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Specification for

Performance of mechanical and compression joints in electric cable and wire connectors —

**Part 3: Mechanical and compression
joints in aluminium conductors**

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- Association of Manufacturers Allied to the Electrical and Electronics Industries
- Copper Development Association
- Electrical Installation Equipment Manufacturers' Association
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- National Coal Board

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Contents

	Page
Cooperating organizations	Inside front cover
Foreword	ii
1 Scope	1
2 References	1
3 Definitions	1
4 Classification	1
5 Requirements	1
6 Test specimens	2
7 Sequence of tests	3
8 Resistance measurement	3
9 Short circuit test	3
10 Electrical load cycling test	4
11 Tensile strength test	5
12 Test reports	5
Appendix A Electrical load cycling test rigs	6
Appendix B Graphical representation of electrical load cycling test results	9
Appendix C Mathematical acceptance criterion	11
Appendix D Tensile tests	17
Appendix E Determination of equivalent r.m.s. short circuit current	20
Appendix F Schedule of technical information	21
Figure 1 — Potential points for resistance measurement	2
Figure 2 — Through connectors	6
Figure 3 — Terminations	6
Figure 4 — Branch and service connectors (current injection method)	7
Figure 5 — Branch and service connectors (reactance control method)	7
Figure 6 — Mathematical acceptance criterion for specimen A	15
Figure 7 — Mathematical acceptance criterion for specimen B	16
Figure 8 — Moulds for cast resin blocks machined from aluminium block	17
Figure 9 — Tensile testing jig for “right angle” connectors	18
Figure 10 — Jig in position in tensile testing machine	19
Figure 11 — Tensile testing jig with interchangeable plates for “parallel” type connectors	19
Figure 12 — Jig in position in tensile testing machine	20
Publications referred to	Inside back cover

Foreword

This British Standard has been prepared under the authority of the Electrical Industry Standards Committee and is based on a proposal submitted by the Electricity Council.

When a connector or termination, forming a joint, meets the requirements of this standard, it is expected that in service:

- a) the resistance of the joint will remain stable;
- b) the temperature of the joint will be of the same order as that of the conductor;
- c) if the intended use demands, application of short circuit currents will not cause undue deterioration;
- d) the mechanical strength will be adequate.

The standard is generally representative of service conditions but does not, for example, take into account the tensile and compressive stresses to which the conductor is subjected as a result of variations in load currents. The stresses depend considerably on the overall design of the installation in which the conductor is used. It will be understood that these tests in air cannot simulate operations in all possible environments.

NOTE The performance of compression joints on conductors other than aluminium is the subject of BS 4579-1 and BS 4579-2.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 22, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 4579 specifies requirements for the performance of mechanical joints and compression joints in electric cable and wire connectors, for use on aluminium conductors of cross-sectional area 16 mm² and above. These conductors may be solid circular, solid sector shaped, solid sectoral circular, stranded circular, shaped stranded and compacted circular. The type of cable concerned may be either paper-insulated in accordance with BS 6480 or polymeric insulated in accordance with BS 6346, having solid or stranded aluminium conductors in accordance with BS 6360.

2 References

The titles of the publications referred to in this standard are listed on the inside back cover.

3 Definitions

For the purposes of this Part of BS 4579 the following definitions apply.

3.1

connector

a device for connecting two or more conductors

3.2

termination

a device for connecting a conductor to other equipment

3.3

through connector

a connector for connecting two consecutive lengths of conductor

3.4

branch connector

a connector for connecting a branch conductor to a main conductor

3.5

service connector

a connector for connecting a service conductor to a main conductor

3.6

joint

the body of the connector or termination and that part of the conductor that has been brought into intimate contact with it by compression or other mechanical means

3.7

control conductor

a length of unjointed conductor the central part of which is used during load cycling to provide the reference for temperature and resistance measurement

4 Classification

For the purposes of this standard, connectors and terminations are classified as follows:

- type 1 connectors and terminations used on circuits of comparatively high fault level and designed accordingly
- type 2 connectors and terminations used on circuits protected by high breaking capacity fuses and not required to possess any special short circuit characteristics

Type 1 connectors shall satisfy all the requirements of this standard.

Type 2 connectors shall satisfy all the requirements of this standard except that they are not required to be subjected to the short circuit test (see clause 9).

