

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Solderless connections –

Part 2: Crimped connections – General requirements, test methods and practical guidance

Connexions sans soudure –

Partie 2: Connexions serties – Exigences générales, méthodes d'essai et guide pratique



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SOLDERLESS CONNECTIONS –**Part 2: Crimped connections –
General requirements, test methods and practical guidance****FOREWORD**

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This third edition cancels and replaces the second edition published in 2006 and Amendment 1:2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) the former Clauses 6 through 15 have been moved into a new informative Annex A titled "Practical guidance";

- b) several definitions have been added (conductor, wire, cable, crimping, crimped connection, crimp contact, terminal, terminal end, pre-insulated terminal end, termination, connecting device, splice, insulation support, insulation grip, pre-insulated crimped connection, crimping tool, locator, positioner, full cycle crimp mechanism, crimp anvil, crimp nest, crimp indenter, crimp height, crimp inspection hole, crimp barrel wire range, nominal cross-sectional area, geometric (actual) cross-sectional area, stranded conductor, crimp funnel, crimp depth, manufacturer, user, process indicator (PID));
- c) a three-level classification by end-product class has been introduced in Clause 4 Workmanship, based on the expected level of reliability of the end-use application for which the crimped connections under subject are suitable, similar to what was done in 4.3 of IEC 61191-1:2018 for soldered electrical and electronic assemblies;
- d) for better clarification, former subclause 4.5 Crimped connections, now renumbered and renamed 5.5 Prerequisites for crimped connections, has been split in several third level subclauses with assigned title;
- e) allowable strand damage has been introduced with reference to the classification in three levels by end-use application, for the production of test specimens;
- f) based on industry experience, in 5.3.1 the minimum copper content of a copper alloy suitable for making crimp barrels has been lowered to 57 % from original 60 %;
- g) the elongation at break of annealed copper suitable for conductors to be crimped has been increased to 15 % from original 10 %;
- h) the cross-sectional area of conductors for testing purposes is allowed to be the nominal (commercial) one, instead of the geometric (actual) one for wires with nominal cross-sectional area larger than 2,5 mm² (see 5.4.3), the geometric (actual) one being the reference in case of dispute on test results;
- i) consideration about wire insulation concentricity has been added in 5.4.5;
- j) former subclause 5.2.1 General examination is now renumbered and renamed as 7.1 General examination of crimp barrels and wires (examination of parts as called later) and a new subclause 7.2 Examination of crimp dimensions has been added, to cover examination of dimensions after crimping, with several new third-level subclauses: 7.2.1 Crimp height C_h , crimp width C_w and measurable crimp width C_{wm} , 7.2.2 Contact deformation after crimping, 7.2.3 Visual examination of insulation distance and conductor overhang, 7.2.4 Visual examination of splice crimped connections, 7.2.5 Visual examination of crimped connections on closed (machined) crimp barrels, 7.2.6 Visual examination of crimped connections on B-crimp open crimp barrels, 7.2.7 Visual examination of crimped connections with open crimp barrel with insulation grip;
- k) the pull-out force (tensile strength) requirements covering safety requirements of crimped connections in IEC 60352-2:2006, Table 1 have been kept, here renumbered Table 5; interpolated values for most used cross-sectional areas 0,34 mm² and 0,37 mm² have been added. Reference to IEC 61210 as source for these safety values has been removed, as partially inaccurate. Optional specification of higher pull-out force requirements, based on classification by end-use product as specified in 5.1, and more representative of what can be achieved based on the type of crimp barrel, the form of the crimping, the material and plating of barrel and wire, has been introduced in A.7.3;
- l) a microsection test (optional) has been added in 7.3.2;
- m) a vibration test (optional) has been added in 7.3.7;
- n) a current-carrying capacity test (optional) has been added in 7.4.3;
- o) an alternative current loading, cyclic test method has been added in 7.5.5;
- p) a flowing mixed gas corrosion test (optional) has been added in 7.6.2;
- q) crimping at low temperature (former subclause 5.4.2.5) has been completed in 7.5.6 by re-entering the test method already present in IEC 60352-2:1990, 11.4.5;
- r) types of test specimens have been expanded: a new type A specimen is added, type B is former type A, type C is former type B, type D is former type C, type E is former type D modified with addition of reference wires, type F is former type E, and new specimen types G and H were added to perform tests on splices;

s) normative references, as well as Bibliography, have been updated and expanded as required;

The text of this International Standard is based on the following documents:

Draft	Report on voting
48B/3110/FDIS	48B/3128/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60352 series, published under the general title *Solderless connections*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document includes requirements and relevant tests as well as practical guidance in Annex A for crimped connections.

Two test schedules are provided:

- the basic test schedule which applies to solderless crimped connections which conform to all of the prerequisites of Clause 5. It is derived from experience with successful applications of such connections;
- the full test schedule which applies to solderless crimped connections which do not fully conform to all prerequisites of Clause 5, for example which are made with solid wires, using materials or finishes not included in Clause 4.

This philosophy permits cost- and time-effective performance verification using a limited basic test schedule for established crimped connections and an expanded full test schedule for connections requiring more extensive performance validation.

A detail product specification or the manufacturer's specification for crimped connections or associated cable assemblies or both, as well as for crimp contacts, terminal ends or splices, can include additional tests to verify enhanced performance or conformance with specified product classes or both. It can also reference this document with test severities and acceptance criteria other than those provided by either one of the two test schedules, as well as foresee an intermediate test schedule. The requirements of the detail product specification or the manufacturer's specification prevail.

The suitability of the crimped connection implies that the specified requirements and tests apply to all factors involved in producing a suitable crimped connection, namely:

- the crimp barrel, which can be part of a splice, a terminal end or a crimp contact, the contact deemed to be used in a single-pole or multipole connector;
- the wire (or range of wires) for which the termination is suitable;
- the tools required to produce that type of solderless connection.

The practical guidance in Annex A serves as a guideline for the required workmanship. Attention is drawn to the fact that some industries (e.g. automotive, aerospace, nuclear, military) can have specific workmanship standards or quality requirements, or both, which are outside the scope of this document.

IEC Guide 109 advocates the need to minimize the impact of a product on the natural environment throughout the product life cycle.

It is understood that some of the materials permitted in this document can have a negative environmental impact.

As technological advances lead to acceptable alternatives for these materials, they will be eliminated from future editions of this document.

SOLDERLESS CONNECTIONS –

Part 2: Crimped connections – General requirements, test methods and practical guidance

1 Scope

This part of IEC 60352 is applicable to solderless crimped connections made with:

- appropriately designed uninsulated or pre-insulated crimp barrels as parts of crimp contacts, terminal ends or splices, and
- stranded wires of 0,05 mm² to 10 mm² cross-section or
- solid wires of 0,25 mm to 3,6 mm diameter;

for use in electrical and electronic equipment.

Information on the materials and data from industrial experience is included in addition to the test procedures to provide electrically stable connections under prescribed environmental conditions.

This part of IEC 60352 is not applicable to crimping of coaxial cables.

This part of IEC 60352 determines the suitability of solderless crimped connections as described above, under specified mechanical, electrical and atmospheric conditions and provides a means of comparing test results when the tools used to make the connections are of different designs or manufacture.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-581, *International Electrotechnical Vocabulary (IEV) – Part 581: Electromechanical components for electronic equipment*

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-60, *Environmental testing – Part 2-60: Tests – Test Ke: Flowing mixed gas corrosion test*

IEC 60228, *Conductors of insulated cables*

IEC 60512-1, *Connectors for electrical and electronic equipment – Tests and measurements – Part 1: Generic specification*

IEC 60512-1-1, *Connectors for electronic equipment – Tests and measurements – Part 1-1: General examination – Test 1a: Visual examination*

IEC 60512-1-2, *Connectors for electronic equipment – Tests and measurements – Part 1-2: General examination – Test 1b: Examination of dimension and mass*

IEC 60512-2-1, *Connectors for electronic equipment – Tests and measurements – Part 2-1: Electrical continuity and contact resistance tests – Test 2a: Contact resistance – Millivolt level method*

IEC 60512-2-2, *Connectors for electronic equipment – Tests and measurements – Part 2-2: Electrical continuity and contact resistance tests – Test 2b: Contact resistance – Specified test current method*

IEC 60512-2-5, *Connectors for electronic equipment – Tests and measurements – Part 2-5: Electrical continuity and contact resistance tests – Test 2e: Contact disturbance*

IEC 60512-4-3, *Connectors for electronic equipment – Tests and measurements – Part 4-3: Voltage stress tests – Test 4c: Voltage proof of pre-insulated crimp barrels*

IEC 60512-5-2, *Connectors for electronic equipment – Tests and measurements – Part 5-2: Current-carrying capacity tests – Test 5b: Current-temperature derating*

IEC 60512-6-4, *Connectors for electronic equipment – Tests and measurements – Part 6-4: Dynamic stress tests – Test 6d: Vibration (sinusoidal)*

IEC 60512-9-5, *Connectors for electrical and electronic equipment – Tests and measurements – Part 9-5: Endurance tests – Test 9e: Current loading, cyclic*

IEC 60512-11-1, *Connectors for electrical and electronic equipment – Tests and measurements – Part 11-1: Climatic tests – Test 11a – Climatic sequence*

IEC 60512-11-4, *Connectors for electronic equipment – Tests and measurements – Part 11-4: Climatic tests – Test 11d: Rapid change of temperature*

IEC 60512-11-7, *Connectors for electronic equipment – Tests and measurements – Part 11-7: Climatic tests – Test 11g: Flowing mixed gas corrosion test*

IEC 60512-11-9, *Connectors for electronic equipment – Tests and measurements – Part 11-9: Climatic tests – Test 11i: Dry heat*

IEC 60512-11-10, *Connectors for electronic equipment – Tests and measurements – Part 11-10: Climatic tests – Test 11j: Cold*

IEC 60512-11-12, *Connectors for electronic equipment – Tests and measurements – Part 11-12: Climatic tests – Test 11m: Damp heat, cyclic*

IEC 60512-16-4, *Connectors for electronic equipment – Tests and measurements – Part 16-4: Mechanical tests on contacts and terminations – Test 16d: Tensile strength (crimped connections)*

IEC 60512-16-7, *Connectors for electronic equipment – Tests and measurements – Part 16-7: Mechanical tests on contacts and terminations – Test 16g: Measurement of contact deformation after crimping*

IEC 60512-16-8, *Connectors for electronic equipment – Tests and measurements – Part 16-8: Mechanical tests on connections and terminations – Test 16h: Insulating grip effectiveness (crimped connections)*

IEC 60512-19-1, *Connectors for electronic equipment – Tests and measurements – Part 19-1: Chemical resistance tests – Test 19a: Fluid resistance of pre-insulated crimp barrels*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-581, IEC 60512-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

conductor

part of the cable or wire intended to carry electric current

Note 1 to entry: The conductor may be

- a) solid – made of a single strand of circular cross-section;
- b) stranded – made of several strands of circular cross-section assembled either by laying up concentrically or by bunching, and without insulation between them.

[SOURCE: IEC 60189-1:2018, 3.1]

3.2

wire

insulated conductor or assembly of several insulated conductors, laid up together and which may be provided with a screen

Note 1 to entry: The wire may be

- a) single – consists of a single insulated conductor;
- b) multiple – consists of several insulated conductors.

