BS EN 61515:2016

BSI Standards Publication

Mineral insulated metal-sheathed thermocouple cables and thermocouples

bsi.

National foreword

This British Standard is the UK implementation of EN 61515:2016. It is identical to IEC 61515:2016. It supersedes BS EN 61515:1996 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/65, Measurement and control, to Subcommittee GEL/65/2, Elements of systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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English Version

Mineral insulated metal-sheathed thermocouple cables and thermocouples (IEC 61515:2016)

Câbles et couples thermoélectriques à isolation minérale dits "chemisés" (IEC 61515:2016)

Mineralisolierte metallgeschirmte Mantelthermoelementleitung und Mantelthermoelemente (IEC 61515:2016)

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European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 65B/1034/FDIS, future edition 2 of IEC 61515, prepared by SC 65B "Measurement and control devices", of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61515:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2017-03-01
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-06-01

This document supersedes EN 61515:1996.

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Endorsement notice

The text of the International Standard IEC 61515:2016 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60068-2-6	-	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	-
IEC 60584-1	-	Thermocouples - Part 1: EMF specifications and tolerances	EN 60584-1	-
ISO 1302	-	Geometrical Product Specifications (GPS) - Indication of surface texture in technical product documentation	EN ISO 1302	-

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MINERAL INSULATED METAL-SHEATHED THERMOCOUPLE CABLES AND THERMOCOUPLES

FOREWORD

International Standard IEC 61515 has been prepared by subcommittee 65B: Measurement and control devices, of IEC technical committee 65: Industrial-process measurement, control and automation.

This second edition cancels and replaces the first edition published in 1995. This edition constitutes a technical revision.

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

a) Duplex and triplex are standardized.

b) Specification of insulation resistance is revised so that the user can choose the best product to fit for the purpose.

c) "Table 2 Recommended maximum operating temperatures" in the previous version is expanded significantly including newly developed sheath material and it is moved to Annex C.

d) Test items and their methods are expanded and a guide table (Table 4) is added for userfriendliness.

The text of this standard is based on the following documents:

FDIS	Report on voting
65B/1034/FDIS	65B/1038/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This new edition of IEC 61515 reflects recent developments in production technology, sheath materials and insulation materials. It aims to be a flexible standard allowing suppliers to provide fit-for-purpose products at an acceptable cost.

It includes informative guidance to help users choose the products that meet their needs.

Annex A gives alternative adjacent conductor configurations for duplex and triplex MIMS thermocouple cables and thermocouples.

Annex B gives recommendations to suppliers with respect to insulation composition.

Annex C gives guidelines to users with regard to temperature limits of operation.

MINERAL INSULATED METAL-SHEATHED THERMOCOUPLE CABLES AND THERMOCOUPLES

1 Scope

This International Standard establishes the requirements for simplex, duplex and triplex mineral-insulated metal-sheathed thermocouple cables and thermocouples, which are intended for use in general industrial applications. The abbreviation MIMS (for "mineral-insulated metal-sheathed") will be used hereafter. It covers thermocouple cables and thermocouples with only base-metal conductors of Types T, J, E, K and N. The specifications in this standard apply to new thermocouple cables and thermocouple units as delivered to the user. They do not apply to the product after use.

External seals, terminations, connections and other accessories are not within the scope of this International Standard.

This standard does not apply to precious metal thermocouple cables and thermocouples. The special requirements for nuclear primary loop applications are dealt with in the other standards.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60584-1, *Thermocouples: Part 1 – EMF specifications and tolerances*

ISO 1302, *Geometrical Product Specifications (GPS) — Indication of surface texture in technical product documentation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60584-1 and the following apply.

3.1
mineral insulated metal-sheathed thermocouple cable
bendable cable consisting of one or more pairs of thermocouple conductors encapsulated in a metal protecting sheath, insulated from each other and from the sheath by a compacted mineral material

Note 1 to entry: Abbreviation MIMS for "mineral insulated metal-sheathed" is used hereafter.

3.2
MIMS thermocouple
thermocouple manufactured from mineral-insulated metal-sheathed thermocouple cable

Note 1 to entry: This note applies to the French language only.

3.3
simplex thermocouple
thermocouple unit comprising one pair of thermocouple conductors

3.4
duplex thermocouple
thermocouple unit comprising two pairs of thermocouple conductors

3.5
triplex thermocouple
thermocouple unit comprising three pairs of thermocouple conductors

3.6
measuring junction
junction of the thermocouple conductors which is subjected to the temperature to be measured

3.7
grounded junction
bonded junction
earthed junction
measuring junction electrically connected to the metal sheath

3.8
insulated junction
ungrounded junction
measuring junction electrically insulated from the metal sheath

3.9
thermal response time
time a thermocouple takes to respond at a specified percentage to a step change in temperature

Note 1 to entry: The time to register 50 % of the step change, for example, is written $\tau_{0,5}$.

Note 2 to entry: The test medium and its flow conditions shall be specified (usually flowing water or flowing air).

3.10
type test
test conducted on one or more samples of the production to verify that the product is compliant with the requirements of IEC 61515 following the introduction or change of material specification, design or manufacturing process

3.11
routine test
test to which each individual product is subjected during or after manufacture to ascertain whether it complies with the requirements of IEC 61515

3.12
optional test
test that is performed upon agreement between a supplier and a user to ensure compliance with the user's specific application

4 General principles

4.1 A MIMS thermocouple

A MIMS thermocouple specified in this standard shall be made of a MIMS thermocouple cable that complies with this standard.

4.2 Electromotive force

The electromotive force (abbreviated EMF hereafter) versus temperature relationship shall comply with IEC 60584-1. The EMF tolerance, as specified in IEC 60584-1, should be agreed between the supplier and the user.

