

Specification for

Custom-built transformers and inductors of assessed quality: generic data and methods of test

Committees responsible for this British Standard

This British Standard was published under the direction of the Electronic Components Standards Policy Committee ECL/-. Its preparation was entrusted to Technical Committee ECL/18 upon which the following bodies were represented:

- British Telecommunications plc
- Electronic Components Industry Federation
- Ministry of Defence
- National Supervising Inspectorate
- Power Supply Manufacturers Association (PSMA)
- Telecommunication Engineering and Manufacturing Association (TEMA)

This British Standard, having been prepared under the direction of the Electronic Components Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 31 October 1989

© BSI 10-1999

First published September 1976
First revision 1983
Second revision October

The following BSI references relate to the work on this standard:
Committee reference ECL/18
Draft for comment 86/26525 DC

ISBN 0 580 17336 4

Amendments issued since publication

Amd. No.	Date of issue	Comments
6348	September 1991	Indicated by a sideline in the margin

Contents

	Page
Committees responsible	Inside front cover
Foreword	v
Section 1. General	
1.1 Scope	1
1.2 Related documents	1
1.3 Definitions	1
1.4 Letter symbols, signs and abbreviations	4
1.5 Graphical symbols	4
1.6 Marking of the component and package	4
1.7 Delayed delivery	4
1.8 Certified test records	4
1.9 Standard ratings and characteristics	4
1.10 Ordering information	5
Section 2. Tests	
2.1 Test and measurement conditions	6
2.1.1 General	6
2.1.2 Measurement uncertainty	6
2.1.3 Alternative test methods	6
2.2 Visual inspection	6
2.2.1 General	6
2.2.2 Isolating screen position	6
2.2.3 Quality of solder joints (isolating screens)	6
2.3 Dimensioning and gauging procedure	7
2.4 Electrical test procedures	7
2.4.1 General	7
2.4.2 Winding resistance	7
2.4.2.1 D.C. winding resistance	7
2.4.2.2 Continuity	8
2.4.3 Insulation resistance	8
2.4.3.1 Insulation resistance (standard atmosphere)	8
2.4.3.2 Insulation resistance (hot)	8
2.4.4 Losses	8
2.4.4.1 No-load current	8
2.4.4.2 No-load loss	9
2.4.5 Voltage proof (electric strength test)	9
2.4.6 Induced high voltage	9
2.4.7 Magnetic fields	10
2.4.7.1 Magnetic shielding	10
2.4.7.2 Magnetic influence (compass safe distance)	11
2.4.8 Inductance and a.c. resistance	12
2.4.9 Screens	12
2.4.9.1 Electrostatic screen(s)	12
2.4.9.2 Isolating screen	12
2.4.10 Q factor	12
2.4.11 Capacitance unbalance	13
2.4.12 Impedance unbalance	13
2.4.13 Voltage unbalance	14
2.4.14 Resistance unbalance	14

	Page
2.4.15 Leakage inductance	14
2.4.16 Capacitance	15
2.4.16.1 Self-capacitance	15
2.4.16.2 Interwinding capacitance	15
2.4.17 Voltage transformation ratio	15
2.4.18 Resonant frequency	15
2.4.18.1 Inherent self-resonance	15
2.4.18.2 Resonant assemblies	16
2.4.19 Signal transfer characteristics	18
2.4.19.1 Insertion loss	18
2.4.19.2 Return loss	19
2.4.20 Frequency response	19
2.4.21 Pulse characteristics	19
2.4.22 Total harmonic distortion	20
2.4.23 Temperature rise	20
2.4.24 Voltage regulation at full load	20
2.4.25 Magnetic radiation	21
2.4.26 Acoustic noise	21
2.4.27 Polarity (phase) test	21
2.4.28 Non-linearity of magnetizing current	22
2.4.29 Maximum surface temperature	23
2.5 Environmental test procedures	23
2.5.1 General	23
2.5.2 Soldering	23
2.5.3 Robustness of terminations	23
2.5.4 Shock	23
2.5.5 Bump	23
2.5.6 Vibration	24
2.5.7 Acceleration, steady state	24
2.5.8 Rapid change of temperature, thermal shock in air	24
2.5.9 Sealing	24
2.5.10 Climatic sequence	24
2.5.11 Damp heat, steady state	24
2.5.12 Dry heat	24
2.5.13 Mould growth	24
2.5.14 Salt mist	24
2.5.15 Sulphur dioxide	24
2.5.16 Flammability	24
2.5.17 Solvent resistance	24
2.6 Endurance test procedures	24
2.6.1 Short-term endurance (load run)	24
2.6.2 Long-term endurance (life test)	24
Section 3. Capability approval procedures	
3.1 Eligibility for capability approval	26
3.2 Application for capability approval	26
3.2.1 General	26
3.2.2 Scope of capability	26
3.2.2.1 General	26

