# IPC/WHMA-A-620B

## This redline document is to help users see significant changes from Revision A.

New or changed text are shown in blue and underlined like this.
~~Deleted or moved text is shown in red and strikethrough like this.~~

Redline document to compare IPC/WHMA-A-620 revision B to A
Red strikeout indicates deletion, blue underline indicates new words
Only significant technical changes are shown

# 1 Foreword

The following topics are addressed in this section:



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

**1.1 Scope** ~~This standard is a collection of visual, electrical and mechanical quality acceptability requirements for Cable, Wire and Harness Assemblies.~~ This standard prescribes practices and requirements for the manufacture of cable, wire and harness assemblies.

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

**1.2 Purpose** This ~~publication~~ Standard describes materials, methods, tests and acceptability criteria for producing crimped, mechanically secured, or soldered interconnections and the ~~associated~~ related assembly activities ~~lacing/restraining criteria~~ associated with cable and harness assemblies.

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

**1.3 Approach To This Document** 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).

All products **shall [D1D2D3]** meet the requirements of the assembly drawing(s)/ documentation and the requirements for the applicable product class specified herein.

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.

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 1.21). 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.

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.

**1.4 Measurement Units and Applications** All dimensions and tolerances, as well as other forms of measurement in this standard are expressed in SI (System International) units (with Imperial English equivalent dimensions provided in brackets). Dimensions and tolerances use millimeters as the main form of dimensional expression; micrometers are used when the precision required makes millimeters too cumbersome.

**1.4.1 Verification of Dimensions** For the purposes of determining conformance to this specification, all specified limits in this standard are absolute limits as defined in ASTM E29.

~~**1.4**~~**1.5 Requirements** ~~**Shall or Should**~~ The word **"shall"** is used in the text of this document wherever ~~a requirement is mandatory.~~ there is a requirement for materials, process or acceptance of cable, wire and harness assemblies.

~~Where the word "**shall**" leads to a hardware defect for at least one class, the requirements for each class are annotated in text boxes located adjacent to that occurrence in the text.~~ Where the word **shall** leads to a hardware defect for at least one class, the requirements for each class are in brackets next to the **shall** requirement.

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 Establish Class 1, Defect Classes 2 and 3
[A1A2D3] is Acceptable Classes 1 and 2, Defect Class 3
[D1D2D3] is Defect for all Classes.

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

~~**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 of unique criteria should include user involvement or consent and the criteria developed should include an~~

~~agreed upon definition for acceptance of each characteristic.~~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.

**~~1.6~~1.7 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.

**1.7.1 Inspection** An evaluation of quality characteristics relating to a standard, specification, or design drawing.

**1.7.2 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.

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

**1.7.4 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.

**1.7.5 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.).

**1.7.6 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 class of product and any variation or restrictions to the requirements of this standard (i.e., the originator/custodian of the contract detailing these requirements).

**1.7.7 Wire Diameter (D)** – In this document, the outside diameter of the wire, including insulation if present.

**~~1.7~~1.8 Classes of Product** Use of this standard requires agreement on the class to which the product belongs. If the user and manufacturer do not establish and document the acceptance class, the manufacturer may do so.~~ Thus, ~~ Accept and/or reject decisions ~~**must**~~ **shall [D1D2D3]** be based on applicable documentation such as contracts, drawings, specifications, standards and reference documents. 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 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.

**~~1.8~~1.9 Order of Precedence ~~Document Hierarchy~~** In the event of conflict, the following order of precedence applies:
1. Procurement as agreed between user and manufacturer.
2. Master drawing or master assembly drawing reflecting the user's detailed requirements.
3. When invoked by the user or per contractual agreement, IPC/WHMA-A-620.
~~4. Other documents to extent specified by the user.~~

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 Requirements for Soldered Electrical and Electronic Assemblies or IPC-A-610 Acceptability of Electronic Assemblies 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 is to be defined in the procurement documents.

The user (customer) has the opportunity to specify alternate acceptance criteria.

**1.10 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, assembly drawing(s), 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, then 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.

**1.11 Personnel Proficiency** All instructors, operators, and inspection personnel **shall [N1D2D3]** be proficient in the tasks to be performed. Objective evidence of that proficiency **shall [N1D2D3]** 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.

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

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, see 1.18.

For operator comfort, 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.

**Note:** 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.

**1.12.1 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.

## ~~1.9~~ 1.13 Tools and Equipment

### 1.13.1 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.

**1.13.2 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 [~~D1~~N1D2D3]** have a documented calibration system in accordance with ANSI/NCSL Z540-1 or other National or International standard. The minimum standard **shall [~~D1~~N1D2D3]** ~~be~~ 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.

**1.13.3~~1.19~~ 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.

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 specification or other documented procedure **shall [D1D2D3]** 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.

**~~1.10~~1.14 Figures and Illustrations** Many of the examples (figures) shown are grossly exaggerated to clearly depict the condition being described.

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

~~**1.11 Defects and Process Indicators** Characteristics or conditions that do not conform to the requirements of this standard that are detectable by inspection or analysis are classified as either defects or process indicators. Not all process indicators are specified by this standard. Process indicators should be monitored but the hardware needs not be dispositioned, see 1.11.3.~~

~~It is the responsibility of the user to define unique defect categories applicable to the product. It is the responsibility of the manufacturer to identify defects and process indicators that are unique to the assembly process.~~

**~~1.12~~1.15 Inspection Conditions** For each section of this document, target, acceptable and defect conditions are listed for each product class. Where applicable, process indicator conditions are also listed. 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. The descriptions of these conditions follow.

~~1.12.1~~1.15.1 **Target** A condition that is close to perfect (in the past has sometimes been labeled as "preferred"). It is a desirable condition, not always achievable, and may not be necessary to ensure reliability of the assembly in its service environment.

~~1.12.2~~1.15.2 **Acceptable** This characteristic indicates a condition that, while not necessarily perfect, will maintain the integrity and reliability of the assembly in its service environment.

~~1.12.3~~1.15.3 **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 **shall [N1N2D3]** 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.

~~1.12.4~~1.15.4 **Defect** A defect is a condition that fails to meet the acceptance criteria of this document and negatively affects the form, fit or function, of the assembly in its end use environment. The manufacturer **shall [~~D~~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.

~~1.12.5~~1.15.5 **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.<June2011>

~~1.12.6~~1.15.6 **Product Classification Implied Relationships** 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.

~~1.12.7~~1.15.7 **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.

~~1.13~~1.16 **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 this 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. Violation of minimum electrical clearance ~~is~~**shall [D1D2D3]** be a defect.~~ condition for all classes.~~

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 1-1may be used as a guideline.

**Table 1-1 Electrical Clearance**

| Voltage | Set* | Clearance |
|---|---|---|
| Up to 64 | A<br>B<br>C | 1.6 mm [0.062 in]<br>3.2 mm [0.125 in]<br>3.2 mm [0.125 in] |
| Over 64-600 | A<br>B<br>C | 1.6 mm [0.062 in]<br>3.2 mm [0.125 in]<br>6.4 mm [0.25 in] |
| Over 600-1000 | A<br>B<br>C | 3.2 mm [0.125 in]<br>6.4 mm [0.25 in]<br>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.

## ~~1.16~~1.17 ~~Visual~~ Inspection

**1.17.1 Sampling** Manufacturers **shall [N1N2D3]** define a sampling inspection program as part of a documented process control plan. If there is no documented process control plan the manufacturer **shall [N1D2D3]** perform 100% inspection (see 1.21).

**~~1.16.1~~ 1.17.2.1 Lighting** Illumination at the surface of workstations should be at least 1000 lm/$m^2$ (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.

**~~1.16.2~~1.17.2.2 Magnification Aids ~~and Lighting~~** When required, magnification power for assembly inspection **shall [A1P2D3]** be at least the minimum inspection power specified in 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 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). ~~Supplemental lighting may be necessary to assist in visual assessment.~~

**Table 1-2 Magnification Aids[1]**

| Wire Size AWG Diameter mm [inch] | Magnification Power | |
|---|---|---|
| | Inspection Range | Maximum Referee |
| larger than 14 AWG<br>>1.63mm~~2 mm~~<br>[~~0.081~~0.064 in] | N/A | 1.75X |
| 14 to 22 AWG<br>1.63 - 0.64~~3~~ mm [0.064 to 0.025 in] | 1.5X - 3X | 4X |

| | | |
|---|---|---|
| ~~smaller than >~~ <22 to 28 AWG <0.64~~3~~mm – 0.032mm [<0.025 - 0.013 in] | 3 – 7.5X | 10X |
| Smaller than 28 AWG <0.32mm [<0.013 in] | 10X | 20X |

**Note 1:** Referee magnification power is 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.

**~~1.17~~1.18 Electrostatic Discharge (ESD) Protection** Assemblies that contain components or parts sensitive to ESD **shall [D1D2D3]** be protected in accordance with either ANSI/ESD-S20.20, MIL-STD-1686 or equivalent.

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

**~~1.18~~1.19 Contamination** Assemblies produced in accordance with this Standard **shall [D1D2D3]** be free of all extraneous matter (including but not limited to: wire clippings, insulation slugs, strands of shielding braid or any other item not required to be present). See 4.2 for cleanliness criteria specific to soldered assemblies.

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

**1.20 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.

**1.20.1 Rework** Rework ~~for Classes 1 or 2 should and for Class 3~~ **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.

**1.20.2 Repair** Repairs **shall [N1D2D3]** be conducted in accordance with a documented procedure. The repair method **shall [N1N2D3]** be determined by agreement between the manufacturer and the user.

**~~1.20~~1.21 Statistical Process Control**

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

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.

## 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**
**3.2 Strand Damage and End Cuts**
**3.3 Conductor Deformation/Birdcaging**
**3.4 Twisting of Wires**
**3.5 Insulation Damage - 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]** be in a solder connection area or prevent contact of the strand group for the full length of the required wrap.

Conductors **shall not [D1D2D3]** 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 ~~16.1.2~~15.1.2 for shield strand damage criteria.

~~Tools utilized to accomplish wire cuts **shall [N1D2D3]** be selected and used to provide repetitive and consistent wire cut terminations that meet the following criteria.~~

~~The process of wire cutting **shall [N1D2D3]** be performed such that the cut ends are uniform and all strands are the same length.~~

**Figure 03-1**

**Defect - Class 1,2,3**

- Variation in strand length within a strand group that prevents installation to the full depth of the crimp contact area.
- Damaged strands exceed the limits specified in Table 3-1.

~~**Acceptable – Class 1,2**~~**<covered in intro>**
~~**Defect - Class 3**~~

- ~~As an exception to Table 3-1, partial or incomplete cuts of strand groups are in the crimp contact area.~~
- ~~As an exception to Table 3-1, partial cuts of a strand group are in a solder connection area or could prevent contact of the strand group for the full length of the required wrap.~~
- ~~Damaged strands exceed the limits specified in Table 3-1.~~

**Table 3-1 Allowable Strand Damage[1,2,3] 620A Table 3-1 with changes highlighted**

| 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 | | |
| ~~Less than 7~~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 of 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.

### 3.3 Conductor Deformation/Birdcaging

Disturbed wire strands should be restored to approximate their original lay.

**Figure 03-2**

**Acceptable – Class 1,2,3**
- ~~Wire strands have separation (birdcaging, shown by arrow) and do not extend beyond wire insulation outside diameter.~~
- Wire strands have separation (birdcaging, shown by arrow) 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.

### 3.4 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 3-8~~3-9~~).

**Figure 03-10**

**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 3-10).

## 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.

# 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 Section 8.

Criteria for heat shrinkable solder ~~sleeves~~ devices are provided in Sections 8 (Splices) and 15 (Shield Terminations).

The following topics are addressed in this section:

## 4.1 Material, Components and Equipment

### 4.1.1 Material, Components and Equipment - Materials

See 1.13.3.
~~The materials and processes used to assemble/manufacture cable and wire harness assemblies **shall [D1D2D3]** be selected such that their use, in combination, produce products acceptable to this standard.~~

~~When major elements of the proven processes are changed, (e.g., flux, cleaning media or system, solder alloy or soldering system) validation of the acceptability of the change(s) **shall [N1N2D3]** be performed and documented.~~

### 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 ~~Sn60A, Pb36B, and Sn63A which~~ 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.

### 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.

### 4.1.2 Material, Components and Equipment - Gold Removal

Gold **shall [N1P2D3]** be removed from the surface to be soldered when the thickness of gold exceeds 2.5 um (0.0001 in).

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 *Guidelines for Cleaning of Printed Boards and Assemblies* and IPC-AJ-820 *Assembly and Joining Handbook* provide additional information about cleaning processes and materials.

### 4.2.2 Cleanliness - Postsoldering

Solder connections ~~produced using processes and materials that are~~ 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.

## 4.3 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 90º contact angles as typical. The acceptable solder connection **shall [D1D2D3]** must 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) is not to **shall not [D1D2D3]** exceed 90º (Figure 4-1-A, B). As an exception, the solder connection to a termination may exhibit a wetting angle exceeding 90º (see Figure 4-1-C), D) when it is created by the solder contour extending over the edge of the solderable termination area.

**Figure 4-1**

The primary difference between the solder connections created with processes using tin-lead alloys and processes using lead free alloys is related to the visual appearance of the solder. This standard provides visual criteria for inspection of both tin-lead and lead-free connections. Figures specific to lead-free connections will be identified with the symbol shown here:

Acceptable lead-free and tin-lead connections may exhibit similar appearances but lead 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 tin-lead 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 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 lead 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 1.15.5 and 1.20.112.5).

**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., e.g., 4.9.4.

**Figure 4-2**

**Target - Class 1,2,3**

- Solder fillet appears generally smooth and exhibits good wetting of the solder to the parts/wires being joined.
- Outline of the part/wire is discernible.
- Solder at the part/wire being joined has a feathered edge.
- Fillet is concave in shape.
- No blowholes, pinholes or voids.

**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.

**Acceptable - Class 1**
**Process Indicator – Class 2,3**

- Blowholes/pinholes/voids, etc., providing the solder connection meets minimum requirements.

**Defect - Class 1,2,3**

- Solder has not wetted to the termination where solder is required (nonwetting, dewetting).
- Solder coverage does not meet requirements for the termination type.
- Nonsoldered.
- Disturbed solder.
- Cold solder.
- Overheated solder
- Fractured solder.
- Insufficient solder.
- Inclusions (foreign material).
- Solder that violates minimum electrical clearance (e.g., bridges, solder splashes, solder balls, solder peaks).
- Lead or wire extensions that violate minimum electrical clearance.
- Contaminated solder connections (e.g., flux residues after cleaning).
- Solder wicking inhibits required flexibility where required.

**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 - Exposed Surface Finishes**~~

~~Exposed surface finish on wires, leads or terminals is acceptable provided it is not part of the required fillet area.~~

**4.3.2.~~3~~2 Solder Connection - Soldering Anomalies - Partially Visible or Hidden Solder Connections**

Partially visible or hidden solder connections are acceptable provided that the following conditions are met:
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, as defined in IPC-T-50: The application of molten solder to a basis metal in order to increase its solderability.

~~Tinning is primarily performed to assure that the wire/lead to be soldered has a uniform and readily solderable surface. Tinning of stranded wire has the added benefit of bonding the individual wire strands together, thereby allowing the wire to be formed to terminals or attachment points without separation of the individual strands. Limited solder wicking during tinning or soldering of wire is permissible as long as the solder does not extend to a portion of the wire that is required to remain flexible.~~

When wires are tinned using alloys other than those listed in section 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.

The following criteria are applicable if tinning is required:

**Figure 4-4**

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

- Tinned wire pinholes, voids, dewetting/nonwetting exceeding 5% of the area required to be tinned.
- Length of untinned strands from end of wire insulation is greater than 1 wire diameter (D).

**Note**: J-STD-002 Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires provides additional information for assessing this requirement.

