

METRIC UNITS

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BRITISH STANDARD : AEROSPACE SERIES
SPECIFICATION FOR
PTFE INSULATED EQUIPMENT WIRES
(WITH SILVER PLATED COPPER CONDUCTORS)

FOREWORD

This British Standard has been prepared at the request of the Aerospace Industry to specify the requirements of PTFE insulated equipment wires which are intended for the internal wiring of aircraft equipment.

The standard is based upon the Ministry of Technology Specification EL 1930, which specifies similar wires having inch conductors of corresponding cross-sectional area.

The standard makes reference to the following British Standards:

- BS 2011. Methods for the environmental testing of electronic components and electronic equipment.
Part 2 T. Soldering.
- BS 3763. International System (SI) units.
- BS 6007. Elastomer-insulated cables for electric power and lighting.
- BS 6360. Copper conductors in insulated cables and cords.
- BS 6746C. Colour chart for PVC insulation and sheath of electric cables.
- 2 G.100. General requirements for electrical equipment and indicating instruments for aircraft.
Part 2. Environmental and operating conditions.

NOTE. Information concerning SI units is given in BS 350, 'Conversion factors and tables', and PD 5686, 'The use of SI units'.

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SPECIFICATION

1. GENERAL

1.1 SCOPE

This British Standard states the requirements for a range of equipment wires for use in electrical instruments and electronic equipment where conductor temperatures between -75°C and 200°C are experienced or where continuous flexibility is necessary between -50°C and 200°C .

Three basic types of wire are specified according to their rating, namely:

Type A	250 volts (r.m.s.)
Type B	500 volts (r.m.s.)
Type C	1000 volts (r.m.s.)

These same types in certain sizes, screened, or screened and sheathed, are also specified as follows:

Type AS	screened Type A wire
Type BS	screened Type B wire
Type CS	screened Type C wire
Type BSM	screened and sheathed Type B wire
Type CSM	screened and sheathed Type C wire

NOTE. Screened and sheathed Type (ASM) wires are not included, as this construction is not recommended.

The size ranges of the above types are listed in Tables 3a, 3b and 3c.

1.2 MATERIALS

1.2.1 Copper conductors and wires. The wires for the conductors and the metal braid shall be annealed copper wires in accordance with BS 6360, as far as applicable, and shall be plated with silver to a minimum radial thickness of $1\ \mu\text{m}^*$, equivalent to the appropriate minimum mass in mg/m stated in Table 8. The conductors only shall comply with the tensile and elongation test requirement of 2.4.5.

1.2.2 Insulation. The insulation shall be of such quality that the finished equipment wire complies with all the requirements of this British Standard.

1.3 CONSTRUCTION

1.3.1 Conductor. The conductor shall consist of a single wire or concentric stranded wires. It shall consist of silver plated copper wires complying with the requirements of 1.2.1. Joints in individual wires of stranded conductors shall be brazed or hard soldered, but the complete conductors shall not be joined.

There shall be no kinks, broken wires or other irregularities in the conductor.

1.3.2 Insulated equipment wire. The equipment wire shall consist of a conductor as specified in 1.3.1, insulated with

* See B.S. 3763, 'International System (SI) units'.

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polytetrafluoroethylene (PTFE) applied by lapping or extrusion. The layers of lapped insulation shall be sintered together to give a consolidated dielectric.

The insulation shall not be loose, but it shall be possible to strip the complete insulation, leaving the conductor sufficiently clean to permit satisfactory connection to be made to terminations.

The wall thickness of the insulation and the overall diameter of the wires shall be within the limits stated in Table 3a.

1.3.3 Screening. Equipment wires Types AS BS and CS shall be metal braided to the dimensions shown in Table 3b. Silver-plated copper wires, as specified in 1.2.1, shall be used to form the overall screen. The screen shall be close fitting, but when the wire is cut it shall be possible to slide the screen back by hand a distance of 100 mm in a length of 600 mm, the other end of the wire being clamped. The screen shall subsequently be capable of being returned to within 12 mm of the free end of the wire.

Where breaks in the individual wires occur, the ends shall be brazed or tucked out of the screen and there shall not be more than one such break in any 25 mm length of equipment wire.

When renewal of the spindles is necessary, the ends shall be tucked out of the screen, and there shall not be more than one spindle renewal in any 300 mm length of equipment wire.

There shall be no joints in the complete screen.

