INTERNATIONAL STANDARD

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2005-02

**Polymeric thermistors –
Directly heated positive step function temperature coefficient –**

**Part 1:
Generic specification**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

POLYMERIC THERMISTORS – DIRECTLY HEATED POSITIVE STEP FUNCTION TEMPERATURE COEFFICIENT –

Part 1: Generic specification

FOREWORD

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International Standard IEC 62319-1 has been prepared by IEC technical committee 40: Capacitors and resistors for electronic equipment.

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

FDIS	Report on voting
40/1505/FDIS	40/1534/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- withdrawn;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.

The contents of the corrigendum of March 2009 have been included in this copy.

POLYMERIC THERMISTORS – DIRECTLY HEATED POSITIVE STEP FUNCTION TEMPERATURE COEFFICIENT –

Part 1: Generic specification

1 General

1.1 Scope

This part of IEC 62319 prescribes terms and methods of test for polymeric positive temperature coefficient thermistors, insulated and non-insulated types, typically intended for use in current limiting and overcurrent protection applications.

It establishes standard terms, inspection procedures and methods of test for use in detail specifications for Qualification Approval and for Quality Assessment Systems for electronic components.

1.2 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 60027-1: *Letter symbols to be used in electrical technology – Part 1: General*

IEC 60050: *International Electrotechnical Vocabulary*

IEC 60068-1: *Environmental testing – Part 1*: *General and guidance*

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

IEC 60068-2-14: *Environmental testing – Part 2: Tests – Test N: Change of temperature*

IEC 60068-2-20: *Environmental testing – Part 2: Tests – Test T: Soldering*

IEC 60068-2-21: *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27: *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock*

IEC 60068-2-29: *Environmental testing – Part 2: Tests – Test Eb and guidance: Bump*

IEC 60068-2-45: *Environmental testing – Part 2: Tests – Test XA and guidance: Immersion in cleaning solvents*

IEC 60294: *Measurement of the dimensions of a cylindrical component having two axial terminations*

IEC 60410: *Sampling plans and procedures for inspection by attributes.*

IEC 60617-DB: 2001[1] *Graphical symbols for diagrams*

IECQ 001003: *IEC Quality Assessment System for Electronic Components – Guidance documents*

IECQ 001002-3: *IEC Quality Assessment System for Electronic Components – Rules of Procedure – Part 3: Approval procedures*

ISO 1000: *SI units and recommendations for the use of their multiples and of certain other units*

2 Technical data

2.1 Units and symbols

Units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following documents:

IEC 60027

IEC 60050

IEC 60617

ISO 1000

The following subclauses contain additional terminology applicable to thermistors.

Where further items are required they shall be derived in accordance with the principles of the documents listed above.

2.2 Terms and definitions

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

2.2.1
thermistor
thermally sensitive semiconducting resistor whose primary function is to exhibit an important change in electrical resistance with a change in body temperature

2.2.2
positive temperature coefficient thermistor
thermistor in which the resistance increases with increasing temperature throughout the useful part of its characteristic. The PTC thermistors covered in this specification typically exhibit a very sharp increase in resistance over a narrow temperature range

2.2.3
directly heated positive temperature coefficient thermistor
thermistor in which the change in temperature is obtained either by the flow of current through the thermo-sensitive element, or by a change in ambient temperature, or by a combination of both of these means

[1] "DB" refers to the IEC on-line database.

2.2.4
zero power resistance
R_T
value of the resistance of a PTC thermistor, at a given temperature, under such conditions that the change in resistance due to the internal generation of heat is negligible with respect to the total error of measurement

NOTE Any resistance value of a PTC thermistor is dependent on the value and the mode of the applied voltage (AC or DC).

2.2.5
nominal zero power resistance
R_n
zero power resistance used as a reference value for which the following conditions should be given in the detail specification:

a) reference temperature, preferably 25 °C

b) applied voltage (DC or AC)

2.2.6
resistance/temperature characteristics
relationship between the zero power resistance of a thermistor and the temperature of the thermosensitive element when measured under specified reference conditions

2.2.7
upper category temperature
UCT
maximum ambient operating temperature of the thermistor

2.2.8
lower category temperature
LCT
minimum ambient operating temperature of the thermistor

2.2.9
trip event
event of rapid increasing resistance of the thermistor in response to an overcurrent surge

2.2.10
minimum initial resistance
R_{min}
minimum resistance of the thermistor

2.2.11
maximum initial resistance
R_{max}
maximum resistance of the thermistor before it's initial trip event

2.2.12
maximum resistance 1 h after tripping
R_{1max}
for leaded thermistors the maximum resistance of the thermistor 1 h after it's first trip event; for surface mount thermistors, the maximum resistance of the thermistor 1 h after reflow

2.2.13
maximum voltage
U_{max}
maximum AC or DC voltage which may be applied to the thermistor

2.2.14
operating temperature range at maximum voltage
range of ambient temperatures at which the thermistor can operate at the maximum voltage

