigid Coax

These criteria are applicable to rigid, semirigid, conformable and similar types of coaxial cable.

The acceptability of semirigid cable assemblies is greatly affected by three factors.

- *Application* – Bends or deformation of a cable will affect characteristic impedance (operation) of the assembly. After forming, the cable **shall [N1N2D3]** be normalized through a process of thermal conditioning prior to termination, unless otherwise documented. See MIL-DTL-17 for more information.
- *Cleanliness* – Mating surfaces, including test equipment **shall [D1D2D3]** be free of all foreign material, i.e., flux residue, metallic or other particles.
- *Tooling* – Proper tooling will prevent cable deformation and surface damage.

The criteria that follow will establish acceptance conditions for the most common applications.

The criteria of 13.1 are applicable.

Visual inspection of the cable cannot in all cases determine its fitness for use. With the exception of obvious damage or improper solder connections, the correct function of the cable assembly will be the determining factor of acceptance.

13.10.1 Semirigid Coax – Bending and Deformation

Figure 13-44

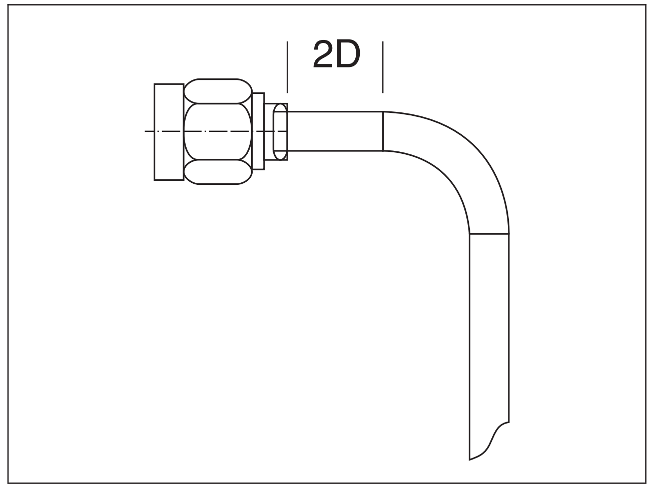


Figure 13-45

Figure 13-46

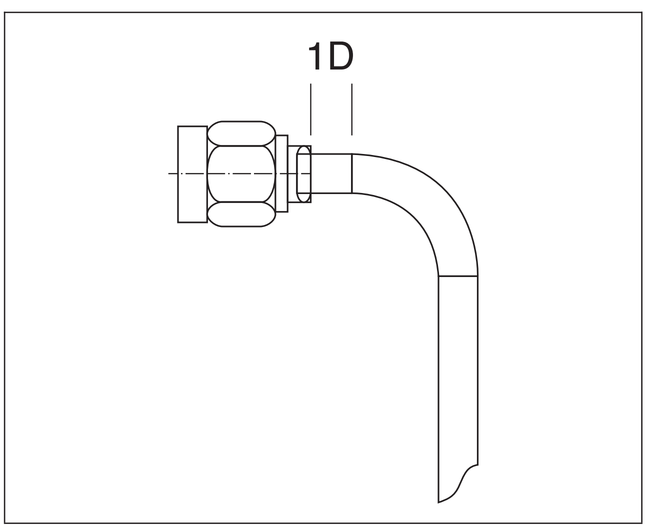


Figure 13-47

Acceptable – Class 1,2,3

- Inside bend radius is equal to or greater than the material manufacturer's specifications.
- No obvious wrinkles.
- Distance from back of connector to start of bend is at least one diameter (D) (see Figure 13-47).
- No physical damage to outer cable.

13.10.1 Semirigid Coax – Bending and Deformation (cont.)

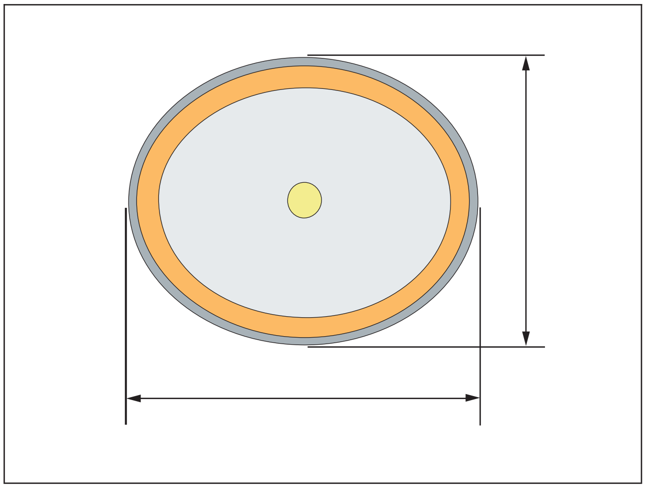


Figure 13-48

Acceptable – Class 1,2
Process Indicator – Class 3

- Deformation (eccentricity, see Figure 13-48) of the cable is within the limits of Table 13-2.

Table 13-2 Semirigid Coax Deformation

Nominal Cable Diameter	Cable Eccentricity Limits in any Dimension	
	Maximum	Minimum
0.141 in	0.151 in	0.131 in
0.086 in	0.092 in	0.080 in
0.047 in	0.051 in	0.043 in

Note: Hard metric dimensions are not provided.

Figure 13-49

Defect – Class 1,2,3

- Cable bend is distorted and not uniform.
- Minimum bend radius is less than the material manufacturer's requirements.
- Deformation (out-of-round) is beyond the limits of Table 13-2.
- Cable jacket has obvious wrinkles.
- Crack in semirigid cable.
- Distance from back of connector to start of bend is less than one diameter (D) (see Figure 13-51).

Figure 13-50

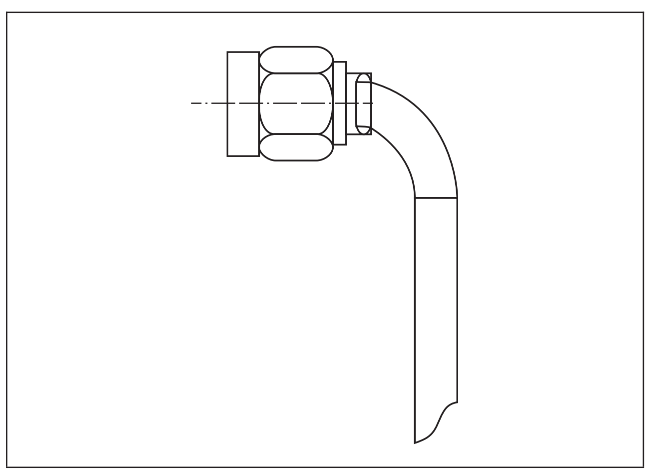


Figure 13-51

13.10.2 Semirigid Coax – Surface Condition

13.10.2.1 Semirigid Coax – Surface Condition – Solid

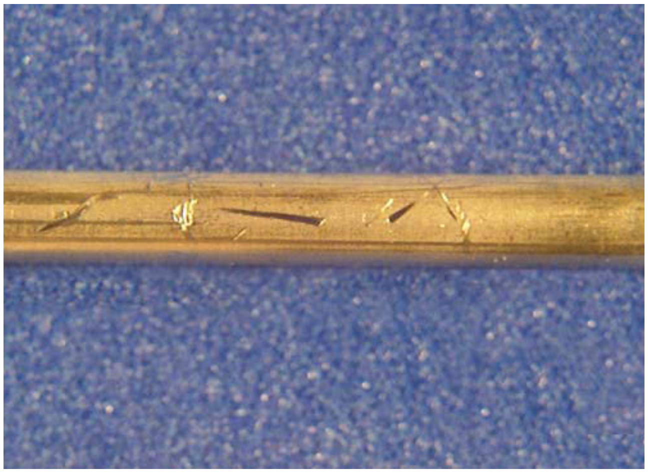


Figure 13-52

Acceptable – Class 1,2,3

- Outside surface of the cable has minor tooling marks, scratches or abrasions.
- If plated, basis metal is not exposed in an area to be soldered.

13.10.2.1 Semirigid Coax – Surface Condition – Solid (cont.)

Figure 13-53

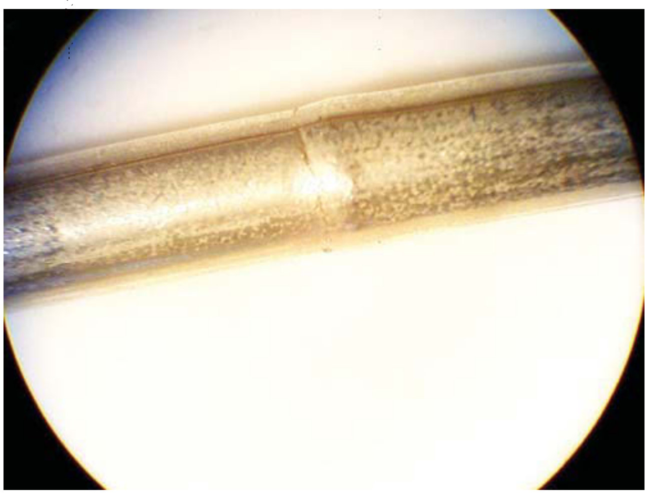


Figure 13-54

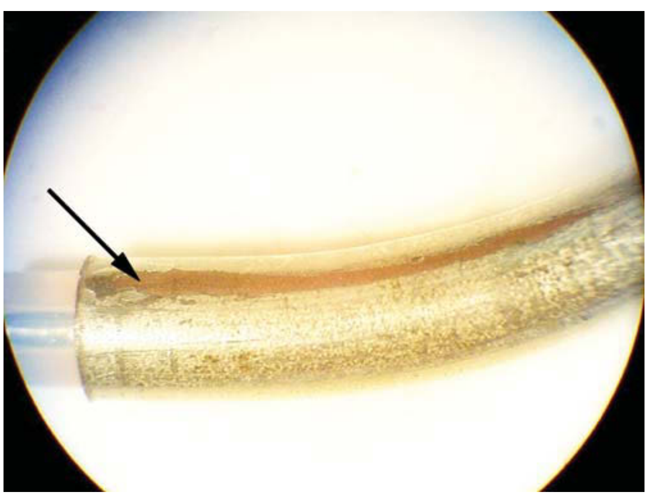


Figure 13-55

Defect – Class 1,2,3

- If plated, basis metal (see Figure 13-55) is exposed in an area to be soldered.
- Outside surface of the cable has tooling marks, scratches, cuts or abrasions that impact form, fit or function. Testing may be required.
- Bulge in semirigid cable (see Figure 13-54).

13.10.2.2 Semirigid Coax – Surface Condition – Conformable Cable

The solder criteria of 13.10.6 are also applicable to conformable cable.

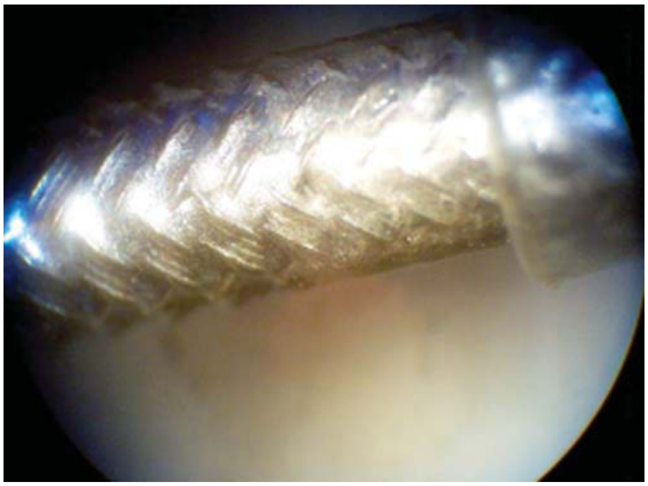


Figure 13-56

Acceptable – Class 1,2,3

- No voids in solder coating.

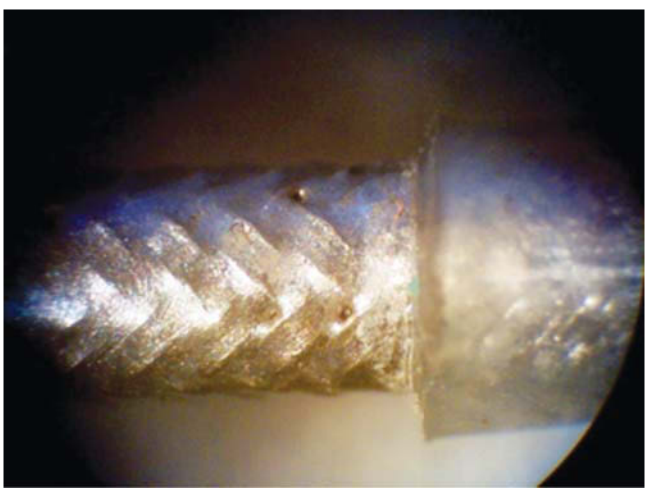


Figure 13-57

Defect – Class 1,2,3

- There are voids in solder coating.

13.10.3 Semirigid Coax – Dielectric Cutoff

Figure 13-58

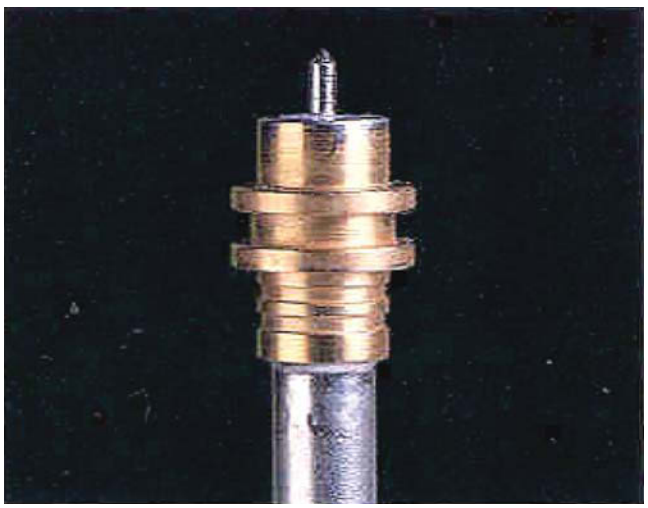


Figure 13-59

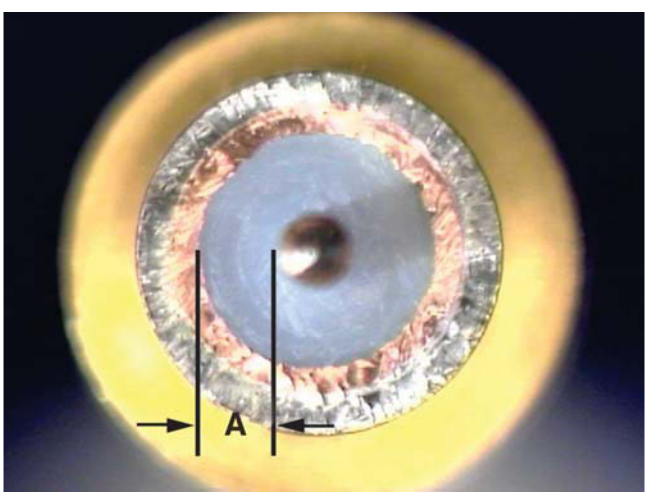


Figure 13-60

Acceptable – Class 1,2,3

- Dielectric position is within connector manufacturer's specification.
- Center conductor is perpendicular to dielectric/connector face.
- Trim area offset does not exceed 10% of the cable diameter (D) beyond the perpendicular angle to the center conductor (see Figure 13-3).
- Shield roll over is minimal. Distance from the edge of the center conductor to the shield (see Figure 13-60-A) is equal to, or greater than the values in Table 13-3.

Table 13-3 Dielectric Cutoff

Nominal Cable Diameter[1]	Minimum Distance - Edge of Center Conductor to Shield
0.141 in	0.75 mm [0.03 in]
0.086 in	0.50 mm [0.02 in]
0.047 in	0.25 mm [0.01 in]

Note 1. Nominal cable diameters are industry-defined using only the Imperial measurements shown.

13.10.3 Semirigid Coax – Dielectric Cutoff (cont.)

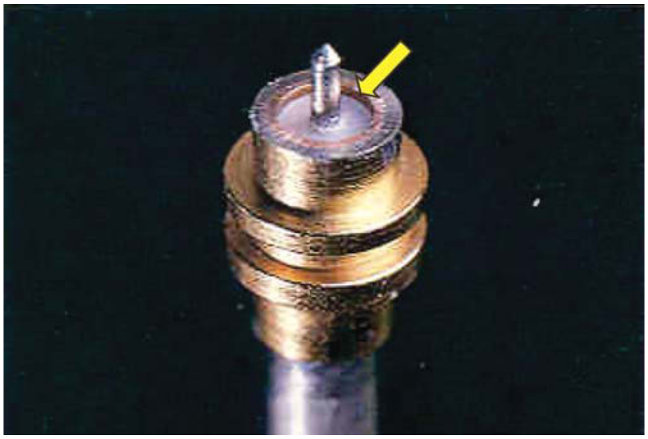


Figure 13-61

Defect – Class 1,2,3

- Dielectric position is not within connector manufacturer's specification (see Figure 13-61).
- Air gap between dielectric and cable shield (see Figure 13-62).
- Dielectric protrudes above connector face (see Figure 13-63).
- Center conductor is bent (see Figure 13-63).
- Shield roll over reduces the distance from the edge of the center conductor to the shield less than the limits of Table 13-3 (see Figures 13-64, 65).
- Trim area offset exceeds 10% of the cable diameter (D) beyond the perpendicular angle to the center conductor (see Figure 13-4).

Figure 13-62

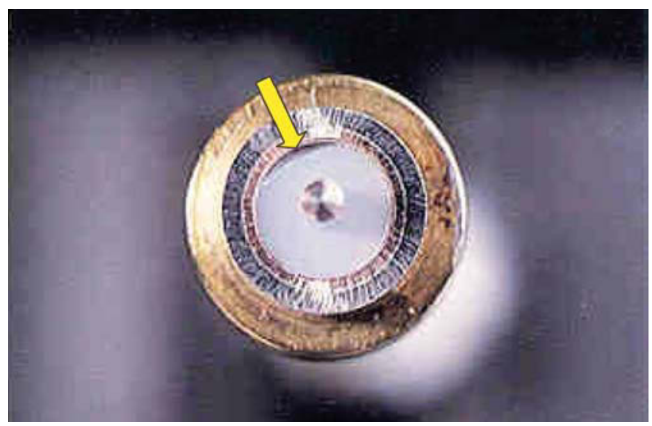


Figure 13-64

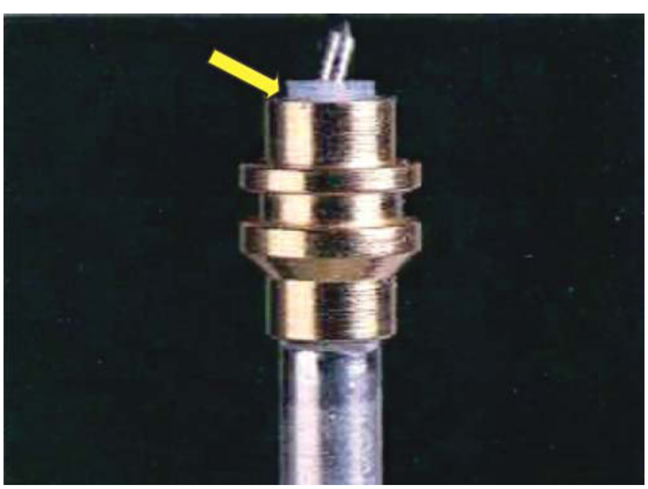


Figure 13-63

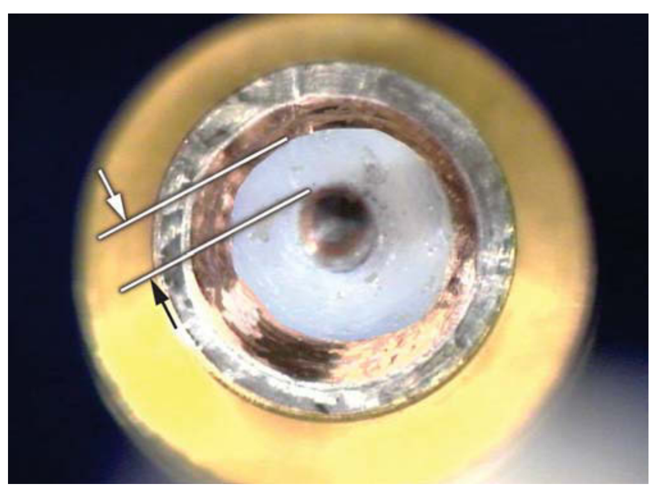


Figure 13-65

13.10.4 Semirigid Coax – Dielectric Cleanliness

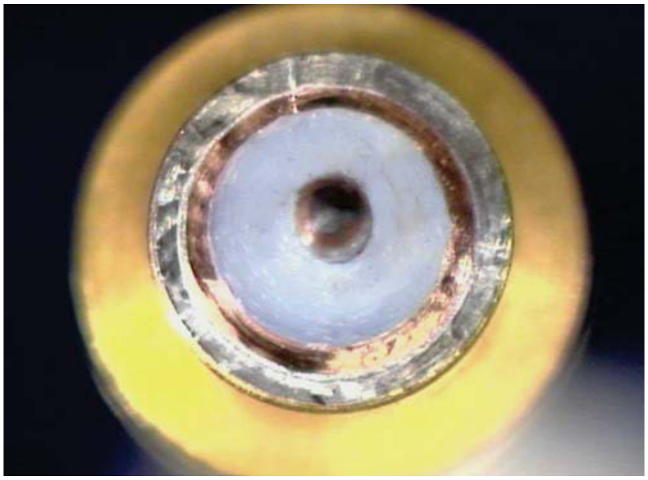


Figure 13-66

Acceptable – Class 1,2,3

- Dielectric material has no foreign particles (metallic or non-metallic) embedded in or on its surface.

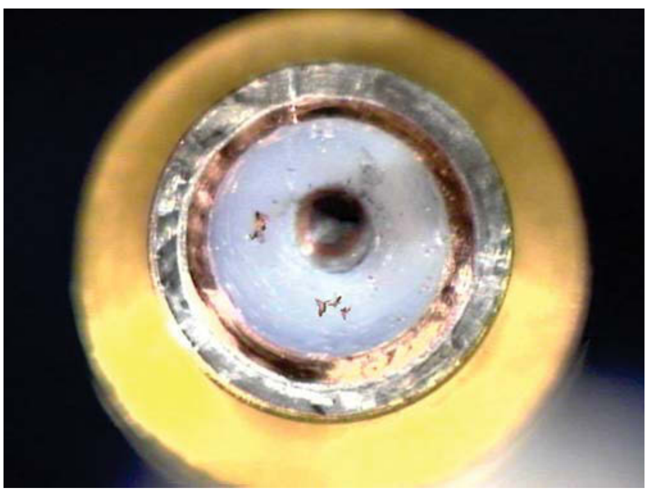


Figure 13-67

Defect – Class 1,2,3

- Dielectric material is contaminated with foreign particles.

13.10.5 Semirigid Coax – Center Conductor Pin

Figure 13-68 identifies the layers of the center conductor pin:

A. Steel core
B. Copper layer
C. Silver finish

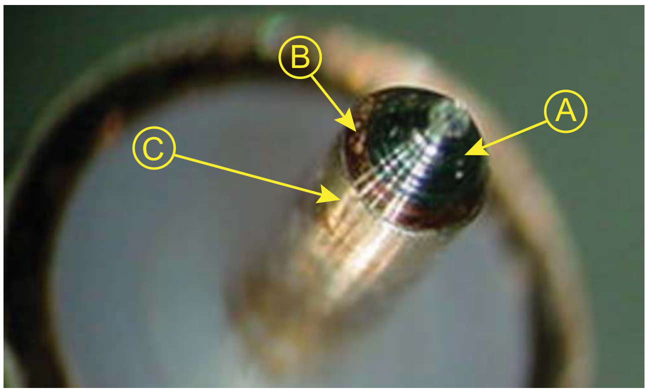


Figure 13-68

13.10.5.1 Semirigid Coax – Center Conductor Pin – Point

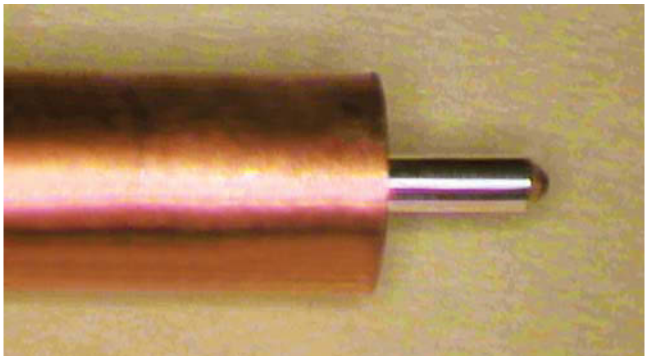


Figure 13-69

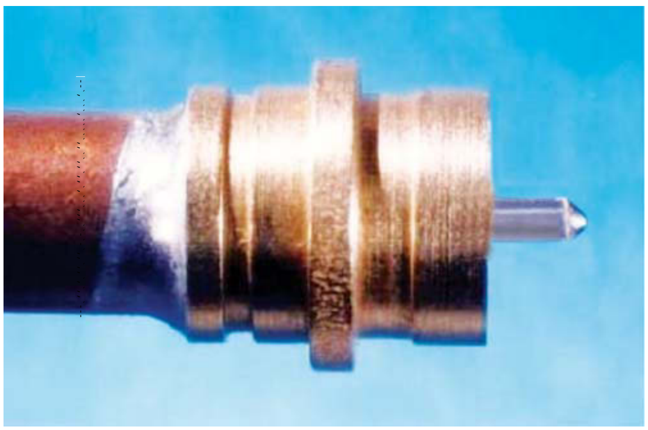


Figure 13-70

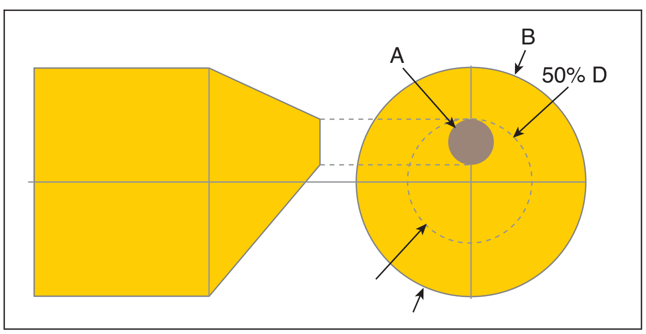


Figure 13-71
A. Point Flat
B. Conductor

Acceptable – Class 1,2,3

- Point flat diameter 0.38 mm [0.015 in] or less (see Figure 13-69).
- Pin point center slightly off conductor center but no portion of point flat is greater than 50% of conductor diameter from conductor center (see Figures 13-70, 71).
- Center conductor surface cuts, scrapes and nicks do not expose under-plating or basis metal (except center point).
- Light blemishes in plating due to test mating or burr removal.
- Smooth edge at the base of the pin point.

13.10.5.1 Semirigid Coax – Center Conductor Pin – Point (cont.)

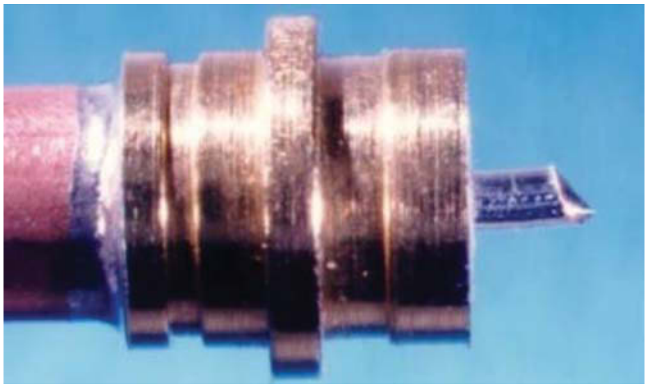


Figure 13-72

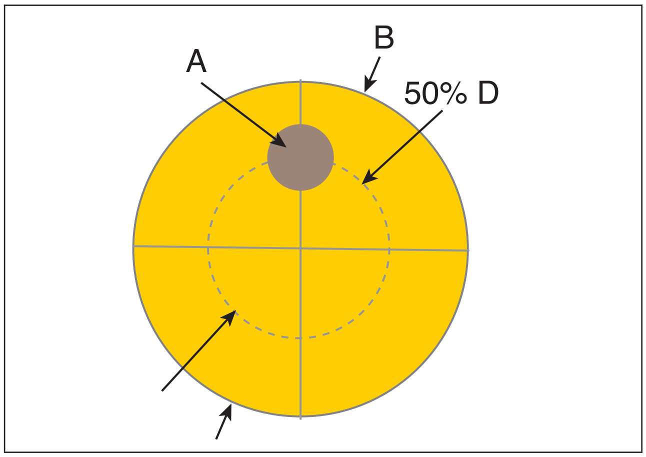


Figure 13-73
A. Point Flat
B. Conductor

Defect – Class 1,2,3

- Burrs.
- Pin point greater than 0.38 mm [0.015 in] diameter.
- Any portion of point flat is greater than 50% of conductor diameter from conductor center (see Figure 13-73).
- Exposed under-plating or basis metal on the center conductor (except center point) (see Figure 13-68).

13.10.5.2 Semirigid Coax – Center Conductor Pin – Damage

Figure 13-74

Acceptable – Class 1,2

- Cuts, nicks or scrapes in the center conductor less than 10% conductor diameter and/or surface area, and do not expose basis metal.

Note: The effects of nicks or scrapes vary with the applied signal frequency and will require engineering determination for acceptability.

Acceptable – Class 3

- No cuts, nicks or scrapes in the center conductor contact area.

Defect – Class 1,2

- Damage greater than 10% diameter of the center conductor.

Defect – Class 3

- Any damage to the surface of the center conductor contact area that exposes basis metal.

13.10.6 Semirigid Coax – Solder

These solder criteria are also applicable to conformable cable, see 13.10.2.2.

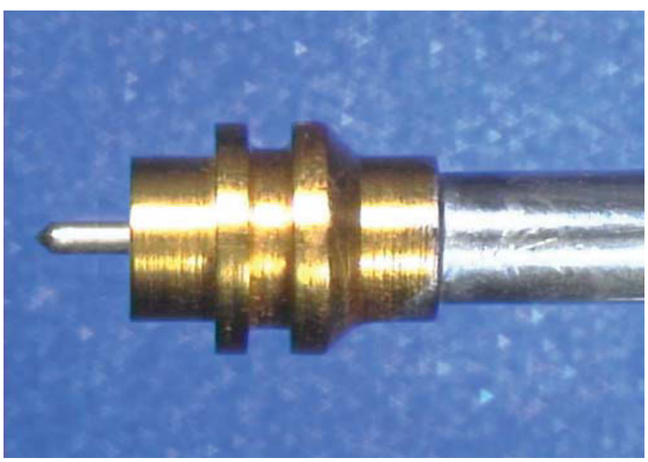


Figure 13-75

Acceptable – Class 1,2,3

- Solder film/build-up on connector body but will not interfere with subsequent assembly steps (see Figure 13-75).

Acceptable – Class 1
Defect – Class 2,3

- Solder fillet has voids (not shown).

13.10.6 Semirigid Coax – Solder (cont.)

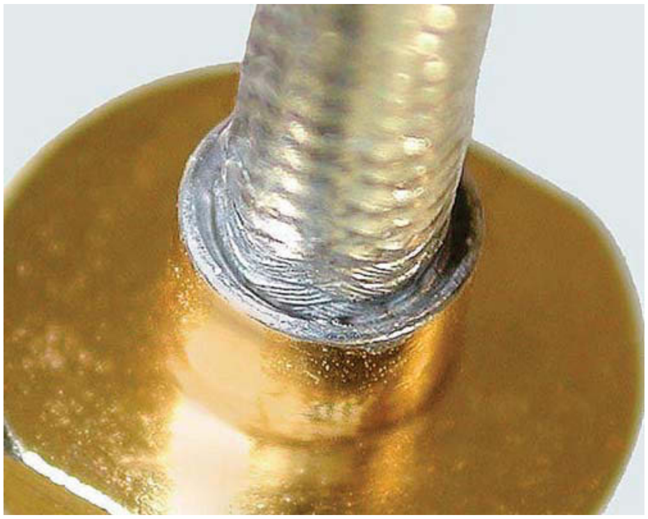


Figure 13-76

Defect – Class 1

- Solder fillet is less than 270°.

Figure 13-77

Defect – Class 2,3

- Solder fillet is less than 360°.

Figure 13-78

Defect – Class 1,2,3

- Excess solder onto cable or connector impedes subsequent assembly operations.
- Residue when connection is required to be clean.
- Solder is nonwetted or dewetted.
- Shield strand is not contained in connector barrel (not shown).
- Insufficient solder.

13.11 Swage-Type Connector

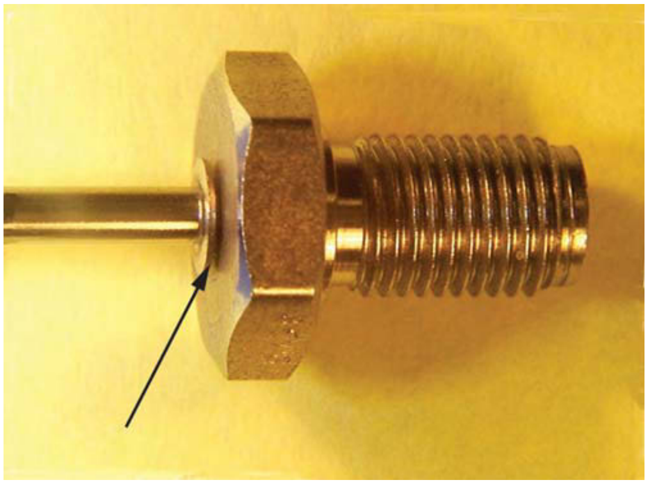


Figure 13-79

Acceptable – Class 1,2,3

- Swage ferrule is compressed into the connector body.
- Gap between ferrule shoulder and nut face does not exceed 0.5 mm [0.02 in].

