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INTERNATIONAL ELECTROTECHNICAL COMMISSION

THERMAL-RESISTANT ALUMINIUM ALLOY WIRE FOR OVERHEAD LINE CONDUCTOR

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International Standard IEC 62004 has been prepared by IEC technical committee 7: Overhead electrical conductors.

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

FDIS	Report on voting
7/569/FDIS	7/571/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 maintenance result date indicated on the IEC web site 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

THERMAL-RESISTANT ALUMINIUM ALLOY WIRE FOR OVERHEAD LINE CONDUCTOR

1 Scope

This International Standard is applicable to thermal-resistant aluminium alloy wires before stranding for manufacture of stranded conductors for overhead lines. It specifies the mechanical, electrical and thermal resistant properties of wires in the diameter range commercially available.

2 Normative references

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

IEC 60468:1974, *Method of measurement of resistivity of metallic materials*

IEC 60104:1987, *Aluminium-magnesium silicon alloy wire for overhead line conductors*

IEC 60889:1987, *Hard-drawn aluminium wire for overhead line conductors*

3 Terms and definitions

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

3.1
diameter
mean of two measured values at right angles taken at the same cross section

NOTE For non-round wires, the equivalent diameter of the round wire with the same section is used.

3.2
type
thermal-resistant aluminium alloy wires defined as “AT1”, “AT2”, “AT3” and “AT4”

3.3
thermal-resistant aluminium alloy wire
all types of aluminium-zirconium alloy wire, used at operation temperature higher than that of conventional aluminium-magnesium-silicon alloy wire, as specified in IEC 60104, or hard-drawn aluminium wire for overhead line conductors, as specified in IEC 60889, with an allowable operating temperature as described in Table 1

4 Designation

The wire designations included in this standard are as follows:

– thermal-resistant aluminium alloy wire with maximum allowable continuous operating temperature of 150 °C, designated AT1;

– extra high-strength, thermal-resistant aluminium alloy wire with maximum allowable continuous operating temperature of 150 °C, designated AT2;

– super thermal-resistant aluminium alloy wire with maximum allowable continuous operating temperature of 210 °C, designated AT3;

– extra thermal-resistant aluminium alloy wire with maximum allowable continuous operating temperature of 230 °C, designated AT4.

5 Values for thermal-resistant aluminium alloy wire

For calculation purposes, the values given in Table 1 shall be used for thermal-resistant aluminium alloy wire.

Table 1 – Values for thermal-resistant aluminium alloy wire

Type		AT1	AT2	AT3	AT4
Density at 20 °C	(g/cm^3)	2,703	2,703	2,703	2,703
Allowable continuous operating temperature (40 years)	(°C)	150	150	210	230
Allowable operating temperature in 400 h	(°C)	180	180	240	310
Coefficient of linear expansion	(/ °C)	23×10^{-6}	23×10^{-6}	23×10^{-6}	23×10^{-6}
Constant-mass temperature coefficient of resistance at 20 °C	(/ °C)	0,004 0	0,003 6	0,004 0	0,003 8

6 Requirement

6.1 Material

The wires shall be of aluminium-zirconium alloy having a composition appropriate to the mechanical, electrical and thermal-resistant properties specified hereunder for type AT1, AT2, AT3 and AT4, respectively.

6.2 Freedom from defects

The wires shall be smooth and free from all imperfections such as cracks, roughness, grooves, inclusions or other defects which may endanger the performance of the product.

6.3 Diameter and tolerance on diameter

The nominal diameter of the wires shall be expressed in millimetres to two decimal places. Each measured value of wire diameter shall not depart from the nominal diameter by more than the amounts given in Table 2.

For the purpose of checking compliance with the above requirement, the diameter shall be determined by the mean of the two measurements at right angles taken at the same cross-section.

Table 2 – Diameter and tolerance on diameter

Nominal diameter		Tolerance
Over (mm)	Up to and including (mm)	
–	3,00	± 0,03 mm
3,00	–	±1 %

6.4 Tensile stress

The wire shall comply with the requirements given in Table 3. The tensile stress of a single wire shall be computed by dividing the breaking load by the cross-sectional area. The cross-sectional area shall be determined using the measured diameter of the test specimen.

For non-round wire, shaped before stranding, its equivalent diameter of the round wire with the same section shall be used and the calculation result of tensile stress shall comply with the requirements given in Table 3.

