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# SPECIFICATION FOR FIXED CAPACITORS USED IN ELECTRONIC EQUIPMENT

## PART I - GENERAL REQUIREMENTS

SRI LANKA STANDARDS INSTITUTION

DRAFTING COMMITTEE ON FIXED CAPACITORS USED IN ELECTRONIC EQUIPMENT

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# PART 1 - GENERAL REQUIREMENTS

## FOREWORD

This Sri Lanka Standard was authorised for adoption and publication by the Council of the Sri Lanka Standards Institution on 1986-06-06 after the draft, finalised by the Drafting Committee on Fixed Capacitors used in Electronic Equipment, has been approved by the Electrical Engineering Divisional Committee.

This specification lays down the test methods and requirements for judging the electrical, mechanical and physical properties of capacitors used in electronic equipment.

This specification which covers the general aspects of capacitors must be referred to when other standards on specific types of capacitors are used. Other standards to be prepared in parts of this standard will cover different types of capacitors such as Ceramic dielectric, Polypropylene film dielectric metal foil capacitors for direct current.

All values in this specification have been given in metric units.

For the purpose of deciding whether a particular requirement of this specification is complied with, the final value observed or calculated expressing the result of a test or observation shall be rounded off in accordance with CS : 102. The number of significant figures to be retained in the rounded off values should be the same as that of the specified value in this specification.

The assistance derived from the publications of the International Electrotechnical Commission and Indian Standards Institution in the preparation of this specification is gratefully acknowleged.

## 1. SCOPE

This specification prescribes the general requirements and methods of test applicable to different types of fixed capacitors, intended for use in electronic and other similar equipment.

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## 2. REFERENCES

| | | |
|---|---|---|
| IEC | 63 | Preferred number series for resistors and capacitors |
| IEC | 68 | Part 2 : Basic environmental testing procedure. (This will be adopted as a Sri Lanka Standard) |
| CS | 103 | Preferred numbers |
| SLS | 374 | Standard atmospheric conditions for conditioning and testing |
| SLS | 520 | Marking Codes for resistors and Capacitors |
| SLS | 580 | Basic Environmental testing procedure |

## 3. DEFINITIONS

For the purpose of this specification the following definitions shall apply.

3.1 bipolar capacitor (for electrolytic capacitors) : An electrolytic capacitor designed to withstand an alternating voltage and/or reversal of the applied direct voltage.

3.2 a.c.capacitor : A capacitor designed essentially for application with alternating voltages.

3.3 pulse capacitor : A capacitor for use with pulses of current or voltage.

3.4 rated capacitance ($C_R$): The capacitance value for which the capacitor has been designed and which is usually indicated upon it.

3.5 category temperature range :The range of ambient temperatures for which the capacitor has been designed to operate continuously ; this is defined by the temperature limits of the appropriate category.

3.5.1 upper category temperature: The maximum ambient temperature for which a capacitor has been designed to operate continuously.

3.5.2 lower category temperature: The minimum ambient temperature for which a capacitor has been designed to operate continuously.

3.6 rated temperature : The maximum ambient temperature at which the rated voltage may be continuously applied.

3.7 rated voltage ($V_R$) : The maximum direct voltage or the maximum r.m.s. alternating voltage or peak value of pulse voltage which may be applied continuously to a capacitor at any temperature between the lower category temperature and the rated temperature.(see 3.6)

3.8 temperature derated voltage :For any temperature between the rated temperature and the upper category temperature, the temperature derated voltage is the maximum voltage that may be applied continuously to a capacitor.

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NOTE - Information on the voltage/temperature dependance at temperatures between the rated temperature and the upper category temperature should, if applicable, be given in the relevant standard specification.

3.9 surge voltage ratio : The quotient of the maximum instantaneous voltage which may be applied to the terminations of the capacitor for a specified time at any temperature within the category temperature range and the rated voltage or the temperature derated voltage as appropriate.

The number of times per hour that this voltage may be applied shall be specified.

3.10 rated ripple voltage: The r.m.s. value of the maximum allowable alternating voltage of a specified frequency superimposed on the d.c. voltage at which the capacitor may be operated continuously at a specified temperature. The sum of the direct voltage and the peak value of the alternating voltage or temperature derated voltage as applicable.

3.11 category voltage : The maximum voltage which may be applied continuously to a capacitor at its upper category temperature.

3.12 reverse voltage (for polar capacitors only): A voltage applied to the capacitor terminations in the reverse polarity direction.

3.13 rated ripple current : The r.m.s. value of the maximum allowable alternating current of a specified frequency, at which the capacitor may be operated continuously at a specified temperature.