~~**Process Indicator – Class 2,3**~~

- ~~Strands are not discernible.~~

## 4.6 Insulation Sleeving

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, 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 2 wire diameters.
- Insulation sleeving is more than 50% wire diameter and not more than 2 wire diameters from the point where the connector terminal enters the connector insert.

**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.

**Figure 4-15**

**Defect – Class 1,2,3**
- Insulation sleeving is damaged, i.e., split (A), charred (not shown).
- Insulation sleeving overlaps the wire insulation by less than 2 wire diameters (B).
- Insulation sleeving is more than 2 wire diameters from the point where the connector terminal enters the connector insert (C).
- Insulation sleeve is loose on the terminal (could slide or vibrate off, exposing more than the allowed amount of conductor or terminal) (D).
- Insulation sleeving prevents movement of floating contact in the insert, when movement is required.

~~**Defect – Class 1,2,3**~~
- ~~Required sleeving is missing.~~

## 4.7 Birdcaged Wire (Soldered)

**Figure 4-16**

**Target - Class 1,2,3**
- No birdcaging.

**Acceptable – Class 1,2,3**
- ~~Wire strands have separation (birdcaging) (see Figure 4-17) but it does not exceed 1 strand diameter and does not extend beyond wire insulation outside diameter.~~
- Wire strands have separation but:
  - do not exceed 1 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 1 strand diameter but do not extend beyond wire insulation outside diameter.~~

**Acceptable – Class 1**
**Defect - Class 2, 3**
- Wire strands:
  - have separation exceeding 1 strand diameter.
  - extend beyond wire insulation outside diameter.

## 4.8 ~~Connection Requirements~~Terminals

The terminal wire wrap summarized in Table 4-1 apply equally to wires and component leads. The criteria associated with each terminal type or connection in clauses 4.8.1 through 4.8.8 apply only to that connection.

**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**

**Table 4-1 Terminal Lead/Wire Placement 610E Table 6-3 except additions highlighted**

| Terminal Type | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| Turret & Straight Pin | <90° Defect | <90° Defect<br>>90° to 180° Process Indicator | Defect <180° |
| Bifurcated | Defect <90° | | |
| Hook | <90° Defect | <90° Defect<br>>90° to 180° Process Indicator | Defect <180° |
| Pierced/Perforated | Makes Contact with Terminal Surface | Defect <90°[1] | |

**Note 1:** When wire does not contact 2 surfaces of the terminal.

~~These criteria apply to both wires and component leads.~~ 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 180º mechanical wrap to effect mechanical connection.

For Class 2 and 3, 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.

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.

Wires connected to terminals **shall [D1D2D3]** have stress relief. For additional stress relief criteria see 4.8.7, 6.2.6, 6.2.8, 15.3.3, 17.3.1 and 17.3.2.

Terminals **shall not [N1D2D3]** be modified to accept oversize 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). The lead or wire **shall [A1P2D3]** continue the curvature of the dress of the lead/wire (see Figure 4-19) and **shall not [A1D2D3]** interfere with the wrapping of other leads or wires on the terminal or overlap itself or each other.

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 is typically stated in general terms to apply to all similar combinations. For example, a solid wire and a ~~multi~~stranded wire connected to turret terminals have the same wrap and placement requirements, but only the ~~multi~~stranded wire could be subject to birdcaging.

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

**Figure 4-19**

**Target - Class 1,2,3**

- ~~100% solder fillet around wire/lead and terminal interface (full extent of wrap).~~
- ~~Solder wets the wire/lead and terminal and forms a discernible fillet feathering out to a smooth edge.~~

~~Wire/lead is clearly discernible in the solder connection.~~

- Solder fillet flows to 100% of the wire/lead and terminal interface (full extent of wrap).
- Height (climb on wire) of solder is greater than 75% of wire diameter.
- Solder wets the wire/lead and terminal and forms a discernible fillet feathering out to a smooth edge.
- Wire/lead is clearly discernible in the solder connection.

**Acceptable - Class 1,2,3**

- ~~Solder fillet is at least 75% of the circumference of the wire/lead and terminal interface.~~
- ~~Height of solder is greater than 75% of wire diameter in the wire to post contact area.~~
- Solder fillet at least 75% of the wire/lead and terminal interface.
- Height (climb on wire) of solder is greater than 50% of wire diameter.
- Wire/lead is discernible in solder.

**Figure 4-20**

**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 ~~greater than~~deeper than 50% of wire radius (r).
- Height (climb on wire) of solder is less than 25% of wire diameter (D).

**Process Indicator - Class 2**
**Defect – Class 3**

- Height (climb on wire) of solder greater than 25% but less than 50% of wire diameter (D).

**Defect – Class 3**

- Depression of solder between the post and the wrap of the wire is ~~greater than~~deeper than 25% of wire radius (r).

**Defect - Class 1,2,3**
- Solder fillet is less than 75% of the circumference of the wire/lead and terminal interface.

## 4.8.1 ~~Connection Requirements - Turret Terminals~~Terminals – Turrets and Straight Pins

The requirements of 4.3 and 4.8 also apply to this terminal.

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

Table 4-2 is applicable to leads and wires attached to turret and straight pin terminals.

**Table 4-2 Turret and Straight Pin Terminal Lead/Wire Placement 610E Table 6-4 including notes; highlights new**

| 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 AWG 30 and smaller wires.

**Figure 4-23**

**Acceptable - Class 1**
~~**Process Indicator - Class 2**~~
**Defect – Class 2,3**
- ~~Wire end overlaps~~Wire overlaps itself.

**Process Indicator - Class 2**
- Wrap for round posts 90º to less than 180º of contact between the wires and the terminal.

**Defect – Class 1,2**
- Wrap for round posts has less than 90º 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.

## ~~4.9.1 Solder Connection - Turret Terminals~~ 4.8.1.2 Terminals – Turrets and Straight Pins – Solder

**Figure 4-24**

**Figure 4-25**

**Target - Class 1,2,3**
- Lead outline is discernible, smooth flow of solder on wire and terminal.
- Solder fillet at all points of wire/lead and terminal interface.

**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 180º.

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

**Figure 4-26**

**~~Defect - Class 1,2,3~~**
- ~~Poor wetting.~~
- ~~Less than 100% fillet of the lead to terminal contact when the wrap is less than 180º.~~
- ~~Less than 75% fillet of the lead to terminal contact when the wrap is 180º or more.~~

**Defect – Class 1,2**
- 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 180º or more.

**4.8.2 Terminals – Bifurcated~~Connection Requirements - Bifurcated Terminals~~**

The requirements of 4.3 and 4.8 also apply to this terminal.

**4.8.2.1 ~~Connection Requirements - Bifurcated Terminals~~ Terminals - Bifurcated – Lead/Wire Placement - Side Route ~~Attachments~~**

Table 4-3 is applicable to leads and wires attached to side-route bifurcated terminals.

**Table 4-3 Bifurcated Terminal Lead/Wire Placement – Side Route 610E Table 6-5. some cells merged, highlighted new**

| Criteria | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| $<90^{O}$ wrap | Defect | | |
| $\geq 90^{O}$ wrap | Acceptable | | |
| >360° and wire overlaps itself | Acceptable | Defect | |
| ~~Violates Minimum Electrical Clearance~~ | ~~Defect~~ | | |

**Figure 4-27**

**Target - Class 1,2,3**

- The wire or lead contacts 2 parallel faces (180° bend) of the terminal post.
- ~~The cut end of the wire contacts the terminal.~~
- No overlapping of wraps.
- Wires placed in ascending order with largest on the bottom.
- Multiple wire attachments alternate terminal posts.

**Figure 4-29**

**Acceptable - Class 1**
**Process Indicator - Class 2**
**Defect - Class 3**

- Any portion of the wrap extends above the terminal post.

~~Wire/lead < 0.75 mm [0.0295 in] in diameter is wrapped around a post less than 90º~~.

**Acceptable - Class 1**
**Defect - Class 2,3**

- Wire overlaps itself.

**Figure 4-30**

**Defect – Class 3**

- Wire/lead ≥ 0.75 mm [0.0295 in] in diameter is wrapped less than 90º 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 <0.75 mm [0.0295 in] in diameter is wrapped around a post less than 90º.

**4.8.2.2 ~~Connection Requirements - Bifurcated Terminals~~ Terminals - Bifurcated – Lead/Wire Placement - Bottom and Top Route ~~Attachments~~**

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

**Table 4-4 Bifurcated Terminal Lead/Wire Placement – Bottom Route 610E Table 6-5**

| Criteria | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| <90$^{O}$ wrap | Acceptable | Process Indicator | Defect |
| 90$^{O}$ to 180$^{O}$ wrap | | Acceptable | |

**4.8.2.3 ~~Connection Requirements - Bifurcated Terminals~~ Terminals - Bifurcated – Lead/Wire Placement – Staked/Constrained Wires**

As an alternative to wrap requirements of 4.8.2.1, the following criteria apply to wires/leads/components that are staked, bonded or otherwise constrained to provide support for the solder connection.

**Figure 4-34**

**Target - Class 1,2,3**

- Wire is permanently staked or constrained by a permanent mounting device.
- Wire contacts base of terminal or the previous wire.
- Wire extends through posts of bifurcated terminal.
- ~~Wire extends beyond the eye of the pierced/perforated terminals.~~
- ~~Wire contacts 2 sides of pierced/perforated terminals.~~

~~**Acceptable – Class 1,2**~~

- ~~Wires or leads ≥ 0.75 mm [0.0295 in] and wrapped less than 90º are not staked.~~

**Acceptable – Class 1**
**Process Indicator – Class 2**
- Wires or leads < 0.75 mm [0.0295 in] and wrapped less than 90° are not staked.

Figure 4-35

**Acceptable – Class 1**
**Process Indicator – Class 2**
**Defect – Class 3**
- Any straight throughwire less than 90° wrap is not staked, bonded or otherwise constrained.

**Defect - Class 1,2,3**
- When required, the wire is not staked or component body not bonded to board or adjacent surface or retained by a mounting device.

**4.9.2 Solder Connection - Bifurcated Terminals 4.8.2.4 Terminals - Bifurcated – Solder**

**4.8.3 Connection Requirements Terminals - Slotted Terminals**

The requirements of 4.3 and 4.8 also apply to this terminal.

**4.8.3.1 Terminals - Slotted – Lead/Wire Placement**

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**
- Lead end not discernible on exit side of terminal.
- 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 4-46**

**Acceptable – Class 1,2,3**
- Solder fills terminal slot.
- Lead or wire end is discernible in the solder on the exit side of terminal.

**Acceptable - Class 1**
**Process Indicator - Class 2**
**Defect - Class 3**
- Lead end not discernible on exit side of terminal

**Figure 4-47**

**Defect – Class 1,2,3**
- Fillet not formed with 100% of the portion of the wire that is in contact with the terminal (not shown).
- Lead or wire end not discernible on exit side of terminal.

### 4.8.4 Connection Requirements Terminals – Pierced/Perforated/Punched Terminals

The requirements of 4.3 and 4.8 also apply to this terminal.

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

Table 4-5 is applicable to leads and wires attached to pierced or perforated terminals.

**Table 4-5 Pierced or Perforated Terminal Lead/Wire Placement 610E Table 6-8 changes highlighted deleted three rows**

| Criteria | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| <90° wrap | Acceptable | Defect | |
| ≥90° wrap | Acceptable | | |
| Wire overlaps itself | Acceptable | Defect | |
| Wire does not pass through the eye | Acceptable | Defect | |
| Wire does not contact at least 2 surfaces of the terminal. | Acceptable | Defect | |
| Wire end violates minimum electrical clearance | Defect | | |

**Figure 4-48**

**Figure 4-49**

**Figure 4-50**

**Target - Class 1,2,3**
- Wire passes through the eye of the terminal.
- Wire wrapped to contact opposite sides 2 surfaces of the terminal.

**Acceptable Class 2,3**
- Wire wrap equal to or greater than 90º or wire contacts 2 surfaces of the terminal (see Figure 4-50 bottom view).

**Figure 4-51**

**Acceptable - Class 1**
**Defect - Class 2,3**
- Wire wrap less than 90° and or wire does not contact 2 nonadjacent sides surfaces of the terminal.
- Wire does not pass through the eye of the terminal (not shown).

**Acceptable - Class 1**
**Defect Process Indicator - Class 2,3**
- Wire end overlapsWire overlaps itself.

**Defect – Class 2,3**

- Terminal altered to accept oversize wire or wire group.

Strands not in conformance with Table 3-1.

**Defect - Class 1,2,3**
- Wire end violates minimum electrical clearance to noncommon conductor (not shown).
- Strands not in conformance with Clause 3.2.

### 4.8.4.2 Terminals – Pierced/Perforated/Punched – Solder

**Figure 4-53**

**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 180º or more.
- Solder fillet joins the wire to the terminal for 100% of the wire and terminal interface for wraps <180º.

**Acceptable – Class 1**
**Process Indicator – Class 2,3**

- Wire/lead not discernible in solder connection.

~~**Defect - Class 1,2,3**~~

- ~~Solder dewetted from terminal.~~
- ~~Solder contact angle greater than 90 °.~~
- ~~Less than 100% fillet of the lead to terminal contact when the wrap is less than 180º.~~
- ~~Less than 75% fillet of the lead to terminal contact when the wrap is 180º or more.~~

**Figure 4-54**

**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 180º.
- Less than 75% fillet of the lead to terminal contact when the wrap is 180 º 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 ~~Connection Requirements~~Terminals - Hook ~~Terminals~~

The requirements of 4.3 and 4.8 also apply to this terminal.

### 4.8.5.1 Terminals - Hook – Lead/Wire Placement

Table 4-6 is applicable to leads and wires attached to hook terminals.

**Table 4-6 Hook Terminal Lead/Wire Placement ~~as~~ 610E Table 6-9, periods at end of criteria column**

| 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 the lead/wire and terminal post. | Acceptable | | |
| Wire overlaps itself. | Acceptable | Defect | |
| Distance less than 1wire diameter from end of hook to closest wire. | Acceptable | Process Indicator | Defect |
| Wire attached outside the arc of the hook and less than 2 lead diameters or 1 mm [0.039 in], whichever is greater, from the terminal base. | Acceptable | Process Indicator | Defect |

**Figure 4-57**

**Acceptable - Class 1**
**Process Indicator - Class 2**
**Defect - Class 3**
- Wire is wrapped less than 1 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 2 lead diameters or 1.0 mm [0.039 in], whichever is greater, from the base of the terminal.

**Acceptable - Class 1**
**Defect ~~Process Indicator~~ - Class 2,3**
- ~~Wire end overlaps~~Wire overlaps itself.

**Defect – Class 1,2**
- Wire wrap is less than 90º.

**Defect - Class 1,2,3**
- Wire end violates minimum electrical clearance to noncommon conductor.

## 4.8.5.2 Terminals - Hook – Solder

**Figure 4-58**

**Target - Class 1,2,3**
- Lead outline is discernible; smooth flow of solder on wire and terminal.
- Solder fillet at all points of wire/lead and terminal interface.

**Figure 4-59**

**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 180º 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 180º.

**Acceptable – Class 1**
**Process Indicator – Class 2,3**
- Wire/lead not discernible in solder connection

~~**Defect - Class 1,2,3**~~
~~Solder contact angle greater than 90 °.~~
~~Less than 100% fillet of the lead to terminal contact when the wrap is less than 180º.~~
~~Less than 75% fillet of the lead to terminal contact when the wrap is 180º or more.~~

**Figure 4-60**

**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 180º.

**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 º or more.

### 4.8.6 ~~Connection Requirements~~Terminals - Cup ~~Terminals~~

The requirements of 4.3 and 4.8 also apply to this terminal.