[SOURCE: IEC 60189-1:2018, 3.2, modified – In the term, "low frequency" has been deleted. Note 2 to entry has been deleted.]

3.3

cable

assembly of one or more conductors, with a protective covering and possibly filling, insulating and protective material

[SOURCE: IEC 60050-151:2001, 151-12-38, modified – In the definition, "and/or optical fibres" has been deleted.]

3.4

crimping

method of permanently attaching a termination to a conductor by pressure deformation or by reshaping a crimp barrel around the conductor to establish good electrical and mechanical connection

[SOURCE: IEC 60050-581:2008, 581-23-10, modified – In the definition, "the barrel" has been replaced with "a crimp barrel".]

3.5

crimped connection

permanent solderless connection made by crimping a crimp barrel

[SOURCE: IEC 60050-581:2008, 581-23-02, modified – In the definition, the existing definition of "crimping" is used to avoid text duplication, the terms "solderless" and "crimp" have been added, and the Note has been deleted.]

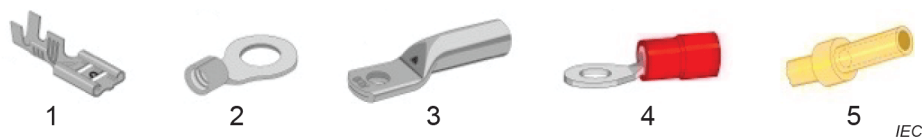
3.6

crimp contact

contact having a conductor barrel designed to be crimped

Note 1 to entry: The contact may be male or female, or may provide means for attachment to a terminal such as a pin/stud or a flattened end, fork or eyelet shaped (see Figure 1).

Note 2 to entry: Items 2, 3 and 4 of Figure 1 are also known as terminal ends or cable lugs.



1 = open barrel stamped crimp contact,

2 = closed barrel stamped crimp cable lug,

3 = closed barrel tubular cable lug,

4 = pre-insulated closed barrel crimp cable lug,

5 = closed barrel machined crimp contact

Figure 1 – Examples of crimp contact

[SOURCE: IEC 60050-581:2008, 581-22-05 modified – Notes 1 and 2 to entry and Figure 1 have been added.]

3.7

terminal

conductive part of a device, electric circuit or electric network, provided for connecting that device, electric circuit or electric network to one or more external conductors

[SOURCE: IEC 60050-581:2008, 581-23-17]

3.8

terminal end

device with barrel(s) accommodating electrical conductor(s) with or without additional provision to accommodate and support the conductor insulation, for connecting conductor(s) to equipment

3.9

pre-insulated terminal end

terminal end having a pre-insulated crimp barrel

[SOURCE: IEC 60050-581:2008, 581-23-19]

3.10

termination

part of a contact, terminal or terminal end, to which a conductor is normally connected

[SOURCE: IEC 60050-581:2008, 581-23-20]

3.11

connecting device

device for the electrical connection of two or more conductors, comprising one or more terminals, and – if necessary – insulation and/or ancillary parts

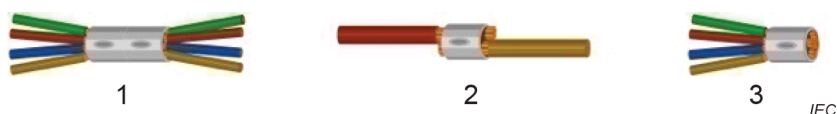
[SOURCE: IEC 60050-442:1998, 442-06-01]

3.12

splice

connecting device with barrel(s) accommodating conductor(s) with or without additional provision to accommodate and secure the insulation

Note 1 to entry: It may be single- or double-sided, the crimp barrel being either closed or open, with or without insulation (see Figure 2).



1 = double through-splice,

2 = single through-splice,

3 = single end-splice

Figure 2 – Examples of splice

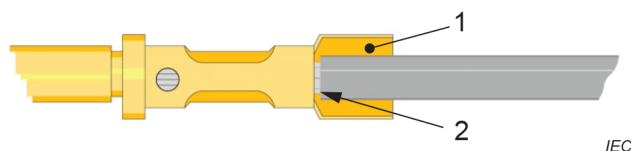
[SOURCE: IEC 60050-581:2008, 581-24-19, modified – Note 1 to entry and Figure 2 have been added.]

3.13

insulation support

part of a terminal end which accommodates but does not secure the wire insulation

Note 1 to entry: It may be larger than the conductor insulation outer diameter (see Figure 3)



1 = insulation support sleeve,

2 = conductor insulation

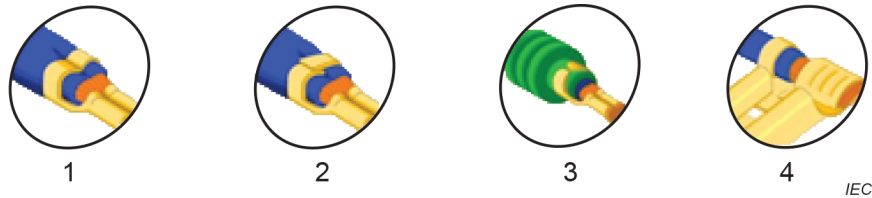
Figure 3 – Example of insulation support

[SOURCE: IEC 60050-581:2008, 581-22-17 modified – In the definition, "terminal" has been replaced with "terminal end" and "cable" has been replaced with "wire". Note 1 to entry and Figure 3 have been added.]

3.14 insulation grip

part of a terminal end in which the wire insulation is secured by crimping

Note 1 to entry: Figure 4 provides examples of insulation grip.



- 1 = B crimp,
- 2 = Overlap crimp,
- 3 = Open O crimp,
- 4 = Single rolled angle crimp (angle crimp barrel)

Figure 4 – Examples of insulation grip

[SOURCE: IEC 60050-581:2008, 581-22-16 modified – In the definition, "cable" has been replaced with "wire". Note 1 to entry and Figure 4 have been added.]

3.15 pre-insulated crimped connection

crimped connection formed with a pre-insulated terminal end or a pre-insulated splice

3.16 crimping tool

mechanical device used to make a crimp

Note 1 to entry: Figure 5 provides examples of crimping tool.



- 1 = hand crimping tool,
- 2 = adjustable tool for automatic crimping machine

Figure 5 – Examples of crimping tool

[SOURCE: IEC 60050-581:2008, 581-24-16, modified – Note 1 to entry and Figure 5 have been added.]

3.17 locator

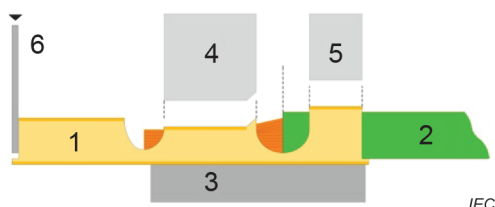
<crimping tool> device for positioning a crimp barrel in a crimping tool

[SOURCE: IEC 60050-581:2008, 581-24-17]

3.18 positioner

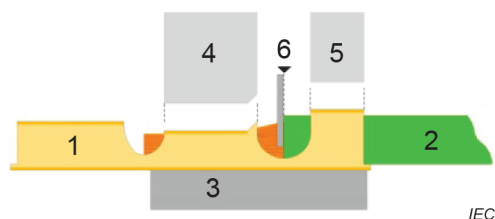
<crimping tool> locator with additional features which control the reciprocal correct position of parts while crimping

Note 1 to entry: A positioner can control either the correct position of the crimp barrel or that of the stripped conductor with respect to the crimp barrel (see Figure 6 and Figure 7).



- 1 = crimp contact,
- 2 = insulated conductor,
- 3 = anvil,
- 4 = wire crimping die,
- 5 = insulation crimping die,
- 6 = positioner for the crimp barrel

Figure 6 – Example of positioner holding the crimp barrel



- 1 = crimp contact,
- 2 = insulated conductor,
- 3 = anvil,
- 4 = wire crimping die,
- 5 = insulation crimping die,
- 6 = positioner for the stripped conductor

Figure 7 – Example of positioner holding the stripped wire

[SOURCE: IEC 60050-581:2008, 581-24-18, modified – In the definition, "depth of the crimp" has been replaced by "reciprocal correct position of parts while crimping". Note 1 to entry with relevant Figure 6 and Figure 7 has been added.]

3.19 full cycle crimp mechanism

feature of a crimping tool that prevents the tool from returning to the open position before the crimping operation has been completed

[SOURCE: IEC 60050-581:2008, 581-23-23]

3.20**crimp anvil**

part of a crimping tool which supports the crimp barrel or ferrule during crimping

[SOURCE: IEC 60050-581:2008, 581-24-14, modified – In the definition, "conductor" has been replaced by "crimp".]

3.21**crimp nest**

in a hand crimping tool having multiple-nest crimping die to cover multiple conductor or barrel sizes, each cavity of the die dedicated to a specific size or range of conductor or barrel sizes

3.22**crimp indenter**

part of a crimping tool which indents or compresses the crimp barrel or ferrule

[SOURCE: IEC 60050-581:2008, 581-24-15, modified – In the definition, "conductor" has been replaced by "crimp".]

3.23**crimping die**

part of a crimping tool which deforms or reshapes the crimp barrel(s) during crimping and usually incorporates the crimp anvil(s), the crimp indenter(s) and the positioner

Note 1 to entry: Crimping dies may have separate or integral sections for compressing the insulation grip, if provided.

[SOURCE: IEC 60050-581:2008, 581-24-26, modified – In the definition, "forms" has been replaced with "deforms or reshapes", and "during crimping" has been added. Note 1 to entry has been added.]

3.24**crimp height**

distance the crimp indenter(s) penetrates into the crimp barrel, measured by gauging the thickness of the crimping zone between two opposite points on the crimped surface(s)

Note 1 to entry: Crimp height is measured as the distance between two opposing points on the sides of the crimp barrel.

3.25**crimp barrel**

open or closed shape metal barrel designed to accommodate one or more conductor ends and to be crimped by means of a crimping tool

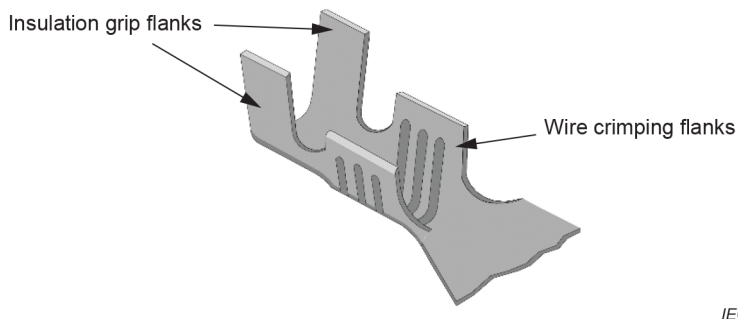
[SOURCE: IEC 60050-581:2008, 581-23-47, modified – In the definition, "conductor" has been replaced by "open or closed shape metal" and "conductors" has been replaced by "conductor ends".]

3.26

open crimp barrel

crimp barrel with an open shape before crimping, for example U- or V-shape

Note 1 to entry: Figure 8 provides an example of an open crimp barrel.



