
**Active implantable medical devices —
Four-pole connector system for
implantable cardiac rhythm
management devices — Dimensional
and test requirements**

*Dispositifs médicaux actifs implantables — Systèmes de branchement
à quatre pôles pour dispositifs implantables de gestion du rythme
cardiaque — Exigences de dimensions et d'essai*



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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared jointly by Technical Committee ISO/TC 150, *Implants for surgery*, Subcommittee SC 6, *Active implants*, and Technical Committee IEC/SC 62D, *Electromedical equipment*. The draft was circulated for voting to the national bodies of both ISO and IEC.

This second edition cancels and replaces the first edition (ISO 27186:2010), which has been technically revised.

The main changes compared to the previous edition are as follows:

- minor typographical errors have been corrected;
- the notch feature on lead connector pins has been made optional whereas previously it was required;
- the use of the notch feature for retention is no longer permitted;
- a clarification has been made to verify the functional sealing and functional contact zone requirements in [4.4.1.2](#) and [4.4.1.3](#).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The four-pole connector was created to reduce the number of individual lead connectors, to reduce pocket bulk associated with existing bifurcated or trifurcated leads, to reduce interaction of the lead bodies in the pocket and to reduce set screw connections.

The intent of this document is to define a four-pole connector assembly that provides interchangeability between implantable leads and pulse generators from different manufacturers.

This document establishes two types of connector assembly: a “high-voltage connector” and a “low-voltage only connector”, each of which has several configurations. The high-voltage connectors either have two low-voltage contacts combined with one or two high-voltage contacts, or they have only two high-voltage contacts. The low-voltage only connectors have either three or four low-voltage contacts.

The high-voltage and low-voltage only connectors and their voltage configurations are not intended to be interchangeable. This document specifies a dimensional lockout feature that prevents the low-voltage contacts of the lead connectors from contacting the high-voltage contacts of high-voltage connector cavities.

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WARNING — The low-voltage only connector cavity specified in this document is not to be used if the implantable pulse generator is capable of introducing dangerous non-pacing stimuli (e.g. defibrillation shocks) through the contacts of that connector cavity. Likewise, the high-voltage lead connector specified in this document is not to be used on leads intended for low-voltage only therapy.

1 Scope

This document specifies a four-pole connector system for implantable cardiac rhythm management (CRM) devices which have pacing, electrogram sensing and/or defibrillation functions. This document includes requirements for the connector portion of an implantable lead as well as for the mating connector cavity attached to an implantable pulse generator. Essential dimensions and performance requirements are specified together with appropriate test methods.

NOTE The safety, reliability, biocompatibility, biostability and function of any particular part are the responsibility of the manufacturer.

This document is not intended to replace or provide alternatives for unipolar or bipolar connector standards that currently exist (such as ISO 11318 and ISO 5841-3).

This document is not applicable to high-voltage systems with intended outputs greater than 1 000 V and/or 50 A. This document is not applicable to systems which include sensors or unique electrodes that are not capable of conventional pacing, electrogram sensing and/or defibrillation functions.

This document does not specify all connector features.

This document does not address all aspects of functional compatibility, safety or reliability of leads and pulse generators assembled into a system.

NOTE Lead and pulse generator connector systems not conforming to this document can be safe and reliable and can have clinical advantages.

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.

ISO 7436, *Slotted set screws with cup point*

ASTM B348, *Standard Specification for Titanium and Titanium Alloy Bars and Billets*

ASTM F562, *Standard Specification for Wrought 35Cobalt-35Nickel-20Chromium-10Molybdenum Alloy for Surgical Implant Applications*

ASTM F746-04, *Standard Test Method for Pitting or Crevice Corrosion of Metallic Surgical Implant Materials*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1 axial pin movement

axial movement of a *lead connector pin* (3.18) with reference to the *lead connector* (3.16) body as present in some designs, particularly those with a rotating connector pin

3.2 bipolar

having two poles or electrodes

Note 1 to entry: See also *tripolar* (3.31), *integrated bipolar* (3.15), and *four-pole* (3.8).

3.3 connector system

assembly consisting of a *lead connector* (3.16) and a *connector cavity* (3.4) that are electrically and mechanically joined

3.4 connector cavity

cavity within the *pulse generator* (3.27) which is intended to receive a *lead connector* (3.16)

3.5 contact mechanism

conductive hardware within the *connector cavity* (3.4) provided for making electrical connection to corresponding contacts on a *lead connector* (3.16)

3.6 distal

farthest from a point of reference

Note 1 to entry: The point of reference for a lead is the *lead connector pin* (3.18). Therefore, the most distal electrode of a lead is the electrode that is farthest from the lead connector pin. See also *proximal* (3.26).

3.7 fixation zone

zone located on the *lead connector pin* (3.18) and within the *connector cavity* (3.4) where the *lead connector* (3.16) is mechanically secured within the connector cavity

3.8 four-pole

having four poles or electrodes

Note 1 to entry: Generally a four-pole ICD lead has two *low-voltage* (3.21) electrodes and two *high-voltage* (3.12) electrodes. A four-pole low-voltage only lead has four low-voltage electrodes. See also *bipolar* (3.2) and *tripolar* (3.31).

3.9 functional contact zone

zone in the *connector cavity* (3.4) where electrical contact with a *lead connector* (3.16) occurs

3.10 functional seal zone

zone within the *connector cavity* (3.4) where sealing contact with a *lead connector* (3.16) occurs

3.11**grip zone**

area of the *lead connector* (3.16) which is provided for grasping during insertion and withdrawal of the lead connector from the *connector cavity* (3.4)

3.12**high-voltage**

electrical potential greater than 20 V and that can go up to 1 000 V

Note 1 to entry: High-voltages are generally used for defibrillating the heart.

3.13**high-voltage connector**

lead connector (3.16) or *connector cavity* (3.4) that has *high-voltage* (3.12) contacts

Note 1 to entry: A high-voltage connector may also contain *low-voltage* (3.21) contacts. See also *low-voltage only connector* (3.22).

3.14**insertion indicator zone**

zone on the pin of the *lead connector* (3.16) allocated for manufacturers to provide a visual indicator for use in verifying full insertion of a lead connector into a *connector cavity* (3.4)

3.15**integrated bipolar**

two lead poles or *lead electrodes* (3.20) that are electrically common

Note 1 to entry: A typical integrated bipolar ICD lead has a *distal* (3.6) shock electrode that doubles as a *proximal* (3.26) pace/sense ring electrode and is electrically attached to two separate *lead connector contacts* (3.17).

3.16**lead connector**

part of a lead that is intended for insertion into the *connector cavity* (3.4) of a *pulse generator* (3.27)

3.17**lead connector contacts**

conductive elements on the *lead connector* (3.16) which include the *lead connector pin* (3.18) and *lead connector rings* (3.19)

3.18**lead connector pin**

most *proximal* (3.26) conductive element of a *lead connector* (3.16) provided for making electrical contact as well as for securing the lead connector within the *connector cavity* (3.4)

3.19**lead connector ring**

annular conductive element on the *lead connector* (3.16) intended for making electrical contact within the *connector cavity* (3.4)

Note 1 to entry: The *four-pole* (3.8) connector has three lead connector rings and a *lead connector pin* (3.18).

3.20**lead electrode**

distal (3.6) part of a lead through which electrical impulses are transmitted to or from cardiac tissue

Note 1 to entry: *High-voltage* (3.12) electrodes are capable of delivering high-voltage electrical impulses. *Low-voltage* (3.21) electrodes are used for transmitting and sensing low-voltage impulses and are generally not suitable for delivering high-voltage.

3.21

low-voltage

electrical potential less than or equal to 20 volts

Note 1 to entry: Low-voltage is generally used for pacing and sensing the heart. See also *high-voltage* (3.12).

3.22

low-voltage only connector

lead connector (3.16) or *connector cavity* (3.4) that has only *low-voltage* (3.21) contacts

Note 1 to entry: See also *high-voltage connector* (3.13).

3.23

pin visibility zone

zone within the *connector cavity* (3.4) which is allocated for visual verification that the *lead connector* (3.16) is fully inserted

Note 1 to entry: It corresponds to the *insertion indicator zone* (3.14) of the lead connector.

3.24

pristine contact zone

zone on the *lead connector* (3.16) which defines the minimum surface required for making electrical contact with the mating contact in the *connector cavity* (3.4)

Note 1 to entry: The pristine contact zones of the lead connector align with the *functional contact zones* (3.9) of the *connector cavity* (3.4) when the connectors are mated.

3.25

pristine seal zone

zone on the *lead connector* (3.16) which defines the minimum surface required for sealing with the mating seals in the *connector cavity* (3.4)

Note 1 to entry: The pristine seal zones of the lead connector align with the *functional seal zones* (3.10) of the *connector cavity* (3.4) when the connectors are mated.

3.26

proximal

nearest to a point of reference

Note 1 to entry: The point of reference for a lead is the *lead connector pin* (3.18). Therefore, the most proximal electrode of a lead is the electrode closest to the lead connector pin. See also *distal* (3.6).

3.27

pulse generator

device that delivers electrical energy to affect cardiac rhythms

3.28

sealing mechanism

circumferential barriers within the *connector cavity* (3.4) intended to maintain electrical isolation between electrically insulated parts of an assembled and implanted *connector system* (3.3)

3.29

securing mechanism

mechanism within the *connector cavity* (3.4) intended for mechanically securing the *lead connector* (3.16), typically a set screw

3.30**strain relief zone**

zone on the *lead connector* (3.16) provided for making a gradual transition from a more rigid section to a more flexible section

Note 1 to entry: The gradual transition results in an area over which strain is distributed so that concentrated mechanical forces do not occur when the lead is flexed.

3.31**tripolar**

three poles or electrodes

Note 1 to entry: See also *bipolar* (3.2) and *four-pole* (3.8).

4 Requirements**4.1 General**

Not all connector features or pulse generator features are specified nor do the requirements in this document address all aspects of functional compatibility, safety or reliability of leads and pulse generators assembled into a system. Each manufacturer is responsible for any requirements and tests necessary to address these as well as the biocompatibility and biostability of their material choices.

The test methods provided for the requirements are type (qualification) tests and are not intended to be used as routine production tests. Alternate test methods may be used, including those which result in equivalent or more stringent test conditions. However, in the event of dispute, the test methods described in this document shall be used.

The following tests should be conducted under ambient conditions unless otherwise specified. Each manufacturer is responsible for any preconditioning required to represent "as-shipped" configurations, as well as for selection of appropriate sample sizes.

Leads and pulse generators marked according to [Table 1](#) and [Table 2](#) shall comply with all requirements in this document.

4.2 Lead connector physical requirements**4.2.1 Dimensions****4.2.1.1 General**

Lead connectors shall have the dimensions specified in [Figure 1](#) and [Figure 2](#) and shall meet the requirements outlined in [4.2.1.2](#) to [4.2.1.11](#) according to each zone. See [Annex O](#) for rationale.

4.2.1.2 Total axial pin movement, M

Total axial pin movement is the difference in lead connector pin length from when the connector pin is fully seated against datum A to when the connector pin is fully extended from datum A. Total axial pin movement shall not be greater than 0,25 mm.

4.2.1.3 Pristine contact zones

The minimum length of each of the pristine contact zones shall be 0,90 mm + M , where M is the total axial pin movement in millimetres.

Lead connectors shall have an electrically conductive contact surface over the entire length of each of the pristine contact zones. Contact surfaces may extend beyond the pristine contact zones.

The surface finish in these zones shall be Ra 0,8 μm maximum. The entire surface area shall be considered when measuring surface finish. No indentations, protrusions, gaps or steps exceeding surface finish allowance are allowed in these zones.

4.2.1.4 Pristine seal zones

The minimum length of each pristine seal zone shall be 1,81 mm + M , where M is the total axial pin movement in millimetres.

Lead connectors shall have a seal surface over the entire length of each of the pristine seal zones. Seal surfaces may extend beyond the pristine seal zones. No indentation, protrusions, gaps or steps exceeding surface finish allowance are allowed in these zones.

For surfaces of materials with hardness 75D or less, the surface finish in this zone shall be Ra 0,8 μm maximum. The entire surface shall be considered when measuring surface finish except that uniform linear protrusions, such as caused by mould parting lines, may be excluded from the measurement if they do not exceed 0,025 mm in height as measured radially or 0,12 mm in width.

For surfaces in this zone made from materials with hardness above 75D, the surface finish shall be Ra 0,4 μm maximum when the entire surface is considered, including any uniform linear protrusions.

4.2.1.5 Lead connector body

The diameter for all conductive components and surfaces within this zone shall be 3,2 mm $\pm$ 0,03 mm.

The diameter for all non-conductive components and surfaces within this zone shall be 3,2 mm $\pm$ 0,05 mm.

For all areas in this zone except pristine seal zones and pristine contact zones, the following requirements apply.

- a) Any radial steps or protrusions, such as can occur between two adjacent components or by welds, shall not exceed 0,05 mm (in height) and shall not cause the diameter to go outside the tolerance specified with the following exception. Uniform linear protrusions that do not exceed 0,025 mm in height as measured radially or 0,12 mm in width are allowed only for surfaces of materials that are at 75 Shore D or below.
- b) Any gap shall not exceed 0,1 mm in width when measured to include all edge breaks at the gap edge. There shall not be more than one gap between each pristine zone. For any gap that meets these requirements, the area within the gap need not meet the other requirements of this subclause, for example diameter and radial step requirements.
- c) Any indentations, such as holes or weld depressions, shall not exceed 0,5 mm in diameter.
- d) Surface finish for zone 3 of [Figure 1](#) shall be Ra 0,8 μm maximum from datum A to 16,04 mm and shall be Ra 1,6 μm maximum from 16,04 mm to the transition zone 7, excluding the chamfer area. Surface finish measurements need not include any surface features that meet the above requirements [4.2.1.5 a\) to c\)](#).

4.2.1.6 Strain relief zone

The diameter in this zone shall be 4,1 mm maximum and 3,8 mm minimum.

4.2.1.7 Grip zone

The diameter in this zone shall be 4,3 mm maximum.

4.2.1.8 Chamfer zone

The length of the chamfer in this zone shall be 0,35 mm minimally and 0,7 mm – M maximally, where M is the total axial pin movement in millimetres.

4.2.1.9 Transition zone

The transition between the Ø3,2 mm nominal and the Ø4,1 mm maximum shall occur within the theoretical envelope between datum B, which intersects the Ø4,1 mm at the 17,7 mm dimension, and Datum C.

The diameter in this zone shall not exceed 4,1 mm.

NOTE The 60° dimension defines datum B; transition geometry does not need to match this angle.

4.2.1.10 Insertion indicator zone

This zone is provided for an optional insertion indicator. If an insertion indicator is present it shall meet the following requirements.

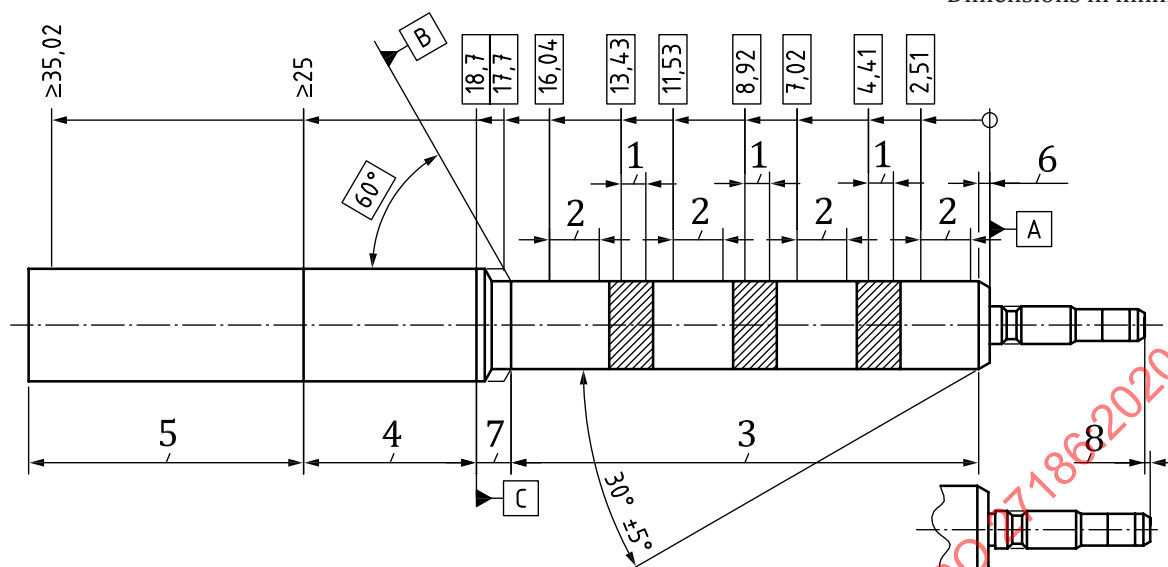
- a) The indicator shall not extend beyond the zone.
- b) The proximal edge shall meet the 5,10 mm ± 0,10 mm dimension.
- c) The diameter shall fall within the nominal diameter specified and the tolerance of $\frac{+0,03}{-0,10}$ mm.
- d) Any gaps shall not exceed 0,10 mm in width. For any gap that meets this requirement, the area within the gap need not meet the other requirements of this section, for example diameter and radial step requirements.
- e) Any radial steps shall not exceed 0,05 mm.

4.2.1.11 Pin pristine contact zone

Lead connectors shall have an electrical contact surface over the entire length of this zone.

The surface finish in this zone shall be Ra 0,8 µm maximum.

Dimensions in millimetres



Key

- | | | | |
|---|------------------------|---|-------------------------------|
| 1 | pristine contact zones | 5 | grip zone |
| 2 | pristine seal zones | 6 | chamfer zone |
| 3 | lead connector body | 7 | transition zone |
| 4 | strain relief zone | 8 | total axial pin movement, M |

NOTE The diameter dimensions of the soft sections, in zone 4, zone 5 and zone 7, of the lead can be determined as the mean value of three measurements taken at locations oriented approximately 120° apart around the principal axis of the lead connector.

Figure 1 — Four-pole lead connector body



- 1 pin fixation zone
- 2 pin pristine contact zone
- 3 insertion indicator zone

- Figure 2 — Four-pole lead connector high-voltage and low-voltage only pin details**

4.2.2 Materials

4.2.2.1 Contact materials

Lead connector contact materials shall meet the requirements of [Annex M](#).

Based on observations made during the development of this document, it is recommended that manufacturers consider selecting 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562 as a material for lead connector contacts. This material performed acceptably when evaluated by multiple manufacturers and was more consistent than several other materials tried. Contact material was identified as critical to connector performance and therefore verification to the requirements in this document should be made when using this or any other material.

4.2.2.2 Seal surface material

Lead connector seal zone materials are not specified; however, recommendations are provided in [Annex H](#).