#### 4.8.6.1 Terminals - Cup – Lead/Wire Placement

**Figure 4-61**

**Target - Class 1,2,3**

- Solder cups ~~having~~ have the wire(s) inserted straight in and contact the back wall or other inserted wires for the full depth of the cup.

**Figure 4-62**

**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.
- ~~Conductor strands not cut or modified to fit into the terminal.~~
- Multiple conductors are not twisted together.

**Acceptable – Class 1**
**Process Indicator - Class 2,3**

- Wire does not contact the back wall for the full depth of the insertion.

~~**Acceptable - Class 1**~~
~~**Defect - Class 2,3**~~

- ~~Solder cup altered to accept oversized wire or wire group.~~

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

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

**Defect - Class 1,2,3**

- Strand damage exceeds allowance of Clause 3.2.
- Wire strands outside of the cup.
- Wire placement interferes with subsequent assembly operations.
- Multiple conductors are twisted together.
- ~~Wire not inserted to the full depth of the cup. (Not visually inspectable; determined through process control.)~~

### 4.8.6.2 Terminals - Cup – Solder

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

**~~Defect - Class 2,3~~**
- ~~Solder buildup on the outside of the cup affects form, fit, function or reliability.~~
- ~~Solder vertical fill less than 75%.~~

**Figure 4-67**

**Figure 4-68**

**Defect - Class 1,2,3**
- Solder vertical fill less than 75%.
- Solder buildup on outside of the cup negatively affects form, fit or function.
- Solder not visible in the inspection hole (if one is provided).

**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 ~~Connection Requirements~~ - Series Connected ~~Terminals~~

The requirements of 4.3 and 4.8 also apply to this terminal.

When a common bus wire connects 3 or more terminals, the end terminals **shall [D1D2D3]** meet the required wrap for individual terminals. Solder criteria are based on the individual terminal attachment.

**Figure 4-69**

**Target - Class 1,2,3**
- Stress relief provided between each terminal.
- ***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 2 nonadjacent sides of each terminal.

**Figure 4-70**

**Defect - Class 1,2,3**
- No stress relief between any 2 terminals (arrows).

## 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 one1 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 [D1D2D3]** be cut or modified in any manner to reduce circular mil area (CMA) to fit a termination. Contacts **shall not [D1D2D3]** 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 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 drawing or by manufacturing engineering and documented in the process. Any material used for CMA buildup **shall [N1D2D3]** be specified on the drawing.

All crimping needs to comply with the terminal manufacturer's2 published requirements, e.g. crimp height, pull test, etc., without regard to the specific tooling used. For 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.

~~The terminal manufacturer's recommended tooling should be used to crimp the terminal. 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. Alternate tooling may be used if there is objective evidence available to show validity of the alternate process.~~

~~**Process Controls**~~

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.

The following topics are addressed in this section:
**5.1 Stamped and Formed - Open Barrel**
5.1.1 Insulation Support ~~Crimp~~
5.1.1.1 Inspection Window
5.1.1.2 Crimp

## 5.1 Stamped and Formed - Open Barrel

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

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

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 ~~circular mil area~~CMA range for the terminal.

## 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 5-5**

**Figure 5-6**

**Defect – Class 1,2,3**
- Insulation extends into conductor crimp area (see Figure 5-5~~11~~, arrow points to end of insulation within the crimp area).
- Insulation and conductor transition line is not visible within the insulation inspection window~~insulation crimp area~~ (see Figure 5-6~~12~~, arrow points to end of insulation within the crimp area).

## 5.1.1.2 Stamped and Formed - Open Barrel - Insulation Support - Crimp

**Figure 5-9**

**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 both at least one tabs 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.

**Figure 5-10**

**Figure 5-11**

**Figure 5-12**

**Defect – Class 1,2,3**

- The insulation crimp tabs pierce the insulation (see Figure 5-105).
- The insulation crimp tabs do not provide support at least 180º around the insulation (see Figure 5-105).
- Both insulation crimp tabs are not in contact with the top of the insulation ( Figure 5-6) At least one tab does not contact the top of the wire insulation..
- The second tab does not contact either 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 5-11106).
- Insulation crimp tabs that encircle the wire, but leave an opening of more than 45° at the top (see Figure 5-127).

**5.1.2 Stamped and Formed – Open Barrel - Insulation Windowmoved to beginning of clause**

**5.1.25.1.2.2 Stamped and Formed – Open Barrel – No Insulation Clearance if No Support Crimp - Insulation Clearance**

**Figure 5-13**

**Target – Class 1,2,3**

- Less than 50% overall wire diameter (D) clearance (C) between the insulation and contact barrel.

**Acceptable – Class 2,3**

- Conductor is visible between the insulation and contact barrel but no greater than 1 wire diameter.

**Acceptable – Class 1**
**Process Indicator – Class 2,3**

- Insulation is flush to the end of the contact barrel.
- Insulation is greater than 1 but less than 2 wire diameters from the end of the contact barrel.
- Insulation is flush with but does not enter the wire crimp area.

**Defect – Class 2,3**

- Insulation is greater than 2 wire diameters from the end of the contact barrel.

**5.1.3 Stamped and Formed – Open Barrel - Conductor Crimp**

These criteria apply to stamped and formed contacts with insulation support (see Figure 5-14) or without (see Figure 5-15).

Figure 5-14 identifies the conductor crimp area.

**Figure 5-17**

**Defect – Class 1,2,3**

- Insulation extends into conductor crimp area (see Figure 5-175-15, arrow points to end of insulation within the crimp area).
- Conductor end does not meet requirements of 5.1.5 (Figure 5-16).
- Deformation (banana) of the contact/terminal that affects form, fit, function or reliability (see Figure 5-1817).
- Any loose conductor strands that are outside the crimp area, trapped strands, folded back strands (see Figure 5-1918).

**5.1.5 Stamped and Formed – Open Barrel - Conductor Brush**

Figure 5-2422 identifies the conductor brush area.

**Figure 5-25**

**Acceptable – Class 1,2,3**

- The conductor end is flush to the end of the bellmouth conductor crimp area (see Figure 5-23 5-25-1). (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 5-23 5-25-2).(2)).

**Figure 5-26**

**Figure 5-27**

**Defect – Class 1,2,3**

- Wire end is less than flush to the end of the bellmouthconductor crimp area (see Figure 5-26).
- Any conductor strands extending beyond the outer perimeter of the crimp barrel (see Figures 5-27, 28).5-25, 5-26).
- The conductor strands extend into the mating area of the contact (see Figure 5-29).Figures 5-27, 5-28.).

**5.2.1 Stamped and Formed – Closed Barrel – Insulation Clearance**

The following criteria are applicable to uninsulated closed barrel contacts.

**Figure 5-34**

**Acceptable – Class 1,2,3**

- Insulation is flush to less than 1 wire diameter from the entry bellmouth.

**Process Indicator – Class 2,3**

- Insulation is greater than 1 but less than 2 wire diameters from the entry bellmouth.

**Figure 5-35**

**Defect – Class 1,2,3**

- Insulation is greater than 2 wire diameters from the entry bellmouth.
- Insulation enters barrel of terminal.

## ~~5.2.1~~5.2.2 Stamped and Formed – Closed Barrel – Insulation Support Crimp

**Figure 5-37**

**Acceptable – Class 1,2,3**
- Irregular shaped insulation crimp contacts the wire insulation providing support (A, B, C).
- Wire insulation crimp 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 (D) is within the insulation crimp and does not extend beyond the outer lug insulation.

**Figure 5-38**

**Defect –Class 1,2,3**
- The wire insulation is not within the insulation crimp area~~.~~ (see Figure 5-38-A).
- Wire insulation damage exceeds the criteria of 3.5. ~~(B)~~
- Outer insulation of terminal is not secure on the terminal~~.~~ (see Figure 5-38-C).
- Filler wire extends beyond the terminal insulation~~.~~ (see Figure 5-38-D).
- No evidence of deformation of the insulation support crimp.
- ~~Insulation support crimp (with metal support) does not support the wire. (E)~~
- Wire strands folded back or visible in the insulation crimp~~.~~ (see Figure 5-38-F).

## 5.3.1 Machined Contacts - Insulation Clearance

**Figure 5-45**

**Acceptable – Class 2,3**
- Conductor is visible between the insulation and contact barrel but no greater than 1 wire diameter.

~~**Acceptable – Class 1**~~
~~**Process Indicator – Class 2,3**~~
- ~~Insulation is flush to the end of the contact barrel.~~

**Figure 5-46**

**Acceptable – Class 1**
**Process Indicator – Class 2,3**
- Insulation is flush to the end of the contact barrel.
- Insulation is greater than 1 but less than 2 wire diameters from the end of the contact barrel.

## 5.3.3 Machined Contacts - Conductor ~~Location~~

This section is applicable to all machined crimp contacts.

**Figure 5-54**

**Target – Class 1,2,3**

- Conductor bottomed in the contact.
- Conductor strands fill the inspection window.
- ~~No conductor strands outside of the contact.~~

## 5.3.4 Machined Contacts - Crimping

**Figure 5-62**

**Figure 5-63**

**Acceptable– Class 1**
**Defect – Class 2,3**

- <u>The crimp indent is outside the crimp area (see Figure 5-62).</u>
- Wire entry end of the barrel is deformed by the crimp<u> (see Figure 5-63)</u>.
- ~~The crimp indent is outside the crimp area.~~

**Figure 5-64**

**Figure 5-65**

**Figure 5-66**

**Defect – Class 2,3**

- The crimp deforms the inspection window.
- Contact has exposed base metal.

~~**Defect – Class 1,2,3**~~

- Wire is not secured by crimp.
- Contact has visible fracture or cracks.
- ~~Double crimping of electrical terminations or connector contacts unless otherwise specified.~~
- Contact barrel is deformed or bent.

## 5.3.5 Machined Contacts - CMA Buildup

**Figure 5-69**

**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 base 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 (red arrow).
- The flair or splay of any fill conductor does not extend past or exceed the contact diameter.

~~**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.~~

**Figure 5-70**

**Defect - Class 2,3**

- Fill conductor extends beyond the contact more than one wire diameter of the primary wire.
- ~~Fill conductor extends beyond the insulation 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 5-71**

**Figure 5-72**

**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.

## 5.4 Termination Ferrule Crimp

Termination ferrules are intended to terminate stranded wires for insertion into terminal blocks.

# 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.

It is also recognized that in some insulation displacement 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 End Cutting
6.1.2 Notching
6.1.3 Planar Ground Plane Removal
6.1.4 Connector Position
6.1.5 Connector Skew & Lateral Position
6.1.6 Retention

**6.2 Discrete Wire Termination**
6.2.1 General
6.2.2 Position of Wire
6.2.3 Overhang (Extension)
6.2.4 ~~Wire Holder~~Insulation Crimp
6.2.5 Damage in Connection Area
6.2.6 End Connectors
6.2.7 Pass Through Connectors
6.2.8~~6.2.7~~ Wiremount Connectors
6.2.9~~6.2.8~~ Subminiature D-Connector (Series Bus Connector)
6.2.10~~6.2.9~~ Modular Connectors (RJ Type)

## 6.1.4 Mass Termination, Flat Cable - Connector Position

**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.
- Strain relief (cover) installed backwards (Figure 6-12).

## 6.2.6 Discrete Wire Termination - End Connectors

**Figure 6-36**

**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.
- Exposed conductors do not violate minimum electrical clearance.
- Wire extends at least 50% of the distance between the contact edge and the back wall of the connector.

**Figure 6-37**

**Figure 6-38**

**Defect - Class 1,2,3**

- Wire stripped or partially stripped before being inserted into the connector.
- Wire not within retaining tabs.
- 2 wires into a single contact unless the contact or connector specifications indicate that this is acceptable.
- Deformation of the connector body. due to wires with oversize insulation.
- Insufficient stress relief on wires entering connector.
- Wire size does not meet match connector sizeparameters.
- Wire not fully seated in both sets of v-notches of the IDC contact.
- The wire extends less than 1 wire diameter out of the rear contact.
- Length (L) of the wire past the electrical (second) contact is equal or greaterless than 50% overall wire diameter.
- Broken retaining tab(s) on the connector.

| 6.2.7 Discrete Wire Termination – Pass Through Connectors | |
|---|---|

**Figure 6-39**

**Figure 6-40**

**Target - Class 1,2,3**

- Wire fully seated into the contact.
- Wire passes through the connector uninterrupted.
- Bare conductor not visible.

**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.
- 2 wires into a single contact unless specified.
- Deformation of the connector body due to wires with oversize insulation.
- Wire size does not match connector.
- Wire not fully seated in both sets of v-notches of the IDC contact.
- 2 wires spliced together mechanically by IDC contact.

## 6.2.8 6.2.7 Discrete Wire Termination - Wiremount Connectors

## 6.2.9 6.2.8 Discrete Wire Termination - Subminiature D-Connector (Series Bus Connector)

**Figure 6-46**
**Figure 6-47**
**Figure 6-48**
**Figure 6-49**

**Defect – Class 1,2,3**

- Wire recessed (Figure 6-44). is less than flush (not visible in the free space beyond the cover plate) (see Figure 6-46).
- Wire is bent upwards in the free space over the top of the connector body (see Figure 6-47 6-45).
- Termination cover plate is broken or deformed (see Figures 6-48, 49 6-46, 47).
- Contact base 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).

## 6.2.10 6.2.9 Discrete Wire Termination - Modular Connectors (RJ Type)

# 7 Ultrasonic Welding

## 7.1 Insulation Clearance

## 7.2 Weld Nugget

**Figure-7-7**

**Defect – Class 1,2,3**

- Any loose wire strands.

~~**Defect – Class 1,2,3**~~

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

# 8 Splices

~~Using~~ Splices **shall not [N1D2D3]** be used to repair broken or damaged conductors ~~is not permitted for Classes 2 and 3~~ 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 Section 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 1 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 1 end of the wire to limit the splice to just 1 splice. If necessary, replace 1 section of the wire, which may require 2 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 Section 5 apply.

~~Wire bulges will not pierce the sleeving under normal circumstances. Wire peaks may pierce the sleeving under normal circumstances.~~

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
~~4.9 Solder Connection~~
16.2 Sleeving/Shrink Tubing

The following topics are addressed in this section:
**8.1 Soldered Splices**
8.1.1 Mesh
8.1.2 Wrap
8.1.3 Hook
8.1.4 Lap
8.1.4.1 Two or More Conductors
8.1.4.2 Insulation Opening (Window)
8.1.5 Heat Shrinkable Solder Devices

**8.2 Crimped Splices**

8.2.1 Barrel
8.2.2 Double Sided
8.2.3 Contact
8.2.4 Wire In-Line Junction Devices (Jiffy Junctions)

**8.3 Ultrasonic Weld Splices**

## 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 1 diameter of the wire group.

When wires are tinned using alloys other than those listed in section 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 Clauses 3, 4.1 through 4.4, 4.5.2 and 16.2 are applicable to soldered wire splices.

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

### 8.1.1 Soldered Splices - Mesh

Meshed splices use the least amount of wire. Each wire should have insulation removed exposing from 3 to 5 wire diameters of the stranded wire (see Figure 8-1). 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**

**Figure 8-2**

**Acceptable – Class 1,2,3**

- Interlocking of conductor strands into a smooth joined section for a minimum of 3 but not more than 5 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 1 wire diameter.
- Sleeve or wire insulation is slightly discolored but not ~~burned or~~ charred.

**Figure 8-3**

**Process Indicator – Class 2,3**

- Wire bulges the sleeving but does not pierce it.

**Figure 8-4**

**Figure 8-5**

**Defect – Class 1,2,3**

- Conductor strands interlock less than 3 wire diameters.
- Insufficient solder fillet.
- Wire splice area is exposed.
- Sleeving is loose (not shown).
- Conductor strands or sharp points pierce the sleeving.
- Sleeving does not overlap wire insulation (on both ends) a minimum of 1 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 3 wraps (not twists) of each wire around the other.