2.2.15
isolation voltage (applicable only to insulated thermistors)
maximum peak voltage which may be applied under continuous operating conditions between any of the thermistor terminations and any conducting surface

2.2.16
maximum current
I_{max}
value of current for the operating temperature range, which should not be exceeded

2.2.17
residual current
I_{res}
value of current in the tripped thermistor at a specified ambient temperature (preferably 25 °C) under steady state conditions; the applied voltage is the maximum voltage unless otherwise specified

2.2.18
trip current
I_t
lowest current which will cause the thermistor to trip to its high resistance state at a specified temperature (preferably 25 °C) and within a time specified in the detail specification

2.2.19
hold current
I_h
the maximum current at specified ambient temperature, preferably 25 °C, which will not cause the trip event

2.2.20
fault current
I_{fault}
current used when measuring time to trip

2.2.21
power dissipation
P_d
product of the current flowing through a device and the voltage across it, under steady state conditions; the applied voltage is the maximum voltage unless otherwise specified

2.2.22
time-to-trip
t_{trip}
under specified ambient conditions, starting from the time the fault current (I_{fault}) is applied, the time-to-trip is the time required for a device to switch into the tripped state

2.2.23
insulated thermistors
thermistors capable of meeting the requirements of the insulation resistance and voltage proof tests when specified in the test schedule

2.3 Preferred values

2.3.1 Climatic categories

The thermistors covered by this specification are classified into climatic categories according to the general rules given in the annex to IEC 60068-1. The detail specification prescribes the appropriate category.

2.3.2

Void

2.3.3 Shock test severities

Test severities given in detail specifications shall preferably be the following:

Test Ea (IEC 60068-2-27)

Pulse shape: Half sine

Acceleration: 500 m/s^2

Pulse duration: 11 ms.

Severity: 3 successive shocks in each axis direction per specimen. Separate specimens to be used for each axis (6 shocks total per specimen).

NOTE The shock and bump tests are normally specified as alternatives.

2.3.4 Vibration severities

Test severities given in the detail specifications shall preferably be selected from the following:

Test Fc (IEC 60068-2-6)

Frequency range: 10 Hz to 55 Hz or 10 Hz to 500 Hz

Amplitude: 0,75 mm or 100 m/s^2 (whichever is the less severe)

Sweep endurance: Total duration 6 h.

Thermistors shall be mounted by their normal means, in such a manner that there shall be no parasitic vibration. During vibration testing there shall be no interruption in electrical continuity greater than 0,5 ms.

2.4 Marking

2.4.1 General

The following shall be clearly marked on the thermistor in the following order of precedence as space permits:

a) values of the primary characteristics appropriate to the application of the thermistor to be specified in the detail specification. When these values are coded (including colour coding), details shall be given in the detail specification or type designation;

b) manufacturer's name and/or trade mark;

c) date of manufacture or date code;

d) the number of the detail specification and style.

The package containing the thermistors shall be clearly marked with all the information listed above.

Any additional marking shall be so applied that no confusion can arise.

3 Quality assessment procedures

3.1 General

When these documents are being used for the purposes of a full quality assessment system such as the IEC Quality Assessment System for Electronic Components (IECQ), compliance with 3.5 is required.

When these documents are used outside such quality assessment systems for purposes such as design proving or type testing, the procedures and requirements of 3.5.1 and 3.5.3 b) may be used, but if used, the test and parts of tests shall be applied in the order given in the test schedule.

Before thermistors can be qualified according to the procedures of this clause, the manufacturer shall obtain the approval of his organisation in accordance with the provisions of IECQ 001002-3.

The method for the approval of thermistors of assessed quality given in 3.5 is qualification approval according to the provisions of Clause 3 of IECQ 001002-3.

3.1.1 Applicability of qualification approval

Qualification approval is appropriate for a standard range of thermistors manufactured to similar design and production processes and conforming to a published detail specification.

The programme of tests defined in the detail specification for the appropriate assessment and performance levels applies directly to the subfamily of thermistors to be qualified, as prescribed in 3.5 and the relevant blank detail specification.

3.2 Primary stage of manufacture

The primary stage of manufacture is defined as the initial compounding process of the ingredients.

3.3 Subcontracting

If subcontracting of the primary stage of manufacture and/or subsequent stages is employed it shall be in accordance with 4.2.2 of IECQ 001002-3.

The blank detail specification may restrict subcontracting in accordance with 4.2.2.2 of IECQ 001002-3.

3.4 Structurally similar components

Thermistors may be grouped as structurally similar for the purpose of forming inspection lots provided the following requirements are met:

a) they shall be produced by one manufacturer on one site using essentially the same design, materials, processes and methods;

b) the sample taken shall be determined from the total lot size of the grouped devices;

c) structurally similar devices should preferably be included in one detail specification but the details of all claims to structural similarity shall be declared in the qualification approval test reports.

3.4.1 For electrical tests, devices having the same electrical characteristics may be grouped provided the element determining the characteristic is similar for all the devices concerned.