5 Requirements

5.1 Joint resistance

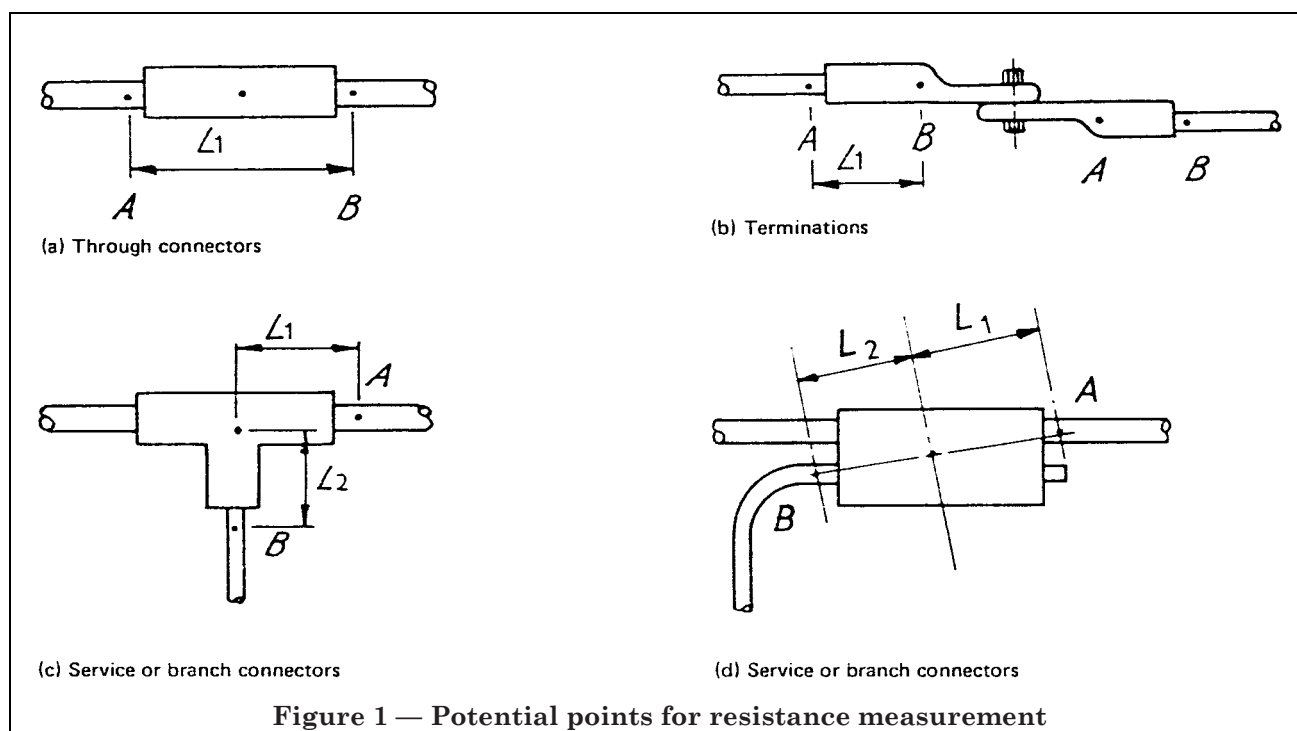
5.1.1 Initial value. The initial resistance, *A* to *B* (see Figure 1), of each specimen, when measured as described in clause 8, shall not differ by more than 50 % or 5 µΩ, whichever is the greater, from the mean of the overall resistance of the six specimens prepared as described in 6.1.

5.1.2 Values measured in the course of the short circuit test. The resistance, *A* to *B* (see Figure 1), of each specimen, measured after each of the three applications of short circuit current as described in clause 9, shall not exceed the initial value by more than 50 % or 5 µΩ, whichever is the greater.

5.1.3 Values measured during electrical load cycling tests

5.1.3.1 The average resistance, *A* to *B* (see Figure 1), of the test specimen taken over the last 1 000 cycles shall not exceed the average equivalent conductor resistance (see A.3), taken over the same period, by more than 50 % or 5 µΩ, whichever is the greater.