4.3 Materials and their properties

4.3.1 Sheath

The sheath material shall be of qualified stainless steel or high nickel alloy or other metals selected by agreement between users and suppliers. It shall be chosen to suit user's application in order to protect the thermocouple during use. The general surface finish of the sheath upon delivery shall be equal to, or better than, roughness grade ISO 1302 scale 8 (3,2 μm Ra).

4.3.2 Conductors

Conductors shall be those forming thermocouple types T, J, E, K or N as specified in IEC 60584-1.This standard applies to thermocouple cables and thermocouples that have 1, 2 and 3 pairs of thermocouple conductors.

For duplex and triplex, cables basic adjacent conductor configurations are specified. Alternative configurations are acceptable by the agreement between supplier and user provided that all the other requirements of this standard are met.

Some examples of alternative adjacent conductor configurations are given in Annex A.

4.3.3 Insulation materials

The mineral insulation shall consist of compacted ceramic powder.

The purity of insulating material should be at least 96 % and informative compositions are shown in Annex B.

Specific requirements, concerning the purity of the insulation material, can be customized by agreement between the user and the supplier.

4.4 Maximum operating temperature

Definitive maximum operating temperatures cannot be specified because of the number of influencing factors. Instead Annex C gives indicative temperature limits which are the recommended maximum operating temperatures for the standardized thermocouples and some commonly used sheath materials and diameters. They are to be considered only as guidance for users.

4.5 Dimensions

4.5.1 Transverse section of MIMS thermocouple cables and thermocouples

The outside diameter, conductor diameter and sheath wall thickness shall be as specified in the following 4.5.2 to 4.5.4. Throughout this standard the following symbols are used.

- outside diameter D;
- conductor diameter C;
- sheath wall thickness S;
- insulation thickness I.

The insulation thickness I is not quantified in this standard. It shall be such that the specified requirements for dielectric strength (specified in 5.2.2.3 and 5.3.2.3) and insulation resistance (specified in 5.2.2.5 and 5.3.2.4) shall be met. (The maximum value of the insulation thickness can be deduced from the specified value of *D, S* and *C*). Conductors shall be approximately evenly spaced unless specified otherwise. The following Figures 1, 2 and 3, as well as Figures A.1, A.2, A.3 and A.4 clarify which part the specifications of *D*, *C* and *S* are applied to. Insulation thickness is always given in brackets in those figures because it is not numerically specified.

4.5.2 Transverse section of simplex cable and thermocouple

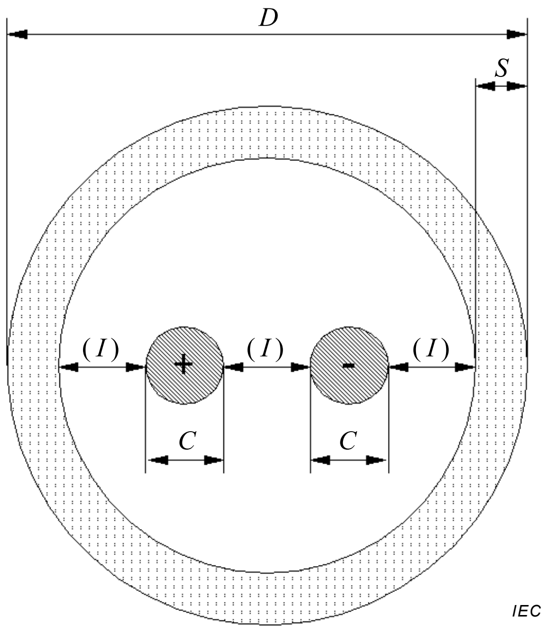


Figure 1 – Transverse section of simplex

Table 1 – Dimensional specifications of simplex

Outside diameter *D* and its tolerance mm	Minimum sheath wall thickness *S* mm	Minimum diameter of conductor *C* mm
0,5 ± 0,025	0,05	0,08
1,0 ± 0,025	0,10	0,15
1,5 ± 0,025	0,15	0,23
2,0 ± 0,025	0,20	0,30
3,0 ± 0,030	0,30	0,45
3,2 ± 0,032	0,32	0,48
4,0 ± 0,040	0,40	0,60
4,5 ± 0,045	0,45	0,68
4,8 ± 0,048	0,48	0,72
6,0 ± 0,060	0,60	0,90
6,4 ± 0,064	0,64	0,96
8,0 ± 0,080	0,80	1,20
9,5 ± 0,095	0,95	1,43
10,8 ± 0,108	1,08	1,62

Sizes not included in Table 1 are acceptable provided that the sheath wall thickness is not less than 10 % of the thermocouple cable diameter (D) and the conductor diameter (C) is not less than 15 % of D. The tolerance on D shall be the greater of 0,025 mm or $0{,}01 \cdot D$.

4.5.3 Transverse section of duplex cable and thermocouple

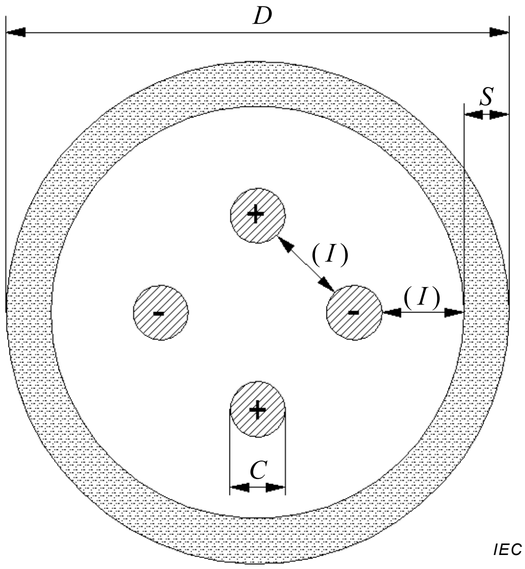


Figure 2 – Transverse section of duplex

Table 2 – Dimensional specifications of duplex

Outside diameter *D* and its tolerance mm	Minimum sheath wall thickness *S* mm	Minimum diameter of conductor *C* mm
1,5 ± 0,025	0,14	0,17
2,0 ± 0,025	0,18	0,22
3,0 ± 0,030	0,27	0,33
3,2 ± 0,032	0,29	0,35
4,0 ± 0,040	0,36	0,44
4,5 ± 0,045	0,41	0,50
4,8 ± 0,048	0,43	0,53
6,0 ± 0,060	0,54	0,66
6,4 ± 0,064	0,58	0,70
8,0 ± 0,080	0,72	0,88
9,5 ± 0,095	0,86	1,05
10,8 ± 0,108	0,97	1,19