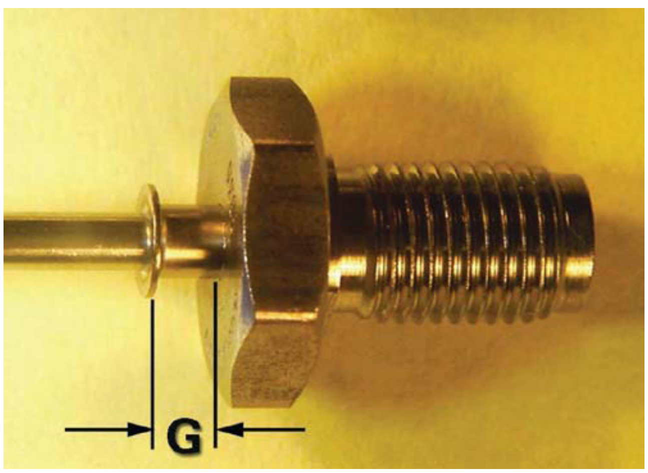


Figure 13-80

Defect – Class 1,2,3

- Gap (G) between ferrule shoulder and nut face exceeds 0.5 mm [0.02 in] (see Figure 13-80).
- Swage ferrule is not compressed into connector body.

13.12 Soldering and Stripping of Biaxial/Multi-Axial Shielded Wire

13.12.1 Soldering and Stripping of Biaxial/Multi-Axial Shielded Wire – Jacket and Tip Installation

Figure 13-81 shows the parts of this connector. All adjacent parts need to contact each other to insure the stability of connector.

These criteria apply to both pin and socket connectors.

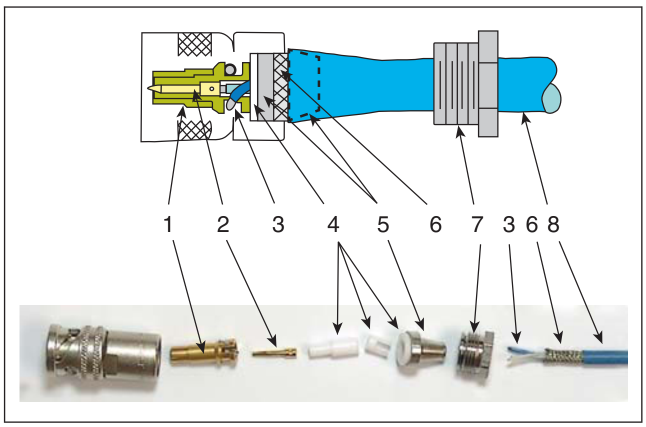


Figure 13-81
1. Ring
2. Center Contact (Tip)
3. Conductors
4. Dielectric
5. Cone
6. Shield
7. Nut
8. Jacket

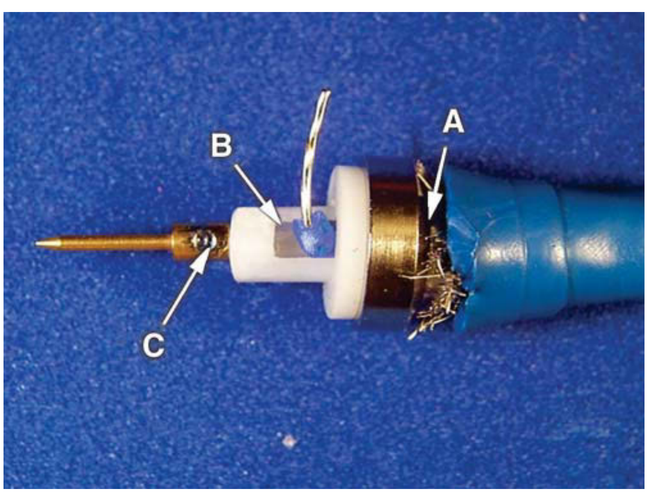


Figure 13-82
A. Cone Area
B. Dielectric Window
C. Center Contact (Tip) Inspection Window

Note: Complete connector assembly not shown.

13.12.1 Soldering and Stripping of Biaxial/Multi-Axial Shielded Wire – Jacket and Tip Installation (cont.)

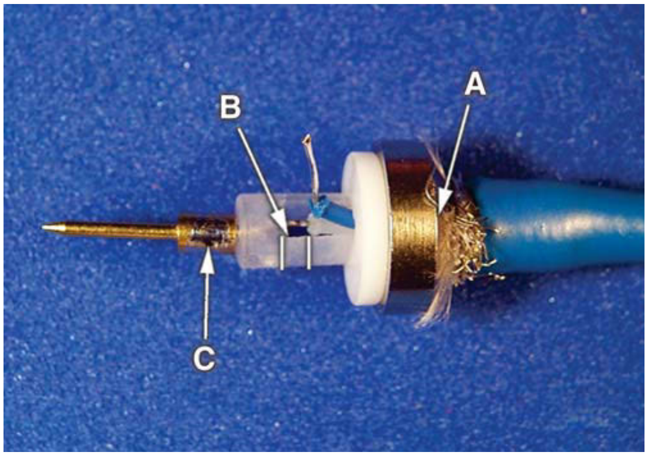


Figure 13-83

Acceptable – Class 1,2,3

- Tip conductor exposed wire is less than 50% of window length (see Figure 13-83-B).
- Ring conductor insulation is more than 50% of window length (see Figure 13-83-B).

Acceptable – Class 1
Process Indicator – Class 2,3

- Shield and jacket extends over more than 50% of cone (see Figure 13-83-A).
- A thin film of solder is on the outside solder section of tip surface (see Figure 13-83-C). (Solder film is not allowed on contact's mating surface.)

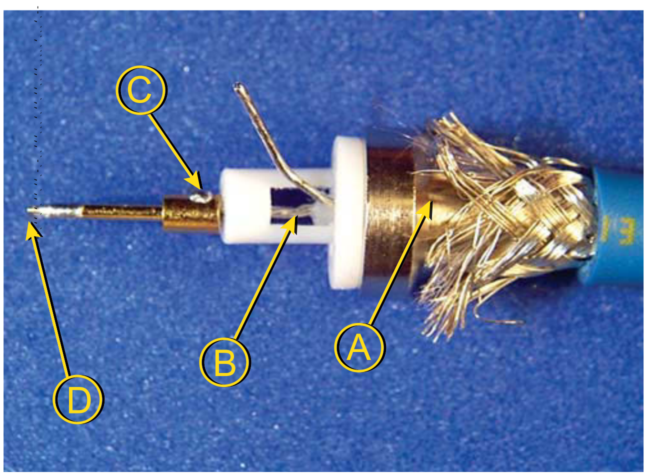


Figure 13-84

Defect – Class 1,2,3

- Shield and jacket extend less than 50% over cone (see Figure 13-84-A).
- Tip conductor exposed wire is greater than 50% of window length (see Figure 13-84-B).
- Insulation on ring conductor is less than 50% of window length (see Figure 13-84-B).
- Solder buildup on solder section of tip (see Figure 13-84-C).
- Solder film on the mating surface (see Figure 13-84-D).
- Insulation is melted or charred (not shown).

13.12.2 Soldering and Stripping of Biaxial/ Multi-Axial Shielded Wire – Ring Installation

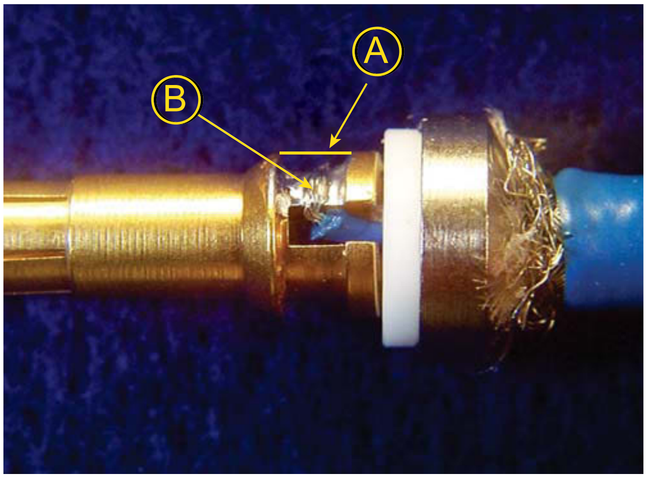


Figure 13-85

Acceptable – Class 1,2
Process Indicator – Class 3

- Solder is present on the surface of the ring shoulder but does not prevent assembly of the connector (see Figure 13-85-A).
- Conductor wrap is less than 180° but more than 90° (see Figure 13-85-B).
- Conductor wrap of 180° (or more) has solder fillet for at least 75% of the length of the conductor wrap, but less than 100%.
- Conductor wrap of less than 180° has solder fillet for the complete length of the wrap.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Conductor does not contact the surface to be soldered for the entire wrap length.
- With conductor wrap of less than 180° the solder fillet of conductor wrap less than 100% of the length of the conductor wrap.
- With conductor wrap of 180° or more the solder fillet of conductor wrap is less than 75% of the length of the wrap.

13.12.2 Soldering and Stripping of Biaxial/ Multi-Axial Shielded Wire – Ring Installation (cont.)

Figure 13-86

Defect – Class 1,2,3

- Solder on any mating surface.
- Solder on any surface that prevents assembly of the connector.
- Wire, insulation, or solder extends above ring profile.
- Insulation is melted or charred (not shown).
- Wire wrap less than 90°.

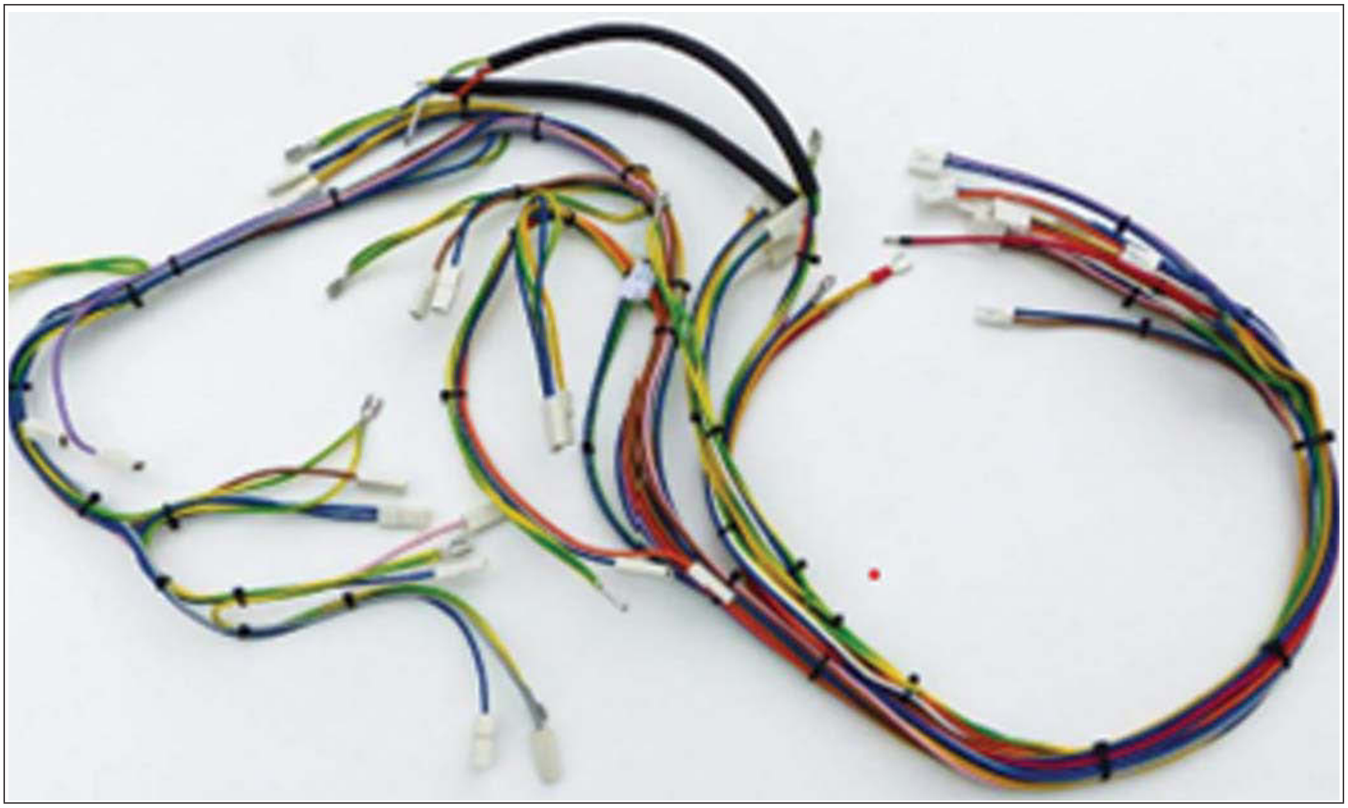
14 Securing

These criteria are applicable to cable and wire harness fabrication. Should tie wrap/lacing be required during installation of cables or wire harnesses (17 (Finished Assembly Installation)), the requirements of 14 (Securing) apply.

Temporary holding devices, e.g., spot ties, plastic straps and lacing, **shall [N1D2D3]** be removed prior to completion.

The following topics are addressed in this section.

14.1 Tie Wrap/Lacing Application



Figures 14-1, 2 and 3 are provided as guidance for applying lacing. Figure 14-1 shows running lock stitches. Figure 14-2 shows a clove hitch secured by a square knot, and Figure 14-3 is an example of a surgeon's knot.

A clove hitch knot **shall [D1D2D3]** secure the bundle and the clove hitch **shall [D1D2D3]** be secured with a locking knot, e.g., square knot, surgeon's knot.

Continuous lacing may not be applicable for some applications, e.g., for aerospace, per AS50881.

Processing cut ends to prevent fraying of lacing is optional; frayed cut ends are not cause for rejection.

Beeswax impregnated lacing tape **shall not [N1N2D3]** be used for Class 3 products. Wax impregnated lacing tape **shall not [N1N2D3]** be subjected to cleaning solvents.

14.1 Tie Wrap/Lacing Application (cont.)

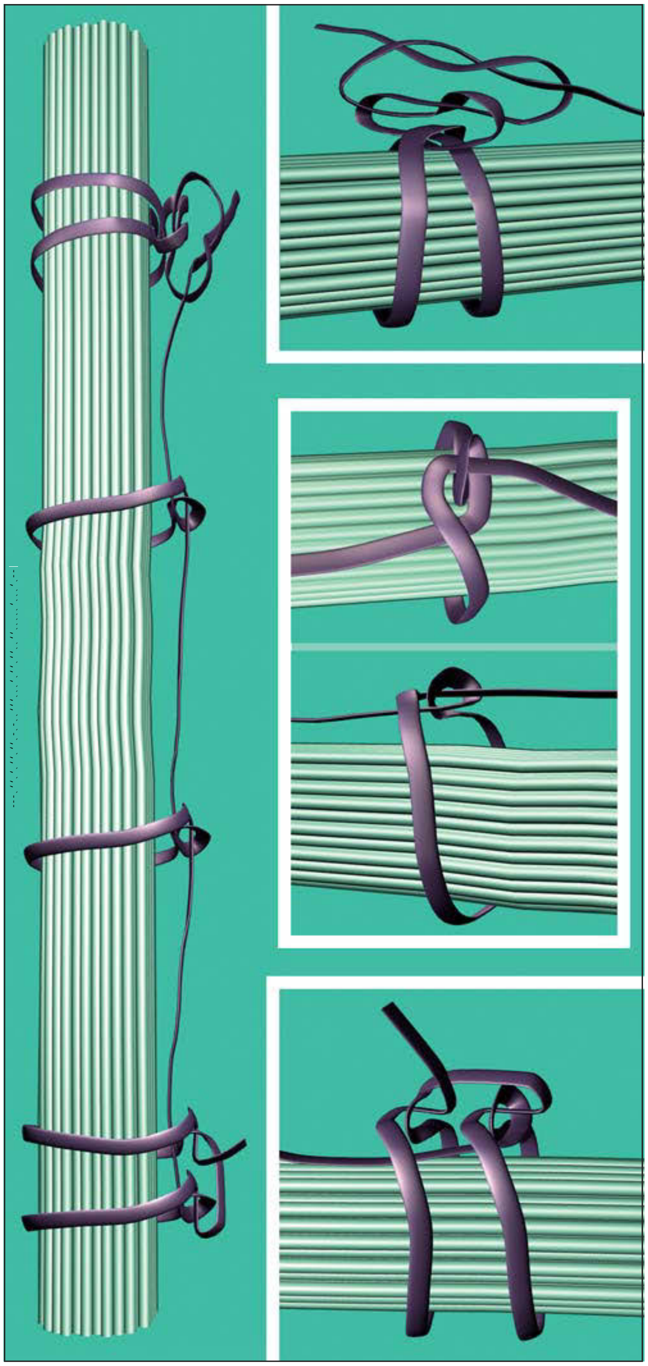


Figure 14-1
Continuous Lacing

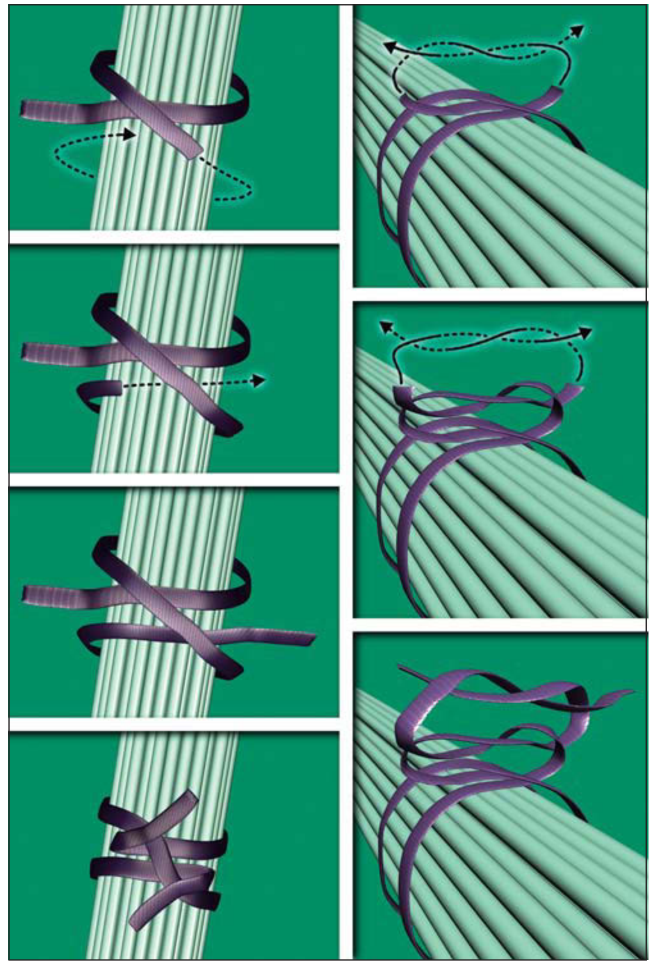


Figure 14-2
Clove Hitch (Left Side)
Locking Square Knot (Right Side)

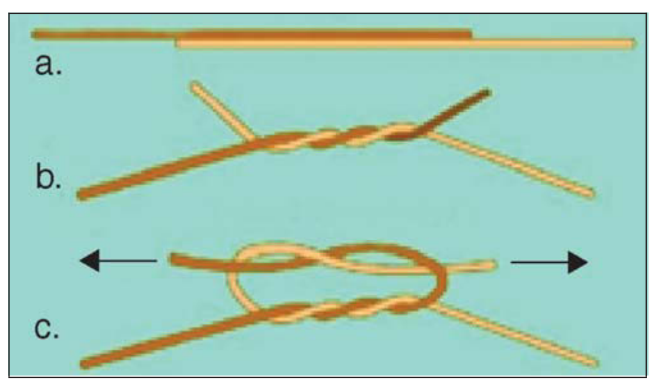


Figure 14-3
Surgeon's Knot

14.1 Tie Wrap/Lacing Application (cont.)

Figure 14-4

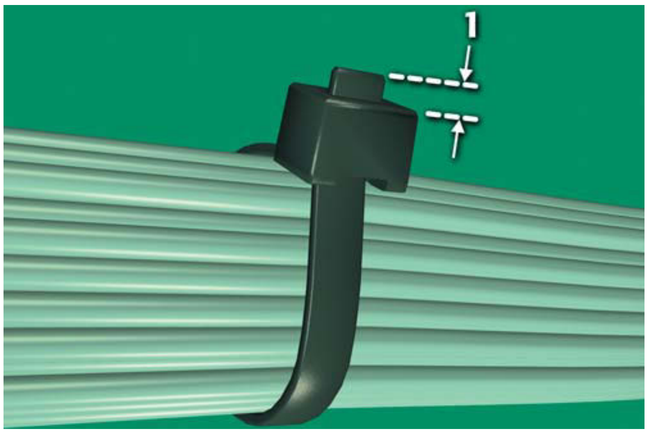


Figure 14-5

Acceptable – Class 1,2,3

- The end of the tie wrap is cut off not greater than one tie wrap thickness and is reasonably square to the face of the tie wrap.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Cut end protrusion (see Figure 14-5-1) greater than tie wrap thickness.

14.1 Tie Wrap/Lacing Application (cont.)

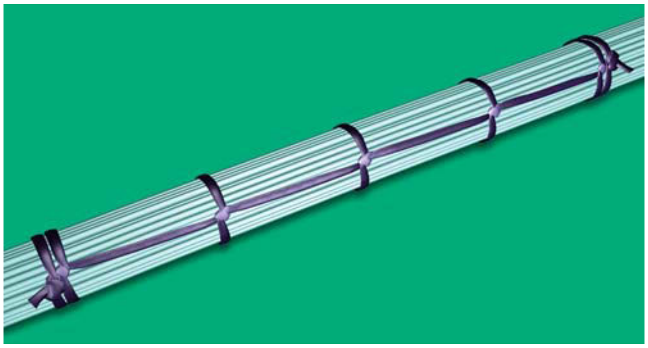


Figure 14-6

Acceptable – Class 1,2,3

- Cable lacing begins and ends with a locking knot.
- Lacing is tight and wires are kept secure in a neat bundle.

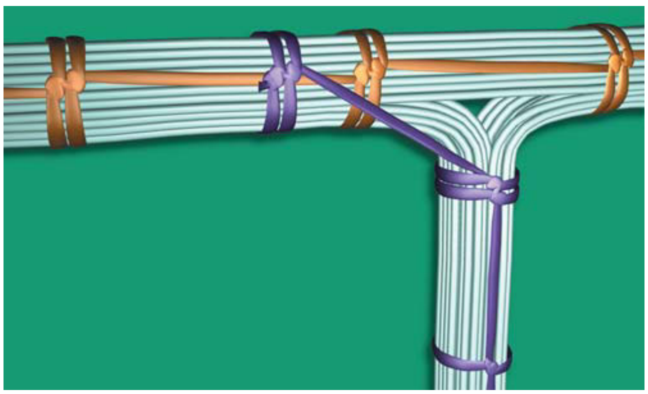


Figure 14-7

Acceptable – Class 2,3

- Continuous lacing may utilize a single lock stitch on a branch after a double lock stitch.

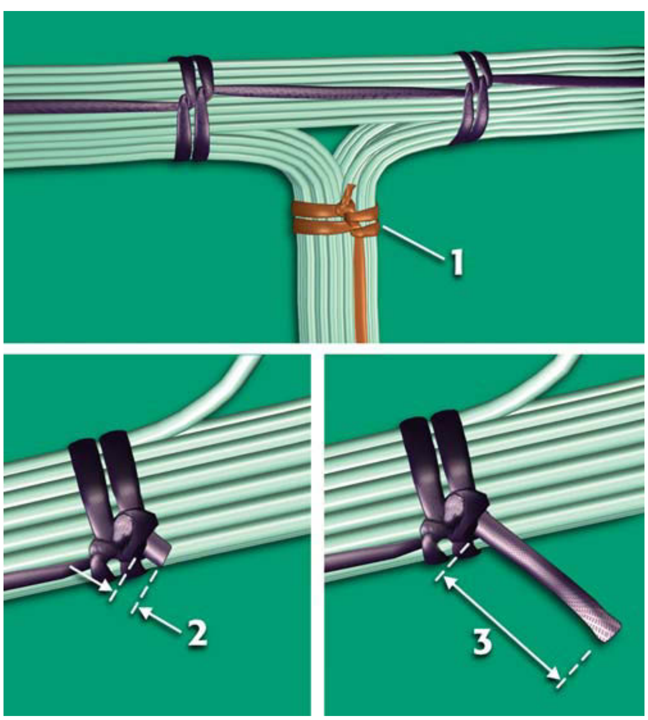


Figure 14-8

Defect – Class 2,3

- Double lock stitch not used where required.
- Branch lacing not started on trunk (see Figure 14-8-1).
- Final lacing cut end length either too close to knot (less than 6 mm [0.25 in]) (see Figure 14-8-2) or too far from knot (greater than 13 mm [0.5 in]) (see Figure 14-8-3).

14.1 Tie Wrap/Lacing Application (cont.)

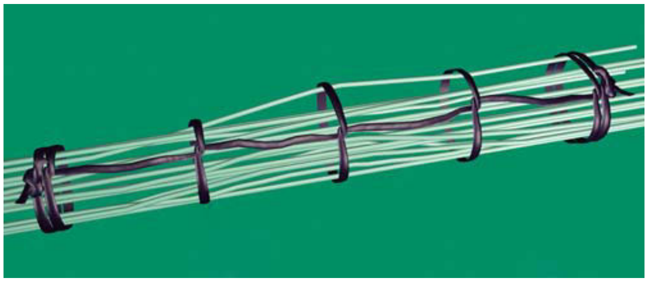


Figure 14-9

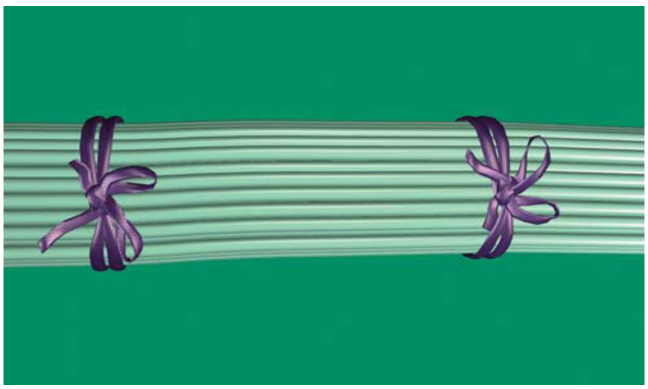


Figure 14-10

Defect – Class 1,2,3

- Continuous lacing does not use lock stitches.
- Wires not constrained securely and uniformly or are birdcaged.
- Cable tied with a bowknot or other nonlocking knot (see Figure 14-10).
- Tie wraps/straps are inverted or not locked.
- The first and last stitch of continuous lacing is not tied with a clove hitch or equivalent and secured with a square knot, surgeon's knot, or other lock knot.
- Spot ties do not start with a clove hitch or equivalent and finish with a square knot, surgeon's knot, or other lock knot.

14.1.1 Tie Wrap/Lacing Application – Tightness

Figure 14-11

Acceptable – Class 2,3

- Restraining device does not have any longitudinal movement, but may rotate.

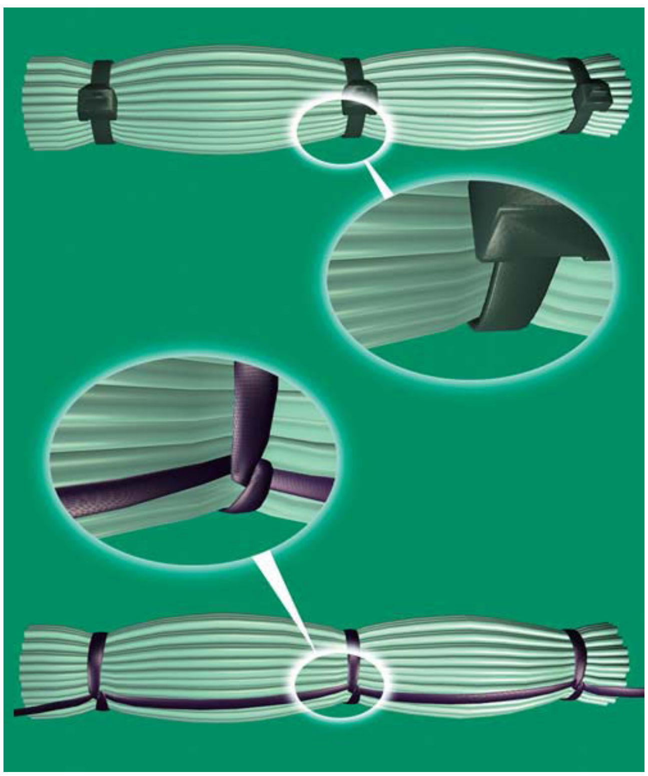


Figure 14-12

Defect – Class 1,2,3

- Bundle is distorted by the restraining devices.
- Insulation is compressed by more than 20% (see 3.5) or damaged by the restraining device.
- Restraining devices move longitudinally.

14.1.2 Tie Wrap/Lacing Application – Damage

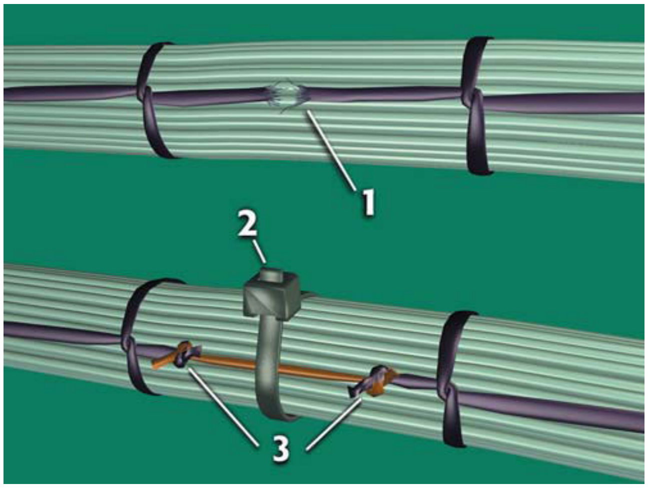


Figure 14-13

Acceptable – Class 1,2

- Restraining devices exhibit minor fraying, nicks, or wear of less than 25% of the device thickness.

Defect – Class 1,2,3

- Sharp edges that are a hazard to personnel or equipment (see Figure 14-13-2).
- Broken lacing ends are not tied off using a square knot, surgeon's knot, or other approved knot (see Figure 14-13-3).

Defect – Class 1,2

- Damage or wear to restraining devices exceeding 25% of the device thickness.

Defect – Class 3

- Damage or wear to restraining device (see Figure 14-13-1).

14.1.3 Tie Wrap/Lacing Application – Spacing

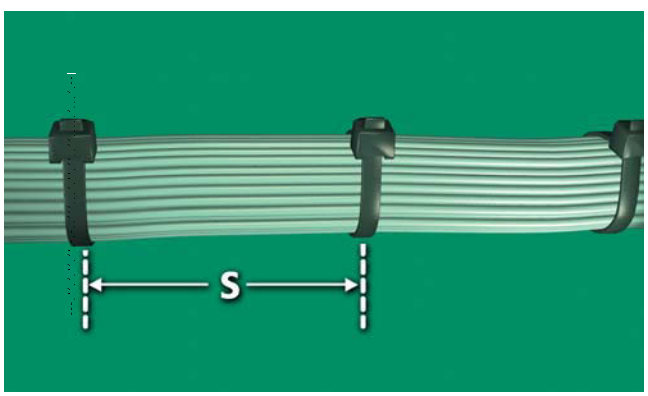


Figure 14-14

Acceptable – Class 1,2,3

- Unless otherwise specified, spot ties or tie wraps/straps are spaced evenly and at an increment that maintains the bundle's desired form (see Figure 14-14).

Acceptable – Class 1
Process Indicator – Class 2,3

- Restraining devices are irregularly spaced.

Defect – Class 1,2,3

- Spacing of restraining devices does not maintain bundle's desired form.

14.2 Breakouts

14.2.1 Breakouts – Individual Wires

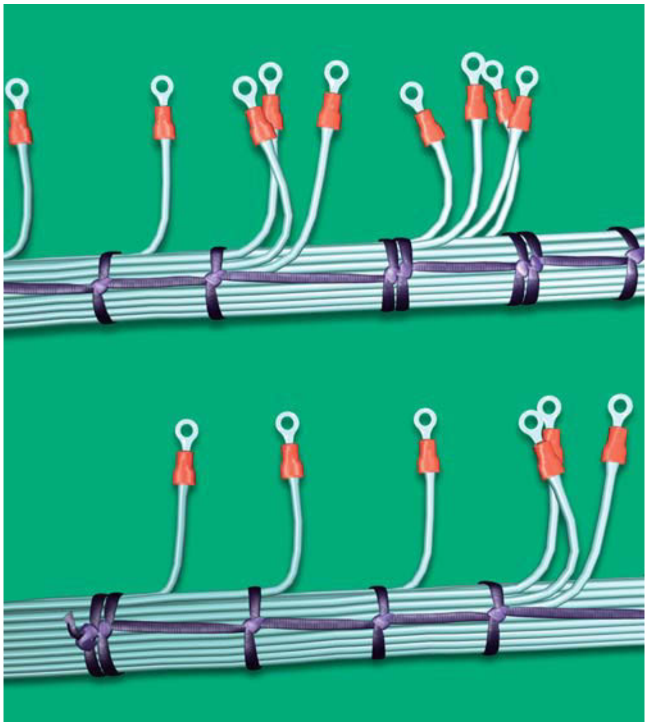


Figure 14-15

Acceptable – Class 1,2,3

- A restraining device is used prior to each breakout.
- If continuous lacing is used, the first wire breakout in a series is double lock stitched (not shown).
- A double lock stitch is used before and after any breakout of four or more wires.

14.2.1 Breakouts – Individual Wires (cont.)

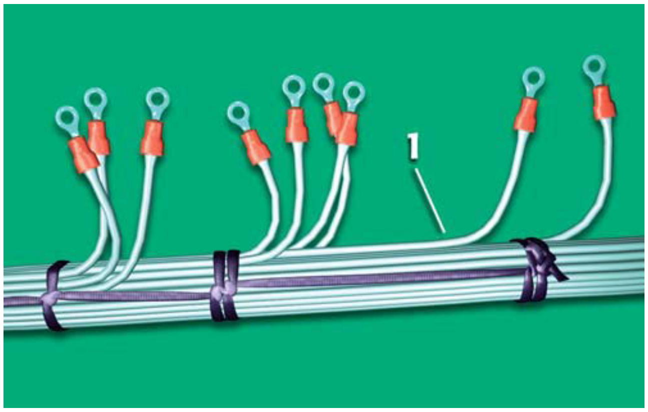


Figure 14-16

Defect – Class 2,3

- Restraining device not used prior to an individual wire breakout (see Figure 14-16-1) or a group of up to three individual wires in proximity to each other.
- For continuous lacing, a double lock stitch is not used before and after any breakout of four or more wires.