The nominal diameter of wire used shall be as stated in Table 3b. The lay shall be such as to ensure that the filling factor is not less than 0.45 (70% approximately) and the limiting factor not greater than 0.09. The formulae to be used for the calculation of the above details are given in Appendix A.

1.3.4 Sheath. The outer sheath of equipment wires Types BSM and CSM, as listed in Table 3c, shall be of PTFE applied by extrusion, or as a lapped unsintered tape, and sintered. The sheath shall not be loose, but it shall be possible to remove it without damaging the metal braid. The minimum wall thickness and diameter over sheath shall be as specified in Table 3c. The colour of the sheath shall be the same as that of the underlying insulation.

1.3.5 Colours. The PTFE insulation and sheath shall be coloured as shown in Table 4. The colours shall match reasonably those shown in BS 6746C, and shall not be appreciably affected by any of the tests to which the equipment wire is subjected. Wires may be coloured by the use of an appropriately coloured extrusion compound or tape, or by the application of a coloured PTFE finishing coat over natural PTFE insulation.

Bi-colouring, where specified, shall be in the form of non-conductive spiral marking or, when specified by the purchaser, by bands, obtained by the use of differently coloured tapes, by dual extrusion, or by the application of stripes in PTFE ink, on the base colours (see footnote to Table 4).

The wire, when viewed from any one direction, shall be readily identifiable in any 12 mm length.

1.4 DESIGNATION OF EQUIPMENT WIRE

For the purposes of references on drawings and orders, the wires shall be designated by the number of this British

Standard, together with the cable type and conductor details and, if relevant, the colour or colours:

- e.g. 'British Standard G 210 Type A1/0.25 Red',
'British Standard G 210 Type A7/0.10 Red',
'British Standard G 210 Type B7/0.15 Black/orange'

1.5 PACKING AND LABELLING

All wire shall be delivered on non-returnable bobbins or reels, each containing 100 m or as stated in the contract. The 100 m length of wire on the bobbin shall consist of not more than 4 lengths, and the minimum length of any one piece, unless stated in the contract, shall be 20m. Actual lengths shall be stated.

Each bobbin or reel shall bear a durable label upon which the following particulars shall be plainly and permanently printed:

- (1) Name of manufacturer.
- (2) Name of wire, e.g. Equipment wire, PTFE Type A, 1/0.315, Red.
- (3) British Standard number and year of issue.
- (4) Date of manufacture (month and year).
- (5) Release reference number or contract number or both.
- (6) Total length in metres and number of lengths.

If the manufacturer so desires, the information may be written, provided that a permanent ink is used and the characters are legible. The label may be attached permanently to the side of the bobbin or reel by adhesive or staples, or may be a tie-on label with one side blank.

2. TESTS

2.1 GENERAL

Tests shall be made to prove compliance with all requirements of this specification. It is not intended or recommended that complete tests shall be made on every wire supplied.

Tests to be applied to wires shall be as scheduled in Table 2.

The manufacturer shall produce evidence to the satisfaction of the Approving Authority* that wire of the type to be supplied to the specification fulfils its requirements.

The manufacturer shall disclose to the purchaser and Approving Authority any proposal to introduce constructions or processes differing from those used for the wire submitted, to type tests, and shall obtain the Approving Authority's written approval before applying the change to production.

Three kinds of test are specified, as follows:

(1) *Type tests* (2.2.1 to 2.2.6, 2.3.1 to 2.3.4 and 2.4.1 to 2.4.7) which shall be made on two samples selected by the manufacturer from each of the following groups of wires. These samples shall be regarded as representative of all the sizes of wire within the group from which they are selected, provided they are made by the same process and with the same materials.

- Group 1. Type A and AS, single colour, bi-colour.
- Group 2. Type B and BS, single colour, bi-colour.
- Group 3. Type C and CS, single colour, bi-colour.
- Group 4. Types BSM and CSM.

* For wires for aircraft subject to British Civil Aviation Authority requirements, the Approving Authorities are the Air Registration Board (through a design authority approved by the Board) and the Ministry of Technology respectively.

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Wires in each group shall include the smallest and largest size for which type approval is desired, but it is permissible, for example, to submit the smallest size in a single colour and the largest in a bi-colour, if approval is sought for both single and bi-coloured wires.

(2) *Production routine tests* (2.3.1 to 2.3.4) which shall be made on every length of wire.