Sizes not included in Table 2 are acceptable provided that sheath wall thickness is not less than 9 % of the thermocouple cable diameter (D) and conductor diameter (C) is not less than 11 % of D. The tolerance on D, shall be the greater of 0,025 mm or $0{,}01 \cdot D$.

4.5.4 Transverse section of triplex cable and thermocouple

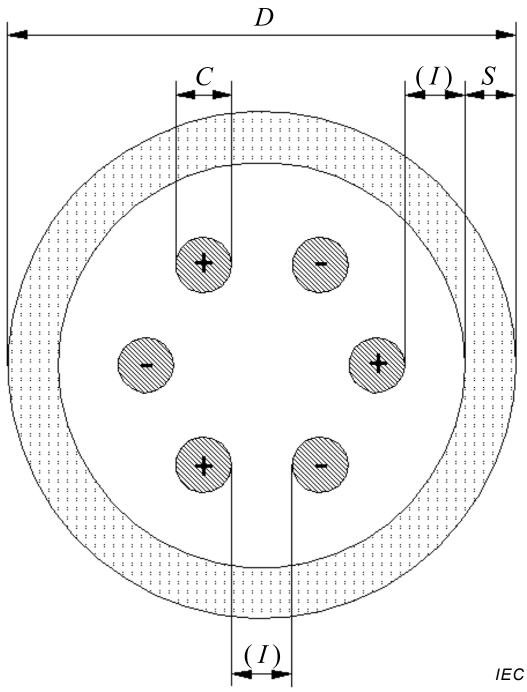


Figure 3 – Transverse section of triplex

Table 3 – Dimensional specifications of triplex

Outside diameter *D* and its tolerance mm	Minimum sheath wall thickness *S* mm	Minimum diameter of conductor *C* mm
3,0 ± 0,030	0,24	0,27
3,2 ± 0,032	0,26	0,29
4,0 ±0,040	0,32	0,36
4,5 ± 0,045	0,36	0,41
4,8 ± 0,048	0,38	0,43
6,0 ± 0,060	0,48	0,54
6,4± 0,064	0,51	0,58
8,0 ± 0,080	0,64	0,72
9,5 ± 0,095	0,76	0,86
10,8 ± 0,108	0,86	0,97

Sizes not included in the Table 3 are acceptable provided that sheath wall thickness is not less than 8 % of the thermocouple cable diameter (D) and conductor diameter (C) is not less than 9 % of D. The tolerance on D shall be $0{,}01 \cdot D$.

5 Requirements and verification tests

5.1 General

Tests are divided into three categories, type tests, routine tests and optional tests. The type tests and the routine tests are mandatory. Therefore suppliers shall keep the record of the test result which shall be provided to users upon request. Optional tests are not required unless they are requested. Details of the optional tests shall be determined by agreement between the supplier and the user.

Some routine tests can be replaced by sampling tests provided technically established control procedures are in place to demonstrate that the statistical sample testing is sufficient. In this case the supplier shall make documentation of the statistical process available to the user upon request.

Table 4 – Tests for MIMS thermocouple cables and thermocouples

Test item	MIMS cable			MIMS thermocouple		
	Type test	Routine test	Optional test	Type test	Routine test	Optional test
Dimensions	5.2.1.1					
Outside diameter	5.2.1.2	5.2.1.2				
Surface finish	5.2.1.3	5.2.1.3				5.3.1.3
Verification of sheath integrity	5.2.1.4	5.2.1.4				
Sheath ductility	5.2.1.5					
Conductor ductility	5.2.1.6					
Sheath material identification			5.2.1.7			
Electrical continuity	5.2.2.1	5.2.2.1		5.3.2.1	5.3.2.1	
Electrical resistance of conductor	5.2.2.2	5.2.2.2				5.3.2.6
Dielectric strength	5.2.2.3	5.2.2.3		5.3.2.3		
Verification of EMF-temperature relationship	5.2.2.4	5.2.2.4				5.3.2.7
Insulation resistance at ambient temperatures	5.2.2.5	5.2.2.5		5.3.2.4	5.3.2.4	
Insulation resistance at elevated temperatures			5.2.2.6			5.3.2.5
Outside diameter of a thermocouple at the measuring junction				5.3.1.1	5.3.1.1	
Dimensions of longitudinal section of measuring junction of a thermocouple				5.3.1.2		
Weld closure integrity				5.3.1.4		5.3.1.4
Cold seal immersion test (Insulated thermocouples only)				5.3.1.5		
Radiographic inspection						5.3.1.6
Vibration test						5.3.1.7
Drop test						5.3.1.8
Polarity				5.3.2.2	5.3.2.2	
Thermal response time						5.3.2.8

5.2 MIMS thermocouple cables: requirements and verification tests

5.2.1 Structure and mechanical properties

5.2.1.1 Dimensions of transverse section

The outside diameter, sheath thickness, conductor diameter and insulation thickness shall be optically measured at necessary magnification. Dimensions specified in 4.5 shall be met.

5.2.1.2 Outside diameter

The outside diameter of each MIMS thermocouple cable shall be measured in two planes 90° apart using a flat anvil micrometer. Outside diameter specified in 4.5 shall be met.