14.2.2 Breakouts – Spacing

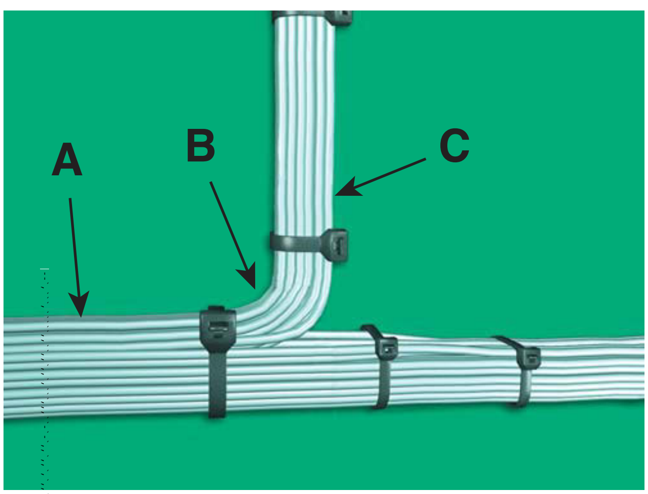


Figure 14-17
A. Main bundle
B. Breakout
C. Branch

Acceptable – Class 1,2,3

- Restraining devices are placed before and after each breakout.
- Restraining devices are placed on each breakout.
- Restraining devices are placed in a manner that maintains the desired form and location and do not stress wires at the breakout.
- Restraining devices are not more than three bundle diameters from a breakout.

Note: Restraining devices may be placed on the main bundle between the breakout points.

Note: For these criteria, the bundle diameter is referenced to the specific bundle section that the restraining device is placed on.

Note: Figures 14-17 through 14-22 provide examples of typically acceptable restraining configurations.

14.2.2 Breakouts – Spacing (cont.)

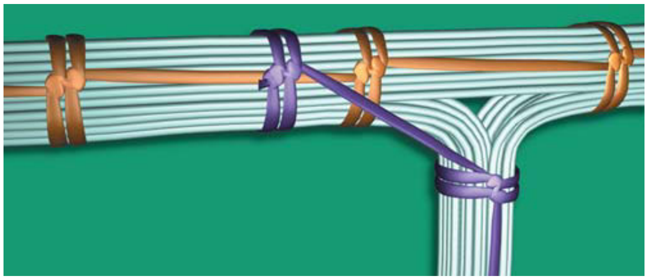


Figure 14-18

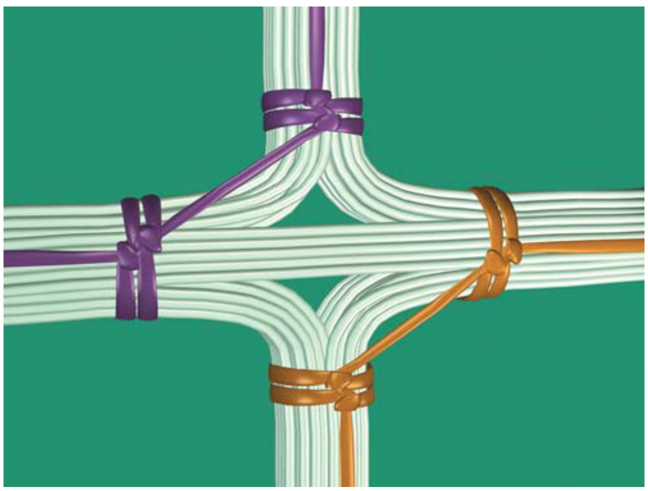


Figure 14-19

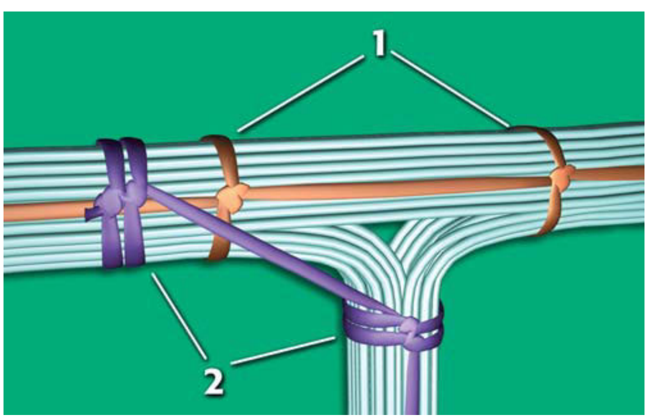


Figure 14-20
1. Single lock stitch
2. Double lock stitch

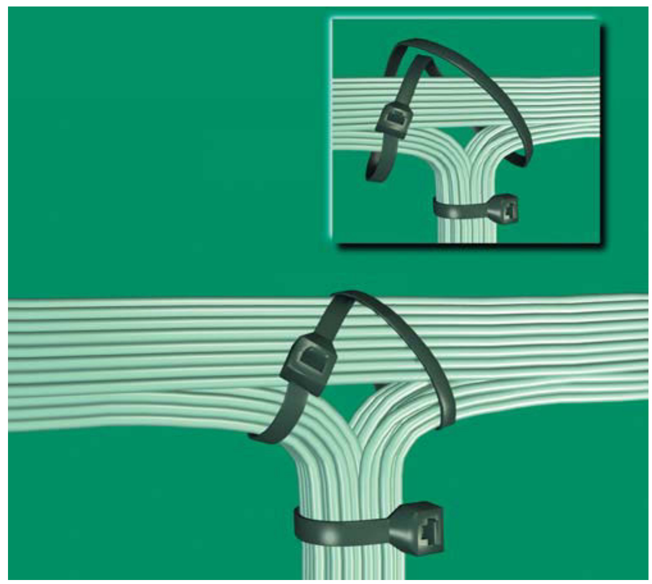


Figure 14-21
Inset shows how to form tie.

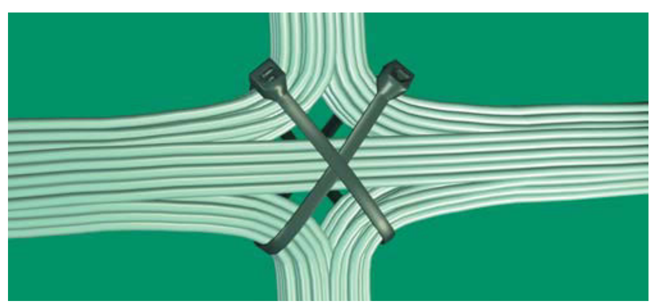


Figure 14-22

14.2.2 Breakouts – Spacing (cont.)

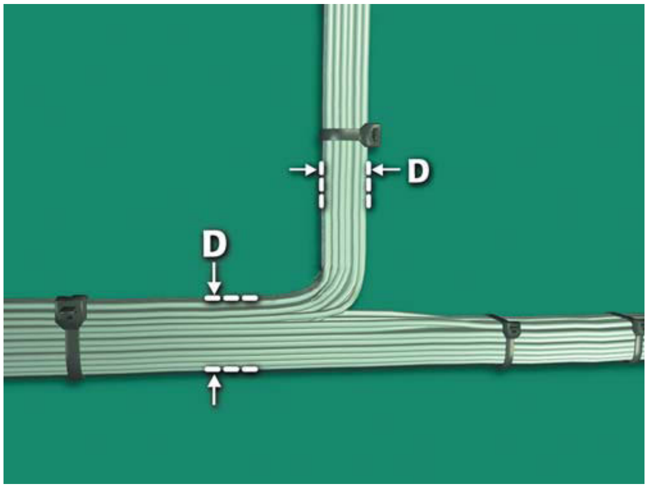


Figure 14-23

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Spacing of first restraint from the breakout is more than three diameters of the breakout wire bundle.

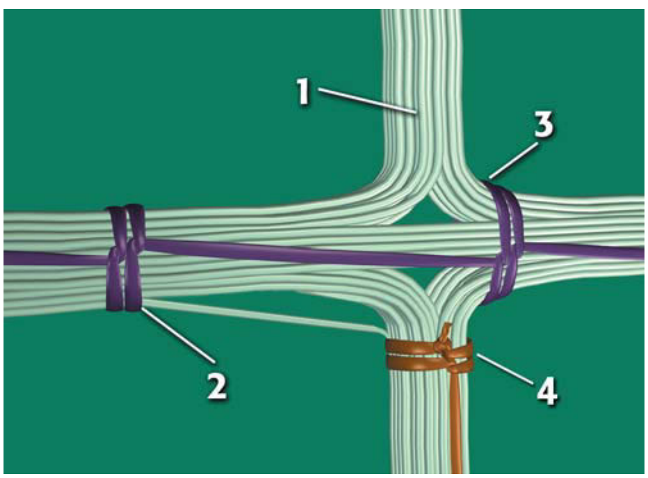


Figure 14-24

Defect – Class 1,2,3

- Restraining device imparts stress on any wires in the bundle by deforming the radius (see Figure 14-24-2, 3).
- Continuous lacing does not use lock stitches.
- Wires are stressed at the breakout.

Defect – Class 2,3

- Restraining device not used at each branch (see Figure 14-24-1).
- Branch lacing is not snug and moves on the branch (see 14.1.1) (see Figure 14-24-4).

14.3 Routing

14.3.1 Routing – Wire Crossover

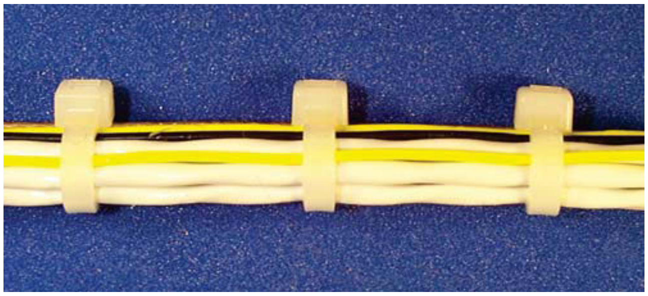


Figure 14-25

Acceptable – Class 1,2,3

- Wires may twist or cross over, but bundle is essentially uniform in diameter (not shown).
- Wire lay is essentially parallel to the axis of the bundle with minimal crossover.

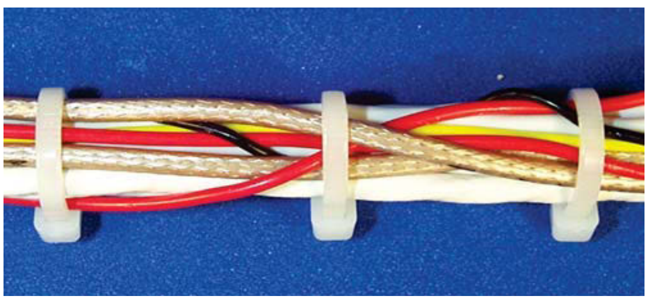


Figure 14-26

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Wires twist and cross over underneath a restraining device.

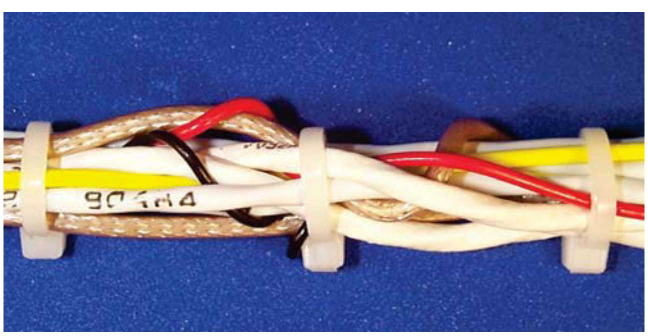


Figure 14-27

Acceptable – Class 1
Defect – Class 2,3

- Bundle is not uniform in diameter.
- Excessive crossover.

Defect – Class 1,2,3

- Wire insulation is damaged (see 3.5).
- Any kinks that violate minimum bend radius (see Table 14-1).

14.3.2 Routing – Bend Radius

Bend radius is measured along the inside curve of the wire or wire bundles.

The minimum bend radius of a harness bundle **shall not [D1D2D3]** be less than whichever wire/cable in the assembly has the largest bend radius defined in Table 14-1.

Table 14-1 Minimum Bend Radius Requirements

Wire/Cable Type	Multiple of Wire/Cable Outer Diameter		
	Class 1	**Class 2**	**Class 3**
Coaxial Flexible Cable[1]	10X		
Coaxial Fixed Cable[2]	5X		
Semi-rigid Coax	Not less than manufacturer's stated minimum bend radius (see 13.10.1)		
Ethernet cable	4X		
Shielded Wires and Cables[3]	No Requirement Established		5X
Unshielded Cable[3]	No Requirement Established		3X for AWG 10 and smaller 5X for larger than AWG 10
Insulated Wire Flat Ribbon Cable Bare Bus Wire Enamel Insulated Wire	2X		
Polyimide Insulated Wires (Shielded or Unshielded)	No Requirement Established		10X
Composite Insulation	No Requirement Established		6X[4]

Note 1: Coaxial Flexible Cable Coaxial cable that is or may be flexed during operation of the equipment.
Note 2: Coaxial Fixed Cable Coaxial cable that is secured to prevent movement; not expected to have the cable repeatedly flexed during operation of the equipment.
Note 3: As supplied by the wire/cable manufacturer.
Note 4: Applies to AS22759/80 through /92 and /180 through /192. See the appropriate specification if not covered by these.

Acceptable – Class 1,2,3

- Minimum bend radius meets requirements of Table 14-1.

Defect – Class 1,2,3

- Bend radius does not meet the requirements of Table 14-1.

14.3.3 Routing – Coaxial Cable

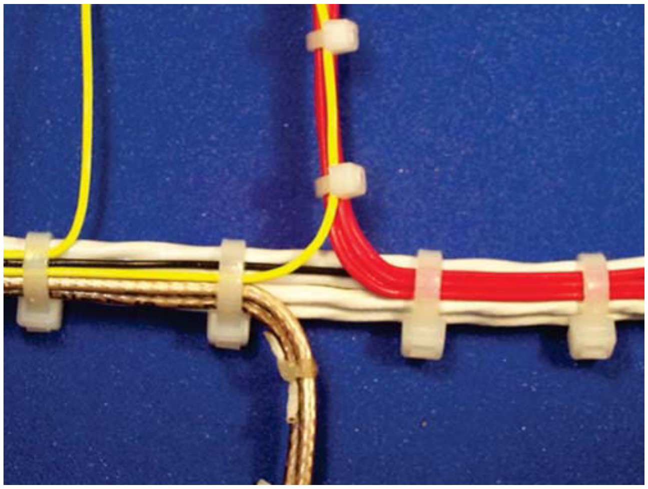


Figure 14-28

Acceptable – Class 1,2,3

- Inside bend radii meet the criteria of Table 14-1.

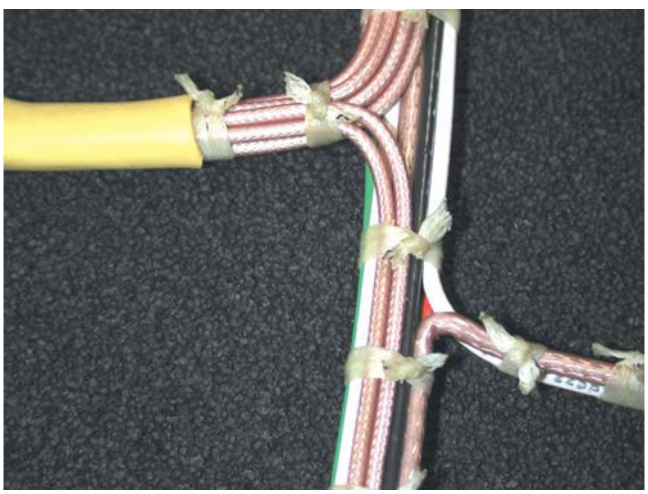


Figure 14-29

Defect – Class 1,2,3

- Inside bend radii do not meet the criteria of Table 14-1.

Defect – Class 3

- Spot ties or tie wraps that cause any deformation of coaxial cables.

14.3.4 Routing – Unused Wire Termination

14.3.4.1 Routing – Unused Wire Termination – Shrink Sleeving

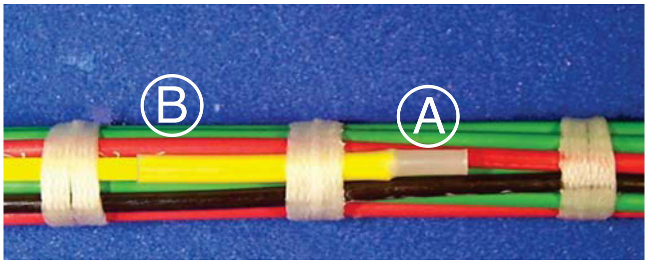


Figure 14-30

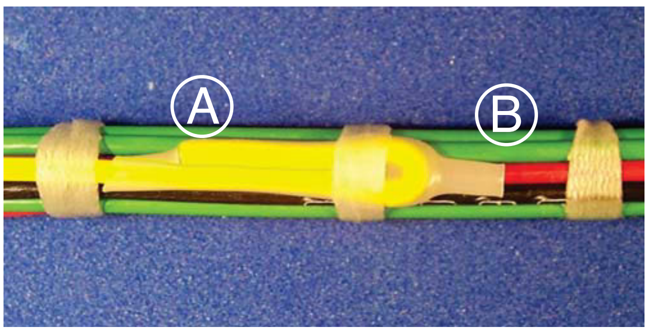


Figure 14-31

Acceptable – Class 1,2,3

- Wire may extend straight down length of bundle (see Figure 14-30) or be folded back (see Figure 14-31-A).
- Shrink sleeving extends at least two wire diameters beyond end of wire (see Figure 14-31-B).
- Shrink sleeving extends on to the wire insulation for a minimum of four wire diameters (see Figure 14-31-A).
- Unused wire is tied into the wire bundle (see Figures 14-30, 31).

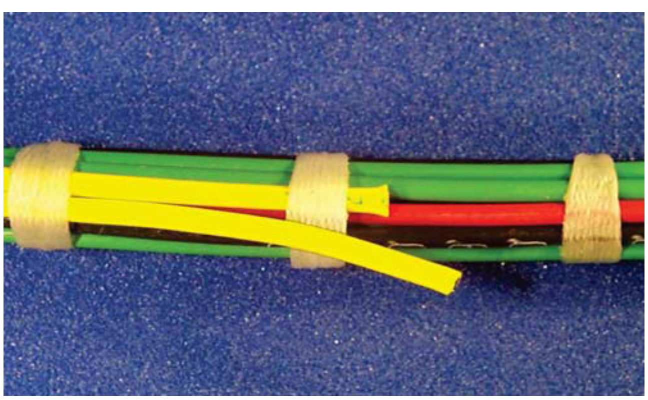


Figure 14-32

Defect – Class 1,2,3

- Ends of unused wires are exposed.
- Unused wire is not tied into the wire bundle.
- Any part of the conductor is exposed.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Insulating shrink sleeving extends beyond end of wire less than two wire diameters.
- Insulating shrink sleeving extends onto wire insulation less than four wire diameters.
- Shrink sleeving is not secure to the wire.

14.3.4.2 Routing – Unused Wire Termination – Flexible Sleeving

Acceptable – Class 1,2,3

- Wire may extend straight down length of bundle (see Figure 14-30) or be folded back (see Figure 14-31).
- Flexible sleeving is folded back and restrained.

Defect – Class 1,2,3

- Ends of unused wires are exposed.
- Unused wire is not tied into the wire bundle.
- Any part of the conductor is exposed.

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Flexible sleeving is not folded back and is not restrained.

14.3.5 Routing – Ties over Splices and Ferrules

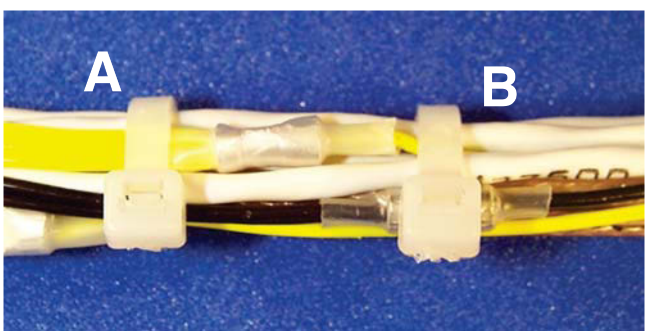


Figure 14-33

Acceptable – Class 1,2,3

- Spot ties or tie wraps/straps are placed near splices or solder ferrules contained in the wire bundle.
- No stress on wires exiting splices (see Figure 14-33-A).

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- Spot tie or tie wraps/straps are placed over splices or solder ferrules contained in the wire bundle (see Figure 14-33-B).

14.3.5 Routing – Ties over Splices and Ferrules (cont.)

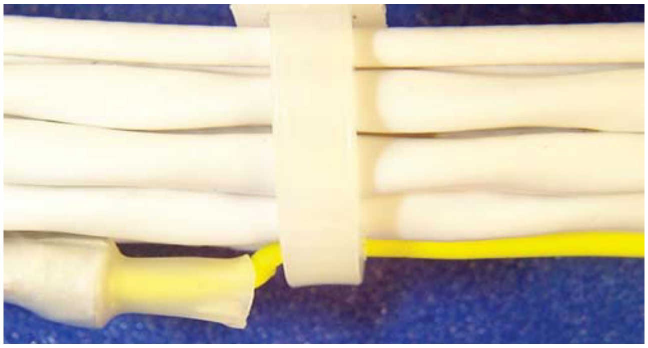


Figure 14-34


Figure 14-35

Defect – Class 1,2,3

- Spot tie or tie wrap is placing stress on the wire(s) exiting the splice or ferrule.

14.4 Broom Stitching

Broom stitch ties can be used to secure wires or cables together. Each group **shall [D1D2D3]** be tied with a clove hitch or equivalent. The end of the run **shall [D1D2D3]** be tied with a securing knot.

The position and quantity of ties are as specified on the engineering documentation, but **shall [D1D2D3]** be of a quantity necessary to assure that the finished harness complies with the requirements of this specification and retains its shape.

If not otherwise specified, the criteria of 14.1, 14.2 and 14.3 are applicable. Figures 14-36, 37 and 38 show examples of acceptable broom stitching.

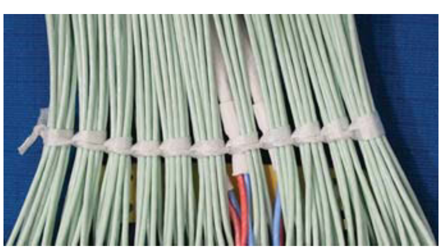


Figure 14-36

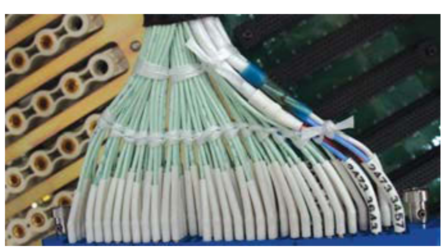


Figure 14-37

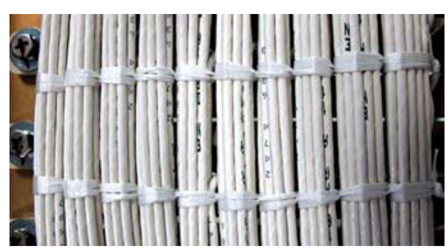


Figure 14-38

15 Harness/Cable Electrical Shielding

The following topics are addressed in this section.

15.1 Braided

Metal braid shielding can either be woven directly over a core or obtained in prefabricated form and installed by sliding it over the wire bundle. All breakouts need to be properly secured prior to applying the braid. Figure 15-1 shows using tape to provide the breakouts. Lacing or cable ties may also be used (see 14 (Securing)).

Figure 15-1

Directly applied braid **shall [D1D2D3]** be back braided to lock the weave. Prewoven braids **shall [D1D2D3]** be secured at the ends. When using cable straps or spot ties, fold the braid over itself, secure, and cover the end with heat shrink tubing or tape. Depending on final usage, prewoven metallic braid may need to be cleaned to remove contamination prior to installation over the harness.

Temporary holding devices, e.g., spot ties, plastic straps and lacing, **shall [N1D2D3]** be removed from wire bundles prior to braid application. Flat tapes may be left under braid if the tape has a low profile.

15.1.1 Braided – Direct Applied

Not illustrated.

Acceptable – Class 1,2,3

- Braiding is not to be so tight as to cause indention or distortion to the wires of the assembly.
- Braid is free of loops.
- All loose strands are trimmed flush and terminated with solder or tape.
- No fraying or unraveling of braid ends.
- There is no visible wire or shield braid through the top braid.
- Braid strands smooth and evenly placed.
- Braid overlap is between one and three diameters of the largest bundle at breakouts and branches.
- Back braid lock stitch is a minimum of 13 mm [0.5 in].
- Braid damage meets requirements of Table 13-1 less Note 3.

Process Indicator – Class 2,3

- Braid overlap exceeds three diameters of the largest bundle.

Figure 15-2

Defect – Class 2,3

- Braid strands bunched (excess overlap).
- Wire or shield braid visible through top braid.

15.1.1 Braided – Direct Applied (cont.)

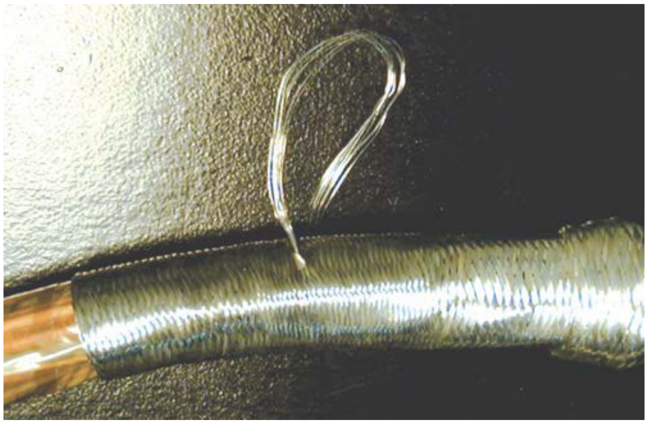


Figure 15-3

Figure 15-4

Defect – Class 1,2,3

- Braid has loops.
- Ends frayed, unraveling or not secured.
- Tears and/or cuts of braiding.
- Broken/end strands not trimmed.
- Braid damage is more than allowed in Table 13-1 less Note 3.
- Braid overlap is less than one diameter of the largest bundle at breakouts and branches.

15.1.2 Braided – Prewoven

(Not illustrated.)

Acceptable – Class 1,2,3

- Braid damage meets requirements of Table 13-1 less Note 3.
- Braid overlap is between one and three diameters of the largest bundle at breakouts and branches.

Process Indicator – Class 2,3

- Braid overlap exceeds three diameters of the largest bundle.

Defect – Class 1,2,3

- Ends not secured.
- Tears and/or cuts of braiding.
- Braid damage is more than allowed in Table 13-1 less Note 3.
- Overlap is less than one diameter of the largest bundle where multiple braids meet including breakouts and branches.
- Ends frayed or unraveling.
- Loose ends protruding from potting or shrink sleeving.

Defect – Class 3

- Braid ballooned or bunched.

15.2 Shield Termination

15.2.1 Shield Termination – Shield Jumper Wire

15.2.1.1 Shield Termination – Shield Jumper Wire – Attached Lead

Shield should terminate as close as possible to inner conductor termination point. Terminations made with self-sealing heat shrinkable devices are exempt from the cleaning requirements.

15.2.1.1.1 Shield Termination – Shield Jumper Wire – Attached Lead – Solder

These criteria apply to connections made by hand soldering or using heat shrinkable solder devices. The criteria of 8.1.5 apply when using heat shrinkable solder devices.

Note: To enable viewing of strands and solder fillets, some of the illustrations in this section were made with the sleeving removed.

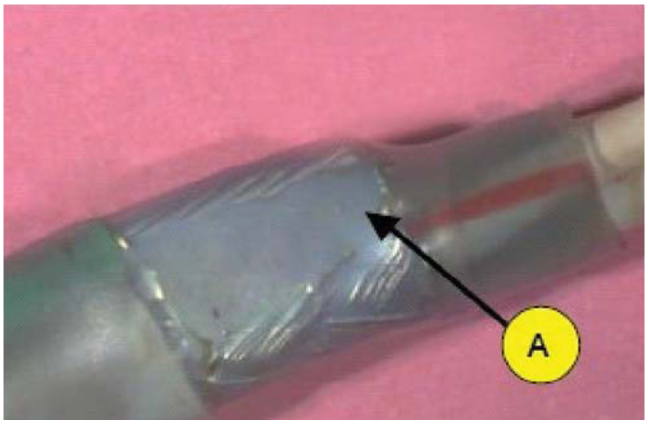


Figure 15-5

Figure 15-6
Note: Sleeving removed

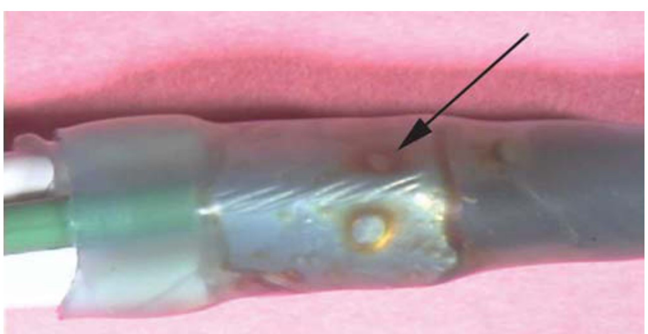


Figure 15-7

Figure 15-8
Note: Sleeving removed

Acceptable – Class 1,2,3

- Solder fillet has formed between the shield and shield wire, solder joint indicates minimum flow.
- Shield and shield wire are discernible (see Figure 15-5).
- Solder fillet is at least 75% of the stripped length of the shield wire.

15.2.1.1.1 Shield Termination – Shield Jumper Wire – Attached Lead – Solder (cont.)

Figure 15-9

Figure 15-10
Note: Sleeving removed

Acceptable – Class 1,2,3

- Length of contact between the shield and the drain wire being attached is at least three wire diameters of the drain wire (see Figure 15-9).
- Plastic sleeve is slightly discolored but not burned or charred.
- Sleeve conforms to the contour of the lead and the cable.
- Shield weave pattern is disturbed but a smooth concave solder fillet is visible.
- Minimum solder fillet has formed between shield and shield wire.

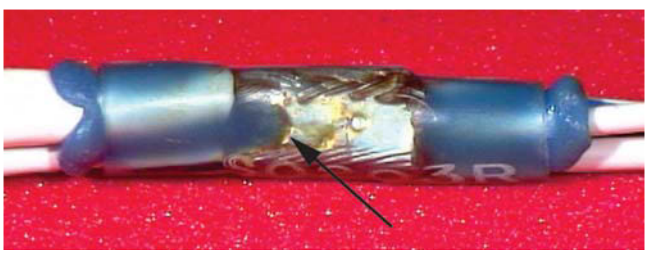


Figure 15-11

Acceptable – Class 1,2,3

- Meltable sealing ring has flowed over the outside of the solder fillet but is not affecting the solder fillet.

15.2.1.1.1 Shield Termination – Shield Jumper Wire – Attached Lead – Solder (cont.)

Figure 15-12

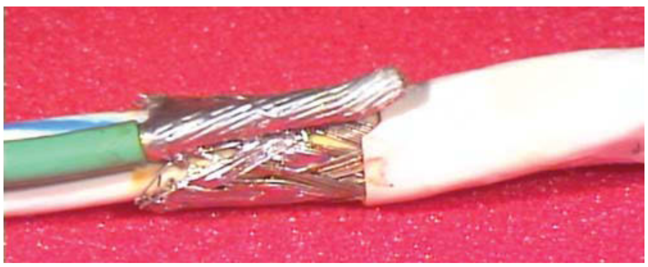


Figure 15-13
Note: Sleeving removed

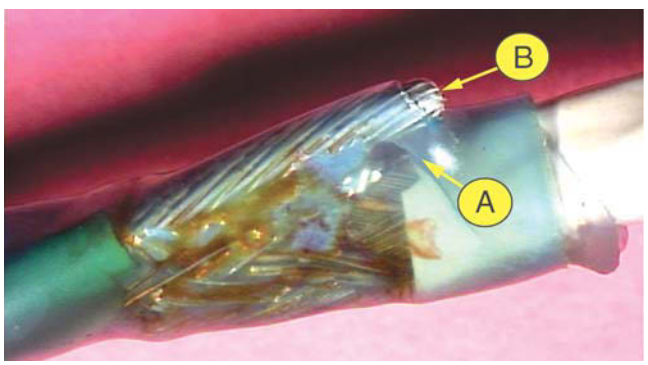


Figure 15-14

Defect – Class 1,2,3

- Length of contact between the shield and the drain wire being attached is less than three wire diameters of the drain wire.
- Shield wire is not aligned with the stripped portion of the shield.
- Solder is not wetted between shield wire and shield (see Figure 15-13).
- Meltable sealing ring precludes formation of acceptable solder connection.
- Solder has flowed out of the solder connection area onto wire insulation.
- Shield wire extends beyond stripped surface of shield preventing wire from contacting shield (see Figure 15-14-A).
- Shield wire has pierced the insulation sleeving (see Figure 15-14-B).
- Solder fillet is less than 75% of the stripped length of the shield wire.

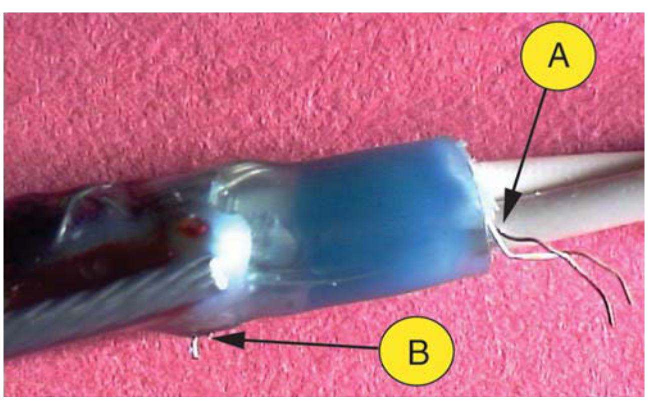


Figure 15-15

Defect – Class 1,2,3

- Shield strand is protruding from end of insulation sleeving (see Figure 15-15-A).
- Shield strand has pierced the insulation sleeving (see Figure 15-15-B).