**Figure 8-6**

**Figure 8-7**

**Figure 8-8**

**Figure 8-9**

**Figure 8-10**

**Figure 8-11**

**Acceptable – Class 1,2,3**

- Interlocking of 2 wires into a smooth joined section for a minimum of 3 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 1 wire diameter.
- Sleeve or wire insulation is slightly discolored but not charred.

**Process Indicator – Class 2,3**

- Wire bulge in the sleeving does not pierce it.

**Defect – Class 1,2,3**

- Less than 3 wraps of each conductor.
- Insufficient solder fillet.
- Wire splice area is exposed.
- Sleeving is loose (not shown).
- Conductor strands or sharp points pierce the sleeving.
- Sleeving does not overlap wire insulation (on both ends) a minimum of 1 wire diameter.
- Sleeve or wire insulation is charred.
- Sleeving is split or damaged.

## 8.1.3 Soldered Splices - Hook

**Figure 8-12**

**Acceptable – Class 1,2,3**

- Interlocking of 2 conductors into a smooth joined section for a minimum of 3 wraps (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 1 wire diameter.
- Sleeve or wire insulation is slightly discolored but not charred.

**Figure 8-13**

**Process Indicator – Class 2,3**

- Wire bulges the sleeving but does not pierce it.

**Figure 8-14**

**Figure 8-15**

**Defect – Class 1,2,3**

- Less than 3 wraps of each conductor.
- Insufficient solder fillet.
- Wire splice area is exposed.
- Sleeving is loose (not shown).
- Conductor strands or sharp points pierce the sleeving.
- Sleeving does not overlap wire insulation (on both ends) a minimum of 1 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 2 or more conductors overlap, are parallel and soldered. These criteria apply to in-line wire lap splices (see Figure 8-16) 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 3 wire conductor diameters (see Figure 8-1614). Conductors should be in full contact and parallel (no twisting of the conductors). Conductors **shall not [N1D2D3]** overlap the insulation of the other wire.

While overwrapping of a lap splice with a smaller diameter wire (see Figure 8-1716), sometimes 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 drawing.

Solder **shall [D1D2D3]** wet all elements of the required termination forming a visible solder fillet. joining the wires for the length of the overlapped area of the splice. Individual wire strands should remain discernible.

### 8.1.4.1 Soldered Splices - Lap – Two or More Conductors

**Figure 8-16**
**Figure 8-17**
**Figure 8-18**

**Acceptable - Class1,2,3**

- Wires overlap at least 3 wire conductor diameters.
- If required, splice is overwrapped with smaller diameter wire (see Figures 8-17, 18).
- 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 wire conductor strands are discernible.

**Figure 8-19**
**Figure 8-20**
**Figure 8-21**
**Figure 8-22**

**Acceptable - Class1,2,3**

- Sleeving overlaps the wire insulation on both ends of the spliced area by a minimum of 1 wire group (largest group) diameter (see Figure 8-19).
- The sleeving or insulation may be discolored but not burncharreded or charred.
- End splice insulating shrink sleeving is less than 2 wire group diameters beyond the cut end and is sealed (see Figure 8-20).
- End splice insulating shrink sleeving is greater than 2 wire group diameters beyond the cut end (see Figure 8-22).(not shown)

**Figure 8-23**

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

- End splice insulating shrink sleeving overlaps the wire less than 1 diameter of the wire group (not shown).
- End splice insulating shrink sleeving is not sealed when it is less than 2 wire group diameters beyond the cut end (see Figure 8-23).

**Figure 8-24**

**Process Indicator - Class 2,3**

- Wire bulges the sleeving but does not pierce it.

**Figure 8-26**

**Defect – Class 1**

- No evidence of solder wetting.

**Defect – Class 2**

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

**Defect – Class 3**

- Solder fillet less than 100% of the length of the overlap interface.

**Figure 8-27**

**Figure 8-28**

**Defect - Class 1,2,-3**

- Wires do not overlap a minimum of 3 conductor diameters of the largest wire.
- Conductor overlaps insulation of the other wire.
- ~~Bulges in the sleeving.~~
- ~~Sharp points or projections.~~
- ~~Conductor strands pierce the sleeving.~~
- ~~Sleeving is burned/charred, split or damaged (not shown).~~
- ~~Conductor overlaps insulation of the other wire.~~
- Insufficient solder fillet.
- Wire splice area is exposed.
- Sleeving is loose (not shown).
- Conductor strands or sharp points pierce the sleeving.
- ~~Sleeving is split or damaged (not shown).~~
- Sleeving does not overlap the insulation on both ends of the spliced area by a minimum of 1 wire group (largest group) diameter.
- Sleeve or wire insulation is charred.
- Sleeving is split or damaged.

## 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. ~~When a shrink sleeve is 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.~~

**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.
- ~~Solder preform (ring) is fully melted with a visible fillet between the wire and pickoff wire.~~
- ~~Conductor contour is discernible.~~
- ~~Meltable sealing rings, if present, have flowed.~~
- ~~No wire strands are exposed.~~
- ~~Sleeve is not split or damaged.~~
- ~~Sleeve or wire insulation may show slight discoloration.~~

**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.

~~**Figure 8-23**~~

~~1. Meltable Sealing Ring(s)~~
~~2. Pickoff Wire~~
~~3. Solder Preform (solder ring)~~

~~**Figure 8-24**~~

~~**Figure 8-25**~~

~~**Figure 8-26**~~

~~**Defect – Class 1,2,3**~~

- ~~Conductor overlaps insulation of the other wire (Figures 8-25, 26).~~
- ~~The solder preform (ring) is not fully melted (Figures 8-25, 26).~~
- ~~No visible fillet between the wire and pickoff lead (not shown).~~
- ~~Conductor contour is not discernible(not shown).~~
- ~~Meltable sealing rings, if present, have not flowed (not shown).~~
- ~~Wire stands are exposed (not shown).~~
- ~~Sleeve or wire insulation burnt or charred (not shown).~~
- ~~The sleeve does not meet minimum overlap requirements (not shown).~~

## 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.

~~Terminations made using heat shrinkable solder devices are exempt from the cleaning requirements.~~

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**
**Figure 8-31**
**Figure 8-32**

**Acceptable – Class 1,2,3**

- 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 1 wire diameter.
- No conductor strands piercing the sleeving.
- Sleeve is discolored but not ~~burned or~~ charred.
- Meltable sealing ring does not interfere with formation of required solder connection.
- Meltable sealing ring provides 360º of seal at both ends.
- ~~Solder preform (ring) is fully melted with a visible fillet between the wire and pickoff wire.~~
- 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.

**Figure 8-33**
**Figure 8-34**
**Figure 8-35**
**Figure 8-36**
**Figure 8-37**

**Defect – Class 1,2,3**

- Solder fillet not wetted to both wires.
- The solder preform ring is not fully melted (see Figures 8-33, 34).
- There are sharp points or projections.
- Conductor strands pierce the sleeving.
- Wires do not overlap at least 3 conductor diameters.
- Sleeving does not cover wire insulation on both ends at least 1 wire diameter (see Figure 8-35).
- Meltable sealing ring interferes with formation of required solder connection.
- Meltable sealing ring does not provide 360º of seal at either end.
- Sleeving or wire insulation is burncharreded or 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).

## 8.2.1 Crimped Splices – Barrel

The criteria in this section are applicable to crimped in-line splices, where 2 or more conductors overlap, are parallel and crimped inside a sleeve. These criteria apply to in-line wire splices (see Figure 8-38) or end lap splices (see Figure 8-39). 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 3 wire 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.

Section 16.216.3 provides criteria for shrink sleeving.

**Acceptable – Class 1,2,3**

**Figure 8-40**

- ~~Wire insulation gap is within 2 wire diameters (A).~~

**Figure 8-41**

- Bare wire end is less than flush, but is visible and included in crimp indentation (see Figure 8-40-B).
- Crimp not centered but bellmouth is evident at each end and ends of all conductors are visible (see Figure 8-40-C).
- ~~Crimp slightly offset but properly formed, bellmouth is evident (C).~~
- Barrel splice is not cracked.
- Sleeving, if required, overlaps the wire insulation at least 1 wire/bundle diameter on both sides of the barrel splice.
- End splice insulating shrink sleeving is less than 2 wire group diameters beyond the cut end and is sealed (see Figure 8-43).
- End splice insulating shrink sleeving is greater than 2 wire group diameters beyond the cut end (not shown).
- Does not violate minimum electrical clearance.

**Figure 8-42**

**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 2 wire diameters.
- Conductor ends extend no more than 2 wire diameters beyond crimp barrel.

**Figure 8-43**

**Process Indicator – Class 3**

- Wire insulation gap is more than 1 but less than two wire diameters (see Figure 8-40-A).
- Conductor ends extend more than 1 but less than 2 wire diameters beyond crimp barrel.

~~**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**~~
~~**Process Indicator – Class 3**~~

- ~~Crimp not centered but bellmouth is evident and ends of all conductors are visible.~~.

~~**Defect – Class 2,3**~~
- ~~Heat shrinkable sleeve does not overlap wire insulation on both ends at least 1 wire/bundle diameter (not shown).~~

**Acceptable – Class 1**
**Process Indicator – Class 2**
**Defect – Class 3**
- End splice insulating shrink sleeving overlaps the wire less than 1 diameter of the wire group.
- End splice insulating shrink sleeving is not sealed when it is less than 2 wire group diameters beyond the cut end.

**Figure 8-44**
**Figure 8-45**
**Figure 8-46**

**Defect – Class 1,2,3**
- Insulation gap exceeds 2 wire diameters (see Figure 8-44~~not shown~~).
- Conductors extend greater than 2 wire diameters beyond crimp barrel.
- Wire insulation extends into barrel splice crimp. (not shown).
- Barrel splice is cracked (see Figure 8-45 arrow).
- Crimp indentation is off the end of the barrel splice, bellmouth is not evident (see Figure 8-46).
- 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 overlaps the wire insulation at least 1 wire/bundle diameter on both sides of the barrel splice.
- When required, sleeving is missing.

## 8.2.2 Crimped Splices – Double Sided

**Figure 8-47**

**Figure 8-48**

**Target – Class 1,2,3**

- Ends of wires are visible through the inspection window and are flush to the wire stop (see Figure 8-47-A).
- Bellmouth is evident (see Figure 8-47-B).
- Wire insulation is flush with ends of splice.
- Crimp is centered and properly formed to retain wires.
- Sleeving, if required, is centered on ferrule and overlaps wire insulation a minimum of 1 wire diameter (see Figure 8-48).
- If present, the color-code on heat shrinkable sleeve matches color code on contact (see Figure 8-48-A).
- Meltable sealing rings, when present, have flowed.

**Figure 8-49**

**Acceptable – Class 1,2**

- Wire insulation gap is less than 2 wire diameters at both ends.

**Figure 8-50**

**Figure 8-51**

**Acceptable – Class 1,2,3**

- Ends of wires are visible through the inspection window ~~and are flush to the wire stop~~ (see Figure 8-49, arrows).
- ~~Wire insulation gap is less than 2 wire diameters including insulation.~~
- Bellmouth is evident.
- Wire insulation gap is within 2 wire diameters including insulation on both ends, (not shown).
- Heat shrinkable sleeve ends are sealed to the wire insulation (no wire strands are exposed)~~.~~ when heat shrinkable sleeving has sealing rings.
- Crimp indents on seamless splices are rotated (see Figure 8-51) (seamless splices only).

**Figure 8-52**

**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 8-52).

**Process Indicator – Class 3**

- Wire insulation gap is greater than 1 but less than 2 wire diameters at either end.

**Figure 8-53**
**Figure 8-54**
**Figure 8-55**

**Defect – Class 1,2,3**

- Wire insulation extends into the wire crimp barrel (see Figure 8-53-A).
- Crimp indent is off the end of the splice (see Figure 8-53-B).
- Wire end(s) are not visible through the inspection window(s) (see Figure 8-53-C).
- Wire insulation gap is greater than 2 wire diameters including insulation (see Figure 8-53-D).
- Sleeving, if required, does not overlap wire insulation at least 1 wire diameter on both ends (not shown).
- Wire strands extend out of inspection window (see Figure 8-54).
- Wire strands have pierced the heat shrinkable sleeve (see Figure 8-55).
- Multiple conductors twisted together before insertion into the ~~contact~~crimp barrel (not shown).

### 8.2.3 Crimped Splices – Contact

These criteria apply to crimped end lap splices formed in a machined contact (see Figure 8-56). 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 8-56**
**Figure 8-57**

**Target – Class 1,2,3**

- Less than 50% overall wire diameter clearance between the insulation and contact barrel.
- Conductors bottomed in the contact.
- Conductor strands fill the inspection window.
- Crimp indent is centered between the inspection window and the wire entry end of the barrel.
- Crimp indents around the contact barrel are evenly spaced and of equal depth.
- Contact has no visible fractures, cracks, or exposed base metal in the crimp barrel area.
- Machined contact pin cut end does not have sharp edges.

**Figure 8-58**

**Acceptable – Class 1,2,3**
- End splice insulating shrink sleeving is less than 2 wire group diameters beyond the cut end and is sealed.
- End splice insulating shrink sleeving is greater than 2 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.

**Acceptable – Class 2,3**
- Conductors visible between the insulation and contact barrel but no greater than 1 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.

**Acceptable – Class 1**
**Process Indicator – Class 2**
**Defect – Class 3**
- End splice insulating shrink sleeving or cap overlaps the wire less than 1 diameter of the wire group.
- End splice insulating shrink sleeving or cap is not sealed when it is less than 2 wire group diameters beyond the cut end.

**Acceptable – Class 1**
**Process Indicator – Class 2,3**
- Insulation is flush to the end of the contact barrel.
- Insulation is greater than 1 but less than 2 wire diameters from the end of the contact barrel.

**Defect – Class 2,3**
- Contact has visible fractures, cracks, or exposed base 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.

**8.2.4 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 8-59) and then inserted into the in-line junction device as it would be with a rear-entry machined contact connector (see Figure 8-60~~,~~ 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 Chapters 1 (general), 5 (crimp) and 19 (testing).

When the ~~circular mil area~~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 8-59**

**Figure 8-60**

**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.

# 9 Connectorization

When torque requirements are established, see 17.2.

The following topics are addressed in this section:

## 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.

Hardware stack-up for mounted connectors may be varied in order to locate the face of the jackpost flush to ±0.75 mm [0.030 in] below with the face of the connector.

**Figure 9-1**

**Acceptable – Class 1,2,3**

- Jackpost face is flush to ±0.75 mm [0.030 in] below with the face of the connector.
- Height is obtained by adding or removing washers (supplied with jackpost).

**Figure 9-2**

**Figure 9-3**

**Defect – Class 1,2,3**

- Jackpost face extends above the connector face (**620A Figure** 9-2).
- Face of jackpost is more than ±0.75 mm [0.030 in] below with the connector face (see Figure 9-3).

## 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.
- Retaining clip (**620A Figure 9**-NEWE2-A) is properly oriented

**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).
  - o Flat side of retaining clip is not oriented on the mating side of the connector
  - o Upside down (**620A Figure 9**-NEW4)
- 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.

### 9.2.1 Strain Relief – Clamp Fit

Clamps, as specified on the 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.

**Figure 9-12**

**Acceptable – Class 1,2,3**
- Sleeving is flush with the end of clamp (arrow).
- There is space between at least 1 of the inner surfaces of a clamp and the backshell ear on 1 side.
- Spacers, if present, are mounted under the same adapter clamp on both sides of the cable.

**Figure 9-13**

**Figure 9-14**

**Defect – Class 1,2,3**
- Sleeving extension beyond clamp causes stress on the wires (A).
- The split lock washers are not collapsed (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 (not shown).
- 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.