4.2.3 Lead connector electrical connections

4.2.3.1 According to the appropriate configuration, each lead connector contact shall be in electrical continuity with the specific and distinct lead electrode described in [Table 1](#) when the following applies:

- “Low-voltage” refers to stimulating electrodes having pacing and electrogram sensing function;
- “High-voltage” refers to stimulating electrodes having high-voltage defibrillation capability;
- “OPEN” refers to lead connector contacts that are not in electrical continuity with any lead electrode.

Ring 2 and ring 3 contacts of high-voltage lead connectors shall not be in direct electrical continuity with lead electrodes that are not intended for high-voltage because they could be exposed to high voltage during use.

4.2.3.2 The lead connector pin of low-voltage only lead connectors shall conform to [Figure 2 b](#)).

4.2.3.3 The lead connector pin of high-voltage lead connectors including integrated bipolar connectors shall conform to [Figure 2 a](#)).

4.2.4 Lead marking

4.2.4.1 Marking symbol

Lead connectors shall be marked with the appropriate symbol according to [Table 1](#) and sized appropriately for the component being marked.

4.2.4.2 Marking location

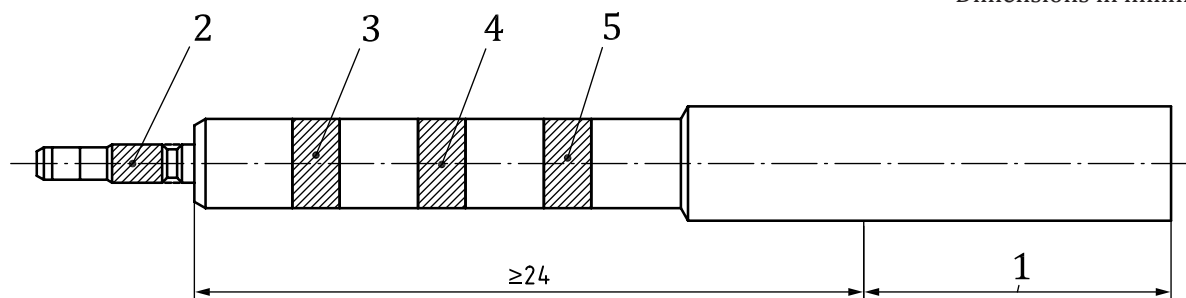
Marking shall be located in the marking zone (see [Figure 3](#)).

4.2.4.3 Marking orientation

Marking shall read left to right when the lead connector is oriented with the connector pin to the left.

NOTE It is the responsibility of the manufacturer to ensure marking on lead connectors is permanent and legible under intended use conditions.

Dimensions in millimetres

**Key**

- | | | | |
|---|-----------------------|---|-----------------------|
| 1 | marking zone | 4 | lead connector ring 2 |
| 2 | lead connector pin | 5 | lead connector ring 3 |
| 3 | lead connector ring 1 | | |

Figure 3 — Identification of lead connector contacts**Table 1 — Lead marking symbols and electrical connections within the lead — Permitted configurations**

	Configuration and marking symbol	Connector pin	Ring 1	Ring 2	Ring 3
Low-voltage only	IS4-LLLL	Most distal Low-voltage electrode	2nd most distal Low-voltage electrode	3rd most distal Low-voltage electrode	Most proximal Low-voltage electrode
	IS4-LLLO	Most distal Low-voltage electrode	2nd most distal Low-voltage electrode	3rd most distal Low-voltage electrode	OPEN
	IS4-LOLL	Most distal Low-voltage electrode	OPEN	2nd most distal Low-voltage electrode	Most proximal Low-voltage electrode
High-voltage	DF4-LLHH	Most distal Low-voltage electrode	2nd most distal Low-voltage electrode	Most distal High-voltage electrode	Most proximal High-voltage electrode
	DF4-LLHO	Most distal Low-voltage electrode	2nd most distal Low-voltage electrode	Most distal High-voltage electrode	OPEN
	DF4-OOHH	OPEN	OPEN	Most distal High-voltage electrode	Most proximal High-voltage electrode
Integrated bipolar	DF4-LLHH	Most distal Low-voltage electrode	Most distal High-voltage electrode ^a	Most distal High-voltage electrode	Most proximal High-voltage electrode
	DF4-LLHO	Most distal Low-voltage electrode	Most distal High-voltage electrode ^a	Most distal High-voltage electrode	OPEN

^a For integrated bipolar leads, the most distal high-voltage electrode may also be used for low-voltage pacing and sensing function.

4.2.5 Lead package labels and literature

Package labels and product literature are the responsibility of the lead manufacturer; however, the appropriate marking symbols shown in [Table 1](#) should be used at all times when referring to lead connectors conforming to this document.

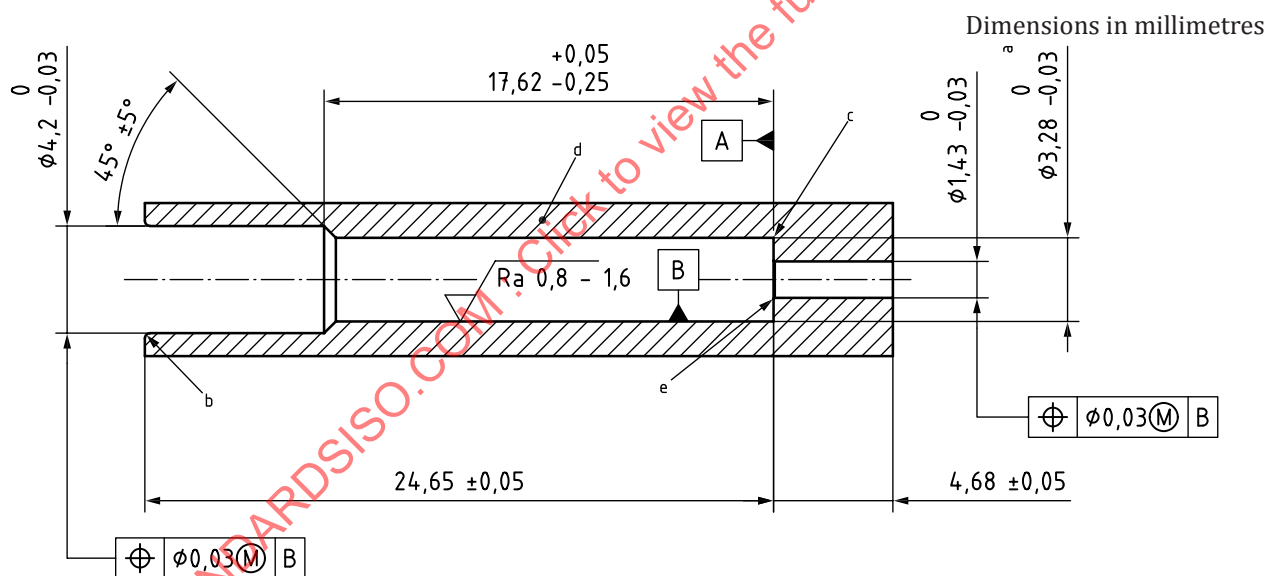
NOTE The four-pole lead connectors specified in this document might not be compatible with the wide variety of existing analyser cables that are currently used with other connectors (such as IS-1 and DF-1). Specifically, the terminals of some analyser cables can result in bridging and shorting of the more closely-spaced lead connector contacts of the four-pole connector. Bridging and shorting during an implant procedure can result in erroneous measurements of performance characteristics (e.g. R waves, P waves, impedances, pacing thresholds) or a temporary inability to provide pacing therapy. Manufacturers are individually responsible for providing appropriate warnings, education or other means of mitigating the risk of bridging and shorting as can occur due to use of analyser cable terminals with their respective lead connectors. See also [P.3](#).

4.3 Lead connector functional requirements

4.3.1 Functional dimensional check

4.3.1.1 Test method

Insert the lead connector into the lead connector go gauge conforming to [Figure 4](#). Perform this test both with the lead connector in an initial state and after a 10 d minimum soak in saline (nominally 9 g/l at $37\text{ °C} \pm 5\text{ °C}$).



- a The 3,28 mm maximum diameter exceeds the largest permissible lead diameter by 0,03 mm to accommodate axis curvature of the lead connector or localized offsets that might be present between lead connector components.
- b Radius or chamfer 0,20 mm maximum.
- c Radius or chamfer 0,1 mm maximum.
- d Material: Steel, Stainless Steel, Titanium, Titanium Alloys or 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562.
- e Edge break 0,05 mm maximum.

Figure 4 — Lead connector go gauge

4.3.1.2 Requirement

Both initially and after soaking, the force to fully insert the lead connector into the lead connector gauge shall be less than 4,5 N. The lead connector is considered fully inserted into the gauge when the connector pin is visible outside the 1,43 mm diameter. The lead connector need not be bottomed out in the gauge in order to be considered fully inserted.

4.3.2 Tensile loads

4.3.2.1 Test method

Soak the lead connector in saline (nominally 9 g/l at $37\text{ °C} \pm 5\text{ °C}$) for 10 d minimum prior to testing. After soaking and while in a wetted state, fasten the lead connector at the lead connector pin and apply a tensile load of 14 N minimum at the grip zone. Maintain the load for at least 10 s. Repeat tensile loading a minimum of five cycles.

4.3.2.2 Requirement

After tensile loading the lead shall meet the linear dimensions in [Figure 1](#) and [Figure 2](#) measured from datum A and the requirements of [4.2.1.2](#), [4.3.6](#), [4.3.7](#) and [4.3.8](#).

4.3.3 Deformation due to pin contact forces

4.3.3.1 Test method

Insert the lead connector into a test cavity that conforms to the bore dimensions of [Figure 7](#) a) for high-voltage and [Figure 7](#) b) for low-voltage only and which has M2 screw threads located within the functional pin contact zone. Use an M2 titanium grade 5 as described in ASTM B348, 860 MPa minimum tensile strength, set screw with cup point that complies with ISO 7436.

Tighten the screw to a torque of $0,15\text{ N}\cdot\text{m} \pm 0,01\text{ N}\cdot\text{m}$. Maintain the load for 10 s minimum and then release the set screw.

4.3.3.2 Requirement

The force to withdraw the lead connector from and re-insert it into the test cavity shall not exceed 4,5 N.

After removal, the lead connector shall meet the contact zone diameter requirements in [Figure 2](#).

For lead connector designs utilizing a through-hole for stylets, it is recommended that the manufacturer verify that the through-hole is still functional following application of the set screw load.

NOTE 1 It is recognized that at the time of publication of this document, most manufactured devices utilize 2–56 hexagon head set screws for lead connector retention. Although they are similar in size, the equivalency between the two types of set screw has not been established. Therefore, an M2 set screw is specified herein for use in a dispute.

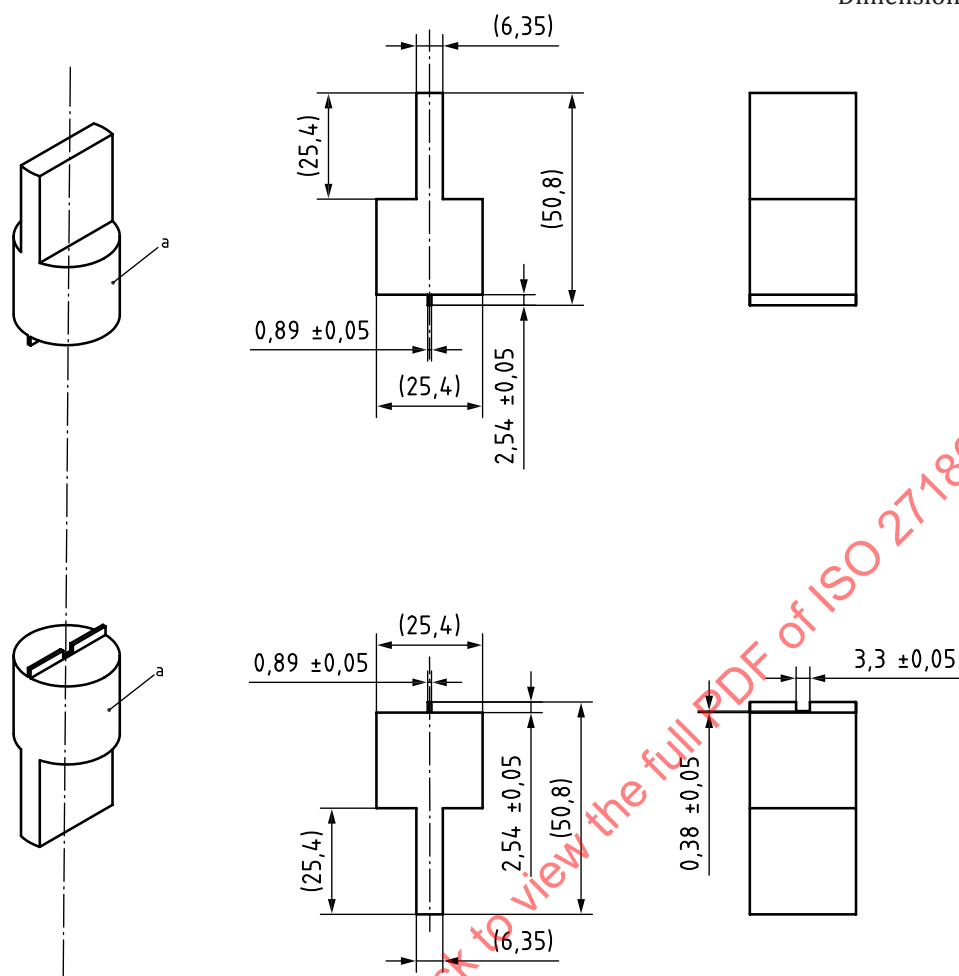
NOTE 2 Additional testing can be necessary to confirm that the insertion indicator withstands other handling and implant conditions such as attachment of patient cable alligator clips.

4.3.4 Deformation due to ring contact forces

4.3.4.1 Test method

Use two aligned metal blade indenters that conform to [Figure 5](#) to apply a compressive load to the outer diameter of each ring in the pristine contact zone (see [Figure 1](#)). Apply a minimum load of 9 N and maintain the load for a minimum of 10 s.

Dimensions in millimetres



- ^a Material: steel, stainless steel, titanium, titanium alloys or 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562.

Figure 5 — Ring contact force test fixture

4.3.4.2 Requirement

After application and release of the load, the lead connector shall meet the requirements of [4.2.1.5](#) with the exception of the surface finish requirement, the functional check of [4.3.1](#) and the electrical requirements of [4.3.6](#), [4.3.7](#) and [4.3.8](#).

4.3.5 Seal zone requirement

There is no functional requirement for seal zones. See [Annex H](#) and [Annex I](#) for design recommendations.

4.3.6 Electrical isolation requirement

The lead connector shall provide electrical isolation between each of the lead connector contacts and between the contacts and the surrounding fluid. Compliance shall be determined as described in [Annex A](#).

4.3.7 Dielectric strength requirement

The lead connector shall provide high-voltage electrical isolation between each of the lead connector contacts and between the contacts and the surrounding fluid. This requirement applies only to high-voltage lead connectors. Compliance shall be determined as described in [Annex C](#) (see [Annex D](#) for rationale to [Annex C](#)).

4.3.8 Current-carrying requirement

The high-voltage lead connectors shall be capable of carrying defibrillation current. Compliance shall be determined as described in [Annex E](#).

4.3.9 Corrosion/environmental

Compliance shall be determined as described in [Annex M](#).

4.4 Connector cavity physical requirements

4.4.1 Dimensions

4.4.1.1 General

The connector cavity shall have the dimensions specified in [Figure 6](#) and [Figure 7](#) and shall meet the following requirements according to each zone.

The connector cavity shall be designed such that it does not make use of the optional notch feature on the lead connector (see [Figure 2](#) note b).

4.4.1.2 Functional contact zones

The electrically active contact surfaces for mating with the lead connector shall be located within the functional contact zones (see [Figure 6](#)) and functional pin contact zone (see [Figure 7](#)). Contact hardware may extend beyond these zones. Compliance is determined by dimensional measurement of the contact locations when a $3,2 \text{ mm} \pm 0,05 \text{ mm}$ diameter pin is installed to deflect the contacts. This requirement does not apply for contacts that are not electrically active.

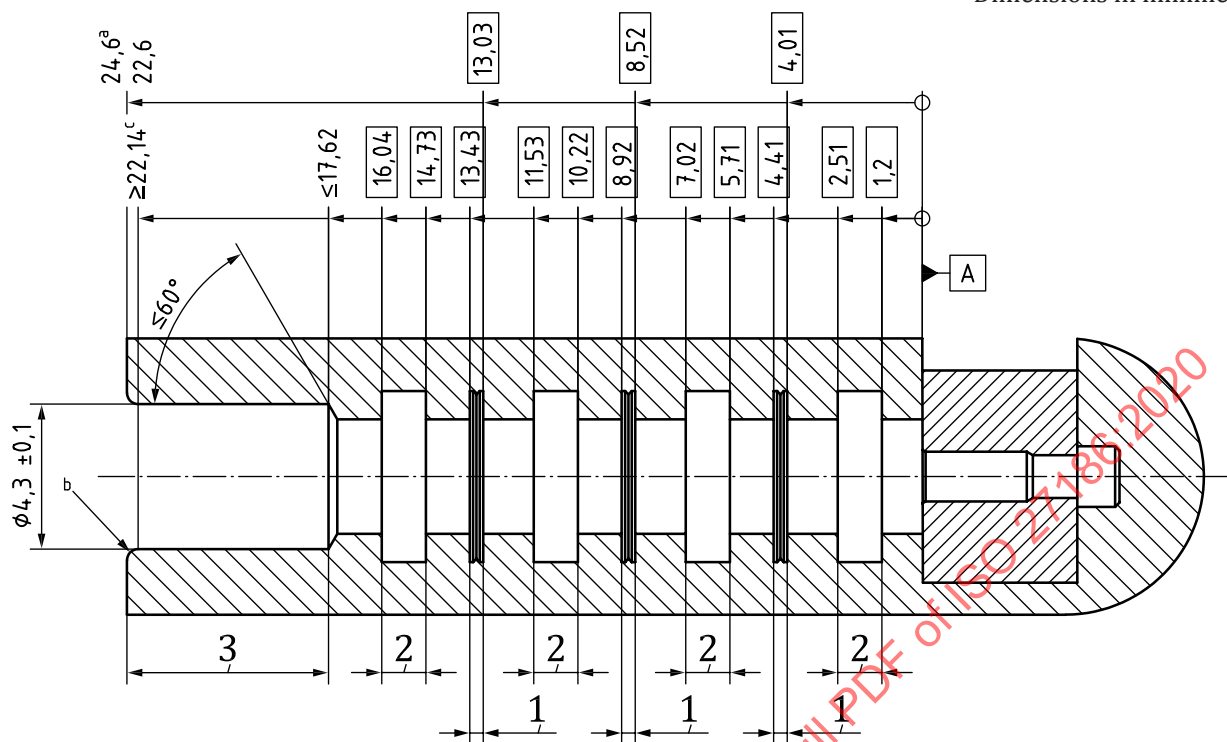
4.4.1.3 Functional seal zones

Connector cavities shall provide for functional sealing within the functional seal zones (see [Figure 6](#)). Seal hardware may extend beyond these zones. Compliance is determined by dimensional measurement of the seal locations when a $3,2 \text{ mm} \pm 0,05 \text{ mm}$ diameter pin is installed to deflect the seals.