3.4.2 For environmental tests, devices having the same type of insulation, basic internal structure and finishing processes may be grouped.

3.4.3 For visual inspection (except marking), devices may be grouped if they have been made on the same production line, have the same dimensions, type of insulation and external finish.

This grouping may also be used for robustness of terminations and soldering tests where it is convenient to group devices with different internal structures.

3.4.4 For endurance tests, thermistors may be grouped if they have been made on the same production line using the same design and differing only in electrical characteristics. If it can be shown that one type from the group is more heavily stressed than the others then tests on this type may be accepted for the remaining members of the group.

3.5 Qualification approval procedures

3.5.1 Eligibility for qualification approval

The manufacturer shall comply with 3.1.1 of IECQ 001002-3.

3.5.2 Application of qualification approval

The manufacturer shall comply with 3.1.3 of IECQ 001002-3.

3.5.3 Test procedures for qualification approval

One of the two following procedures shall be followed:

a) the manufacturer shall produce test evidence of conformance to the specification requirements on three inspection lots for lot-by-lot inspection taken in as short a time as possible and one lot for periodic inspection. No major changes in the manufacturing process shall be made in the period during which the inspection lots are taken.

Samples shall be taken from the lots in accordance with IEC 60410. Normal inspection shall be used, but when the sample size would give acceptance on zero non-conformances, additional specimens shall be taken to meet the sample size requirements to give acceptance on one non-conforming item.

b) the manufacturer shall produce test evidence to show conformance to the specification requirements on the fixed sample size test schedule given in 3.5.4.

The specimens taken to form the sample shall be selected at random from current production or as agreed with the National Supervising Inspectorate (NSI).

For the two procedures, the same sample sizes shall be of comparable order. The test conditions and requirements shall be the same.

3.5.4 Qualification approval on the basis of the fixed sample size procedure

The fixed sample size test schedule for qualification approval given hereinafter is appropriate to the intended application of the thermistor that is to be approved. The schedule provides information on the test grouping and sampling and acceptance criteria. The conditions of test and the end of test requirements shall be identical to those specified in the related blank detail specification for the lot-by-lot and periodic tests.

Tests

The complete series of tests specified in Table 1 are required for the approval of thermistors covered by the detail specification. The tests of each group shall be carried out in the order given.

The whole sample shall be subjected to the tests of Group 0 and then divided for the other groups.

Non-conforming specimens during the tests of Group 0 shall not be used for the other groups.

“One non-conforming item” is counted when a thermistor has not satisfied the whole or a part of the tests of a group.

The approval is granted when the number of non-conformances does not exceed the specified number of permissible non-conforming items for each group or subgroup and the total number of permissible non conformances.

The following list applies to the test schedule detailed in Table 1:

a) clause number references are to clauses in this specification;

b) 1) where the test schedule of a blank detail specification omits a test, that test may be omitted from the fixed sample size schedule in this specification;

2) where additional tests are specified in the detail specification, that test shall be included in the fixed sample schedule, either by its addition to an existing group or, by the addition of another group. In the former case there shall be no change in the number of specimens to be tested or in the acceptance criteria. In the latter case the number of specimens to be tested and the acceptance criteria shall be comparable to those already specified;

c) in this table:

n is the sample size;

c is the group acceptance criteria (permitted number of defectives per group);

D indicates a destructive test;

ND indicates a non-destructive test;

d) the temperature at which the zero power resistance shall be measured is specified in the detail specification. The temperature shall be stated, where required, in the test schedule;

e) data for conditions of test are defined in the detail specification;

f) the additional specimens are to permit substitution for incidents not attributable to the manufacturer. The specimens may be used to replace non-conforming specimens which occur as a result of a test in a group which is identified as being “destructive”. Where a specimen is used for this purpose, it shall be subjected to those tests in the group to which the non-conforming item had already been subjected, before proceeding with the remaining tests in the group;

g) the specimens used for this group may, at the discretion of the manufacturer, be used for any subsequent group which is identified as being “destructive”;