**9.2.2.1 Strain Relief – Wire Dress - Straight Approach**

**Figure 9-17**

**Process Indicator – Class 2,3**
**Defect – Class 3**
- Wire length is excessive outside the contour of the wire bundle (A).

**9.2.2.2 Strain Relief – Wire Dress – Side Approach**

**Figure 9-20**

**Process Indicator – Class 2**
**Defect – Class ,3**
- Wire length is outside the contour of the wire bundle excessive (A).

**9.3.1 Sleeving and Boots - Position**

**Not Established – Class 1**
**Process Indicator – Class 2**
**Defect – Class 3**
- Boot does not extend to the end of the first accessory attachment area.

**9.4.2 Connector Damage - Limits - Hard Face - Mating Surface**

**Figure 9-42**

**Figure 9-43**

**Acceptable – Class 1**
**Process Indicator – Class 2,3**
- Connector face has been chipped but dielectric between seals is intact.
- Chipping does not extend from 1 cavity to the outer diameter of any adjacent cavity.

**Defect – Class 1,2,3**
- Chipping of the dielectric extends from cavity to the outside diameter of any adjacent cavity.
- Crack extends from 1 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 9-46**

**Defect – Class 1,2,3**

- Cut, fracture or tear is in both the dielectric face and the extends beyond cup diameter.
- Cut, fracture or tear that extends from cup through dielectric face or from 1 cup into another.

## 9.5 Installation of Contacts and Sealing Plugs into Connectors

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

Contacts 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 19.7.5). Verification **shall [D1D2D3]** be accomplished prior to addition of any restraining devices, including potting or molding.

## 9.5.1 Installation of Contacts

**Figure 9-50**

**Figure 9-51**

**Figure 9-52**

**Defect – Class 1,2,3**

- Contact is not seated as visible through inspection window, (see Figure 9-50).48.
- Pin or socket is not seated and locked, (see Figure 9-51).49.

**Defect - Class 1,2,3**

- Contact(s) missing when unused positions are required to be filled, (see Figure 9-52).50.

## 9.5.2 Installation of Sealing Plugs

These criteria apply only to a connector cavity with a contact.

# 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, 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 thermoplastic 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.

Thermoset potting is widely used in extremely harsh environments and operating conditions such as the modern battlefield.

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

See 1.13.3 for additional material requirements.

The following topics are addressed in this section:

Table 10-1 is a partial listing of common definitions for molded and potted visual characteristics. This chapter 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 know 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. |

| | |
|---|---|
| **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:<br>1. Thermal stress cracking is caused by prolonged exposure of the part to elevated temperatures or sunlight.<br>2. Physical stress cracking occurs between crystalline and amorphous portions of the part when the part is under an internally or externally induced strain.<br>3. Chemical stress cracking occurs when a liquid or gas permeates the parts surface. All of these types of stress cracking have the same end result the splitting or fracturing of the molding. |
| **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. |
| **Wisps** | Similar to stringing but smaller in size. These also may occur as slight flashing when the mold is over packed or forced open slightly. Mold-parting-line wear or misalignment can also cause wisps. |

## 10.1 Over-Molding

### 10.1.1 Over-Molding – Mold Fill ~~– Initial~~

#### 10.1.1.1 Over-Molding – Mold Fill – ~~Initial~~Inner

This is step one of a multistep molding process.

**Figure 10-1**
**Figure 10-2**

Target – Class 1,2,3
- No sink marks, bubbles or physical abnormalities.
- No exposed wire, foil, insulation, ferrules, braid, etc.
- Inner-molding has no voids or rough edges.
- No flow lines.

**Figure 10-3**
**Figure 10-4**
**Figure 10-5**
**Figure 10-6**

**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).

**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) ~~(short shot)~~.
- Voids greater than 3 mm [0.12 in] length or 2 mm [0.08 in] width or 1.5 mm [0.06 in] depth (see Figure 10-8).
- ~~Voids with sharp edges (not shown).~~

| 10.1.1.2 ~~Molding~~Over-Molding – Mold Fill – ~~Final~~Outer | |
|---|---|

Figure 10-9
Figure 10-10
Figure 10-11

**Target – Class 1,2,3**
- Smooth surfaces, uniform texture (see Figure 10-9).
- ~~Over~~Outer-mold filled completely with no recessions, bubbles, blow-through, voids or other cosmetic or functional abnormalities (see Figure 10-10).
- ~~Smooth surfaces, uniform texture (see Figure 10-9).~~
- Uniform color.
- Part lines discernible but not raised (see Figure 10-11).
- ~~Uniform texture.~~
- No flash.

Figure 10-12
Figure 10-13
Figure 10-14
Figure 10-15

**Acceptable – Class 1,2,3**
- Part has all features required by the drawing or specification.
- All required marking is legible.
- Cosmetic anomalies do not affect form, fit or function (see Figure 10-12, 13).
- Streaking (see Figure 10-14).
- Complete fill.
- Sink marks in material without cracks (see Figure 10-15).

**Acceptable – Class 1,2**
**~~Defect~~ Process Indicator – Class 3**
- Air marks (not shown).

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

**Figure 10-16**
**Figure 10-17**
**Figure 10-18**
**Figure 10-19**

**Defect – Class 1,2,3**

- Voids where ~~over~~outer-molding material should be present (see Figure 10-16).
- Marking is incomplete or not legible (see Figure 10-17).
- Incomplete material fill (see Figure 10-17).
- Sink marks in material with cracks (see Figure 10-18).
- Exposed insulation, sleeving, jacket, braid or foil (see Figure 10-19).

**~~10.1.3~~ 10.1.1.2.1 Over-Molding – Mold Fill – ~~Final~~Outer - Mismatch**

**~~10.1.6~~ 10.1.1.2.2 Over-Molding – Mold Fill – ~~Final~~Outer - Fit**

**Figure 10-22**
**Figure 10-23**

**Target – Class 1,2,3**

- Cable jacket, insulation, sleeve, boot ~~is round with~~ has no deformation~~s~~ or damage (see Figure 10-22).
- ~~Molded~~ Outer-mold material ~~adheres~~ conforms to the entire ~~circumference~~ contour of the wire, sleeving, cable jacket or connector~~,~~ (see Figure 10-23). ~~when required by drawing or specification.~~
- ~~Molded material completely captures the connector body and wire, sleeving or cable jacket.~~

**Figure 10-24**

**Acceptable – Class 1**

- ~~Molding~~ Outer-mold captures 75% of the circumference of the wire or cable jacket.

**Figure 10-25**

**Acceptable – Class 2,3**

- Outer-molding ~~captures~~ conforms to the entire ~~circumference~~ 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 ~~captures~~ 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 circumference contour of the wire, or cable jacket or connector..
- molding material that does not adhere to the entire circumference of the connector body.
- 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.

**Figure 10-26**
**Figure 10-27**

**Defect – Class 1,2,3**

- Wire, sleeving or cable jacket pulled out (pop-out) of over-molding (see Figure 10-26).
- Outer-molded material does not adhere to the circumference of the wire, or cable jacket or connector body when required by drawing or specification, (see Figure 10-276).
- Any gaps between molded material and cable jacket, insulation, sleeve or boot.

**10.1.8 10.1.1.2.3 Over-Molding – Mold Fill – FinalOuter - Cracks, Flow Lines, Chill Marks (Knit Lines), or Weld Lines**

**Figure 10-29**
**Figure 10-30**

**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 10-29).
- Flow lines at injection gate (see Figure 10-30).

**Figure 10-31**
**Figure 10-32**
**Figure 10-33**

**Defect – Class 1,2,3**

- Cracks.
- Knit lines (flow front).Chill marks/knit lines (flow front) if the depth exceeds 20% of the outer-mold material thickness (see Figure 10-31).
- Cracks (see Figures 10-32, 33).

**10.1.9 10.1.1.2.4 Over-Molding – Mold Fill – FinalOuter - Color**

## ~~10.1.4~~ 10.1.2 Over-Molding – Blow Through

**Figure 10-35**
**Figure 10-36**

**Defect – Class 1,2,3**
- Blow through present on an electrical mating surface (see Figure 10-35) or prevents proper mating or function of the connector (see Figure 10-36).

~~**Defect – Class 3**~~
- ~~Blow through is present.~~

## ~~10.1.5~~ 10.1.3 Over-Molding - ~~Terminal /Contact~~ Position

**Figure 10-37**
**Figure 10-38**

**Target – Class 1,2,3**
- Terminals fully inserted and aligned as required by drawing or specification.
- Over-molding aligned as specified with connector or terminal(s). (Not illustrated.)

**Figure 10-39**
**Figure 10-40**

**Acceptable – Class 1,2,3**
- Any variation in contact height or alignment that ~~does not compromise the electrical or physical function of the connector,~~ meets requirements of drawing or specification.
- Unless otherwise specified, the connector or terminal(s) is within 10º of perpendicular with molding material.
- No impact on intended form, fit or function.

**Figure 10-41**
**Figure 10-42**
**Figure 10-43**
**Figure 10-44**

**Defect – Class 1,2,3**
- If not otherwise specified, the connector or terminal misalignment is greater than 10º from perpendicular (see Figure 10-41).
- Terminals not fully seated or aligned as required by drawing or specification (see Figure 10-42).
- Any variation in contact height or alignment that does not meet requirements of drawing or specification~~,~~ (see Figures 10-43, 44).
- Impacts form, fit or function.

**Figure 10-45**

**Defect – Class 1,2,3**
- Connector insert misaligned.

### 10.1.7 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 10-47**
**Figure 10-48**

**Acceptable – Class 1,2,3**

- Flashing is not present on electrical mating surfaces.
- No exposed sharp edges (see Figure 10-47).
- Part line (flash) raised no greater than 0.75 mm [0.03 in] (see Figure 10-48).
- Flashing does not interfere with mating of the connector.
- Flash at the connector/mold interface that does not interfere with the mechanical or electrical function.
- Textured surface after the removal of flash.
- Flash at the cable/wire interface.

**Figure 10-49**
**Figure 10-50**

**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 10-49).
- Flashing that may break loose (see Figure 10-50, left arrow).
- Flashing present on electrical mating surfaces (see Figure 10-50, right arrow).
- Exposed Sharp edges.

### 10.1.10 10.1.5 Over-Molding - Wire Insulation, Jacket or Sleeving Damage

### 10.1.11 10.1.6 Over-Molding – Curing

### 10.1.12 Molding – Rework

**Acceptable – Class 1,2,3**

- Minute discontinuities indicating blending or filling of surface imperfections that do not affect form, fit or function.

**Defect – Class 1,2,3**

- Discontinuities extend over excessive surface area, or affect form, fit or function.

## 10.2 Potting (Thermoset Molding)

### 10.2.1 Potting – Filling

**Figure 10-57**
**Figure 10-58**

**Target – Class 1,2,3**

- Potting material ~~extends over and surrounds insulation of~~ encapsulates all wires.
- Uniform texture, color.
- Part lines discernible but not raised.
- Complete fill.
- ~~No potting material on the mating surfaces of the connector.~~
- ~~No bubbles or entrapped air.~~
- ~~No spillage.~~
- No:
  - Sink marks
  - Bubbles
  - Flash
  - Recessions
  - Blow-through
  - Rough edges
  - Spillage
  - Cosmetic or functional abnormalities.

**Figure 10-59**
**Figure 10-60**

**Acceptable – Class 1,2,3**

- No bubbles or cavities that bridge between conductors (see Figure 10-59..
- No spillage ~~present~~ or potting material that interferes with the ~~electrical or~~ physical function of the connector.
- No potting material on the mating surfaces of the connector.
- All required marking is legible.
- Part line~~(Figure 10-62)~~ raised no greater than 0.75 mm [0.03 in] (see Figure 10-60).

**Figure 10-61**
**Figure 10-62**
**Figure 10-63**

**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 10-61), rough edges (see Figure 10-62), sink marks without cracks (see Figure 10-63).~~s~~

**Defect – Class 2,3**
- Bubbles, voids or cavities that bridge conductors (not shown).

Figure 10-64
Figure 10-65
Figure 10-66

**Defect – Class 1,2,3**
- Potting material present on electrical mating surfaces of connector (not shown).
- ~~Any~~ Spillage or potting material that interferes with the physical function of the connector (see Figure 10-64).~~68).~~
- Exposed parts (insulation, sleeving, jacket, conductors, braid foil, tape, wire, ferrules, etc.) (see Figure 10-65).
- Sharp edges (not shown).
- Required marking is incomplete or not legible (not shown).
- Incomplete material fill (see Figure 10-66).

## 10.2.2 Potting - Fit to Wire or Cable

Figure 10-67
Figure 10-68

**Target – Class 1,2,3**
- Potting material provides intimate contact with the wire(s) or cable jacket for entire circumference of the wire(s) or cable (see Figure 10-67).
- Cable jacket, insulation sleeve or boot does not have deformations or damage (see Figure 10-68).

Figure 10-69

**Acceptable – Class 1**
- Potting material adheres to at least 75% of the circumference of the wire(s) or cable jacket when the drawing or specification requires the potting material to bond to the wire(s) or cable jacket.
- ~~No exposed conductors.~~

**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 drawing or specification requires the potting material to bond to the wire(s) or cable jacket.
- ~~No exposed conductors.~~

**Figure 10-70**

**Defect – Class 1**

- Potting material that does not adhere to at least 75% of the circumference of the wire or cable jacket when the drawing or specification requires the potting material to bond to the wire or cable jacket (see Figure 10-70)..
- Any exposed conductors.

**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 drawing or specification requires the potting material to bond to the wire or cable jacket.
- Any exposed conductors.

**Defect – Class 1,2,3**

- Any exposed conductors.

# 11 Measuring Cable Assemblies and Wires

The following topics are addressed in this section:



## 11.1 ~~Cable~~ 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 drawing/documentation.

## 11.2 ~~1.1 Cable Measuring – Reference Surfaces~~Measuring – Cable

### 11.2.1 ~~11.1.1.1 Cable Measuring~~ Measuring – Cable – Reference Surfaces – Straight/Axial Connectors

### 11.2.2 ~~11.1.1.2 Cable Measuring~~ Measuring – Cable – Reference Surfaces – Right-Angle Connectors

### 11.2.3 ~~11.1.2 Cable Measuring~~ 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.~~11.1.1.1 and 11.1.1.2. Cable length measurement tolerance **shall [D1D2D3]** be as shown in Table 11-1 unless otherwise defined on the drawing/documentation.~~

~~**Table 11-1 Cable Length Measurement Tolerance**~~

### 11.2.4 ~~11.1.3 Cable Measuring~~ 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 and 11-7) and the ends of the breakout or bundle.

**Figure 11-6**

**Figure 11-7**

#### 11.2.4.2 Measuring – Cable – Breakout Length

## 11.3 ~~11.2 Wire~~ 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). Wire length measurement tolerance shall [D1D2D3] be as shown in Table 11-1 unless otherwise defined on the drawing/documentation. <Jan2011>

If reference locations are not specified on documentation, use the reference surfaces specified in 11.3.1.11.2.1 and 11.2.2.

**11.3.1 11.2.1 Wire Measuring -– Wire - Electrical Terminal Reference Location**

**11.3.2 11.2.2 Wire Measuring - Wire - Length**

## 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 non-permanent internal markings should be removed for Class 2 and **shall [N1N2D3]** be removed for Class 3 products.

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 ~~12.7.2~~ Tie Wrap Markers**

## 12.1 Content

## 12.2 Legibility

## 12.4 Location and Orientation

**Defect – Class 3**

- Marking is placed over spot ties/wraps.

## 12.5 Functionality

## 12.6 Marker Sleeve

## 12.6.1 Marker Sleeve – Wrap Around

These criteria are applicable when wrap around sleeve marking is required.

**Figure 12-11**

**Acceptable – Class 1,2,3**

- The marker sleeve wraps around the cable a minimum of 1.25 times ~~to a maximum of 2 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.
- ~~The marker sleeve is slightly wrinkled and skewed.~~
- ~~The identification legibility is maintained.~~

**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 ~~diameter~~circumference.
- For marker sleeves with a clear section, the clear section renders the marking illegible.