4.4.1.4 Material

The structural support of the connector cavity shall be constructed of a material with a minimum hardness of 70 Shore D.

Dimensions in millimetres

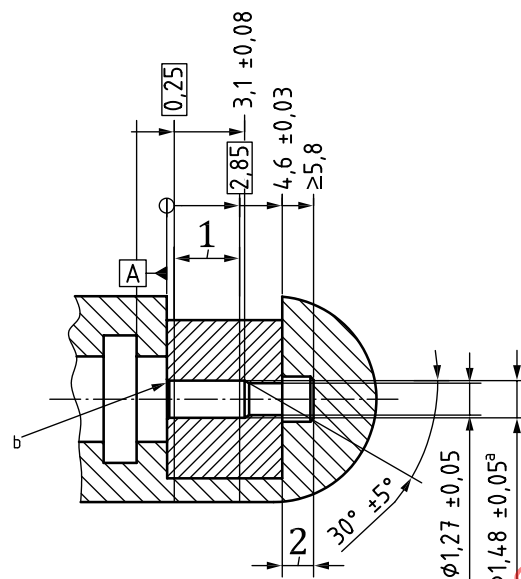
**Key**

- 1 functional contact zones
- 2 functional seal zones
- 3 stabilization zone

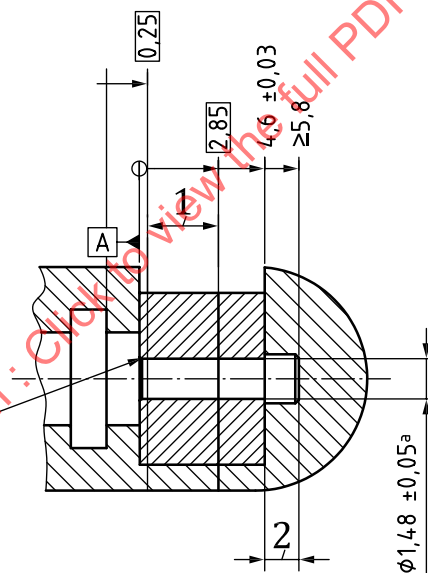
- a The surface of the bore entrance need not be perpendicular to the bore axis as long as the entire circumference of the bore entrance is located within the 22,6 mm minimum and 24,6 mm maximum specified.
- b Radius or chamfer, 0,2 mm minimum.
- c Radius or chamfer shall not start before the 22,14 mm minimum.

Figure 6 — Four-pole connector cavity

Dimensions in millimetres



a) High-voltage pin cavity



b) Low-voltage only pin cavity

Key

- 1 functional contact zone
- 2 pin visibility zone
- a Securing mechanisms may have features that are smaller than the 1,48 mm diameter as necessary to secure the lead connector.
- b Break edge 0,15 mm maximum.

Figure 7 — Four-pole connector cavity tip detail

4.4.2 Connector cavity electrical connections

4.4.2.1 According to the appropriate configuration, each connector cavity contact shall be in electrical continuity with the specific device outputs described in [Table 2](#) when the following applies:

- “LOW” are device outputs less than 20 V;
- “HIGH” are device outputs between 20 V and 1 000 V peak and < 50 A;
- “OPEN” refers to connector cavity contacts that are not in electrical continuity with any device output.

4.4.2.2 Low-voltage only version connector cavities shall conform to [Figure 7 b\)](#).

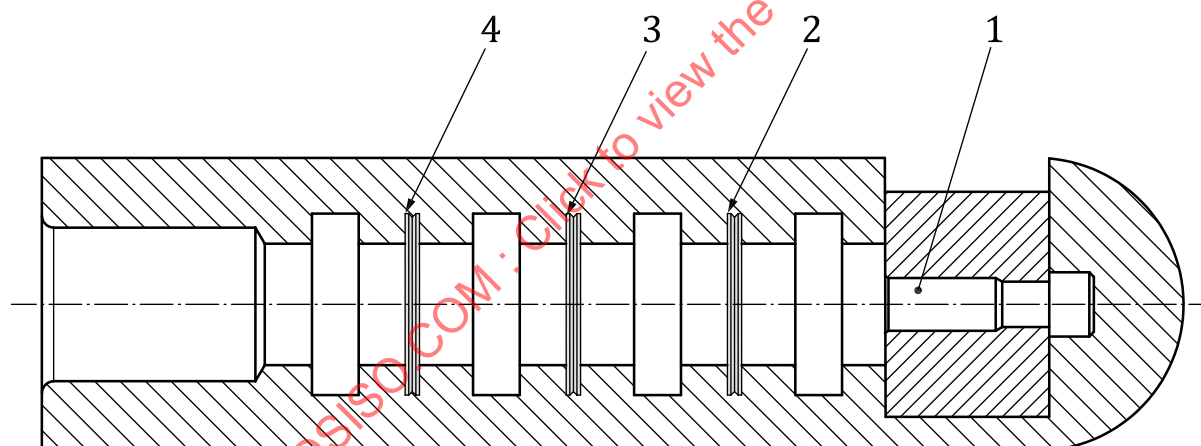
4.4.2.3 High-voltage version connector cavities shall conform to [Figure 7 a\)](#).

NOTE Connector cavity contacts designated as low-voltage are not designed to deliver high-voltage output.

4.4.3 Connector cavity/pulse generator marking

Pulse generators with connector cavities conforming to this document shall be marked with the appropriate symbols in accordance with [Table 2](#) and sized appropriately for the component being marked. See [Figure 8](#) for an illustration of the connector contacts.

NOTE It is the responsibility of the manufacturer to ensure marking on pulse generators is permanent and legible under intended use conditions.



Key

- | | |
|------------------|------------------|
| 1 pin contact | 3 ring 2 contact |
| 2 ring 1 contact | 4 ring 3 contact |

Figure 8 — Identification of contacts in the connector cavity

Table 2 — Pulse generator marking symbols and electrical connections to device outputs — Permitted configurations

	Configuration and marking symbol	Connector cavity contacts			
		Pin contact	Ring 1 contact	Ring 2 contact	Ring 3 contact
Low-voltage only	IS4-LLLL	LOW	LOW	LOW	LOW
	IS4-LLLO	LOW	LOW	LOW	OPEN
	IS4-LOLL	LOW	OPEN	LOW	LOW

Table 2 (continued)

	Configuration and marking symbol	Connector cavity contacts			
		Pin contact	Ring 1 contact	Ring 2 contact	Ring 3 contact
High-voltage	DF4-LLHH	LOW	LOW	HIGH	HIGH
	DF4-LLHO	LOW	LOW	HIGH	OPEN
	DF4-OOHH	OPEN	OPEN	HIGH	HIGH

4.4.4 Pulse generator labels and literature

The appropriate marking symbols shown in [Table 2](#) should be used at all times when referring to connectors conforming to this document.

NOTE Package labels and product literature are the responsibility of the pulse generator manufacturer.

4.5 Connector cavity functional requirements

4.5.1 Insertion force

4.5.1.1 Test method

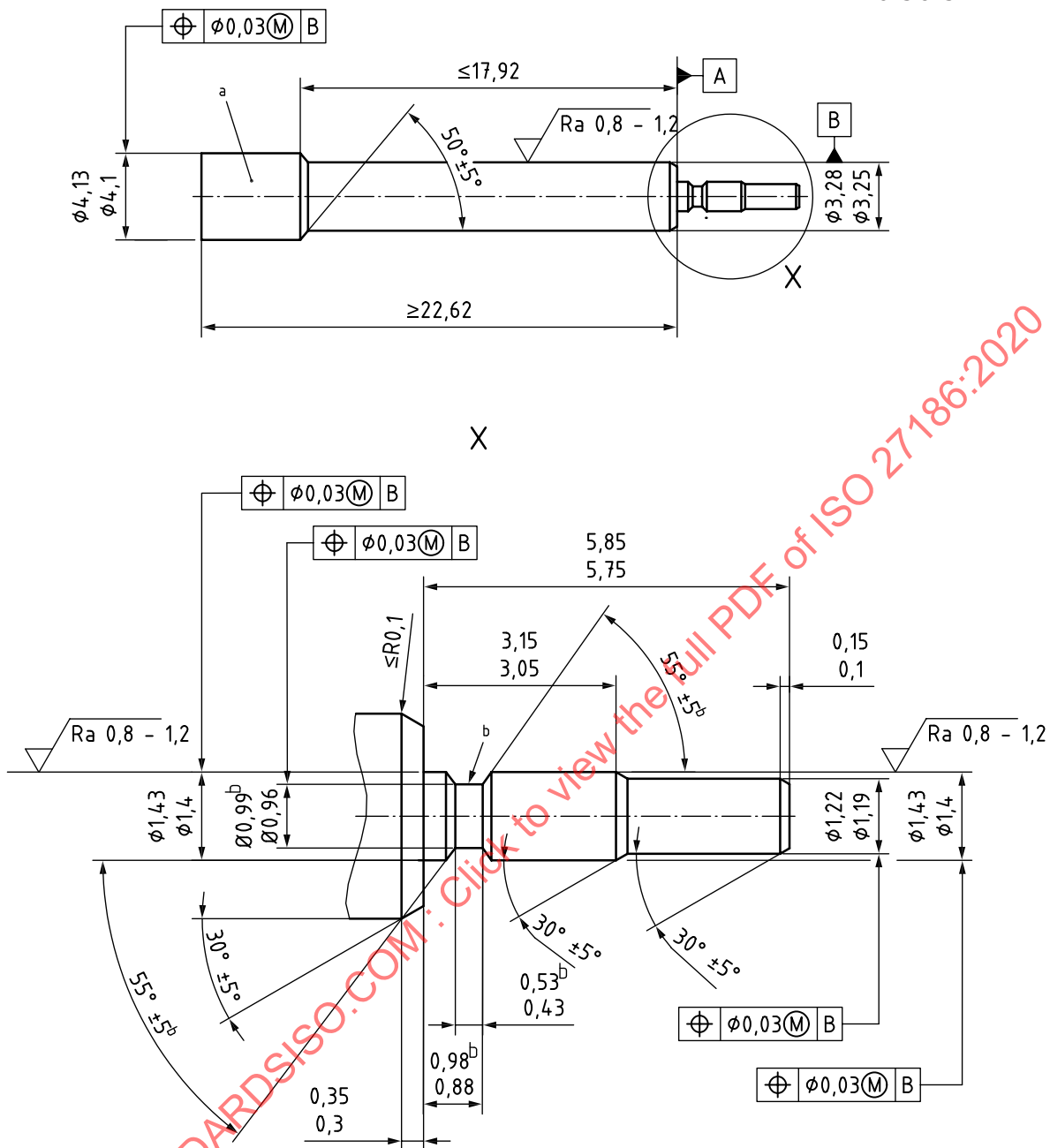
Fully insert the metal gauge pin specified in [Figure 9](#) into the device connector cavity while measuring the maximum force required. Remove the insertion force while monitoring for any displacement of the gauge pin for 15 s minimum.

This test shall be performed in accordance with the manufacturer's recommended implant procedure. This test shall be performed dry.

4.5.1.2 Requirement

The maximum force required to fully insert the gauge pin into the device connector cavity shall not exceed 16 N.

The gauge pin shall not become displaced more than 0,5 mm after the insertion force is removed when verified after 15 s minimum.



- a Material: steel, stainless steel, titanium, titanium alloys or 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562 (entire pin).
- b Dimension applies to the notch feature. Notch feature is optional and may be omitted.

Figure 9 — Maximum connector cavity gauge pin

4.5.2 Retention force

4.5.2.1 Test method

Fully insert the minimum retention gauge pin conforming to [Figure 10](#) into the connector cavity and engage the securing mechanism per manufacturer instructions. Apply an axial tensile load of 10 N for 10 s minimum while monitoring for displacement of the gauge pin.

4.5.2.2 Requirement

The gauge pin shall not become displaced more than 0,5 mm while under the 10 N load.

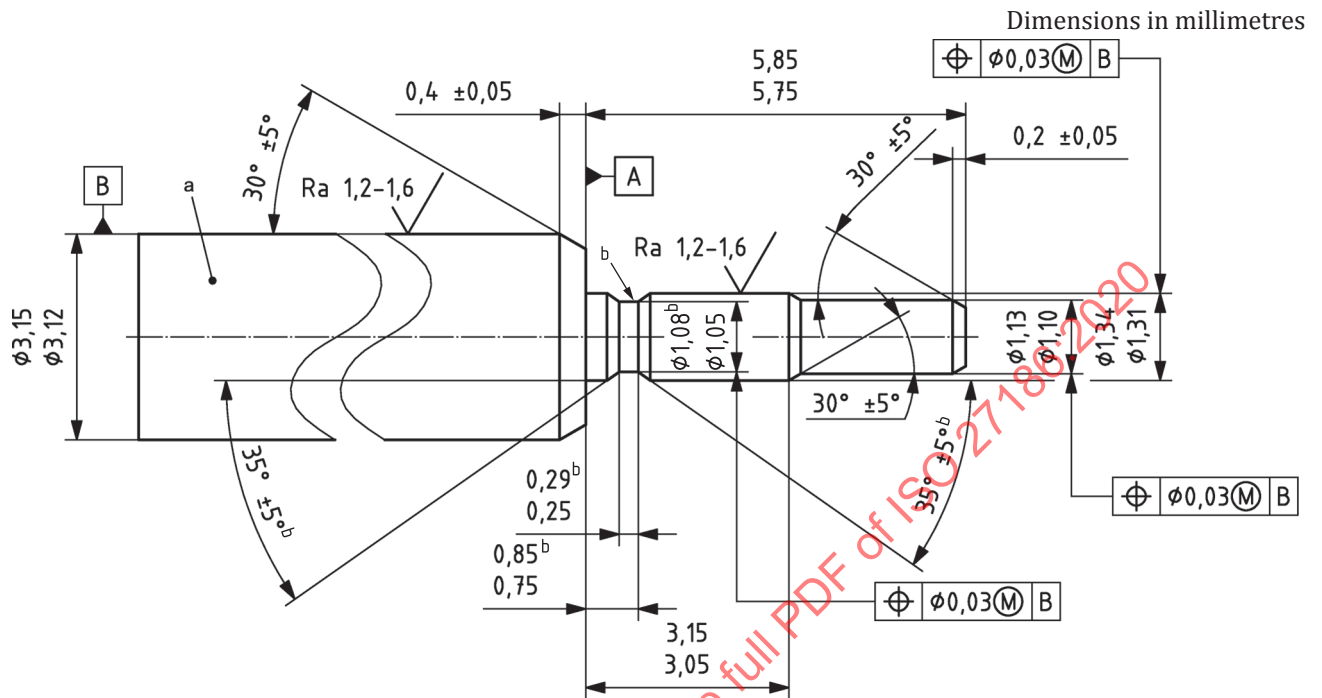


Figure 10 — Minimum retention gauge pin

4.5.3 Withdrawal force

4.5.3.1 Test method

Insert the gauge pin conforming to [Figure 9](#) fully into the connector cavity. Verify that any active retention mechanisms are disengaged. Fully withdraw the gauge pin while measuring the maximum force required.

Perform this test under initial (dry) conditions.

4.5.3.2 Requirement

The maximum force required to fully withdraw the gauge pin shall not exceed 14 N.

4.5.4 Ring contact load

4.5.4.1 Applicability

This requirement applies only to contact mechanisms for lead connector rings that require activation after the lead connector is inserted, such as set screws.

4.5.4.2 Test method

Determine the maximum contact load of the fully activated contact mechanism over a 3,23 mm diameter test pin.

4.5.4.3 Requirement

Contact load shall not exceed the maximum allowed by [4.3.4](#).

4.5.5 Seal zone load requirement

There is no requirement for the forces exerted by the connector cavity seals in the seal zones. See [Annex I](#) for design recommendations.

4.5.6 Electrical isolation requirement

The connector cavity shall provide electrical isolation between each of the connector cavity contacts and between the contacts and the surrounding fluid. Compliance shall be determined as described in [Annex A](#).

4.5.7 Dielectric strength requirement

The connector cavity shall provide high-voltage electrical isolation between each of the connector cavity contacts and between the contacts and the surrounding fluid. This requirement applies to high-voltage connector cavities. Compliance shall be determined as described in [Annex C](#).

4.5.8 Current-carrying requirement (high-voltage connector cavity)

The high-voltage type connector cavity shall be capable of carrying defibrillation current. Compliance shall be determined as described in [Annex E](#).

4.5.9 Contact resistance/stability

There is no requirement for contact resistance/stability since it is dependent on each specific device system's performance.

NOTE [Annex I](#) describes a test method which could be used to evaluate contact resistance/stability as part of device reliability and safety testing or for evaluating the relative performance of various spring contact designs.

Annex A (normative)

Electrical isolation test

A.1 General

A.1.1 Purpose

This annex describes tests to determine compliance with [4.3.6](#) and [4.5.6](#). These are type (qualification) tests and are not intended to be used as routine production tests. The tests are applicable to both high-voltage (DF4) and low-voltage only (IS4) lead connectors and connector cavities.

A.1.2 Specimen preparation

Lead connectors and connector cavities used for test shall be in the as-shipped condition.

A.1.3 Saline solution

Use an aqueous solution that is nominally 9 g/l NaCl.

Maintain the temperature of the saline at $37\text{ °C} \pm 5\text{ °C}$ for soak and test.

A.1.4 Reference electrode

Use a reference electrode made of titanium which has a surface area of $\geq 500\text{ mm}^2$.

A.1.5 Test signal

Frequency: one frequency at or between 50 Hz and 120 Hz.

Voltage: one voltage at or between 0,25 V rms and 1,0 V rms.

A.2 Lead connector test

A.2.1 Purpose

This procedure evaluates isolation of the conductors in the lead connector from datum A to the distal end of the grip zone as defined in [Figure 1](#). The method applies to both high-voltage and low-voltage only lead connectors.

A.2.2 Preconditioning

Soak the entire lead connector in the saline solution for a minimum of 10 d prior to the test. Maintain the lead connector in a soaked state for testing. Return the lead connector to the saline solution between tests or when not testing.

A.2.3 Test method

Carry out the test as follows.

Maintain the entire grip zone, strain relief zone and transition zone of the lead connector (as defined in [Figure 1](#)) in the saline test solution while keeping the exterior of the lead connector rings externally insulated from the fluid.

All three contact rings and the connector pin should be externally electrically isolated from the test solution and from each other. External isolation can be achieved by keeping the rings out of the test solution and drying off the outside, by use of a silicone sleeve or a test fixture with seals, or by another method that provides external isolation while ensuring that the entire transition zone, strain relief zone and grip zone remain submerged in the test solution.

Position the lead connector 50 mm to 200 mm from the submerged reference electrode.