(3) *Production quality tests* (2.4.1 to 2.4.7) which shall be made on each batch of 100 km of wire, or at least once during each month's production, whichever length is the lesser. A batch of wire may consist of different sizes but not of different types. Wherever possible, the sample should be representative of the sizes being produced.

Two samples of wire shall be selected from the production batch, one sample being of the smallest size produced. These samples shall each be subjected to the tests of 2.4.1 to 2.4.7. Should either of the samples fail on any one of the tests, the test shall be repeated on four further samples selected at random. Should any one of these samples fail, the batch shall be deemed not to comply with this British Standard.

The braid shall be removed from metal braided (Types AS, BS, CS) wires prior to the application of the tests of the following subclauses:

2.2.3—Low temperature

2.2.4—Flexibility

2.2.5—Climatic

2.4.1—Voltage

2.4.2—Insulation resistance of main dielectric

The outer sheath and metal braid shall be removed from braided and sheathed (Types BSM and CSM) wires prior to the application of the tests of the following subclauses:

2.2.5—Climatic

2.4.1—Voltage

2.4.2—Insulation resistance of main dielectric

2.2 TYPE TESTS ONLY

2.2.1 Ageing in air. Two samples of wire shall be bent into U loops, each with an internal diameter ten times the maximum specified diameter of the wire. The specimens, retained in U loops, shall then be placed in an air oven at $275 \pm 5^\circ\text{C}$ for 168 hours. At the conclusion of this period the samples shall be removed from the oven and the insulation shall show no signs of splitting or cracking. Slight discoloration of the insulation shall not be deemed a failure.

The samples shall then be immersed in water at $20 \pm 5^\circ\text{C}$ for five minutes with the ends protruding 100 mm above the surface and, whilst thus immersed, they shall withstand without breakdown the appropriate voltage test shown below. The voltage, of waveform specified in 2.4.1, shall be applied gradually and maintained for one minute.

(1.) *Unscreened wire and screened (Type S) wire.* The voltage specified in Table 5, Column 3 shall be applied between the conductor and the water.

(2) *Screened and sheathed (Type SM) wire.*

a. The voltage specified in Table 5, Column 3, shall be applied between the conductor and the screen, the latter being connected to an earth electrode immersed in the water.

b. After disconnecting the earth electrode a voltage of 1 kV shall be applied between the screen and the water.

2.2.2 Voltage at high temperature. Five turns of wire shall be wound on a metal mandrel the diameter of which is ten times the maximum specified diameter of the insulated wire. The assembly shall be placed in an air oven at $275 \pm 5^\circ\text{C}$. After 168 hours and whilst at this temperature, the wire shall withstand without breakdown the appropriate voltage test shown below. The voltage, of waveform as specified in 2.4.1, shall be applied gradually and maintained for 30 minutes.

For unscreened wires and screened wires the voltage specified in Table 5, Column 3, shall be applied between the conductor and the mandrel.

For screened and sheathed types (Type SM) the voltage specified in Table 5, Column 3, shall be applied between the conductor and the screen, the latter being connected to the mandrel.

At the completion of the test and after disconnecting the screen from the mandrel, a voltage of 1 kV shall be applied between the screen and the mandrel.

2.2.3 Low temperature. In the following tests, which apply to unscreened and screened and sheathed wires only, the mandrels shall be of metal and shall be allowed to cool to the specified temperature with the wire.

A sample of the wire at least 300 mm long shall be stored in air at a temperature of $-50 \pm 5^\circ\text{C}$ for a period of six hours, immediately after which it shall be wound on a mandrel the diameter of which is 10 times the maximum specified diameter of the wire. The rate of winding shall be approximately 1 convolution per second. After one minute on the mandrel the wire shall be examined by normal vision and shall show no signs of cracking (of the insulation of an unscreened wire or of the sheath of a screened and sheathed wire).

After recovery to room temperature, the sample, except for 100 mm at the ends, shall be immersed in water at $20 \pm 5^\circ\text{C}$ for five minutes. Whilst immersed it shall withstand without breakdown a voltage of the waveform specified in 2.4.1 applied gradually and maintained for one minute. For unscreened wires the appropriate voltage specified in Table 5, Column 3, shall be applied between the conductor and the water; for screened and sheathed wires the same appropriate voltage shall be applied between the conductor and the screen, after which a voltage of 1 kV shall be applied between the screen and the water.