**Figure 12-12**
**Figure 12-13**
**Figure 12-14**

**Defect – Class 1,2,3**

- ~~The marker sleeve is improperly wrapped, severely wrinkled, or skewed (**Figure** 12-10).~~Any wrinkles or misalignment that affects legibility or further assembly steps (see Figure 12-12).
- The marker sleeve overlap is not secure (see Figure 12-13~~11~~).
- The marker sleeve overlap-is less than 1.25 times the cable circumference (see Figure 12-14~~12~~).
- The wrap covers required marking.

## 12.6.2 Marker Sleeve - Tubular

**Figure 12-17**

**Defect – Class 2,3**

- Any split.
- Any hole~~s~~ greater than 3 mm [0.12 in].

## 12.7 Flag Markers

### 12.7.1 ~~Adhesive~~ Flag Markers - Adhesive

**Figure 12-19**

**Acceptable – Class 2,3**

- The flag marker side or end misregistration is less than 10% of the width of the marker.

**Figure 12-20**

**Defect – Class 2,3**

- The flag marker side or end misregistration exceeds ~~25%~~10% of the width of the marker.

## 12.8~~12.7.2~~ Tie Wrap Markers

# 13 Coaxial and ~~Twinaxial~~Biaxial Cable Assemblies

For coaxial and ~~twinaxial~~biaxial assemblies to function properly, it is critical to follow all assembly instructions provided by the connector manufacturer. 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**
**13.2 Center Conductor Termination**
13.2.1 Crimp
13.2.2 Solder
**13.3 Solder Ferrule Pins**
13.3.1 General
13.3.2 Insulation
**13.4 Coaxial Connector- Printed Wire Board Mount**
**13.5 Coaxial Connector - Center Conductor Length - Right Angle Connector**
**13.6 Coaxial Connector - Center Conductor Solder**
**13.7 Coaxial Connector - Terminal Cover**
13.7.1 Soldering
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**13.8 Shield Termination**
13.8.1 Clamped Ground Rings
13.8.2 Crimped Ferrule
**13.9 Center Pin ~~Position~~**
13.9.1 Position
13.9.2 Damage
**13.10 Semirigid Coax**
13.10.1 Bending and Deformation
13.10.2 Surface Condition
13.10.2.1 Solid
13.10.2.2 Conformable Cable
13.10.3 Dielectric Cutoff
13.10.4 Dielectric Cleanliness
13.10.5 Center Conductor Pin
13.10.5.1 Semirigid Coax– Center Conductor Pin - Point
13.10.5.2 Semirigid Coax– Center Conductor Pin - Damage
~~13.10.5~~ 13.10.6 Solder
**13.11 Swage-Type Connector**
**13.12 Soldering and Stripping of Biaxial/Multi-Axial Shielded Wire**
13.12.1 Jacket and Tip Installation
13.12.2 Ring Installation

## 13.1 Stripping

**Table 13-1 Coaxial and Biaxial Shield and Center Conductor Damage[1,2]**

| Number of Strands | Maximum Allowable Strands[1] Scraped, Nicked or Severed Class Classes 1,2,3 | | |
|---|---|---|---|
| | Shield Braid | Center Conductor | |
| | | Crimped Terminations | 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.

**Figure 13-1**

**Target– Class 1,2,3**
- Smooth, clean cut; no jagged edges.
- No burn marks or damage on insulation or dielectric.
- Braid/shield cut even; no long strands.
- Braid lies smooth and flat after cut with no damaged or loose pieces.
- Trim angle is perpendicular to the center conductor.

**Figure 13-2**

**Acceptable – Class 1,2,3**
- Slight marks on dielectric.
- Minor unraveling of braid.
- 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.

**Acceptable- Class 1**
**Process Indicator- Class 2,3**
- Damaged or missing braid does not exceed allowance of Table 13-1.

**Figure 13-3**

**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 Figures 13-3 and 13-4).

**Figure 13-5**

**Defect – Class 1,2**

- Missing or damaged braid exceeds the allowance of Table 13-1 (2, 4).

**Defect – Class 3**

- Scraped or nicked shield braid exceeds the allowance of Table 13-1.
- As an exception to Table 13-1, any severed shield strands.

**Defect – Class 1,2,3**

- Braid twisted/birdcaged (1).
- ~~Missing or damaged braid exceeds the allowance of Table 13-1 (2, 4).~~
- Any cuts or breaks in outer jacket (not shown).
- Outer jacket thickness is reduced greater than 20% (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 (3).
- Internal dielectric damaged (5).
- Uneven cut on braid; any long strands (6).
- Discernible nicks or cuts in center conductor are greater than allowance of Table 13-1.~~(not shown).~~
- Burns or melted areas on dielectric.
- Damage to center dielectric reducing insulation diameter by more than 10% (not shown).

## 13.2 Center Conductor Termination

### 13.2.1 Center Conductor Termination - Crimp

As an exception to crimping criteria of Chapter 5 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.

### 13.3.1 Solder Ferrule Pins - General

**Figure 13-16**

**Acceptable – Class 1,2,3**

- ~~Wire twist form is disturbed.~~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.

## 13.4 Coaxial Connector- Printed Wire Board Mount

**Figure 13-24**

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

- Shield extends beyond sleeving (A).
- ~~Shield is piercing sleeving (B).~~

**Defect – Class 1,2,3**

- Shield is piercing sleeving (B).
- Solder fillet is not evident between shield and connector.
- Wire is positioned greater than 0.75 mm [0.03 in] from the center (C) of the four connector leads.

## 13.6 Coaxial Connector - Center Conductor Solder

~~**Acceptable - Class 1**~~
~~**Process Indicator - Class 2**~~
~~**Defect - Class 3**~~

- ~~Lead end not discernible on exit side of terminal.~~

**Figure 13-30**

**Acceptable – Class 1**
**Process Indicator – Class 2~~,3~~**
**Defect – Class 3**

- Any pinholes/blowholes.

## 13.8.2 Shield Termination – Crimped Ferrule

**Figure 13-41**
**Figure 13-42**

**Acceptable – Class 1,2,3**

- Gap between connector body and ferrule is less than 0.75 mm [0.030 in].
- Distance between connector body and start of crimp is less than 0.75 mm [0.030 in].
- ~~Connector meets the test criteria of 19.7.7.~~
- No wire strands protrude from the gap between the connector body and ferrule.

**Note:** Figure 13-42 shows cross-section of a ferrule with uniform crimp.

**Figure 13-43**

**Figure 13-44**

**Defect – Class 1,2,3**

- Crimp extends over the cable.
- Double crimps.
- ~~Connector does not meet the criteria of 19.7.7.~~
- Gap between ferrule ~~crimp~~ 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 13-44~~43~~.
- Wire strand protrudes from the gap between the connector body and ferrule.

| **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 13-45**

**Target– Class 1,2,3**

- Center pin fully seated. ~~into housing of connector.~~

**Figure 13-46**

**Defect – Class 1,2,3**

- Center pin not fully seated. ~~into housing of connector.~~
- ~~Center pin is bent (not shown).~~
- Center pin extends beyond proper height (not shown).

## 13.9.2 Center Pin Damage

**(Not illustrated.)**

**Acceptable – Class 1,2**

- Cuts, nicks, or scrapes <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 >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 ~~radii and~~ or deformation of a cable ~~assembly have a greater or lesser effect~~will affect characteristic impedance (operation) of the assembly.~~ depending upon the frequency the cable will carry~~. 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 13-47**
**Figure 13-48**

**Target – Class 1,2,3**

- Bend is uniform and has an inside radius greater than 3.5 times the cable diameter or the manufacturer's specifications, whichever is greater.
- Diameter of cable is constant and does not deform in the bend area.
- No evidence of wrinkles.
- Distance from back of connector to start of bend is at least 2 diameters (D) (see Figure 13-48).

**Figure 13-49**
**Figure 13-50**

**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 1 diameter (D) (see Figure 13-50).
- No physical damage to outer cable.

**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 13-52**
**Figure 13-53**
**Figure 13-54**

**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 1 diameter (D) (see Figure 13-54).

**13.10.2 Semirigid Coax – Surface Condition**

**13.10.2.1 Semirigid Coax – Surface Condition – Solid**

**Figure 13-57**
**Figure 13-58**
**Figure 13-59**

**Defect – Class 1,2,3**
- If plated, base metal (see Figure 13-5955) is exposed in an area to be soldered.
- Outside surface of the cable has tooling marks, scratches, cuts, damaged braid strands or abrasions that impact form, fit or function. Testing may be required.
- Bulge in semirigid cable.

**13.10.2.2 Semirigid Coax – Surface Condition – Conformable Cable**

The solder criteria of 13.10.6 are also applicable to conformable cable.

**Figure 13-60**

**Acceptable – Class 1,2,3**
- No voids in solder coating.

**Figure 13-61**

**Defect – Class 1,2,3**
- There are voids in solder coating.

**13.10.3 Semirigid Coax – Dielectric Cutoff**

**Figure 13-63**

**Acceptable – Class 1,2,3**
- Dielectric position is within interface connector manufacturer's specificationrequirements.
- 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 13-64-A) is equal to, or greater 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] |

1. Nominal cable diameters are industry-defined using only the Imperial measurements shown.

**Figure 13-65**
**Figure 13-66**
**Figure 13-67**
**Figure 13-68**
**Figure 13-69**

**Defect – Class 1,2,3**

- Dielectric position is not within ~~interface requirements~~ connector manufacturer's specification (see Figure 13-65~~59~~).
- Air gap between dielectric and cable shield (see Figure 13-66~~60~~).
- Dielectric protrudes above connector face (see Figure 13-67~~61~~).
- Center conductor is bent (see Figure 13-67~~61~~).
- 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 13-68~~62~~, 69~~63~~).

## 13.10.5.1 Semirigid Coax– Center Conductor Pin - Point

**Figure 13-73**

**Target – Class 1,2,3**

- Point located on center conductor centerline.
- Center conductor is free of burrs, nicks, cuts or scrapes.

**Figure 13-74**

**Acceptable – Class 1,2,3**

- Point flat diameter 0.38 mm [0.015 in] or less.
- Point slightly off center but within 50% of centerline of the conductor diameter.
- 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.

**Figure 13-75**

**Defect**
- Burrs.
- Pin point greater than 0.38 mm [0.015 in] diameter.
- Pin point center more than 50% off conductor centerline (see Figure 13-75).
- Exposed under-plating or basis metal on the center conductor (except center point) (see Figure 13-72).

## 13.10.5.2 Semirigid Coax– Center Conductor Pin - Damage

**Figure 13-76**

**Acceptable – Class 1,2**
- Cuts, nicks, or scrapes in the center conductor <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 >10% diameter of the center conductor.

**Defect – Class 3**
- Any damage to the surface of the center conductor contact area that exposes basis metal.

## ~~13.10.5~~ 13.10.6 Semirigid Coax– Solder

These solder criteria are also applicable to conformable cable, see 13.10.2.2.

**Figure 13-77**

**Target– Class 1,2,3**
- Solder fillet 100% around the connector body and cable.
- No solder outside joint region.
- No residue when connection is required to be clean.
- No voids or separation between connector body and cable.
- No solder on connector body.
- Shield inserted in connector body.

**Figure 13-78**

**Acceptable – Class 1**
**Defect – Class 2,3**

- ~~Insufficient solder.~~
- ~~Solder fillet greater than 270º but less than 360º.~~
- ~~Solder fillet is not continuous around connector.~~
- Solder fillet has voids (not shown).

**Figure 13-81**

**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.

## 13.12 Soldering and Stripping of Biaxial/Multi-Axial Shielded Wire

**Figure 13-85**

**Target – Class 1,2,3**

- Cone is under shield and jacket. Shield is flush with edge of cone (see Figure 13-85-A).
- ~~Tip conductor insulation is extended more than 50% of window length in notched insert (B).~~ No exposed tip conductor wire in window (see Figure 13-85-B).
- Solder in the tip inspection window is flush to slightly concave (see Figure 13-85-C).

**NOTE:** Complete connector assembly not shown.

**Figure 13-86**

**Acceptable – Class 1,2,3**

- Tip conductor exposed wire is less than 50% of window length (see Figure 13-86-B).
- Ring conductor insulation is more than 50% of window length (see Figure 13-86-B).

**Acceptable – Class 1**
**Process Indicator – Class 2,3**

- Shield and jacket extend~~s~~ over more than 50% of cone (see Figure 13-86-A).
- ~~Tip conductor exposed wire is less than 50% of window length (notched insert) (B).~~
- A thin film of solder is on the outside solder section of tip surface (see Figure 13-86-C). (Solder film is not allowed on contacts mating surface).

**Figure 13-87**

**Defect - Class 1,2,3**

- Shield and jacket extend~~s~~ less than 50% over cone~~ as required securing nut~~ (see Figure 13-87-A).
- Tip conductor exposed wire is greater than 50% of window length (see Figure 13-87-B).
- Insulation on ~~both~~ ring conductor~~s~~ is less than 50% of window length ~~(notched insert)~~ (see Figure 13-87-B).
- Solder buildup on solder section of tip (see Figure 13-87-C).
- Solder film on the mating surface (see Figure 13-87-D).
- Insulation is melted or charred (not shown).

## 13.12.2 Soldering and Stripping of Biaxial/Multi-Axial Shielded Wire - Ring Installation

**Figure 13-89**

**Acceptable – Class 1,2,3**

~~**Process Indicator – Class 3**~~

- ~~The ring (A) has a thin film of solder on the outside surface.~~
- No solder ~~film is not~~ on mating surface (see Figure 13-89-B).
- Conductor is in contact with surface to be soldered for entire wrap distance (not shown).

**Process Indicator – Class 3**

- The ring (see Figure 13-89-A) has a thin film of solder on the outside surface.

**Figure 13-90**

**Defect – Class 1,2,3**

- Solder is on mating surface.
- Wire, insulation, or solder extends above ring profile.
- Conductor does not contact the entire surface to be soldered for entire wrap distance.
- Insulation is melted or charred (not shown).

## 14 Securing

These criteria are applicable to cable and wire harness fabrication. They are not intended to be applied to installation of cables or wire harnesses (see Section 17 Installation).

Temporary holding devices, e.g., spot ties, plastics 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, 14-2 and 14-3 are provided as guidance for applying lacing. ~~The ends start and finish with clove hitches that are secured with square knots.~~ Figure ~~14-2~~14-1 ~~also~~ 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 surgeons knot.

A clove hitch knot **shall [N1D2D3]** secure the bundle and the clove hitch **shall [N1D2D3]** be secured with a locking knot, e.g., square knot, surgeons knot.

Continuous lacing **shall not [N1N2D3]** be used unless specified on the engineering drawing.

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. ~~**Note**: Do not subject~~ Wax impregnated lacing tape **shall not** [N1N2D3] be subjected to cleaning solvents.

**Figure 14-4**

**Target – Class 1,2,3**
**Lacing:**

- ~~The~~ Spot ties, or the first and last stitch of continuous lacing is tied with a lock stitch such as ~~clove hitch~~clove hitch or equivalent and secured with a square knot, surgeons knot, or other approved lock knot (1).
- Continuous lacing is done with lock stitches (2).
- Continuous lacing utilizes a double lock stitch before and after each breakout of 4 or more wires (3).
- Continuous branch lacing is started on the trunk.
- ~~Lacing is heat-seared to prevent fraying 10 mm [0.40 in] after the knot (4).~~

**Tie wraps/straps:**

- Restraining devices are locking. ~~(They should remain secure for the expected service life of the product.)~~
- Cut end of tie wrap is square and flush to the face of the tie wrap.