Apply the test voltage between each contact combination under test, for example between the pin and reference electrode. For lead connectors that are not integrated bipolar, test the combinations shown in [Table A.1](#). For integrated bipolar lead connectors, where contact ring 2 and contact ring 1 are intentionally electrically connected, test the contact combinations shown in [Table A.2](#).

Measure the resulting isolation impedances for each test combination.

Table A.1 — Test combinations for lead connectors

	Pin	Ring 1	Ring 2	Ring 3
Reference	test	test	test	test
Pin		test	test	test
Ring 1			test	test
Ring 2				test

Table A.2 — Test combinations for integrated bipolar lead connectors

	Pin	Ring 1 + ring 2	Ring 3
Reference	test	test	test
Pin		test	test
Ring 1 + ring 2			test

A.2.4 Acceptance criteria

The impedance between each contact of the test combinations shown in [Table A.1](#) and [Table A.2](#) shall be greater than 600 kΩ. This requirement applies to both high-voltage and low-voltage only lead connectors. The requirement also applies to all contacts, even those that are not electrically active.

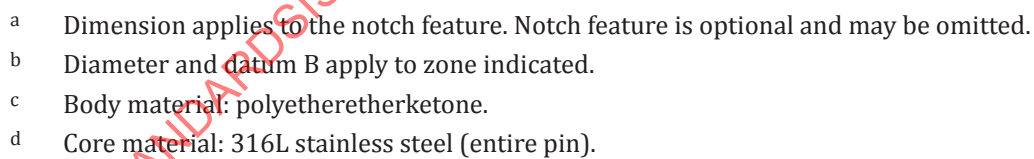
A.3 Connector cavity test

A.3.1 Purpose

This procedure evaluates isolation between the contacts in the connector cavity as well as isolation between the last contact and an external reference electrode when tested with a simulated lead connector as defined in [Figure A.1](#).

A.3.2 Test pin

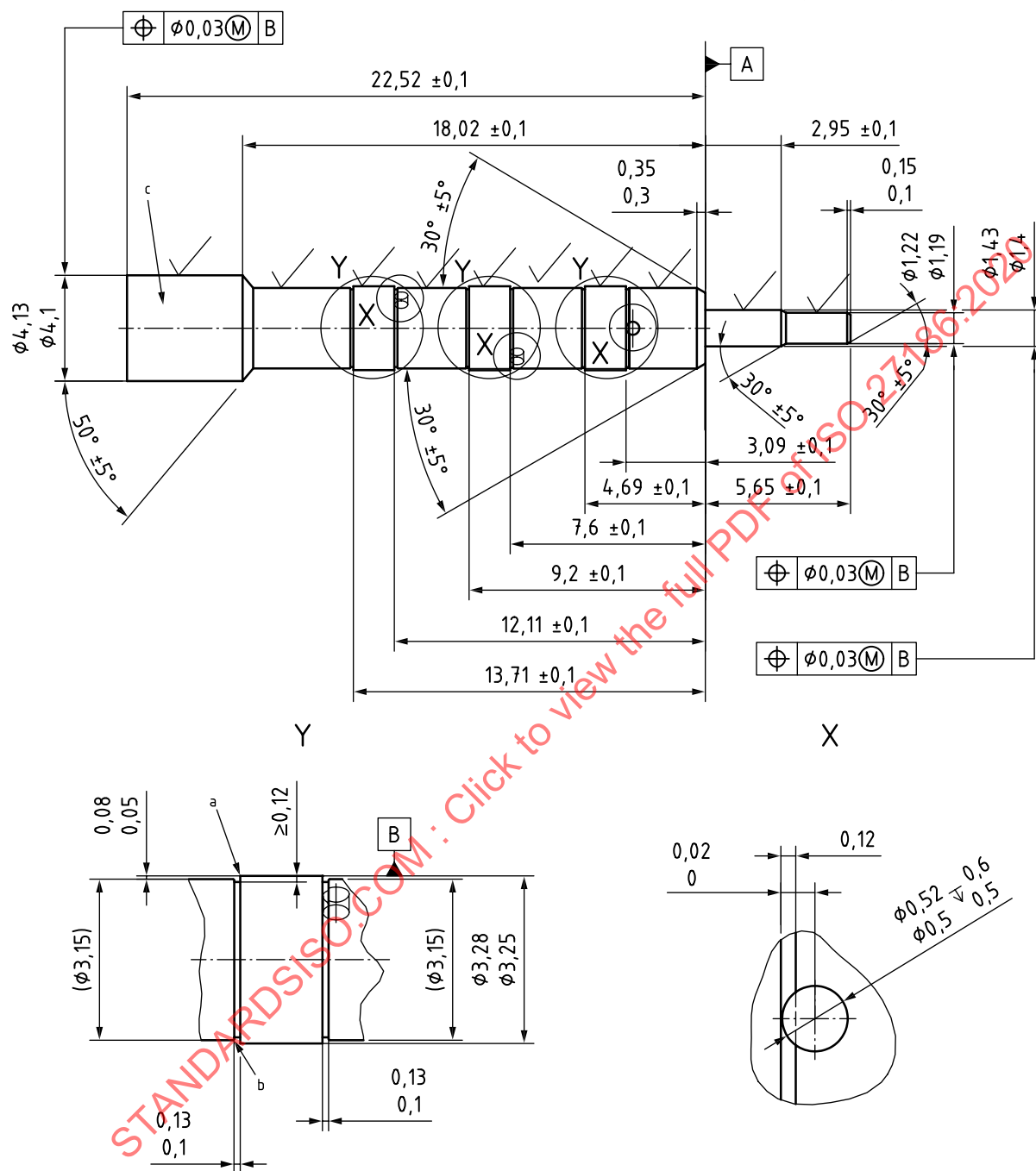
Use a test pin that conforms to [Figure A.1](#).



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Dimensions in millimetres

✓ = ▽ $\sqrt{\text{Ra } 0,8 - 1,2}$



- a Edge break 0,05 mm max (6 places).
- b Edge break 0,02 mm max (6 places).
- c Material: steel, stainless steel, titanium, titanium alloys or 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562 (entire pin).

Figure A.2 — Maximum offset gauge pin

A.3.3 Preconditioning

Precondition and prepare the test samples as follows.

Fully insert and completely withdraw a maximum offset gauge pin conforming to [Figure A.2](#) one (1) time.

Perform the preconditioning in a dry state prior to assembling the connector in the saline solution. Full insertion is when the pin tip is visible beyond the tip connector block, and complete withdrawal is when the pin tip is visible outside the connector cavity.

Immerse the connector cavity in the saline solution and then insert the test pin into the cavity, ensuring no air bubbles are trapped. Fasten or deploy any retention mechanisms that are provided with the connector cavity.

Soak the cavity and pin assembly in saline solution for a minimum of 10 d prior to the test and maintain in the soaked state for testing.

A.3.4 Test method

Carry out the test as follows.

Immerse the reference electrode and locate it 50 mm to 200 mm from the connector cavity.

Measure electrical impedance between each contact combination specified as “test” in [Table A.3](#), both at the start of the test (wet) and after 10 d minimum soak.

Apply a side load of 1 N to the test pin at the bore exit during the electrical testing only, not during the soak. Orient the side load perpendicular to the bore axis and, for devices with a pin retention mechanism, the direction of loading shall be in the same plane as the pin retention mechanism force contact point.

The test combinations shown in [Table A.3](#) are for evaluating electrical isolation of seal rings with regard to interchangeability. It is recommended that manufacturers also test other combinations to establish isolation of other components. See [B.3](#) for additional information.

A.3.5 Acceptance criteria

For both high-voltage and low-voltage only connector cavities the impedance between each contact combination (refer to [Table A.3](#)) shall be greater than 120 kΩ. This requirement applies to all contacts including those that are not electrically active.

Table A.3 — Test combinations for connector cavities

	Pin	Ring 1	Ring 2	Ring 3
Reference				test
Pin		test		
Ring 1			test	
Ring 2				test

Annex B (informative)

Rational for [Annex A](#)

B.1 Isolation impedance

This document allows a minimum lead-cavity isolation impedance of 100 kΩ. This lead-cavity impedance has been used to allocate a parallel equivalent of 600 kΩ for the lead connector and 120 kΩ for the connector cavity.

The four-pole connector system isolation impedance (Z_{system}) is the result of the individual contributions of the lead connector impedance (Z_{lead}) and the connector cavity impedance (Z_{cavity}) as given by [Formula \(B.1\)](#):

$$\frac{1}{Z_{\text{system}}} = \frac{1}{Z_{\text{lead}}} + \frac{1}{Z_{\text{cavity}}} \quad (\text{B.1})$$

A 100 kΩ isolation impedance for the four-pole connector system was derived assuming a minimum electrical input impedance of 100 kΩ and a total input impedance of a device of 50 kΩ. Electrical input impedance of modern pacemakers/ICDs is typically greater than 100 kΩ. A 50 kΩ input impedance on a device is close to 10 × the maximum source impedance of intra-cardiac signals; this ensures that signals from the heart are not significantly attenuated.

Furthermore, the 100 kΩ system isolation impedance was used to allocate 120 kΩ isolation impedance for the connector cavity and 600 kΩ isolation impedance for the lead connector. Lower parallel impedance for the connector cavity was assigned based on the characteristics of the isolation testing. The isolation test for the connector cavity includes both internal isolation plus a simulated effect of the lead/cavity interface. The isolation test for the lead connector evaluates internal isolation only.

A 10 d soaking procedure has been adopted from IS-1 (ISO 5841-3) and DF-1 (ISO 11318). This provides the required time for fluid absorption and electrical impedance stabilization between insulated conductors. This requirement is applicable for lead, device or system testing.

B.2 Mechanical load

The application of the side load during testing was intended to simulate transient loads representative of severe daily activities. A reasonable upper bound of the representative side load for these transient conditions was estimated to be 300 g acting on a flexible connector. The 300 g limit was established by the connector task force (CTF) using relevant cadaver test data, biplane fluoroscopic reconstruction of indwelling leads, bench testing of four-pole connector prototypes and input from leading physicians on typical and non-typical implant conditions. The derating of the 300 g *in vivo* load applied to the flexible lead connector was done to ensure the rigid test pin produced the appropriate deflection in the seal zones under test. The side load of 1 N was chosen based on the testing of actual lead prototypes from three manufacturers. The 1 N applied to the test pin defined in this document was shown to produce a displacement of the seal zone that exceeded the actual displacement of an actual lead connector. Flexible lead connectors tested from three independent manufacturers all produced less displacement of the seal zone under a 300 g external load than the test condition specified in this document.

B.3 Test combinations

Testing adjacent contacts as indicated by “test” in [Table B.1](#) is considered the minimum required to evaluate isolation impedance of seal rings in the connector cavity. It is recommended that

manufacturers also test the other combinations indicated by “recommended” in [Table B.1](#) in order to evaluate isolation impedance of other components such as septums or feedthroughs. The details of such testing, including test combinations, test conditions, test signal and acceptance criteria should be defined by the manufacturer.

Table B.1 — Recommended test combinations for connector cavities

	Pin	Ring 1	Ring 2	Ring 3
Reference	recommended	recommended	recommended	test
Pin		test	recommended	recommended
Ring 1			test	recommended
Ring 2				test

B.4 Connector cavity isolation test pin

The lead seal zone and surface finish requirements described in [4.2.1.4](#) reflect unique surface finish and surface defect allowances based on the materials used in this area of the lead.

During the development of this document, multiple polyetheretherketone (PEEK^{™1}) and 75D polyurethane (Tecothane^{™2}) TT1075D) test pins were used for testing connector cavities in order to establish the sensitivity of seal performance to surface defects and material hardness. Such testing indicated that it was more difficult to seal under high-voltage when using the harder material test pins (PEEK[™]) than for the softer material (Tecothane[™]) given the same diameter and the same created defects. It was believed that this was due to differences in material hardness. Therefore, the requirements in this document reflect two different surface finishes and defect allowances depending on the hardness of the material used. It was also found that defect features on test pins were difficult to define and to tolerance, such that they could be consistently reproduced. Therefore, the test pins in this document include worst-case material, minimum diameter and worst-case surface finish but do not include other types of conditions that might be allowed on lead connectors as specified in this document.

1) PEEK[™] is the trade name of a product supplied by Victrex plc, Thornton Cleveleys, Lancashire, UK. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the products named. Equivalent products can be used if they can be shown to lead to the same results.

2) Tecothane[™] TT1075D is the trade name of a product supplied by The Lubrizol Corporation Wickliffe, OH, USA. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the products named. Equivalent products can be used if they can be shown to lead to the same results.

Annex C (normative)

Dielectric strength test

C.1 General

C.1.1 Purpose

This annex describes tests to determine compliance with [4.3.7](#) and [4.5.7](#). These are type (qualification) tests and are not intended to be used as routine production tests. The manufacturer may use equivalent test methods; however, in a dispute, these test methods shall be used. The tests are applicable to high-voltage (DF4) lead connectors and connector cavities.

WARNING — The following test employs high-voltages. Failure to use safe laboratory practices could result in severe electrical shock, causing personal injury or death to persons handling the equipment or conducting the test. Damage to electrical equipment is also possible.

C.1.2 Specimen preparation

Lead connectors and connector cavities for the test shall be in an as-shipped condition.

C.1.3 Reagent and materials

Saline solution: nominally 9 g/l NaCl at $37\text{ °C} \pm 5\text{ °C}$.

Reference electrode: made of titanium (or similar conductive and stable material) with a surface area of $\geq 500\text{ mm}^2$.

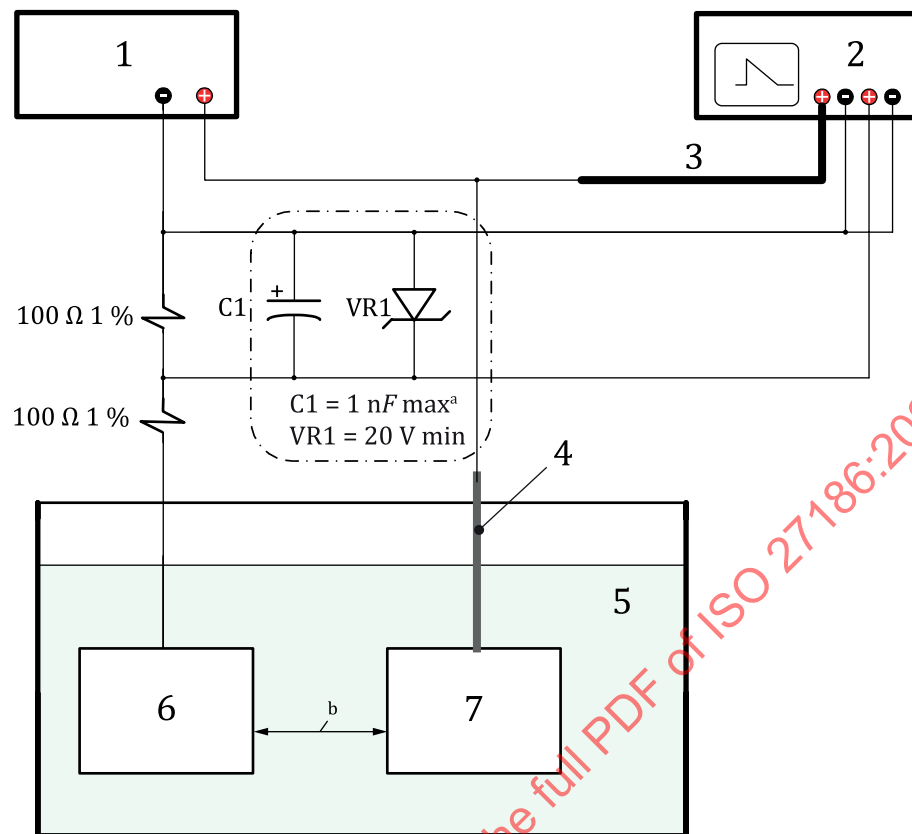
C.1.4 Dielectric strength test set-up

The electrical diagram and test set-up are shown in [Figure C.1](#)

C.1.5 Test signal

The test signal shall have the following elements:

- Form: monophasic truncated exponential specified in [Figure C.2](#) with equipment capable of providing a minimum of 100 mA. The capability of the equipment to deliver a minimum of 100 mA can be verified by use of an appropriate load resistor. For example, for a 1 500 V test signal the minimum current should be met with a 14,8 k Ω resistor load.
- Rise time: $1,5\text{ }\mu\text{s} \pm 0,5\text{ }\mu\text{s}$ from 10 % (minimum) to 90 % (maximum) of the peak voltage with a dV/dt of 2 kV/ μs maximum.
- Pulse duration: 18 ms minimum.
- Amplitude and decay: peak voltage (as specified in [Table C.1](#) to [Table C.4](#)) $\pm 5\%$ with a minimum of 50 % of peak at 18 ms after the peak amplitude. For example, a 1 500 V test pulse would have a minimum amplitude of 750 V at 18 ms.
- Interval: 10 s nominal interval between pulses.



Key

- | | | | |
|--------------|-----------------------------|---|---------------------|
| 1 | test signal generator | 5 | saline solution |
| 2 | oscilloscope | 6 | reference electrode |
| 3 | high-voltage probe | 7 | test unit |
| 4 | lead connector body | | |
| ^a | Optional components. | | |
| ^b | 50 mm to 200 mm separation. | | |

Figure C.1 — Dielectric strength test set-up

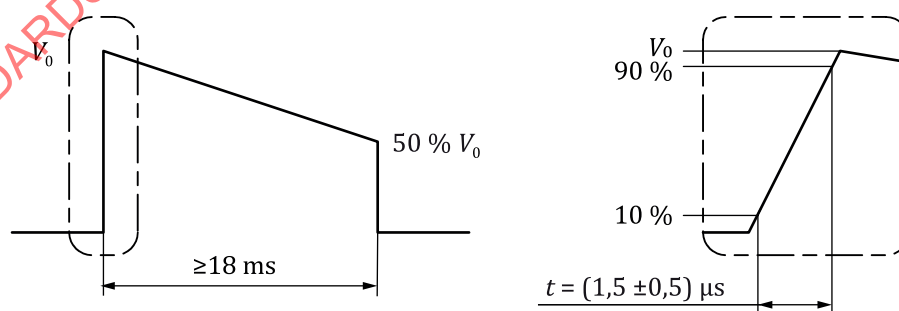


Figure C.2 — Test signal

C.2 Lead connector test

C.2.1 Preconditioning

Soak the entire lead connector in saline solution for a minimum of 10 d prior to testing. Maintain the lead connector in a soaked state for testing.

C.2.2 Test method

Carry out the test as follows.

Maintain the entire grip zone, strain relief zone and transition zone of the lead connector (as defined in [Figure 1](#)) in the saline test solution while keeping the exterior of the lead connector rings externally isolated from the fluid.

External electrical isolation can be achieved by keeping the rings out of the test solution and drying off the outside, by use of a silicone sleeve or a test fixture with seals, or by another method that provides external isolation while ensuring that the entire transition zone, the strain relief zone and the grip zone remain submerged in the test solution. All three contact rings and the connector pin should be externally electrically isolated from the test solution and from each other to prevent external arcing.