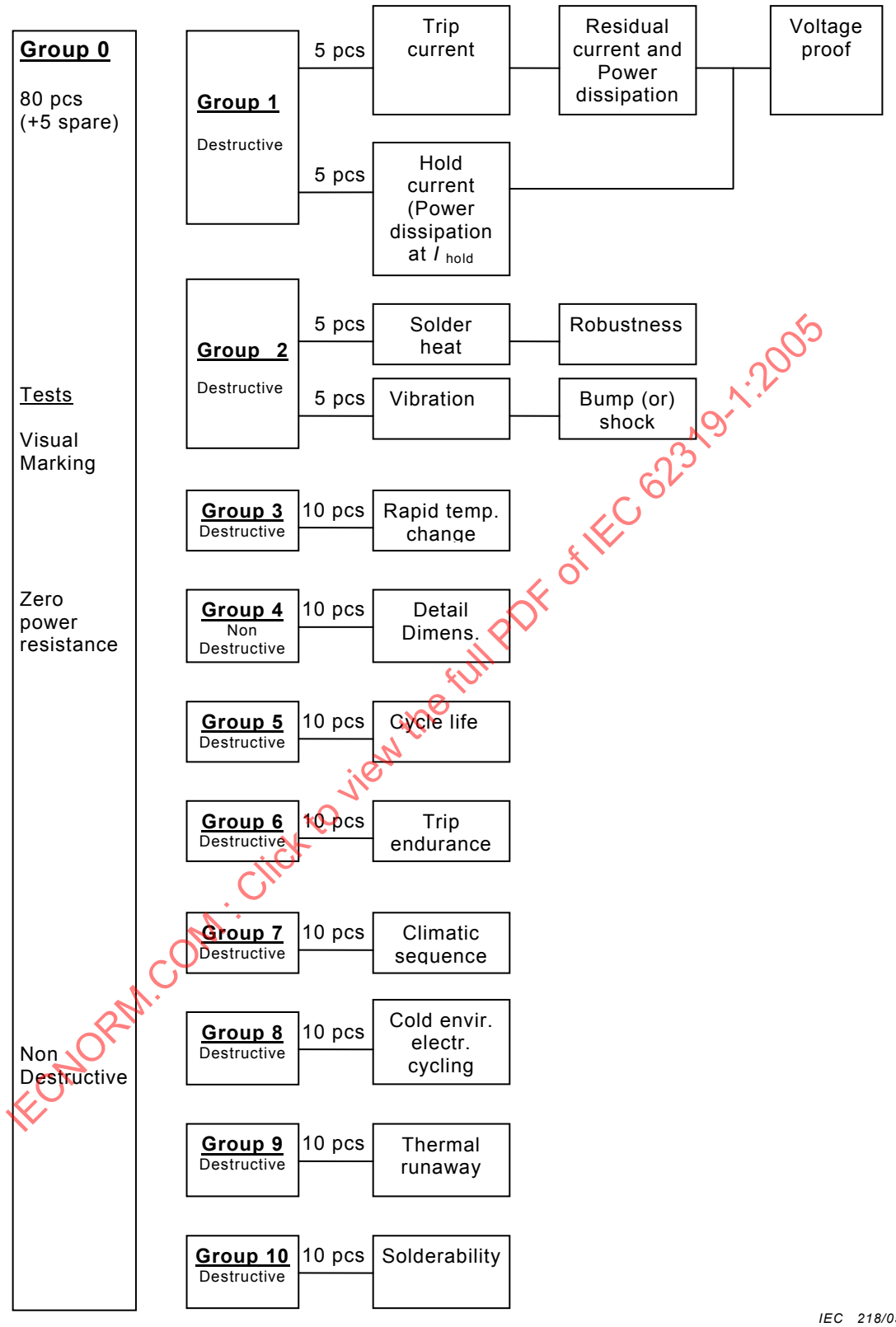
h) ten samples from Group 0 test samples have to be chosen, 5 having the lowest zero power resistance of the samples shall be used for Group 1A, 5 having the highest zero power resistance of the samples for Group 1B;

i) the soldering – solderability and soldering – resistance to soldering heat tests shall only be applied where the thermistor has terminations which are appropriate for soldering;

j) where the terminations are stated to be suitable for printed wiring applications, the appropriate test conditions in IEC 60068 shall apply;

k) the thermistors shall be mounted by their normal means;

l) the vibration, bump and shock tests are only conducted if required in the detail specification.



Vibration, bump and shock tests are not required but may be performed to obtain supplementary information.

Figure 1 – Test schedule flow chart

Table 1 – Fixed sample size test schedule for qualification approval of polymeric PTC thermistors for current limitation, assessment level EZ

Group No	Test	Clause/subclause of this standard	D or ND	Number of specimens *n*	Permissible number of non-conforming items *c*
0	Visual examination Marking Zero power resistance	4.3.1 4.3.2 4.4	ND	80 + 5	0
1			D		
1A	Trip current Residual current and power dissipation Voltage proof	4.14 4.16 4.6		5	0
1B	Hold current Power dissipation at I hold Voltage proof	4.15 4.6		5	0
2					
2A	Resistance to soldering heat Robustness of terminations	4.8.2 4.7	D	5	0
2B	Vibration Bump (or) shock	B.1 B.2 (or) B.3	D	5	0
3	Rapid change of temperature	4.10	D	10	0
4	Detail dimensions	4.3.3	ND	10	0
5	Cycle life	4.12	D	10	0
6	Trip endurance	4.13	D	10	0
7	Climatic sequence	4.11	D	10	0
8	Cold environmental electrical cycling	4.18	D	10	0
9	Thermal runaway	4.19	D	10	0
10	Solderability	4.8.1	D	10	0

3.5.5 Granting of qualification approval

Qualification approval shall be granted when the procedures in accordance with 3.1.4 of IECQ 001002-3 have been completed satisfactorily.