IEC

Figure 8 – Open crimp barrel

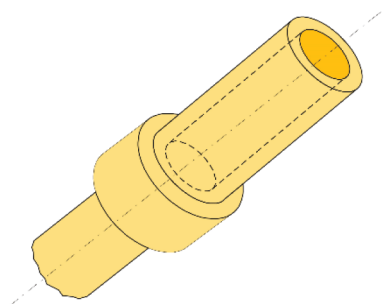
[SOURCE: IEC 60050-581:2008, 581-23-48, modified – Note 1 to entry and Figure 8 have been added.]

3.27

closed crimp barrel

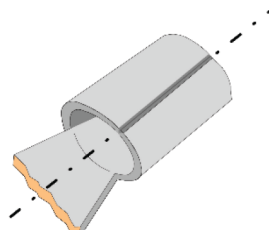
crimp barrel with a closed shape before crimping

Note 1 to entry: Figure 9 provides examples of closed crimp barrels.



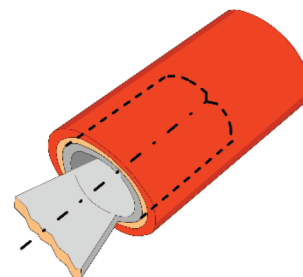
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a) Machined crimp barrel



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b) Brazed/welded crimp barrel



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c) Stamped/rolled crimp barrel

Figure 9 – Closed crimp barrels

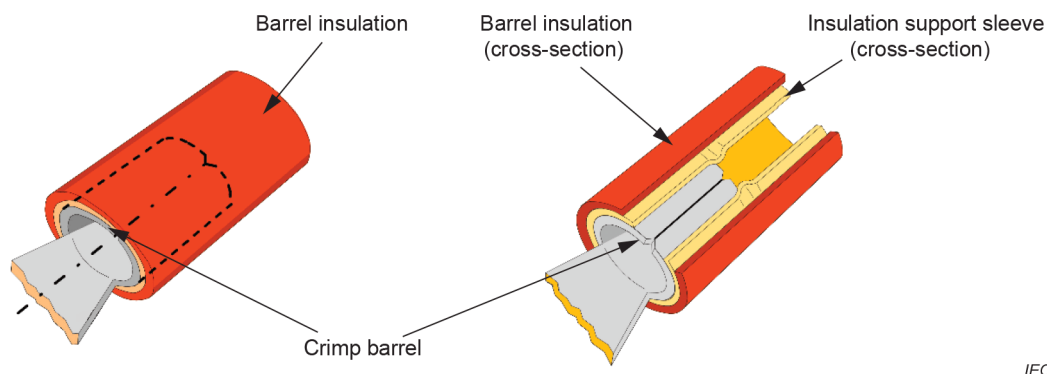
[SOURCE: IEC 60050-581:2008, 581-23-49, modified – Note 1 to entry and Figure 9 have been added.]

3.28

pre-insulated crimp barrel

crimp barrel with a permanent layer of insulation, which provides electrical integrity, through which the crimp is made, the crimp barrel and the pre-insulation being crimped in one operation

Note 1 to entry: Figure 10 provides an example of a pre-insulated crimp barrel.



IEC

Figure 10 – Pre-insulated crimp barrel

[SOURCE: IEC 60050-581:2008, 581-23-50, modified – In the definition, "through which the crimp is made," has been added and "will be" has been replaced with "being". Note 1 to entry and Figure 10 have been added.]

3.29

crimping zone

part of a crimp barrel where the crimped connection is achieved by pressure deformation or reshaping of the barrel around the conductor

Note 1 to entry: Where the crimp barrel is equipped with an insulation grip, this is also reshaped by compression by the crimping tool to secure the insulation of the wire.

Note 2 to entry: Figure 11 provides examples of insulation grip.

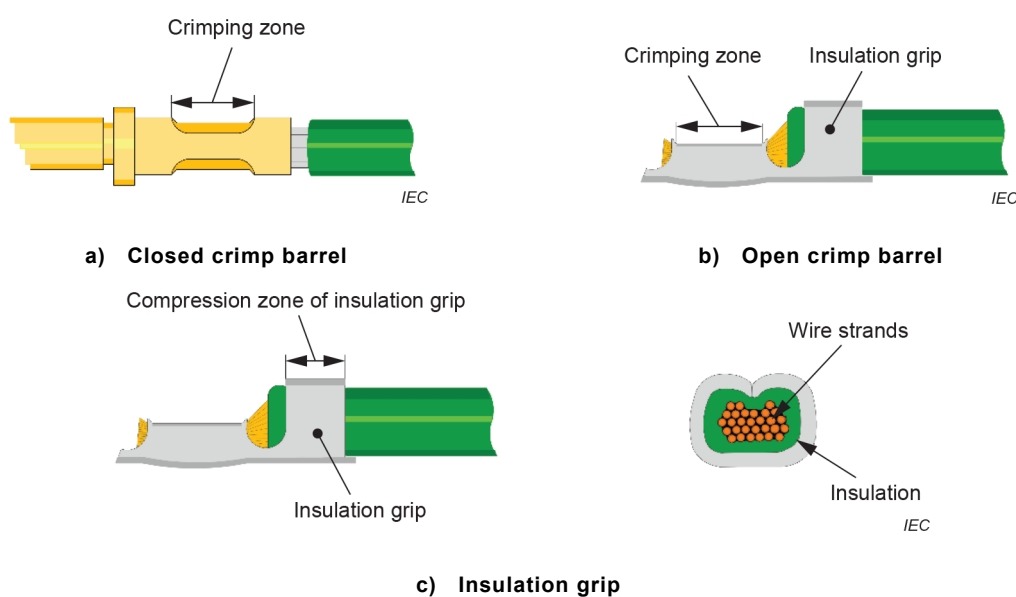


Figure 11 – Crimping zones

[SOURCE: IEC 60050-581:2008, 581-23-56, modified – Notes 1 and 2 to entry and Figure 11 have been added.]

3.30

crimp inspection hole

hole provided in the crimp barrel to permit visual inspection of conductor position

[SOURCE: IEC 60050-581:2008, 581-27-06, modified – In the definition, "conductor" has been replaced with "crimp".]

3.31

crimp barrel wire range

range of geometric cross-sectional areas, from smallest to largest, that a crimp barrel can accept, as specified by the barrel manufacturer

3.32

nominal cross-sectional area

value that identifies a particular size of conductor but is not subject to direct measurement

Note 1 to entry: Each particular size of conductor in IEC 60228 is required to meet a maximum resistance value.

[SOURCE: IEC 60228:2004, 2.2]

3.33

geometric (actual) cross-sectional area

value that identifies the actual size of a conductor based on the product of the number of its individual strands and the area of each strand

3.34

stranded conductor

conductor consisting of a number of wires, all or some of which are wound in a helix

Note 1 to entry: A stranded conductor is defined as class 2 conductor in IEC 60228. The number of strands and their diameter are used, for example, in IEC TR 60344.

[SOURCE: IEC 60050-151:2001, 151-12-36, modified – Note 1 to entry has been added.]

3.35

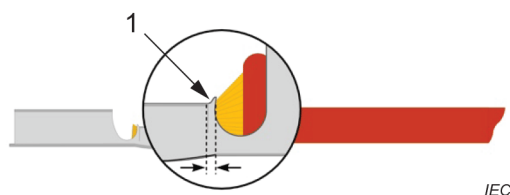
crimp funnel

portion of the crimping zone shaped so as to prevent individual conductor strands from being cut-off during the crimp compaction

Note 1 to entry: There may be an input funnel and an output funnel.

Note 2 to entry: The alternative terms trumpet or bell-mouth are used in some documents.

Note 3 to entry: See Figure 12 as an example of crimp funnel.



1 = input funnel

Figure 12 – Example of crimp funnel

3.36**crimp depth**

path of penetration of a tool part into the crimp barrel

3.37**manufacturer**

individual, organization, company or agency having the technical responsibility for the design, fabrication and supply of specified equipment

EXAMPLE Crimped connection manufacturer, crimp contact manufacturer, terminal end manufacturer, splice manufacturer, crimping tool manufacturer, wire manufacturer.

Note 1 to entry: A crimped connection manufacturer is also user of all the materials and tools required to manufacture the crimped connection.

3.38**user**

individual, organization, company or agency responsible for the procurement of specified equipment and having the authority to define type and class of the equipment and any variation or restrictions

EXAMPLE Crimped connection user, crimp contact user, terminal end user, splice user, crimping tool user, wire user.

Note 1 to entry: A crimp contact user or terminal end user or splice user is necessarily also crimping tool user and wire user, when becoming crimped connection manufacturer.

Note 2 to entry: A crimped connection user is not necessarily the crimped connection manufacturer.

3.39**process indicator****PID**

condition which is not the best, but still within the defined tolerance, thus considered acceptable

Note 1 to entry: If a PID condition is detected, process adjustment is essential, as accumulated PIDs can be considered a failure even if seldom occurring PIDs are within tolerance.

4 Workmanship

The manufacturer of crimp terminations or of a component (e.g. crimp contacts, multipole connectors for the same) using such terminations shall provide an instruction for the assembly of crimped connections.

Crimped connections shall be processed in a careful and workmanlike manner, in accordance with good current practice.

Annex A provides practical guidance and may constitute a benchmark for the assessment of workmanship.

NOTE Some industry sectors (e.g. automotive, aerospace, marine, nuclear, military) use workmanship standards which can be considered upon agreement between manufacturer and user.

5 Prerequisites for basic test schedule

5.1 Classification by end-product class

5.1.1 General

In analogy with IEC 61191-1:2018 dealing with printed board assemblies that establishes the general requirements for soldered electrical and electronic assemblies, this document, dealing with a specific solderless connection technology, recognizes that electrical and electronic assemblies, which are the target for such solderless crimped connections, may be classified by intended end-product use.

Three general end-product classes are established to reflect differences in producibility, functional performance requirements, and verification (inspection or test) frequency.

As there can be overlaps of equipment between classes, the manufacturer of end-use products shall identify the relevant product class for the required crimped connections in accordance with this document and the manufacturer of the crimped connections shall apply the relevant test requirements.

This classification can have impact on some requirements.

5.1.2 Class A – General electrical and electronics products

This class covers electrical and electronic assembly products for general use. It includes consumer products, some computers and computer peripherals, and hardware suitable for applications where the major requirement is function of the completed assembly.

5.1.3 Class B – Dedicated service electrical and electronics products

This class covers electrical and electronic assembly products for special applications where high performance, extended life and uninterrupted service are desired but not mandatory. It includes communications equipment, sophisticated office machines and equipment. Typically, the end-use environment would not cause failures.

5.1.4 Class C – High-performance electrical and electronics products

This class covers electrical and electronic assembly products where continued performance or performance-on-demand is mandatory. Equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment shall function when required, such as life support systems and other critical systems.

5.2 Prerequisites for tools

Crimping tools shall be selected according to the instructions given by the manufacturer of the crimp contact (or terminal end or splice) of which the crimp barrel is an integral part.

Tools from manufacturers other than those recommended by the crimp contact (or terminal end or splice) manufacturer that are compatible with the barrel crimping requirements, may be used under the sole responsibility of the crimped connection manufacturer, who shall be responsible for the qualification according to this document.

Crimping tools shall be used and inspected according to the instructions given by the tool manufacturer.

The crimping tool shall be able to make uniformly reliable connections during its useful life.

The crimping tool shall be equipped with the appropriate dies. Where the dies are adjustable, the correct setting for the barrel to be crimped shall be used.