The tensile stress of the non-round wire shaped during stranding may be measured after un-stranding, whose value shall be not less than 95 % of the applicable stress requirements given in Table 3.

6.5 Elongation

Each measured value of wire elongation shall not be less than the amounts given in Table 3.

Table 3 – Tensile stress and elongation of wires (before stranding)

Type	Nominal diameter mm		Tensile stress minimum MPa	minimum Elongation %
	Over	Up to and including		
AT1	–	2,60 [a]	169	1,5
	2,60	2,90	166	1,6
	2,90	3,50	162	1,7
	3,50	3,80		1,8
	3,80	4,00	159	1,9
	4,00	4,50 [a]		2,0
AT2	–	2,60 [a]	248	1,5
	2,60	2,90	245	1,6
	2,90	3,50	241	1,7
	3,50	3,80		1,8
	3,80	4,00	238	1,9
	4,00	4,50 [a]	225	2,0
AT3	–	2,30 [a]	176	1,5
	2,30	2,60	169	
	2,60	2,90	166	1,6
	2,90	3,50	162	1,7
	3,50	3,80		1,8
	3,80	4,00	159	1,9
	4,00	4,50 [a]		2,0
AT4	–	2,60 [a]	169	1,5
	2,60	2,90	165	1,6
	2,90	3,50	162	1,7
	3,50	3,80		1,8
	3,80	4,00	159	1,9
	4,00	4,50 [a]		2,0

[a] For nominal diameters below 2,60 mm or above 4,50 mm, the requirement shall be agreed between the purchaser and the manufacturer.

6.6 Electrical resistivity

The electrical resistivity at 20 °C shall not be greater than the value given in Table 4.

Table 4 – Electrical resistivity

Type	AT1	AT2	AT3	AT4
Resistivity at 20 °C, maximum (nΩ×m)	28,735	31,347	28,735	29,726
(Conductivity, corresponding to IACS)	(60,0 %)	(55,0 %)	(60,0 %)	(58,0 %)
NOTE IACS stands for the International Annealed Copper Standard (See IEC 60028).				

6.7 Thermal- resistant property

The residual ratio of the tensile stress after heating the wire for the designated duration and temperature given in Table 5 shall not be less than 90 % at room temperature compared with the initial measured value before heating.

Table 5 – Duration and temperature of heating to affirm thermal- resistant property

Duration h	Temperature °C	AT1	AT2	AT3	AT4
1	Temperature of heating	230	230	280	400
	Tolerance in temperature	+ 5 – 3	+ 5 – 3	+ 5 – 3	+ 10 – 6
400	Temperature in heating	180	180	240	310
	Tolerance of temperature	+ 10 – 6	+ 10 – 6	+ 10 – 6	+ 10 – 6

6.8 Length and tolerance on length

The nominal length of each coil or reel of wire and the tolerance on length shall be subject to an agreement between the purchaser and the manufacturer.

6.9 Joints

Joints may be made prior to final drawing. A joint shall be made by electric butt welding, electric butt cold upset welding or cold pressure welding and other approved methods. Those joints shall be made in accordance with good commercial practice. A joint could be made in the finished wire, provided that

a) the coil is 500 kg or heavier,

b) there is not more than one joint in such coils,

c) not more than 10 % of such coils shall contain a joint,

d) when requested by the purchaser, the manufacturer shall provide evidence that the joints have a tensile strength of not less than 130 MPa,

e) coils containing a joint made in the finished wire shall be clearly identified.

6.10 Wrapping

The wire shall not be broken when it is wrapped eight turns around a mandrel of diameter equal to the wire nominal diameter at a speed not exceeding 60 turns/min. For non-round wire shaped before stranding, testing shall be carried out on the round wire before shaping.

6.11 Sampling

Specimen for tests specified in Clause 7 shall be taken by the manufacturer from 10 % of the individual length of wire included in any one consignment.

Where the numbers of wire specimens are large in quantity, they may be reduced, by agreement between the purchaser and the manufacturer, when the manufacturer has demonstrated capability of meeting or exceeding the requirements.

7 Tests

7.1 Place of testing

Unless otherwise agreed between the purchaser and the manufacturer at the time of ordering, all tests shall be carried out at the manufacturer's works.