2.2.4 Flexibility. A sample of the wire shall be wound on a mandrel at room temperature into a close helix of at least three turns. The tensile load applied to the wire during winding, and the diameter of the mandrel, shall be as specified in Table 6.

The complete test shall comprise five test cycles, each cycle consisting of the winding of the wire on the mandrel, unwinding and rewinding in the reverse direction so that the surface of the wire inside the helix during the first winding is on the outside of the helix upon rewinding.

No point of the wire shall show signs of damage after this test.

2.2.5 Climatic. The wire shall comply with the requirements of British Standard 2 G.100: Part 2*, for climatic Class 1 equipment, except that the test sequence for the combined humidity, temperature and pressure tests shall be as follows and all tests shall be made at atmospheric pressure.

1st day. Start of 24-hour period dry heat at $90 \pm 2^\circ\text{C}$.

2nd day. Transfer to cold chamber at $-60 \pm 0 - 10^\circ\text{C}$ for 8 hours.

Transfer to humidity chamber at $40 \pm 1^\circ\text{C}$ and 100% r.h. for 16 hours.

3rd day. Transfer to cold chamber again for 8 hours. Transfer to humidity chamber for 16 hours.

4th day. Transfer to cold chamber for 8 hours. Transfer to humidity chamber for 16 hours.

* Pending the publication of subsections for humidity in British Standard 3G.100: Part 2: Section 3, the reference to BS 2G.100 will remain.

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- 5th day. Transfer to cold chamber for 8 hours.
Transfer to humidity chamber for 16 hours.
- 6th day. Transfer to extra-cold chamber at $-70 \pm 0 - 5^\circ\text{C}$ for 6 hours.
Remove from extra-cold chamber and leave at room temperature for 1 hour.

The functioning test shall consist of a visual examination. For the purposes of the humidity, temperature and pressure tests it is permissible to use three separate chambers as follows:

- (1) Dry heat chamber.
- (2) Low temperature chamber, but without low pressure facilities.
- (3) High humidity chamber.

When separate chambers are used the samples shall be transferred as quickly as possible from one chamber to the other.

For the humidity, temperature and pressure tests and for the tropical exposure tests, a sample of the wire shall be made into a coil, the ends of the wire being sealed and brought outside the test chamber. The mandrel diameter shall be six times the maximum specified diameter of the wire and there shall be six turns of wire. At the conclusion of the tests the wire shall be examined and shall not show to normal vision any appreciable signs of deterioration. In addition, the sample shall be immersed in water, except for approximately 100 mm at each end, and a voltage as specified in Table 5, Column 3, and of waveform as specified in 2.4.1, shall be applied between the conductor and the water for one minute. There shall be no breakdown.

After the application of the voltage test, the insulation resistance of the wire shall be measured in the water at room temperature using a 500 V d.c. source and shall be not less than the equivalent of 100 M Ω for 1 km of cable at a temperature of $20 \pm 5^\circ\text{C}$.

2.2.6 Mould growth. Tests for resistance to mould and fungus growth are not required.

2.2.7 Flammability. (Care shall be exercised in making this test as toxic fumes are given off from the wire.)

Five specimens of wire shall be cut consecutively from the same coil and shall be freely exposed in an atmosphere of 75% relative humidity at a temperature of $20 \pm 5^\circ\text{C}$ for a period of 16 hours before testing.

Each specimen of wire shall then be supported at an angle of 45° in a draught-free chamber. The hottest point of a vertical 75 mm non-luminous flame from a 9.5 mm bunsen burner, with a blue cone 25 mm high, shall be arranged to impinge on the central portion of the specimen for 15 seconds. After the source of the flame has been removed, the cable shall meet the following requirements:

- (1) The cable shall cease to burn within 10 seconds.
- (2) The total length burned or charred shall not exceed 75 mm.

NOTE. Satisfactory operation of the flame may be confirmed by inserting a bare copper wire 0.71 ± 0.025 mm diameter, having a free length of not less than 100 mm, in the flame in the position to be occupied by the specimen. The flame is satisfactory for the test if the wire melts in not more than 6 seconds and not less than 4 seconds.

2.3 TYPE AND PRODUCTION ROUTINE TESTS

2.3.1 Construction. All wire shall be checked to ensure compliance with the requirements of this British Standard relating to construction and dimensions.

All completed wires shall be examined along the entire length for defective workmanship.