	Page
3.2.2.2 Environmental characteristics	26
3.2.2.3 Core type	26
3.2.2.4 Range of mass	26
3.2.2.5 Type of construction	26
3.2.2.6 Form of statement	26
3.2.3 Add-on and built-in components	26
3.3 Description of capability	27
3.4 Appraisal of capability	27
3.4.1 Capability qualifying components (CQCs)	27
3.4.2 CQC test schedules	27
3.4.2.1 General	27
3.4.2.2 Sample selection and test flow chart for the appraisal of capability	27
3.4.2.3 Failure procedure	28
3.4.3 Schedule 1: Preconditioning	30
3.4.4 Schedule 2A: Assessment of climatic durability	31
3.4.5 Schedule 2B: Assessment of long-term endurance	32
3.4.6 Schedule 2C: Assessment of mechanical/environmental durability	32
3.4.7 Schedule 3: Selective assessment of mechanical/environment durability	34
3.5 Announcement of capability approval	35
3.6 Maintenance of capability approval	35
3.6.1 General	35
3.6.2 Annual testing	36
3.6.3 Three-yearly testing	36
3.6.4 Additional boundaries to the approval	36
3.6.5 Procedure in the event of failure	36
3.7 Quality conformance inspection	36
3.8 Changes to the approved capability	36
Appendix A Allocation of numbers to generic, sectional and blank detail specifications	38
Appendix B Sample format for certified test record	38
Appendix C Sample format for abstract of manufacturer's report	39
Appendix D List of clauses corresponding to those in BS 9720:1983	39
Index	44
Figure 1 — Pulse waveform parameters	3
Figure 2 — Examples of good solder joints	6
Figure 3 — Examples of poor solder joints	7
Figure 4 — Helmholtz structure	11
Figure 5 — Measurement of capacitance unbalance	13
Figure 6 — Measurement of impedance unbalance	14
Figure 7 — Measurement of voltage transformation ratio	16
Figure 8 — Measurement of resonant frequency: Inherent self-resonance	17

	Page
Figure 9 — Measurement of resonant frequency: resonant assemblies	17
Figure 10 — Measurement of insertion loss and frequency response	18
Figure 11 — Use of two identical transformers when transformation ratio is not unity	19
Figure 12 — Measurement of non-linearity of magnetizing current	22
Figure 13 — Maximum non-linearity of magnetizing current	23
Figure 14 — Sample selection and test flow chart for the appraisal of capability	29
Figure 15 — Sample selection and test flow chart for the maintenance of capability approval	37
Table 1 — Preferred values of acceleration and displacement for vibration testing	5
Table 2 — Proof test voltages	9
Table 3 — Data for magnetic radiation test	21

Foreword

This revision of BS 9720 has been prepared under the direction of the Electronic Components Standards Policy Committee: it supersedes BS 9720:1983, which is withdrawn. This edition incorporates technical changes to the previous text as well as new material whose purpose is primarily to clarify both tests and procedures.

This standard is a generic specification for use in the BS 9000 scheme for electronic components of assessed quality. It includes the general information, terminology and methods of test required for the assessment of the performance of transformers and inductors. Because such components are usually manufactured to comply with a particular customer's order, the capability approval procedure is invoked in accordance with clause 15 of BS 9000-1:1981 and BS 9005, and the standard therefore contains the appropriate capability approval test schedules and requirements.

For convenience, the following outline of the sequence of events in the capability approval procedure is given.

- a) A manufacturer wishing to obtain capability approval writes a "capability manual", which clearly defines the scope of his design capability, manufacturing processes and quality control, to the satisfaction of the National Supervising Inspectorate (NSI).
- b) The manufacturer in collaboration with the NSI selects sample components to demonstrate the limits of this scope, and the sample is assessed.
- c) These components are submitted to a test programme in accordance with section 3 of this standard.
- d) When testing is successfully completed and the manufacturer's systems approved against the capability manual, capability approval is granted and the fact published in PD 9002. The capability approval is maintained by periodic testing of sample components at the limits of the scope of their capability.
- e) A potential customer makes an enquiry to the manufacturer for a component within the scope of capability published in PD 9002 (or by CODUS).
- f) The specification is negotiated between the manufacturer and the customer until an agreed customer's detail specification (based on one of the blanks included in the appropriate sectional specification (see Appendix A) is finalized.
- g) The manufacturer allocates a reference number to the resulting detail specification which is filed and is available for scrutiny by the NSI. The component is inspected and released in accordance with this detail specification.

BS 9720:1989, from the point of view of system users, differs from BS 9720:1983 in details of the capability approval (CA) procedures, the most significant of which is the elimination of quarterly testing for the maintenance of CA.

The portfolio of test procedures is substantially the same, even though some of the test procedures have been amended.

It is expected that those seeking approval to the BS 9720 CA procedure would take advantage of the latest published generic specification: however, the existing and current sectional specifications refer to tests listed in BS 9720:1983, and the reference numbers to these tests in BS 9720:1989 have changed.

Appendix D contains a list giving the necessary correspondences between these reference numbers for the convenience of users of these sectional specifications.

This standard calls for the use of substances and/or test procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and in no way absolves either the supplier or the user from statutory obligations relating to health and safety at any stage of manufacture or use.

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 to vi, pages 1 to 45 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.

Section 1. General

1.1 Scope

This British Standard specifies the requirements that manufacturers of custom-built transformers and inductors need to comply with in order to achieve and maintain capability approval to BS 9000, and the component test schedules to be used for the assessment of that capability. It applies to components, including polyphase types, that are primarily intended for use in electronic equipment. This standard also specifies marking requirements and related symbols and terminology; and describes the methods of test for transformers and inductors that are required by the relevant sectional specifications (which contain the customer's blank detail specification), and the schedules for the assessment and maintenance of capability.