7.2 Classification of tests

Test requirements are as follows and shall be made on each sample before stranding.

7.2.1 Type tests

Type tests shall be made only once for the following test items, before supplying a type of wire covered by this standard to demonstrate satisfactory performance characteristics for meeting its intended application. Type tests shall only be carried out on a wire which also meets the requirements of the relevant factory acceptance tests described in 7.2.2. These tests are of such a nature that, after they have been completed, they do not need to be repeated unless significant changes are made to the wire material, design or type of manufacturing process, which might change the performance characteristics.

– thermal- resistant property in 400 h;
– thermal-resistant property in 1 h.

7.2.2 Factory acceptance tests

Tests shall be made, if required in the presence of the purchaser's representative, for the following test items, using sample wires taken from the finished products to verify that they meet design specifications. The sampling of the factory acceptance tests shall be agreed between the purchaser and the manufacturer:

a) appearance;
b) diameter;
c) tensile stress;
d) elongation;
e) electrical resistivity;
f) thermal-resistant property in 1 h;
g) wrapping resistant property.

Failure of a test specimen to comply with any one of the requirements of this standard shall constitute grounds for rejection. If any lot is so rejected, the manufacturer shall have the right to re-test only once for all individual wires in the lot, and then re-submit them for acceptance.

7.2.3 Routine tests

Tests shall be made by the manufacturer for the following test items on the production wire to demonstrate their integrity. Sample for tests shall be taken by the manufacturer from 10 % of the individual lengths of finished wire:

a) appearance;
b) diameter;
c) tensile stress;
d) elongation;
e) electrical resistivity;
f) thermal resistant property in 1 h;
g) wrapping resistant property.

Failure of a test specimen to comply with any one of the requirements of this standard shall constitute grounds for rejection. If any lot is so rejected, the manufacturer shall have the right to re-test only once for all individual wires in the lot, and then re-submit them for acceptance.

7.3 Test method

7.3.1 Appearance

The surface of the wire shall be visually observed to check for smoothness and freedom from imperfections that are not consistent with good commercial practice.

7.3.2 Diameter

The specimen shall be measured by means of a micrometer or another suitable apparatus whose accuracy is 5/1 000 mm. The diameter shall be determined by two measurements at right angles taken at the same cross-section.

7.3.3 Tensile stress

The breaking load of the specimen shall be determined by means of a suitable tensile testing machine. The load shall be applied gradually and the rate of separation of the jaws of the testing machine shall be not less than 25 mm/min and not greater than 100 mm/min.

In calculating the tensile stress from the measured breaking load, the diameter of the finished wire before stressing shall be used.

7.3.4 Elongation

The elongation test may be made on the same specimen in the same operation as the tensile stress test described in 7.3.3.

The ultimate elongation measured under no load shall be determined on the specimen. The specimen shall be straightened by hand and an original gauge length of 250 mm marked on the wire and loaded, as described in the tensile stress test. After the wire has been broken, the ends of the specimen shall be carefully placed together and the distance between the gauge marks measured.

The elongation is the increase in gauge length expressed as a percentage of the original gauge length.

If the fracture occurs outside the gauge marks, or within 25 mm of either mark, and the required elongation is not obtained, another test shall be made.

7.3.5 Electrical resistivity

The electrical resistance of the specimen shall be measured by the method specified in IEC 60468 at a temperature which shall be not less than 10 °C or more than 30 °C. The measured resistance shall be corrected to the value at 20 °C by means of the following formula:

$$R_{20} = R_T \left[\frac{1}{1 + \alpha(T - 20)} \right]$$

where

T is the temperature of measurement in °C;

R_T is the resistance at T °C;

R_{20} is the resistance at 20 °C;

α is the constant-mass temperature coefficient of resistance at 20 °C.

The volume resistivity at 20 °C shall then be calculated from the resistance at 20 °C according to the method specified in IEC 60468.

7.3.6 Thermal-resistant property

Two specimens shall be secured from a continuous wire, and one of them shall be kept in a suitable heater for the designated duration and temperature given in Table 5 for the tensile stress test of the specimen at room temperature after heating. The other one shall be measured at room temperature without heating. The ratio of residual strength after heating to the initial strength before heating shall be calculated.