3.5.6 Maintenance of qualification approval

Qualification approval shall be maintained by regular demonstration of compliance with the requirements for quality conformance (see 3.5.7).

3.5.7 Quality conformance inspection

3.5.7.1 The blank detail specifications associated with this specification shall prescribe the test schedule for quality conformance inspection. This schedule shall also specify the grouping, sampling and periodicity for the lot-by-lot and periodic inspection (see Table 2 and Table 3).

Sampling plans and inspection levels shall be selected from those given in IEC 60410.

If required, more than one schedule may be specified.

An inspection lot shall consist of thermistors of the same style. It should be representative of those extremes of resistance and switching temperature range produced during the inspection period.

The sample for Groups C and D shall be collected over the last 13 weeks of the inspection procedure.

3.5.7.2 Assessment level

The assessment level given in the blank detail specification shall be in accordance with Table 2 and Table 3.

Table 2 – Quality conformance inspection for lot-by-lot inspection

Inspection subgroup[d]	Assessment level				
	EZ				
	IL[a]	*n*[a]	*c*[a]		
A0	100 %[b]				
A1	S-4	[c]	0		
A2	S-3	[c]	0		
B1	S-2	[c]	0		
B2	S-2		0		

[a] *IL* is the inspection level.

n is the sample size

c is the permissible number of non-conforming items

[b] 100 % testing shall be followed by re-inspection by sampling in order to monitor outgoing quality level by non-conforming items per million (10^{-6}). The sampling level shall be established by the manufacturer. For the calculation of 10^{-6} values parametric failures shall be counted as a non-conforming item. In case one or more non-conforming items occur in a sample, this lot shall be rejected.

[c] Number to be tested: sample size as directly allocated to the code letter for *IL* in Table IIA of IEC 60410 (single sampling plan for normal inspection)

[d] The content of the inspection subgroups is described in Clause 2 of the relevant blank detail specification.

Table 3 – Quality conformance inspection for periodic testing

Inspection subgroup [b]	Assessment level				
	EZ				
	p[a]	*n*[a]	*c*[a]		
C1A	24	5	0		
C1B	24	5	0		
C1	24	10	0		
C2A	24	5	0		
C2B	24	5	0		
C3	24	10	0		
C4	24	10	0		
D1	24	10	0		
D2	24	10	0		
D3	24	10	0		

[a] *p* is the periodicity in months;

n is the sample size;

c is the permissible number of non-conforming items.

[b] The content of the inspection subgroups is described in Clause 2 of the relevant blank detail specification.

3.6 Rework and Repair

3.6.1 Rework

Rework, as defined in 4.1.4 of IECQ 001002-3, shall not be carried out if prohibited by the relevant specification. The relevant specification shall state if there is a restriction on the number of occasions that rework may take place on a specific component.

All rework shall be carried out prior to the formation of the inspection lot offered for inspection to the requirements of the detail specification.

Such rework procedures shall be fully described in the relevant documentation produced by the manufacturer and shall be carried out under the direct control of the designated management representative (DMR). Rework shall not be subcontracted.

3.6.2 Repair

Thermistors which have been repaired as defined in IECQ 001002-3, shall not be released under the IECQ system.

3.7 Release for delivery

Thermistors shall be released for delivery according to 3.2.6 and 4.3.2 of IECQ 001002-3, after the Quality Conformance Inspection prescribed in the detail specification has been carried out.

3.7.1 Release for delivery under qualification approval before the completion of Group B tests

When the conditions of IEC 60410 for changing to reduced inspection have been satisfied for all Group B tests, the manufacturer is permitted to release components before the completion of such tests.

3.8 Certified test records of released lots

When certified test records are requested by a purchaser, they shall be specified in the detail specification.

3.9 Delayed delivery

Thermistors held for a period exceeding three years (unless otherwise specified in the relevant specification) following the release of the lot shall, before delivery, be re-examined as specified in the relevant specification.

The re-examination procedure adopted by the manufacturer's DMR shall by approved by the NSI.

Once a lot has been satisfactorily re-inspected, its quality is re-assured for the specified period.

3.10 Alternative test methods

See 3.2.3.7 of IECQ 001002-3 with the following details:

- in case of dispute, for referee and reference purposes, only the specified methods shall be used.

3.11 Manufacture outside the geographical limits of IECQ NSIs

A manufacturer may have his approval extended to cover part or complete manufacture of thermistors in a factory of his company located in a country which does not have a NSI for the technical area concerned, whether this country is a IECQ member country or not, provided that the requirements of 2.5.1.3 of IECQ 001002-3 are met.

3.12 Unchecked parameters

Only those parameters of a component which have been specified in a detail specification and which were subject to testing shall be assumed to be within the specified limits.

It cannot be assumed that any unspecified parameter will remain unchanged from one component to another. Should for any reason it be necessary for further parameters to be controlled, then a new, more extensive specification shall be used.

The additional test method(s) shall be fully described and appropriate limits, sampling plans and inspection levels specified.