NOTE 1 The transformers and inductors that are the subject of this specification may include other components essential to the operation of the device, e.g. capacitors associated with constant voltage transformers and resonated windings.

NOTE 2 This standard should be read in conjunction with BS 9000 and BS 9005; such general details and definitions given in those standards as are appropriate to this standard should be held to be part of this standard unless otherwise stated herein.

NOTE 3 The allocation of numbers to generic sectional and blank detail specifications in the 9700 series is given in Appendix A.

1.2 Related documents

BS 171, *Power transformers — Part 4: Specification for tappings and connections.*

BS 2011, *Basic environmental testing procedures.*

BS 3939, *Guide for graphical symbols for electrical power, telecommunications and electronics diagrams.*

BS 4727, *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms.*

BS 5775, *Specification for quantities, units and symbols.*

BS 5938, *Cores for inductors and transformers for telecommunications — Part 1: Methods of measurement.*

BS 5969, *Specification for sound level meters.*

BS 6001, *Sampling procedures for inspection by attributes.*

BS 9000, *General requirements for a system for electronic components of assessed quality — Part 1: Specification of basic rules and procedures.*

BS 9005, *Specification for general procedures to be followed for the capability approval of electronic components covered by BS 9000-1.*

NOTE 1 Other standards concerned with quality assessment procedures for transformers and inductors for electronic equipment are listed in Appendix A.

PD 9002, *BS 9000 component selection guide.*

NOTE 2 Information in this publication may also be accessed by subscribers to CODUS Limited via their computer terminals. CODUS Limited, Institute for Information Technology, is at 196-198 West Street, Sheffield S1 4ET.

British Standard G 118, *Specification for aircraft magnetic compass, direct-reading.*

1.3 Definitions

For the purposes of this British Standard the following definitions apply, together with those given in BS 4727.

1.3.1 component

a transformer or inductor in accordance with this specification

1.3.2 sealed components

components designed to prevent ingress of moisture, etc., under arduous climatic conditions. This includes components enclosed in a hermetically sealed can or encapsulated in a manner that may or may not include the core

1.3.3 non-sealed components

components other than sealed components

1.3.4 peak working voltage

the maximum instantaneous voltage for which the winding is rated under working circuit conditions

1.3.5 pulse waveform parameters (see Figure 1)

1.3.5.1 peak pulse amplitude

the maximum value of a smooth curve through the top of the pulse, excluding any initial "spike" or "overshoot" the duration of which is less than 10 % of the pulse duration

1.3.5.2 pulse duration

the time interval between the first and last instants at which the pulse amplitude equals 50 % of the peak pulse amplitude

1.3.5.3 pulse rise time

the interval between the first instant at which the pulse amplitude reaches 10 % of the peak pulse amplitude and the first instant at which the pulse amplitude reaches 90 % of the peak pulse amplitude, excluding any unwanted or irrelevant portion of the waveform

1.3.5.4**pulse decay time**

the interval between the last instant at which the pulse amplitude reaches 90 % of the peak pulse amplitude and the next instant at which the pulse amplitude reaches 10 % of the peak pulse amplitude, excluding any unwanted or irrelevant portion of the waveform

1.3.5.5**droop**

the percentage difference between the peak pulse amplitude and the amplitude of the extrapolated smooth curve through the top of the pulse, excluding any initial “spike” or “overshoot”, at its intersection with the time ordinate when the pulse has fallen to 90 % of its peak pulse amplitude

1.3.5.6**pulse crest**

the maximum amplitude of the pulse

1.3.5.7**overshoot**

the amount by which the pulse crest exceeds the peak pulse amplitude, expressed as a percentage of the peak pulse amplitude

1.3.5.8**backswing**

the maximum amplitude of the reverse pulse, i.e. the portion of the pulse after the zero-crossing, expressed as a percentage of the peak pulse amplitude

1.3.5.9**return back swing**

the maximum amplitude of the swing that follows the backswing, expressed as a percentage of the peak pulse amplitude

1.3.5.10**recovery time**

the time interval between the end of the pulse decay time and the time at which the pulse amplitude last reaches ± 10 % of the peak pulse amplitude

NOTE Exceptionally a figure less than 10 % may be used, in which case the interval is termed “the x % recovery time”.

1.3.5.11**pulse repetition frequency (p.r.f.)**

the average number of pulses per unit time, when this is independent of the period over which it is measured

1.3.6**Q factor**

of a winding, the ratio of the series reactance to the series resistance or the parallel resistance to the parallel reactance, at a given frequency

1.3.7**harmonic distortion**

the square root of the sum of the squares of all harmonic voltages up to and including the seventh harmonic (excluding the fundamental), expressed as a percentage of the fundamental

1.3.8**maximum winding temperature**

the winding temperature rise of the component under full load conditions added to the maximum ambient temperature as specified in the detail specification

1.3.9**voltage-time product limit**

the product of the voltage peak pulse amplitude and the time elapsed from the start of the pulse corresponding to which the non-linearity of the magnetizing current does not exceed a value specified in the detail specification

1.3.10**electrostatic screen**

a conducting screen inserted between windings that, when it is connected to earth, considerably reduces the transference of unwanted signals from one winding to the other via the interwinding capacitance

1.3.11**isolating screen**

a conducting screen inserted between windings that, when it is connected to earth, effectively prevents fault currents flowing between those windings in the event of an insulation breakdown