5.1.3.2 The average resistance, *A* to *B* (see Figure 1), of the test specimen taken over the last 1 000 cycles shall not exceed the resistance of the test specimen as measured immediately before the start of the electrical load cycling test by more than 50 % or 5 µΩ, whichever is the greater.



5.1.3.3 The graph of resistance, *A* to *B* (see Figure 1), against number of cycles shall demonstrate with a reasonable probability that the change (rise or fall) of resistance over the last 1 000 cycles is not more than 20 % of the average resistance over the same period. If the graph of resistance is unacceptable to either the purchaser or the supplier, the method given in Appendix C shall be used to determine the acceptability of a connector or termination.

5.1.3.4 In the event of the results of the statistical test in **5.1.3.3** being considered inconclusive by either the purchaser or the supplier, then the test shall be extended by periods of 1 000 load cycles, and the results shall be assessed as described in **5.1.3.3**.

5.2 Temperature. The temperature of the connector or termination as measured during electrical load cycling in accordance with clause **10** shall not exceed the temperature of the control conductor by more than 5 °C.

5.3 Tensile strength. Connectors and terminations, when tested in accordance with the provisions of clause **11**, shall satisfy the following requirements.

- a) A through connector, branch connector or termination shall have a breaking load not less than 60 % of that of the unjointed main or branch conductor, as appropriate.

- b) A service connector shall have a breaking load not less than 25 % of that of the unjointed service conductor.

6 Test specimens

6.1 Preparation. Test specimens shall be made upon insulated conductors taken from any of four types of cable namely:

- a) mass-impregnated, non-draining, paper-insulated cable in accordance with BS 6480;
- b) mass-impregnated, paper-insulated cable in accordance with BS 6480;
- c) pre-impregnated, paper-insulated cable in accordance with BS 6480;
- d) polymer-insulated cable in accordance with BS 6346.

A test made with conductors from mass-impregnated, non-draining cable will be considered satisfactory evidence for all types a) to d). However, tests may be carried out using any of the types b) to d), in which case the connector or termination will be accepted as suitable only for that particular type of cable.

Connectors and terminations shall be so prepared as to satisfy the requirements of **10.1** and shall be assembled and installed strictly in accordance with the manufacturer's instructions without further preparation. No subsequent tightening of the connectors or terminations shall be made.

In the case of through connectors, care shall be taken to ensure that the ends of the conductors are not in direct contact unless the design of the connector specifically provides for butting of the conductors.

The insulation shall be retained on the conductor except as necessary to enable the connector to be assembled and the potential measuring points to be provided (see A.2) and to enable temperature-measuring devices to be placed in contact with the control conductors.

6.2 Number. The number of specimens tested shall be as specified in 6.2.1 to 6.2.4.

6.2.1 If one size of connector or termination is offered for more than one size of conductor, tests shall be made on six specimens incorporating the largest size of conductor and on six specimens incorporating the smallest conductor.

In the case of branch or service connectors, tests shall be made on six specimens incorporating the largest sizes of conductor and on six specimens incorporating the smallest sizes of conductor.

6.2.2 If a connector or termination is offered for more than one shape of solid conductor, six specimens shall be tested for each shape of conductor.

6.2.3 Where a design is common over a range of connectors or terminations that includes three or more different sizes, the specimens tested shall comprise six of the largest, six of the smallest and six of one of the intermediate sizes of connector or termination.

6.2.4 Where terminations for a given shape and size of conductor are available with different palm sizes but are otherwise identical, tests shall be carried out on six terminations with the smallest palm size only.

7 Sequence of tests

Before the tests are made, the testing organization shall satisfy itself that the test specimens and arrangements comply with the requirements of clause 6.

Tests on each specimen shall be made in the following sequence.

- a) Before the specimens have been assembled into the load cycling rig:
 - 1) initial resistance measurement by the procedure described in clause 8;
 - 2) short circuit tests on type 1 connectors by the procedure described in clause 9.
- b) After the specimens have been assembled into the load cycling rig:
 - 1) electrical load cycling by the procedure described in clause 10;

- 2) resistance measurement by the procedure described in clause 8.

- c) After completion of the load cycling test: tensile strength test by the procedure described in clause 11.

8 Resistance measurement

8.1 Procedure. The devices and instruments used for resistance measurements shall be capable of measuring resistance to within 1 % or $0.5 \mu\Omega$, whichever is the greater, and the through-current used by the instrument shall be such that it does not materially affect the temperature of the test specimen.