5.2.1.3 Surface finish

Thermocouple cables shall be visually free from defects, indentations and inclusions. The general surface finish of the sheath upon delivery shall be equal to, or better than, roughness grade ISO 1302 scale 8 (3,2 μm Ra).

5.2.1.4 Verification of sheath integrity

To ensure that the sheath is free from holes, cracks and other defects and protects thermocouple conductor adequately from penetration of gases and liquids the following test shall be carried out. Thermocouple cables shall be immersed in water for 5 min (excluding thermocouple cable ends). Upon removal, the insulation resistance shall be measured and the insulation resistance shall comply with the specification provided in 5.2.2.5. Alternative test method and acceptance criteria shall be established by agreement between the user and the supplier.

5.2.1.5 Sheath ductility

A sample thermocouple cable length shall be coiled 3 turns round a mandrel with a diameter of 6 times the sample diameter. The ends of the sample shall be sealed to prevent ingress of moisture. The sample, excluding the sealed thermocouple cable ends, shall be immersed in water. Upon removal from the water, the insulation resistance shall be measured. It shall meet the requirements of the specification provided in 5.2.2.5.

5.2.1.6 Conductor ductility

The sheath of a sample thermocouple cable length shall be stripped back to expose a minimum of 25 mm of the conductors. Each conductor shall be bent back and forth around a mandrel whose diameter is 4 times the minimum conductor diameter C specified in 4.5 without visible signs of fracture.

5.2.1.7 Sheath material identification

Identification of the sheath materials shall be performed by means of quantitative spectral analysis on a representative sample taken from the coil of the cable. The acceptance criteria shall be established by agreement between the user and the supplier.

Alternative methods and acceptance criteria shall be established by agreement between the user and the supplier.

5.2.2 Electrical characteristics and performance

5.2.2.1 Electrical continuity

The electrical continuity of each conductor in each coil of thermocouple cable shall be verified.

5.2.2.2 Electrical resistance of a conductor

The resistance of each conductor shall be measured, calculated to 1 m length and corrected to 20 °C. It shall be less than the supplier’s specified maximum resistance.

5.2.2.3 Dielectric strength

A test voltage as indicated in Table 5 shall be applied between each conductor and the sheath and between a pair of conductors under ambient conditions (20 °C ± 15 °C and a relative humidity of not more than 80 %) for a period of 1 min (in the case of AC voltage, Table 5 refers to the peak voltage value.) For duplex and triplex cables, the same test procedure between each conductor and the sheath and between every pair of conductors shall be applied. During this test no breakdown shall occur.

Table 5 – Test voltage for dielectric strength

Thermocouple cable diameter *D* mm	**Test voltage** *V*dc		
	Simplex	**Duplex**	**Triplex**
$D \leq 1{,}6$	100	–	–
$1{,}6 < D \leq 2{,}0$	100	100	–
$2{,}0 < D \leq 3{,}2$	250	250	100
$3{,}2 < D$	500	500	500

5.2.2.4 Verification of EMF-temperature relationship

EMF of a sample from every production length of thermocouple cable shall be measured at intended maximum upper temperature and at two or more other temperatures, evenly distributed in the range. The EMF tolerance, as specified in IEC 60584-1, should be agreed between the supplier and the user.

5.2.2.5 Insulation resistance at ambient temperature

The insulation resistance between the sheath and each conductor, and between the two conductors, under ambient conditions (20 °C ± 15 °C and a relative humidity of not more than 80 %) shall be measured on thermocouple cables. Both ends of the cables shall be sealed to prevent moisture ingress. The minimum insulation resistance values specified in Table 6 shall be attained within 1 minute of the test voltage application. The measured value of the insulation resistance shall be made available to the user on request.

Table 6 – Minimum insulation resistance at ambient temperature (MIMS cables)

Thermocouple cable diameter *D* mm	**Test voltage** *V*dc	**Minimum insulation resistance** MΩ·m[a]
$D \leq 1{,}0$	50 to100	1 000
$1{,}0 < D \leq 1{,}6$	50 to 100	5 000
$1{,}6 < D$	450 to 550	10 000

[a] The insulation of a MIMS thermocouple cable has finite conductivity and therefore the insulation resistance decreases as the length of the thermocouple cable increases. The conductance of a specific thermocouple cable is therefore expressed in $S \cdot m^{-1}$ (equivalent to $\Omega^{-1} \cdot m^{-1}$) and the minimum specified insulation resistance is expressed in Ω·m, kΩ·m or MΩ·m for thermocouple cables.

5.2.2.6 Insulation resistance at elevated temperatures

The insulation resistance of a sample from production length of thermocouple cable shall be measured at elevated temperatures. If it is necessary, EMF effect shall be cancelled by averaging the two measurements with alternative polarity. Thermocouple cable end or ends not immersed into the furnace shall be sealed. Immersed length at each test temperature shall be not less than 0,3 m where the temperature uniformity must be assured within listed value of the test temperature. Those lengths of the thermocouple cable being not at elevated temperatures shall be maintained at 20 °C ± 15 °C. The minimum insulation resistance values specified in Table 7 shall be attained within 1 minute of the test voltage application. Acceptance criteria other than those in Table 7 shall be established by agreement between the user and the supplier.

Table 7 – Insulation resistance at elevated temperatures (MIMS cables)

Applicable thermocouple type	Test temperature °C	Minimum insulation resistance		
		0,5 < *D* ≤ 1,6 (Test voltage is 50 *V*dc) MΩ·m	**1,6 < *D* ≤ 3,2** (Test voltage is 100 *V*dc) MΩ·m	**3,2 < *D*** (Test voltage is100 *V*dc) MΩ·m
T, J, E, K, N	300 ± 15	150	300	1 000
J, E, K, N	500 ± 15	7,5	15	30
E, K, N	800 ± 15	0,075	0,15	0,3
K, N	1 000 ± 15	–	0,003	0,006
NOTE *D* denotes thermocouple cable diameter in mm.				