Locate the lead connector 50 mm to 200 mm from the submerged reference electrode.

Apply a total minimum of 500 test voltage pulses, 250 minimum consecutive in one polarity and 250 minimum consecutive in the reverse polarity, to each contact combination using the test voltage indicated for the combination. For high-voltage lead connectors that are not integrated bipolar, apply the pulses to the contact combinations shown in [Table C.1](#). For integrated bipolar high-voltage lead connectors (where ring 1 and ring 2 are electrically common) use [Table C.2](#). The peak voltage of the test pulse shall have a peak amplitude as shown in [Table C.1](#) and [Table C.2](#) according to the combination being tested.

Measure the resulting maximum leakage current between 4 μ s and 1 ms into the pulse and between 1 ms and 18 ms into the pulse as illustrated in [Figure C.3](#).

Monitor at least the first 10 pulses and last 10 pulses of each polarity for each combination.

Test all contacts, even those that are intended to be electrically inactive (open).

The test may be performed by tying multiple electrodes together in parallel, as long as the maximum leakage current requirement is satisfied. For example, the reference electrode could be tested against a parallel combination of pin + ring 1 + ring 2 + ring 3.

Table C.1 — Test combinations for high-voltage (DF4) lead connectors that are not integrated bipolar

	Pin	Ring 1	Ring 2	Ring 3
Reference	1 500 V	1 500 V	1 500 V	1 500 V
Pin			1 500 V	1 500 V
Ring 1			1 500 V	1 500 V
Ring 2				1 500 V

Table C.2 — Test combinations for integrated bipolar high-voltage (DF4) lead connectors

	Pin	Ring 1 + ring 2	Ring 3
Reference	1 500 V	1 500 V	1 500 V
Pin		1 500 V	1 500 V
Ring 1 + ring 2			1 500 V

C.2.3 Acceptance criteria

The measured maximum leakage current shall not exceed the values specified in [Table C.3](#) according to the test signal voltage used. This requirement applies to all contacts including those that are intended to be electrically inactive (open).

Table C.3 — Acceptance criteria

Test signal peak voltage V_0	Maximum leakage current mA	
	I_1 , 4 μ s to 1 ms	I_2 , 1 ms to 18 ms
1 500	100	20

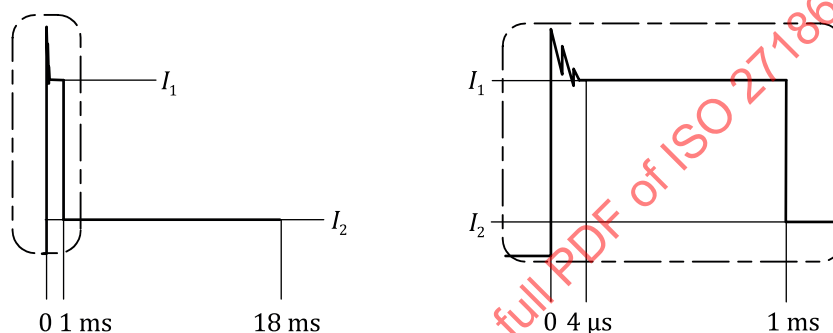


Figure C.3 — Leakage current waveform

C.3 Connector cavity test

C.3.1 Test pin

Use a test pin that conforms to [Figure A.1](#).

C.3.2 Preconditioning

Precondition and prepare the test samples as follows.

Fully insert and completely withdraw a maximum offset gauge pin conforming to [Figure A.2](#) one (1) time. Perform the preconditioning in a dry state prior to assembling the connector in the saline solution. Full insertion is when the pin tip is visible beyond the tip connector block, and complete withdrawal is when the pin tip is visible outside the connector cavity.

Immerse the connector cavity in the saline solution and then insert the test pin into the cavity, ensuring no air bubbles are trapped. Fasten or deploy any retention mechanisms that are provided with the connector cavity.

Soak the cavity and pin assembly in the saline solution for a minimum of 10 d prior to the test and maintain in the soaked state for testing.

C.3.3 Test method

Carry out the test as follows.

Locate the cavity and pin assembly in the saline test solution so that it is 50 mm to 200 mm from the submerged reference electrode.

Apply a 1 N side load to the test pin at the bore exit perpendicular to the bore axis only during the electrical testing (not during soaking). For devices with a directional pin retention mechanism (such as a set screw), apply the load so it aligns with the direction of the pin retention mechanism.

Apply a minimum total of 200 test voltage pulses, 100 minimum consecutive in one polarity and 100 minimum consecutive in the reverse polarity, to each contact combination. The test voltage shall have a peak amplitude (V_0) that is at least $1,5 \times$ the peak output voltage of the device and not less than 1 200 V. Test high-voltage connector cavities according to the combinations listed in [Table C.4](#).

Measure the resulting leakage current between 4 μ s and 1 ms into the pulse and between 1 ms and 18 ms into the pulse illustrated in [Figure C.3](#).

Monitor the first 10 test cycles and the last 10 test cycles of each polarity for each combination of connector contacts and reference electrode.

Test all contacts, even those that are intended to be electrically inactive (open).

NOTE 1 Visible arcing might produce damage to the connector seals, including material loss and contamination. These can affect performance. Any observations of arcing during the test might require further evaluation by the manufacturer.

NOTE 2 Additional testing between electrical conductors or between electrical conductors and the reference electrode can be performed. Refer to [Annex D](#).

Table C.4 — Test combinations for high-voltage (DF4) connector cavities

	Pin	Ring 1	Ring 2	Ring 3
Reference				1 200 V to 1 500 V ^a
Pin		1 200 V to 1 500 V ^a		
Ring 1			1 200 V to 1 500 V ^a	
Ring 2				1 200 V to 1 500 V ^a

^a Test voltage is based on device output. Refer to [C.3.3](#).

C.3.4 Acceptance criteria

The measured maximum leakage current shall not exceed the values specified in [Table C.5](#) according to the test signal voltage used. This requirement applies to all contacts, including those that are intended to be electrically inactive (open).

Table C.5 — Acceptance criteria

Test signal peak voltage V_0	Maximum leakage current mA	
	I_1 , 4 μ s to 1 ms	I_2 , 1 ms to 18 ms
1 200	80	16
1 500	100	20
Other	100 V_0 /1 500	20 V_0 /1 500

Annex D (informative)

Rationale for [Annex C](#)

D.1 Rationale for performing a high-voltage electrical isolation test

The performance of the implantable defibrillator system depends on the ability of keeping electrical conductors insulated from each other and from the outside. This test simulates the effect of high-voltage exposure between conductors in order to evaluate the ability of connectors to maintain high-voltage electrical isolation.

For the connector cavity, testing adjacent contacts (for example pin - ring 1, ring 1 - ring 2, ring 2 - ring 3, and ring 3 - reference) is specified to evaluate leakage current between seal rings of the connector cavity. Other combinations may be tested to evaluate other components or design features. The need for these other test combinations should be defined by each manufacturer.

D.2 Rationale for test method

D.2.1 Test signal

Rationale for aspects of the test signal is as follows.

Form: a truncated exponential monophasic waveform with a rise time of $1,5 \mu\text{s} \pm 0,5 \mu\text{s}$ was selected because it is similar to the output capabilities of implantable defibrillators that the manufacturers expect to employ for the foreseeable future. The electrical stress of a biphasic waveform is simulated by testing both polarities.

Pulse duration: the minimum duration of 18 ms was selected as being longer than any value considered clinically useful.

Amplitude and decay: the test amplitude was selected as being $1,5 \times$ the maximum service voltage currently envisaged by the manufacturers, 1 kV for the lead connector (see [Clause 1](#)) and the maximum output of the pulse generator for the connector cavity. The $1,5 \times$ safety factor between the test and maximum allowed service voltage provides reasonable assurance that electrical isolation will be maintained during normal operation. The 50 % decay at 18 ms reflects output capabilities of implantable defibrillators.

NOTE The major difference between ISO 11318 (DF-1) and this document is that seals reside within the connector cavity instead of on the lead connector. Because of this, the connector cavity need only be tested to what the pulse generator is capable of delivering plus the $1,5 \times$ safety factor. Lead connectors could be used in any pulse generator so still need to be tested to voltages up to the maximum allowed plus the safety factor (same as DF-1).

Interval: the 10 s nominal frequency allows flexibility in testing and is being specified for resolving any potential disputes. Testing with smaller or longer intervals was not thought to be critical to test outcome.

Test system current: the test system's capability of delivering 100 mA at any time during the test pulse allows for verification of the maximum allowable leakage current.

D.2.2 Mechanical load

The 1 N side load is used to simulate transient loads representative of severe daily activities (see [Annex B](#)).

D.2.3 Test duration and combinations

Lead connector: 500 test cycles for the lead connector was considered to exceed a worst-case single patient delivery. This includes re-use of the lead.

Connector cavity: 200 test cycles for the connector cavity was considered a worst-case condition based on device output.

D.2.4 Test combinations

Lead connector: the lead connector test combinations include all combinations of high-voltage contacts relative to each other in order to test high-voltage isolation between these. Also included are all combinations of contacts relative to a reference electrode in order to test high-voltage isolation for areas of the lead connector that will be outside the connector cavity.

Connector cavity combinations: the connector cavity combinations are intended to evaluate seal performance in the presence of active potentials. Reference-to-pin, reference-to-ring 1 and reference-to-ring 2 combinations do not apply as this document is intended for the lead/cavity interface only. The test combination reference-to-ring 3 verifies function of the most distal seal assembly.

D.3 Rationale for acceptance criteria

D.3.1 Maximum allowed leakage current

Leakage current limits of 100 mA and 20 mA for a test signal of 1 500 V were adopted from ISO 11318 (DF-1). Other current leakage requirements specified by this document are proportional to the test signal amplitude.

D.3.2 Measurement

Similar to DF-1, maximum leakage current is measured between 4 μ s and 1 ms into the pulse and between 1 ms and 18 ms into the pulse. The current is not measured during the first 4 μ s in recognition of the extreme difficulty of accurately monitoring a small current in the presence of a large and rapid voltage step. This was considered acceptable since it is unlikely that a unit under test could produce enough current leakage during the first 4 μ s to cause tissue damage, and subsequently meet the specified leakage criteria.

D.3.3 Frequency of monitoring

The test requires that, as a minimum, the leakage current be monitored during the first 10 cycles and the last 10 test cycles. Experience indicates that most failures will occur early in the test procedure. It is possible that an early failure could generate gas inside the connector cavity by electrolysis and drive out the saline. This in turn could increase the isolation impedance and result in passing results for the same connector cavity by cycles 191 to 200. Therefore, it seems prudent to monitor the results at the beginning of the test as well as at the end. It is pointless to require the test of an early failing connector to be run to 200 minimum cycles.

D.4 Informative test combinations for connector cavities and lead connectors

D.4.1 General

The test combinations and voltages specified in [Annex C](#) were selected to ensure function and interchangeability of lead connectors and connector cavities. Other test combinations could be used by manufacturers to evaluate isolation of connector contacts in areas other than the seals such as to evaluate performance of specific design features or manufacturing processes. The need for such testing and the details of the test method should be defined by each manufacturer. Some suggested combinations are described in [D.4.2](#) to [D.4.4](#).

Testing of the connector for voltages or currents which could be induced by internal or external defibrillation was considered to be outside the scope of this document. Requirements for induced voltages are dependent on the design of the leads and pulse generators and other system factors. Even though this document does not address this, the test methods of [Annex C](#) could be useful for evaluating four-pole connectors under induced voltages as described in [D.4.5](#). The need for such testing and the details of the test method should be defined by each manufacturer.

D.4.2 High-voltage (DF4) connector cavities

Combinations additional to those specified in [Table C.4](#) could be used to evaluate high-voltage isolation between connector cavity contacts related to wire routings or other design aspects other than sealing. Manufacturers should decide which combinations and test methods (e.g. number of pulses) are appropriate for the specific components or features they want to evaluate. For example, the combination pin-to-reference could be used to evaluate isolation of the septum (grommet) which might be particularly important for devices where the can of the pulse generator could be configured as high-voltage relative to the pin connector contact.

D.4.3 Low-voltage only (IS4) connector cavities used in high-voltage devices

The methods described in [C.3](#) could be used to evaluate low-voltage only connector cavities used in devices capable of delivering high-voltage output. Manufacturers should decide if such testing is appropriate, and which combinations to test given their particular device design. For example, testing pin to reference or testing ring 3 to reference could be useful to evaluate the isolation and sealing in devices where the can of the pulse generator could be configured as high-voltage relative to the low-voltage only connector cavity contacts.

D.4.4 Low-voltage only lead connectors

The method described in [C.2](#) could be used to evaluate low-voltage only lead connectors, particularly those that might be used in pulse generators capable of delivering high-voltage output. Manufacturers should decide if such testing is appropriate, and which combinations and voltages to use for test. For example, testing lead connector contacts relative to a reference electrode could be useful to evaluate isolation integrity of the lead connector by simulating a system where the can of the pulse generator could be configured as high-voltage relative to the low-voltage connector contacts.

D.4.5 Induced voltages on four-pole connectors

Lead connectors and connector cavities, both high-voltage and low-voltage only, could be subjected to induced voltages from other electromagnetic environments such as internal or external defibrillation. Manufacturers may consider using the dielectric strength test procedures provided in [Annex C](#) to evaluate the potential effects of induced voltages on four-pole connector designs. Manufacturers should decide the applicable combinations and number of pulses used for such an evaluation. Possible test combinations and test voltages for each combination are presented in [Table D.1](#).

Table D.1 — Suggested tests for evaluating induced voltages on high-voltage and low-voltage only lead connectors and connector cavities

	Pin	Ring 1	Ring 2	Ring 3
Reference	1 200 V	1 200 V	1 200 V	1 200 V
Pin		500 V	500 V	500 V
Ring 1			500 V	500 V
Ring 2				500 V

Data collected by the AAMI EMC task force developing AAMI PC69 indicate potentials of no more than 1 200 V could be induced on a device during external defibrillation. A conservative estimate for voltage induced on any pair of electrodes during internal defibrillation is half the maximum voltage delivered or 500 V.

Ten (10) test pulses at each combination should be sufficient to reflect the number of shocks typically delivered by an external defibrillator (seven shocks plus a safety factor).

Manufacturers could use high-voltage protection circuits that will reduce or prevent the presence of induced potentials in four-pole connectors.

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Annex E (normative)

Current-carrying test high-voltage types

E.1 General

This annex describes the test to be employed to determine compliance with [4.3.8](#) and [4.5.8](#). This is a type (qualification) test and is not intended to be used as a routine production test. The manufacturer may use equivalent test methods. However, in case of dispute this test method shall be used. See [Annex F](#) for rationale.

WARNING — The following test employs high-voltages and currents. Failure to use safe laboratory practices might result in severe electrical shock, causing personal injury or death to persons handling the equipment or conducting the test. Damage to electrical equipment is also possible.

E.2 Specimen preparation

Lead connectors and connector cavities for the test shall be in the as-shipped condition.

E.3 Test signal

Use a test circuit that conforms to [Figure E.2](#) for lead connector testing and a test circuit that conforms to [Figure E.3](#) for the connector cavity testing. Charge the $(200 \pm 10 \%) \mu\text{F}$ capacitor to a voltage of 1 000 V minimum.

Discharge the capacitor through the contact being tested and the series power resistor for a minimum of 18 ms.

Allow a 10 s nominal interval between successive capacitor discharges.

E.4 Equipment

The test equipment shall consist of the current-carrying test pin as shown in [Figure E.1](#) and the current-carrying test arrangement as shown in [Figure E.2](#) or [Figure E.3](#).

E.5 Lead connector testing

E.5.1 General

This procedure evaluates ability of the contacts and conductors in the lead connector to withstand the current associated with high-voltage therapy.

E.5.2 Lead connector current-carrying capacity test method

Perform the test at $37 \text{ }^{\circ}\text{C} \pm 5 \text{ }^{\circ}\text{C}$ while the lead connector is dry. Use a test circuit that conforms to [Figure E.2](#). Connect to the external surface of the ring contact to be tested. Complete the circuit by

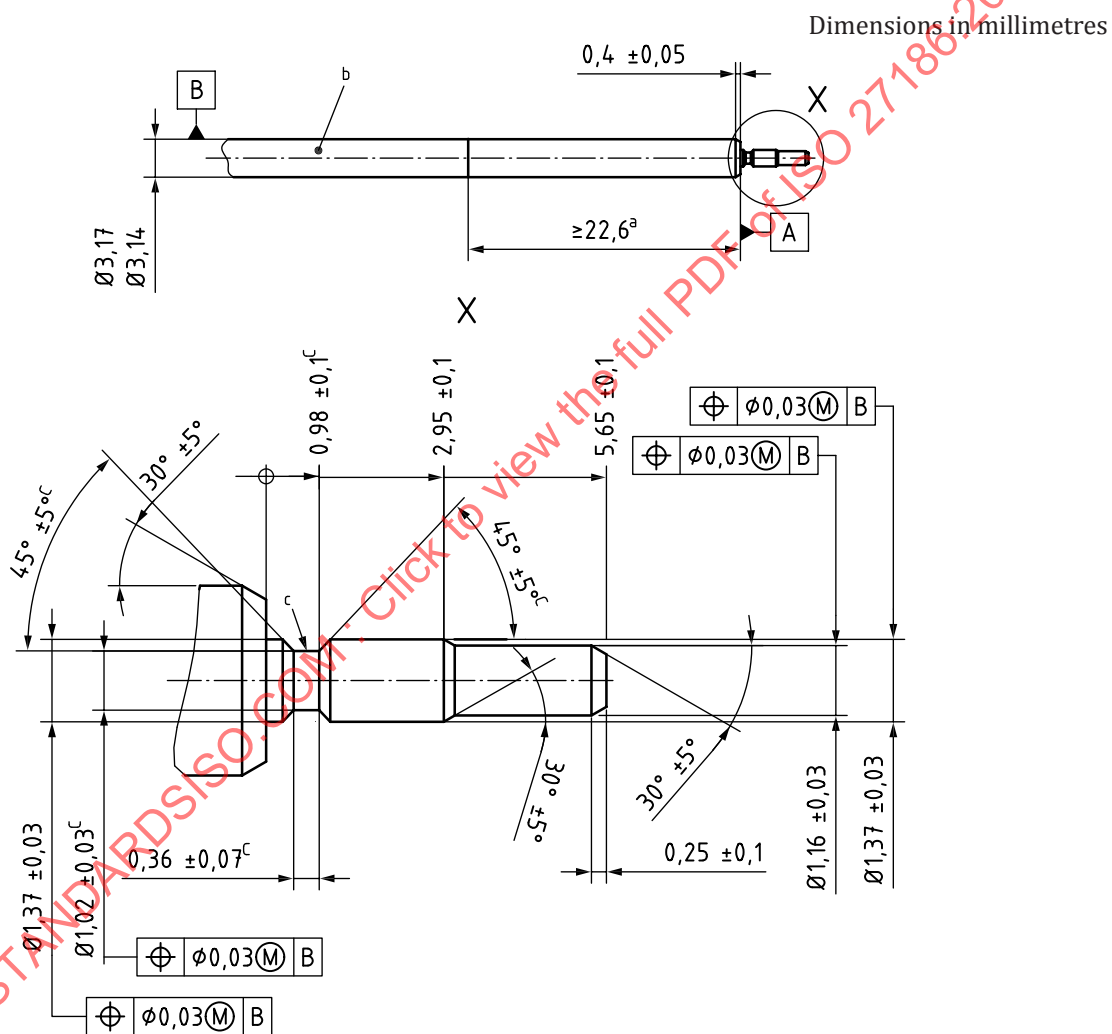
connecting to the conductor corresponding to the contact at a location distal to the strain relief zone as defined in [Figure 1](#).