7.3.7 Wrapping test property

One specimen, cut from one end of the sample, shall be subjected to a wrapping test. It shall be wrapped by eight turns around a mandrel of diameter equal to the wire nominal diameter and at a speed not exceeding 60 turns/min. The wire shall not break.

8 Acceptance and rejection

8.1 Failure of a test specimen to comply with any one of the requirements of this standard shall constitute grounds for rejection on the lot represented by the specimen.

8.2 If any lot is so rejected, the manufacturer shall have the right to test only once all individual reels or coils in the lot and submit those which meet requirements of acceptance.

Annex A
(informative)

Thermal-resistant property

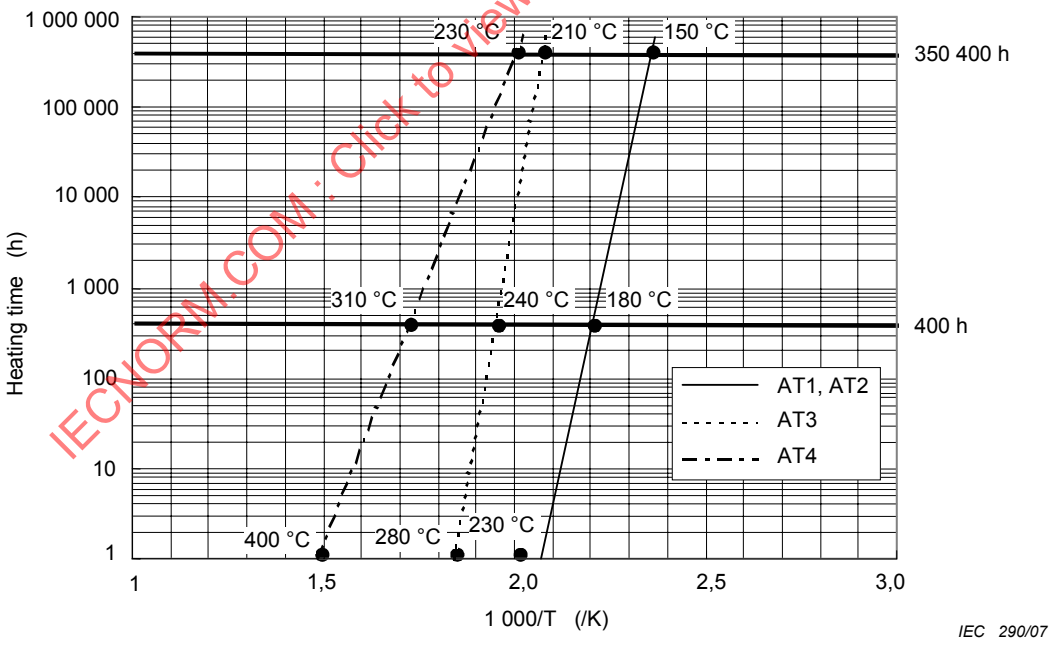
A.1 Thermal-resistant property

The thermal-resistant property of aluminium alloy wire means that the material does not anneal after heating and the reduction of its tensile strength is limited to a certain value, as described below. These phenomena can be experimentally described by the Arrhenius plot, of which the typical plots for several aluminium alloy wires were published. The thermal-resistant properties of aluminium wires generally used in overhead transmission lines are determined by a heat endurance (temperature x duration) equivalent to a heat condition above room temperature, where the tensile strength can be maintained at a minimum 90 % of the initial one after heating.

The term “thermal-resistant property” in this standard is expressed by its capability of enduring the required high temperature for a duration of 400 h while maintaining a minimum strength of 90 % of the initial tensile strength at room temperature prior to heating.

A.2 Thermal-resistant property for each aluminium wire

Figure A.1 shows the published thermal-resistant property for each aluminium alloy wire, described in this typical Arrhenius plot.



Explanation of the Arrhenius plot:

Each aluminium wire material can maintain a minimum 90 % of the initial tensile strength when it is heated at the temperature and duration (for either 1 h, 400 h, 350 400 h) described in the Arrhenius plot. In another words, the thermal-resistant property in 400 h can be verified in shorter duration by testing at the higher temperature, being as 1 h in terms of the Arrhenius plot. In the same manner, if the said line is extended towards the lower temperature, it is possible to speculate the temperature where 90 % of the initiall tensile strength can be maintained , even if used over 40 years.

Figure A.1 – Arrhenius plot (residual stress 90 %)