5.3 MIMS thermocouples: requirements and verification tests

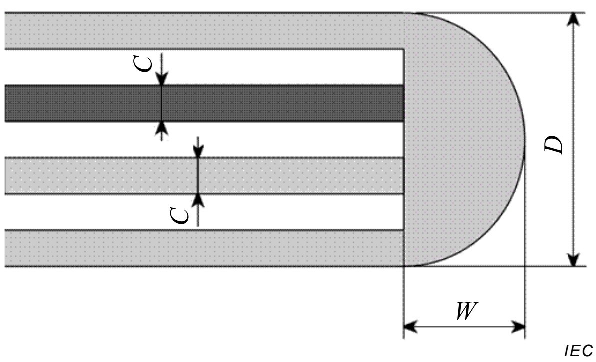
5.3.1 Structure and mechanical properties

5.3.1.1 Outside diameter of a thermocouple at the measuring junction

The outside diameter of grounded and insulated junction thermocouple at the measuring junction shall be measured in two planes 90° apart using a flat anvil micrometer or gauge from the top to a distance of five times the outside diameter. The tolerance of the outside diameter at the measuring junction shall be the greater of 0,05 mm or 0,01·*D*.

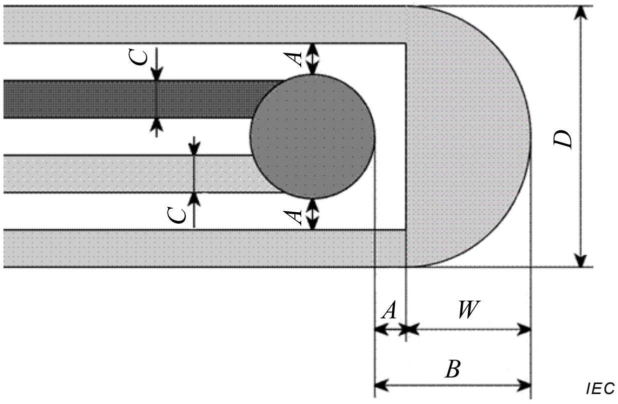
5.3.1.2 Dimensions of longitudinal section of measuring junction of a thermocouple

Dimensional requirements of weld thickness at the measuring junction for a MIMS thermocouple shall be as specified in Figure 4 for grounded measuring junction thermocouple and as specified in Figure 5 for insulated junction thermocouple.



Dimension	Magnitude
W = Weld thickness	Min. 0,1·*D* Max. 0,8·*D*

Figure 4 – Longitudinal section of a grounded junction



Dimension	Magnitude
A = Insulation thickness at the junction	Min. 0,05·D
W = Weld thickness	Min. 0,1·D Max. 0,8·D
B = Bead position	Min. 0,15·D Max. 1,5·D

Figure 5 – Longitudinal section of an insulated junction

5.3.1.3 Surface finish of a thermocouple

The surface of the finished thermocouple shall be visually clean and dry. The general surface finish shall be equal to or better than roughness grade number ISO 1302 Scale 8 (3,2 μm Ra). The roughness shall be determined by means of roughness comparison specimens.

5.3.1.4 Weld closure integrity

5.3.1.4.1 General

Weld closure integrity of both of insulated and grounded junction thermocouples shall be verified by one of the tests specified in 5.3.1.4.2 to 5.3.1.4.4. The test method shall be agreed between the supplier and user.

5.3.1.4.2 Water quench test (insulated junction thermocouples only)

The measuring junction of the thermocouple of which the cold end is sealed shall be subjected to a minimum temperature of 300 °C for a minimum time of 5 min with the immersion length being more than 10 times the diameter and then immediately plunged into water at room temperature. The insulation resistance shall be measured while the thermocouple is immersed. The insulation resistance shall meet the requirements of 5.3.2.4.

NOTE This test may affect the EMF characteristics of the thermocouple under test.

5.3.1.4.3 Test by pressurization with inert gas

The measuring junction of the thermocouple of which the cold end is sealed shall be externally pressurized in an inert gas for approximately 60 s at a minimum of 1 MPa or at a pressure of 2,5 MPa for 30 s. After pressurization, it shall be immediately immersed in water or alcohol. There shall be no bubbling from the weld closure.

5.3.1.4.4 Liquid nitrogen test

The measuring junction of the thermocouple of which the cold end is sealed shall be immersed in liquid nitrogen with immersion length of minimum of 3 times the diameter of the thermocouple until the temperature is stabilized, after which it shall be immediately immersed in water or alcohol. There shall be no bubbling from the weld closure.

5.3.1.4.5 Dye penetration test

By agreement between a user and a supplier, dye penetration test can be arranged as an additional alternative test method for the weld closure integrity. The test is a visual examination of the surface of the weld. The examiner first applies dedicated liquid penetrant to the surface of the weld and wipes off surplus residue. Defects such as weld porosity or cracks which are present on the surface of the material can be detected visually.

5.3.1.5 Cold seal immersion test (insulated junction thermocouples only)

Permanent cold seal terminations shall be immersed in water for a minimum of 1 h. Upon removal, the surface of the seal shall be hand dried without heating and immediately the insulation resistance shall be measured. The result shall meet the criteria specified in 5.3.2.4.

5.3.1.6 Radiographic inspection

Radiographs of the measuring junction region shall be made in two mutually perpendicular planes to confirm dimensional requirements specified in 5.3.1.2.

5.3.1.7 Vibration test

Vibration tests may be performed for the thermocouples used in a specific environment with possible vibrations. The thermocouple shall be mounted as it will be installed. Test methods shall comply with IEC 60068-2-6.The parameters such as frequency range and forcing acceleration of the vibration shall be determined by the agreement between the user and the supplier. The tested thermocouple shall comply with all the other applicable requirements specified in 5.3 of this standard.