**Figure 14-5**
**Figure 14-6**

**Acceptable - Class 1,2,3**

- The end of the tie wrap is cut off not greater than 1 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 (1) greater than tie wrap thickness.
- ~~Cut end of lacing has not been heat-seared.~~

**Figure 14-10**
**Figure 14-11**

**Defect – Class 1,2,3**

- ~~Lacing or spot tie is loose, leaving wires loose in the wire bundle (1).~~
- ~~Lacing or spot tie is too tight, cutting into insulation (2).~~
- Continuous lacing does not use lock stitches.
- Wires not constrained securely and uniformly or are birdcaged.
- Cable tied with a bowknot or other non-locking knot (Figure 14-11). ~~This tie may eventually loosen.~~
- 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, surgeons knot, or other lock knot.
- Spot ties do not start with a clove hitch or equivalent and finish with a square knot, surgeons knot, or other lock knot.

## 14.1.1 Tie Wrap/Lacing Application - Tightness

**Figure 14-13**

**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.
- ~~Tie wraps/straps are inverted or not locked.~~
- Restraining devices move longitudinally.

## 14.1.2 Tie Wrap/Lacing Application - Damage

**Figure 14-15**

**Acceptable – Class 1,2**
~~**Defect - Class 3**~~

- Restraining devices exhibit minor fraying, nicks, or wear of less than 25% of the device thickness.

**Defect – Class 1,2,3**

- ~~Damage or wear to restraining device (1).~~
- Sharp edges that are a hazard to personnel or equipment (2).
- Broken lacing ends are not tied off using a square knot, surgeons knot, or other approved knot (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 (1).

## 14.1.3 Tie Wrap/Lacing Application - Spacing

## 14.2 Breakouts

### 14.2.1 Breakouts – Individual Wires

### 14.2.2 Breakouts – Spacing

**Figure 14-19**
**Figure 14-20**
**Figure 14-21**
**Figure 14-22**
**Figure 14-23**
**Figure 14-24**
**Figure 14-25**

**Acceptable – Class 1,2,3**
- Restraining devices are placed before, after, and 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 3 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 14-19 through 14-24 provide examples of typically acceptable restraining configurations.

## 14.3 Routing

### 14.3.1 Routing – Wire Crossover

**Figure 14-29**

**Acceptable - Class 1**
**Defect - Class 2,3**
- ~~Any kinks that violate minimum bend radius (see Table 14-1).~~
- 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 assembly **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**

| Cable Type | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| Coaxial Flexible Cable[3] | 10X OD[1] | 10X OD[1] | 10X OD[1] |
| Coaxial Fixed Cable[2] | 5X OD[1] | 5X OD[1] | 5X OD[1] |
| Semi-rigid Coax | Not less than manufacturer's stated minimum bend radius (see 13.10.1). | | |
| Cable bundles with coax cables | 5X OD[1] | 5X OD[1] | 5X OD[1] |
| Cable bundles with no coax cables | 2X OD[1] | 2X OD[1] | 2X OD[1] |
| Ethernet cable | 4X OD[1] | 4X OD[1] | 4X OD[1] |
| Shielded Wires and Cables | No Requirement Established | | 5X OD[1] |
| Unshielded Wires | No Requirement Established | | 3X OD for ≤AWG 10<br>5X OD for >AWG 10 |
| Insulated wire and flat ribbon cable | 2X OD[1] | 2X OD[1] | 2X OD[1] |
| Polyimide Insulated Wires (Shielded or Unshielded) | No Requirement Established | | 10X OD[1] |
| Bare bus or enamel insulated wire | 2X OD[1] | 2X OD[1] | 2X OD[1] |

**Note 1:** OD is the outer diameter of the wire or cable, including insulation.
**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: Coaxial Flexible Cable** Coaxial cable that is or may be flexed during operation of the equipment.

### 14.3.3 Routing – Coaxial Cable

### 14.3.4 Routing – Unused Wire Termination

## 14.3.4.1 Routing – Unused Wire Termination – Shrink Sleeving

**Figure 14-33**

**Acceptable - Class 1,2,3**
- Wire may extend straight down length of bundle (see Figure 14-33) or be folded back (see Figure 14-32).
- Shrink sleeving extends at least 2 wire diameters beyond end of wire (see Figure 14-33).
- Shrink sleeving extends on to the wire insulation for a minimum of 4 wire diameters (see Figure 14-33). ~~or 6 mm [0.24 in], whichever is greater.~~
- Unused wire is tied into the wire bundle (see Figures 14-32, 33).

**Figure 14-34**

**Defect - Class 1,2,3**
- Ends of unused wires are exposed.
- Unused wire is not tied into the wire bundle.
- Any part of the ~~terminal~~ conductor is exposed.

**Acceptable - Class 1**
**Process Indicator - Class 2**
**Defect - Class 3**
- Insulating shrink sleeving extends beyond end of wire less than 2 wire diameters.
- Insulating shrink sleeving extends onto wire insulation less than 4 wire diameters. ~~or 6 mm [0.24 in], whichever is greater.~~
- Shrink sleeving is not secure to the wire.

## 14.3.4.2 Routing – Unused Wire Termination – Flexible Sleeving

**Target - Class 1,2,3**
- Unused wire is folded back and tied into the wire bundle.

**Acceptable - Class 1,2,3**
- Wire may extend straight down length of bundle (Figure 14-32) or be folded back (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

## 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 drawing, 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 14-38, 14-39 and 14-40 show examples of acceptable broom stitching.

# 15 Harness/Cable Electrical Shielding

The following topics are addressed in this section:

**15.1 Braided**
15.1.1 Direct Applied
15.1.2 Prewoven

**15.2 Shield Termination**
15.2.1 Shield Jumper Wire
15.2.1.1 Attached Lead
15.2.1.1.1 Solder/~~Heat Shrinkable Solder Device~~
15.2.1.1.2 Crimp
15.2.1.2 Shield Braid
15.2.1.2.1 Woven
15.2.1.2.2 Combed and Twisted
15.2.1.3 Daisy Chain
15.2.12.4 Common Ground Point
15.2.2 No Shield Jumper Wire
15.2.2.1 Shield Not Folded Back
15.2.2.2 Shield Folded Back

**15.3 Shield Termination - Connector**
15.3.1 Shrink ~~and Crimp~~
15.3.2 ~~Shrink and~~ Crimp
15.3.3 Shield Jumper Wire Attachment
15.3.4 Soldered

**15.4 Shield Termination – Splicing Prewoven**
15.4.1 Soldered
15.4.2 Tie/Tape On

**15.5 Tapes – Barrier and Conductive, Adhesive or Nonadhesive**

**15.6 Conduit (Shielding)**

**15.7 Shrink Tubing – Conductive Lined**

## 15.1 Braided

### 15.1.1 Braided - Direct Applied

**Acceptable – Class 1,2,3**

- ~~Braid coverage meets drawing requirements.~~
- 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 fabric braid.
- Braid strands smooth and evenly placed.
- 38 mm [1.5 in] overlap of material at branches and breakouts.
- Back braid lock stitch is a minimum of 13 mm [0.5 inch].
- Braid damage meets requirements of Table 13-1.

**Defect – Class 2,3**

- Braid strands bunched (excess overlap).
- ~~Braid coverage does not meet drawing requirements.~~
- Wire or shield braid visible through top braid.

### 15.1.2 Braided - Prewoven

**Target – 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 2 bundle diameters.
- ~~Braid damage meets requirements of Table 13-1.~~

**Acceptable – Class 1,2,3**

- Braid damage meets requirements of Table 13-1.

## 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. Heat shrinkable solder devices, including those supplied with an integral shield wire, may be changed 1 size up or down to achieve correct fit when size is not called out on the engineering drawing.

**15.2.1.1.1 Shield Termination – Shield Jumper Wire – Attached Lead - Solder/Heat Shrinkable Solder Device**

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 15-6**

**Figure 15-7**

**Target - Class 1,2,3**

- The solder preform (ring) is melted and a fillet is visible between shield and shield wire. Shield and shield wire lead contour is tinned and discernible (A).
- Shield and shield wire strip length are the same length and are lined up (B).
- Meltable sealing rings have flowed.
- Sleeve and wire insulation shows no discoloration due to excessive heat.
- Shield weave pattern is intact.
- Mechanical barrier, e.g. sleeving, is placed between the sharp ends of the soldered shield and inner wires.

**Figure 15-10**

**Figure 15-11**

**Acceptable - Class 1,2,3**

- Strip length on braid and shield wire is greater than 3 mm [0.12 in] and does not exceed 6 mm ([0.245 in].) and is greater than 3 mm (0.15 in).
- 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 15-13**
**Figure 15-14**
**Figure 15-15**

**Defect - Class 1,2,3**
- Shield wire is not aligned with the stripped portion of the shield.
- Solder ~~fillet~~ is not wetted between shield wire and shield (see Figure 15-14). ~~is insufficient.~~
- Meltable sealing ring precludes formation of acceptable solder connection (not shown).
- Solder has flowed out of the solder connection area onto wire insulation.

~~**Defect - Class 1,2,3**~~
- Shield wire extends beyond stripped surface of shield preventing wire from contacting shield (see Figure 15-15-A).
- Shield wire has pierced the insulation sleeving (see Figure 15-15-B).
- ~~Solder joint is insufficient (Figure 15-16).~~

**Figure 15-20**

**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**

**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 15-24**

**Acceptable - Class 1,2,3**
- Shield used as a shield wire, shield weave pattern is intact.
- Less than ~~10~~6% of shield strands broken.

**Defect – Class 2, 3**
- ~~10~~6% or more shield strands broken.

**15.2.1.2.2 Shield Termination – Shield Jumper Wire – Shield Braid - Combed and Twisted**

**15.2.1.3 Shield Termination – Shield Jumper Wire – Daisy Chain**

**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

### 15.2.2.1 Shield Termination – No Shield Jumper Wire – Shield Not Folded Back

### 15.2.2.2 Shield Termination – No Shield Jumper Wire – Shield Folded Back

**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 ~~and Crimp~~

**Figure 15-35**

**Acceptable - Class 1,2,3**
- Shrinkable ring is shrunk (see Figure 15-35-A).~~(A).~~ No movement of the ring or shield is evident. (Ring has lost its original color).
- Shield is visible between shrinkable ring and the backshell (see Figure 15-35-B).~~(B).~~
- Shield weave pattern is disturbed (not shown).

~~**Acceptable - Class 1,2,3**~~
- Shield is against backshell and is visible between backshell and ring (see Figure 15-35).

## 15.3.2 Shield Termination – Connector – Shrink and Crimp

**Figure 15-37**

**Target – Class 1,2,3**

- Band-It ClampMetal shield termination band is wrapped around the shield twice and clinched (see Figure 15-37-A). No movement of the ring or shield is evident.
- Sharp edges on the buckle or of the band cut off area have been removed (see Figure 15-37-B) or covered, e.g. with epoxy.
- Shield is approximately 3 mm [0.12 in] from backshell (see Figure 15-37-C).
- Shield is visible between band and the backshell (see Figure 15-37-D).
- Shield weave pattern is intact.

**Figure 15-38**

**Acceptable - Class 1,2,3**

- Shield weave pattern is disturbed; gaps in weave pattern are present (see Figure 15-38-A).
- Shield is visible between ring and the backshell (see Figure 15-38-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 10%6% of total strands.

**Figure 15-39**

**Figure 15-40**

**Figure 15-41**

**Defect - Class 1,2,3**

- Crimp ring extends greater than 10% of the crimp ring length beyond backshell (see Figure 15-39-A).

**Defect - Class 1,2,3**

- Shield extends beyond backshell crimp area (see Figure 15-40-A).
- Sharp edges are present in the buckle or band cut off area (see Figure 15-40-B).
- Shield strands not contained within crimp ring have not been trimmed (see Figure 15-40-C).
- Band-It ClampMetal shield termination band is not wrapped around backshell 2 times.
- 10% or more shield strands broken.

**Defect - Class 1,2,3**

- Backshell is damaged, (see Figure 15-41-A).(A).
- Shield is not visible at edge of crimp ring, (see Figure 15-41-B).(B).
- Sleeved sharp points or projections (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.

~~**Acceptable – Class 1,2**~~
- ~~A spacer (A) is used to prevent the cable from being crushed. Terminal lug is secured.~~
- ~~Shield jumper (B), wire is not within envelope dimension of the connector, where it is possible to do so.~~
- ~~Spacers are mounted under the same adapter clamp on both sides of the cable.~~

**Figure 15-44**

**Defect – Class 1,2,3**
- ~~Shield jumper wire length is excessive.~~
- Terminal lug is not secured.
- Shield jumper wire is taut causing stress on the solder or crimp connections.

### 15.3.4 Shield Termination – Connector - Soldered

Terminations soldered directly to connector bodies as shown in Figure 15-46 **shall [D1D2D3]** only be used when required by approved drawings.

### 15.4 Shield Termination – Splicing Prewoven

When prewoven metal shielding is applied over a cable/harness all overlap locations ~~may~~ should be tack soldered, tied, taped or otherwise secured to prevent the overlap junction from pulling apart during subsequent operations and handling. ~~Typically the shield is tack soldered on 2 adjacent sides and~~ When completed, the junction should remain flexible.

### 15.4.1 Shield Termination – Splicing Prewoven - Soldered

**Figure 15-49**

**Process Indicator - Class 2,3**
- A solder fillet is present around the entire shield overlap area (arrow) and shield overlap area is still flexible.
- Shield weave pattern is disturbed but does not exceed the limits of 15.1.
- Shield overlap is greater than 3 wire bundle diameters.

**Figure 15-50**
**Figure 15-51**

**Defect - Class 1,2,3**
- Tack solder has not flowed to inner shields (arrows).
- Shield overlap is less than 1 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.

**15.4.2 Shield Termination – Splicing Prewoven - Tie/Tape On**

**15.5 Tapes – Barrier and Conductive, Adhesive or Nonadhesive**

**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.

**15.7 Shrink Tubing – Conductive Lined**

**Target – Class 1,2,3**
- Tubing is tight on cable and connector/~~cable~~ connector accessories.
- No cracks or tears.
- No overlapping of tubing.
- Multiple pieces electrically connected.

**Acceptable – Class 1**
- Tubing tight on connector/~~cable~~ connector accessories, but not tight on cable.

**Defect – Class 1,2,3**
- Tubing not tight on connector/~~cable~~ connector accessory.
- Cracks or tears in the tubing.
- Multiple pieces not electrically connected.

**Defect – Class 2,3**
- Tubing is not tight on cable.

## 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 Direct Applied
16.1.2 Prewoven

**16.2 Sleeving/Shrink Tubing**
**16.2.1 Sealant**

**16.3 Spiral Plastic Wrap (Spiral Wrap Sleeving)**

**16.4 ~~Conduit (Containment Loom)~~Wire Loom Tubing – Split and Unsplit**

**16.5 Tapes, Adhesive and Nonadhesive**

## 16.1 Braid

### 16.1.1 Braid - Direct Applied

**Defect – Class 3**

- Gap or absence of braid where coverage is required.
- Back braid lock stitch is ~~Braiding overlap~~ less than 13 mm [0.5 in] at breakouts and branches.
- Overlap of materials at branches and breakouts is less than 38 mm [1.5 in].

### 16.1.2 Braid – Prewoven

**Figure 16-6**
**Figure 16-7**

**Defect – Class 2,3**

- Ends frayed or unraveling.
- Pulled loops.
- ~~Damage to mesh strands ≥5%.~~

**Figure 16-9**

**Defect – Class 1,2,3**

- Ends not secured.
- ≥5% damage to braiding~~mesh strands~~, e.g. tears, cuts, melting. ~~≥5%.~~
- ~~Damage to braiding, i.e., tears, cuts, melting.~~
- Overlap is less than 1 bundle diameter where multiple braids meet.