15.2.1.1.1 Shield Termination – Shield Jumper Wire – Attached Lead – Solder (cont.)

Figure 15-16

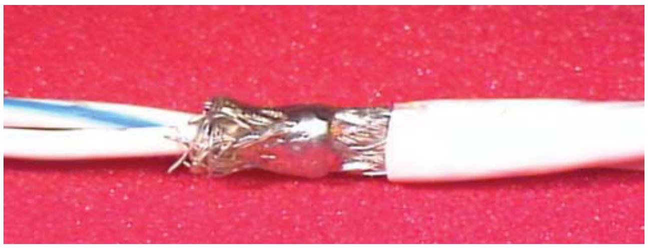


Figure 15-17
Note: Sleeving removed

Defect – Class 1,2,3

- Insufficient solder flow, contour of solder preform is discernible.

Figure 15-18

Defect – Class 1,2,3

- Plastic sleeve burned/charred.
- Discoloration of sleeving obscures solder connection.

Figure 15-19

Defect – Class 1,2,3

- Heat shrinkable solder device/protective sleeving is not properly positioned on the shield and bare shield is exposed.
- Sleeve does not conform to the contour of the lead and the cable.

15.2.1.1.2 Shield Termination – Shield Jumper Wire – Attached Lead – Crimp

Figure 15-20

Figure 15-21

Acceptable – Class 1,2,3

- Inner and outer ferrules are centered over each other.
- Exposed shield is less than 3 mm [0.12 in] in length.
- Shield wire is located on a flat of the hex crimp.
- Sleeving overlaps 6 mm [0.24 in] minimum beyond the exposed shield in each direction.
- No loose strands of shield or shield wire outside ferrules.

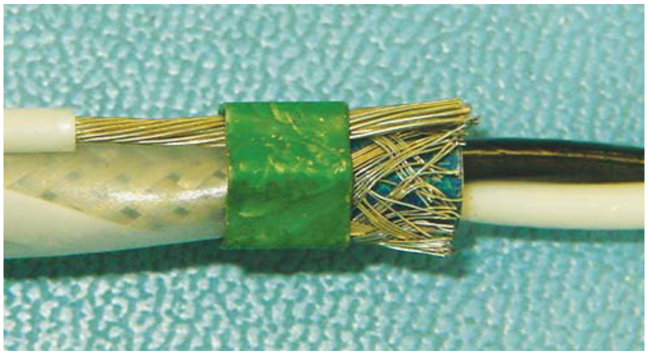


Figure 15-22

Defect – Class 1,2,3

- Inner and outer ferrules are not centered over each other.
- Exposed shield is more than 3 mm [0.12 in] on either side.
- Shield wire is located in a corner of the hex crimp.
- Sleeving overlap is less than 6 mm [0.24 in] on either side.
- Loose strands of shield or shield wire outside ferrule.

15.2.1.2 Shield Termination – Shield Jumper Wire – Shield Braid

15.2.1.2.1 Shield Termination – Shield Jumper Wire – Shield Braid – Woven

Figure 15-23

Acceptable – Class 1,2,3

- Shield used as a shield wire, shield weave pattern is intact.
- Less than 6% of shield strands broken.

Defect – Class 2,3

- 6% or more shield strands broken.

15.2.1.2.2 Shield Termination – Shield Jumper Wire – Shield Braid – Combed and Twisted

Figure 15-24

Acceptable – Class 1,2,3

- Shield used as a shield wire is combed out and retwisted.
- After retwist, strands have been trimmed to an equal length.

Defect – Class 2,3

- After retwist, unequal trimming precludes capture of all twisted strands in the crimp or solder termination.

15.2.1.3 Shield Termination – Shield Jumper Wire – Daisy Chain

Figure 15-25

Acceptable – Class 1,2,3

- Shield terminations are staggered within the specified design limits from end of wire.

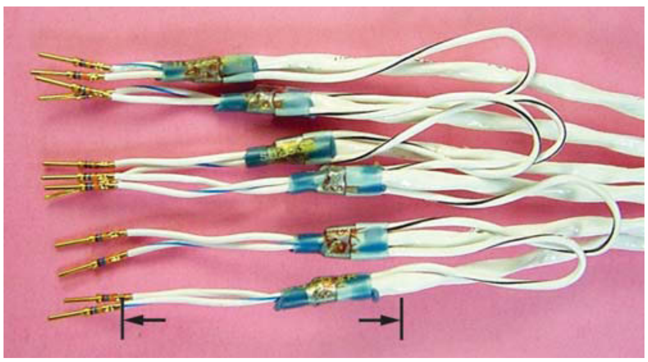


Figure 15-26

Defect – Class 2,3

- Shield terminations are not staggered within the specified design limits from end of wire.

15.2.1.4 Shield Termination – Shield Jumper Wire – Common Ground Point

Requirements for shield jumper wires spliced to a common point ground **shall [D1D2D3]** be the same as the splice requirements documented in 8.1 or 8.2 for the type of splice called out, e.g., lap.

15.2.2 Shield Termination – No Shield Jumper Wire

When the braid is not terminated it **shall [D1D2D3]** be covered with heat shrink sleeving.

15.2.2.1 Shield Termination – No Shield Jumper Wire – Shield Not Folded Back

Figure 15-28 illustrates the exposed shield (A) and sleeving overlap (B).

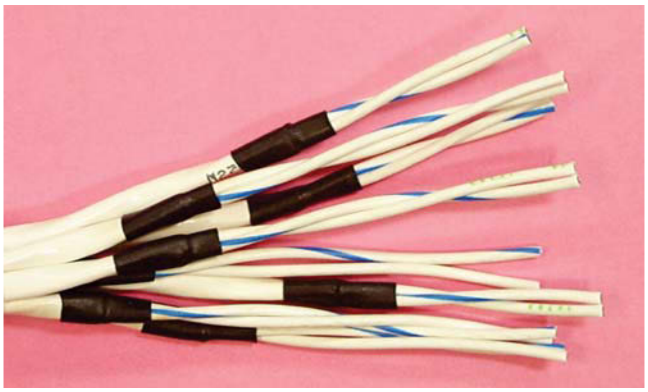


Figure 15-27

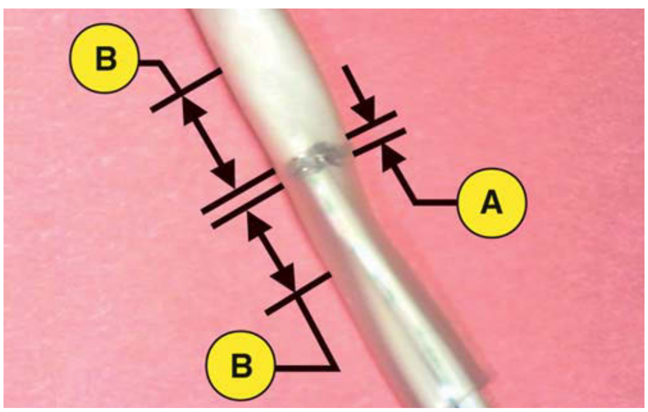


Figure 15-28

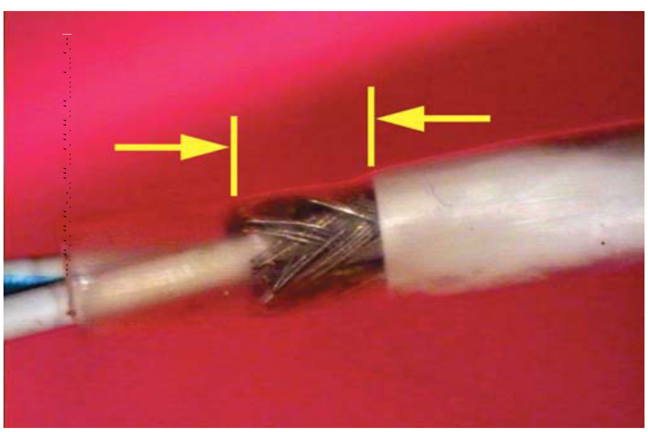


Figure 15-29

Acceptable – Class 1,2,3

- Sleeving overlaps a minimum of one wire or bundle diameter, whichever is greater, beyond the exposed shield in each direction (see Figure 15-28-B).
- Stripped shield length is equal to or less than 3 mm [0.12 in] (see Figure 15-28-A).
- Sleeving or wire insulation may be discolored but may not be burned or charred.

Process Indicator – Class 1,2,3

- Stripped shield length exceeds 3 mm [0.12 in].

15.2.2.1 Shield Termination – No Shield Jumper Wire – Shield Not Folded Back (cont.)

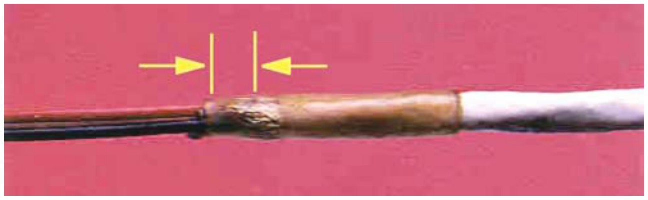


Figure 15-30

Figure 15-31

Acceptable – Class 1
Defect – Class 2,3

- Sleeving overlap is less than one wire or bundle diameter, whichever is greater, beyond the exposed shield in each direction.
- Any split in sleeving.

Figure 15-32

Defect – Class 1,2,3

- Sleeving is loose.
- Sleeving pierced by wire strand.
- Sleeve or wire insulation is burned or charred.

15.2.2.2 Shield Termination – No Shield Jumper Wire – Shield Folded Back

(Not illustrated.)

Acceptable – Class 1,2,3

- Shield strands are folded back over the outer jacket.
- Shrink sleeving extends two wire diameters past both ends of the shield strands.

Defect – Class 1,2,3

- Shield strands not folded back over the outer jacket prior to covering with shrink sleeving.
- Shrink sleeving extends less than two wire diameters past both ends of the shield strands.

15.3 Shield Termination – Connector

15.3.1 Shield Termination – Connector – Shrink

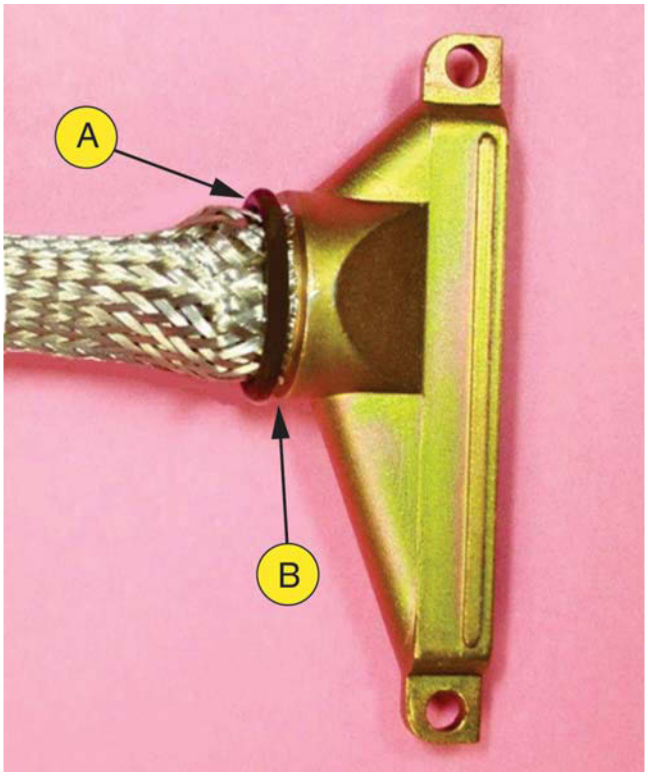


Figure 15-33

Acceptable – Class 1,2,3

- Shrinkable ring is shrunk with no movement of the ring or shield (see Figure 15-33-A).
- Thermochromatic paint on shrinkable ring has changed color from its original color, e.g., green, blue, red, to its transition color, e.g., black, black/brown (see Figure 15-33-A).
- Shield weave pattern is disturbed (not shown).
- Shield is against backshell and is visible between backshell and ring (see Figure 15-33-B).

15.3.1 Shield Termination – Connector – Shrink (cont.)

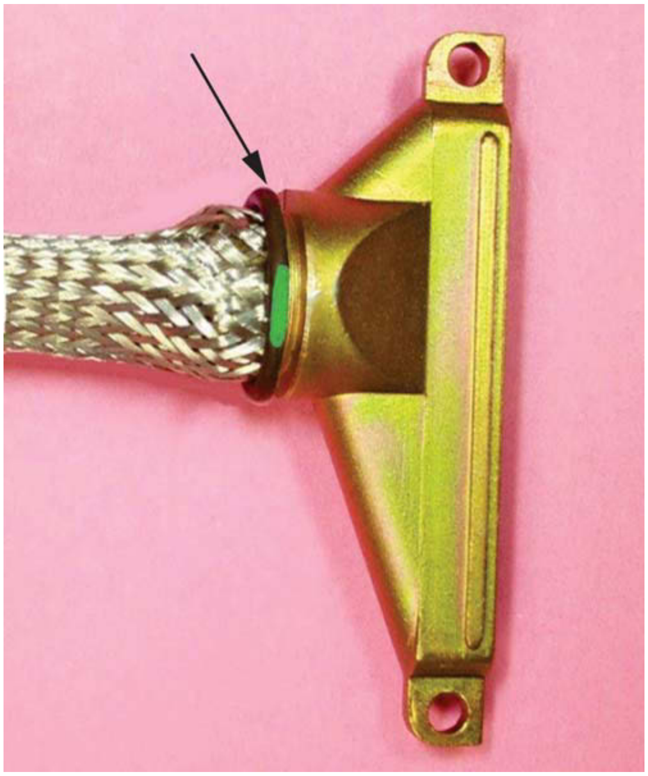


Figure 15-34

Defect – Class 1,2,3

- Shield is not visible between shrinkable ring and backshell.
- Shrinkable ring is not shrunk with movement of the ring or shield (see Figure 15-34).
- Thermochromatic paint on shrinkable ring has not changed color from its original color, e.g., green, blue, red, to its transition color, e.g., black, black/brown (see Figure 15-34).

15.3.2 Shield Termination – Connector – Crimp

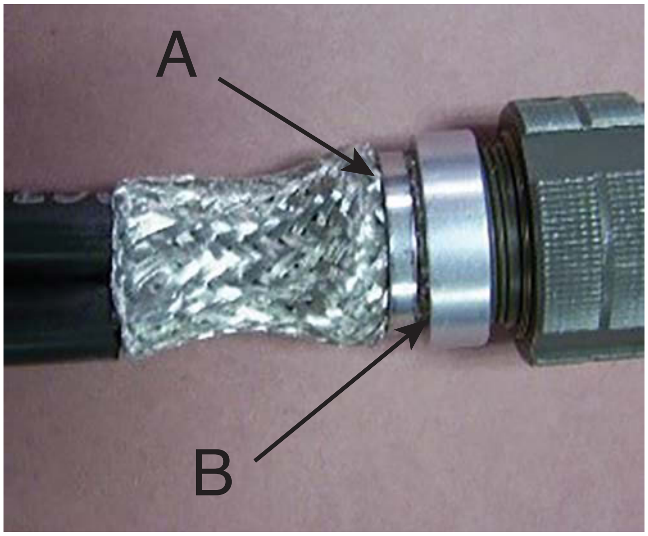


Figure 15-35

Acceptable – Class 1,2,3

- Shield weave pattern is disturbed; gaps in weave pattern are present (see Figure 15-35-A).
- Shield is visible between ring and the backshell (see Figure 15-35-B).
- Crimp ring is crimped. No movement of the ring or shield is evident.
- Shield strands not contained prior to the crimp ring are trimmed and do not exceed 6% of total strands.

15.3.2 Shield Termination – Connector – Crimp (cont.)

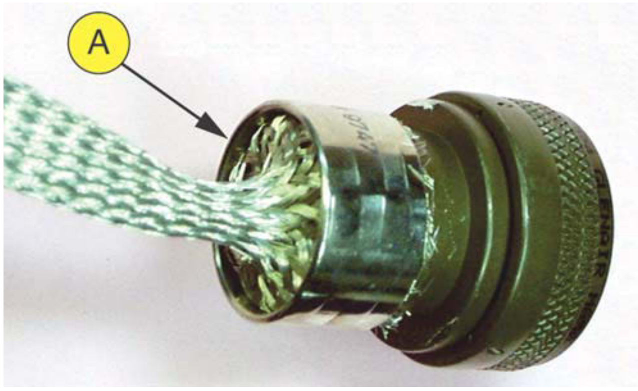


Figure 15-36

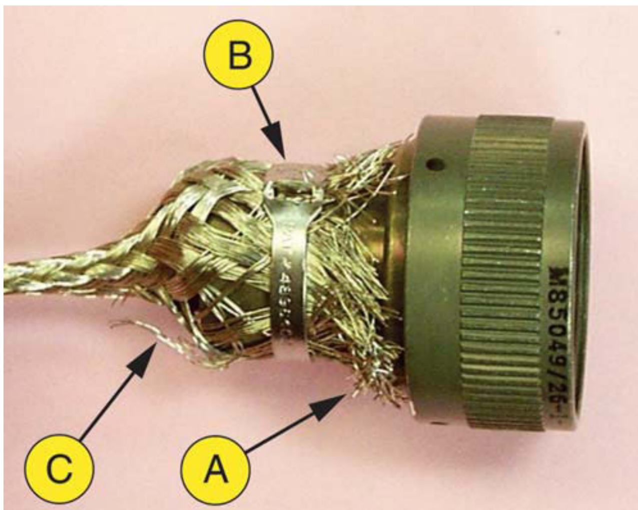


Figure 15-37

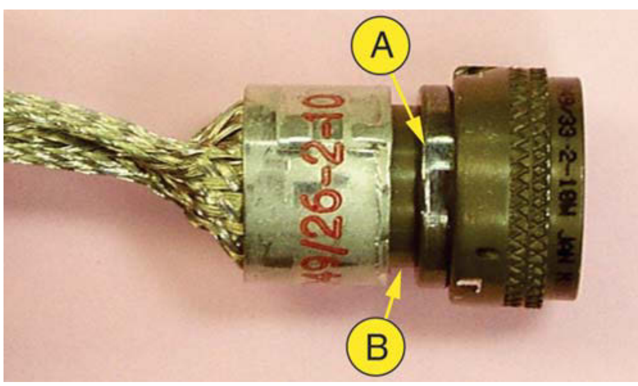


Figure 15-38

Defect – Class 1,2,3

- Crimp ring extends greater than 10% of the crimp ring length beyond backshell (see Figure 15-36-A).
- Crimp ring is under-crimped resulting in movement of the ring or shield.
- Shield extends beyond backshell crimp area (see Figure 15-37-A).
- Sharp edges are present in the buckle or band cut off area (see Figure 15-37-B).
- Shield strands not contained within crimp ring have not been trimmed (see Figure 15-37-C).
- Metal shield termination band is not wrapped around backshell in accordance with the band manufacturer's instructions.
- 10% or more shield strands broken.
- Backshell is damaged (see Figure 15-38-A).
- Shield is not visible at edge of crimp ring (see Figure 15-38-B).
- Sleeved sharp points or projections in the shield termination area (not shown).
- Metal shield termination band pierces or damages the sleeving (not shown).

15.3.3 Shield Termination – Connector – Shield Jumper Wire Attachment

See 9.2.1 for additional clamp fit requirements.

In the absence of specified length requirements, the shield jumper wire **shall [N1N2D3]** be as short as possible without violating other requirements, e.g., bend radius, stress relief.

When torque requirements are established, see 17.2.

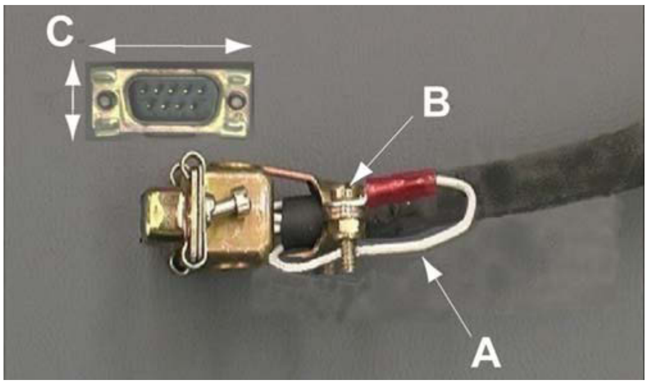


Figure 15-39

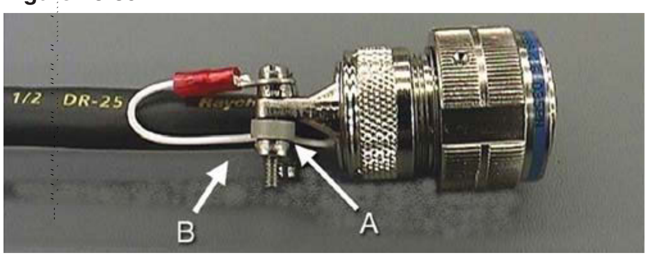


Figure 15-40

Acceptable – Class 1,2,3

- Shield jumper wire (see Figures 15-39-A , 40-B) has stress relief and is routed within the connector envelope (see Figure 15-39-C) where possible.
- The terminal lug (see Figure 15-39-B) is secured.

Figure 15-41

Defect – Class 1,2,3

- Terminal lug is not secured.
- Shield jumper wire is taut causing stress on the solder or crimp connections.

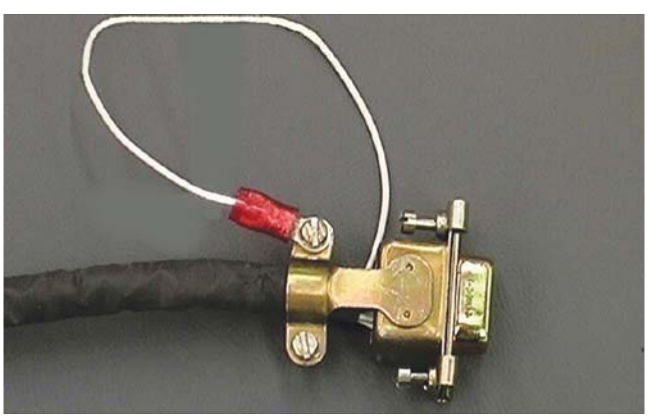


Figure 15-42

Defect – Class 3

- Shield jumper wire is not within the envelope dimension of the connector (where possible).

15.3.4 Shield Termination – Connector – Soldered

Terminations soldered directly to connector bodies as shown in Figure 15-43 **shall [D1D2D3]** only be used when required by engineering documentation.

The wetting and other soldering requirements in 4 (Soldered Terminations) apply when using this termination process.

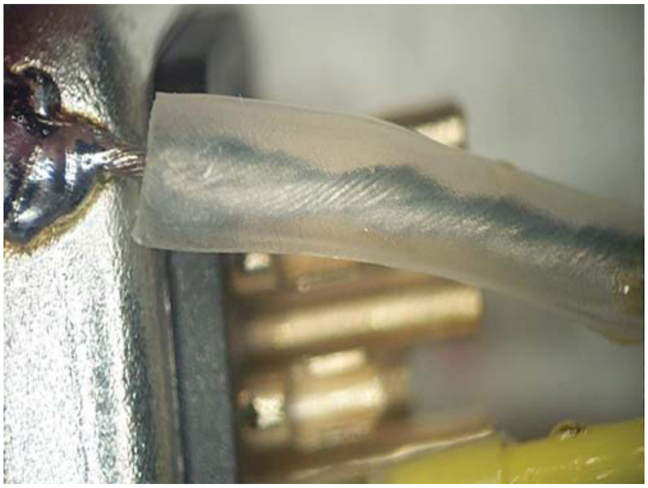


Figure 15-43

15.4 Shield Termination – Splicing Prewoven

When prewoven metal shielding is applied over a cable/harness all overlap locations should be tack soldered, tied, taped or otherwise secured to prevent the overlap junction from pulling apart during subsequent operations and handling. When completed, the junction should remain flexible.

15.4.1 Shield Termination – Splicing Prewoven – Soldered

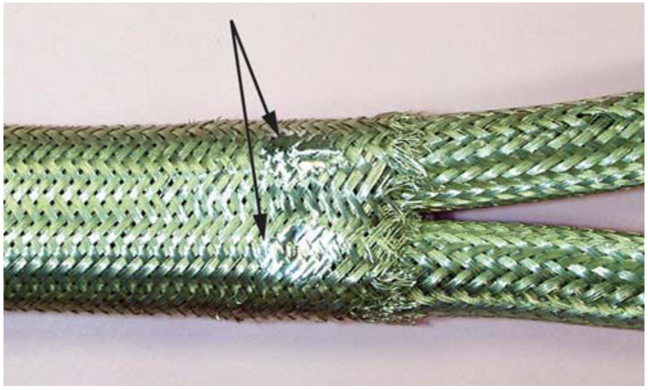


Figure 15-44

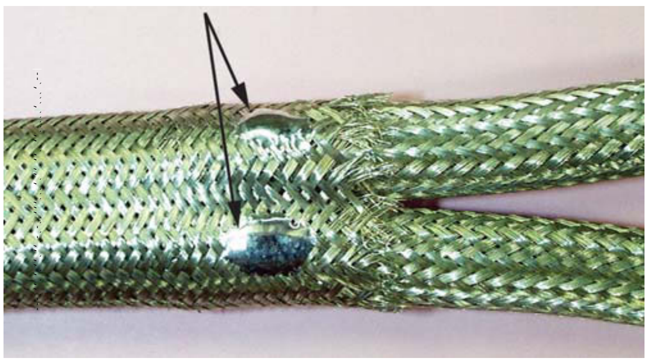


Figure 15-45

Acceptable – Class 1,2,3

- Tack solder is attaching all breakouts with sufficient solder flow (see Figures 15-44, 45).
- Shield overlap is from one to three times the diameter of the large (combined) wire bundle.

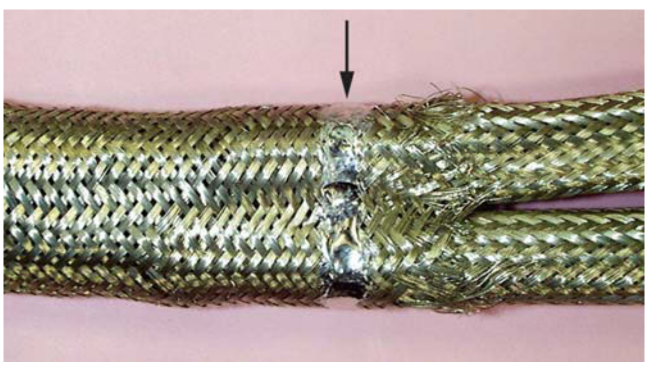


Figure 15-46

Process Indicator – Class 2,3

- A solder fillet is present around the entire shield overlap area (see Figure 15-46, arrow) and shield overlap area is still flexible.
- Shield weave pattern is disturbed but does not exceed the limits of 15.1, 15.1.1 and 15.1.2.
- Shield overlap is greater than three wire bundle diameters.

15.4.1 Shield Termination – Splicing Prewoven – Soldered (cont.)

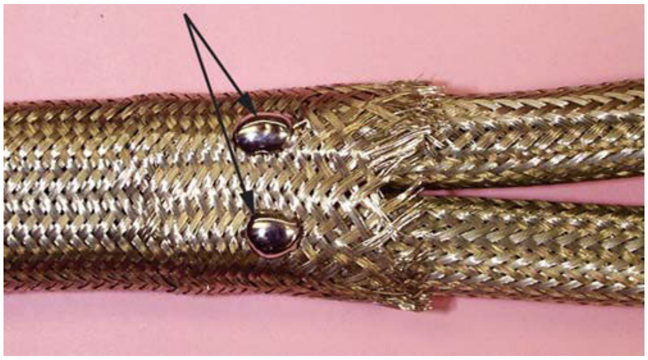


Figure 15-47

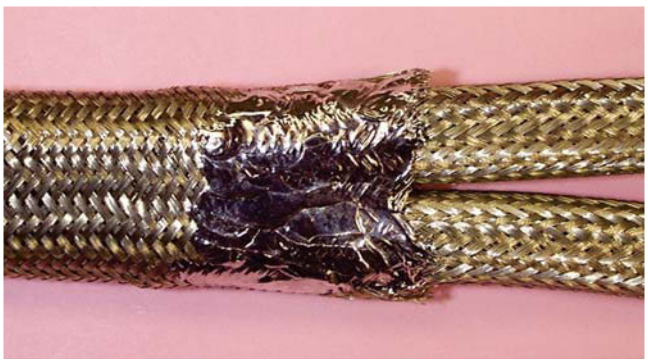


Figure 15-48

Defect – Class 1,2,3

- Tack solder has not flowed to inner shields (arrows).
- Shield overlap is less than one times the diameter of the large (combined) wire bundle (not shown).
- Solder flow in the shield overlap area is excessive with no flexibility.
- Shield weave pattern is disturbed and exceeds the limits of 15.1, 15.1.1 and 15.1.2.

15.4.2 Shield Termination – Splicing Prewoven – Tie/Tape On

Figure 15-49

Acceptable – Class 1

- 25% or greater overlap of tape width.

Acceptable – Class 2,3

- 50% or greater overlap of tape width.

Acceptable – Class 1,2,3

- Initial shield on legs are secured.
- Shield mesh tape conforms to bundle.
- Shield tape is secured on each leg.

Process Indicator – Class 2,3

- Tape overlap is less than 50%.

Figure 15-50

Defect – Class 1

- No tape overlap.

Defect – Class 2,3

- Tape overlap is less than 25%.

Defect – Class 1,2,3

- Shield not secured.
- Tape ends not secured.

15.5 Tapes – Barrier and Conductive, Adhesive or Nonadhesive

Figure 15-51

Acceptable – Class 1

- 25% overlap of tape width.

Acceptable – Class 2,3

- Minimum overlap is greater than 25% but less than 50% tape width.

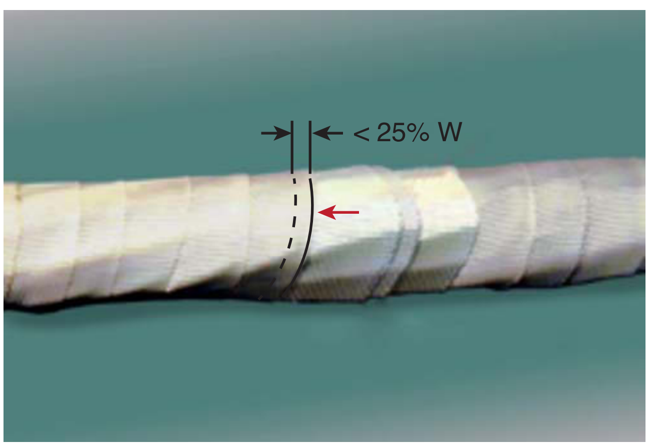


Figure 15-52

Process Indicator – Class 2,3

- Tape does not conform to bundle.

Defect – Class 1

- No tape overlap.

Defect – Class 2,3

- Tape overlap less than 25% of tape width (see Figure 15-52).

Defect – Class 1,2,3

- Tape loose or unraveling.
- Ends not secure.

15.6 Conduit (Shielding)

The term conduit in this standard refers to any tubular shape (metal or non-metal, rigid or flexible) that is used as a protective covering and guide for wiring. These criteria are specific to metal tube conduit.

(Not illustrated.)

Acceptable – Class 1

- Cracks that do not expose wire bundle.

Acceptable – Class 2

- Dents that do not compress or restrict passage of wire bundle.

Defect – Class 1

- Cracks that expose wire bundle.

Defect – Class 2,3

- Any cracks.
- Exposed basis metal when plating is required.
- Any kinks.
- Sharp edges or burrs at conduit ends.

Defect – Class 3

- Any dents or deformation.

15.7 Shrink Tubing – Conductive Lined

(Not illustrated.)

Acceptable – Class 1

- Tubing tight on connector/connector accessories, but not tight on cable.

Defect – Class 1,2,3

- Tubing not tight on connector/connector accessory.
- Cracks or tears in the tubing.
- Multiple pieces not electrically connected.

Defect – Class 2,3

- Tubing is not tight on cable.

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16 Cable/Wire Harness Protective Coverings

Protective coverings can take several forms and they may completely cover a cable harness or only selected portions. The primary purpose is abrasion resistance to protect internal wires. If woven, they can either be woven directly over a core or obtained in prefabricated form and installed by sliding it over the wire bundle. Other types of protective covering include heat shrink tubing, extruded jacket, spiral wrap sleeving, and taping.

The following topics are addressed in this section.

16.1 Braid

16.1.1 Braid – Direct Applied

Fabric braids woven directly on interconnecting harnesses or cables may be loose or tight, as necessary to produce the degree of flexibility required. The braid should be smooth and should be free of gaps through which wires can be seen. No frayed ends should be visible. All pigtails should be secured. Braids applied tightly should not terminate so close to connectors that they stress wires attached to solder cups or open connector sealing grommets. Temporary holding devices, e.g., spot ties, plastic straps and lacing, **shall [N1D2D3]** be removed from wire bundles prior to braid application.

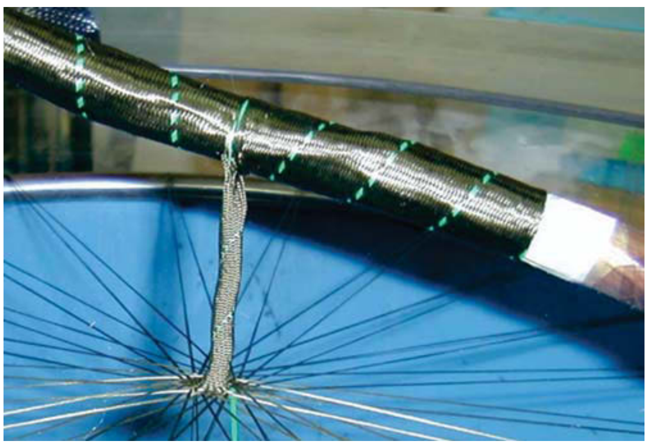

Figure 16-1

Figure 16-2

Acceptable – Class 1,2,3

- Braiding is not so tight as to cause indention or distortion to the wires of the assembly.
- No fraying or unraveling of braid ends.
- Braid strands smooth and evenly placed.
- Braid overlap is between one and three diameters of the largest bundle at breakouts and branches.
- Back braid lock stitch is a minimum of 13 mm [0.5 in].

Process Indicator – Class 2,3

- Braid overlap exceeds three diameters of the largest bundle.

16.1.1 Braid – Direct Applied (cont.)


Figure 16-3

Defect – Class 1,2,3

- Ends not secured.
- Tears and/or cuts of braiding.
- Broken/end strands not trimmed.
- Braid overlap is less than one diameter of the largest bundle at breakouts and branches.

Defect – Class 2,3

- Ends frayed or unraveling.

Defect – Class 3

- Gap or absence of braid where coverage is required.
- Back braid lock stitch is less than 13 mm [0.5 in] at breakouts and branches.