1.3.12**polarity** (applicable to single phase windings)

a terminal on one winding has the same polarity as a terminal on another winding if, when the other ends of the windings are connected to form a common terminal and the transformer/inductor is energized with a sinusoidal voltage, the induced voltage appearing between each of the two terminals and the common terminal is rising positively through zero at the same instant of time

1.3.13**uniformly-insulated winding**

a winding in which the insulation to earth is at all points designed to withstand an electric strength test of a value appropriate to the insulation of the high-voltage end

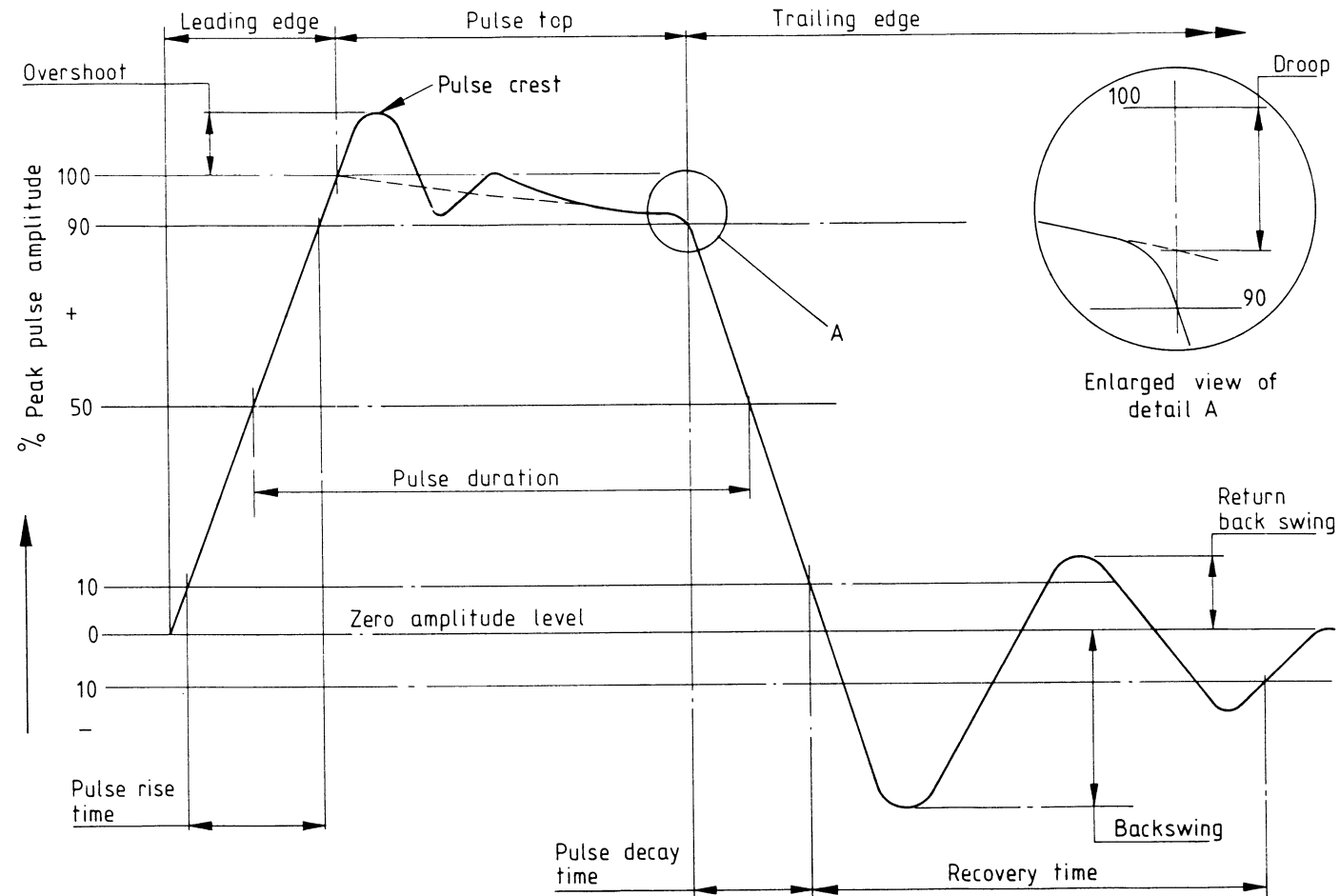


Figure 1 — Pulse waveform parameters

1.3.14

graded-insulated winding

a winding in which the insulation to earth is graded from the amount at the high-voltage end to a smaller amount at the low-voltage end

NOTE Such a winding should withstand an electric strength test of a value appropriate to the insulation of the low-voltage end.

1.4 Letter symbols, signs and abbreviations

Letter symbols, signs and abbreviations shall comply with the relevant Parts of BS 5775.

1.5 Graphical symbols

Graphical symbols shall comply with BS 3939.

1.6 Marking of the component and package

Unless otherwise specified in the customer detail specification, each component shall be marked as far as is practicable with the items given below, in the order of precedence stated:

- a) terminal identification;
- b) type number¹⁾;
- c) lot identification and/or date code²⁾;
- d) factory identification code;
- e) detail specification number (see **15.10** and **15.11** of BS 9000-1:1981);
- f) any additional marking required by the detail specification.

All the above information except the terminal identification shall appear also on the primary package.