Hand crimping tools shall be provided with a full cycle crimping mechanism.

Adjustable crimping tools for automatic or semi-automatic crimping machines shall be provided with a full cycle crimping mechanism or equivalent safeguard.

They shall be correctly set and the setting shall be maintained.

NOTE See Clause A.2 c) for details about full cycle crimping mechanism.

Tools shall be evaluated by testing crimped connections made with the tools to be evaluated.

Certain end-use applications of crimped connections, e.g. installation in single-pole or multipole connectors, can be more sensitive than others to undue axial or transverse barrel deformation, or both, after crimping (verified with test 16g of IEC 60512-16-7, see 8.2.2 and 8.3.2). A locator system for the crimping tool is recommended in such cases, in order to avoid the deformations that an incorrect positioning of the crimping over the barrel can produce. See the instructions of the crimp barrel manufacturer.

5.3 Prerequisites for crimp barrels

5.3.1 Crimp barrel materials

Crimp barrels shall be made of copper or copper alloy with a minimum copper content of 57 %.

NOTE The ability of a material to deform plastically without breaking is correlated to its tensile strength R_m . The historical requirement – now abandoned – was $R_m \leq 600$ MPa, as measured in accordance with ISO 6892-1.

For crimped connections realized with crimp barrels made with materials according to these requirements, the basic test schedule of 8.2 shall apply (see 6.1).

Other materials of suitable characteristics can be used, for example nickel, steel, stainless steel. It is possible that materials with a high resistivity coefficient (K values, see 7.4.1) or materials exceeding the tensile strength mentioned above are not suitable for certain applications. In these cases, the full test schedule of 8.3 shall apply (see 6.1).

5.3.2 Crimp barrel dimensions

The dimensions shall be suitable for stranded wires as specified in 5.4.

NOTE A crimp barrel can be designed to cover a range of wire sizes.

5.3.3 Crimp barrel surface finishes

The crimp barrel shall be either unplated or plated with tin, tin-alloy, silver, gold or palladium, with nickel or copper underplate, as applicable, acting as diffusion barrier.

In these cases, the basic test schedule of 8.2 shall apply (see 6.1).

The surface shall be free of contamination and corrosion. This requirement shall be verified by visual inspection as detailed in 7.1.

Other plating materials, such as nickel (unless used as under-plate), may be used provided their suitability has been proven.

In these cases, the full test schedule of 8.3 shall apply (see 6.1).

5.3.4 Crimp barrel design features

The crimp barrel shall be so designed that the crimped connection is achieved by pressure deformation or reshaping of the crimp barrel around the stripped conductor.

NOTE Techniques where the connection is achieved by parts of barrel penetrating through the insulation of an insulated conductor are not covered by this document.

The following barrel types shall be used:

- open crimp barrels, uninsulated;
- closed crimp barrel, either pre-insulated or uninsulated.

The crimp barrels shall be free of sharp edges likely to damage the conductors.

Where the crimp barrel is equipped with an insulation support or insulation grip, the overall diameter of the wire insulation shall be compatible with the dimensions of the support or grip, i.e. the wire insulation shall be correctly located in the support or grip.

5.4 Prerequisites for wires

5.4.1 General

Stranded conductors should be used (class 2, 5, or 6 as defined in IEC 60228, according to the crimp barrel manufacturer's instruction). Solid round conductors of 0,25 mm to 3,6 mm diameter (class 1 as defined in IEC 60228) may be used – when specified by the crimp barrel detail specification or manufacturer's specification – provided their suitability has been proven through the full test schedule of 8.3.

NOTE For the sake of clarity, the attributes "stranded" and "solid round" are each now associated with the corresponding relevant class defined by IEC 60228. "Stranded" can be associated to class 2, class 5 or class 6 (the last two are defined therein as "flexible", class 6 being elsewhere described as "extra flexible" due to a higher strand count with lower diameter than the correspondingly sized class 5 conductor, to achieve higher flexibility at the expense of higher apparent cross-sectional area), whereas "solid round" corresponds to class 1 in accordance with IEC 60228. Reminder: IEC 60228 does not cover conductors for wires used in the telecommunication industry, which are covered by IEC 60189 series, for example, IEC 60189-3:2007 listed in the Bibliography of this document.

5.4.2 Conductor materials

Annealed copper shall be used, having an elongation at break of:

- not less than 8 % for stranded conductors with individual strand diameter from 0,04 mm to 0,08 mm, or
- not less than 13 % for stranded conductors with individual strand diameter above 0,08 mm.

NOTE EN 13602 includes suitable copper alloys.

5.4.3 Conductor dimensions

The nominal cross-sectional area (CSA) of the stranded conductor (class 2, 5, or 6 as defined in IEC 60228 and as specified by the crimp barrel detail specification or manufacturer's specification) shall be within the range 0,05 mm² to 10 mm².

The diameter of the solid round conductor (class 1 as defined in IEC 60228, when specified by the crimp barrel detail specification or manufacturer's specification) shall be within the range 0,25 mm to 3,6 mm.

The geometric (actual) cross-sectional area shall be computed and considered in case of dispute on test results.

NOTE 1 This information is relevant for tests, for example, 7.3.1 Tensile strength.

Considering the nominal CSA instead of the geometric (actual) CSA is acceptable only if all results are acceptable.

5.4.4 Conductor surface finishes

Conductors which are unplated or finished with tin, tin-alloy or silver shall be used.

The surface shall be free of contamination and corrosion. This requirement shall be verified by visual inspection as detailed in 7.1.

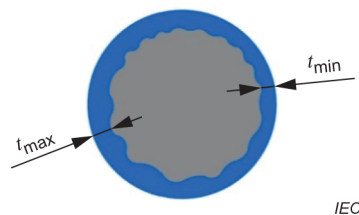
Other plating materials, such as nickel, may be used provided their suitability has been proven. In these cases, the full test schedule of 8.3 shall apply (see 6.1).

5.4.5 Wire insulation

The insulation shall be capable of being readily stripped from the conductor without changing the physical characteristics of the conductor or its individual strands.

Sufficient concentricity of the wire insulation around the core conductor is required for stripping stranded conductors without damaging it. This shall be at least 60 %.

Figure 13 shows measurement of the wire insulation thickness (stranded conductor) according to IEC 60811-201, while Formula (1) provides calculation of the concentricity X .



Key

$t_{\min}$	minimum insulation thickness,
$t_{\max}$	maximum insulation thickness

Figure 13 – Concentricity of wire insulation

$$X = \frac{t_{\min}}{t_{\max}} \times 100(\%) \quad (1)$$

5.4.6 Wire cutting and stripping

After cutting, the conductor should appear cut at right angles and without burrs. Suitable cutting tools should be used for this.

The wire shall be stripped to the correct length according to the crimp barrel manufacturer's instruction.

Upon stripping, the wire insulation shall be removable from the conductor without changing or damaging the physical properties of the conductor.

Markings on the wire insulation caused by the stripping tool are permitted, provided the insulation is not damaged more than 20 % of the wall thickness.

The strands of the stripped part of the conductor shall not be excessively damaged, for example partially or totally broken.

Nicks or scrapes on individual strands that are less than 10 % of the strand diameter shall not be considered as damage to the conductor. Acceptable overall strand damage shall be according to Table 1, based on the classification by end-product of 5.1.

The allowable strand damage shall not exceed 6 % of the geometric (actual) CSA of the conductor. This shall be determined by calculation. If the geometric (actual) CSA is already reduced (e.g. by 6 %) compared to the nominal CSA, values in Table 1 shall no longer apply.

Table 1 – Allowable strand damage

Number of strands	Maximum allowable strands scraped, nicked or severed		
	For class A	For class B	For class C
1	No damage in excess of 10 % of conductor diameter		
2 to 6	0	0	0
7 to 15	1	1	0
16 to 25	3	2	1
26 to 40	4	4	3
41 to 60	5	5	4
61 to 120	6	6	5
> 121	6 %	6 %	5 %
There shall be no damaged strands for wires deemed to be used at a voltage of 6 kV or greater.			
For plated wires, a visual anomaly that does not expose basis metal is not considered to be strand damage.			
Nicks or scrapes less than 10 % of conductor diameter are not considered to be strand damage.			

The stripped part of the conductor shall be clean and free from particles of insulation.

The stranding of the wires shall be correct. If the stranding has been disturbed, it can be restored by a light pressure forming with light rotation, to ensure the original stranding structure and compactness of the strands.

Except for action to compact strands, by light twist or pressure, the parallel stranding structure shall be maintained. Overtwisting of stranded wires for crimped connections is not permitted, as it would increase the detectable diameter of the conductor.

Stranded wires or wire bundles shall not be:

- twisted beyond a light pressure forming required to rebuild the original stranding structure,
- soldered or dip-tin plated in the area intended for the crimped connection.

Table A.1 shows acceptable stripped wires with stranded conductors. The condition of the stripped wires identified with "PID" (process indicator) is acceptable, but the process shall be controlled and adjusted.

Table A.2 shows some examples of stripping faults.

5.5 Prerequisites for crimped connections

5.5.1 Compatibility of combination

The combination of tool (including the appropriate crimping dies and, where specified, the appropriate contact locator or positioner), crimp barrel and wire or range of wires shall be compatible.

5.5.2 Conductor location

The conductor shall be correctly located in the barrel, i.e. to the correct depth. This shall be verified as follows:

- in the case of open crimp barrels or closed crimp barrels with inspection provision, for example an inspection hole, this shall be visually checked;
- in the case of closed crimp barrels without inspection provisions, this shall be measured indirectly by measuring the possible insertion depth of the barrel, the stripping length of the wire and the distance between the end of the barrel and the beginning of the wire insulation.

Having considered acceptable strand damage as defined in Table 1, all undamaged strands of the wire shall be within the barrel.

NOTE For crimped connections made with more than one wire, see A.5.2.

5.5.3 Crimping location

The crimping shall be correctly located along the crimp barrel. This is generally achieved by using suitable contact locator or positioner to control the correct position of the dies along the contact crimp barrel.

NOTE An incorrect location of the crimping can result in damage or deformation, or both, of the crimped barrel of a crimp contact likely to impair the correct retention of the crimped connection in the dedicated cavity of a single or multipole connector insert. See also 5.2.

5.5.4 Contact deformation

The deformation of the crimp barrel of a contact after crimping shall be within the limits specified by the detail product specification.

5.5.5 Prerequisites for crimped connections with more than one conductor in the crimp barrel

When crimped connections are made with more than one conductor in a crimp barrel, the following shall be observed:

- the conductors, the crimping zone of the crimp barrel and the crimping tool used shall be matched (compatible);
- the pull-out force for each conductor of the crimped connection shall meet the requirements;
- when two or more conductors are crimped, the mechanical and electrical tests shall be performed on each conductor and in accordance with the requirements;
- the conductor combination shall be suitable;
- the conductor with the smallest cross-sectional area – as far as technically possible – shall be located at the bottom of the crimp barrel for stamped, open crimp barrel crimped connections.

Multiple-conductor crimped connections should be made with the same conductor cross-sectional areas and conductor diameters.

When crimping stranded wires with different individual strand diameters for a multiple crimp joint, the diameter ratio defined in Figure 14 shall be observed.