NOTE The connection to the conductors distal to the strain relief zone can include part or all of the lead body resistance.

Use the test signal for lead connectors from [E.3](#). Select a series power resistor (R_1) and peak capacitor voltage as necessary so that the peak circuit current (I_{peak}) is 50 A minimum when measured at 4 μ s into the pulse.

Apply a minimum total of 500 test voltage pulses separately to each of the following lead connector contacts: contact ring 2 and contact ring 3.

Do not apply pulses to open or low-voltage contact rings.



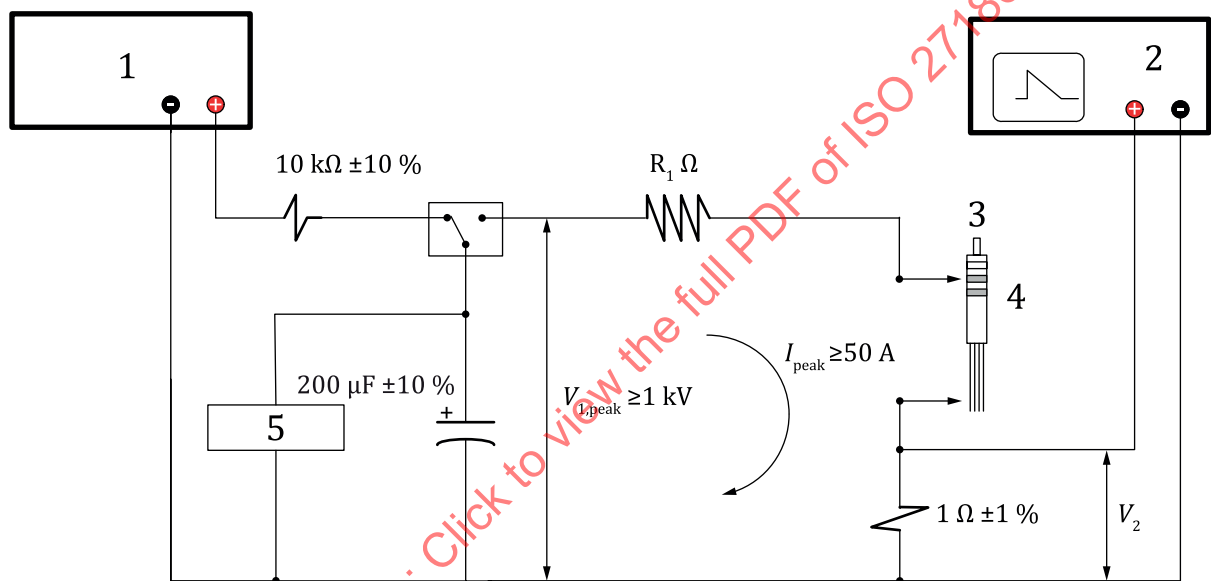
- a The diameter specified and a surface finish of *Ra* 0,8 to *Ra* 1,2 applies over this zone excluding the chamfer. Geometry beyond the minimum length is determined by each manufacturer.
- b Material 316L stainless steel (entire pin).
- c Dimension applies to the notch feature. Notch feature is optional and may be omitted.

Figure E.1 — Current-carrying test pin

E.5.3 Acceptance criteria

After testing, the following acceptance criteria shall be met:

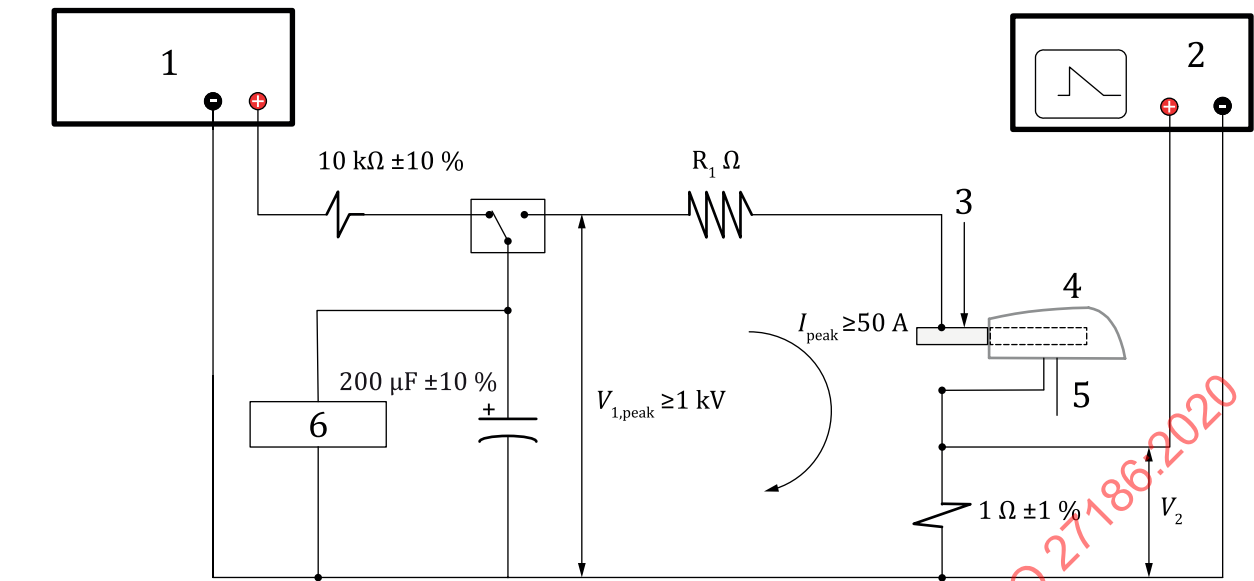
- the lead connector shall meet the electrical isolation requirements of [4.3.6](#);
- the lead connector shall meet the dielectric strength requirement of [4.3.7](#) as verified for 10 pulses at each polarity;
- the lead connector shall meet the requirements of [4.2.1.5](#) with the exception of the surface finish requirement;
- the electrical current after 4 μs into the pulse shall be 50 A minimum;
- the voltage drop across the 1 Ω measurement resistor shall be exponential according to [Figure E.4](#) as verified for the first and last test pulses.



Key

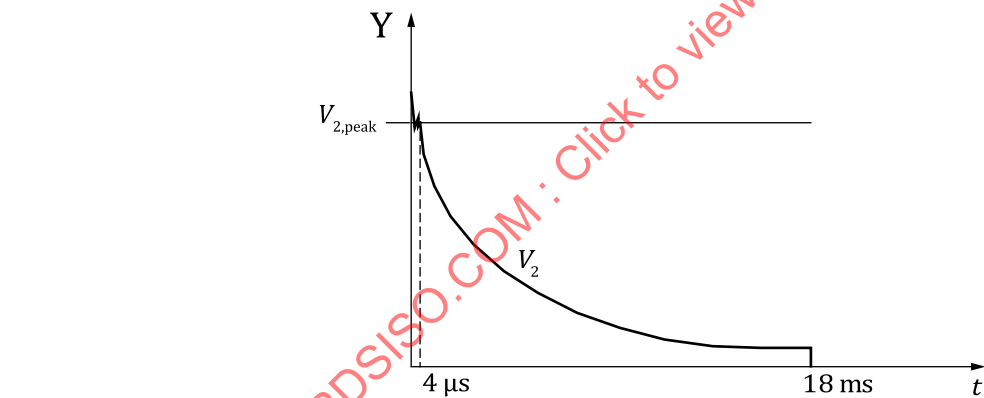
- | | | | |
|---|---------------------------|---|----------------------------|
| 1 | 1 kV minimum power supply | 4 | ring 2 and ring 3 contacts |
| 2 | Oscilloscope | 5 | voltmeter |
| 3 | lead connector | | |

Figure E.2 — Lead connector current-carrying test set-up



- Key**
- | | | | |
|---|---------------------------|---|----------------------------|
| 1 | 1 kV minimum power supply | 4 | connector cavity |
| 2 | oscilloscope | 5 | ring 2 and ring 3 contacts |
| 3 | current carrying test pin | 6 | voltmeter |

Figure E.3 — Connector cavity current-carrying test set-up



where

$$V_2 = V_{2,\text{peak}} e^{-\left(\frac{t}{RC}\right)}$$

V_2 is the voltage across the measurement resistor;

$V_{2,\text{peak}}$ is the peak voltage as measured at 4 μs into the pulse;

t is the time;

R is the total circuit resistance;

C is the circuit capacitance.

Figure E.4 — Voltage across the 1 Ω measurement resistor during a pulse

E.6 Connector cavity testing

E.6.1 General

This procedure evaluates the ability of the contacts in the connector cavity to carry currents associated with high-voltage therapy.

E.6.2 Connector cavity current-carrying capacity test method

Perform the test at $37\text{ °C} \pm 5\text{ °C}$ while the connector cavity is dry. Install the current-carrying test pin, which conforms to [Figure E.1](#), into the connector cavity, and fasten with the securing mechanism that the manufacturer has provided for clinical use (e.g. set screw, leaf spring, collet). Complete the electrical contact to the current-carrying test pin as shown in [Figure E.3](#) and to the end of the feedthrough that enters the pulse generator (or the electrical equivalent).

Use the test signal for a device connector cavity according to [E.3](#). Select a series power resistor (R_1) and peak capacitor voltage as necessary so that the peak circuit current, I_{peak} , is 50 A minimum when measured at 4 μs into the pulse.

Apply a minimum total of 200 test voltage pulses to each of the following connector cavity contacts: ring 2 and ring 3. Measure the resulting voltage across the capacitor ($V_{1,\text{peak}}$) and use an oscilloscope to measure voltage (V_2) across the 1 Ω measurement resistor (R_2).

Do not apply pulses to low-voltage or open contacts.

E.6.3 Acceptance criteria

E.6.3.1 The peak voltage across the 1 Ω measurement resistor shall be as follows as verified for the first and last test pulses:

$$V_{2,\text{peak}} \geq \frac{(V_{1,\text{peak}} \times 1\Omega)}{(R_1 + 2\Omega)} \text{ and } V_{2,\text{peak}} \geq 50\text{ V} \quad (\text{E.1})$$

where

$V_{1,\text{peak}}$ is the peak voltage measured across the capacitor, expressed in volts (V);

$V_{2,\text{peak}}$ is the peak voltage across the 1 Ω measurement resistor as measured after 4 μs into the pulse, expressed in volts (V);

R_1 is the set value of the series resistor, expressed in ohms (Ω).

The voltage drop, V_2 , across the 1 Ω measurement resistor shall be exponential according to [Figure E.4](#) as verified for the first and last test pulses.

After application of current, the maximum force required to fully withdraw the test pin shall not exceed 14 N.

Annex F (informative)

Rationale for [Annex E](#)

F.1 Rationale for performing a current-carrying test

An implantable defibrillator system relies on the ability of the connector cavity to make sufficient electrical contact between the pin on the lead connector and the defibrillator generator to carry the defibrillation current to the patient with minimal resistive losses. If the contact is too resistive, or is unable to handle the current required, sufficient power might be dissipated in the connector assembly causing damage to it, or the defibrillation output might be reduced to the point where it is ineffective.

The CTF agreed that passivated stainless 316L stainless steel, exhibiting higher contact resistance readings of the commonly used materials, would be the appropriate material to use for this current-carrying test vehicle as the “worst-case” test pin. For the connector cavity the current-carrying test indirectly evaluates the high-voltage contact resistance.

This test is applicable to ring 2 and ring 3 connections that are used for high-voltage therapies only.

F.2 Test parameters

A capacitor discharge test was selected to provide a means of delivering high peak currents in a repeatable, and easy to implement, fashion. It also represents the waveform that the test assembly is expected to experience clinically.

A 200 μF capacitor was selected to provide 100 J of stored energy, which is far in excess of what the manufacturers contemplated using.

The number of test cycles selected for the lead connector was a minimum of 500 because it was considered far in excess of what is expected to be experienced clinically in any one patient.

The number of test cycles selected for connector cavity testing was a minimum of 200, based on a very severe but clinically possible situation.

A peak circuit current of 50 A was selected based on a 20 Ω defibrillation load in order to represent a very severe but clinically possible situation.

A minimum 18 ms capacitor discharge time was selected to ensure that the capacitor would be discharged 99 % on a 20 Ω load under normal conditions; 18 ms is intended to be a longer discharge time than the typical monophasic or biphasic defibrillation.

Peak voltage drop is measured after 4 μs into the pulse to avoid transients. This results in minimal error since the 4 μs represents only 0,1 % of the capacitor discharge, which corresponds to approximately 0,05 V for a 50 V measurement.

The 10 s nominal interval between capacitor discharges allows flexibility in testing and is being specified for resolving potential disputes. The experts participating in the development of this document agreed that testing with smaller or longer time intervals would be adequate.

F.3 Voltage drop across contact for the connector cavity

The resistance between the connector cavity and lead connector pin should not exceed 1 Ω during the delivery of the high-voltage defibrillation. For two connectors in series with a typical heart load of 40 Ω ,

this represents a 5 % loss in output voltage from the device. Any greater voltage loss was considered to be highly undesirable.

Verification that the voltage drop during a pulse is exponential is to confirm acceptable electrical performance over the duration of the pulse.

Measurement of the voltage drop across a fixed 1 Ω measurement resistor, V_2 , is used as an indirect measurement of the voltage drop across the connector assembly in order to simplify testing and obtain more stable readings. A requirement that $V_{2,\text{peak}} \geq (V_{1,\text{peak}} \times 1 \Omega) / (R_1 + 2 \Omega)$ corresponds to a connector system resistance of less than or equal to 1 Ω . Likewise, an exponential drop across the measurement resistor reflects an exponential drop across the connector assembly. A 1 Ω measurement resistor was selected to maintain a low-voltage reading.

F.4 Post-test requirements for the lead connector

The lead connector should be capable of delivering 50 A minimum peak current during 500 defibrillation shocks without functional or dimensional damage. A post-test verification of the dimensional requirements, electrical isolation and dielectric strength is to confirm that no functional or dimensional damage has occurred as a result of the high current pulses.

F.5 Connector cavity post-test withdrawal force

A withdrawal force requirement at the end of the test is included to check that the connector cavity/test pin assembly have not become welded together.

Annex G (informative)

Lead connector fatigue strength test

G.1 General

Since lead flex fatigue strength requirements are defined in existing standards (see EN 45502-2-1 and EN 45502-2-2), there are no additional test requirements included in this document. The following information, however, is provided to facilitate implementation of the existing requirements and test methods to four-pole lead connectors.

Figure G.1 defines a holding fixture intended for use in conjunction with the procedures in EN 45502-2-1:2003, 23.5. The holding fixture of Figure G.1 should be made of a rigid material. It should have a bore depth that is maximally set to the minimum allowed for the applicable connector cavity. The entrance edge should be rounded to a radius as shown, and the centre of rotation of flexing should be in the plane where this rounded edge begins (as also described in EN 45502-2-1).

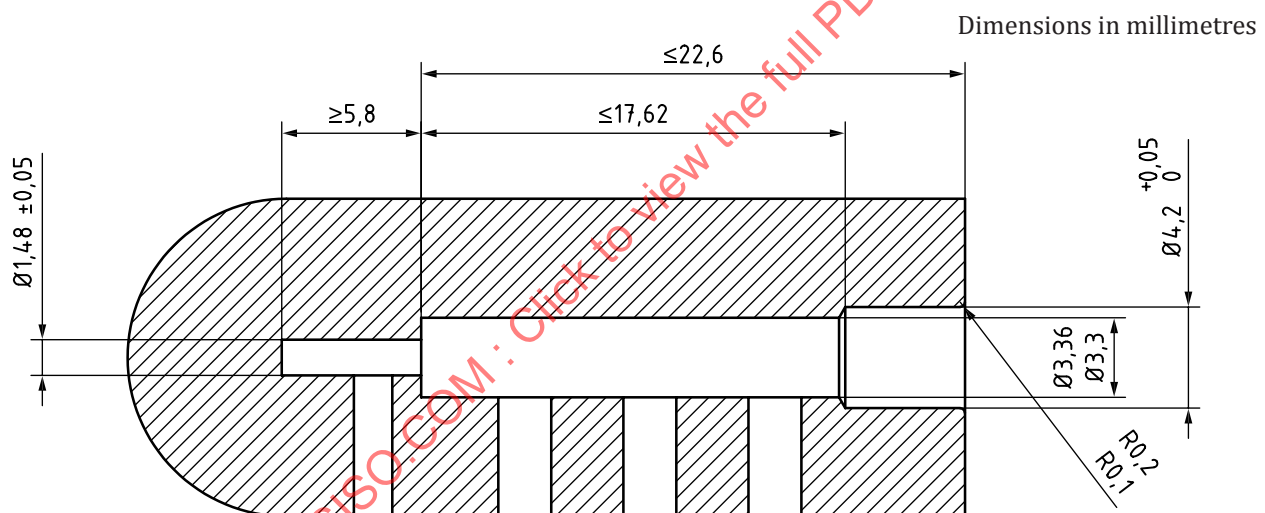


Figure G.1 — Holding fixture

G.2 Rationale for flex fatigue strength testing

Flex fatigue strength testing is performed to ensure that leads can withstand the mechanical stresses that normally occur after implantation. For the flex test described in EN 45502-2-1 and EN 45502-2-2, the leads are evaluated at a critical location which is at the interface between the relatively stiff connector cavity and the relatively flexible lead body.

The four-pole lead connectors defined in this document might be relatively stiffer than similar IS-1 and DF-1 lead connectors. The reason for this is because four-pole lead connectors have a sealing area that is relatively rigid (i.e. made up of metal and hard plastic) since the softer sealing elements are incorporated in the four-pole connector cavity. Additionally, the complexity of the electrical connections necessary for four contacts places a higher demand on the mechanical and electrical integrity of the lead. Therefore, it is important that lead connector designs be evaluated for flex fatigue performance to ensure that they will maintain functional integrity under the flexural stresses that they might encounter *in vivo*.