16.1.2 Braid – Prewoven

Prewoven braid or sleeving is to be secured at the ends by spot ties, clamps, tape or heat shrink tubing. When secured, the covering will not slide freely. The mesh may be folded under, adhesive bonded, hot knife seared or other process used to prevent end fraying.

For breakouts and branches the sleeving is not to be cut to allow passage of the wire. Depending on the weave the strands may be separated to allow wires to pass through. The number of wires is not to cause deformation or bunching of the sleeving.

The cut ends of some insulation materials, particularly those with a fiberglass barrier, may show unavoidable fraying. Acceptability of this fraying should be agreed upon between the User and Manufacturer.

Figure 16-4

Acceptable – Class 1,2,3

- Braid is smooth with firm contact against the wires.
- Free of ballooning or bunching.
- Ends secured with no fraying or unraveling.
- Multiple braids overlap at least two bundle diameters.
- Free of pulled loops.
- Braid overlap is between one and three diameters of the largest bundle at breakouts and branches.

Figure 16-5

Process Indicator – Class 2,3

- Braid overlap exceeds three diameters of the largest bundle.

16.1.2 Braid – Prewoven (cont.)

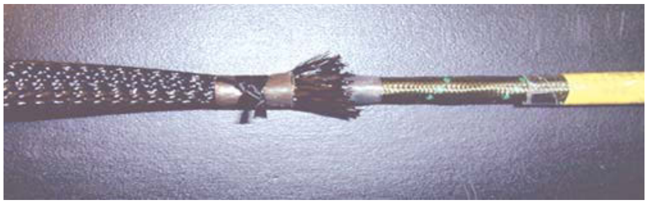

Figure 16-6

Defect – Class 2,3

- Ends frayed or unraveling.
- Any pulled loops.

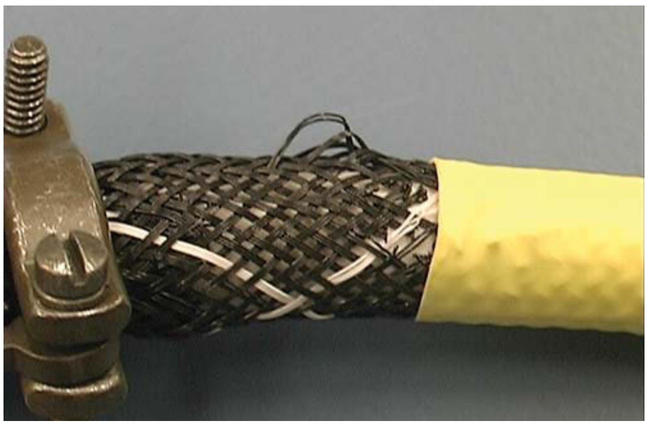

Figure 16-7

Figure 16-8

Defect – Class 3

- Braid ballooned or bunched.

Figure 16-9

Defect – Class 1,2,3

- Ends not secured.
- Equal to or greater than 5% braid strands damaged, e.g., tears, cuts, melting.
- Braid overlap is less than one diameter of the largest bundle at breakouts and branches.

16.2 Sleeving/Shrink Tubing

(Not illustrated.)

Criteria for boots can be found in 9.3.

Acceptable – Class 1

- Sleeving/tubing is tight on connector/connector accessories, but not tight on cable.

Acceptable – Class 2,3

- Sleeving/tubing is tight on cable and connector/connector accessories.
- Multiple pieces overlapped by at least three cable diameters, or 13 mm [0.5 in], whichever is larger.

Defect – Class 1

- Sleeving/tubing is not tight on connector/connector accessories.

Defect – Class 2,3

- Sleeving/tubing is not tight on cable or the connector/connector accessories.
- Overlap is less than 13 mm [0.5 in], or less than three cable diameters, if three cable diameters exceed 13 mm [0.5 in].

Defect – Class 1,2,3

- Cracks, tears or pinholes in the tubing.
- Sleeving/tubing is burned/charred.

16.2.1 Sleeving/Shrink Tubing – Sealant

These criteria are applicable if sealant is required. The criteria of 16.2 are also applicable. (Not illustrated.)

Note: Sealant may be applied as a separate material to the sleeving or may be integral to the sleeving, e.g., ''sealant-lined/coated,'' ''inner/dual wall sealant lined/coated.'' Criteria in this section applies to both types, however, not all criteria may be applicable for when sealant is integral to the sleeving.

Acceptable – Class 1,2,3

- Sleeving has been shrunk before curing the sealant.
- Sealant is cured to the sealant manufacturer's specifications.
- Sealant is visible at the ends of the sleeving.
- Sealant use does not violate stress relief requirements.
- Sealant present.
- Sealant is not burned/charred.
- Voids in sealant, where bottom of void can be seen.
- Voids that do not expose conductive surfaces.
- No voids or separation between the sleeving, sealant and wire/cable insulation.
- Sealant adheres to sleeving and wire/cable insulation.
- Sealant does not interfere with subsequent assembly steps.

Defect – Class 2,3

- Sleeving not shrunk before curing the sealant.
- Sealant is not cured.
- Sealant is not visible at the ends of the sleeving.

Defect – Class 1,2,3

- Excessive sealant use violates stress relief requirements.
- Sealant missing.
- Sealant is burned/charred.
- Voids in sealant, where bottom of void cannot be seen.
- Voids that expose conductive surfaces.
- Incomplete material fill.
- Void or separation between the sleeving, sealant and wire/cable insulation.
- Sealant has not adhered to sleeving or wire/cable insulation.
- Sealant interferes with subsequent assembly steps.

16.3 Spiral Plastic Wrap (Spiral Wrap Sleeving)

Spiral wrap sleeving is used for two purposes. One is to contain a group of wires/cables. Another is for abrasion protection. The sleeving may be applied as a closed or an open spiral and frequently the inner cables and wires are visible (see Figures 16-10, 11).

Figure 16-10

Figure 16-11

Acceptable – Class 1,2,3

- Spiral sleeving makes firm contact with the bundle.
- Ends trimmed to eliminate sharp edges or points.
- The ends of the wrap are secured.

Defect – Class 2,3

- Ends not secured.
- Ends have sharp edges or points.

16.4 Wire Loom Tubing – Split and Unsplit

The term wire loom tubing in this standard refers to any tubular shape (metal or non-metal, rigid or flexible) that is used as a protective covering and guide for wiring. Flexible wire loom tubing is corrugated, and may or may not have a metallic film coating for ESD/EMI purposes.

(Not illustrated.)

Acceptable – Class 1,2,3

- Dents or kinks that do not interfere with wire bundle installation.

Defect – Class 2,3

- Cracks.
- Dents or kinks interfere with wire bundle installation.
- Sharp edges or burrs at ends.
- Ends not secure.

16.5 Tapes, Adhesive and Nonadhesive

The taping criteria in 15.5 are also applicable when tape is used as a protective covering.

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17 Finished Assembly Installation

A finished assembly is a harness, cable or wire(s) that may be covered or uncovered.

The following topics are addressed in this section.

17.1 General

In many cases cable and wire harness assemblies are manufactured at one facility and shipped with or without end termination as a completed harness assembly to another facility where the harnesses are installed into an end-item, e.g., chassis, drawer or enclosure. This section provides process requirements and acceptance criteria for installation of a harness.

Mechanical assembly refers to mounting of assemblies including, but not limited to, the use of any of the following: screws, bolts, nuts, washers, fasteners, clips, component studs, adhesives, tie downs, rivets, connector pins, etc.

Compliance to torque requirements is to be verified as specified by User documentation. The verification procedure ensures that no damage to components or assembly occurs. Where torque requirements are not specified, follow standard industry practices.

Engineering documentation specifies the hardware to use.

Note: Criteria in this section do not apply to attachments with self-tapping screws.

When no specific requirements have been established by other documentation, the following criteria apply.

Acceptable – Class 1,2,3

- Wires and cables are positioned or protected to avoid contact with rough or irregular surfaces and sharp edges and to avoid damage to conductors or adjacent parts.
- Minimum electrical clearance is maintained.
- Installation hardware including accessories is tight, including applicable torque if required.
- Wiring connections to ground are free of any protective finishes, e.g., paint, anodized coating, etc., that can preclude an adequate ground connection.
- Wire routing meets requirements for drip loops, no mechanical interference, etc.
- Soldered connections meet the requirements of 4 (Soldered Terminations).
- Crimping meets the requirements of 5 (Crimp Terminations).
- Splice connections meet the requirements of 8 (Splices).
- Wiring is terminated at the destination specified by the wire marker/documentation.
- Wire is not routed through ''keep out'' zones, e.g., hot surfaces or mechanical interference areas.
- Adhesives are applied at the required location and properly cured.
- Cable wire/harness bend radius maintained as specified. If not otherwise specified, the minimum bend radius is in accordance with Table 14-1.
- The harness is supported with mounting hardware to preclude stress.
- Nothing interferes with mounting of required hardware.
- Cable restraints do not compress or damage wire insulation.
- If required, a service loop is provided to allow at least one field repair.
- The harness is installed to meet required form, fit and function.

Defect – Class 1,2,3

- Product that does not conform to requirements or the above criteria.

17.2 Hardware Installation

This section illustrates several types of mounting hardware.

All hardware **shall [D1D2D3]** be assembled in accordance with the supplier's (see 1.8.6) specifications or a documented process.

Visual inspection is performed to verify the following conditions:

a. Correct parts and hardware.
b. Correct sequence of assembly.
c. Correct security and tightness of parts and hardware.
d. No discernible damage.
e. Correct orientation of parts and hardware.
f. Existence and correct application of materials to the fastener system.

Compounds applied to fasteners (thread-lock, torque identification/witness/anti-tampering stripes, corrosion protection, sealants, adhesives, staking, etc.) **shall not [N1D2D3]** be applied unless identified on the engineering documentation, and **shall [N1D2D3]** be mixed and cured following the material manufacturer's instructions or other documented procedure (see 1.16).

Fasteners requiring staking **shall [N1D2D3]** be retained with a minimum of 50% circular coverage (either one continuous bead for 50% of the circumference, or two beads each with at least 25% of the circumference).

Threaded fasteners that have been retained by the use of locking compounds **shall not [N1D2D3]** be reused unless cleaned and inspected.

17.2.1 Hardware Installation – Threaded Fasteners

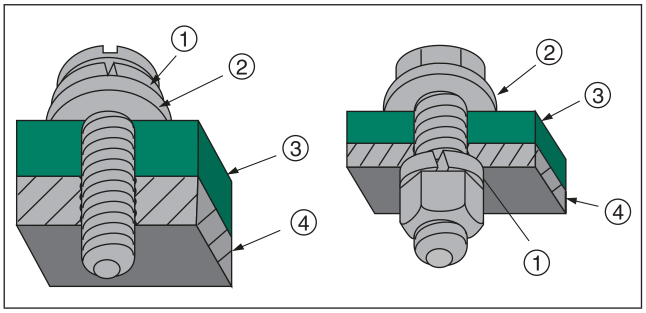

Figure 17-1
1. Lock washer
2. Flat washer
3. Nonmetal
4. Metal (not conductive pattern or foil)

Acceptable – Class 1,2,3

- Proper hardware sequence.
- Slot or hole are covered with flat washer (see Figure 17-3, bottom view).
- Flat washer spans the width and contacts both sides of the slot (see Figure 17-3, top view).
- Proper hardware orientation (see Figures 17-1, 2).

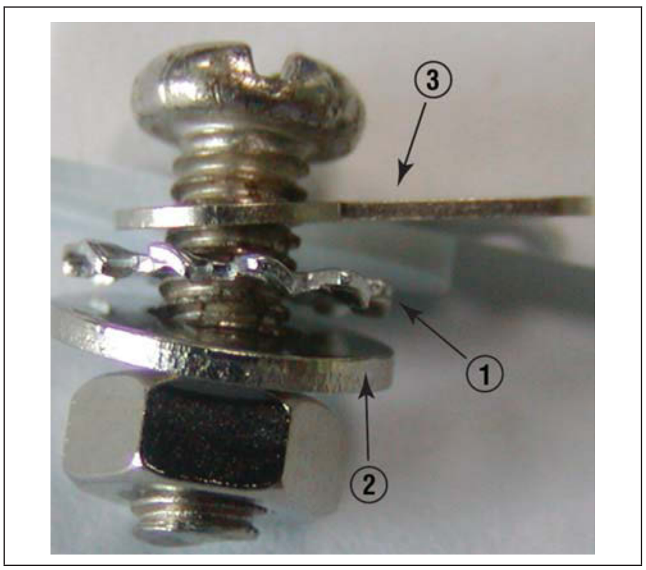

Figure 17-2
1. Lock washer, sharp edges towards flat washer
2. Flat washer
3. Solder lug

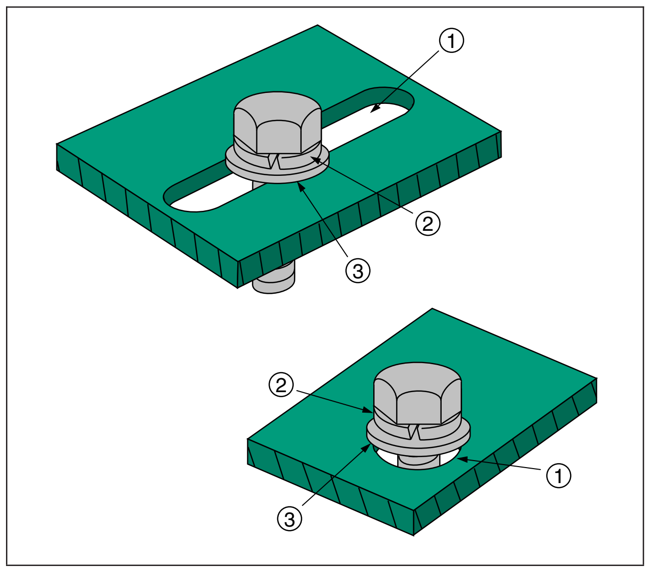

Figure 17-3
1. Slot or hole
2. Lock washer
3. Flat washer

Acceptable – Class 1
Defect – Class 2,3

- Less than one and one-half (1.5) threads extend beyond the threaded hardware, e.g., nut, unless otherwise specified by engineering documentation.

17.2.1 Hardware Installation – Threaded Fasteners (cont.)

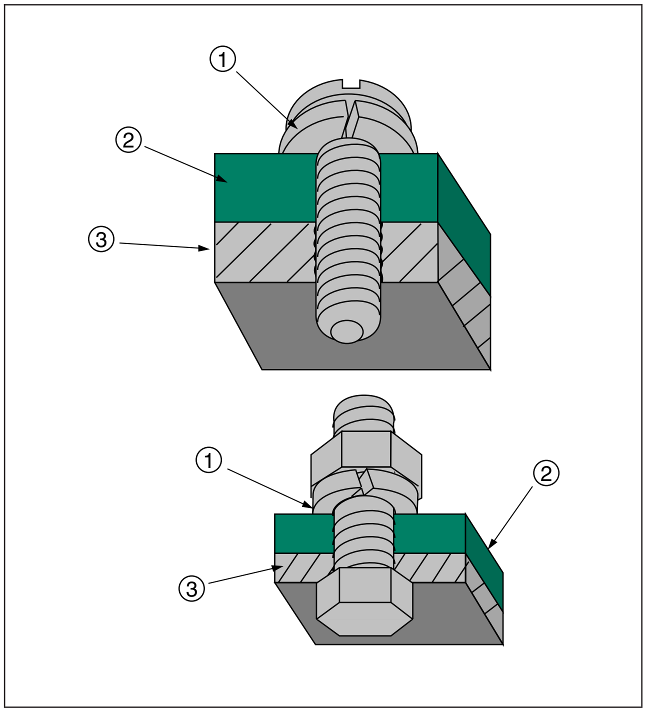

Figure 17-4
1. Lock washer
2. Nonmetal
3. Metal (not conductive pattern or foil)

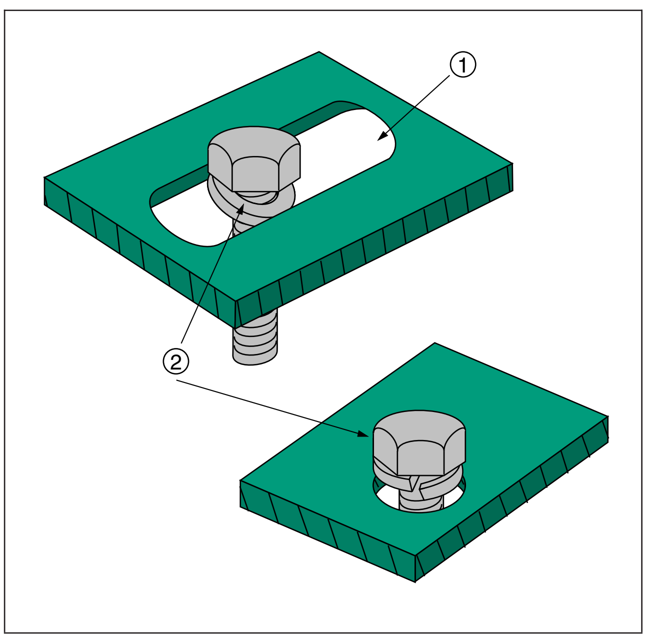

Figure 17-5
1. Slot or hole
2. Lock washer

Defect – Class 1,2,3

- Thread extension interferes with adjacent component.
- Hardware material or sequence not in conformance with engineering documentation.
- Lock washer against nonmetal/laminate.
- Hardware missing or improperly installed (see Figure 17-6).
- Hardware is not seated (see Figure 17-7).
- Fasteners are damaged (burrs, cross-threading, rounding, etc.).
- Evidence of damage to the parts being secured.

Figure 17-6

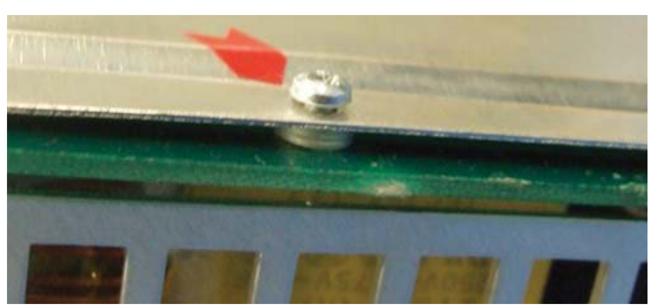

Figure 17-7

17.2.1.1 Hardware Installation – Threaded Fasteners – Minimum Torque

When connections are made using threaded fasteners they should be sufficiently tight to ensure the reliability of the connection. When required, fasteners **shall [D1D2D3]** be tightened to the specified torque.

Threaded fasteners which have been over-torqued **shall [N1D2D3]** be removed and discarded.

Torque tool settings/values **shall [N1D2D3]** be adjusted to compensate for additions to the torque tool, e.g., extensions, adapters, etc.

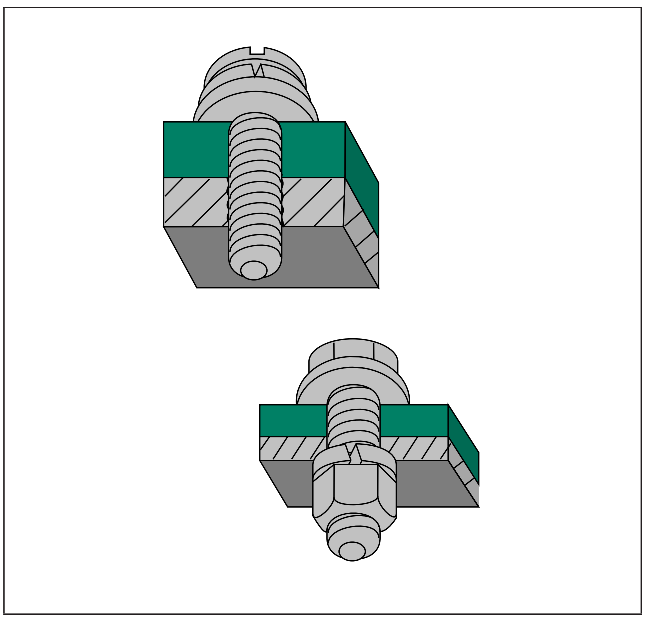

Figure 17-8

Figure 17-9

Acceptable – Class 1,2,3

- Fasteners are tight and split-ring lock washers, when used, are fully compressed.
- Proper torque applied when torque is a requirement.
- Torque stripe on fasteners (witness/anti-tampering stripe), when required (see Figure 17-9):
  - Is continuous between the fastener and the substrate.
  - Extends from the top of the fastener onto the adjacent substrate (at minimum).
  - Is aligned with the center line of the fastener.
  - Is undisturbed (indicating no movement of the fastener and stripe after torquing).

17.2.1.1 Hardware Installation – Threaded Fasteners – Minimum Torque (cont.)

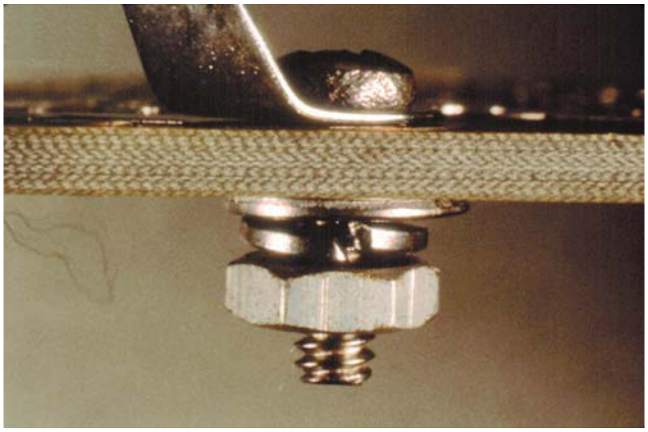

Figure 17-10

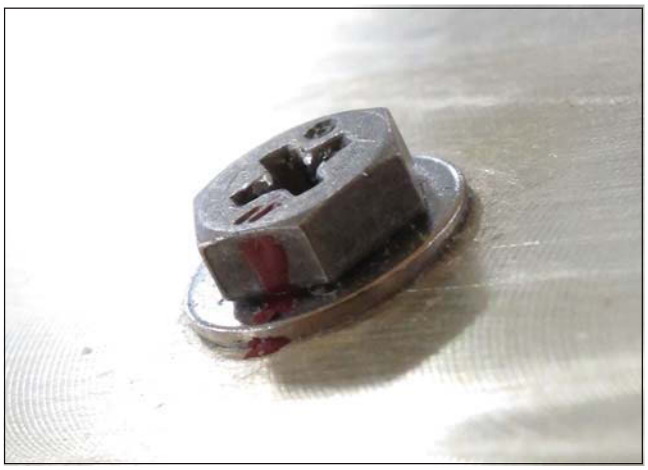

Figure 17-11

Defect – Class 1,2,3

- Split ring lock washer, if used, is not compressed.
- Proper torque not applied when torque is a requirement.
- Required torque stripe is not continuous between the fastener and the substrate.
- Required torque stripe does not extend from the top of the fastener onto the adjacent substrate (at minimum).
- Required torque stripe is not aligned with the center line of the fastener.
- Required torque strip is disturbed (indicating movement of the fastener and stripe after torquing).
- Hardware is loose (see Figure 17-10).

17.2.2 Hardware Installation – Threaded Fasteners – Wires

When the use of terminal lugs is not required, conductors may be wrapped around screw type fasteners in a manner that precludes loosening when the screw or other conductor termination devices are tightened, and the ends of the conductor are kept short to preclude violating minimum electrical clearance.

If a washer is used, the conductor is to be mounted under the washer.

See 17.3.2 for additional wire dress requirements if the wires will be installed using fasteners.

Figure 17-12

17.2.2.1 Hardware Installation – Threaded Fasteners – Solid Wires

Figure 17-13

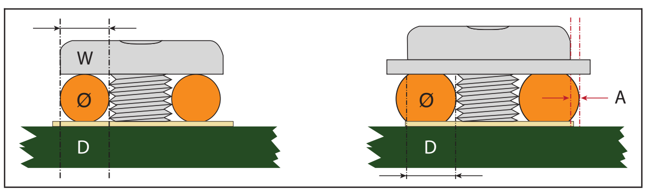

Figure 17-14
A. Less than or equal to 1/3 D

Acceptable – Class 1,2,3

- 1/3 or less of the conductor diameter protrudes from under the screw head.
- Mechanical attachment of the conductor is in contact between the screw head and the contact surface for a minimum of 180° around the screw head.
- Conductor is not wrapped more than 360°.
- Conductor extending outside the screw head does not violate minimum electrical clearance.
- Wire wrapped in the correct direction.
- No insulation in the contact area.

17.2.2.1 Hardware Installation – Threaded Fasteners – Solid Wires (cont.)

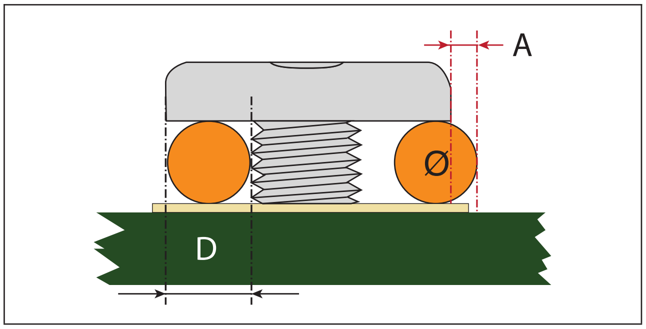

Figure 17-15
A. Overhang greater than 1/3 D

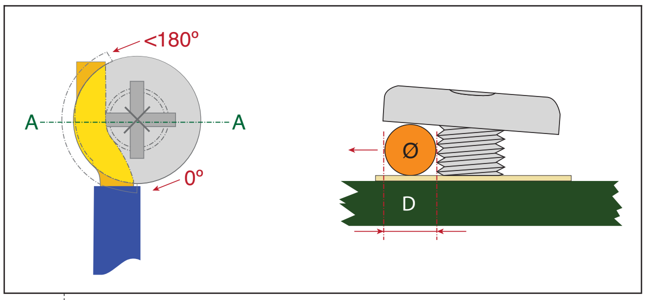

Figure 17-16

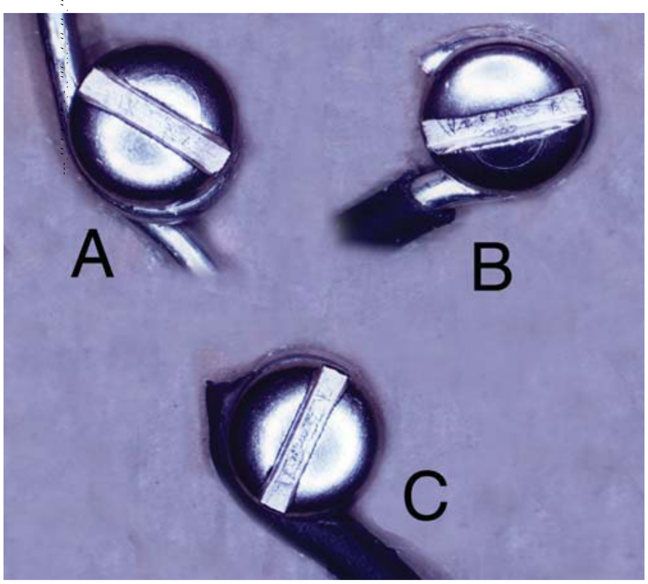

Figure 17-17

Defect – Class 1,2,3

- More than 1/3 of the conductor diameter protrudes from under the screw head (see Figure 17-15).
- Conductor not wrapped around screw body for at least 180° (see Figure 17-16-A).
- Conductor is wrapped more than 360° (see Figure 17-17-A).
- Conductor wrapped in wrong direction (see Figure 17-17-B).
- Insulation in the contact area (see Figure 17-17-C).

17.2.2.2 Hardware Installation – Threaded Fasteners – Stranded Wires

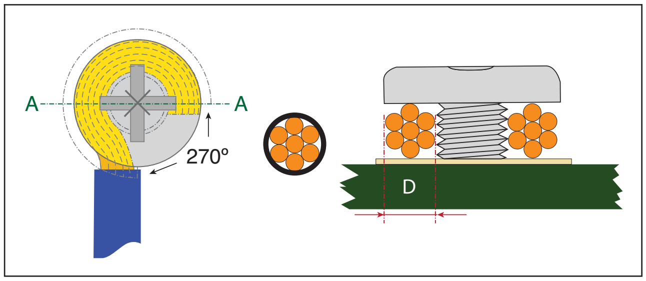

Figure 17-18

Acceptable – Class 1,2,3

- Less than 1/3 of the conductor diameter protrudes from under the screw head.
- Conductor extending outside the screw head does not violate minimum electrical clearance.
- Mechanical attachment of the conductor is in contact between the screw head and the contact surface for a minimum of 180° around the screw head.
- No insulation in the contact area.
- Conductor is not wrapped more than 360°.

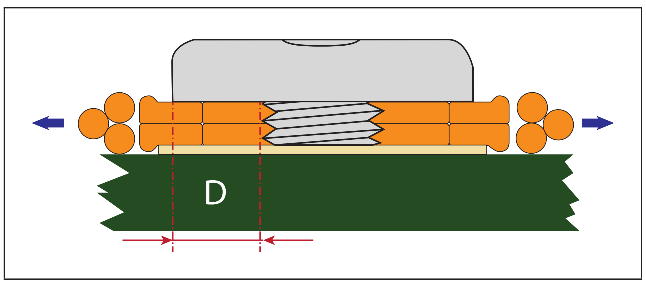

Figure 17-19

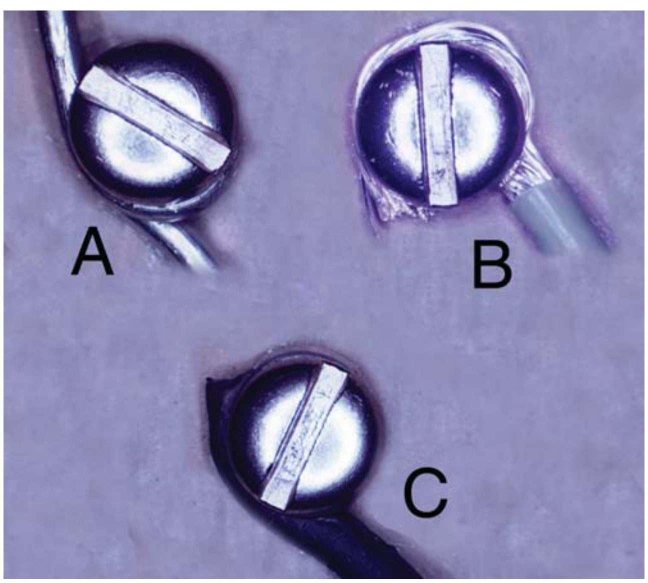

Figure 17-20

Defect – Class 1,2,3

- Conductor not wrapped around screw body for at least 180° (see Figure 17-16).
- Stranded conductor was tinned (not shown).
- More than 1/3 of the conductor diameter protrudes from under the screw head (see Figure 17-19).
- Stranded conductor wrapped in wrong direction (tightening the screw unwinds the twisted conductor) (see Figure 17-20-B).
- Insulation in the contact area (see Figure 17-20-C).

17.2.3 Safety Wiring

Safety wiring should be in accordance with SAE AS567, NASM33540, or equivalent, and include the following.

The double-twist method of safety wiring **shall [N1D2D3]** be used (see Figures 17-21, 22), except single wire may be used in a closely spaced (5.08 cm [2 in] or less between centers), closed geometrical pattern (triangle, square, rectangle, circle, etc.) of parts (see Figure 17-23).

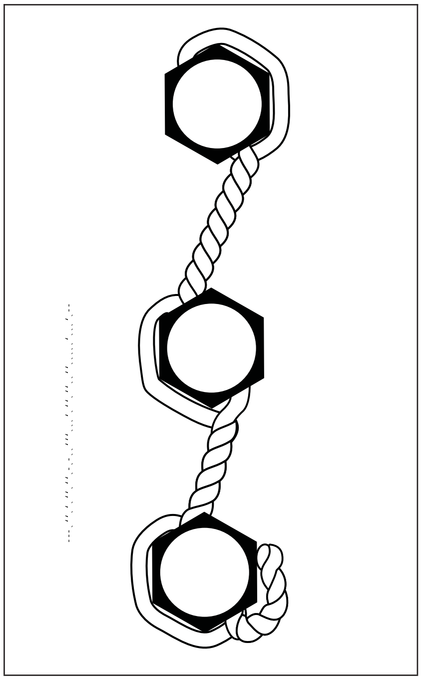

Figure 17-21

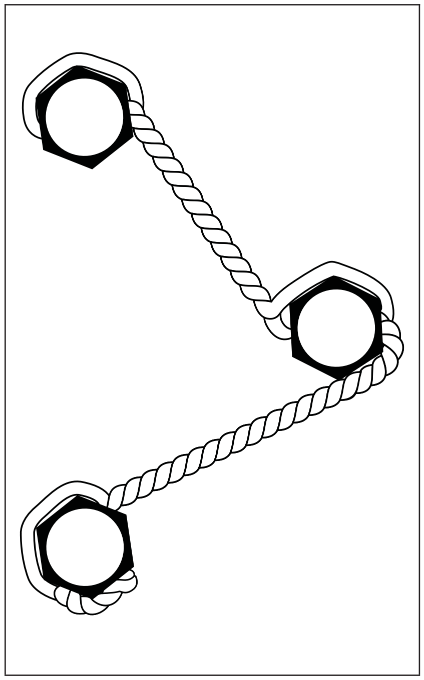

Figure 17-22

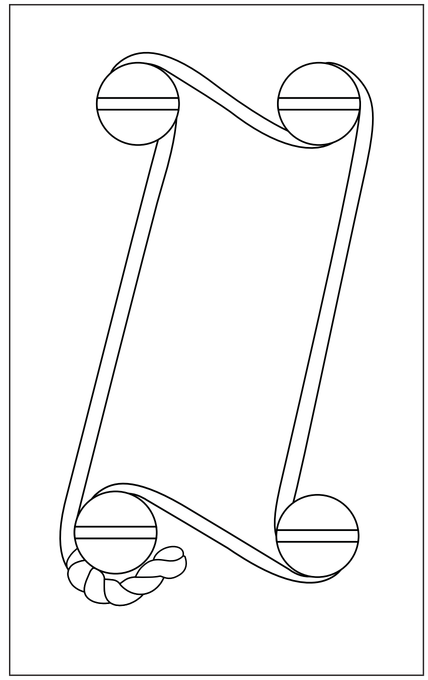

Figure 17-23

17.2.3 Safety Wiring (cont.)

Devices **shall not [N1D2D3]** be over-torqued or loosened to align lock wire holes (not shown).