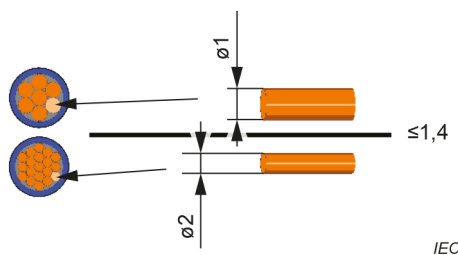


Figure 14 – Diameter ratio when crimping wires with different individual strand diameters

The ratio of largest individual strand diameter ($\varnothing 1$) to smallest individual strand diameter ($\varnothing 2$) shall be less than or equal to 1,4.

5.5.6 Adjustment of conductor cross-sectional area to the crimp barrel

If crimp barrels are provided for accepting a certain range of conductor cross-sectional areas, it is not always possible to adjust the pressure forces to the different cross-sectional areas, especially for hand crimping tools with end stop without adjustment of the crimp height.

Therefore, unless otherwise specified in the product detail specification or in the manufacturer's specification, the following shall apply:

- only conductors with a cross-sectional area that corresponds to the cross-sectional area of the crimp barrel may be crimped;
- exceptions are only permitted if the tool allows adjustment of the crimp height range within a specified range (specified by the crimp barrel manufacturer) and this guarantees that the crimp barrel can be crimped according to the requirements;
- if the crimp barrel is crimped with tools, e.g. hand crimping tools, that do not allow adjustment to different conductor cross-sectional areas, a cross-sectional area adjustment (e.g. with filler strands) is necessary. The conductor cross-sectional area is increased to the maximum value of the specified conductor cross-sectional area of the crimp barrel.

5.5.7 Crimp contacts and terminal ends

5.5.7.1 General

For the purpose of this document, the terms "crimp terminal", "crimp contact", "crimped connection", etc. are used for both crimp terminal ends (cable lugs) and crimp contacts.

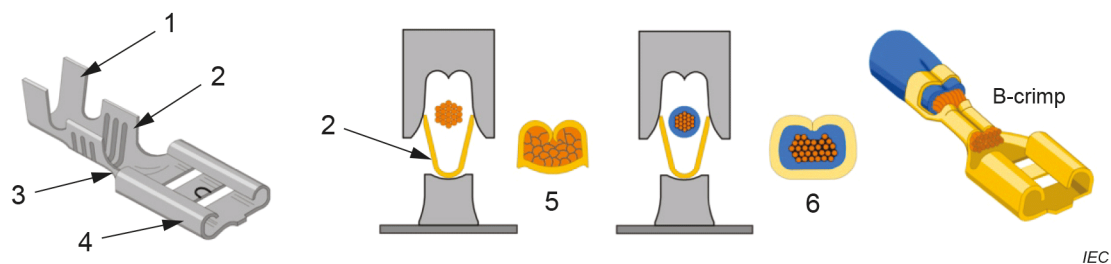
5.5.7.2 Open crimp barrels with or without insulation grip

The crimp contacts for use as B-crimp are typically open stamped strip products (in-line) as shown in Figure 15.

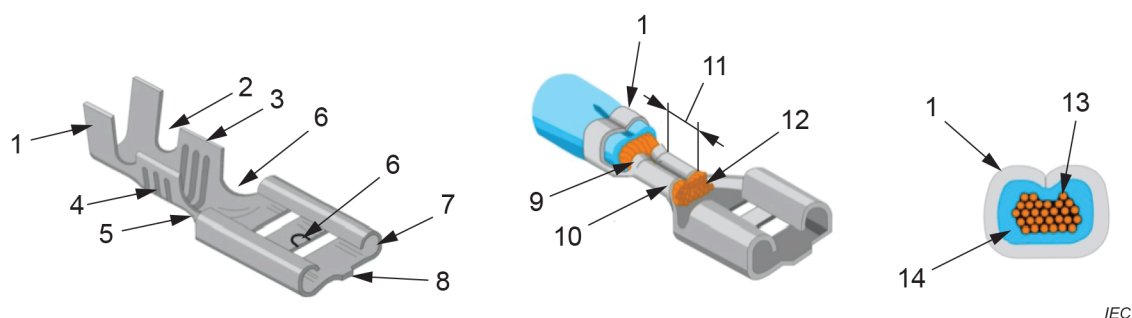


Figure 15 – Examples of open stamped crimp contacts for automatic production

The B-crimp shown in Figure 16 and Figure 17 is a development for industrial mass production. Due to its open design, however, it has disadvantages, such as springback forces or displacements in the crimping die, which require careful tooling adjustment and corresponding quality control.

**Key**

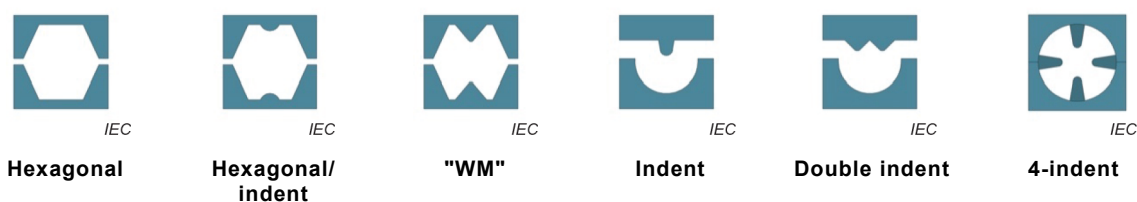
- 1 = insulation grip flanks
- 2 = wire crimping flanks
- 3 = transition
- 4 = contact area
- 5 = wire crimping
- 6 = insulation grip

Figure 16 – Stamped open B-crimp contact with anvil and punch shapes**Key**

- 1 = insulation grip flanks
- 2 = insulation test window
- 3 = wire crimping flanks
- 4 = embossing grooves
- 5 = transition
- 6 = contact locking
- 7 = contact area
- 8 = punching rest
- 9 = input funnel
- 10 = output funnel
- 11 = crimping zone
- 12 = conductor overhang
- 13 = conductor strands
- 14 = insulation of conductor wires

Figure 17 – Designations on open B-crimp contact**5.5.7.3 Crimping dies for closed crimp barrels**

Figure 18 illustrates examples of crimping dies.

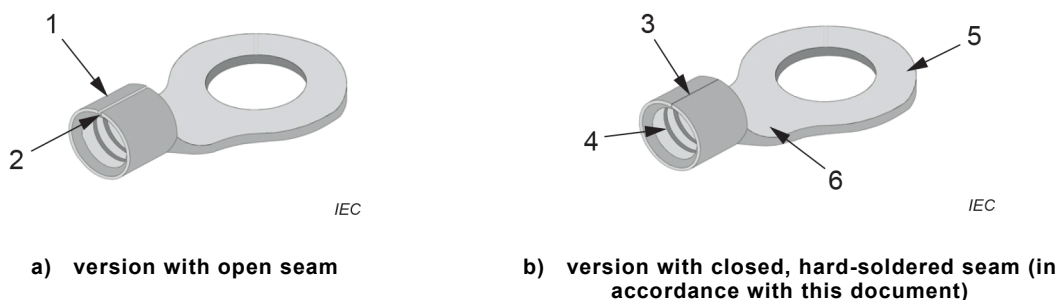
**Figure 18 – Examples of crimping dies (press dies)**

5.5.7.4 Closed crimp barrel (stamped crimp cable lugs)

Crimp cable lugs, such as those described by DIN 46234 in ring form and shown in Figure 19 (uninsulated), are stamped from metal sheets and shall have a closed, hard-soldered seam.

Their conductor cross-sectional area range is from 0,1 mm² to 300 mm².

NOTE Cross-sectional areas up to and including 10 mm² are relevant for this document.



Key

- | | |
|--------------------------------------|----------------------------------|
| 1 = punch-formed closed crimp barrel | 4 = embossing grooves |
| 2 = open seam | 5 = contact area (ring) |
| 3 = closed, hard-soldered seam | 6 = transition (transition area) |

Figure 19 – Stamped closed crimp barrel (crimp cable lug)

Typical crimp shapes for such type of cable lugs are shown in Figure 20, while Figure 21 provides examples of crimping dies for closed crimp barrels.

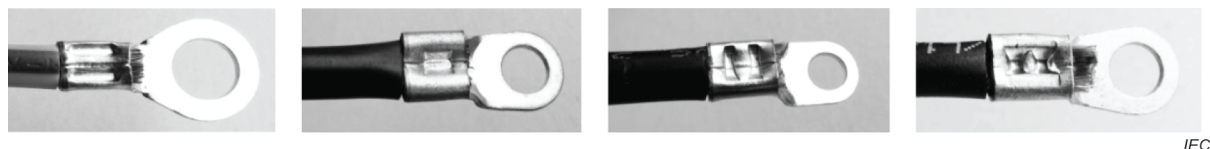


Figure 20 – Different crimp shapes

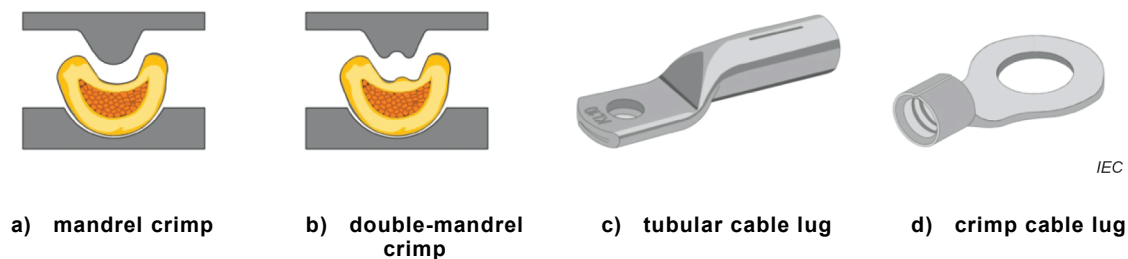


Figure 21 – Examples of crimping dies for closed crimp barrels

5.5.7.5 Closed crimp barrel (tubular cable lugs)

Tubular cable lugs are the low-cost variant of the longer and thicker-walled compression cable lugs, and are made from a cut and stamped tube, e.g. in accordance with DIN 46235.

An even cheaper variant consists of stamped, closed crimp barrels, with open end towards the contact, for wire protrusion, for conductor cross-sections from 0,5 mm² to 240 mm², the seam of which is brazed, e.g. in accordance with DIN 46234 (see Figure 21 d)).

The use of class 5 and class 6 (finest-stranded) conductors according to IEC 60228 requires different designs.

Figure 22 shows examples of a tubular cable lug with eyelet and a tubular cable lug with fork for class 5 conductors.

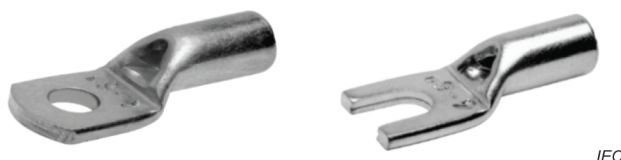


Figure 22 – Tubular cable lugs for class 5 conductors

Figure 23 shows examples of a tubular cable lug and a splice for class 6 conductors.



Figure 23 – Tubular cable lugs for class 6 conductors

NOTE Compression cable lugs like those depicted in Figure 21 c), Figure 22 and Figure 23 (left) are not covered by this document.

5.5.7.6 Closed crimp barrel (machined contacts for 4-indent crimping)

This form of crimp contacts as shown in Figure 24 enables the greatest possible electric power transmissions whilst requiring at the same time little space.