Annex H (informative)

Lead connector seal zone materials

H.1 General

In order to allow for design flexibility, this document specifies functional requirements for the lead connector seal zones but does not include specific material requirements. However, three recommendations concerning lead connector seal zone material are provided in [H.2](#), [H.3](#) and [H.5](#).

H.2 Annealing

During the development of this document, measurable seal zone creep exceeding 0,02 mm was observed only when polyurethane test pins or lead connectors were not properly annealed to remove moulding stresses.

Manufacturers should be aware of the potential for unacceptable creep performance if residual stresses are not properly removed from their lead connectors.

H.3 Hardness

It is recommended that materials for lead connector seal zones have a minimum hardness of 70 Shore D (nominally) for mechanical considerations. For electrical considerations, refer to [4.2.1.4](#) and [B.4](#).

H.4 Rationale for hardness

The recommended minimum hardness for the lead connector seal zone material is based on concerns that a lead connector could potentially become damaged when inserted past the contacts within a connector cavity. Because the details of contact design are not specified in this document, it is not possible to establish a functional requirement for the lead connector. Since materials softer than 75 Shore D (nominal) were not evaluated during the development of this document and might have a greater potential for becoming damaged by contacts, a recommendation is given to use materials that are 70 Shore D or harder for the seal zones of the lead connector. Harder materials can also reduce the potential for damage occurring during handling of the lead connector, such as during attachment of temporary electrical connections made at implant. However, due to its unknown and unbounded nature, inappropriate handling was not addressed by this document and should be addressed separately by each manufacturer by their individual designs, in product literature, written instructions and/or adequate training.

H.5 Use of silicone rubber compounds

It is recommended that the lead connector seal zone surface be of a material other than silicone rubber compounds/composites unless the manufacturer demonstrates that silicone-to-silicone adhesion or bonding will not occur.

H.6 Rationale for recommendation against using silicone rubber compounds/composites

The recommendation for not using silicone rubber compounds/composites for the lead connector seal zone surface is based on the fact that it has been industry practice to use silicone rubber compounds to fabricate seal components and it is expected that this material will be used for seals in connector cavities. Some silicone rubber compounds have been known to adhere to each other when in contact, especially under loading conditions. If lead connector seal zone surfaces and connector cavity seals were both made from silicone rubber compounds they could adhere to each other, making the lead difficult to remove and potentially damaging the lead and/or pulse generator.

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Annex I

(informative)

Seal zone creep

I.1 General

Since leads might remain implanted for more than 10 years and might be used with multiple pulse generators during the life of the lead, the lead connector should be designed and manufactured to survive pulse generator change-outs and function with multiple pulse generators. Thus, it is important to ensure dimensional and functional stability under expected use conditions. Consideration should be given to the integrity of the lead connector seal zones under seal pressures, since compressive creep or deformation in these areas could prevent proper sealing with a replacement pulse generator.

This document does not include an explicit requirement to control creep performance of the lead connector seal zone. During development of this document, the experts in the CTF evaluated a number of potential requirements intended to control creep performance of the lead connector seal zone. Creep testing would ensure that the lead connector seal zones would not become deformed to an extent that sealing with a replacement pulse generator might be compromised. After considerable experimentation, no practical solution was found; the CTF was unable to develop a satisfactory and reproducible test method.

However, the data generated in these studies confirmed that existing requirements in this document are adequate under specified conditions. Specifically, the requirement for maximum insertion force indirectly limits seal pressure by restricting the normal loads that can be applied by the seals to the lead connector. No exact correlation between seal insertion forces and seal pressures can be determined due to the variation allowed in the seal designs. However, based on intercompany testing of actual leads and pulse generators, this condition is adequate as long as sealing mechanisms are passive (i.e. they are not activated or enhanced after the lead connectors are inserted).

It is recommended that manufacturers do not incorporate active sealing in their connector cavities or pulse generators unless it is demonstrated that the resulting pressure on the lead connector seal zones do not exceed those of passive sealing mechanisms. Active sealing is where seals are activated or enhanced after the lead connector is inserted. Passive sealing does not have such activation or enhancement and therefore seal pressures are limited by insertion force requirements.

It is also recommended that manufacturers take effective measures to ensure their lead connectors are creep resistant. They should control both design elements and fabrication parameters (including adequate annealing) to ensure the seal zones are robust enough to withstand anticipated seal zone pressures.

I.2 Summary of efforts to develop creep requirements

I.2.1 General

During the development of this document, several experiments were performed to identify and quantify sources of variability in creep performance of lead connectors. The results of the two most salient studies are summarized in this annex. For these studies, the specimens were soaked in saline at $37\text{ °C} \pm 5\text{ °C}$ for 30 d to 32 d. Even though creep can be a long-term phenomenon, experience during the development of this document indicated that when creep was observed on 75 Shore D polyurethane, it presented within 30 d of soaking in 37 °C saline under loading conditions.

I.2.2 Interchangeability testing

In one study, leads and pulse generators manufactured by three different manufacturers were assembled in all possible combinations (nine in total). The specimens were soaked in saline at $37\text{ °C} \pm 5\text{ °C}$ for 30 d to 32 d. The leads were removed from the pulse generators and the depths of the impressions left by the seal rings were measured using a precision optical measuring system. The depth of the impression was less than 0,02 mm for all specimens.

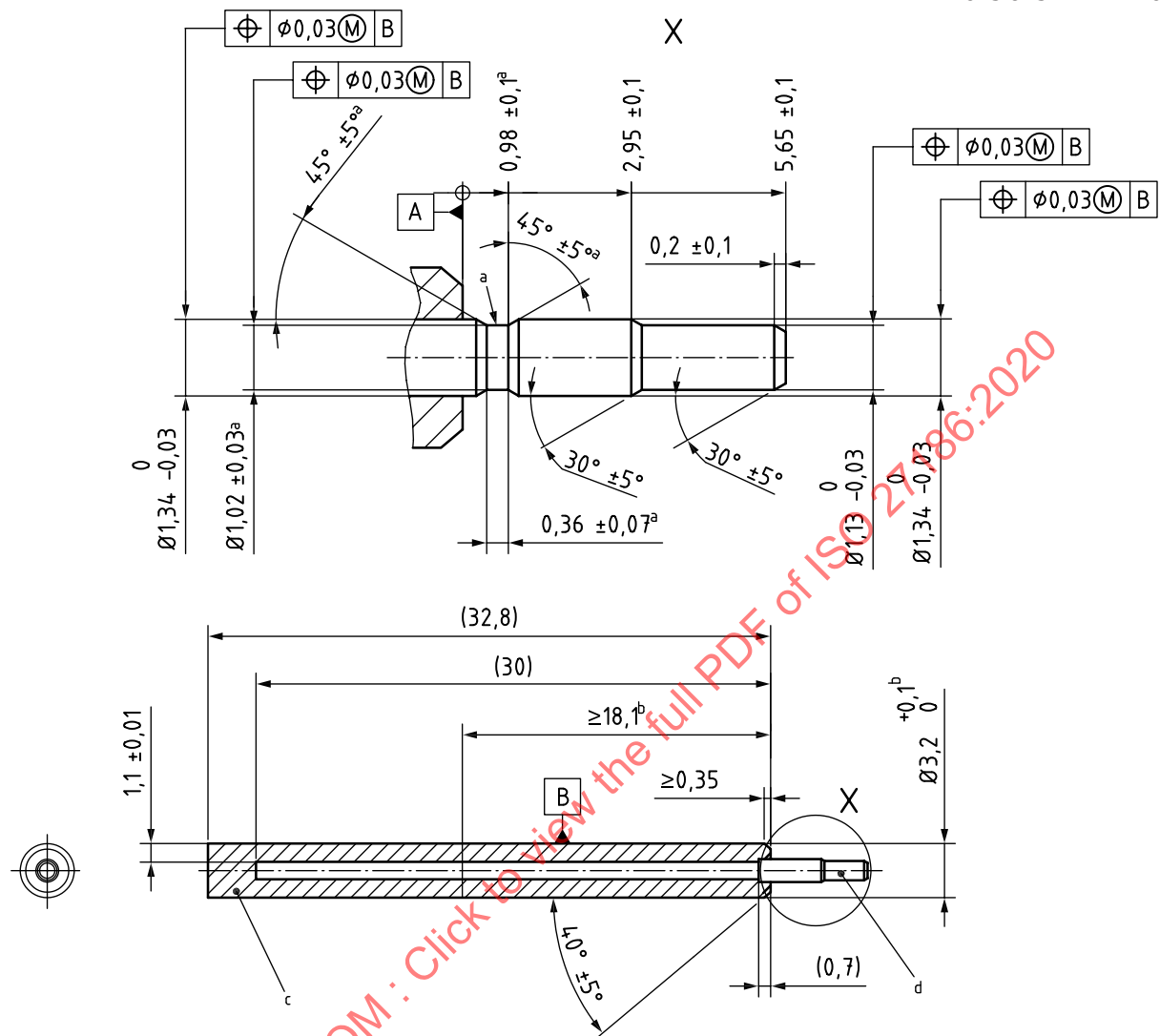
I.2.3 Design limit testing

The second study used standard test pins meant to simulate a typical lead connector and o-rings meant to produce seal pressure considerably greater than would be expected for a practical seal design. These pressures are considered greater than expected since they produced frictional drag that would result in unacceptable insertion forces in a connector system.

The study was performed using creep test pins manufactured in accordance with [Figure I.1](#). Three sets of creep test pins were fabricated by three different suppliers. The same grade of polyurethane material was used for all pins, Tecothane[®] TT-1075D-M³⁾. Creep test pins were annealed at 60 °C to 80 °C for 4,0 h minimum. Experience has suggested that this annealing schedule is sufficient to fully anneal the test pins.

3) Tecothane[®] TT-1075D-M is the trade name of a product supplied by the lubrizol corporation, Wickliffe, OH, USA. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named.

Dimensions in millimetres



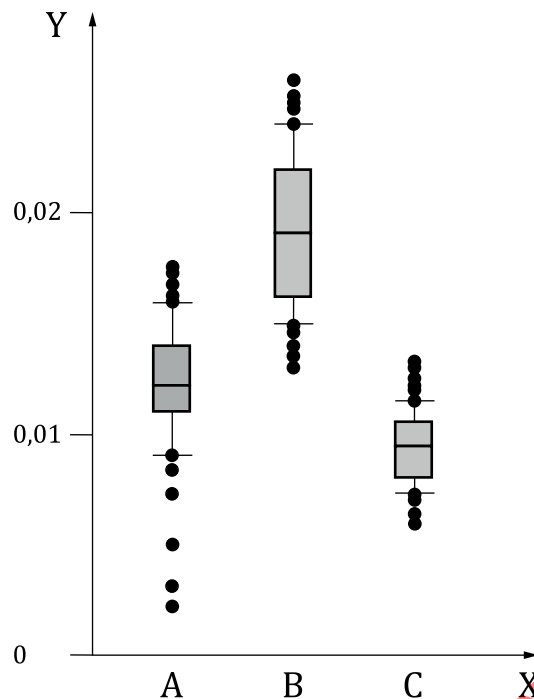
- a Dimension applies to the notch feature. Notch feature is optional and may be omitted.
- b Diameter and datum B apply to the zone indicated.
- c Body material: Tecothane[®] TT1075D moulded polyurethane.
- d Core material: 316L stainless steel.

Figure I.1 — Creep test pin

Three groups of o-ring were tested. The o-rings met the requirements of AS568-005. Each group of o-rings was moulded with a different compound of EPDM (ethylene-propylene-diene rubber). Two suppliers provided material with a Shore hardness of 70A. One supplier provided material with a Shore hardness of 75A.

Four o-rings were placed on each test pin in the approximate location of seal rings in the pulse generator header. A total of 54 test pins (18 from each supplier) and 216 o-rings (72 from each supplier) were tested in a balanced design. The specimens were soaked in saline at $37\text{ °C} \pm 5\text{ °C}$ for 30 d to 32 d. The depth of the impression made by each seal ring was measured using a video measuring system.

Results are summarized in [Figure I.2](#).

**Key**

A, B, C test pin suppliers

Y depth of impression in millimetres

Figure I.2 — Depth of o-ring impressions after specimens were soaked in saline at 37 °C ± 5 °C for 30 d to 32 d

There was a statistically significant difference between the three creep test pin suppliers and also between the three o-ring suppliers. These results show that differences in test pin fabrication (for example mould gate design, moulding parameters, anneal procedure or other unknown factors) can have a significant effect on creep performance, even when final dimensions, dimensions of the underlying support pin, and specific material grade are specified and held constant. Even though testing was conducted using seal pressures considerably greater than expected for practical seal designs and testing was conducted using test pins, it is supposed that lead connectors could exhibit such variation if not properly processed. Actual lead connectors could have additional variation due to construction details beyond the homogeneous test pins.

I.3 Limits on lead connector creep

During development of this document, the CTF considered and rejected a proposed requirement for lead connector creep performance. The reason for rejection is described in [I.5](#). The proposed requirement had the following elements:

- acceptance limits: when tested in accordance with the method outlined in [I.2.2](#), creep in the lead connector seal zone shall be less than 0,026 mm;
- statistical basis for acceptance:

$$\bar{X} + KS < 0,026 \text{ mm} \quad (\text{I.1})$$

where

- $\bar{X}$ is the sample mean;
- K is the one-sided 95/99,9 normal tolerance limit factor;
- S is the sample standard deviation.

I.4 Limits on connector cavity seal pressure

During development of this document a proposed requirement for limiting the amount of seal pressure that a connector cavity could place on a lead connector was considered and rejected. The reason for rejection is described in [I.5](#). The proposed requirement had the following elements:

- Test pin: use a test pin that conforms to [Figure I.1](#). Test pins shall be fully annealed to relieve residual stresses in the polyurethane prior to being used for the test. Anneal at 60 °C to 80 °C for 4,0 h minimum followed by cooling in air to ambient temperature.
- Test samples: connector cavities for the test shall be in the as-shipped condition.
- Procedure: verify that the test pin dimensions comply with [Figure I.1](#). Immerse the connector cavity in 9 g/l saline solution. Fully insert the test pin into the connector cavity and fasten the securing mechanism that the manufacturer has provided for clinical use (e.g. set screw, leaf spring, collet). After a minimum of 30 d soaking at 37 °C ± 5 °C, remove the test pin and measure the seal contact areas on the test pin for any deformation caused by the seals. Measure the maximum depth of the deformation using appropriate magnification.
- Acceptance limits: the outside diameter of the test pin shall not exhibit surface deformation due to seal contact that exceeds 0,02 mm in depth at any location.

I.5 Rationale for rejecting proposed requirements for lead connector creep performance and connector cavity seal pressure

After extensive testing and review of results, the experts participating in the CTF concluded that the proposed requirements for lead connector creep performance and connector cavity seal pressure would be inadequate for a document because the limits could neither be quantified nor verified by repeatable test methods. Variability in creep performance attributable to test pins, o-rings, apparatus and methods was too great. The test pin manufacturer was the most significant source of variability identified through experimental testing. The o-ring supplier was the second most significant source of variability. The test laboratory was the third most significant source of variability.

It would be possible to refine the method by controlling o-ring material and dimensions more closely. It might be feasible to perform additional, carefully controlled, designed experiments to better quantify the effect of variability in test specimens, apparatus and methods on creep performance, and to establish valid specification limits. However, the available evidence is insufficient to adequately characterize the sensitivity and specificity of the proposed requirements.

Although these studies show that it is not practical to establish functional requirements for creep performance, it is concluded that, for lead connector designs and processes developed by competent medical device engineering organizations, potential hazards associated with lead connector creep are adequately controlled by other provisions of this document. Existing information in this document is adequate under specified conditions; specifically, the requirement for maximum insertion force indirectly limits seal pressure by restricting the normal loads that can be applied by the seals to the lead connector. The results of tests summarized in this annex, particularly the results in [I.2.2](#), confirm this conclusion.

Annex J (informative)

Contact resistance stability

J.1 General

This annex describes a test method for measuring the short-term static no-load contact resistance and dynamic contact resistance stability of contacts in connector cavities. This test method defines the minimum applied side load/moment, maximum excitation input (voltage or current), and minimum sampling frequency/resolution recommended for detecting contact resistance intermittencies. Alternative test methods may be used. This is a characterization test and is not intended for use as a routine production test.

J.2 Limits for contact resistance

Pulse generator manufacturers should demonstrate that the electrical contacts within their connector cavity make sufficient electrical contact with lead connectors under static and dynamic loading conditions such that pulse generator function is not compromised. To do this, manufacturers should first establish acceptable limits for (1) static no-load contact resistance, and (2) maximum contact resistance variability and a dynamic threshold time, T , for proper functioning of their specific devices. Then they should perform testing to demonstrate that the contacts in their connector cavities meet those limits.

J.3 Set-up

J.3.1 Specimens

The manufacturer should determine the test sample configuration for this test. Internal jumpers may be used to monitor contact resistance of one or more contacts at a time. All non-set screw contacts should be tested. Samples under test should be representative of product processed in accordance with typical manufacturing operations including test pin insertions and sterilization cycles.

J.3.2 Test pin

The test pin for contact resistance testing should be made of 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562 and should meet the dimensional requirements of the current-carrying test pin specified in [Figure E.1](#). Test pin hardness should be 45 HRC (Rockwell C scale) minimum.

J.3.3 Current-carrying test equipment

For the current-carrying test used for preconditioning, refer to the equipment and set-up specified in [Figure E.2](#).

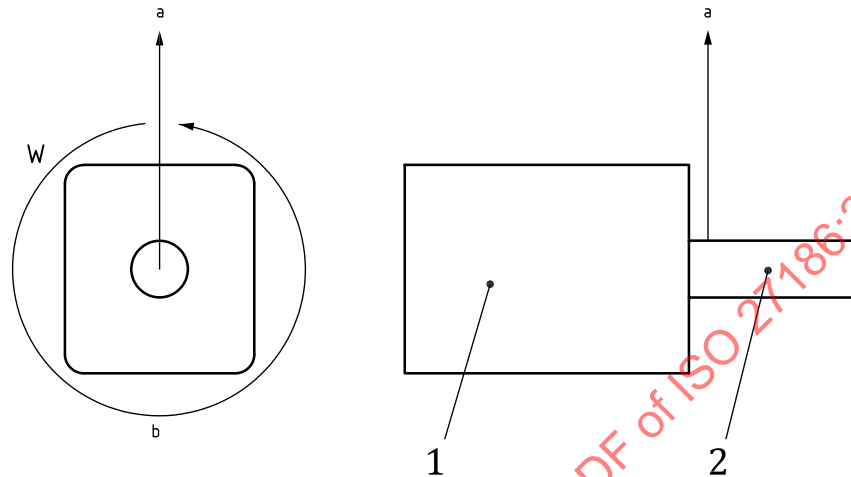
J.3.4 Contact resistance test equipment

The test equipment comprises a mechanical fixture and an electrical tester which can do the following.

- a) Apply a minimum moment equivalent to the moment supplied by a 1 N side load at the bore entrance. A fixture is required to hold and stabilize the connector cavity while applying a rotating

side load to the test pin. One example is a fixture with a rotating handle with spring load applied perpendicular to the test pin as shown in [Figure J.1](#).