**16.2 Sleeving/Shrink Tubing**

**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.)

**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.

**Defect – Class 2,3**

- Sleeving not shrunk before curing the sealant.
- Sealant is not cured to the sealant manufacturer's specifications.
- Sealant is not visible at the ends of the sleeving.

**16.3 Spiral Plastic Wrap (Spiral Wrap Sleeving)**

**16.4 ~~Conduit (Containment Loom)~~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.

**16.5 Tapes, Adhesive and Nonadhesive**

## 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

## 17.2 Hardware Installation

This section illustrates several types of mounting hardware.

All hardware **shall [D1D2D3]** be assembled in accordance with the supplier's (1.7.5) specifications or a documented process.

~~Process documentation will specify what to use (drawings, prints, parts list, build process); deviations need to have prior user approval.~~

Visual inspection is performed ~~in order~~ 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 [N1D2D3]** be mixed and cured following the material manufacturer's instructions. See 1.13.3.

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**

A minimum of one and one half threads ~~need~~ **shall [A1D2D3]** ~~to~~ extend beyond the threaded hardware, (e.g., nut) unless otherwise specified by engineering drawing. ~~Bolts or screws may be flush with the end of the threaded hardware only where threads could interfere with other components or wires and when locking mechanisms are used.~~

Thread extension ~~should~~ **shall not [A1D2D3]** be more than 3 mm [0.12 in] plus one and one-half threads for bolts or screws up to 25 mm [0.984 in] long or more than 6.3 mm [0.248 in] plus one and one-half threads for bolts or screws over 25 mm [0.984 in]. ~~This is providing that the extension does not interfere with any adjacent part and that the designed electrical clearance requirements are met.~~

**Figure 17-3**

**Figure 17-4**

**Defect - Class 1,2,3**

- Thread extension interferes with adjacent component.
- Hardware material or sequence not in conformance with drawing.
- Lock washer against nonmetal/laminate.
- ~~Flat washer missing.~~
- Hardware missing or improperly installed.
- Hardware is not seated.
- Fasteners are damaged (burrs, cross-threading, rounding, etc.).

**17.2.2 Hardware Installation - Threaded Fasteners – Minimum Torque ~~for Electrical Connections~~**

When connections are made using threaded fasteners they need to be sufficiently tight to ensure the reliability of the connection. When required, fasteners are tightened to the specified minimum torque value. ~~Torque tool settings may need to be adjusted to compensate for tooling in use, e.g., extensions, crowsfoot, etc.~~

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 17-5**

**Figure 17-5**

**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.
- Fasteners requiring torque stripe (witness/anti-tampering stripe) (see Figure 17-6):
  - Are continuous.
  - Extend from the top of the fastener onto the adjacent substrate.

**Figure 17-7**

**Figure 17-8**

**Defect - Class 1,2,3**
- Lock washer not compressed.
- Proper torque not applied when torque is a requirement.
- Required torque stripe is not continuous.
- Required torque stripe does not extend from the top of the fastener onto the adjacent substrate.

## 17.2.3 Hardware Installation – Threaded Fasteners - Wires

**Figure 17-10**

**Figure 17-11**

**Acceptable - Class 1,2,3**
- ~~Wire wrapped around the screw body in the correct direction, but a few strands have unraveled in tightening the screw.~~
- Less than 1/3 of the wire diameter protrudes from under the screw head.
- Wire extending outside the screw head does not violate minimum electrical clearance.
- Mechanical attachment of the wire 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.
- Wire does not overlap itself.

**Figure 17-12**

**Defect - Class 1,2,3**
- More than 1/3 of the wire diameter protrudes from under the screw head.
- Wire not wrapped around screw body (A).
- Wire is overlapped (B).
- Solid wire wrapped in wrong direction (C).
- Stranded wire wrapped in wrong direction (tightening the screw unwinds the twisted wire) (D).
- Insulation in the contact area (E).
- Stranded wire was tinned (not shown).

## 17.2.4 Hardware Installation - Threaded Fasteners - High Voltage Applications

## 17.3 Wire/Harness Installation

## 17.3.1 Wire/Harness Installation - Stress Relief

**Figure 17-16**

**Acceptable - Class 1**
**Process Indicator - Class 2**
**Defect - Class 3**

- There is insufficient stress relief.
- The wire is under stress at the wrap.
- Spot ties or wraps/straps are under sleeving or markers.

## 17.3.2 Wire/Harness Installation – Wire Dress

**Figure 17-19**

**Acceptable - Class 1**
**Process Indicator – Class 2**
**Defect - Class ~~2,~~3**

- The wire is formed around the terminal opposite to the feed-in direction.

## 17.3.3 Wire/Harness Installation – Service Loops

**Figure 17-22**

**Acceptable - Class 1**
**Process Indicator - Class 2**
**Defect - Class 3**

- When a service loop is required, wire does not have sufficient length to allow at least 1 field repair.
- ~~the wire is too short to allow an additional wrap if repair is necessary.~~

## 17.3.4 Wire/Harness Installation – Clamping

**Target – Class 1,2,3**
- Wires/harness assembly is supported to prevent strain on conductors or terminals.

**Figure 17-23**

**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 17-23).

**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 – Intersecting

When intersecting wire bundles or cables are secured to each other, the tie wrap and lacing requirements of Chapter 14 are applicable.

## 18 Solderless Wrap

This section establishes visual acceptability criteria for connections made by the solderless wrap method.

It is assumed that the terminal/wire combination has been designed for this type of connection.

It is also assumed that a monitoring system exists using test connections to verify that the operator/tooling combination is capable of producing wraps that meet strip force requirements.

Depending on the service environment, the connecting instructions will specify whether the connection will be conventional or modified.

Once applied to the terminal, an acceptable solderless wrap connection should not be subjected to excessive heat nor have any mechanical operations performed on it.

The reliability and maintainability advantages of the solderless wrap connection method are such that no repair of a defective wrap by soldering is to be made.

The defective connections **shall [D1D2D3]**~~must~~ be unwrapped using a special tool (not stripped off the terminal) and then a new wire wrapped. New wire **shall [D1D2D3]** be used for each rewrap, but the terminal post may be rewrapped if it is not damaged.

The following topics are addressed in this section:

**18.1 Number of Turns**

**18.2 Turn Spacing**

**18.3 End Tails, Insulation Wrap**

**18.4 Raised Turns Overlap**

**18.5 Connection Position**

**Figure 18-14**

**Figure 18-15**

**Defect - Class 1,2,3**

- ~~Any countable turns of bare wire off either end of working length.~~ Insufficient number of countable turns in contact with the terminal.
- Any countable minimum turns of bare wire overlapping wire turns of a preceding connection.

**18.6 Wire Dress**

**18.7 Wire Slack**

**18.8 Plating**

**18.9 Damage**

**18.9.1 Insulation**

**18.9.2 Damage – Wires and Terminals**

## 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**

**19.2 Testing After Rework or Repair**

**19.3 Intended Table Usage**

**19.4 Electrical Test**

**19.4.1 Electrical Test - Selection**

**19.5 Electrical Test Methods**

**19.5.1 Electrical Test Methods - Continuity**

**Table 19-2 Continuity Test Minimum Requirements**

| Parameter | Class 1 | Class 2 | Class 3 | Other Defined Value |
|---|---|---|---|---|
| Max Resistance | Tester Default | | 2 ohms or 1 ohm plus the maximum specified resistance of wire whichever is greater | ____ Ohms |
| Max Current | Tester Default | | | ____ mA |
| Max Voltage | Tester Default | | | Volts |

**19.5.2 Electrical Test Methods - Shorts**

**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 90VAC 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 a limit is specified and included in the “Other Defined Value” column of Table 19-4, the DWV test **shall [D1D2D3]** verify the DWV measurement does not exceed that limit. 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 VDC or equivalent peak AC voltage[2] | 1500VDC or equivalent peak AC voltage[2] | ____ VDC or ____ VAC |
| Max Leakage Current | | | 1 mA | 1 mA | ____ mA |
| Dwell time | | | 0.1 Seconds | 1 Second | ____ Second(s) |

**Note 1:** See 19.1
**Note 2:** Voltage Level is applicable when clearance distance tested is ≥0.58 mm [0.019 in]. When clearance distances are <0.58 mm [0.019 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 a limit is specified and included in the "Other Defined Value" column of Table 19-5, the IR test **shall [D1D2D3]** verify that the measured IR is not below that limit. 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.

## 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 Voltage Standing Wave Ratio (VSWR) testing is specified, ~~then the parameters of Table 19-6 **shall [D1D2D3]** be used in these tests and these tests **shall [D1D2D3]** be performed.~~
the tests **shall [D1D2D3]** be performed to parameter values of Table 19-6, as agreed between User and Manufacturer.

### 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, then the parameters of Table 19-7 **shall [D1D2D3]** be used in these tests and these tests **shall [D1D2D3]** be **performed**.the tests **shall [D1D2D3]** be performed to parameter values of Table 19-7, as agreed between User and Manufacturer.

### 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, , then the parameters of Table 19-8 **shall [D1D2D3]** be used in these tests and these tests **shall [D1D2D3]** be performed. the tests **shall [D1D2D3]** be performed to parameter values of Table 19-8, as agreed between User and Manufacturer.

### 19.5.8 Electrical Test Methods - User Defined

### 19.6 Mechanical Tests

### 19.6.1 Mechanical Test - Selection

**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:<br>[ ] ____ parts<br>[ ] shift(s),<br>[ ] ___ workday(s)<br>[ ] Not Required |
| 19.7.2 | Pull Force/Tensile Testing | Required for Class 3<br>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:<br>[ ] ____ parts<br>[ ] shift(s),<br>[ ] ___ workday(s)<br>[ ] 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 | Coaxial RF Connector Shield Pull Test | User Specified | [ ] Required |
| 19.7.7 | RF Connector Shield Ferrule Torsion 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 Class.

## 19.7 Mechanical Test Methods

## 19.7.1 Mechanical Test Methods - Crimp Height (Dimensional Analysis)

## 19.7.1.1 Mechanical Test Methods - Crimp Height (Dimensional Analysis) - Terminal Position

## 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 the Manufacturer, the values used **shall [D1D2D3]** equal or exceed the values of Table 19-12.

For crimped multiple-wire applications, pull tests **shall [D1D2D3]** be performed on the smallest wire in the crimp. Unless otherwise agreed between the User and Manufacturer, Tables 19-11 and 19-12 **shall [D1D2D3]** be applied accordingly for the specific wire size that is being pulled.

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

**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 or 19-13)[1] | | Table 19-12 | ____ N<br>____ Kp<br>____ Pounds |
| Pull-Rate[2] | Not Specified | Controlled Rate | ≤1 inch/minute | ____/minute |
| Method | Not Specified | Not Specified | Not Specified | [ ] Pull & Break<br>[ ] Pull & Return<br>[ ] Pull & Hold<br>[ ] 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.

Table 19-12 provides pull-force acceptance values for crimps on stranded copper wire. Where the ~~Crimp~~ Pull Force values are not established, the tensile strength of the crimp connection **shall [D1D2D3]** be no less than 60% of the tensile strength of the wire.

**Table 19-12 Pull Test Force Values** 620A Table 19-12 minor changes

| Conductor Size | | Machined ~~Connector~~ Contacts | | | | Crimp Splices | | Stamped and Formed Contacts and Terminals ~~Lugs~~ | |
|---|---|---|---|---|---|---|---|---|---|
| AWG | (mm2) | Silver/Tin Plated Wire | | Nickel Plated Wire | | Pounds | (N) | Pounds | (N) |
| | | Lbs | (N) | Lbs | (N) | | | | |
| 30 | 0.050 | 1.5 | 6.7 | 1.5 | 6.7 | 1.5 | 6.7 | 1.5* | 6.7* |
| 28 | 0.080 | 3 | 13.4 | 2 | 8.9 | 2 | 8.9 | 2* | 8.9* |
| 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 |

* Value per UL 486A specification and established only for Class 1 assemblies

**Table 19-13 Pull Test Force Values (Classes 1 & 2) For UL, Mil, SAE, IEC, GM and Volvo**

| Size of Conductor | | UL 486A Table 12.1 | | SAE AS7928 Table II | | Conductor | IEC 60352-2 (Europe) | GMI 12590 GM (Europe) | STD 7611,151 Volvo (Europe)[1] |
|---|---|---|---|---|---|---|---|---|---|
| AWG | ($mm^2$) | Pounds | (N) | Pounds | (N) | ($mm^2$) | N | 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 | 37.1 | 40 | 40 |
| 22 | 0.324 | 8 | 35.6 | 15 | 66.8 | 0.35 | 51.2 | 50 | 50 |
| 20 | 0.519 | 13 | 57.9 | 19 | 84.6 | 0.50 | 73.1 | 70 | 70 |
| 18 | 0.823 | 20 | 89.0 | 38 | 169.1 | 0.75 | 101.3 | 90 | 90 |
| 16 | 1.310 | 30 | 133.5 | 50 | 222.5 | 1.00 | 135 | 115 | 115 |
| 14 | 2.080 | 50 | 222.5 | 70 | 311.5 | 1.50 | 203 | 155 | 155 |
| 12 | 3.310 | 70 | 311.5 | 110 | 489.5 | 2.00 | 248 | 195 | 195 |
| 10 | 5.261 | 80 | 356.0 | 150 | 667.5 | 2.50 | 309 | 235 | 235 |
| 8 | 8.367 | 90 | 400.5 | 225 | 1001.3 | 3.00 | 371 | 260 | 260 |
| 6 | 13.300 | 100 | 445.0 | 300 | 1335.0 | 4.00 | 495 | 320 | 320 |
| 4 | 21.150 | 140 | 623.0 | 400 | 1780.0 | 5.00 | 506 | 360 | 360 |
| 3 | 26.670 | 160 | 712.0 | N/A | N/A | 6.00 | 608 | 400 | 400 |
| 2 | 33.620 | 180 | 801.0 | 550 | 2447.5 | 10.00 | 1013 | 600 | 600 |
| 1 | 42.410 | 200 | 890.0 | 650 | 2892.5 | 16.00 | 1440 | N/A | 1400 |
| 1/0 | 53.490 | 250 | 1112.5 | 700 | 3115.0 | 25.00 | 2250 | N/A | 1900 |
| 2/0 | 67.430 | 300 | 1235.0 | 750 | 3337.5 | 35.00 | 3150 | N/A | 2275 |
| 3/0 | 85.010 | 350 | 1557.5 | 825 | 3671.3 | 50.00 | 4500 | N/A | 2800 |
| 4/0 | 107.200 | 450 | 2202.5 | 875 | 3893.8 | 70.00 | 6300 | N/A | 3500 |
| 250 | 127 | 500 | 2225.0 | N/A | N/A | 95.00 | 8550 | 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 spec's for 16 $mm^2$ – 95 $mm^2$ are for "Sheet" type terminals.

## 19.7.3 Mechanical Test Methods - Crimp Force Monitoring

## 19.7.4 Mechanical Test Methods - Crimp Tool Qualification

## 19.7.5 Mechanical Test Methods - Contact Retention Verification

## 19.7.6 Mechanical Test Methods - ~~Coaxial~~ 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 ~~without maintaining that peak value~~ 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, ~~then the parameters of Table 19-13 **shall [D1D2D3]** be used in these tests and these tests **shall [D1D2D3]** be performed.~~ the tests **shall [D1D2D3]** be performed to parameter values of Table 19-14, as agreed between User and Manufacturer.

**Table ~~19-13~~19-14 RF Connector Shield Pull Force Testing**

| Parameter | Defined Value |
|---|---|
| Pull Force | ____ N<br>____ Kp<br>____ Pounds |
| Pull-Rate[1] | ____/minute |
| Method | [ ] Pull & Break<br>[ ] Pull & Return<br>[ ] Pull & Hold<br>[ ] Pull, Hold & Break |
| Hold Time[2] | ____ Seconds |

**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~~ches~~] 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