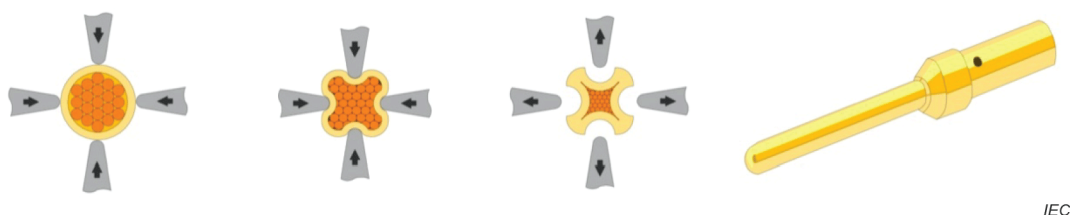


Figure 24 – Crimping process of 4-indent crimping with adjustable tools

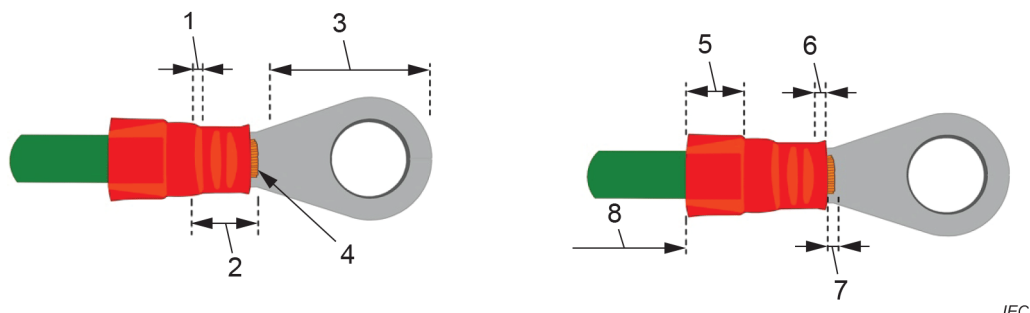
5.5.7.7 Pre-insulated closed crimp barrel (stamped crimp cable lugs)

Figure 25 shows area definitions for pre-insulated, stamped closed barrel crimp cable lugs.

Figure 26 shows examples of such lugs in two versions: a) with plastic insulation grip and b) with metal insulation grip.

Figure 27 shows examples of pre-insulated crimp cable lugs as strip parts with various transport options, for use in machine processing in quick-change crimp tools.

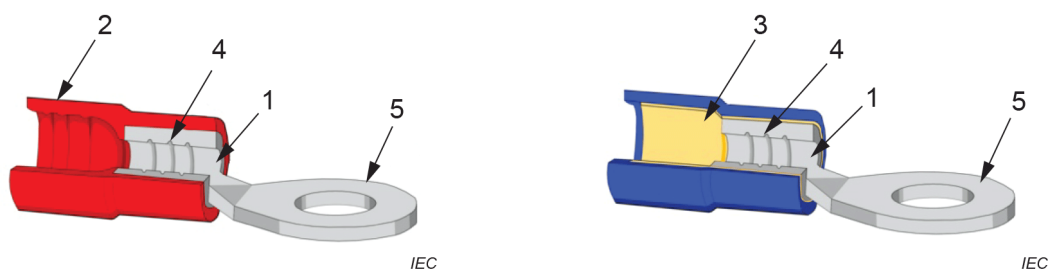
These crimp barrels clearly do not allow crimping zone visual examination and crimp height measurement.



- 1 = input funnel wire crimping (not visible)
- 2 = crimping zone
- 3 = contact area
- 4 = conductor overhang

- 5 = insulation grip
- 6 = output crimping zone (not visible)
- 7 = conductor overhang
- 8 = core

Figure 25 – Pre-insulated stamped close crimp barrel, area definitions



a) version with plastic barrel for insulation grip

b) version with brass barrel for insulation grip

Key

- 1 = crimp barrel
- 2 = plastic insulation grip area
- 3 = brass barrel for insulation grip
- 4 = embossing grooves
- 5 = contact area (ring)

Figure 26 – Pre-insulated closed crimp barrels of various designs

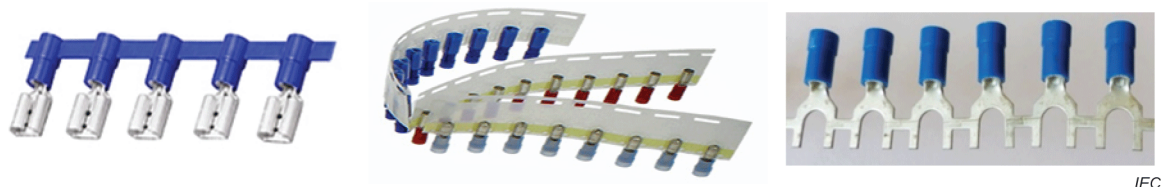


Figure 27 – Examples of pre-insulated crimp cable lugs as strip parts

5.5.8 Splice crimp barrels

Splices of conductors are crimped with crimp barrels without contact area.

The materials used for splice crimp barrels shall be the same as those specified in 5.3.1

The crimped connections prerequisites of 5.5 shall apply also to crimped splices. Additional prerequisites for splice crimp barrels are provided in 5.6.

As multiple conductors are connected to a splice crimp barrel, each conductor shall meet the same acceptance criteria as the connection of a single conductor.

As multiple conductors are connected to a splice crimp barrel, the resulting total cross-sectional area shall be within the cross-sectional area of the splice crimp barrel.

5.6 Prerequisites for splice crimped connections

5.6.1 General

Figure 28 shows possible uninsulated splice variants.

NOTE Pre-insulated splice variants are similar and for simplicity are not represented.

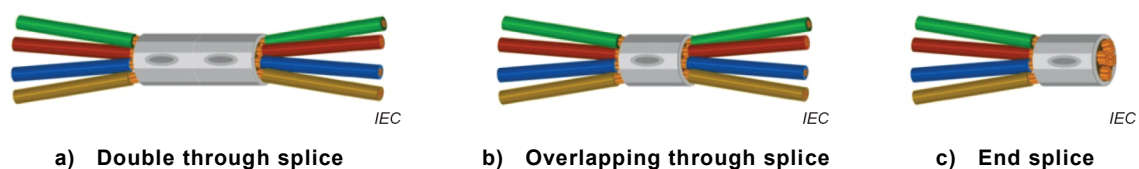


Figure 28 – Uninsulated splice variants

Overlapping through splices require the shortest wire stripping length.

The wire ends shall be stripped in such a way that the bare conductors overlap at least along the length of the crimp barrel (single crimp barrel, not double-sided) and have an insulation distance that corresponds to the requirements in Table 4.

The conductors should remain parallel (not twisted) and have full length contact.

The strands shall not overlap with the wire insulation of the other wires.

Splices shall not be used to repair broken or damaged conductors without prior approval by the end user.

The maximum number of cores per splice shall be 10, and the maximum number of cores per splice end side (end splices) shall be 6.

The minimum cross-sectional area of a single core shall be 10 % of the total cross-sectional area of all conductors.

5.6.2 Conductor requirements for crimped splices

Not only the different construction (number of individual strands) but also the associated individual strand diameters are important for the crimping of splice.

Not all diameters of the individual strands can be combined in a crimped splice: if the difference is too large, smaller diameter strands can be crimped before larger diameter strands deform.

When crimping stranded wires with different individual strand diameters for a multiple crimp joint, the diameter ratio shown in Figure 29 shall be observed.

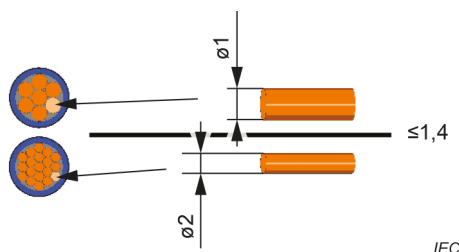


Figure 29 – Diameter ratio when crimping wires with different individual strand diameters in splices

The ratio of largest conductor strand diameter ($\varnothing 1$) to smallest conductor strand diameter ($\varnothing 2$) shall be less than or equal to 1,4.

6 Testing

6.1 General

Two test schedules shall be applied according to the following conditions:

- crimped connections, which conform to all of the prerequisites of Clause 5 shall be tested to and meet the requirements of the basic test schedule of 8.2;
- crimped connections, which do not fully conform to all of the prerequisites of Clause 5, for example which are made with solid wires, different materials, more than one stranded conductor in a crimp barrel, such as splices, etc., shall be tested to and meet the requirements of the full test schedule of 8.3.

NOTE For crimped connections made with more than one wire, see A.5.2.

Table 2 summarizes the prerequisites given in 5.3 for crimp barrels (conductors) while Table 3 summarizes the prerequisites given in 5.4 for wires, providing access to the basic test schedule of 8.2.

Table 2 – Prerequisites of 5.3 for crimp barrels to access the basic test schedule of 8.2

Material	Material features	Dimensions	Surface finishes	Surface	Design features	Insulation support or insulation grip
5.3.1	5.3.1	5.3.2	5.3.3	5.3.3	5.3.4	5.3.4
Copper or copper alloy with minimum copper content of 57 %	Suitable tensile strength and elongation at break	Suitable for stranded wires with cross-sectional area 0,05 mm ² to 10 mm ² (according to manufacturer's specification)	Unplated Plated with tin, tin alloy, silver, gold, or palladium, with nickel underplate, as applicable	Free from contamination and corrosion	Open crimp barrel, uninsulated Closed crimp barrel, pre-insulated or uninsulated Free of sharp edges	Dimensions of support or grip compatible with overall diameter of wire insulation
Subclause numbers in the header row indicate where the feature is specified.						

Table 3 – Prerequisites of 5.4 for wires to access the basic test schedule of 8.2

Product	Construction	Material	Material features	Dimensions	Surface finishes	Surface	Insulation
5.4.1	5.4.1	5.4.2	5.4.2	5.4.3	5.4.4	5.4.4	5.4.5
Stranded conductor	Class 2, 5, or 6 as defined in IEC 60228	Annealed copper or copper alloy	Elongation at break: ≥ 8 %, or ≥ 13 % depending on individual strand Ø (Tensile strength)	Cross-sectional area 0,05 mm ² to 10 mm ²	Unplated Plated with tin, tin-alloy, or silver	Free from contamination and corrosion	Capable of being readily stripped from the conductor without changing the physical characteristics of the conductor or strands
Subclause numbers in the header row indicate where the feature is specified.							

A detail product specification, or the manufacturer's specification, for crimped connections or associated cable assemblies, as well as for crimp contacts, terminal ends or splices, can include additional tests, to verify enhanced performance or conformance with specified product classes.

It can also reference this document with different test severities and acceptance criteria than those of either one of the two test schedules provided herein, as well as foresee an intermediate test schedule. The requirements of the detail product specification or the manufacturer's specification (of the crimp barrel in crimp contacts, terminal ends or splices, or of the crimped connection or associated cable assemblies, as applicable) shall prevail, once the deviations from what is specified in this document are documented in the product literature.

6.2 Standard conditions for testing

Unless otherwise specified in the product detail specification or in the manufacturer's specification, all tests shall be carried out under the standard conditions for testing as specified in IEC 60512-1.