NOTE 1 If a transparent package is used, the information may be marked on a label that can be read without opening the package.

If the termination identification is not given on the component, it shall be included in the primary pack either in the form of a drawing or by a reference to a standard outline.

NOTE 2 For polyphase components it is desirable to give a connection symbol as defined in BS 171-4:1978.

1.7 Delayed delivery

Components held for a period exceeding one year after acceptance testing shall be re-examined prior to despatch and shall satisfy the inspection requirements specified below, unless another period is specified in the relevant customer's detail specification.

a) Voltage proof	2.4.4	100 %
b) Insulation resistance (standard atmosphere)	2.4.2.1	100 %
c) Soldering	2.6.1	Minimum: 2 terminations Maximum: 10 %

1.8 Certified test records

Certified test records (CTRs) shall be provided only when specifically required by the customer's detail specification. When so provided, CTRs shall be printed on size A4 paper in the format, for example, illustrated in Appendix B of this standard (see also, for example, section 6 of BS 9000-1:1981).

1.9 Standard ratings and characteristics

Preferred values for ratings and characteristics, in accordance with the appropriate Part of BS 2011, are as follows.

- a) *Minimum ambient temperature* (lower category temperature) in accordance with BS 2011-2.1A: Test A. Cold

– 10 °C
– 25 °C
– 40 °C
– 55 °C
– 65 °C

- b) *Maximum ambient temperature* (upper category temperature) in accordance with BS 2011-2.1B: Test B. Dry heat

40 °C
55 °C
70 °C
85 °C
100 °C
125 °C

¹⁾ For components supplied against customer detail specifications, the type number is that required by the customer. For components supplied against detail specification for standard catalogue items, the type number is the manufacturer's type number.

²⁾ Where the date code also serves as lot identification, only the date code need appear on the component and package.

c) *Damp heat, steady state exposure* (in accordance with BS 2011-2.1Ca: Test Ca. Damp heat, steady state)

4 days

10 days

21 days

56 days

NOTE to a), b) and c) Climatic categories are often expressed in the coded numerical form:

minimum ambient temperature/maximum ambient temperature/ number of days exposure to damp heat, in accordance with Appendix A of BS 2011-1.1.

d) *Shock* (in accordance with BS 2011-2.1Ea)

294 m/s², 18 ms

490 m/s², 11 ms

981 m/s², 6 ms

e) *Bump* (in accordance with BS 2011-2.1Eb)

Number of bumps

1 000 ± 10

4 000 ± 10

This number of bumps is the total to be applied to any one sample.

Severity

98 m/s² for 16 ms duration

390 m/s² for 6 ms duration

f) *Vibration* (in accordance with BS 2011-2.1Fc)

Frequency ranges

10 Hz to 55 Hz

10 Hz to 500 Hz

10 Hz to 2 000 Hz

g) *Acceleration, steady state* (in accordance with BS 2011-2.1Ga)

98 m/s²

196 m/s²

490 m/s²

981 m/s²

h) *Low air pressure* (in accordance with BS 2011-2.1M)

30 kPa (300 mbar)

8.5 kPa (85 mbar)

1.10 Ordering information

A component ordered by a customer shall be the subject of a detail specification based on the customer's detail specification (blank) appropriate to the component sub-family.

The specification shall comply with the generic specification and the appropriate sectional specification and, when read in conjunction with them, shall adequately describe the component.

The specification, which is normally written by the customer, shall be allocated a component identity number including issue status within his own system. The characteristics, ratings and dimensions included in the customer's detail specification, which are subject to negotiations between the customer and the manufacturer, shall fall within the scope of the manufacturer's capability approval.

When the contents of the specification have been agreed with the manufacturer (if necessary, following the acceptance by the customer of a proven sample), the manufacturer shall allocate a reference number which shall consist of the number of the sectional specification followed by the manufacturer's factory identification code (see Appendix A of PD 9002-1) followed by a unique number (e.g. BS 9721, FRR 2031). After the customer's detail specification has been allocated the manufacturer's reference number, it will be considered a contractual part of the order.

The manufacturer's chief inspector shall retain a copy of each completed customer detail specification which has been allocated such a reference.

Table 1 — Preferred values of acceleration and displacement for vibration testing

Acceleration amplitudes above crossover frequency	Displacement amplitudes below crossover frequency
m/s ²	mm
19.6	0.15
49	0.35
98	0.75
196	1.5

Section 2. Tests

2.1 Test and measurement conditions

2.1.1 General

Unless otherwise specified, all tests shall be carried out under standard atmospheric conditions for testing as specified in clause 5 of BS 2011-1.1:1983. Where there is a requirement for component to attain thermal stability, this shall be in accordance with 4.8 of BS 2011-1.1:1983.

Further conditions of test that are required to complete the descriptions of test methods in this clause shall be specified in the customer's detail specification for the component.

2.1.2 Measurement uncertainty

The limits quoted in detail specifications shall be absolute. The tolerance values applying to the actual measurement system shall be taken into account when the measurements are assessed against specification limits. Where tolerances in respect of set conditions or instrument error have been specified, these shall be regarded as additional minimum requirements.

2.1.3 Alternative test methods

The test and measurement methods given in the relevant specification shall not be regarded as the only methods to be used. However, the manufacturer shall satisfy the NSI that any alternative methods will give results equivalent³⁾ to those obtained by the methods specified. In case of dispute, for referee and reference purposes only the specified methods shall be used. Alternative test methods shall not be shown in detail specifications.