- b) Measure the manufacturer's specified contact resistance and dynamic contact resistance variability above the manufacturer's specified threshold time. The sampling frequency of the equipment should be ≥ 1 sample per degree of rotation of the side load or $\geq 2/T$, where T is the threshold time requirement defined in [J.2](#). The equipment excitation input should not exceed 100 mV or 100 mA.



Key

- 1 connector under test
- 2 test pin
- a Load.
- b 360° rotation of side load.

Figure J.1 — 360° rotation contact resistance fixture

J.4 Procedure

J.4.1 General

The test procedure consists of three steps in the following sequence:

- preconditioning;
- static no-load contact resistance;
- dynamic contact resistance stability.

J.4.2 Preconditioning

The object of preconditioning is to appropriately precondition the connector cavity under test by simulating multiple lead insertion/withdrawal cycles and other appropriate known stresses that the contacts might encounter during service. To precondition, fully insert and withdraw the maximum connector cavity gauge pin ([Figure 9](#)) from the connector cavity one time. Then expose the high-voltage contacts of high-voltage cavities to the current-carrying test in [Annex E](#) for a minimum of 20 pulses.

J.4.3 Static no-load contact resistance

J.4.3.1 Objective

To measure the short-term static no-load contact resistance between each connector non-set screw contact and the test pin.

J.4.3.2 Method

Perform the test dry in air at room temperature as follows.

- a) Clean the contact resistance test pin with isopropyl alcohol and allowed to dry before insertion into the connector cavity. Wear clean laboratory gloves when handling the clean test pin to avoid contaminating it.
- b) Fully insert the contact resistance test pin into the connector cavity. Do not activate the fixation mechanism (e.g. do not tighten the set screw). Mount the connector cavity in the fixture described.
- c) With no load or motion applied to the test pin, use a four-wire (or equivalent) method to measure the contact resistance between the test pin and each intended contact. This measured value is the static no-load contact resistance. It is recommended that the static no-load contact resistance for each spring contact be determined from an average of at least 100 data points.

J.4.3.3 Acceptance criterion

The static no-load contact resistance should not exceed the manufacturer's predetermined requirements for proper function of the device.

J.4.4 Dynamic contact resistance stability

J.4.4.1 Objective

To evaluate the dynamic contact resistance stability of the connector cavity contacts using a fully inserted test pin with a radially applied side load.

J.4.4.2 Method

NOTE It is not necessary to repeat steps a) to c) if already performed as part of the static no-load contact resistance test in [J.4.3](#).

Perform the test dry in air at room temperature as follows.

- a) Clean the contact resistance test pin with isopropyl alcohol and allow to dry before inserting into the connector cavity. Wear clean laboratory gloves when handling the clean test pin to avoid contaminating it.
- b) Fully insert the contact resistance test pin into the connector cavity. Do not activate the fixation mechanism such as by tightening the set screw. Mount the connector cavity in the fixture described in [J.3.4](#).
- c) Apply a side load to the test pin relative to the connector cavity as shown in [Figure J.1](#). The minimum applied moment should be equivalent to a 1 N side load applied at the bore entrance.
- d) With the side load applied, monitor the resistance on the contact(s) of interest while completing a minimum of three full clockwise handle rotations then reversing direction and completing a minimum of three full anticlockwise handle rotations. The duration of each full rotation should be between 2 s and 5 s.

J.4.4.3 Acceptance criteria

The maximum dynamic contact resistance and contact resistance fluctuations should not exceed the manufacturer's predetermined requirements of threshold time, T , (in seconds) and contact resistance variability, Ω , for proper function of the device.

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Annex K (informative)

Rationale for [Annex J](#)

K.1 General

[Annex J](#) describes a test method for evaluating connector cavity contacts used in four-pole connectors. This test method has been used to identify contact design performance differences that were deemed meaningful in selecting an appropriate contact for use in a particular system. This annex lists the rationale for the parameters of the test method described in [Annex J](#).

The common feature that is mandated by this document is the delivery of high-voltage defibrillation therapy on the high-voltage leads. The contact performance for this therapy is tested as defined in [4.5.8](#) and [Annex E](#). The testing described in [Annex J](#) is intended for low-voltage signals of various therapy and measurement features, some of which might reside on high-voltage designated contacts, thus testing of all contacts is required.

K.2 Limits for contact resistance

A contact resistance test method is specified in [Annex J](#). The material properties and geometry of lead contact surfaces have been specified elsewhere in this document in terms of the attributes that affect contact resistance, so that a device manufacturer can be sure that leads conforming to this document have a minimum level of performance in terms of the lead-to-device contact interface. However, during the development of this document, it was recognized that individual spring contact designs of the same material can have different contact resistance and intermittency performances specific to their design, which is not tested elsewhere in this document. Since the device features and spring contact performance both reside in the device, it is recommended that each device manufacturer perform a test to ensure that the contact resistance and stability are acceptable for the performance of their device.

K.3 Rationale for method

K.3.1 Preconditioning

Contact resistance requirements should be met after simulation of typical stress conditions. Multiple lead insertions are expected in normal use. The test pin is being used to simulate a lead.

K.3.2 Static no-load contact resistance

A 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy test pin meeting the dimensional requirements of [Figure E.1](#) is recommended. The test pin material was chosen to represent lead connector materials that meet the other requirements of this document and provide consistent contact resistance results. If individual manufacturers plan to use other lead connector materials, they are advised to perform a similar test with those lead connector materials in addition to the 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy. The minimum hardness of the test pin was chosen to ensure that it is a worst-case representative of the acceptable lead connector material. Test pins greater than 45 HRC have been shown to cause increasing variation in contact resistance after multiple insertion cycles.

K.3.3 Short-term dynamic contact resistance stability

K.3.3.1 General

The set screw (or other active retention mechanism) is not tightened, to allow for movement that can occur with passive retention mechanisms or with lead connectors that have a rotating pin. This test is based on the expectation that some level of motion between the spring contact interface and the lead contact surface can occur. The actual magnitude of this motion is a function of many factors including but not limited to: applied external load, lead design/stiffness in the strain-relief zone, connector cavity seal design, spring contact design, and overall structural integrity of the connector cavity. The impact of this motion on electrical stability might be a critical factor for some features and might be highly dependent on the spring contact design. This test is defined to evaluate the performance of candidate contact designs for sensitivity to relative motion.

K.3.3.2 Minimum applied load

The 1 N minimum side load applied at the bore entrance was chosen based on reported physiologic loading and to be consistent with the electrical isolation testing. See [Annex D](#) for rationale.

K.3.3.3 Maximum applied voltage

The maximum applied voltage of 100 mV nominal was chosen to enable detection of contact resistance intermittencies, based on experience gained during the development of this document.

K.3.3.4 Maximum applied current

The maximum input current of 100 mA was chosen to enable detection of contact resistance intermittencies, based on experience gained during the development of this document.

K.3.3.5 Sampling resolution

The sampling resolution of at least one sample per degree of rotation, or at least $2/T$ (where T is the threshold time requirement), was chosen to enable detection of intermittencies.

K.3.3.6 Equipment

The equipment recommendation includes a simple fixture and equipment that is commercially available at a reasonable cost. Experience gained during the development of this document led to the development of a manually rotated fixture to avoid electrical noise that might be introduced by a motor.

Several commercially available digital multi-meter (DMM) units are suitable for this test. Two examples of units used during the development of this document are the following:

- a) a DMM used in a dry circuit mode with 20 mV open circuit voltage and 100 mA maximum current with approximately 13 Hz sampling rate;
- b) a DMM used in a dry circuit mode with 100 mV open circuit voltage and 10 mA maximum current with approximately 360 Hz sampling rate.

Experience gained during the development of this document indicated that lower voltages enabled detection of contact resistance intermittencies and that the voltage should not be greater than 100 mV nominal. A four-wire measurement method (or equivalent) should be used to measure contact resistance between the test pin and spring contact, subtracting test cable resistances which can be of the same order of magnitude.

The sampling rate and handle rotation rate should be coordinated for a minimum sampling resolution of one sample per degree of rotation, or at least $2/T$ (where T is the threshold time requirement). Examples include rotating the handle at a rate of 1 cycle/min with a sampling rate of 13 Hz or rotating the handle at a rate of 0,8 cycles/s with a sampling rate of 360 Hz.

Annex L (informative)

Selection of contact materials

L.1 General

Careful consideration should be made when selecting the conductive materials for the electrical contacts within the connector cavity and for the lead connector, e.g. lead connector rings, lead connector pin and connector cavity contacts. At a minimum, materials for electrical contacts should be selected with consideration for electrical performance and corrosion resistance as described in [Annex J](#), [Annex K](#), [Annex M](#) and [Annex N](#). Manufacturers should also consider possible system level interactions of electrical contacts and interfaces including mechanical, electrical and electrochemical variables that could affect the clinical performance of the mated connector system.

L.2 Potential system level considerations

Several factors are believed to affect the electrochemical performance of electrical contacts within the mated connector system, particularly that of metal spring contacts in the connector cavity and their interface with contacts of the lead connector. These factors, at a minimum and in no particular order, are as follows.

- Material selection: including the connector cavity contacts, mating lead connector contacts and, if applicable, the connector blocks within which the connector cavity contacts reside.
- Contamination: either in the material and/or on the surface of the material at the contact site.
- Interface geometry: multiple contact points are preferred; the normal force should be considered, and care should be taken to minimize asymmetric loading.
- Interface surface morphology: surface roughness on either side of the interface might generate inappropriate particulates that could potentially become entrapped between the mating surfaces.
- Device connector cavity geometry: lead bore should sufficiently constrain/stabilize the lead connector.
- Fluid ingress: system level testing of the interface should involve some controlled ingress of fluid into the device-to-lead connector cavity area. Neither a zero fluid or open fluid situation is sufficient to adequately characterize the performance.
- Electrical parameters: pacing, shocking, polarity and/or the unique electrical characteristics of each device can affect the electrochemical stability of lead connector-to-device cavity interfaces. For example, reversing the polarity of the shocking pulse might drive corrosion preferentially to one side of the interface, i.e. the lead connector conductor versus the device connector cavity contact.

It is for these reasons that the CTF recommends that manufacturers perform system level testing relative to mechanical, electrical and electrochemical variables to assess short- and long-term performance of metal contacts and contact interfaces.

L.3 Additional considerations

During the development of this document, several observations were made regarding the performance of lead connector materials. Lead connector contact material selection should consider 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562, which, during the development of

this document, was evaluated to have acceptable performance by multiple manufacturers. Regardless of any references here, the materials used should meet all requirements of this document, including the requirements of [Annex M](#).

During the development of this document various grades of titanium specified in ASTM B348 were evaluated to a limited degree without conclusive results.

Grade 316L stainless steel material specified in ASTM A276 was also evaluated as a lead connector contact material. Contact resistance testing specified in [Annex M](#) resulted in contact resistance levels significantly above the requirement limits. Crevice corrosion testing specified in [M.3.2](#) resulted in pitting potentials less than 200 mV against a saturated calomel reference electrode, SCE. 316L stainless steel is therefore not recommended based on these test results.

During the development of this document, connector cavity spring contact assemblies composed of 316L stainless steel external housings and 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy canted coil spring contacts also exhibited higher contact resistance variability than similar design spring contact assemblies which used 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy for both the external housing and spring contact. However, previous industry experience shows that some applications with low-voltage lead connectors and connector cavities exhibited acceptable performance.

Annex M **(normative)**

Lead connector contact material requirements

M.1 General

This annex describes the requirements and test method for evaluating contact materials used on the lead connector. It covers three separate but related material requirements:

- a) surface contact resistance: contact resistance properties of the conditioned surface when contact is made to a reference electrode; this requirement is described in [M.2](#);
- b) corrosion: corrosion resistance of the material surface when tested in multiple tests to ensure acceptable corrosion resistance of the lead connector surface; this series of requirements is described in [M.3](#);
- c) hardness: maximum hardness for materials used for the lead connector contacts is defined in [M.4](#).

M.2 Contact resistance

M.2.1 Requirement

The average values of the surface contact resistance shall be below the curve shown in [Figure M.1](#) when tested in accordance with [M.2.3](#) and the associated references.

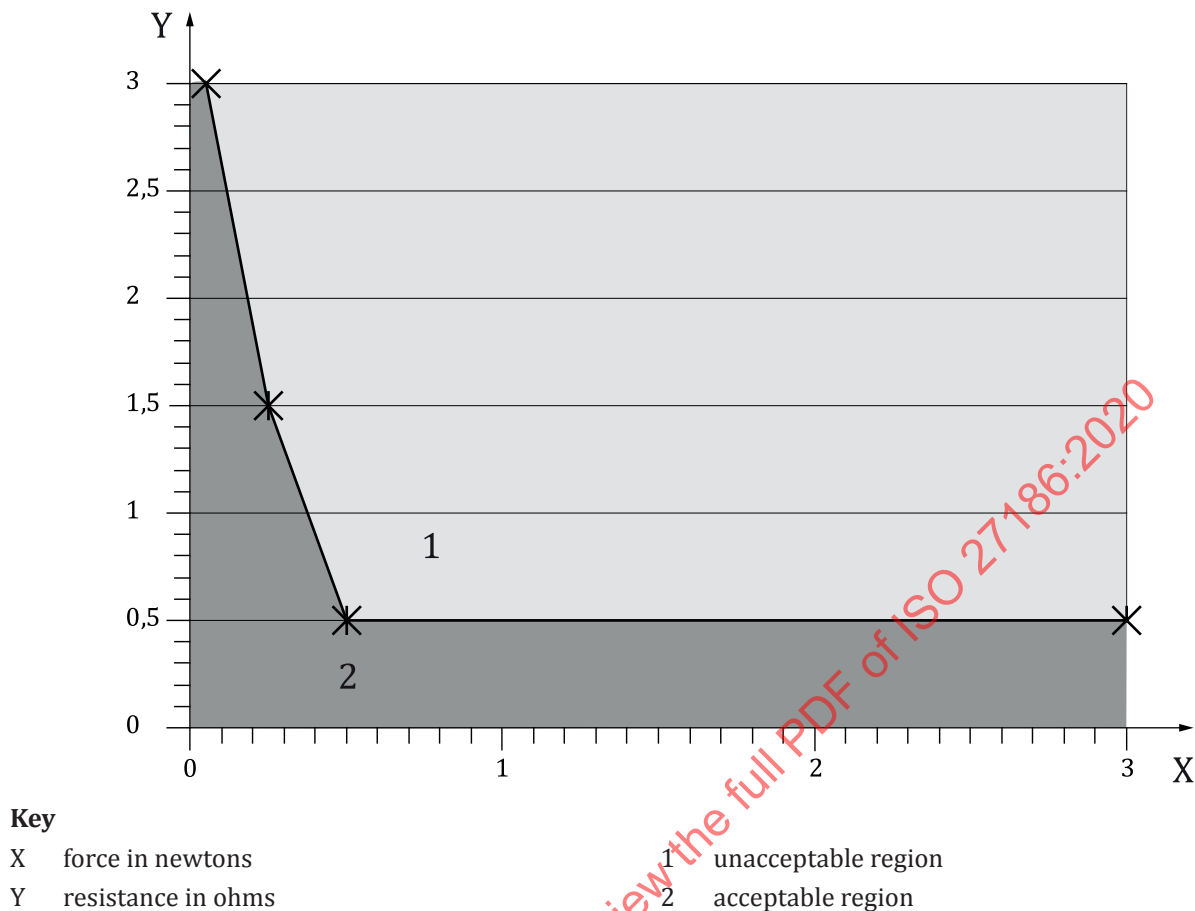


Figure M.1 — Cross rod resistance requirement — Force versus resistance

M.2.2 Test samples and preconditioning

Contact resistance requirements shall be met by the lead connector in the condition intended for implant. Preconditioning of test samples shall include simulation of manufacturing processes including sterilization. Preconditioning shall also include an additional soak in 60 °C aerated de-ionized water for 10 d minimum.

The surface condition of the lead connector test sample shall represent normal manufacturing processing (e.g. machining, chemical cleaning), and shall include sterilization cycles. Actual lead assemblies should be used for this test.

M.2.3 Test method

This test is based on a method in ASTM B896. The reference cross wire shall be wrought 35Cobalt-35Nickel-20Chromium-10Molybdenum alloy specified in ASTM F562 and is considered part of the test fixture. The cross rod shall have a nominal diameter of 1 mm ± 0,1 mm and shall have a surface finish no rougher than 0,4 µm Ra.

Orientate specimens perpendicular to each other in a “cross” with the contact point of the mating electrode in the appropriate contact zone of the lead connector.

Support specimens in a V-groove support block to prevent bending due to applied contact load.

Make electrical connections to the test specimens using flexible leads to ensure no stiffening effects of the lead connections are contributing to the force measured.

Use instrumentation that provides a means for measurement of contact force, contact current, contact voltage and correlation of the resistance measurement to the force measurement. The maximum open circuit voltage should be 10 mV and the maximum current should be 100 mA.

This test may be performed using either of the following methods.

- a) Automated force/displacement method: bring the electrical contacts together at a rate of 1 mm per min or less until contact is established. After contact is established, increase the force at a rate of 0,5 N per min until a load of 0,5 N minimum is reached.
- b) Discrete loading point method: data should be taken at a minimum of three (3) force values – 0,10 N, 0,25 N, and 0,50 N (maximum at each level). Data should be taken at the lowest force value first and then at increasing load values. Resistance measurements should be taken within 10 s of the application of each load value.

M.3 Corrosion

M.3.1 General

The corrosion requirements herein are for the selection of materials for lead connector contacts. All materials utilized for testing should represent the bulk and surface chemical and metallurgical conditions of the actual components to be used in the final device.

M.3.2 Corrosion resistance to localized or crevice corrosion

M.3.2.1 General

This requirement applies to all metals and alloys considered for use as lead connector contacts conforming to this document. It involves testing based on methods in ASTM F746 for the determination of pitting and crevice corrosion of metallic implant materials.

All materials utilized should represent the bulk and surface chemical and metallurgical conditions of the actual components to be used in the final device.

Test description: all applicable test equipment, sample fabrication, test electrolytes and test procedures should be made in accordance with ASTM F746. The following modifications may be made.

- a) The test electrolyte should be nominally 9 g/l saline at $37\text{ °C} \pm 2\text{ °C}$.
- b) The PTFE collar dimensions and collar material can be changed to represent actual components' chemistry and crevice geometry. The collar crevice should face upwards in order to account for gravity effects.

M.3.2.2 Acceptance

The critical potential for pitting or crevice corrosion shall be equal to or greater than 200 mV against a saturated calomel electrode (SCE). Determine the critical potential according to ASTM F746-04. If a different stable reference electrode is used, convert potentials to reflect a SCE reference electrode prior to determining compliance.

M.3.3 General corrosion

No requirement is specified for general corrosion. However, recommendations for selecting and testing materials are included in N.6.3.