5.3.1.8 Drop test

This test is intended to reveal any weakness of construction. The thermocouple shall be held with its longitudinal axis horizontal then be dropped ten times from the height of 250 mm on to a 6 mm thick steel plate on a rigid floor. After that the thermocouple shall be inspected for mechanical damage. The tested thermocouple shall comply with all the other applicable requirements specified in 5.3 of this standard.

5.3.2 Electrical characteristics and performance

5.3.2.1 Electrical continuity of a conductor pair

Electrical continuity of each conductor pair shall be verified. For a grounded junction thermocouple, electrical continuity of each pair of conductors to sheath shall be verified. This test shall be so conducted that stable continuity is assured including any kind of incorporated electric connection such as lead wires, a connector and electric terminals.

5.3.2.2 Polarity

A pair or pairs of thermocouple conductors including any kind of electric connection which is incorporated with the thermocouple shall be checked for polarity identifications.

5.3.2.3 Dielectric strength (insulated junction thermocouples only)

A test voltage as indicated in Table 5 shall be applied between the conductors and the sheath of the thermocouple under ambient conditions (20 °C ± 15 °C and a relative humidity of not more than 80 %) for a period of 1 min (in the case of AC voltage, Table 5 refers to the peak voltage value.) For duplex and triplex thermocouple, the same test procedure between every pair of conductors and sheath and between any two thermocouple pairs shall be applied. During this test, no breakdown shall occur.

5.3.2.4 Insulation resistance at ambient temperature (insulated junction thermocouples only)

The insulation resistance under ambient conditions (20 °C ± 15 °C and relative humidity of not more than 80 %) shall be measured on the thermocouple. The minimum insulation resistance values specified in Table 8 shall be attained within 1 min of the test voltage application. For duplex and triplex thermocouple the same test procedure between every pair of conductors and sheath and between any two thermocouple pairs shall be applied. The measured value of the insulation resistance shall be made available to the user on request.

Table 8 – Minimum insulation resistance at ambient temperature

Thermocouple diameter D (mm) **and test voltage** (Vdc)	**Minimum insulation resistance** MΩ
0,5 < D ≤ 1,6; 100 Vdc	20
1,6 < D; 500 Vdc	1 000
For thermocouples longer than 10 m, minimum insulation resistance value shall be determined by agreement between user and supplier.	

5.3.2.5 Insulation resistance at elevated temperatures (insulated junction thermocouples only)

The insulation resistance shall be measured on a thermocouple under the following conditions. The thermocouple shall be immersed so that it is exposed to the specified temperature for a length not less than 0,1 m. If it is necessary, EMF effect shall be cancelled by averaging the two measurements with alternative polarity. The minimum insulation resistance specified in Table 9 shall be attained within 1 min of the test voltage application. Acceptance criteria other than those in Table 9 shall be established by agreement between the user and the supplier.

Table 9 – Insulation resistance at elevated temperatures (MIMS thermocouples)

Applicable thermocouple type	**Test temperature** °C	**Minimum insulation resistance**		
		0,5 ≤ D ≤1,6 (Test voltage is 50 Vdc) MΩ	1,6 < D ≤ 3,2 (Test voltage is 100 Vdc) MΩ	3,2 < D (Test voltage is 100 Vdc) MΩ
T, J, E, K, N	300 ± 15	250	500	1 000
J, E, K, N	500 ± 15	25	50	100
E, K, N	800 ± 15	0,25	0,5	1
K, N	1 000 ± 15	–	0,01	0,02
NOTE D denotes thermocouple diameter in mm. The length of the test sample immersed in the elevated temperature is 0,1 m and the listed values of the table refer to the insulation resistance of this test unit.				

5.3.2.6 Electrical resistance of a conductor pair

The conductor loop resistance shall be measured for each conductor pair. The resistance shall be less than the supplier’s specified maximum loop resistance.

5.3.2.7 Verification of EMF-temperature relationship

A thermocouple shall be calibrated at temperatures agreed between the supplier and user. The EMF tolerance, as specified in IEC 60584-1, should be agreed between the supplier and the user.

5.3.2.8 Thermal response time

Starting from a steady temperature, the thermocouple shall quickly be inserted into flowing fluid, the temperature of which differs by at least 10 °C from the starting temperature. The thermal response time shall be recorded. Typically it is $\tau_{0,5}$, $\tau_{0,9}$ or $\tau_{0,1}$. Fluid velocity shall be more than 0,2 m/s for water and (3 ± 0,3) m/s for air. The velocity data shall be recorded.

6 Delivery condition for thermocouple cables

The ends of the thermocouple cable shall be sealed prior to shipping in order to prevent the ingress of moisture. Seal welding, epoxy or heat-shrink sleeves may be used.

7 Packaging

Prior to packaging, the thermocouple cable and thermocouple shall be free from grease, oil, dirt, scale and other foreign matter. The thermocouple cable and thermocouples shall be transported straight or in coils. When transported straight, they shall be boxed or supported to prevent bending. Coiled cable shall be bound together to prevent abrasion.

8 Marking

Each coil of thermocouple cable, or thermocouple unit, shall be clearly labelled or marked with at least the supplier's name and the following information, which may be in the form of an identification code:

- type of thermocouple;
- tolerance class;
- nominal diameter of a thermocouple cable or a thermocouple;
- number of pairs of conductors (simplex, duplex, triplex);
- material of sheath;
- length;
- traceable identification number (thermocouple cable only).

9 Certification

Upon request the supplier should provide certification data including

- nominal calibration temperatures, in ºC;
- tolerance class and deviations from IEC 60584-1 in terms of temperature or EMF;
- conductor material and batch number;
- sheath material and batch number;
- insulation material and batch number.