2.2 Visual inspection

2.2.1 General

Visual inspection shall be performed under normal factory lighting conditions without visual aids. The condition, workmanship, marking and finish shall be satisfactory.

2.2.2 Isolating screen position

Purpose. To determine the position of the isolating screen in relation to adjacent windings.

Procedure. The fitted and positioned isolating screen shall be inspected before being obscured by subsequent windings to ensure that the following requirements are complied with.

Requirements. The isolating screen shall:

- a) totally cover the winding around which it is wrapped such that the "finish" end overlaps the "start" end by not less than 5 mm;
- b) be so insulated that it does not comprise a short-circuit winding;
- c) have edges extending sufficiently along the winding being screened to prevent direct contact between windings.

NOTE Screens fitted to toroidal transformers may consist of a number of turns provided that each turn overlaps the adjacent turn by not less than 5 % of the strip width.

2.2.3 Quality of solder joints (isolating screens)

NOTE A good solder joint is one that has excellent electrical contact between the parts joined and good mechanical strength. Examples of good solder joints are shown in Figure 2. Figure 3 illustrates defective joints.

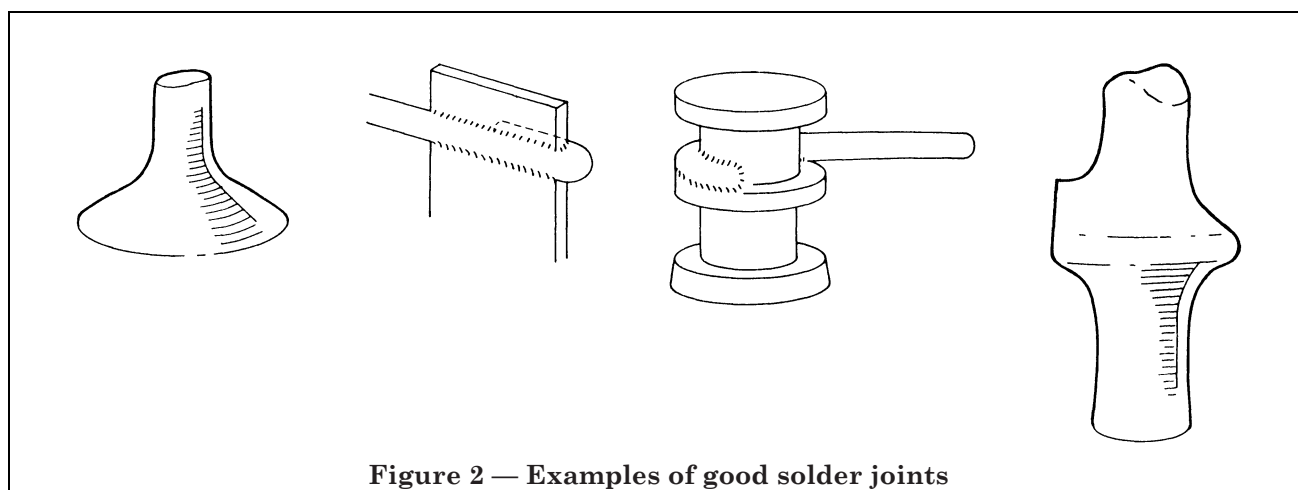


Figure 2 — Examples of good solder joints

³⁾ By "equivalent" is meant that the value of a characteristic established by such an alternative method, and acceptable in accordance with the limits ascribed to that method, will fall within the specified limits when measured by the specified method.