4 Test and measurement procedures

This clause contains test and measurement procedures applicable to polymeric PTC thermistors.

4.1 Standard conditions for testing

Unless otherwise specified, all tests shall be carried out under standard atmospheric conditions for testing as specified in IEC 60068-1.

The thermistors shall attain thermal equilibrium before results are recorded.

The ambient temperature during the measurements shall be stated in the test report.

During measurements, the thermistor shall not be exposed to draughts, direct sun rays or other influences likely to cause error.

The total error of measurement from power dissipation, temperature tolerance and the tolerance of the measuring equipment shall not exceed 10 % of the tolerance in the detail specification.

The test shall be carried out in the prescribed order.

4.2 Drying and recovery

4.2.1 Drying

Where drying is called for in the specification, the thermistor shall be conditioned before measurement is made, using Procedure 1 or Procedure 2 as called for in the detail specification.

Procedure 1

For (24 ± 4) h in an oven at a temperature of (55 ± 2) °C and relative humidity not exceeding 20 %.

Procedure 2

For (36 ± 4) h in an oven at (100 ± 5) °C

The thermistor shall then be allowed to cool in a desiccator using a suitable desiccant such as activated alumina or silica gel, and shall be kept therein from the time of the removal from the oven to the beginning of the specified tests.

4.2.2 Recovery

Where recovery is required, the thermistor shall be stored at standard atmospheric conditions for testing for 1 h to 2 h.

4.3 Visual inspection and check of dimensions

4.3.1 Visual examination

The condition, workmanship and finish shall be satisfactory as determined by visual examination.

4.3.2 Marking

Marking shall be legible as determined by visual examination.

4.3.3 Dimensions (detail)

All dimensions prescribed in the detail specification shall be checked and they shall comply with the values prescribed. Where applicable, measurements shall be made in accordance with IEC 60294.

4.4 Zero-power resistance

4.4.1 The zero power resistance shall be measured at the temperature given in the detail specification.

4.4.2 The thermistors shall be mounted by their normal means.

All measurements shall be made without self-heating of the devices (zero power condition).

The measuring method shall be such that:

a) for absolute resistance measurement, the error does not exceed 10 % of the resistance tolerance;

b) for measurements of variation of resistance, the error does not exceed 10 % of the specified maximum change of resistance.

The zero power resistance shall be within the limits given in the detail specification.

4.5 Insulation resistance (for insulated types only)

4.5.1 The insulation resistance of the protective coating shall be measured.

4.5.2 According to the instructions given in the detail specification one of the following test methods is used.

Method 1

The thermistor is placed in a vessel containing metallic balls of (1,6 ± 0,2) mm diameter, so that only the insulated parts of the thermistor are immersed (the metal of the balls shall be such that it does not develop a resistive surface).

An electrode is placed in the metallic balls.

Method 2

A metal foil shall be wrapped closely around the body of the thermistor.

For those types not having axial terminations, a space of 1 mm to 1,5 mm, or as specified in the detail specification for devices with V_{max} > 100 V, shall be left between the edge of the foil and each termination. For those types having axial terminations, the foil shall be wrapped round the whole body of the thermistor protruding by at least 5 mm from each end, provided that the minimum space of 1 mm between the foil and the termination can be maintained. The ends of the foil shall not be folded over the ends of the thermistor.

4.5.3 The insulation resistance shall be measured with a direct voltage of (100 ± 15) V, or as specified in the detail specification for devices with V_{max} > 100 V, between both terminations of the thermistor connected together as one pole and the metallic balls, or metal foil as the other pole.

The voltage shall be applied for 1 min, or for such shorter time as is necessary to obtain a stable reading, the insulation resistance being read at the end of that period.

4.5.4 When thermistors are tested as specified, the insulation resistance shall be not less than the appropriate figure specified in the detail specification.

4.6 Voltage proof (for insulated types only)

4.6.1 The thermistors are tested as specified below.

4.6.2 As required by the detail specification one of the test methods given in 4.5.2 is used.

4.6.3 The applied voltage shall be that specified in the applicable safety document, otherwise it should be as follows:

- an alternating voltage with a frequency of 40 Hz to 60 Hz and with a peak value of 1,4 times the isolation voltage specified in the detail specification, shall be applied for 1 min ± 5 s between all terminations of the thermistor connected together as one pole and the metallic balls, or the metal foil as the other pole; the voltage shall be applied gradually at a rate of approximately 100 V/s.

4.6.4 There shall be no breakdown or flashover.

4.7 Robustness of terminations (for leaded types only)

a) The appropriate parameter(s) given in the detail specification shall be measured and shall be recorded.

b) The thermistors shall be subjected to the procedure of tests Ua, Ub and Uc of IEC 60068-2-21 as appropriate.

c) Tests Ub and Uc shall not be applied if the detail specification describes the terminations as rigid.