2.3.2 Voltage test on wires. A spark test in accordance with BS 6007, with a voltage as given in Table 5, Column 2, shall be made on all wire except screened wires. Metal screened wires shall, in the dry state, withstand the voltage given in Table 5, Column 3, applied for one minute between the conductor and the metal braiding.

Screened and sheathed wires shall in addition be subjected to a spark test in which a voltage of 2 kV is applied between the screen and a suitable electrode system on the outside of the wire.

2.3.3 Conductor resistance. The conductor resistance shall be measured by any convenient method on all wires. The resistance per kilometre shall not exceed the values stated in Table 3a when corrected to the specified temperature.

2.3.4 Packing and labelling. Each reel or bobbin of completed wires, when cut to length and wound appropriately, shall satisfy the requirements of 1.5 of this British Standard for packing and labelling.

2.4 TYPE AND PRODUCTION QUALITY TESTS

2.4.1 Voltage. A 1 m length of wire, except for approximately 100 mm at each end, shall be immersed in water at room temperature for not less than 12 consecutive hours; at the end of that time and whilst so immersed, it shall withstand the voltage shown in Table 5, Column 3, applied between the conductor and the water. The voltage shall be applied gradually and maintained continuously for 15 minutes. The regulation of the supply for the voltage test shall be such as to maintain the specified voltage on the wire throughout the test. The peak value of the voltage wave shall be within $\pm 5\%$ of $\sqrt{2} \times \text{r.m.s. value}$ and the frequency shall be in the range 40-62 Hz.

2.4.2 Insulation resistance. After the application of the voltage test specified in 2.4.1 and whilst the wire is still immersed, the insulation resistance for the equivalent of 1 km measured between the conductor and the water after one minute's electrification with 500 V d.c., shall not be less than the value stated in Table 5, Column 4. The change of apparent insulation resistance during the one minute's electrification shall be steady.

2.4.3 Continuity of silver plating on conductors and metal braids. The continuity of the silver plating on copper wires used for conductors and metal braids shall be determined by the method given in Appendix B.

There shall be no blackening (indicating exposed copper) of the test piece surface. Blackening within 12 mm of a cut end is permissible.

2.4.4 Thickness of silver plating on conductors and metal braids. The copper wires used for the conductors and screens shall be shown by any convenient method to be coated with silver to the thickness specified in 1.2.1.

2.4.5 Tensile strength and elongation of conductors. The tensile strength and minimum elongation of each copper wire taken from the conductor of the finished wire shall conform to the values given in Table 7.

For these tests, the gauge length on the test sample shall be 250 mm and the clamps shall be separated at a rate not

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exceeding 125 mm per minute. The tensile strength shall be calculated on the original cross-sectional area of the wire.

2.4.6 Stability of insulation and sheath. A 2 m length of wire shall be stored in an oven at a temperature of $275 \pm 5^\circ\text{C}$ for one hour. At the end of this time it shall be examined for any tendency of the insulation to retract on the conductor or for the sheath to retract on or extend from the screen. Any such retractions of either shall not exceed 3 mm total (i.e. the sum of the retractions at the two ends of the wire), and such extension of the sheath shall not exceed

6 mm total, (i.e. the sum of the extensions at the two ends of the wire).

2.4.7 Solderability. A solderability test shall be made, using the solder globule method as described in 3.4 of BS 2011, Part 2T 1966.

The temperature of test shall be $235 \pm 2^\circ\text{C}$ and the wires shall be tested under the conditions stated in Table 1.

The solderability test shall be carried out on 10 specimens of wire in the unaged condition and no time shall exceed 5 seconds. The mean time for the batch shall not exceed 2.5 seconds.

TABLE 1. SOLDERABILITY TEST CONDITIONS

Size	Conductor number and size of wires	To be tested as	Solder pellet size	Sample length
32	mm 7/0-08	Complete strand	mg 75	mm 100
30	7/0-1	Complete strand	75	100
28	7/0-125	Complete strand	75	100
26	7/0-15	Complete strand	75	100
24	7/0-2	Complete strand	75	100
22	19/0-15	Complete strand	125	100
20	19/0-2	Complete strand	200	100
18	19/0-25	Single wire removed from strand	75	100
16	19/0-3			
14	19/0-335			
12	19/0-45			
10	37/0-4			
30	1/0-25	Single wire	75	100
28	1/0-315	Single wire	75	100
26	1/0-4	Single wire	75	100
23	1/0-6	Single wire	125	100
19	1/0-9	Single wire	125	100