The ambient temperature and the relative humidity at which the measurements are made shall be stated in the test report.

In case of dispute about test results, the test shall be repeated at one of the referred conditions of IEC 60068-1.

6.3 Pre-conditioning

Where specified, the connection shall be pre-conditioned under standard conditions for testing for a period of 24 h, in accordance with IEC 60512-1.

6.4 Recovery

Where specified, the specimen shall be allowed to recover under standard conditions for testing for a period of 1 h to 2 h, after conditioning.

6.5 Mounting of the specimen

When mounting is required in a test, the specimens shall be mounted using the normal mounting method, unless otherwise specified in the product detail specification or in the manufacturer's specification.

7 Test methods and test requirements

7.1 General examination of crimp barrels and wires

The tests shall be carried out in accordance with test 1a of IEC 60512-1-1 and test 1b of IEC 60512-1-2.

Unless otherwise specified in the detail product specification, the visual examination test shall be carried out with at least the optical test magnification (dioptré) specified in Table 4. The test magnification is based on the overall diameter of the electrical conductor (stripped wire).

The tolerances for magnification aids are $\pm 15\%$ of the selected test magnification. Magnification aids should be checked, maintained and calibrated at appropriate intervals.

For assemblies with different conductor diameters, the highest test magnification corresponding to the smallest conductor diameter can be used for the entire assembly.

If no defect is detected at the corresponding test magnification, the unit shall be classified as acceptable.

Table 4 – Magnification aids for visual examination

Conductor diameter d (mm)	Test magnification	Reference magnification ^a
$d > 1,5$ (> 16 AWG)	1,5×	1,75×
$0,75 < d \leq 1,5$	1,5× to 3×	4×
$0,3 < d \leq 0,75$	3× to 7,5×	10×
$d \leq 0,3$ (≤ 30 AWG)	10×	20×
^a To be used only if a defect has been detected that cannot be fully identified with the existing test magnification.		

All parts shall be examined to ensure that the applicable prerequisites of 5.3 for crimp barrels (see Table 2 in 6.1) and of 5.4 for wires (see Table 3 in 6.1) have been met.

NOTE 1 Prerequisites for tools (5.2) can only be assessed once wires and crimp barrel prerequisites have been assessed in view of the preparation of specimens.

NOTE 2 Examination of crimped connections, including visual examination, examination of dimensions (e.g. crimp height) as well as contact deformation after crimping when required, belongs to so-called initial examination of test specimens (as far as applicable) in 8.2.2 (basic test schedule) and 8.3.2 (full test schedule).

7.2 Examination of crimp dimensions

7.2.1 Crimp height C_h , crimp width C_w and measurable crimp width C_{wm}

The specimens to be used are those intended for the subsequent tests.

The crimp height measurements are performed according to the specifications of the crimp connector manufacturer or crimp tool manufacturer with the permissible tolerances according to, for example, Table 5.

The specified crimp height C_h gives an indication of correct crimping of the conductor and of sufficiently high pull-out force in consideration of the tolerances.

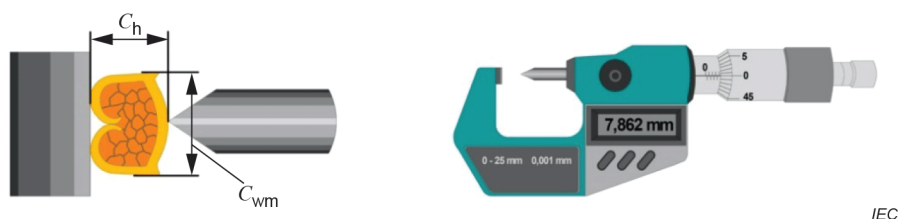
The crimp width C_w is specified as a tool-dependent dimension of the crimp form width and is defined as the distance between the tangent points of both roll-in radii and the vertical.

It is not possible to check the crimp width C_w as a production control.

The measurement of the crimp width C_w at the bottom of the crimp (measurable crimp width C_{wm}) enables a check whether the correct crimp form width was used.

The values of crimp height C_h , crimp width C_w and measurable crimp width C_{wm} can also be determined in a microsection (see 7.3.2).

Figure 30 shows the crimp height C_h measurement on an open crimp barrel (B-crimp).



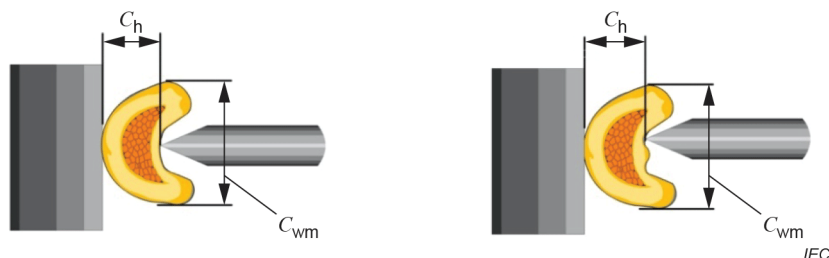
Key

C_h crimp height

C_{wm} measurable crimp width

Figure 30 – Crimp height measurement on open crimp barrel (B-crimp)

Figure 31 shows the crimp height C_h measurement on a closed crimp barrel with mandrel crimping.



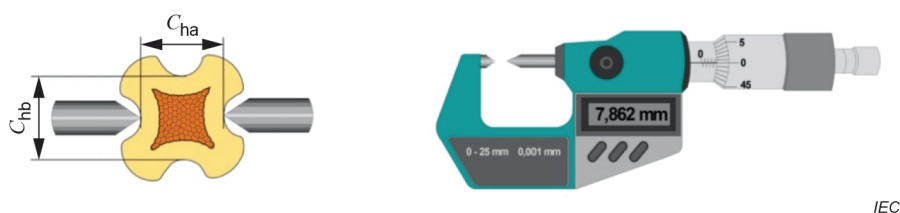
Key

C_h crimp height

C_{wm} measurable crimp width

Figure 31 – Crimp height measurement on closed crimp barrel (mandrel crimping)

Figure 32 shows the crimp height C_h measurement on closed crimp barrels with 4-indent crimping.



Key

C_{ha} crimp height 1

C_{hb} crimp height 2

Figure 32 – Crimp height measurement on closed crimp barrel (4-indent crimping)

Table 5 provides examples of permissible tolerances for crimp height C_h as a function of the relevant conductor cross-sectional area range.

Table 5 – Example of permissible tolerances for crimp height measurements

Cross-sectional area, S mm ²	$0,03 < S \leq 0,2$	$0,2 < S \leq 0,5$	$0,5 < S \leq 6$	$6 < S \leq 25^a$	$25 < S \leq 50^a$
Crimp height tolerance mm	$\pm 0,02$	$\pm 0,03$	$\pm 0,05$	$\pm 0,1$	$\pm 0,15$
^a Values of crimp height tolerance according to conductor cross-sectional area ranges exceeding the limit covered by this document (up to and including 10 mm ²) are for information only.					

7.2.2 Contact deformation after crimping

Type A specimens shall be used for this test.

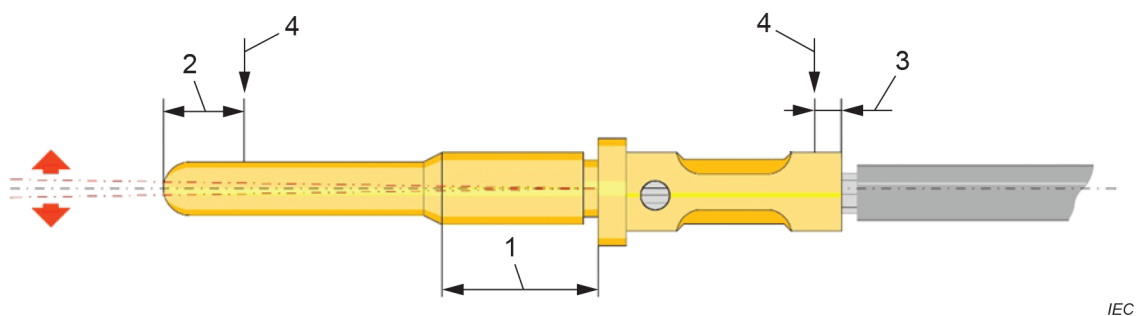
The test of contact deformation after crimping shall be carried out according to test 16g of IEC 60512-16-7, depending on the detail product specification of the component using the crimp contacts.

Number of specimens: 10 for each crimp barrel size (for contacts covering a range of conductor cross-sectional areas: 5 for the smallest cross-sectional area and 5 for the largest cross-sectional area), unless otherwise specified in the detail product specification of the component using the crimp contacts.

For cylindrical contacts, the values of the contact position before and after crimping, measured preferably with a dial gauge, shall be read off.

The total runout when the contact is turned around its axis is halved; this value is the deformation (or damage).

Figure 33 provides an example of holding and measuring points for contact deformation after crimping for a machined cylindrical contact (with closed crimp barrel).



IEC

- 1 = holding range (range in which the contact should be held during application)
- 2 = distance for measuring point 4: twice the diameter of the contact (if not round, then the characteristic dimension of the contact)
- 3 = distance for measuring point 4: half the distance between the end of the crimp barrel and the beginning of the crimp
- 4 = measuring points

Figure 33 – Example of holding and measuring points for contact deformation

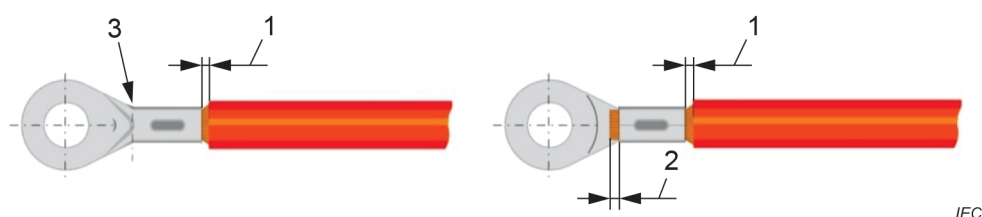
Information to be provided by the detail product specification of the component using the crimp contacts under test:

- conductor type(s) and size(s) (the contact may accept more than one type or more than one size, or both);
- specification of the crimping tool(s) and accessories to be used;
- holding range (crimp contact area held by the clamping device);
- measuring points on the contact, if different from those shown in Figure 33;
- permissible values for the deformation for each measuring point;
- number of specimens, if different from the number specified here;
- any deviation from the specifications of this document.

7.2.3 Visual examination of insulation distance and conductor overhang

The specimens to be used are those intended for all subsequent tests.

Determination of the dimensions on crimp barrels is as defined in Figure 34. Table 6 provides values of insulation distance and conductor overhang for closed crimp barrels according to the cross-sectional area range.



IEC

- 1 = Insulation distance
- 2 = Conductor overhang
- 3 = Barrel end wall

Figure 34 – Insulation distance and conductor overhang

Table 6 – Insulation distance and conductor overhang on closed crimp barrels

Cross-sectional area, S mm²	$S \leq 1,0$	$1 < S \leq 2,5$	$2,5 < S \leq 4$	$4 < S \leq 6$	$6 < S \leq 10$	$10 < S \leq 25^a$
Insulation distance mm	$\leq 0,5$	$\leq 1,0$	$\leq 1,5$	$\leq 2,0$	$\leq 3,0$	$\leq 3,5$
Conductor overhang mm	$\leq 0,5$	$\leq 1,0$	$\leq 1,5$	$\leq 2,0$	$\leq 3,0$	$\leq 3,5$
^a Values above 10 mm ² are for reference only as outside the scope of this document.						