4.7.1 Test Ua – Tensile

The loading weight to be applied for 10 s shall be:

- for all types of terminations except wire terminations: 20 N;
- for wire terminations: see Table 4.

Table 4 – Loading weight for wire terminations

Cross-sectional area S of the wire mm²	Nominal diameter D mm	Load N
$S > 0,5$	$D > 0,8$	20
$0,2 < S \leq 0,5$	$0,5 < D \leq 0,8$	10
$0,1 < S \leq 0,2$	$0,35 < D \leq 0,5$	5
$S \leq 0,1$	$D \leq 0,35$	2,5

4.7.2 Test Ub – Bending (half the number of terminations – not applicable to thermistors encapsulated in glass or in envelopes)

Two consecutive bends shall be applied (Method 1).

4.7.3 Test Uc – Torsion (remaining terminations)

Two rotations of 180 ° shall be applied (Severity 2).

4.7.4 Visual examination

After each of these tests, the thermistors shall be visually examined. There shall be no visible damage.

4.7.5 Final measurements and requirements

After the test, the appropriate parameter(s) given in the detail specification shall be measured and shall comply with the requirements prescribed in the detail specification.

4.8 Soldering

These tests only apply to devices which require termination by soldering.

4.8.1 Solderability

The thermistors shall be subjected to Test Tb of IEC 60068-2-20 for leaded thermistors and to Test Td of IEC 60068-2-58 for surface mount thermistors. The relevant detail specification shall prescribe which method is preferred and shall give the additional information as required in the above referenced standards.

The thermistors shall be visually examined. Immersed parts shall be correctly tinned.

4.8.2 Resistance to soldering heat (for leaded devices only)

The appropriate parameter(s) given in the detail specification shall be measured using the method specified and shall be recorded.

The thermistors shall be subjected to the resistance to soldering heat test using Method 1A of Test Tb of IEC 60068-2-20. All terminations of the thermistor shall be tested.

The thermistors shall be visually examined. There shall be no visible damage.

After recovery according to 4.2, the appropriate parameter(s) given in the detail specification shall be measured, and shall comply with the requirements prescribed in the detail specification.

4.9 Mounting

4.9.1 Surface mount thermistors shall be mounted on a suitable substrate, the method of mounting will depend on the thermistor construction. The substrate material shall normally be 1,6 mm thick epoxide woven glass fabric laminated printed board or an 0,635 mm alumina substrate and shall not affect the result of any test or measurement. The detail specification shall indicate which material is to be used for the electrical measurements.

The substrate shall have metallized land areas of proper spacing to permit mounting of surface mount thermistors and shall provide electrical connection to the surface mount thermistor terminals. The details shall be specified in the detail specification

If another method of mounting applies, the method should be clearly described in the detail specification.

4.9.2 When the detail specification specifies wave soldering, a suitable glue, details of which may be specified in the detail specification, shall be used to fasten the component to the substrate before soldering is performed.

Small dots of the glue shall be applied between the conductors of the substrate by means of a suitable device securing repeatable results.

The surface mount thermistors shall be placed on the dots using tweezers. To ensure that no glue is applied to the conductors, the surface mount thermistors shall not be moved about.

The substrate with the surface mount thermistors shall be heat-treated in an oven at 100 °C for 15 min.

The substrate shall be soldered in a wave soldering apparatus. The apparatus shall be adjusted to have a pre-heating temperature of 80 °C to 100 °C, a solder bath at 260 °C ± 5 °C and a soldering time of 5 s ± 0,5 s.

The soldering operation shall be repeated once more (two cycles in total).

The substrate shall be cleaned for 3 min in a suitable solvent (see 3.1.2 of IEC 60068-2-45).

4.9.3 When the detail specification specifies reflow soldering, the following mounting procedure applies:

a) the solder used in preform or paste form shall be silver bearing (2 % minimum) eutectic Sn/Pb solder together with a non-activated flux as stated in IEC 60068-2-20 Test T: Soldering. Alternative solders such as 60/40 or 63/37 may be used on surface mount thermistors whose construction includes solder leach barriers;

b) the surface mount thermistor shall then be placed across the metallized land areas of the test substrate so as to make contact between thermistor and substrate land areas;

c) the substrate shall then be placed in or on a suitable heating system (molten solder, hot plate, tunnel oven etc.). The temperature of the unit shall be maintained between 215 °C and 260 °C, until the solder melts and reflows forming a homogeneous solder bond, but for not longer than 10 s.

NOTE 1 Flux should be removed by a suitable solvent (see 3.1.2 of IEC 60068-2-45). All subsequent handling should be such as to avoid contamination. Care should be taken to maintain cleanliness in test chambers and during post test measurements.

NOTE 2 The detail specification may require a more restricted temperature range.

NOTE 3 If vapour phase soldering is applied, the same method may be used with the temperatures adapted.

4.10 Rapid change of temperature

The appropriate parameter(s) given in the detail specification shall be measured using the method specified and shall be recorded.