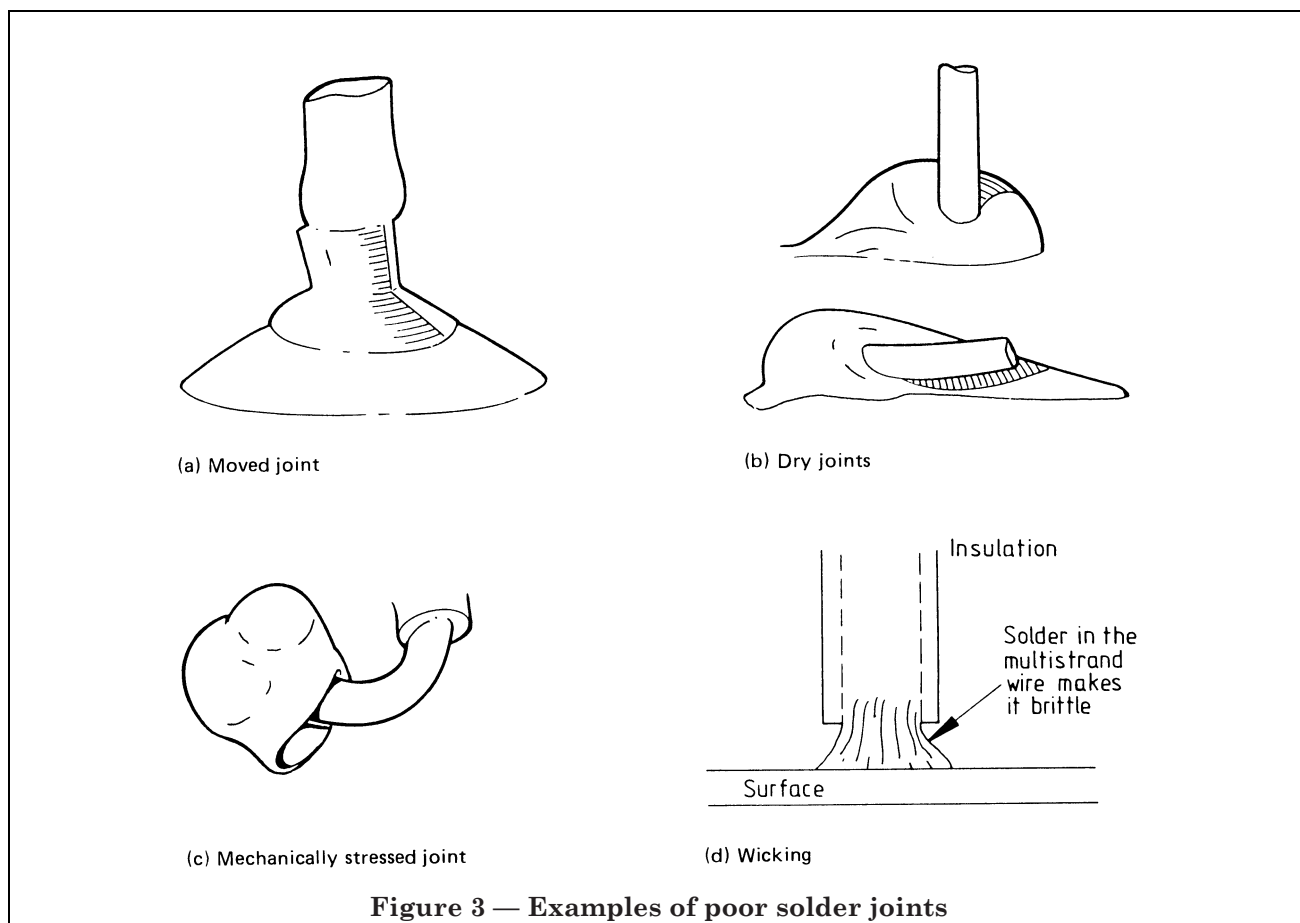


Figure 3 — Examples of poor solder joints

Purpose. To determine the quality of all solder joints necessary to connect the isolating screens to their terminations.

Procedure. All solder joints between the isolating screen and the isolating screen termination shall be inspected to ensure that the following requirements are complied with.

Requirements. Solder joints shall:

- a) exhibit good tinning as evidenced by the free flowing of solder with wetting of the termination;
- b) be smooth with no spikes;
- c) be bright and shiny;
- d) be without rough patches;
- e) have a concave surface with the outline of the wire visible under the surface of the solder;
- f) not be moved during soldering [such joints exhibit an “orange peel” effect as shown in Figure 3(a)];
- g) not be “dry” [i.e. shall not exhibit a distinct line where the solder fillet joins the wire or have a high contact angle between the solder and the wire; see Figure 3(b)];

h) be wired at terminals in such a way as to leave no residual stress [see Figure 3(c)];

i) not exhibit “wicking” [i.e. the joining wire shall not be overheated, leading to the movement of solder into multi-stranded wires; see Figure 3(d)].

2.3 Dimensioning and gauging procedure

The dimensions shall be verified as being in accordance with the detail specification.

2.4 Electrical test procedures

2.4.1 General

Unless otherwise stated, all voltages and currents shall be sinusoidal, values given shall be taken as r.m.s. values and polyphase supplies shall be assumed to be balanced.

2.4.2 Winding resistance

2.4.2.1 D.C. winding resistance

Purpose. To determine the d.c. resistance of a winding or windings between specified terminations.

Procedure 1. The component shall be maintained under standard atmospheric conditions (see 2.1.1) until it has reached thermal stability. The ambient temperature shall be measured. The d.c. resistance between terminations specified in the detail specification shall be measured and the resistance R_{20} (in Ω) referred to 20 °C shall be calculated from the following equation:

$$R_{20} = \left(\frac{k + 20}{k + t} \right) R_m$$

where

k is related to the thermal coefficient of resistivity (in °C) (for the purposes of this procedure, the value for copper shall be taken as 235);

t is the ambient temperature (in °C);

R_m is the d.c. resistance at temperature t between terminations (in Ω).

Procedure 2. The d.c. resistance between terminations specified in the detail specification shall be checked, without regard to thermal stability or to the temperature of measurement.

Information to be stated in the detail specification

- 1) The maximum measuring current, if necessary to avoid core polarization effects.
- 2) The terminations between which the measurement is to be made.
- 3) Whether procedure 1 or procedure 2 is to be used.

2.4.2.2 Continuity

Purpose. To verify the continuity of windings specified in the detail specification.

Procedure. The continuity between the specified terminations shall be established; the current through a winding shall be minimal in order to avoid any possible core polarization effects.

NOTE Where there are parallel paths, as with multiple windings or in polyphase components, a d.c. resistance check may be necessary to ensure that the path under examination is not being influenced by shunt paths.

Information to be stated in the detail specification

- 1) The maximum measuring current, if necessary to avoid core polarization effects;
- 2) The winding(s) to be connected.

2.4.3 Insulation resistance

2.4.3.1 Insulation resistance (standard atmosphere) (see 2.1.1)

Purpose. To check the quality of the insulating material of the component.