The resistance of each specimen shall be measured between the potential points indicated in Figure 1.

For both terminations and connectors the resistance between *A* and *B* shall be recorded. In the case of all types of connector, the resistance between both points *A* and *B* and the body of the connector shall also be recorded. The points on the conductor shall be as close as is practicable to the connector or termination.

The resistance of a suitable length of control conductor shall also be measured to enable the equivalent resistance of the connectors to be determined.

Resistance measurements shall be carried out in steady temperature conditions, time being allowed for the specimens to acquire the temperature of their surroundings.

NOTE It is important to note that errors in resistance measurement increase the chances of rejection when applying the method of assessment described in Appendix C.

It is possible for thermoelectric e.m.f.'s to affect the accuracy of low resistance measurements (of the order of $10 \mu\Omega$). To compensate for this, two resistance measurements may be taken with the measuring current reversed, the mean of two readings being regarded as the resistance of the sample.

The length of time for which samples are allowed to stand/cool before resistance measurements are made can have an effect on the value of resistance measured, and ideally an interval of 12 h should be allowed to elapse after switching off the load cycling test current.

9 Short circuit test

9.1 General procedure. The test shall be carried out on the specimens prepared as described in 6.1.

The short circuit current and duration shall be such as to raise the temperature of the conductor from ambient to 160°C , or to a higher temperature if considered suitable for a particular application. For the smaller sizes of conductor the duration of the current shall be 1 s, its value being adjusted so that the specified temperature rise is produced.

For a conductor such that the current required to raise its temperature to the specified value in 1 s would exceed 44 kA, the current applied shall be 44 kA and the duration shall be adjusted to produce the specified temperature rise. The peak-to-peak value of the first complete cycle of the oscillogram shall not exceed twice the peak-to-peak value of the last complete cycle of the oscillogram. The declared current of the test shall be calculated in accordance with the method described in Appendix E.

Samples may be constrained as necessary during the application of short circuit current to prevent undue bending of the conductors.

Three applications of short circuit current shall be made following the initial resistance measurement. The electrical resistance of the specimens shall be measured after each short circuit current application, time being allowed for the temperatures of the specimens to become stable.

10 Electrical load cycling tests

10.1 Testing conditions

10.1.1 General. The tests shall be carried out in reasonably draught-free conditions. The test loop (see **10.1.2** or **10.1.3**, as appropriate) shall be erected so that the distance between connectors or terminations or any other connections introduced to facilitate testing shall be sufficient to ensure negligible thermal interference.

Each connector or pair of terminations shall be supported in such a way that air may freely circulate around the assembly to provide cooling by natural convection.

If a connector is such that two sizes of conductor are being connected into the main loop, the smaller of the two shall be used as the control conductor.

The main loop shall contain a length of unjointed conductor of not less than 1.2 m, the central part of which shall be used as the control for temperature and resistance measurements. The size and type of this conductor shall be the same as that used in the specimens being tested, except in the following case.

Where connectors for use on concentric conductors or sheaths are to be tested, the control conductor shall be made up from a length of solid aluminium conductor having equivalent cross section to the concentric conductor or sheath. If the connector is intended for use only on a part of the conductor, the test current shall be adjusted accordingly.

10.1.2 Through connectors and terminations.

Typical arrangements of the test loop are shown in Figure 2 and Figure 3. Where terminations are to be tested, the terminations shall be fitted to each end of the unjointed conductor. Only terminations of the same size and make shall be bolted together. Linking bars may be used provided that the temperature of the termination does not differ by more than 5 °C from the temperature attained when the terminals are bolted palm to palm.

10.1.3 Branch and service connectors. Typical arrangements of the test loop are shown in Figure 4 and Figure 5 (except in the case of connectors with similar main and branch conductors).

In the case of a test on a branch connector with similar main and branch conductors, the test shall be carried out as for a through connector, the current being passed from one limb of the main conductor to the branch conductor, the remaining limb of the main conductor being unloaded.

Where a type of connector makes it necessary for the main conductor to be cut, that part of the connector which acts as a through connector shall meet the requirements of this standard applicable to through connectors.