The thermistors shall then be subjected to Test Na of IEC 60068-2-14 for five cycles. The time of exposure at each extreme temperature is 30 min.

The thermistors shall be visually examined. There shall be no visible damage.

After recovery according to 4.2, the appropriate parameter(s) given in the detail specification shall be measured and shall comply with the requirements in the detail specification.

4.11 Climatic sequence

In the climatic sequence, an interval of not more than three days is permitted between any of these tests, except between damp heat, cyclic, first cycle and dry cold. In this case the cold test shall follow immediately after the recovery period specified for the damp heat test.

The test and measurements shall be performed in the order stated hereinafter.

4.11.1 Initial measurements

The thermistors shall be dried using Procedure 1 of 4.2.1. The appropriate parameters given in the detail specification shall be measured using the method specified and shall be recorded.

4.11.2 Dry heat

The thermistors shall be subjected to the procedure of Test Bd of IEC 60068-2-2 for a duration of 16 h, using the appropriate degree of severity.

4.11.3 Damp heat (cyclic) first cycle

The thermistors of categories -/-/56, -/-/21, -/-/10 and -/-/04 shall be subjected to Test Db of IEC 60068-2-30 for one cycle of 24 h. After recovery, the thermistors shall be subjected immediately to the cold test.

4.11.4 Cold

The thermistors shall be subjected to the procedure of Test Aa of IEC 60068-2-1 for a duration of 2 h, using the appropriate degree of severity.

4.11.5 Low air pressure

The thermistors shall be subjected to the procedure of Test M of IEC 60068-2-13 using the appropriate degree of severity. The test shall be made at any temperature between 15 °C and 35 °C and the duration of the test shall be 1 h.

4.11.6 Damp heat (cyclic) remaining cycles

The thermistor shall be subjected to the procedure of test Db of IEC 60068-2-30, for the following number of cycles:

Table 5 – Number of cycles

Categories	Number of cycles
-/-/56	5
-/-/21	1
-/-/10	1
-/-/04	0

After the test, the thermistors shall be subjected to recovery according to 4.2.

4.11.7 Final measurements

The thermistors shall be visually examined. There shall be no visible damage and the marking shall be legible.

The appropriate parameter(s) given in the detail specification shall be measured and shall comply with the requirements in the detail specification.

For insulated types, the insulation resistance shall be measured according to 4.5 and shall be not less than that specified in the detail specification. The thermistors shall withstand the voltage proof test as defined in 4.6 without breakdown or flashover.

4.12 Cycle life testing

The thermistors shall be subjected to cycle life testing at ambient temperature under standard atmospheric conditions of testing (IEC 60068-1).

For all thermistors, the cycle described by “time on” and “time off” will be defined in the detail specification.

Thermistors with wire leads shall be connected so that their terminations have an effective length of 20 mm to 25 mm unless otherwise specified in the detail specification.

Other thermistors shall be mounted by their normal means as prescribed in the detail specification.

The thermistors shall be so placed that the temperature of any one thermistor shall not appreciably influence the temperature of any other thermistor. There shall be no undue draught on the thermistor.

For high breaking current devices *Test a)* will be applied and for low breaking current devices *Test b)* should be used.

Test a) – High breaking current thermistors (I_{max} > 100 A)

For high breaking current thermistors (I_{max} > 100 A) the number of cycles will be specified in the detail specification (see NOTE 13 in Annex A). The applied voltage will be U_{max} and the current should be at least large enough to switch the thermistor into the high resistance state ($I_e \geq I_t$). During the "time on" period of each cycle, the thermistor must enter the high resistance state.

After the specified number of cycles, the thermistor shall be allowed to recover under standard atmospheric conditions of testing for not less than 1 h. The removal from test shall take place at the end of the "time off" period.

After cycling, the thermistors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The appropriate parameter(s) as given in the detail specification shall be measured using the method specified. The thermistor must still perform its safety function as defined in the detail specification.

Test b) – Low breaking current thermistors ($I_{max} \leq 100$ A)

For low breaking current thermistors ($I_{max} \leq$ 100 A) the devices will be subjected to 10 cycles at maximum voltage (U_{max}) and 120 % of maximum current (I_{max}). Each cycle is comprised of energising the thermistor for a period "time on" and then allowing the thermistor to reset by removing the power to the device for the period "time off".

After 10 cycles, the thermistor is allowed to cool under standard atmospheric conditions for not less than 1 h. The removal shall take place after the "time off" period. The resistance of the thermistor shall be recorded.

Having completed the initial 10 cycles, the low current thermistors will then be tested for a further 6 000 cycles at maximum voltage (U_{max}) and a current large enough to switch the device (typically 5 times specified hold current for the device). During the "time on" period of each cycle, the thermistor must enter the high resistance state.

After the specified number of cycles, the thermistor shall be allowed to recover under standard atmospheric conditions of testing for not less than 1 h. The removal from test shall take place at the end of the "time off" period.

After cycling, the thermistors shall be visually examined.

There shall be no visible damage and the marking shall be legible.