Annex A
(informative)

Alternative adjacent conductor configurations

A.1 General

The following Figures A.1, A.2, A.3 and A.4 show alternative adjacent conductor configurations (in addition to those shown in Figures 2 and 3) which are acceptable, by agreement between the supplier and the user. These products are compliant with this standard provided that all the other properties meet the requirements of this standard.

A.2 Duplex cable and thermocouple

Figure A.1 shows an alternative conductor configuration to that of Figure 2.

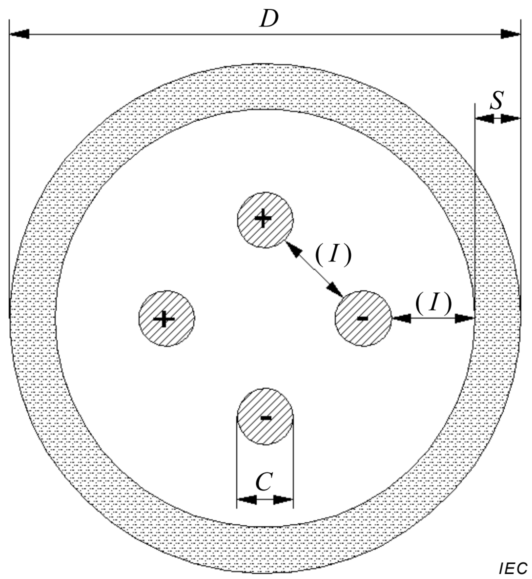


Figure A.1 – Alternative adjacent conductor configuration for duplex

A.3 Triplex cable and thermocouple

Figures A.2, A.3 and A.4 show alternative conductor configurations to that of Figure 3.

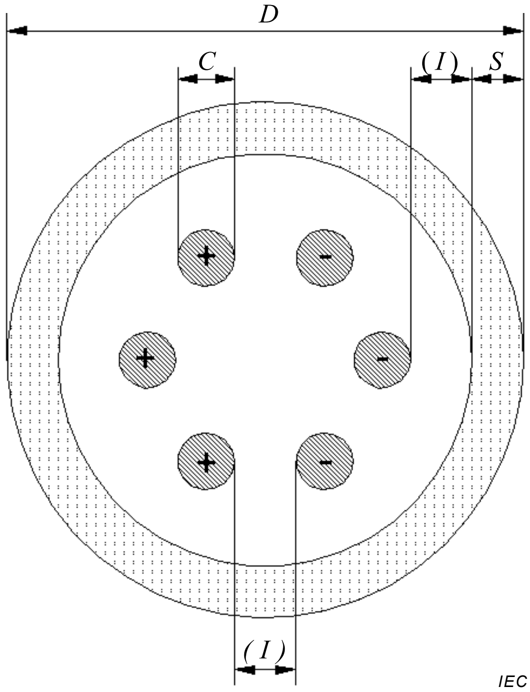


Figure A.2 – Alternative adjacent conductor configuration for triplex (1)

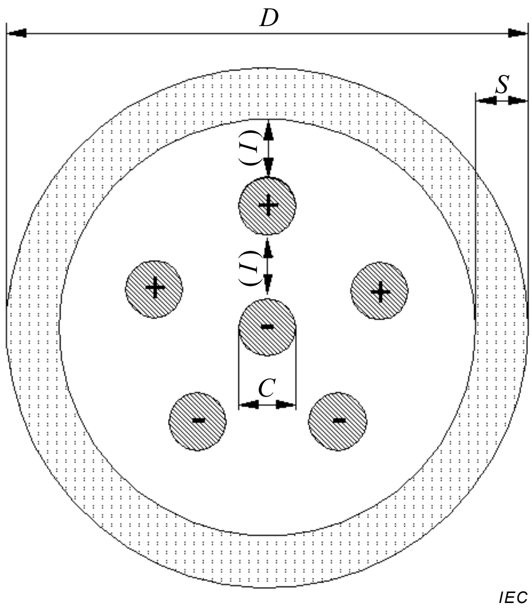


Figure A.3 – Alternative adjacent conductor configuration for triplex (2)

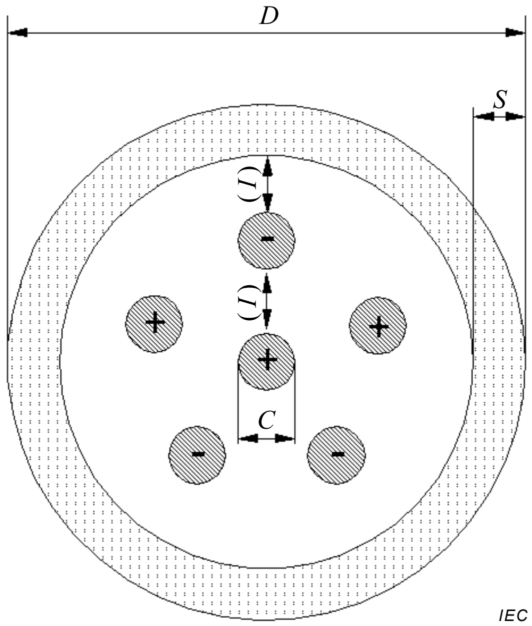


Figure A.4 – Alternative adjacent conductor configuration for triplex (3)

Annex B
(informative)

Mineral insulation material chemical composition

Tables B.1 and B.2 show typical chemical composition of insulation material for MIMS thermocouple cables and thermocouples.