7.2.4 Visual examination of splice crimped connections

Type F specimens shall be used.

Splice crimp barrels have no contact area. Splice crimp barrels are available either uninsulated or pre-insulated. The handling with many wires makes their correct crimping difficult.

The prerequisites according to 5.6 shall be observed. This applies in particular to the conductor diameter ratios of 5.6.2.

Possible resulting faults are shown in Table A.17.

For insulation distance and conductor overhang distances for splice crimped connections, see Table 6.

Requirements for the stripping of the conductor shall be observed (see Table 1).

7.2.5 Visual examination of crimped connections on closed (machined) crimp barrels

The specimens to be used are those intended for the subsequent tests.

Requirements for the stripping of the conductors shall be observed (Table 1).

The visual examination of crimped connections on closed (machined) crimp barrels with 4-indent crimping shall be performed. Table A.3 provides examples of crimping of closed machined crimp barrels and the relevant condition: "Good" (acceptable), "PID" (still acceptable, but process to be adjusted) or "Fault".

7.2.6 Visual examination of crimped connections on B-crimp open crimp barrels

The specimens to be used are those intended for the subsequent tests.

Requirements for the stripping of the conductors shall be observed (Table 1).

The visual examination of crimped connections on B-crimp open crimp barrels shall be performed. Table A.4 provides examples of crimping of B-crimp open crimp barrels, and the relevant condition: "Good" (acceptable), "PID" (still acceptable, but process to be adjusted) or "Fault".

7.2.7 Visual examination of crimped connections with open crimp barrel with insulation grip

The wire insulation has different mechanical and electrical properties due to different thermoplastic materials, additives, colorants, etc., employed.

For each material (insulation thickness, hardness, colorant, etc.) there are different effects, which are also related to operating conditions (temperature, humidity, etc.)

It is known that temperature has a significant influence on the flexibility of the wire insulation. These tests should be performed under normal laboratory conditions unless otherwise specified in the relevant design specification.

The insulation grip is designed to mechanically hold in place the wire insulation, relieving the crimping zone of the crimped connection from stresses that can occur under normal use such as bending or oscillation (due to vibration) of the wire, to prevent wire breakage or other mechanical and electrical damage to the crimped connection. However, the insulation grip is not a strain relief.

Requirements:

- a) grip of the wire insulation at least every 90°;
- b) no cutting of the wire insulation;
- c) no squeezing or separation of the wire insulation;
- d) no cutting of single wire seals (SWS).

Figure 35 shows four different open crimp barrel insulation grip die shapes: B-crimp, O-crimp with symmetrical overlap, O-crimp with symmetrical wrap, and E-crimp with roll-in.

For each die, the crimp anvil (lower part) and the crimp indenter or former (upper part) for the insulation grip are shown in cross-section before starting the compression of the insulation grip and the resulting shape of the insulation grip after compression.

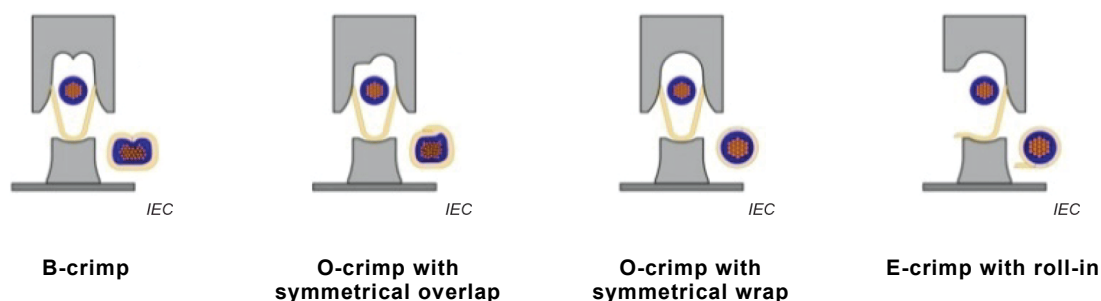


Figure 35 – Examples of insulation grip die shapes

Figure 36 shows perspective view (1, 2, 3) or again in cross-sectional view (4) of the corresponding insulation grips of Figure 35.

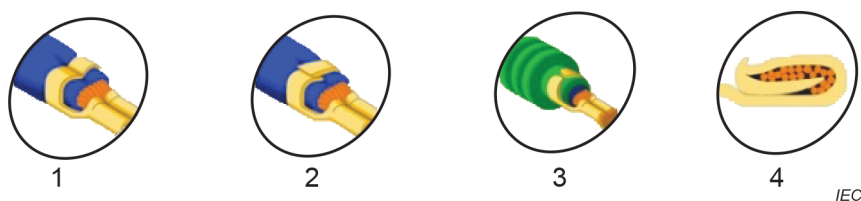


Figure 36 – Examples of insulation grip

Table A.6 provides examples of position of the wire insulation in the insulation grip and the relevant condition: "Good" (acceptable), "PID" (still acceptable, but process to be adjusted) or "Fault".

A required visual examination of the wires (cut, scraped, notched according to Table 1), either by the stripping process or after the crimping process, would otherwise not be possible.

Table A.14 shows examples of insulation grips for B-crimp, O-crimp (asymmetrical and symmetrical overlap and enclosure crimp), whose condition is good (acceptable).

Table A.15 shows examples of insulation grips for B-crumps, O-crumps (asymmetrical and symmetrical overlap and enclosure crimps), with the condition "PID" (still acceptable, but the process should be adjusted).

If a fault cannot be excluded, a microsection shall be created and evaluated.

NOTE If two conductors are crimped in one crimp, the weaker conductor is always at the bottom.

The larger wires lying above prevent deformation or damage during the crimping process due to the application of force from above.

Table A.16 shows examples of insulation grips for B-crimp, asymmetrical and symmetrical overlap, and O-crimp (enclosure crimp) to be considered "Fault".

In case of doubt, a microsection shall be created and evaluated.

7.3 Mechanical tests

7.3.1 Tensile strength

The pull-out force is representative of the mechanical strength of a crimped connection. It is the axial pull force, applied in a controlled way, required to separate the wire from the crimped barrel. It depends on the best combination of:

- crimp barrel: barrel type (open or closed), manufacturing technology (machine turned from a solid wire or rod or stamped and rolled from sheet metal), materials (alloy type, annealing or tempering) and finishes (plating);
- wire: size, strand formation (class according to IEC 60228), material;
- crimp tool: shape of indenting or forging, crimp depth, suitable crimping dies and contact locator or positioner, where applicable.

A minimum value of pull-out force is specified to fulfil the safety requirements of crimped connections.

The test shall be carried out in accordance with test 16d of IEC 60512-16-4.

Unless otherwise specified by the manufacturer of the crimp barrel (terminal), the minimum values of the tensile strength given in Table 7 shall be applied.

Table 7 – Pull-out force of crimped connections

Conductor cross-section		Pull-out force
mm ²	AWG ^a	N
0,05	30	6
0,08	28	11
0,12	26	15
0,14		18
0,22	24	28
0,25		32
0,32	22	40
0,34		42,5
0,37		46
0,5	20	60
0,75		85
0,82	18	90
1		108
1,3	16	135
1,5		150
2,1	14	200
2,5		230
3,3	12	275
4		310
5,3	10	355
6		360
8,4	8	370
10		380
^a For information only.		

NOTE Table 7 provides minimum pull-out force values for crimped connections made with copper wires fulfilling the prerequisites of 5.4, and which are suitable for class A products and class B products.

The conductor cross-section in Table 7 is the geometric (actual) one; however, for practicality, it can be considered as the nominal one and only in case of dispute on test results, the pull-out force requirement shall be reduced by interpolation to that corresponding to the geometric (actual) conductor cross-section.

The minimum pull-out force requirement for conductors whose cross-sectional area is not included in Table 7 can be obtained by interpolation.

For certain types of crimp barrel, higher values of pull-out force represent their minimum performance characteristic. The environmental constraints likely to be encountered by a crimped connection in specific end-use applications may require the adoption of certain types of crimped barrel with inherently higher capability to withstand mechanical or thermal stresses, or both, for example, high energy vibration and shock or high current loads, or both, ability to withstand a short-circuit.

Upon agreement between crimp barrel manufacturer and user, A.6.3 can be used, providing more detailed, application-oriented specification of the pull-out force, based on the nature of the crimp barrel and of the wire used, and useful, for example, in process control based on end-use product classification of 5.1, particularly for class C products.

7.3.2 Microsection

Microsections are used to identify failure characteristics and can be agreed upon between manufacturer and user as a product qualification test or required as an optional test (e.g. in manufacturing process control). See also 8.2.3.5 (test group B5) and 8.3.3.3 (test group F2).

NOTE 1 While this test is essentially a computer optically-aided visual test, it is associated with the evaluation and search for the optimal crimp height leading to the optimal tensile pull-out force and the preparation of microsections implies mechanical operations. Hence it is detailed in 7.3 Mechanical tests.

Three type A specimens (type H specimens for splices) suitable for one wire size only – or, in the case of a range n of wire sizes (CSA) specified for a crimp barrel, $(n \times 3)$ type A specimens (type H specimens for splices) – shall be prepared for further sectioning. For the preparation of these specimens the shortest length of wire should be used, as allowed by the microsectioning equipment and the crimped connection manufacturing means.

The above number of specimens is required for initial qualification and can be reduced upon agreement between manufacturer and user when microsections are performed for process control purposes.

To avoid deformation during cutting (e.g. for class C products), each crimped joint to be sectioned may be mounted in a low exothermic resin capable of being moulded without the application of external pressure. For industrial applications, the crimped joint can be cut, processed and evaluated even without embedding.

The microsection plane should be correctly located, i.e. perpendicular to the axis of the wire and in the area where the crimped connection is more compressed, normally at the centre of the crimping die's footprint.

NOTE 2 If the point of maximal compression and the centre of the crimping die's footprint are not coincident, additional microsections can be necessary: one at the point of maximal compression and one at the centre of the crimping dies footprint.

To expose its mid-section, the sectioned crimped joint (specimen) should be polished.

NOTE 3 As an example, it can be ground with the aid of appropriate grades of silicon carbide papers. This section is then polished with successively finer grades of diamond paste.

To aid microscopic examination, a suitable processing technique should be used to enhance the contours of the elementary conductor strands and the crimp barrel.

NOTE 4 As an example, the polished section can be very lightly etched with an accepted chemical reagent specific to the composition of the materials being crimped.

The sectioned specimens should be visually examined using suitable equipment such as a metallographic microscope, the magnification of which should be at least $\times 10$ up to $\times 400$.

The requirements below give characteristics of acceptable connections but in all cases mechanical, electrical and climatic tests shall be carried out either for the full test schedule or for the basic test schedule.

- All strands (or the solid conductor) should show deformation from the circular cross-section. Exception: the number of non-deformed strands should be less than or equal to the allowed damaged strands given in Table 1.
- The voids should be within the value of porosity ratio (II) requirements provided in A.8.4 for class B and class C products. For crimp shapes that do not provide for uniform crimping, it is recommended to take microsections at several positions and with different crimp settings (e.g. 4-indent crimps).