10.2 Test procedure

10.2.1 General. The test shall be carried out on the six specimens prepared as described in **6.1**. After the samples have been assembled into the test loop, but prior to load cycling, the resistance across each connector or termination shall be measured as specified in clause 8.

10.2.2 Through connectors and terminations

10.2.2.1 The current shall be such that the temperature of the control conductor is raised to a minimum of 80 °C above ambient temperature.

The current applied shall be only slightly above that needed to maintain the temperature of the control conductor at the required level.

The temperature of the control conductor shall then be maintained at or above this value for a minimum period of 5 min.

At the end of this period the current shall be switched off and the control conductor allowed to cool naturally to within 5 °C of the ambient temperature.

The stages described above shall together constitute one electrical load cycle.

During load cycling the temperature of the control conductor and the current shall be measured as frequently as is necessary.

Tests made at a higher temperature shall be deemed to comply with the requirements of this subclause.

10.2.2.2 At the end of approximately 100¹⁾ load cycles, the current shall be switched off and the test loop allowed to cool until the connectors have acquired the temperature of their surroundings. Resistances as specified in clause 7 shall be measured and recorded.

This procedure shall be repeated every 100 cycles until 2 000 cycles have been completed, thereby recording 20 sets of resistance measurements, the last 11 of these being used for assessment as described in 5.1.3.

The temperature of the connectors and of the control conductor, together with the ambient temperature, shall be measured and recorded during the “heat on” period of the load cycle prior to each resistance measurement.

The devices and instruments used for temperature measurement shall have accuracy of 2 °C or better.

10.2.3 Branch and service connectors. Electrical load cycling of the branch or service conductor loops shall be automatically maintained in step with that of the main loop. The current in each branch or service loop shall be such that the conductor temperature is raised to a minimum of 80 °C above ambient in the case of branch conductors or 70 °C above ambient in the case of service conductors. Tests made at a higher temperature shall be deemed to comply with the requirements of this subclause.

The current required in the branch or service conductor shall be determined by a preliminary experiment in which a length of similar conductor is arranged as control conductor in a test loop as shown in Figure 3.

This supplementary test shall also be used to measure the resistance of a known length of branch or service conductor (see A.3).

The current flowing in the branch loop from the loading transformer shall be approximately in phase with the current that flows with the transformer de-energized. (If an injection transformer is used, the circuit connections will be correct if, as the voltage is increased at the variable transformer, the current rises without falling to a minimum value.)

The procedure specified in 10.2.2.2 in respect of through connectors and terminations shall also apply to tests on branch and service connectors.

The load cycle described in 10.2.2.1 shall apply for the main loop.

10.3 Presentation of results. The results of the test may be presented graphically in the form shown in Appendix B, the scales of the graphs being chosen to show clearly any significant changes of resistance or temperature. Alternatively, if the method as described in Appendix C is being used, the results may be presented in tabular form.

11 Tensile strength test

This test shall be carried out on all types of connector or termination. Where a type of branch or service connector makes it necessary for the main conductor to be cut, that part of the connector that acts as a through connector shall meet the requirements of this standard applicable to through connectors.

The test shall be carried out on three of the six specimens subjected to the electrical load cycling test in accordance with clause 10. When removing the test specimens from the electrical load cycling test rig, and during preparation for the tensile test, care shall be taken to minimize disturbance to the specimens.

Specimens shall be prepared for test in accordance with Appendix D.

Test specimens shall be inserted into the tensile test apparatus in such a manner as to ensure that the load is applied directly along the axis of the conductor in the case of through connectors and terminations or of the branch or service conductor in the case of branch and service connectors, and that the body of the connector is not gripped by the jaws of the tensile testing machine.

The axial pull shall be applied by separating the jaws of the tensile testing machine at a steady rate between 25 mm/min and 50 mm/min.

The same test shall be applied to a length of unjointed main, branch or service conductor cut from the same length as that used to make the test loop for the load cycling test but which has not been subjected to that test.

12 Test reports

Test reports shall include the particulars required in Appendix F together with any other relevant information.

The results of each measurement called for in the sequence of tests set out in clause 7 shall be recorded together with the date when the joints were made, the date of making tests and, in the case of resistance measurements, the ambient temperature.

¹⁾ ± 20 cycles is permitted on the timing of any reading.