Procedure. Unless otherwise specified, the insulation resistance shall be measured with a direct voltage of either 100 ± 15 V (for windings with a peak working voltage < 500 V) or 500 ± 50 V (for windings with a peak working voltage ≥ 500 V).

The test voltage shall be applied until a steady reading is obtained, or for 60 ± 5 s. It shall be applied between each winding and:

- a) the case or core (if accessible);
- b) each remaining winding and screen.

Information to be stated in the detail specification

- 1) The peak working voltage.

2.4.3.2 Insulation resistance (hot)

Purpose. To check the quality of the insulating and impregnating materials of the component at a temperature equivalent to the maximum winding temperature.

Procedure. The component shall be maintained at the maximum winding temperature for a period of 6 h, or until two measurements of winding resistance at intervals of 30 min give the same result, whichever is the lesser.

The insulation resistance shall be measured immediately, with a direct voltage of either 100 ± 15 V (for windings with a rated peak working voltage < 500 V) or 500 ± 50 V (for windings with a rated peak working voltage ≥ 500 V) unless otherwise specified. The test voltage shall be applied until a steady reading is obtained, or for 60 ± 5 s. It shall be applied between each winding and

- a) the case or core (if accessible); and
- b) each remaining winding and screen.

Information to be stated in the detail specification

- 1) The maximum winding temperature;
- 2) The conditioning period, if other than 6 h;
- 3) The peak working voltage.

2.4.4 Losses

2.4.4.1 No-load current

Purpose. To verify that the core material is of the required quality and is correctly assembled, and that there are no short-circuited parts of the windings.

Procedure. The component shall have the specified value of input voltage at the specified frequency applied to the input winding. All other windings shall be unloaded. The input current shall be measured when its value is stabilized. For polyphase components all input currents shall be measured.

Information to be stated in the detail specification

- 1) The alternating voltage level.
- 2) The measuring frequency.

2.4.4.2 No-load loss

Purpose. To verify that the core material is of the required quality and is correctly assembled, and that there are no short-circuited parts of the windings.

Procedure. The component shall have the specified voltage and frequency applied to the input winding via a suitable wattmeter. For polyphase components the appropriate number of wattmeters shall be used. All other windings shall be open circuited. The power loss shall be measured when its value is stabilized. A correction shall be made for the internal losses of the wattmeter.

Information to be stated in the detail specification

- 1) The alternating voltage level.
- 2) The measuring frequency.
- 3) For polyphase components, details of the method.

2.4.5 Voltage proof (electric strength test)

Purpose. To demonstrate that the insulation of uniformly-insulated windings and the low-voltage end insulation of graded-insulated windings is adequate.

NOTE 1 This test is not suitable for the high-voltage end insulation of windings having graded-insulation or designed to have one point earthed. The high-voltage end insulation of such windings can only be tested by the application of an appropriate induced voltage test [see item b) of special conditions of test of 2.4.6].

NOTE 2 In certain cases it may be appropriate to demonstrate the adequacy of the low-voltage end insulation of graded-insulation windings during the induced voltage test [see item b) of special conditions of test of 2.4.6].

Procedure. Each winding in turn shall be short-circuited. An alternating test voltage at a frequency in the range 48 Hz to 62 Hz (unless otherwise specified in the detail specification) of appropriate value selected from Table 2 shall be applied.

Table 2 — Proof test voltages

Peak working voltage, V_p	Peak test voltage
V	V
≤ 25	70
> 25 to 50	140
> 50 to 100	420
> 100 to 175	700
> 175 to 700	$4 V_p$
> 700	$2 V_p + 1\,400$

The test voltage shall be applied between each separate winding and the remaining windings connected together and to the core, frame and screens, where possible.

In fluid-filled components, except for those designed for operation in one plane only and so marked, approximately half the quantity shall be tested with terminals uppermost and half with the terminals underneath.

The duration of the application of the test voltage shall be as specified in the detail specification, and is normally one of the following.

- a) 60 ± 5 s. The voltage shall be raised from one-third of the maximum value as is consistent with the time constant of the indicating instrument. The full test voltage shall be maintained for the specified duration and shall then be rapidly reduced to one-third of its value before being switched off.
- b) 5 s to 10 s (value to be stated).

Requirements. There shall be no heating, breakdown or deterioration. Ionization shall not be regarded as a criterion of breakdown.

Information to be stated in the detail specification

- 1) The peak working voltage for each winding (for a winding having graded-insulation, values shall be given for both ends of the winding).
- 2) The duration of application of the test voltage.
- 3) The frequency (if outside the range 48 Hz to 62 Hz).

2.4.6 Induced high voltage

Purpose. To verify the adequacy of interturn and interlayer insulation of transformers and inductors, and also to verify the adequacy of the high-voltage end insulation of windings having graded-insulation.

Special conditions of test. The following special conditions apply.

- a) Windings having uniform insulation are normally tested as in procedures 1, 2 or 3, as appropriate. Any point of a winding may be earthed during the test as specified.
- b) Windings having graded-insulation are normally tested as in procedures 1, 2 or 3, as appropriate. A point on such a winding may be earthed or raised to a specified voltage above earth during the test. The induced voltage shall be such that, when added vectorially to any applied voltage, the high-voltage end of the winding is raised to the appropriate peak test voltage given in Table 2 (see 2.4.5).