Lock wire **shall not [N1D2D3]** be reused (not shown).

Lock wire **shall not [N1D2D3]** be stretched, nicked, or kinked (over-twisted) (not shown).

The lock wire **shall not [N1D2D3]** have a slack loop that enables the wire to move up over the device being secured (see Figure 17-24-A). The loop around the fastener head **shall [N1D2D3]** be routed under the strand protruding from the hole, and drawn sufficiently tight to prevent its lifting and becoming a slack loop (see Figure 17-24-B).

The lock wire **shall [N1D2D3]** be installed such that the wire is put in tension if the device tends to loosen (see Figure 17-25).

The wire pigtail **shall [N1D2D3]** be a minimum of four turns and **shall not [N1D2D3]** be longer than 19 mm [0.75 in] (see Figure 17-26).

The wire pigtail **shall [N1D2D3]** be bent into a loop or otherwise positioned to prevent a sharp end from causing personal injury (see Figure 17-26).

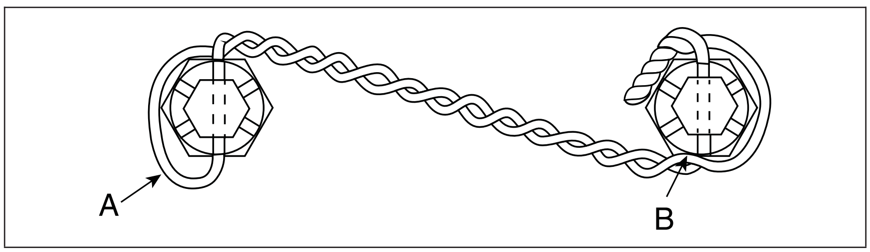

Figure 17-24

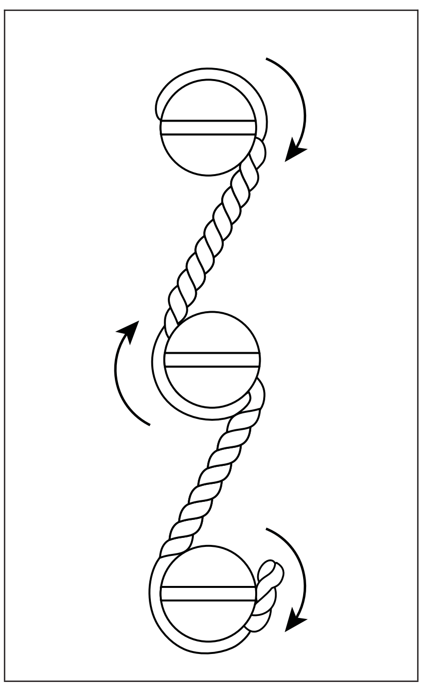

Figure 17-25

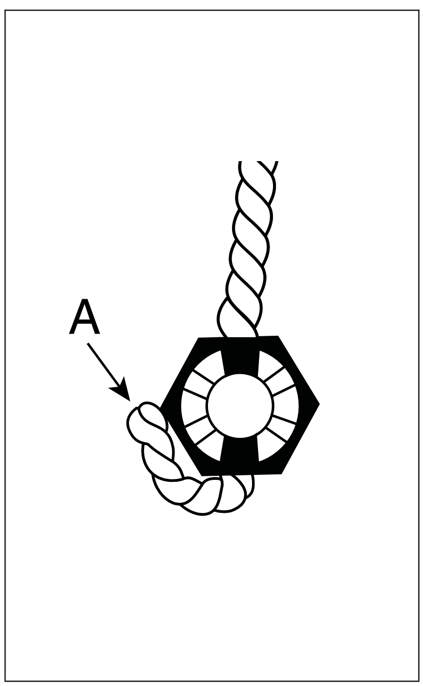

Figure 17-26

17.2.4 Safety Cable

Safety cable should be in accordance with NASM33540, SAE AS567, or equivalent, and include the following.

Safety cable **shall [N1D2D3]** be installed with a tool that has been verified to meet Table 17-1.

Table 17-1 Minimum Swaged Ferrule Pull-Off Load

Nominal Cable Diameter	Minimum Swaged Ferrule Pull-Off Load
0.51 mm [0.022 in]	133.4 N [30 lbf]
0.81 mm [0.032 in]	311.4 N [70 lbf]
1.02 mm [0.040 in]	489.3 N [110 lbf]
1.58 mm [0.062 in]	1245.5 N [280 lbf]

Safety cable **shall [N1D2D3]** be installed such that the cable is put in tension if the fastener tends to loosen.

Safety cable **shall not [N1D2D3]** have nicks, frays, kinks or other damage.

Safety cable **shall [N1D2D3]** be installed through holes intended for the parts being secured.

Devices **shall not [N1D2D3]** be over-torqued or loosened to align holes.

Safety cable and ferrules **shall not [N1D2D3]** be reused.

Safety cable **shall not [N1D2D3]** extend beyond the crimped ferrule more than 0.79 mm [0.031 in].

17.3 Wire/Harness Installation

17.3.1 Wire/Harness Installation – Stress Relief

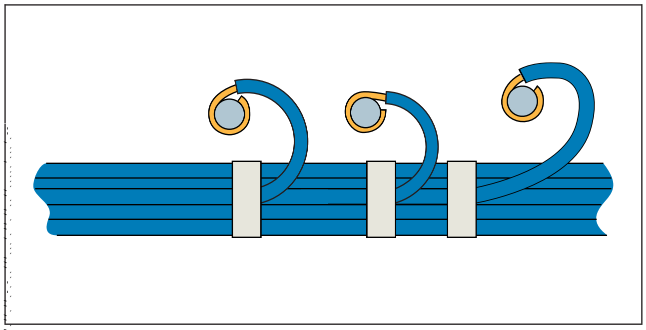

Figure 17-27

Acceptable – Class 1,2,3

- The wire approaches the terminal with a loop or bend sufficient to relieve any tension on the connection during thermal/vibration stress.

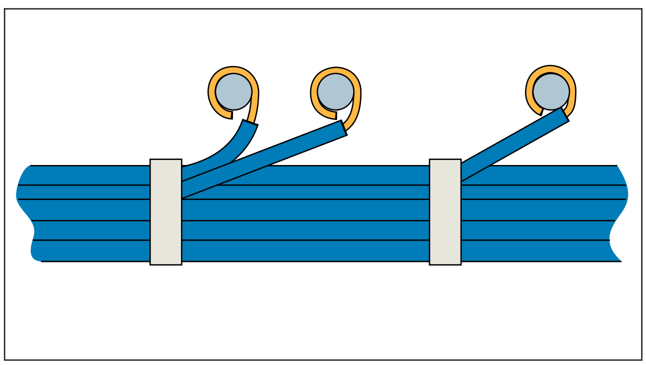

Figure 17-28

Not Established – Class 1
Defect – Class 2,3

- There is insufficient stress relief, e.g., at the breakout, at the terminal.

17.3.2 Wire/Harness Installation – Wire Dress

Attachments to terminals that require a wrap may be wrapped clockwise or counterclockwise (consistent with the direction of potential stress application). Unless the wire/terminal connection is supported to prevent stress at the solder connection, the wire **shall [A1P2D3]** continue the curvature of the dress of the wire (see Figure 17-29). The conductor **shall not [A1D2D3]** interfere with the wrapping of other conductors on the terminal or overlap itself or each other (see 4.8).

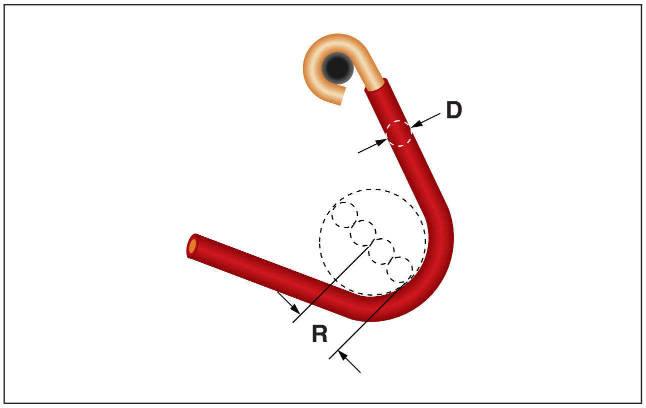

Figure 17-29

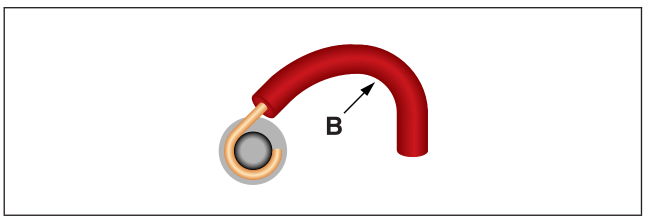

Figure 17-30

Acceptable – Class 1,2,3

- The direction of the stress-relief bend places no strain on the mechanical wrap or the solder connection.
- Stress relief bend radius (R) meets the requirements of Table 14-1.
- Bends are not kinked (see Figure 17-30-B).

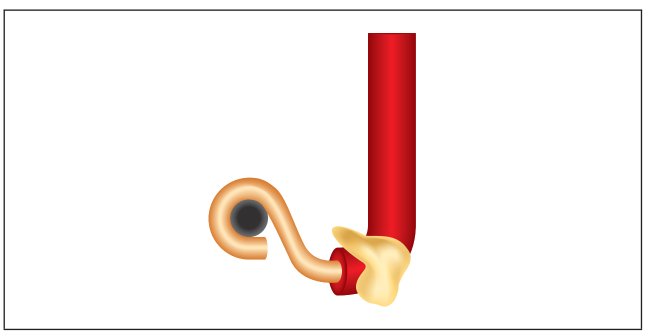

Figure 17-31

Acceptable – Class 1
Process Indicator – Class 2
Defect – Class 3

- The wire is formed around the terminal opposite to the feed-in direction and is not supported to prevent stress at the solder connection.

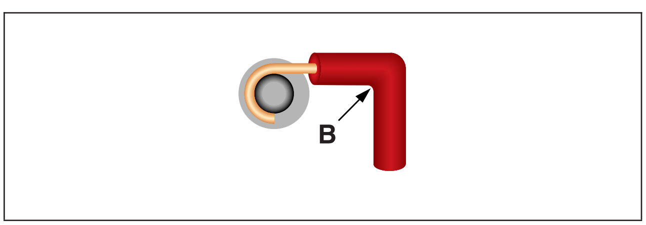

Figure 17-32

Defect – Class 1,2,3

- Bends are kinked (see Figure 17-32-B).
- Stress relief bend radius (R) does not meet the requirements of Table 14-1.

17.3.3 Wire/Harness Installation – Service Loops

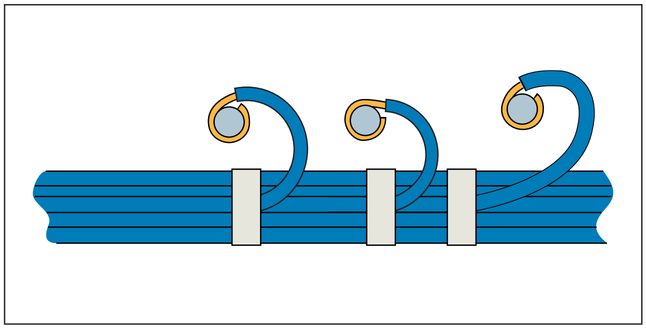

Figure 17-33

Acceptable – Class 1,2,3

- When a service loop is required, wire has sufficient length to allow one field re-termination to be made.

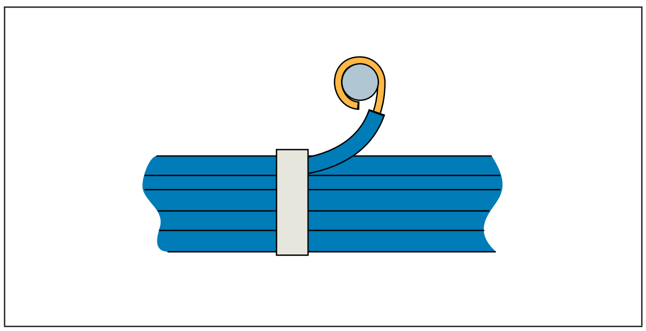

Figure 17-34

Defect – Class 1,2,3

- When a service loop is required, wire does not have sufficient length to allow at least one field re-termination to be made.

17.3.4 Wire/Harness Installation – Clamping

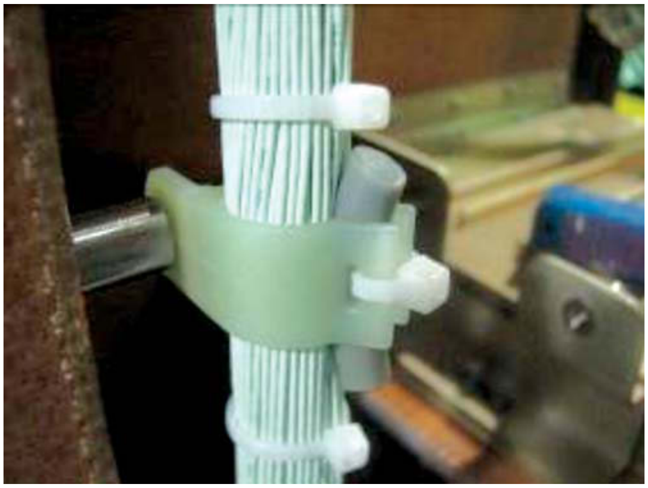

Figure 17-35

Acceptable – Class 1,2,3

- Clamp ends together.
- Wires/harness assembly not pinched.
- Wires/harness assembly held securely.
- Filler rods, if used, extend 1 mm [0.04 in] to 19 mm [0.75 in] on either side of the clamp.
- Filler rods, if used, are located on the gap side of the clamp (see Figure 17-35).

Defect – Class 1,2,3

- Wires/harness assembly not held securely in the clamp.
- Wires/harness assembly pinched in clamp.
- Insulation is compressed by more than 20% or damaged by the clamp.
- Filler rods, if used, extend less than 1 mm [0.04 in] or more than 19 mm [0.75 in] on each side of the clamp.
- Filler rods, if used, are not on the gap side of the clamp.

17.3.5 Wire/Harness Installation – Tie Wrap/Lacing

When wire bundles or cables require tie wrapping/lacing during installation, i.e., to maintain proper bend radius, assist with wire dress, intersect each other and/or to prevent damage to the harness in its final installed state, the requirements of 14 (Securing) are applicable.

17.3.6 Raceways

Wires, cables, and bundles **shall [D1D2D3]** be positioned and spaced within raceways as specified on the engineering documentation. Wires, cables, and bundles **shall [D1D2D3]** be tied using the engineering drawing approved method, e.g., lacing tape, tie wraps, etc., at entry and exit points of the raceway.

Acceptable – Class 1,2,3

- Wires, cables and bundles are contained within the raceway.
- Wires, cables and bundles are secured at entry and exit points of the raceway.
- Wires, cables and bundles do not contact sharp surfaces or other chafe points.
- Wires, cables or bundles are not trapped between the end of the raceway cushion (non-metallic) and the end of the channel.
- No damage to raceway metallic and non-metallic components.
- No distortion of the raceway cushion (non-metallic).
- No separation or misalignment between metallic and non-metallic parts of the raceway.
- Raceway securely fastened to the mounting surface.

Acceptable – Class 1
Process Indicator – Class 2,3

- Scratches, scuffs, or other surface damage to raceway metallic and non-metallic components that do not:
  - compromise protection of the underlying surface.
  - compromise adhesion of the finish.
  - expose basis metal.
  - prevent proper installation of wires, cables or bundles.

Defect – Class 1,2,3

- Wires, cables and bundles are not contained within the raceway.
- Wires, cables and bundles are not secured at entry and exit points of the raceway.
- Wires, cables and bundles contact sharp surfaces or other chafe points.
- Wires, cables or bundles are trapped between the end of the raceway cushion (non-metallic) and the end of the channel.
- Damage to raceway metallic and non-metallic components that:
  - compromises protection of the underlying surface.
  - compromises adhesion of the finish.
  - exposes basis metal.
  - prevents proper installation of wires, cables or bundles.
- Distortion of the raceway cushion (non-metallic).
- Separation or misalignment between metallic and non-metallic parts of the raceway.
- Raceway not securely fastened to the mounting surface.

17.3.7 Grommets

17.3.7.1 Grommets – Wire/Cable/Bundle Sealing Not Required

This section applies for wire, cable, and bundles installed through grommets where sealing is not required.

Wires, cables, and bundles **shall [D1D2D3]** be positioned within grommets as specified on the engineering documentation. Grommets **shall [D1D2D3]** be installed with the proper orientation as specified on the engineering documentation. Wires and cables **shall [D1D2D3]** be secured using the engineering drawing approved method, e.g., lacing tape, tie wraps, etc., at entry and exit points of the grommet.

If an adhesive is used to install the grommet to the chassis / electronic box, the adhesive **shall [D1D2D3]** be applied and cured per 1.16.

Acceptable – Class 1,2,3

- Wires, cables and bundles are secure within the grommet.
- Wires and cables are secured at entry and exit points of the grommet.
- No damage to the grommet, e.g., deformation, splits, cuts, fractures, tears, nicks, missing material, etc.
- Grommet is securely fastened / adhered to the chassis / electronic box.
- If used, adhesive is cured.

Defect – Class 1,2,3

- Wires and cables are not secured at entry and exit points of the grommet.
- Any damage to the grommet, e.g., deformation, splits, cuts, fractures, tears, nicks, missing material, etc.
- Grommet is not securely fastened / adhered to the chassis / electronic box.
- If used, adhesive is not cured.
- If used, excessive adhesive that affects form, fit, function, or interferes with subsequent assembly steps.

17.3.7.1.1 Grommets – Wire/Cable Sealing Required

This section applies for wire and cable installed through grommets where sealing is required. Requirements in 17.3.7.1 apply.

If the wire or cable is smaller so that it does not contact the grommet, the wire / cable diameter **shall [D1D2D3]** be built-up by installing heat shrink tubing or other engineering drawing approved material, as required, to ensure sealing, i.e., full contact, with the grommet.

Acceptable – Class 1,2,3

- Wires and cables are sealed, with full contact between the wire / cable and grommet.
- If installed, heat shrink tubing or other engineering drawing approved material does not compromise the environmental seal.
- The wire or cable insulation adheres to the sealing feature of the grommet.

Defect – Class 1,2,3

- Wires and cables are not sealed, with less than full contact between the wire / cable and grommet.
- If installed, heat shrink tubing or other engineering drawing approved material compromises the environmental seal.
- The wire or cable insulation does not adhere to the sealing feature of the grommet.

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18 Solderless Wrap

See MIL-STD-1130 for solderless wrap criteria.

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19 Testing

This section covers both in-process and final acceptance requirements for electrical and mechanical testing that are not covered elsewhere in this standard. It is not intended to address the various types of environmental and other testing performed to qualify a product for its intended end-use application.

Note: Testing to this standard does not guarantee or imply compliance with applicable local, state, national, or international laws, regulations or safety standards.

The following topics are addressed in this section.

19.1 Nondestructive Tests

Nondestructive tests (procedure/parameters/stimuli/fixtures) **shall [D1D2D3]** be selected and applied in a manner that does not cause damage to the unit under test.

19.2 Testing After Rework or Repair

In the event a rework or repair action takes place, any tests/inspections that were previously performed **shall [D1D2D3]** be repeated in their entirety for the portion of the product that was affected by the rework or repair.

19.3 Intended Table Usage

Tables 19-1 and 19-9 give overviews of the electrical and mechanical tests respectively that are required by default when agreement has not otherwise been made between the User and Manufacturer to specific test requirements. The ‘‘Requirement Decision’’ column in these tables identifies default test requirements that may vary by Product Class or other factors that are more specifically explained in a referenced Clause or table.

Tables 19-2 to 19-8 and Tables 19-10 to 19-15 are tables for each test where relevant parameters are identified. The default requirements are identified in either a requirements column or where these requirements vary by Product Class, in columns identified by Class. Where specific values for these parameters have been agreed upon between the User and Manufacturer that deviate from the default requirements, the ‘‘Other Defined Value’’ column is given as a means to communicate these changes, i.e., fill in the blank with the agreed upon value(s).

19.4 Electrical Test

This section discusses electrical conformance testing.

19.4.1 Electrical Test – Selection

Table 19-1 is a listing of cable/wire harness testing options that may be agreed upon between the User and Manufacturer. The tests are defined in 19.5.1 through 19.5.8 and Tables 19-2 through 19-8 are used to specify test parameters when a test is required. Appendix B is a summary of test requirements as a convenient form for passing information between User and Manufacturer and can be copied freely.

User or Manufacturer defined tests should consider the range of possible defects. For example, when testing cables with mixed wire types, i.e., thermocouple cables or coaxial cable with their center conductors and drains, twisted pairs, etc., a simple comparison against a continuity maximum resistance limit will not suffice to determine whether the cable was wired correctly. Examples of errors that can occur from this type of comparison test are swapping center conductors with drains, splitting pairs in twisted pairs, using wrong wire gauges, etc. Product Class and production processes, including inspection, need to be evaluated for possible missed defects/errors and the justification of further tests. Such tests as lower limits for continuity resistance, measurement of capacitance between wires, and/or cross talk would be appropriate.

In the absence of specific agreed test requirements between User and Manufacturer, or an agreement by the User to accept the Manufacturer's documented test requirements, the requirements of Table 19-1 **shall [D1D2D3]** apply to 100% of multiconductor assemblies including all shielded assemblies.

Table 19-1 Electrical Test Requirements

Clause	Test	Requirements	Requirement Decision
19.5.1	Continuity Test Parameters	Required (see Table 19-2)	[ ] Not Required
19.5.2	Shorts Test (low voltage isolation) Parameters	Required unless DWV or IR tests performed (see Table 19-3)	[ ] Required [ ] Not Required
19.5.3	Dielectric Withstanding Voltage (DWV) Test Parameters	Required for Class 3 and some Class 2 (see Table 19-4)	[ ] Required [ ] Not Required
19.5.4	Insulation Resistance (IR) Test Parameters	Required for Class 3 and some Class 2 (see Table 19-5)	[ ] Required [ ] Not Required
19.5.5	Voltage Standing Wave Ratio (VSWR) Test Parameters	User Specified	[ ] Required
19.5.6	Insertion Loss Test Parameters	User Specified	[ ] Required
19.5.7	Reflection Coefficient Test	User Specified	[ ] Required
19.5.8	User Defined Electrical Tests	User Specified	[ ] Required

19.5 Electrical Test Methods

19.5.1 Electrical Test Methods – Continuity

Continuity testing verifies that the point-to-point electrical connections conform to the engineering documentation. When alternate parameters are specified and included in the ‘‘Other Defined Value’’ column of Table 19-2, the continuity test **shall [D1D2D3]** verify the measurements comply with those requirements.

In the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer's documented test requirements, the requirements of Table 19-2 **shall [D1D2D3]** apply.

Table 19-2 Continuity Test Minimum Requirements

Parameter	Class 1	Class 2	Class 3	Other Defined Value
Max Resistance	Tester Default		2 Ω or 1 Ω plus the maximum specified resistance of wire whichever is greater	____ Ω
Max Current	Tester Default			____ mA
Max Voltage	Tester Default			____ V

19.5.2 Electrical Test Methods – Shorts

Testing for shorts is a low voltage test used to detect unintended connections.

When alternate parameters are specified and included in the ''Other Defined Value'' column of Table 19-3, the shorts test **shall [D1D2D3]** verify that the measurements comply with those requirements. In the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer's documented test requirements, the requirements of Table 19-3 **shall [D1D2D3]** apply.

On points to be tested, harnesses **shall [N1D2D3]** be tested for isolation from all continuity paths as defined in continuity tests. Conductive connector shells and unused contact positions **shall [N1D2D3]** be included where a risk of a short exists.

Table 19-3 Shorts Test (low voltage isolation) Minimum Requirements[1]

Parameter	Class 1[1]	Class 2[1] with clearance/ creepage distances (air gaps) ≥2 mm [0.079 in]	Class 2[2] with clearance/ creepage distances (air gaps) <2 mm [0.079 in]	Class 3[1]	Other Defined Value
Min Resistance	Tester Default		NA	NA	____ Ω
Max Current	Tester Default				____ mA
Max Voltage[2]	Tester Default				____ V

Note 1: Shorts Test (low voltage isolation) is not required when Dielectric Withstanding Test or Insulation Resistance Test has been performed.
Note 2: A maximum voltage and or current should be specified when components within an assembly may be damaged by these tests.

19.5.3 Electrical Test Methods – Dielectric Withstanding Voltage (DWV)

The dielectric withstanding voltage test is a high voltage test, either AC or DC, which is used to validate that the components can operate safely at rated voltage and withstand momentary spikes in voltage due to switching, surges and other similar phenomena. It assures that insulating materials and spacing in the component part are adequate. When a component part is faulty in these respects, application of the test voltage will result in either disruptive discharge (arc-over) or deterioration (dielectric breakdown). The assembly fails when the measured current exceeds the specified value or the test equipment detects an electrical discharge.

Use of AC is usually chosen over DC tests when an assembly is used in applications requiring operating voltages over 90 V AC or where performance under AC stresses is a concern. AC test frequency is 60 Hz unless otherwise specified. When a total leakage current above 2 mA is expected, the test limits should be defined in terms of real current.

On points to be tested, harnesses **shall [N1D2D3]** be tested for DWV for all isolated continuity paths as defined in continuity tests. Conductive connector shells and unused contact positions **shall [N1D2D3]** be included where a risk of a short exists.

When alternate parameters are specified and included in the ‘‘Other Defined Value’’ column of Table 19-4, the DWV test **shall [D1D2D3]** verify the measurements comply with those requirements. If a current and/or dwell time is specified and included in the ‘‘Other Defined Value″ column of Table 19-4, the test setup **shall [D1D2D3]** be verified to meet those parameters. In the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer’s documented test requirements, the requirements of Table 19-4 **shall [N1D2D3]** apply.

Table 19-4 Dielectric Withstanding Voltage Test (DWV) Minimum Requirements

Parameter	Class 1	Class 2 with clearance distances (air gaps or creepage) ≥2 mm [0.079 in] and not coaxial/biaxial/triaxial assemblies	Class 2 with clearance distances (air gaps or creepage) <2 mm [0.079 in] or coaxial/biaxial/triaxial assemblies	Class 3	Other Defined Value
Voltage Level[1]	Test Not Required	Test Not Required	1000 V DC or equivalent peak AC voltage[2]	1500 V DC or equivalent peak AC voltage[2]	____ V DC or ____ V AC
Max Leakage Current			1 mA	1 mA	____ mA
Dwell time			100 ms	1 s	____ s

Note 1: See 19.1.
Note 2: Voltage Level is applicable when clearance distance tested is ≥0.58 mm [0.023 in]. When clearance distances are <0.58 mm [0.023 in] an agreement between the User and Manufacturer to de-rate these test levels would be expected.

19.5.4 Electrical Test Methods – Insulation Resistance (IR)

The insulation resistance test is a high voltage test used to verify the resistance offered by the insulating materials. Failure occurs when the measured resistance value is lower than the specified value or the test equipment detects an electrical discharge.

For the IR test, the duration of the test may be reduced to the time required for steady state current to be established. If a DC test potential is used for the dielectric withstanding voltage test, the insulation resistance required by 19.5.4 may be measured simultaneously.

If both DWV and IR tests are performed independently, the IR test **shall [D1D2D3]** be conducted after the DWV.

On points to be tested, harnesses **shall [N1D2D3]** be tested for IR for all isolated continuity paths as defined in continuity tests. Conductive connector shells and unused contact positions **shall [N1D2D3]** be included where a risk of a short exists.

When alternate parameters are specified and included in the ''Other Defined Value'' column of Table 19-5, the IR test **shall [D1D2D3]** verify that the measurements comply with those requirements. In the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer's documented test requirements, Table 19-5 **shall [N1D2D3]** apply.

Table 19-5 Insulation Resistance (IR) Test Minimum Requirements

<table>
<tr><th>Parameter</th><th>Class 1</th><th>Class 2 with clearance distances (air gaps or creepage) ≥2 mm [0.079 in]</th><th>Class 2 with clearance distances (air gaps or creepage) <2 mm [0.079 in]</th><th>Class 3</th><th>Other Defined Value</th></tr>
<tr><td>Voltage Level[1]</td><td rowspan="3">Test Not Required</td><td rowspan="3">Test Not Required</td><td colspan="2">DC DWV V or tester default</td><td>____ V DC</td></tr>
<tr><td>Minimum Insulation Resistance[2]</td><td colspan="2">≥100 MΩ for assemblies ≤ 3 m [118 in]
≥10 MΩ for assemblies > 3 m [118 in]
≥500 MΩ for coaxial cable of any length</td><td>____ MΩ</td></tr>
<tr><td>Max Dwell Time</td><td colspan="2">10 s</td><td>____ s</td></tr>
</table>

Note 1: See 19.1.

Note 2: IR levels specified applicable at less than 80% relative humidity. When relative humidity exceeds 80% an agreement between User and Manufacturer to de-rate these tests levels would be expected.

19.5.5 Electrical Test Methods – Voltage Standing Wave Ratio (VSWR)

VSWR is one method used to evaluate reflective energy in high frequency coax cables. The result is a ratio of the reflected power to the input power. This test is not required unless specified by the User. If VSWR testing is specified, the tests **shall [D1D2D3]** be performed to parameter values of Table 19-6, as agreed between User and Manufacturer.

Table 19-6 Voltage Standing Wave Ratio (VSWR) Test Parameters

Parameter	Defined Value
Frequency Range	____ MHz
Ratio of input power to reflected power	____ : ____

19.5.6 Electrical Test Methods – Insertion Loss

A measurement of signal loss across a high frequency coax cable at specified frequencies or over a frequency range. This test is not required unless specified by the User. If insertion loss testing is specified, the tests **shall [D1D2D3]** be performed to parameter values of Table 19-7, as agreed between User and Manufacturer.

Table 19-7 Insertion Loss Test Parameters

Parameter	Defined Value
Frequency Range	____ MHz
Max Loss	____ dB

19.5.7 Electrical Test Methods – Reflection Coefficient

Reflection coefficient is one straightforward method used to evaluate reflective energy in high frequency coax cables. The result is the ratio of the reflected wave to the incident wave. This test is not required unless specified by the User. If reflection coefficient testing is specified, the tests **shall [D1D2D3]** be performed to parameter values of Table 19-8, as agreed between User and Manufacturer.

Table 19-8 Reflection Coefficient Test Parameters

Parameter	Defined Value
Frequency Range	____ MHz
Max Loss	____ dB

19.5.8 Electrical Test Methods – User Defined

The User may require additional electrical testing, or otherwise modify the testing parameters and/or methods specified herein. If such additional testing is required, then these tests **shall [D1D2D3]** be performed.

19.6 Mechanical Test

This section discusses mechanical conformance testing.

19.6.1 Mechanical Test – Selection

In the absence of specific agreed test requirements between User and Manufacturer, or an agreement by the User to accept the Manufacturer's documented test requirements, the requirements of Table 19-9 **shall [D1D2D3]** apply to 100% of assemblies.

If the Manufacturer has a documented process control program in place (see 1.6), supported by objective evidence, for maintaining crimp tooling and validating crimped connections, that program may be used in lieu of 19.7.1 and/or 19.7.2.1, as applicable. However, crimp tools **shall not [N1D2D3]** be used for longer than 30 days between verification testing except when based on historical data. If the frequency of crimp tool verification exceeds 30 days, the frequency **shall [N1D2D3]** be determined on the basis of historical data and the data **shall [N1D2D3]** be available for review. For Class 3, if the frequency of crimp tool verification exceeds 30 days, the frequency **shall [N1N2D3]** be agreed between the User and Manufacturer.

Table 19-9 Mechanical Test Requirements

Clause	Test	Requirement[1]	Requirement Decision
19.7.1	Crimp Height Testing	Required for Class 1 and 2 if Pull Force Testing not Performed (see 19.7.2) (Table 19-10)	[ ] Required for each new setup and again every: [ ] ____ parts [ ] shift(s), [ ] ____ workday(s) [ ] Not Required
19.7.2	Pull Force/Tensile Testing	Required for Class 3 Required for Class 1 and 2 if Crimp Height Testing not Performed (see 19.7.1) (Table 19-11)	[ ] Required for each new setup and again every: [ ] ____ parts [ ] shift(s), [ ] ____ workday(s) [ ] Not Required
19.7.3	Crimp Force Monitoring	User Specified	[ ] Required
19.7.5	Contact Retention	In-Process requirement for Classes 1, 2, and 3	[ ] Not Required
19.7.6	RF Connector Shield Pull Test	User Specified	[ ] Required
19.7.7	RF Connector Shield Ferrule Torsion Test	User Specified	[ ] Required
19.7.8	User Defined Mechanical Tests	User Specified	[ ] Required

Note 1: In the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer's documented test requirements, Table 19-9 defines minimum test requirements for each Product Class.

19.7 Mechanical Test Methods

19.7.1 Mechanical Test Methods – Crimp Height (Dimensional Analysis)

Crimp height testing verifies that the terminal crimp height is within the terminal supplier's specifications. Each crimp terminal and conductor combination will have unique crimp height criteria. This is an optional test for all Product Classes if pull force testing is implemented. Where pull force testing is not implemented, in the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer's documented test requirements, crimp height testing **shall [D1D2N3]** be performed to the parameters specified in Table 19-10.

Table 19-10 Crimp Height Testing

Parameter	Requirement	Other Defined Value
Max Flash Height	Use the terminal supplier's specification[1]	____ mm [____ in]
True Crimp Height	Use the terminal supplier's specification[1]	____ mm [____ in]
Width (noncircular crimp, i.e., lugs)		____ mm [____ in]

Note 1: If the User or Manufacturer has objective evidence indicating that the terminal supplier's specification is not sufficient, other values may be agreed upon between User and Manufacturer.

It is critical to ensure that crimp height measurements are taken correctly. Crimp height measurement tools have a flat blade on one side and a pointed contact on the other. The purpose of the pointed contact is to avoid the flash that may form on some terminals during the crimping process. Excessive flash may be a sign that the crimp anvils are worn (see Figure 19-1).