Table B.1 – Example values of recommended magnesia (MgO) – Chemical composition in weight percent

Purity grade (minimum purity of magnesia)	Maximum impurity contents %							
	SiO_2	CaO	Al_2O_3	Fe_2O_3	B	Cd	S	C
Standard purity (96 %)	3,50	1,50	4,00	0,15	0,005	0,001	0,002 5	0,020
Medium purity (97,0 %)	1,20	0,80	1,00	0,10	0,005	0,001	0,002 5	0,020
High purity (99,4 %)	0,13	0,35	0,15	0,10	0,0025	0,001	0,002 5	0,020

Table B.2 – Example values of recommended alumina (Al_2O_3) – Chemical composition in weight percent

Purity grade Minimum purity of alumina)	Maximun impurity contents %									
	SiO_2	CaO	MgO	Fe_2O_3	ZrO_2	B	Cd	Na_2O	S	C
High purity (99,65 %)	0,10	0,08	0,08	0,10	0,080	0,001	0,001	0,06	0,005	0,01

Annex C
(informative)

Indicative upper temperature limits

The following Table C.1 gives recommendations for the maximum temperatures (symbol T_{max}) at which thermocouple cables and thermocouples should be used, continuously in non-circulating air, according to the thermocouple type, sheath material and diameter. Any use of thermocouples in corrosive or other reactive atmospheres will result in decreasing the maximum recommended temperatures. D in this table denotes outside diameter of a thermocouple in mm. Sheath material is specified by UNS (Unified numbering system) There are many other types of sheath materials available for MIMS cables which may be agreed between suppliers and users.

Table C.1 – Indicative temperature limits of MIMS thermocouple sheath and conductor combinations

Material	D mm	T_{max} for thermocouple type °C					Notes on the sheath material characteristics
		N	K	J	E	T	
S30400 S30403 S31600 S31603 S32100 S34700	8	800	800	720	800	370	S30400 is an 18/8 % chromium/nickel austenitic stainless steel and is usable in air to about 800 °C without excessive oxidation or loss in strength. It will not embrittle at sub zero temperatures. Normally non-magnetic but may be slightly so after heavy cold work. This steel contains up to 0,08 % of carbon and is therefore susceptible to weld decay corrosion after heating for prolonged time at 650 °C as would happen in the heat affected zone of a weld. Not recommended in sea water conditions due to susceptibility to stress corrosion. S30403 is a variant that has its carbon content reduced to a maximum of 0,03 % and at this composition becomes immune to weld decay. It is widespread in use. The properties otherwise are the same as Type 30400. S31603/S31600 is similar to the S30400 material with the addition of 2,5 % of molybdenum which greatly improve its resistance to corrosion by sulphuric acid. Stainless steels rely largely on a surface film of chromium oxide for their corrosion resistance but the presence of chlorides (saline solutions) can destroy this film and lead to rapid corrosion. The molybdenum addition makes the surface film more chloride resistant and more effective against stress corrosion cracking. Type S31603 is used more frequently for applications where salt water resistance is required. It is oxidation resistant up to 870 °C. S32100 has the same basic composition as S30400 but has titanium as a stabiliser, at 5 times the carbon content. Titanium has a high affinity for carbon and thus combines preferentially with it and prevents the formation of chromium carbide which is the cause of weld decay. Type S34700 has similar properties to S30400, but it is beginning to lose its status due to the wide availability of S30403.
	6	800	800	720	800	370	
	4,5	800	800	620	730	370	
	3	800	800	520	650	315	
	2	800	800	440	510	260	
	1,5	800	800	440	510	260	
	1	700	700	260	300	260	
	0,5	700	700	260	300	260	
S31000 S31003	8	1 050	1 050	720	820	370	S31000 is a 25/20 % chromium/nickel austenitic stainless steel. It retains strength and oxidation resistance up to 1 050 °C but is otherwise similar to S30400. It is entirely a high temperature material and is not specified in wet corrosive conditions. It is not subject to weld decay because of the higher chromium content.
	6	1 050	1 050	720	820	370	
	4,5	1 050	1 050	620	730	370	
	3	1 050	1 050	520	650	315	
	2	920	920	440	510	260	

Material	*D* mm	T_{max} for thermocouple type °C					Notes on the sheath material characteristics
		N	K	J	E	T	
	1,5	920	920	440	510	260	
	1	700	700	260	300	260	
	0,5	700	700	260	300	260	
S44600	8	1 100	1 100	720	820	370	S44600 is a ferritic stainless steel containing 30 % of chromium but no nickel. It is magnetic and embrittled at low temperatures. It can be used under oxidation conditions to 1 100 °C but has superior resistance to sulphurous atmospheres to 900 °C. It is much more difficult to fabricate than austenitic types.
	6	1 100	1 100	720	820	370	
	4,5	1 100	1 100	620	730	370	
	3	1 070	1 070	520	650	315	
	2	920	920	440	510	260	
	1,5	920	920	440	510	260	
	1	700	700	260	300	260	
	0,5	700	700	260	300	260	
UNS 6600	8	1 150	1 150	720	820	370	Most commonly used High nickel alloy for sheath material is so called Alloy 600 and is a minimum 72 % nickel, 16 % chromium and 7 % iron alloy with exceptionally good oxidation resistance and strength up to temperatures of 1 100 °C to 1 150 °C. It is unsatisfactory in reducing sulphurous atmospheres above 550 °C due to excessive grain boundary attack. It is virtually immune to chloride induced stress corrosion cracking. The other type of high nickel special alloy is available in the market. This was developed for the thermocouple industry with exceptionally good oxidation resistance and strength at temperatures up to 1 250 °C. The limiting temperature in a reducing sulphurous atmosphere is 500 °C. In an oxidising sulphurous atmosphere it is 800 °C.
	6	1 150	1 150	720	820	370	
	4,5	1 150	1 150	620	730	370	
	3	1 070	1 070	520	650	315	
	2	920	920	440	510	260	
	1,5	920	920	440	510	260	
	1	700	700	260	300	260	
	0,5	700	700	260	300	260	
Not all combinations of sheath materials and conductor materials are manufactured. The recommended temperatures are dictated by the survival of the sheath material and/or the stability of the thermocouple. They are intended as a guide, but they should not be taken as a guarantee of performance. In practice there will be considerable variability, depending on the conditions, total time of exposure, and especially at the higher temperatures. The user should discuss these and other aspects of performance with the supplier.							

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BSI Group Headquarters

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