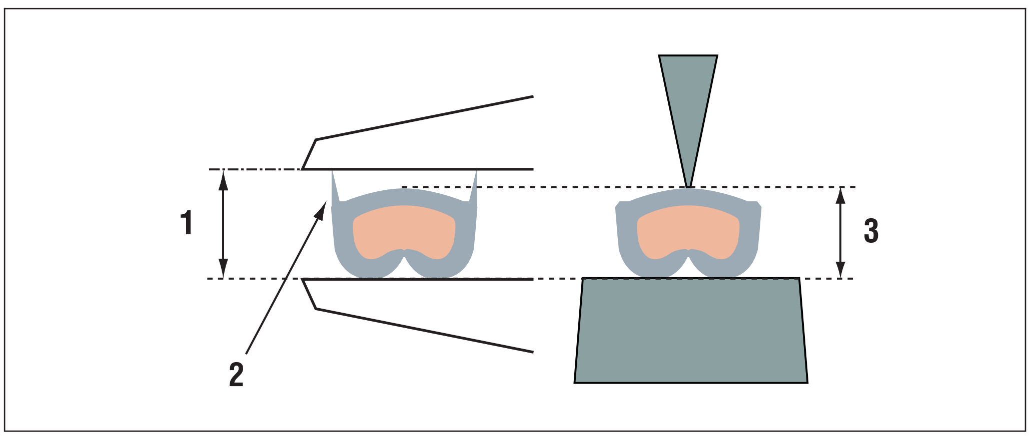

Figure 19-1
1. **Incorrect height measurement (using calipers)**
2. **Flash**
3. **Correct (true) height measurement (using crimp height micrometer)**

19.7.1.1 Mechanical Test Methods – Crimp Height (Dimensional Analysis) – Terminal Positioning

As shown in Figure 19-2, the terminal is positioned so that the rolled side of the crimp is perpendicular to and lays flat on the micrometer anvil blade edge. If the terminal is angled the measurement may be incorrect.

The upper point contact (micrometer pin/spindle) is positioned in the center of the crimped area to measure the tallest part of the crimp. If the upper contact is not in the center of the crimp, then the crimp height measurement may be wrong.

The terminal is at a right angle to the anvil (in the horizontal plane).

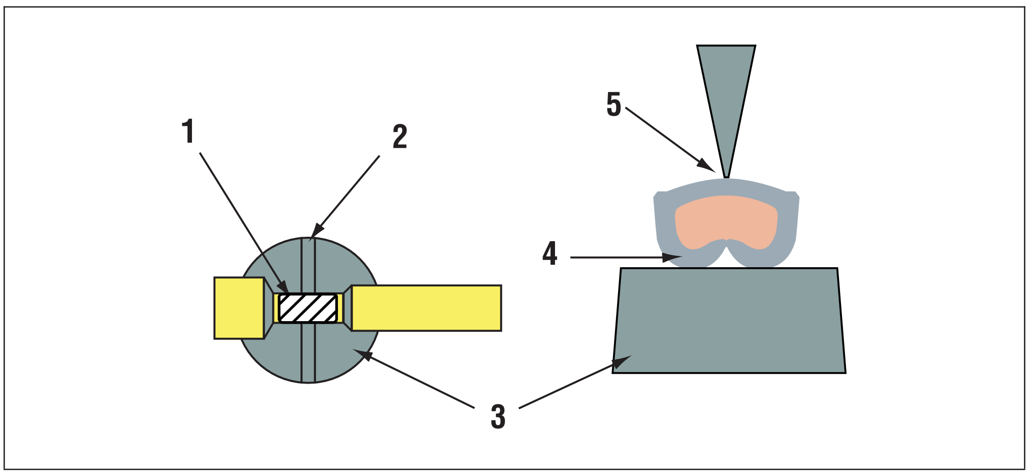

Figure 19-2

1. **Crimp area**
2. **Micrometer anvil blade edge**
3. **Micrometer anvil**
4. **Rolled side of crimp laying flat on micrometer anvil**
5. **Micrometer spindle positioned in the center of the crimp area**

19.7.2 Mechanical Test Methods – Pull Force (Tensile)

Axial (longitudinal) force is applied to evaluate the mechanical integrity of the crimped connection. If the contact has a wire insulation support it **shall [D1D2D3]** be rendered mechanically ineffective by either manually opening the insulation crimp or by making an extra-long strip so that the uninsulated wire extends past the insulation crimp.

For Class 3 and when crimp height testing has not been performed for Classes 1 and 2, in the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer's documented test requirements, pull force testing **shall [D1D2D3]** be performed using the parameters of Table 19-11. Where specific values for pull force have not been agreed upon between the User and Manufacturer, the values used **shall [D1D2D3]** equal or exceed the values of Table 19-12, 19-13, or 19-14, as appropriate.

For multiple wires crimped in the same terminal, pull tests **shall [D1D2D3]** be performed on the smallest wire in the crimp.

Samples used for pull testing **shall not [D1D2D3]** be used for deliverable product. Some examples of destructive pull force test methods are:

- Pull and Break – Increasing axial force is applied to the connection until either the terminal and wire separate or the wire breaks.
- Pull and Return – The terminal is pulled to a specified force. Once the specified force is achieved the force is removed.
- Pull and Hold – The terminal is pulled to a specified force and held for a specified period of time then the force is decreased to zero.
- Pull, Hold and Break – The terminal is pulled to a specified force and held for a specified period of time then the terminal is pulled until either the terminal is separated from the wire or the wire breaks.

19.7.2.1 Mechanical Test Methods – Pull Force – Without Documented Process Control

In the absence of a documented process control program (see 19.6.1):

- When using hand crimp tools and a testing interval is not defined in the contract, the testing interval **shall [D1D2D3]** be once per day for each combination of tool, wire and contact.
- When using machine crimping and the testing interval is not defined in the contract, the testing interval **shall [D1D2D3]** be at least once per applicator set up and monthly. Monthly testing is not required when the machine is not in use but **shall [D1D2D3]** be performed when placed back in service.

Table 19-11 Pull Force Testing Minimum Requirements

Parameter	Class 1	Class 2	Class 3	Other Defined Value
Pull Force	Appropriate Industry Standard (UL, IEC, SAE, Table 19-12, 19-13 or 19-14)[1]		Table 19-12	____ N ____ Kp ____ pounds
Pull-Rate[2]	Not Specified	Controlled Rate	≤1 inch/minute	____ /minute
Method	Not Specified	Not Specified	Not Specified	[ ] Pull & Break [ ] Pull & Return [ ] Pull & Hold [ ] Pull, Hold & Break
Hold Time[3]	Not Specified	Not Specified	Not Specified	____ Seconds

Note 1: It is the responsibility of the Manufacturer and/or the User to determine which set of tensile test values is appropriate.
Note 2: Controlled rate indicates a specified pull rate that is held constant throughout the pull.
Note 3: The Hold Time parameter is relevant only if the ''Pull & Hold'' or ''Pull, Hold & Break'' method is used.

Tables 19-12, 19-13 and 19-14 provide pull-force acceptance values for crimps on plated or unplated stranded copper wire. Where the Pull Force values are not established (NE), the tensile strength of the crimp connection **shall [D1D2D3]** be no less than 60% of the tensile strength of the wire.

19.7.2.1 Mechanical Test Methods – Pull Force – Without Documented Process Control (cont.)

Table 19-12 Pull Test Force Values

Conductor Size		Machined Contacts				Crimp Splices[1]		Stamped and Formed Contacts and Terminals[1]	
		Silver/Tin Plated Wire		Nickel Plated Wire					
AWG	(mm^2)	Pounds	(N)	Pounds	(N)	Pounds	(N)	Pounds	(N)
30	0.050	1.5	6.7	1.5	6.7	1.5	6.7	1.5[2]	6.7[2]
28	0.080	3	13.4	2	8.9	2	8.9	2[2]	8.9[2]
26	0.130	5	22.3	3	13.4	3	13.4	7	31.2
24	0.200	8	35.6	6	26.7	5	22.3	10	44.5
22	0.324	12	53.4	8	35.6	8	35.6	15	66.8
20	0.519	20	89.0	19	84.6	13	57.9	19	84.6
18	0.823	32	142	NE	NE	20	89.0	38	169.1
16	1.310	50	222.3	37	164.6	30	133.5	50	222.5
14	2.080	70	311.5	60	266.9	50	222.5	70	311.5
12	3.310	110	489.5	100	445.0	70	311.5	110	489.5
10	5.261	150	667.5	135	600.5	80	356.0	150	667.5
8	8.367	220	978.6	200	890.0	90	400.5	225	1001.3
6	13.300	300	1235.0	270	1201.0	100	445.0	300	1335.0
4	21.150	400	1780.0	360	1601.4	140	623.0	400	1780.0
3	26.670	NE	NE	NE	NE	160	712.0	NE	NE
2	33.620	550	2447.5	495	2201.9	180	801.0	550	2447.5
1	42.410	650	2892.5	585	2602.2	200	890.0	650	2892.5
1/0	53.490	700	3115.0	630	2757.9	250	1112.5	700	3115.0
2/0	67.430	750	3337.5	675	3002.5	300	1235.0	750	3337.5
3/0	85.010	NE	NE	NE	NE	350	1557.5	825	3671.3
4/0	107.200	875	3893.0	785	3491.9	450	2202.5	875	3893.8
250	127	NE	NE	NE	NE	500	2225.0	NE	NE
300	156	NE	NE	NE	NE	550	2447.5	NE	NE
350	177	NE	NE	NE	NE	600	2670.0	NE	NE
400	203	NE	NE	NE	NE	650	2892.5	NE	NE
500	253	NE	NE	NE	NE	800	3560.0	NE	NE
600	304	NE	NE	NE	NE	900	4005.0	NE	NE
700-2000	355 - 1016	NE	NE	NE	NE	1000	4450.0	NE	NE

Note 1: Plated or unplated copper stranded wire
Note 2: Value per UL 486A specification and established only for Class 1 assemblies

19.7.2.1 Mechanical Test Methods – Pull Force – Without Documented Process Control (cont.)

Table 19-13 Pull Test Force Values (Classes 1 & 2) For UL, SAE, GM and Volvo

Size of Conductor		UL 486A Table 12.1		SAE AS7928 Table II		Conductor	GMI 12590 GM (Europe)	STD 7611,151 Volvo (Europe)[1]
AWG	(mm^2)	Pounds	(N)	Pounds	(N)	(mm^2)	(N)	(N)
30	0.050	1 - 1.5	6.7	N/A	N/A			
28	0.080	2	8.9	N/A	N/A			
26	0.130	3	13.4	7	31.2			
24	0.200	5	22.3	10	44.5	0.22	40	40
22	0.324	8	35.6	15	66.8	0.35	50	50
20	0.519	13	57.9	19	84.6	0.50	70	70
18	0.823	20	89.0	38	169.1	0.75	90	90
16	1.310	30	133.5	50	222.5	1.00	115	115
14	2.080	50	222.5	70	311.5	1.50	155	155
12	3.310	70	311.5	110	489.5	2.00	195	195
10	5.261	80	356.0	150	667.5	2.50	235	235
8	8.367	90	400.5	225	1001.3	3.00	260	260
6	13.300	100	445.0	300	1335.0	4.00	320	320
4	21.150	140	623.0	400	1780.0	5.00	360	360
3	26.670	160	712.0	N/A	N/A	6.00	400	400
2	33.620	180	801.0	550	2447.5	10.00	600	600
1	42.410	200	890.0	650	2892.5	16.00	N/A	1400
1/0	53.490	250	1112.5	700	3115.0	25.00	N/A	1900
2/0	67.430	300	1235.0	750	3337.5	35.00	N/A	2275
3/0	85.010	350	1557.5	825	3671.3	50.00	N/A	2800
4/0	107.200	450	2202.5	875	3893.8	70.00	N/A	3500
250	127	500	2225.0	N/A	N/A	95.00	N/A	4180
300	156	550	2447.5	N/A	N/A			
350	177	600	2670.0	N/A	N/A			
400	203	650	2892.5	N/A	N/A			
500	253	800	3560.0	N/A	N/A			
600	304	900	4005.0	N/A	N/A			
700-2000	355 - 1016	1000	4450.0	N/A	N/A			

Note 1: Volvo specification for 16 mm^2 – 95 mm^2 are for ''Sheet'' type terminals.

19.7.2.1 Mechanical Test Methods – Pull Force – Without Documented Process Control (cont.)

Table 19-14 Pull Test Force Values (Classes 1 & 2) For IEC

Size of Conductor		IEC 60352-2
mm^2	(AWG)	N
0.05	30	6
0.08	28	11
0.12	26	15
0.14		18
0.22	24	28
0.25		32
0.32	22	40
0.5	20	60
0.75		85
0.82	18	90
1.0		108
1.3	16	135
1.5		150
2.1	14	200
2.5		230
3.3	12	275
4.0		310
5.3	10	355
6.0		360
8.4	8	370
10.0		380

19.7.3 Mechanical Test Methods – Crimp Force Monitoring

Crimp force monitoring is a method to electronically monitor the crimping process by comparing crimp force signatures to a known reference. This test is not required in any Product Class unless specified by the User.

The Crimp Force monitor is typically part of the automated crimping equipment that learns the reference signature by analyzing acceptable crimps and creates a time/force curve signature. Each subsequent crimp is compared to the reference signature to detect potential defects. When crimp force monitoring is included as an integral part of the crimping equipment, either crimp height or pull force testing **shall [D1D2D3]** be used to verify an acceptable crimp before referencing the crimp force monitor.

19.7.4 Mechanical Test Methods – Crimp Tool Qualification

See 1.15.1.

19.7.5 Mechanical Test Methods – Contact Retention Verification

See 9.5.

This in-process verification is required for Classes 1, 2 and 3.

If test requirements are not otherwise established, the ''push-click-pull'' method of pushing a contact into the insert until the retaining mechanism clicks and then pulling on the attached lead until it is taut **shall [D1D2D3]** be used. While ''taut'' is a subjective measure, the force is expected to be well above the force required to insert the contact (pull harder than you pushed for contact insertion).

Connectors which use potting or molding as the only contact retention mechanism are exempt from this requirement.

19.7.6 Mechanical Test Methods – RF Connector Shield Pull Force (Tensile)

Axial force is applied to evaluate the mechanical integrity of the shield connection.

The following pull force test methods are destructive and the material is not suitable for use after testing:

- Pull and Break – Increasing axial force is applied to the connection until either the connector and shield separate or the shield breaks.
- Pull and Return – A specified force is applied to the connection. Once the specified force is achieved, the force is removed.
- Pull and Hold – A specified force is applied to the connection and held for a specified period of time, then the force is decreased to zero.
- Pull, Hold and Break – The connection is pulled to a specified force and held for a specified period of time, then the connection is pulled until either the terminal or contact is separated from the wire or the wire breaks.

If RF Connector Shield Pull Force Testing is specified, the tests **shall [D1D2D3]** be performed to parameter values of Table 19-15, as agreed between User and Manufacturer.

Table 19-15 RF Connector Shield Pull Force Testing

Parameter	Defined Value
Pull Force	____ N ____ Kp ____ pounds
Pull-Rate[1]	____ /min
Method	[ ] Pull & Break [ ] Pull & Return [ ] Pull & Hold [ ] Pull, Hold & Break
Hold Time[2]	____ s

Note 1: Controlled rate indicates a specified pull rate that is held constant throughout the pull.
Note 2: The Hold Time parameter is relevant only if the ''Pull & Hold'' or ''Pull, Hold & Break'' method is used.

19.7.7 Mechanical Test Methods – RF Connector Shield Ferrule Torsion

Hold the connector body or ferrule in a fixed position and grip the cable at 50 mm [2 in] or 10 cable diameters (whichever is greater) from the end of the connector termination and rotate (twist) the cable 45° maximum in one direction only. The point where the cable is gripped is where the angle of twist to the body is determined. The cable **shall [D1D2D3]** twist but not rotate at the connector.

19.7.8 Mechanical Test Methods – User Defined

The User may require additional mechanical testing or otherwise modify the testing parameters and/or methods specified herein. If such additional testing is required, these tests **shall [D1D2D3]** be performed. A table is available in Appendix B for conveying this information.

20 High Voltage Applications

This section provides the unique criteria for soldered connections that are subject to high voltages. The term ‘‘high voltage’’ will vary by design and application. The high voltage criteria in this document are only applicable when specifically required by the engineering drawing or procurement documentation. Convex solder fillets may obscure wetting criteria. These criteria are applicable to wires or leads attached to terminals, bare terminals, and through-hole connections. The requirements are to assure that there are no sharp edges or sharp points to help mitigate arcing (corona discharge). Additional mitigation, e.g., wire insulation, encapsulation, may be required. For high voltage strand damage, see Table 3-1.

20 High Voltage Applications (cont.)

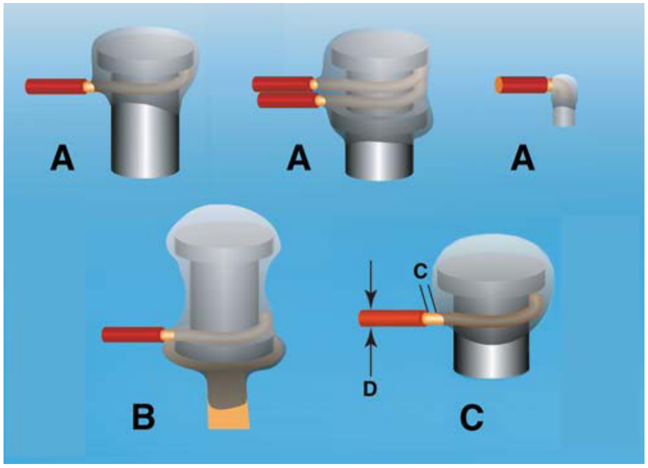

Figure 20-1

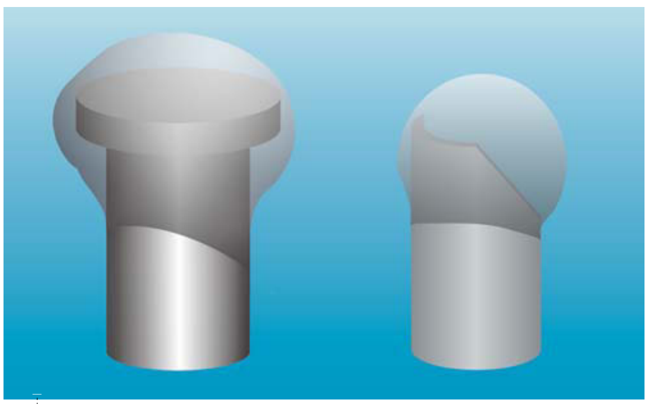

Figure 20-2

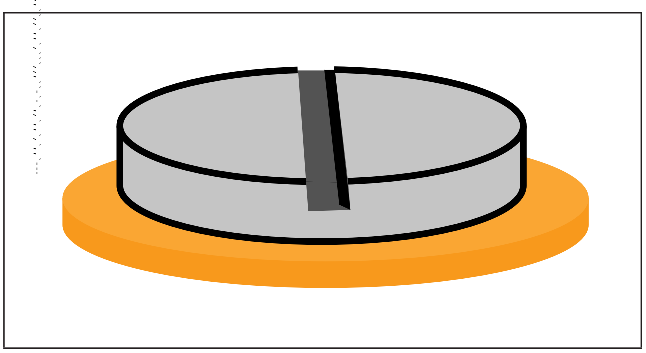

Figure 20-3

Acceptable – Class 1,2,3

- Solder connection has an egg-shaped, spherical or oval profile that follows the contour of terminal and wire wrap.
- All sharp edges of the component lead and terminals are completely covered with a continuous smooth rounded layer of solder forming a solder ball (see Figures 20-1-A, 2).
- Solder connections may have evidence of some layering or reflow lines (disturbed solder).
- No evidence of sharp edges, solder points, icicles, inclusions (foreign material) or wire strands.
- Wire/lead outline is discernible with a smooth flow of solder on wire/lead and terminal. Individual strands may be discernible (see Figure 20-1-B).
- All sharp edges of the terminal's radial split are completely covered with a continuous smooth layer of solder forming a balled solder connection.
- There is no evidence of burrs or frayed edges on the hardware (see Figure 20-3).
- Insulation clearance (C) is less than one overall diameter (D) away from the solder connection (see Figure 20-1-C).
- No evidence of insulation damage (ragged, charred, melted edges or indentations).
- Balled solder connection does not exceed specified height requirements.

20 High Voltage Applications (cont.)

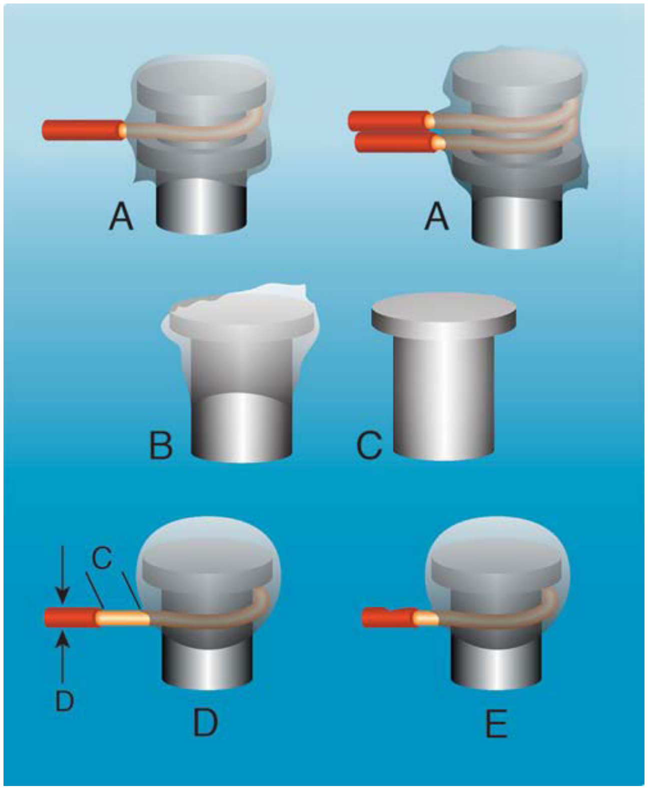

Figure 20-4

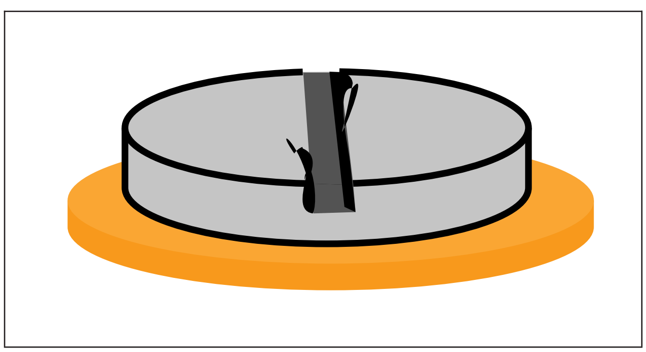

Figure 20-5

Defect – Class 1,2,3

- Discernible sharp edges, solder points, icicles, or inclusions (foreign material) (see Figure 20-4-A).
- Evidence of edges not smooth and round with nicks or crevices.
- Solder follows contour of terminal and wire wrap but there is evidence of the sharp edge of the terminal protruding (see Figure 20-4-B).
- Evidence of wire strands not completely covered or discernible in the solder connection.
- Terminal lug is void of solder (see Figure 20-4-C).
- Hardware has burrs or frayed edges (see Figure 20-5).
- Insulation clearance (C) is greater than or equal to one overall diameter (D) or more (see Figure 20-4-D).
- Evidence of insulation damage (ragged, charred, melted edges or indentations (see Figure 20-4-E).
- Balled solder connection does not comply with height or profile (shape) requirements.

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Appendix A Terms and Definitions

Definitions marked with an * are from IPC-T-50. Additional terms and definitions applicable to cables and wire harnesses may be found in **SAE ARP 914A, SAE ARP 1931A** and **ISO 8815**.

American Wire Gage (AWG) A standard system for designating wire diameter. Primarily used in the United States.

Annealed Wire Wire which, after final drawdown, has been heated and slowly cooled to remove the effects of cold working.

Applicator A mechanism used in a crimping press with strip-form terminals including a feeding mechanism and tooling specific to the terminal. The mechanism will simultaneously feed the strip of terminals and crimp one or more terminals onto the end of one or more wires.

Armored Cable A cable provided with a wrapping of metal, usually steel wires or tapes, primarily for the purpose of mechanical protection.

AWG Equivalent The American Wire Gauge (AWG) round-conductor number that is used to designate a flat conductor with an equal cross-sectional area.

Bellmouth The raised portion at the front and/or back of the wire barrel crimp that provides a gradual entrance and exit for the wire strands without causing damage.

Binder A spirally served tape or thread used for holding assembled cable components in place awaiting subsequent manufacturing operations. (The IPC-T-50 ‘‘binder’’ definition is not applicable to this document.)

Birdcaging Wire strands that have separation from the normal lay of the wire.

Blow Through Any location where the mold material migrates through the connector insert or contacts.

Boot A form placed around wire termination of a connector to contain the liquid potting compound before it hardens. Also, a protective housing usually made from a resilient material to prevent entry of moisture into a connector. Can also be preformed, heat shrinkable and can be purchased with self-adhesive or bonded with an adhesive.

Braid Woven bare metallic or tinned copper wire used as shielding for wires and cables and as ground wire for batteries or heavy industrial equipment. Also, a woven fibrous protective outer covering over a conductor or cable.

Braid Carrier A spool or bobbin on a braider which holds one group of strands or filaments consisting of a specific number of ends. The carrier revolves during braiding operations.

Braid Ends The number of strands used to make up one carrier. The strands are wound side by side on the carrier bobbin and lie parallel in the finished braid.

Braid Fold Back That portion of the braid that is folded back to allow a solder connection between the braid and the foil.

Breakdown Voltage The voltage at which the insulation between two conductors ruptures.

Breakout The point at which a conductor or group of conductors is separated from a multiconductor cable or wiring harness to complete circuits at other points.

Bubbles Spherical voids on the surface of a molded component.

BusBar Wire Uninsulated tinned copper wire used as a common lead.

Butt Splice Device for joining conductors by butting them end to end.

Appendix A Terms and Definitions (cont.)

Cable	A group of individually insulated conductors in twisted or parallel configuration under a common sheath.
Cable, Assembly	A cable with plugs or connectors attached.
Cable, Camber	The planar deflection of a flat cable or flexible laminate from a straight line.
Cable, Clamp	A device used to give mechanical support to the wire bundle or cable at the rear of a plug or receptacle.
Cable, Coaxial	(1) A cable consisting of two cylindrical conductors with a common axis separated by a dielectric. (2) *A cable in the form of a central wire surrounded by a conductor tubing or sheathing that serves as a shield and return.
Cable, Flat	(1) Any cable with two smooth or corrugated but essentially flat surfaces. (2) Two or more parallel, round or flat, conductors that are contained in the same plane of a flat insulating basis material.
Cable, Flat Conductor	A planar construction with two or more flat conductors.
Cable, Flat, Margin	*The distance between the reference edge of a flat cable and the nearest edge of the first conductor.
Cable, Reference Edge	The edge of a cable or conductor from which measurements are made.
Cable, Ribbon	(1) A flat cable of individually insulated conductors lying parallel and held together by means of adhesive film laminate. (2) *A flat cable with round conductors.
Cable, Transmission	*Two or more transmission lines in the form of an interconnection-wiring cable.
Cable/Harness, Indoor Use	(Also Harness) Product intended and designed for indoor use only.
Cable/Harness, Outdoor Use	(Also Harness) Outdoor Use Cables/Harnesses: Product expected to withstand exposure to the elements of weather.
Camber	The planar deflection of a flat cable or flexible laminate from a straight line.
Char/Charred	Result of excess heat causing a charcoal/carbon residue.
Circular Mil	The area of a circle one mil [0.001 in] in diameter; 7.845 x 10-7 sq. in. Used in expressing wire cross sectional area.
Circular Mil Area	Cross-sectional area of a current carrying portion of a conductor expressed in circular mils.
Circumferential Crimp	Final configuration of a terminal barrel made when crimping dies completely surround the barrel and form symmetrical indentations.
Closing	An operation where all leads are to be covered and the jacket insulation is captured by a type of hood or cover.
CMA	See Circular Mil Area
Cold Flow	Deformation of the insulation as a result of mechanical force or pressure (not due to heat softening).
Compression Connector	Connector crimped by an externally applied force; the conductor is also crimped by such force inside the tube-like connector body. Compression connectors are in very intimate contact with the two ends of the conductors being spliced.
Concentricity	In a wire or cable, concentricity is the measurement of the location of the center of the conductor with respect to the geometric center of the surrounding insulation.

Appendix A Terms and Definitions (cont.)

Conductor	An uninsulated wire or the conductor of an insulated wire suitable for carrying electrical current.
Conductor, Flat	A rectangular conductor that is wider than it is high.
Conduit	A tube in which insulated wires and cables are passed.
Connector	(1) A device used to physically and electrically join two or more conductors. (2) A device used to provide mechanical connect/disconnect service for electrical terminations.
Connector Insert	Usually the plastic piece inside the vendor supplied connector that holds electrical contacts in a specific field pattern.
Connector/Mold Interface	The location where the connector is in contact with the mold.
Contact	The conducting part of a connector that acts with another such part to complete or break a circuit.
Contact Angle (Bonding)	*The angle between the bonding lead or wire and the bonding land.
Contact Angle (Soldering)	The angle of a solder fillet that is enclosed between a plane that is tangent to the solder/basis-metal surface and a plane that is tangent to the solder/air interface.
Contact Area	The common area between a conductor and a connector through which the flow of electricity takes place.
Contact Length	The distance of travel made by a contact in touch with another during the insertion and removal of a connector.
Contact Resistance	The electrical resistance of metallic surfaces, under specified conditions, at their interface in the contact area.
Contact Retention	The maximum axial load in either direction that a contact must withstand while remaining firmly fixed in its normal position within the connector insert or housing.
Contact Retention Force	The minimum axial load in either direction that a contact withstands while it is in its normal position in a connector insert.
Contact Size	Defines the largest size wire that can be used with the specific contact. By specification dimensioning, it also defines the diameter of the engagement end of the pin.
Continuity	(1) A continuous path for the flow of current in an electrical circuit. (2) *An uninterrupted path for the flow of electrical current in a circuit.
Core	In cables, a component or assembly of components over which additional components (shield, sheath, etc.) are applied.
Corona	A discharge due to ionization of air around a conductor due to a potential gradient exceeding a certain critical value.
Coupling Ring	A device used on cylindrical connectors to lock a plug and receptacle together.
Crack, Molding	A location where the molded material has visible separation.
Creep	(1) The dimensional change with time of a material under load. (2) Time-dependent strain occurring under stress.
Crimp	Final configuration of a terminal or contact barrel formed by the compression of terminal barrel and wire.
Crimp Height	A measurement taken of the overall wire barrel height after the terminal or contact has been crimped.

Appendix A Terms and Definitions (cont.)

Current

AC DWV Total Current

Total Current is the combination of resistive and capacitive currents. Resistive current is present in both AC and DC DWV tests. The capacitive current is present only with fluctuations in applied voltage, i.e., AC testing.

The capacitive current is proportional to capacitance between wires, which is mostly a function of proximity and length of parallel wire paths.

AC DWV Real Current

Real current is the industry term for resistive currents derived by test equipment by removing the capacitive current from the total current measured.

Cut Off Tab

The small tabs that remain on the front and back of a terminal after it has been applied.

Daisy Chain

Connections in series that render all of the connections common.

Dielectric

(1) Any insulating medium that intervenes between two conductors.
(2) A material with a high resistance to the flow of direct current, and which is capable of being polarized by an electrical field.

Dielectric Breakdown

*The complete failure of a dielectric material that is characterized by a disruptive electrical discharge through the material that is due to deterioration of material or due to an excessive sudden increase in applied voltage.

Dielectric Strength

*The maximum voltage that a dielectric can withstand under specified conditions without resulting in a voltage breakdown, usually expressed as volts per unit dimension. Also called Disruptive Gradient of Electric Strength.

Dielectric Withstanding Voltage

Maximum potential gradient that a dielectric material can withstand without failure.

Discolor/Discoloration

Any change from the designated color of the material or component.

Discontinuity

(1) A broken connection, or the loss of a specific connection characteristic.

Dot Coding

Process of tool imprinting a 22-10 AWG PIDG terminal. Dot coding indicates whether the proper tool has been used.

Double Crimp

The process of two or more mechanical crimping operations on the same location in a single terminal.

Drain Wire

In a cable, the wire in intimate contact with a shield to provide for easier termination of such a shield.

Drip Loop

A loop or wire bend formed to direct condensation or accumulated moisture to a noncritical area, e.g., prevents accumulated moisture from following the span of a cable path into a moisture sensitive area.

Electrical Clearance

Electrical clearance spacing between conductors should be maximized whenever possible. The minimum spacing between conductors and between conductive materials (such as conductive markings or mounting hardware) and conductors should be defined on the applicable drawings or documentation. When mixed voltages appear on the same assembly, the specific areas and appropriate clearances should be identified on the drawings. Failure to adhere to these criteria can cause equipment operating problems, and in the case of high voltages or high power applications, potential severe damage/fire.

Although minimum electrical clearance distances are normally fixed by the design/drawing, e.g., minimum spacing between two terminal studs, it is possible to violate the minimum spacing by the installation method. For example, improper orientation of an uninsulated terminal lug or an excessively long wire wrap/solder connection pigtail with orientation that places the connections closer to non-electrically common conductors could violate the minimum spacing.

Appendix A Terms and Definitions (cont.)

Electrical clearance distance is defined as the shortest point-to-point distance between uninsulated energized parts or between an energized part and ground. The minimum electrical clearance distance depends on the circuit voltage rating and the normal volt-ampere rating. In cases where no minimum electrical clearance value is otherwise defined, the criteria in Table A-1 may be used as a guideline.

Table A-1 Electrical Clearance

Voltage	Set*	Clearance
Up to 64	A B C	1.6 mm [0.062 in] 3.2 mm [0.125 in] 3.2 mm [0.125 in]
Over 64-600	A B C	1.6 mm [0.062 in] 3.2 mm [0.125 in] 6.4 mm [0.25 in]
Over 600-1000	A B C	3.2 mm [0.125 in] 6.4 mm [0.25 in] 12.7 mm [0.5 in]
Over 1000-3000	C	50 mm [2 in]
Over 3000-5000	C	75 mm [3 in]

*Set A = Normal operating volt-ampere rating up to 50.
*Set B = Normal operating volt-ampere rating of 50 to 2000.
*Set C = Normal operating volt-ampere rating over 2000.

Electromagnetic Compatibility (EMC) Describes a device's ability to function properly in the service environment without causing electromagnetic interference to other equipment, or itself being susceptible to external interference.

Electromagnetic Interference (EMI)
(1) The undesirable electromagnetic emissions from a product, which can interfere with the proper operation of other devices.
(2) Unwanted radiated electromagnetic energy that couples into electrical conductors.

EMC See electromagnetic compatibility.

EMI See electromagnetic interference.

End Bell An accessory similar to a cable clamp that attaches to the back of a plug or receptacle. It serves as an adaptor for the rear of connectors.

End Cap Splice An insulated splice in which two or more wires overlap and enter the splice from the same end of the barrel.

Ferrule
(1) A short tube. Used to make solderless connections to shielded or coaxial cable.
(2) An item molded into the plastic inserts of multiple contact and fiber optic connectors to provide strong, wear-resistant shoulders on which contact retaining springs can bear.
(3) A terminal crimped onto stranded wire to allow insertion into terminal blocks.

Filler
(1) A material used in multiconductor cables to occupy voids formed by the assembled conductors.
(2) An inert substance added to plastics to improve properties or decrease cost.
(3) A substance that is added to a material to improve its solidity, bulk, or other properties.

Finished Assembly In this document, finished assembly is a harness, cable or wire(s) that may be covered or uncovered.

Flash Seepage of material along parting lines, and/or mating surfaces, i.e., thin surplus of material, which is forced between mating surfaces during molding or forming operation.

Float Any internal component that is visible at the surface of the mold material.

Flow Lines Marks that are visible on the finished item that indicate the direction of flow in the plastic.

Appendix A Terms and Definitions (cont.)

Gas-Tight
(1) The characteristic of a contact that is impervious to ingress by corrosive gases.
(2) *The common area between mated metal surfaces from which gas vapors and impurities are excluded.

Green Residue
Contamination caused by Copper Abietate, Copper (II) Chloride, Copper Fluoride, or Copper Phthalate.

Grommet
A rubber seal used on the cable side of a connector to seal the connector against moisture, dirt or air.

Harness
A group of wires and cables, usually made with breakouts, which are tied together or pulled into a rubber or plastic sheath. A harness provides interconnection of an electric circuit.

Harness, Indoor Use
(Also Cable) Product intended and designed for indoor use only.

Harness, Outdoor Use
(Also Cable) Outdoor Use Cables/Harnesses: Product expected to withstand exposure to the elements of weather.

Hipot Test
(1) A test designed to verify the integrity of a wire’s insulation when subjected to high AC or DC voltage.
(2) A method in which the unit under test is subjected to a high alternating current (AC) voltage.

Hood
A type of cover used to enclose wires that are assembled into a connector.

Hook-Up Wire
A single insulated conductor used for low current, low voltage (usually under 1000 volts) applications within enclosed electronic equipment.

Hot Stamping
Permanent markings in letters or numbers that are stamped by heat under pressure onto wire.

Hygroscopic
The characteristic of a material to absorb moisture from the air.

IDC
See insulation displacement connector.

Injection Gate
The location on the mold where the molding is injected into the mold cavity.

Insert, Connector
*The element that holds connector contacts in their proper arrangement and electrically insulates the contacts from one another and from the connector shell.

Insert Retention
Axial load in either direction that an insert must withstand without being dislocated from its normal position in the connector shell.

Insertion Force
The effort, usually measured in ounces, required to engage mating components.

Insertion Tool
A small, hand-held tool used to insert contacts into a connector.

Insulation
A material that offers high electrical resistance making it suitable for covering components, terminals and wires to prevent the possible future contact of adjacent conductors resulting in a short circuit.

Insulation Crimp
Area of a terminal, splice or contact that has been formed around the insulation of the wire.

Insulation Displacement Connector (IDC)
A mass termination connector for flat cable with contacts that displace the conductor insulation to establish simultaneous contact with all conductors.

Insulation Resistance
*The electrical resistance of an insulating material that is determined under specific conditions between any pair of contacts, conductors, or grounding devices in various combinations.

Insulation Support
An extension of the rear portion of the contact that gives the wire side support, but not longitudinal support. This section is not crimped.

Insulation Thickness
The wall thickness of the applied insulation.

Insulator
A material with a high resistance to the flow of electrical current. (See also ‘‘Dielectric.’’)

Appendix A Terms and Definitions (cont.)

Interconnection	Mechanically joining devices together to complete an electrical circuit.
Interface, Wire/Cable and Mold	The location where the cable enters into the molded connector.
Interstices	Voids or valleys between individual strands in a conductor or between insulated conductors in a multi-conductor cable during extreme flexing.
Jacket	An outer covering, usually nonmetallic, mainly used for protection against the environment.
Jackscrew	A screw attached to one half of a two-piece, multiple-contact connector and used to draw both halves together and to separate them.
Keying	Mechanical arrangement of guide pins and sockets, keying plugs, contacts, bosses, slots, keyways, inserts or grooves in a connector housing shell or insert that allows connectors of the same size and type to be lined up without the danger of making a wrong connection.
Keying Plug Contact	A component that is inserted into a cavity of a connector housing or insert to assure engagement of identically matched components.
Kinked	An abrupt bend from which a wire strand is not easily restored to its original condition.
Knit Line (Weld line)	(1) A location where two flow fronts meet during the injection mold process. (2) Where melted material flows together to form a line or lines that may cause weakening or breaking of the component.
Lacing Cord or Twine	Used for lacing and tying cable forms, hook-up wires, cable ends, cable bundles and wire harness assemblies. Available in various materials and impregnants.
Lanyard	A device attached to certain connectors that permits uncoupling and separation of connector halves by a pull on a wire or cable.
Lap Joint	(1) When a piece of foil is positioned to lie on top of another conductive surface, i.e., connector, other foil, etc. (2) Two conductors joined by placing them side by side so that they overlap. See Parallel Splice.
Lead	(1) A wire, with or without terminals, that connects two points in a circuit. (2) *A length of insulated or uninsulated metallic conductor that is used for electrical interconnections.
Locator	Device for positioning terminals, splices or contacts in crimping dies.
Lug	A wire terminal.
Mastic	A meltable coating used on the inside of some shrink products which, when heated, flows to encapsulate the interstitial air voids.
Mate	To join two connector halves in a normal engaging mode.
MCM	One thousand circular mils.
Mismatch	Is where matched mold parts are not properly aligned.
Multiple-Conductor Cable	A combination of two or more conductors cabled together and insulated from one another and from sheath or armor where used.
Nest	Part of a crimping die set, the nest provides the location and support for the terminal barrel as it is being deformed into the desired crimp configuration by the indentor. Also called Anvil.
O Crimp	An insulation support crimp for open barrel terminals with a crimped form resembling an O. It conforms to the shape of round wire insulation.

Appendix A Terms and Definitions (cont.)

Parallel Splice A parallel splice is a device for joining two or more conductors in which the conductors lie parallel and adjacent. See Lap Joint.

Part Line/Parting Line Mark on the part indicating where the two halves of the mold met in closing.

Peeling A molding cosmetic defect. An open blister.

Pick Distance between two adjacent crossover points of braid filaments. The measurement in picks per inch indicates the degree of coverage.

Pitch
(1) In flat cable, the nominal distance between the index edges of two adjacent conductors.
(2) The nominal center-to-center distance of adjacent conductors. (When the conductors are of equal size and their spacing is uniform, the pitch is usually measured from the reference edge of the adjacent conductors.)

Plenum The air return path of a central air handling system, either ductwork or open space over a dropped ceiling.

Plenum Cable Cable approved by Underwriters Laboratories for installation in plenums without the need for conduit.

Plug The part of the two mating halves of a connector that is free to move when not fastened to the other mating half.

Polarization A mechanical arrangement of inserts and/or shell configuration (referred to as clocking in some instances) that prohibits the mating of mismatched plugs and receptacles. This is to allow connectors of the same size to be lined up, side by side, with no danger of making the wrong connection.

Polarizing Pin A pin located on one half of a two-piece connector in such a position that, by mating with an appropriate hole on the other half during assembly of the connector, will assure that only related connector halves can be assembled.

Polarizing Slot *A slot in the edge of a printed board that is used to assure the proper insertion and location of the board in a mating connector.

Positioner A device attached to the crimping tool to position conductor barrel between the indentors.

Potting Sealing of a component, e.g., the cable end of a multiple contact connector, with a plastic compound or material to exclude moisture, prevent short circuits and provide strain relief.

Potting Compound A material, usually organic, that is used for the encapsulation of components and wires.

Potting Cup An accessory that, when attached to the rear of a plug or receptacle, provides a pouring form for potting the wires and the wire entry end of the assembly.

Potting Mold An item, solid or split, designed to be used as a hollow form into which potting compound is injected and allowed to cure or set to seal the back of an electrical connector.

Pullout (Pop-out) Where the sleeve, cable jacket or insulation is pulled out of the molded connector.

Raceway Channel that provides a path for wire, cables and bundles; used to protect against physical damage and can be used to protect against EMI.

Ratchet Control A ratchet control is a device to ensure the full crimping cycle of a crimping tool.

Ratchet Hand Tool Tool designed with ratchet device to insure completion of the crimping cycle.

Recovered Diameter Diameter of shrinkable products after heating has caused it to return to its extruded diameter.

Reference Edge The edge of a cable or conductor from which measurements are made.

Repair The act of restoring the functional capability of a defective article in a manner that precludes compliance of the article with applicable drawings or specifications.

Appendix A Terms and Definitions (cont.)

Rework — The act of reprocessing noncomplying articles, through the use of original or alternate equivalent processing, in a manner that assures compliance of the article with applicable drawings or specifications.

RF Connector — Connector used for connecting or terminating coaxial cable.

RFI — Abbreviation for Radio Frequency Interference.

RG/U — Abbreviation for Radio Government Universal, RG is the military designation of coaxial cable in MIL-C-17 and U stands for ''general utility.''

Ribbon Cable — See cable, ribbon.

Ring Tongue Terminal — Round-end tongue terminal with hole to accommodate screw or stud.

Sealing Plug — A plug that is inserted to fill an unoccupied contact aperture in a connector insert. Its function is to seal, especially in environmental connectors.

Sheath — The outer covering or jacket of a multiconductor cable.

Shell — The outside case of connector into which the insert and contacts are assembled.

Shield
(1) A metallic layer placed around a conductor or group of conductors to prevent electrostatic interference between the enclosed wires and external fields.
(2) The material around a conductor or group of conductors that limits electromagnetic and/or electrostatic interference.

Shield Adapter — An intermediate device that allows the termination of the cable shield to the connector shell.

Shield Coverage — The physical area of a cable that is covered by the shielding material and is expressed in percent.

Shielding, Electronic — *A physical barrier, usually electrically conductive, that reduces the interaction of electric or magnetic fields upon devices, circuits, or portions of circuits.

Short Shot — Insufficient filling of the mold tool during the molding process.

Sink Marks
(1) A depression in the molded material that is caused by uneven cooling/solidification of the molded part.
(2) An indentation on the surface of the part as a result of significant local change in wall section. The mark will occur in the thicker area.

Solder Terminal — *An electrical/mechanical connection device that is used to terminate a discrete wire or wires by soldering.

Solder Terminal, Bifurcated — *A solder terminal with a slot or slit opening through which one or more wires are placed prior to soldering.

Solder Terminal, Cup — *A cylindrical solder terminal with a hollow opening into which one or more wires are placed prior to soldering.

Solder Terminal, Hook — *A solder terminal with a curved feature around which one or more wires are wrapped prior to soldering.

Solder Terminal, Perforated (Pierced) — *A flat-metal solder terminal with an opening through which one or more wires are placed prior to soldering.

Solder Terminal, Turret — *A round post-type stud (stand-off) solder terminal with a groove or grooves around which one or more wires are wrapped prior to soldering.

Solder Wicking — Capillary movement of solder between metal surfaces, such as strands of wire.

Appendix A Terms and Definitions (cont.)

Solderless Contact A contact with a back portion that is a hollow cylinder which allows it to accept a wire. After a bared wire is inserted, a crimping tool is applied to crimp the contact metal firmly against the wire. Usually called a crimp contact.

Solderless Wrap The connecting of a solid wire to a square, rectangular, or V-shaped terminal by tightly wrapping a solid-conductor wire around the terminal with a special tool.

Splice
(1) A joint connecting conductors with good mechanical strength and which provides good conductivity.
(2) A termination that permanently joins two or more wires.

Strain Relief A technique or item which reduces the transmission of mechanical stresses to the conductor termination.

Strain Relief Clamp An adjustable collar, usually secured by a nut and bolt, that clamps the wire or cable attached to the connector so as to relieve the strain on the contact terminations. See Cable Clamp.

Strain Relief Connector A receptacle connector device that prevents the disturbance of the contact and cable terminations.

Strand Group A bundle or collection of strands that make up a single conductor or wire.

Strands, Nicked Nicked strands have been partially cut or broken but are still attached. Severed strands have been cut or broken to where they are no longer attached.

Strands, Scraped Strands have been damaged due to a stripping instrument.

Streaking Discoloration of the part usually fanning out from the injection gate.

Stress Relief
(1) A predetermined amount of slack to relieve tension in component or lead wires.
(2) The portion of a component lead or wire lead that is formed in such a way as to minimize mechanical stresses after the lead is terminated.

Supplier The individual, organization or company which provides to the manufacturer (assembler) components (cables, wire harnesses, electronic, electromechanical, mechanical, printed boards, etc.) and/or materials (solder, flux, cleaning agents, etc.).

Surface Imperfections Rough surfaces on the molded component.

Tab
(1) The flat blade portion of certain terminals.
(2) On strip terminals, the projection that results when the point-of-shear is not flush with the terminal body, i.e., cut-off tab.

Tensile Amount of axial load required to break or pull a wire from the crimped barrel of a terminal, splice or contact.

Tensile Strength The pull stress required to break a given specimen.

Terminal
(1) A device designed to terminate a conductor that is to be affixed to a post, stud, chassis, another conductor, etc., to establish an electrical connection. Some types of terminals include ring, tongue, spade, flag, hook, blade, quick-connect, offset and flanged.
(2) *A metallic device that is used for making electrical connections. (See also ''Solder Terminal.'')

Thermocouple A device consisting of two dissimilar metals in physical contact, which when heated will develop an EMF output.

Tinned Copper Tin coating added to copper to aid in soldering and inhibit corrosion.

Tinning The application of molten solder to a basis metal in order to increase its solderability.

Appendix A Terms and Definitions (cont.)

Tracer Stripe When more than one color-coding stripe is required, the first (widest) stripe is the base stripe, the others usually narrower stripes, being termed tracer stripes.

Tray Cable A factory-assembled multiconductor or multi-pair control, signal or power cable specifically approved under the National Electrical Code for installation in trays.

Tubing A tube of extruded nonsupported plastic or metallic material.

User The individual, organization, company, contractually designated authority or agency responsible for the procurement of electrical/electronic hardware, and having the authority to define the class of equipment and any variation or restrictions to the requirements of this standard, i.e., the originator/custodian of the contract detailing these requirements.

Void The absence of mold material in a localized area.

Wetting, Solder The formation of a relatively uniform, smooth, unbroken, and adherent film of solder to a basis metal.

Wire A wire is a slender rod or filament of drawn metal.

Wire – Assembly A wire with one or both ends installed into electrical terminal(s).

Wire Diameter The outside diameter of the wire, including insulation if present.

Wire Wrap See solderless wrap.

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Appendix B Reproducible Test Tables

Pages B-2 through B-13 are a summary of test requirements as a convenient format for passing information between User and Manufacturer and can be copied freely.

These pages may also be downloaded as editable electronic files from **www.ipc.org/downloads**.

IPC/WHMA-A-620 Test Criteria

Table 19-1
Electrical Test Requirements

Assembly Identification ____

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________________ **Name** ____

Clause	Test	Requirements	Requirement Decision
19.5.1	Continuity Test Parameters	Required (see Table 19-2)	[ ] Not Required
19.5.2	Shorts Test (low voltage isolation) Parameters	Required unless DWV or IR tests performed (see Table 19-3)	[ ] Required [ ] Not Required
19.5.3	Dielectric Withstanding Voltage (DWV) Test Parameters	Required for Class 3 and some Class 2 (see Table 19-4)	[ ] Required [ ] Not Required
19.5.4	Insulation Resistance (IR) Test Parameters	Required for Class 3 and some Class 2 (see Table 19-5)	[ ] Required [ ] Not Required
19.5.5	Voltage Standing Wave Ratio (VSWR) Test Parameters	User Specified	[ ] Required
19.5.6	Insertion Loss Test Parameters	User Specified	[ ] Required
19.5.7	Reflection Coefficient Test	User Specified	[ ] Required
19.5.8	User Defined Electrical Tests	User Specified	[ ] Required

IPC/WHMA-A-620 Test Criteria

Table 19-2
Continuity Test Minimum Requirements

Assembly Identification ______________________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________ **Name** ______________________________

Parameter	Class 1	Class 2	Class 3	Other Defined Value
Max Resistance	Tester Default		2 Ω or 1 Ω plus the maximum specified resistance of wire whichever is greater	____ Ω
Max Current	Tester Default			____ mA
Max Voltage	Tester Default			____ V

IPC/WHMA-A-620 Test Criteria

Table 19-3
Shorts Test (low voltage isolation) Minimum Requirements[1]

Assembly Identification ____

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________________ **Name** ____

Parameter	Class 1[1]	Class 2[1] with clearance/ creepage distances (air gaps) ≥2 mm [0.079 in]	Class 2[2] with clearance/ creepage distances (air gaps) <2 mm [0.079 in]	Class 3[1]	Other Defined Value
Min Resistance	Tester Default				____ Ω
Max Current	Tester Default		NA	NA	____ mA
Max Voltage[2]	Tester Default				____ V

Note 1: Shorts Test (low voltage isolation) is not required when Dielectric Withstanding Test or Insulation Resistance Test has been performed.
Note 2: A maximum voltage and or current should be specified when components within an assembly may be damaged by these tests.

Table 19-4
Dielectric Withstanding Voltage Test (DWV) Minimum Requirements

Assembly Identification ____

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________________ **Name** ____

Parameter	Class 1	Class 2 with clearance distances (air gaps or creepage) ≥2 mm [0.079 in] and not coaxial/biaxial/triaxial assemblies	Class 2 with clearance distances (air gaps or creepage) <2 mm [0.079 in] or coaxial/biaxial/triaxial assemblies	Class 3	Other Defined Value
Voltage Level[1]	Test Not Required	Test Not Required	1000 V DC or equivalent peak AC voltage[2]	1500 V DC or equivalent peak AC voltage[2]	____ V DC or ____ V AC
Max Leakage Current			1 mA	1 mA	____ mA
Dwell time			100 ms	1 s	____ s

Note 1: See 19.1.
Note 2: Voltage Level is applicable when clearance distance tested is ≥0.58 mm [0.023 in]. When clearance distances are <0.58 mm [0.023 in] an agreement between the User and Manufacturer to de-rate these test levels would be expected.

IPC/WHMA-A-620 Test Criteria

Table 19-5
Insulation Resistance (IR) Test Minimum Requirements

Assembly Identification ____________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________ **Name** ____________________

Parameter	Class 1	Class 2 with clearance distances (air gaps or creepage) ≥2 mm [0.079 in]	Class 2 with clearance distances (air gaps or creepage) <2 mm [0.079 in]	Class 3	Other Defined Value
Voltage Level[1]	Test Not Required	Test Not Required	DC DWV V or tester default		____ V DC
Minimum Insulation Resistance[2]			≥100 MΩ for assemblies ≤ 3 m [118 in] ≥10 MΩ for assemblies > 3 m [118 in] ≥500 MΩ for coaxial cable of any length		____ MΩ
Max Dwell Time			10 s		____ s

Note 1: See 19.1.
Note 2: IR levels specified applicable at less than 80% relative humidity. When relative humidity exceeds 80% an agreement between User and Manufacturer to de-rate these tests levels would be expected.

IPC/WHMA-A-620 Test Criteria

Table 19-6
Voltage Standing Wave Ratio (VSWR) Test Parameters

Assembly Identification ______________________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________ **Name** ______________________________

Parameter	Defined Value
Frequency Range	____ MHz
Ratio of input power to reflected power	____ : ____

IPC/WHMA-A-620 Test Criteria

Table 19-7
Insertion Loss Test Parameters

Assembly Identification ______________________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________________ **Name** ______________________________

Parameter	Defined Value
Frequency Range	____ MHz
Max Loss	____ dB

IPC/WHMA-A-620 Test Criteria

Table 19-8
Reflection Coefficient Test Parameters

Assembly Identification ____

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________________ **Name** ____

Parameter	Defined Value
Frequency Range	____ MHz
Max Loss	____ dB

IPC/WHMA-A-620 Test Criteria

Table 19-9
Mechanical Test Requirements

Assembly Identification ____________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________ **Name** ____________________

Clause	Test	Requirement[1]	Requirement Decision
19.7.1	Crimp Height Testing	Required for Class 1 and 2 if Pull Force Testing not Performed (see 19.7.2) (Table 19-10)	[ ] Required for each new setup and again every: [ ] ____ parts [ ] shift(s), [ ] ____ workday(s) [ ] Not Required
19.7.2	Pull Force/Tensile Testing	Required for Class 3 Required for Class 1 and 2 if Crimp Height Testing not Performed (see 19.7.1) (Table 19-11)	[ ] Required for each new setup and again every: [ ] ____ parts [ ] shift(s), [ ] ____ workday(s) [ ] Not Required
19.7.3	Crimp Force Monitoring	User Specified	[ ] Required
19.7.5	Contact Retention	In-Process requirement for Classes 1, 2, and 3	[ ] Not Required
19.7.6	RF Connector Shield Pull Test	User Specified	[ ] Required
19.7.7	RF Connector Shield Ferrule Torsion Test	User Specified	[ ] Required
19.7.8	User Defined Mechanical Tests	User Specified	[ ] Required

Note 1: In the absence of specific agreed on test requirements between User and Manufacturer or an agreement by the User to accept the Manufacturer's documented test requirements, Table 19-9 defines minimum test requirements for each Product Class.

IPC/WHMA-A-620 Test Criteria

Table 19-10
Crimp Height Testing

Assembly Identification ______________________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________________ **Name** ______________________________

Parameter	Requirement	Other Defined Value
Max Flash Height	Use the terminal supplier's specification[1]	____ mm [____ in]
True Crimp Height	Use the terminal supplier's specification[1]	____ mm [____ in]
Width (noncircular crimp, i.e., Lugs)		____ mm [____ in]

Note 1: If the User or Manufacturer has objective evidence indicating that the terminal supplier's specification is not sufficient, other values may be agreed upon between User and Manufacturer.

IPC/WHMA-A-620 Test Criteria

Table 19-11
Pull Force Testing Minimum Requirements

Assembly Identification ____________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________ **Name** ____________________

Parameter	Class 1	Class 2	Class 3	Other Defined Value
Pull Force	Appropriate Industry Standard (UL, IEC, SAE, Table 19-12, 19-13 or 19-14)[1]		Table 19-12	____ N ____ Kp ____ pounds
Pull-Rate[2]	Not Specified	Controlled Rate	≤1 inch/minute	____ /minute
Method	Not Specified	Not Specified	Not Specified	[ ] Pull & Break [ ] Pull & Return [ ] Pull & Hold [ ] Pull, Hold & Break
Hold Time[3]	Not Specified	Not Specified	Not Specified	____ Seconds

Note 1: It is the responsibility of the harness Manufacturer and/or the User to determine which set of tensile test values is appropriate.
Note 2: Controlled rate indicates a specified pull rate that is held constant throughout the pull.
Note 3: The Hold Time parameter is relevant only if the ''Pull & Hold'' or ''Pull, Hold & Break'' method is used.

IPC/WHMA-A-620 Test Criteria

Table 19-15
RF Connector Shield Pull Force Testing

Assembly Identification ______________________________

Testing required for a [ ] Class 1, [ ] Class 2, [ ] Class 3 assembly.

Test requirements established by
[ ] A-620 default minimum test requirements for this class except as modified below.
[ ] User's acceptance of Manufacturer's documented test requirements except as modified below.

Requirements below are defined by [ ] Manufacturer or [ ] User.

Date ____________________ **Name** ____

Parameter	Defined Value
Pull Force	____ N ____ Kp ____ pounds
Pull-Rate[1]	____ /min
Method	[ ] Pull & Break [ ] Pull & Return [ ] Pull & Hold [ ] Pull, Hold & Break
Hold Time[2]	____ s

Note 1: Controlled rate indicates a specified pull rate that is held constant throughout the pull.
Note 2: The Hold Time parameter is relevant only if the ''Pull & Hold'' or ''Pull, Hold & Break'' method is used.

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Appendix C Guidelines for Soldering Tools and Equipment

The following guidelines for tools and equipment selection and use have been found through industry practice to be effective in meeting the requirements of this standard, see 4.1.1.5.

C-1 ABRASIVES

Knives, emery cloth, sandpaper, sandblasting, braid, steel wool, and other abrasives are not to be used on surfaces to be soldered.

C-2 BENCHTOP AND HAND SOLDERING SYSTEMS

Selection criteria of benchtop and hand soldering systems include:

a. Soldering systems are selected for their capacity to heat the connection area rapidly and maintain sufficient soldering temperature range at the connection throughout the soldering operation.
b. Equipment should be able to maintain control within ± 10°C [± 18°F] of the selected or required temperature during multiple point-to-points or thermal mass on demand soldering operations to verify temperature stability.
c. Temperature stability-degradation to peak [set] recovery temperature – should be periodically checked to demonstrate soldering device can provide temperature control limits defined in Section (b) for multiple load, point-to-points soldering [for example; soldering of a multi-leaded component (s)] or depending on thermal mass demand soldering.

   Note: Frequency of verification of temperature stability should be dictated by objective evidence of compliance to Section (b).
d. Temperature stability-degradation to recovery overshoot – should be checked using point to point or on thermal mass demand soldering and **shall not** exceed the limits defined in section (b).
e. Resistance between the tip of soldering systems and the workstation common point ground should not exceed 5 ohms. Heated element and tips are measured when at their normal operating temperature.
f. AC and DC current leakage from heated tip to ground should not create deleterious effects on equipment/components.
g. Tip transient voltages generated by the soldering equipment should not exceed 2V peak ($Z_{in} \geq \Omega$).

The appropriate guidelines of this section also apply to nonconventional benchtop soldering equipment; including equipment which utilizes conductive, convective, parallel gap resistance, shorted bar resistance, hot gas, infrared, laser powered devices, or thermal transfer soldering techniques. Tools used are to be maintained such that no detrimental damage results from their use. Tools and equipment are to be clean prior to use and should be kept clean and free of dirt, grease, flux, oil and other foreign matter during use. The heat source is not to cause damage to the printed board or components.

C-3 HEATED SOLDERING TOOL HOLDERS

Soldering tool holders are to be of a type appropriate for the soldering tool used. The holder should leave the soldering tool heating element and tip unsupported without applying excessive physical stress or heat sinking and is to protect personnel from burns.

C-4 WIPING PADS

Sponges and pads for wipe cleaning of soldering iron tips and reflow soldering tool surfaces are to be manufactured from materials which are not detrimental to solderability or which could contaminate soldering tool surfaces. The operator is to keep sponges and pads free of contaminants that are detrimental to solderability or that would contaminate the soldering tool surfaces.

C-5 SOLDERING GUNS

Soldering guns with the transformer incorporated into the hand piece are not to be used.

C-6 SOLDER POTS

Solder pots should maintain the solder temperature within ± 5°C [± 9°F] of the selected temperature. Solder pots are to be grounded.

Appendix C Guidelines for Soldering Tools and Equipment (cont.)

C-7 USE AND CONTROL

All equipment is to be operated in accordance with Manufacturers' recommendations and calibrated where necessary to maintain Manufacturers' specifications. Equipment grounding, protection and temperature control testing should be performed when qualifying equipment for purchase and/or inspection of new or repaired equipment.

C-8 MACHINE SOLDERING SYSTEMS

The design of automated machine soldering systems should provide:

a. The capability to preheat items to be soldered.
b. The capacity to maintain the soldering temperature at the assembly surface within ± 5°C [± 9°F] of the selected temperature throughout the span of any continuous soldering run.
c. The capability to rapidly heat the surfaces to be joined and the capacity to reattain the present temperature within ± 5°C [± 9°F] during repetitive soldering operations.

The heat source should not cause damage to the items to be soldered, or contaminate the solder when direct contact is made between the heat source and metals to be joined.

Soldering equipment should be utilized in accordance with a documented process that is available for User review.

C-9 EQUIPMENT

Equipment related to the soldering process are to be maintained to assure capability and efficiency commensurate with design parameters established by the original equipment manufacturer. Maintenance procedures and schedules should be documented in order to provide reproducible processing.

ANSI/IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits Definition Submission/Approval Sheet

The purpose of this form is to keep current with terms routinely used in the industry and their definitions. Individuals or companies are invited to comment. Please complete this form and return to:

IPC
3000 Lakeside Drive, Suite 105N
Bannockburn, IL 60015-1249
Fax: 847 615.7105

SUBMITTOR INFORMATION:

Name: ______________________

Company: ______________________

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❑ This is a **NEW** term and definition being submitted.
❑ This is an **ADDITION** to an existing term and definition(s).
❑ This is a **CHANGE** to an existing definition.

Term	Definition

If space not adequate, use reverse side or attach additional sheet(s).

Artwork: ❑ Not Applicable ❑ Required ❑ To be supplied
❑ Included: Electronic File Name: ______________________

Document(s) to which this term applies: ______________________

Committees affected by this term: ______________________

Office Use

IPC Office	**Committee 2-30**
Date Received: ____________	Date of Initial Review: ____________
Comments Collated: ____________	Comment Resolution: ____________
Returned for Action: ____________	Committee Action: ❑ Accepted ❑ Rejected
Revision Inclusion: ____________	❑ Accept Modify

IEC Classification

Classification Code • Serial Number

Terms and Definition Committee Final Approval Authorization:

Committee 2-30 has approved the above term for release in the next revision.

Name: ____________ Committee: IPC 2-30 Date: ____________

Standard Improvement Form

IPC/WHMA-A-620D

The purpose of this form is to provide the Technical Committee of IPC with input from the industry regarding usage of the subject standard.

Individuals or companies are invited to submit comments to IPC. All comments will be collected and dispersed to the appropriate committee(s).

If you can provide input, please complete this form and return to:

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E-mail: answers@ipc.org
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1. I recommend changes to the following:

___ Requirement, paragraph number __________

___ Test Method number __________, paragraph number __________

The referenced paragraph number has proven to be:

___ Unclear ___ Too Rigid ___ In Error

___ Other ____

2. Recommendations for correction:

____

____

____

____

3. Other suggestions for document improvement:

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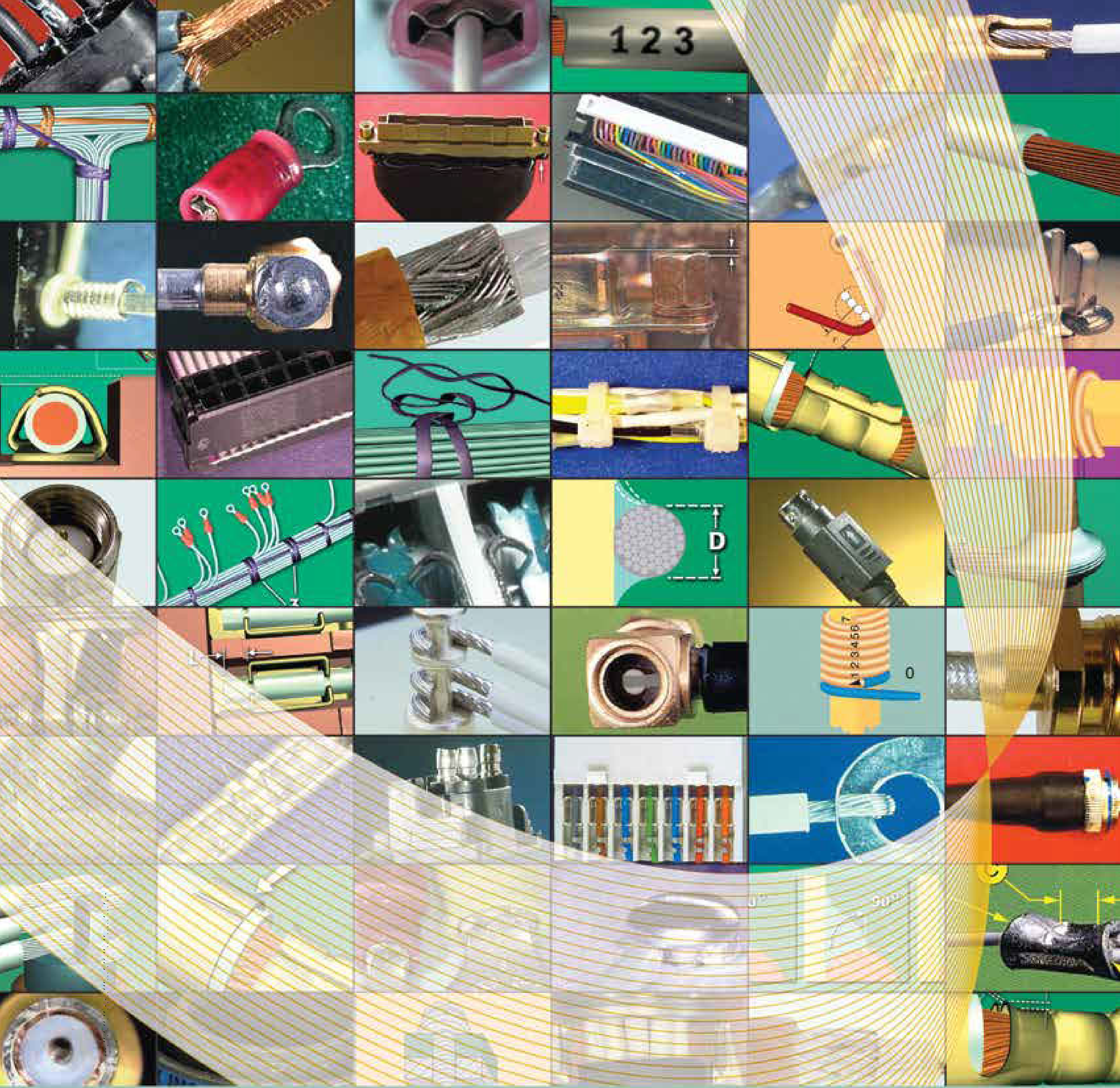

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ISBN #978-1-951577-07-0

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