3.14 time constant :The product of the insulation resistance and the capacitance. It is normally expressed in seconds.

3.15 tangent of loss angle (tan $\delta$): The power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage of specified frequency.

3.16 self-healing : The process by which the electrical properties of the capacitor, after a local breakdown of the dielectric, are rapidly and essentially restored to the values before the breakdown.

3.17 maximum temperature of a capacitor: The temperature at the hottest point of its external surface.

NOTE - The terminations are considered to be part of the external surface.

3.18 minimum temperature of a capacitor : The temperature at the coldest point of its external surface.

NOTE- The terminations are considered to be part of the external surface.

3.19 maximum storage temperature : The maximum permissible ambient temperature which the capacitor shall withstand in the non-operating condition without damage.

3.20 minimum storage temperature : The minimum permissible ambient temperature which the capacitor shall withstand in the non-operating condition without damage.

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3.21 variation of capacitance with temperature : The variation of capacitance with temperature can be expressed in two ways :

a) Temperature characteristic of capacitance.

b) Temperature coefficient of capacitance.

3.21.1 temperature characteristic of capacitance: The term characterizing this property applies mainly to capacitors of which the variations of capacitance as a function of temperature, linear or non-linear, cannot be expressed with precision and certainty.

The temperature characteristic of capacitance is the maximum reversible variation of capacitance produced over a given temperature range within the category temperature range. It is expressed normally as a percentage of the capacitance related to a reference temperature of 20° C. (The standard atmospheric temperature of 27°C as laid down in SLS 374 may also be taken as reference temperature).

3.21.2 temperature coefficient of capacitance and temperature cyclic drift of capacitance : The term characterizing these two properties apply to capacitors of which the variations of capacitance as a function of temperature are linear or approximately linear and can be expressed with a certain precision.

For these capacitors, the variation of capacitance for any temperature, within the category temperature range, can be analysed into two components.

3.21.2.1 temperature coefficient of capacitance ($\alpha$) : The rate of change of capacitance with temperature measured over a specified range of temperature. It is normally expressed in parts per million per degree celsius ($10^{-6}/^{\circ}$ C).

3.21.2.2 temperature cyclic drift of capacitance : The maximum irreversible variation of capacitance observed at room temperature during or after the completion of a number of specified temperature cycles. It is expressed normally as a percentage of the capacitance related to a reference temerature. This is normally 20° C.

(The standard atmospheric temperature 27 C as laid down in SLS 374 may also be taken as the reference temperature).

The conditions of measurement, during or after temperature cycling, a description of the temperature cycle and the number of cycles, shall be stated.

## 4. RATINGS AND CHARACTERISTICS

### 4.1 Rated voltage

Preferred values of rated direct voltage taken from $R_5$ and $R_{10}$ series of Table 3 of CS 103 : 1974 are as follows:

a) For voltage values less than 250V : 1V, 1.6V, 2.5V, 4V, 6.3V, and their decimal multiples ($R_5$ series)

b) For voltage values equal or greater than 250V : 250V, 315V, 350V, 400V, 450V (250, 315 and 400V are in accordance with the $R_{10}$ series. 350V and 450V are permitted in addition).

### 4.2 Rated capacitance and tolerances

Preferred values of rated capacitance and tolerances shall be taken from the series specified in IEC 63.

### 4.3 Climatic category

The capacitors covered by this standard are classified into climatic categories according to the rules given in SLS 580 Part 1.

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## 5. REQUIREMENTS

### 5.1 Electrical

#### 5.1.1 Leakage current

The relevant standard specification shall prescribe the leakage current limit at a reference temperature preferably 27° C and other specified temperatures.

#### 5.1.2 Capacitance

The capacitance when measured as in 7.1, shall comply with the rated value of capacitance within the appropriate tolerance.

#### 5.1.3 Tangent of loss angle

The value of tangent of loss angle when measured as in 7.2 shall conform to the requirements prescribed in the relevant standard specification.

#### 5.1.4 Impedance

The impedance when measured as in 7.4 shall conform to the requirements prescribed in the relevant standard specification.

#### 5.1.5 Inductance

The inductance when measured as in 7.5 shall conform to the requirements prescribed in the relevant standard specification.

#### 5.1.6 Insulation resistance

The insulation resistance when measured as in 7.6 shall conform to the requirements prescribed in the relevant standard specification.

#### 5.1.7 Voltage withstanding ability

There shall be no sign of breakdown during the test, when measured as in 7.7.

#### 5.1.8 Endurance

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to the capacitors when tested as in 7.8.

#### 5.1.9. Variation of capacitance with temperature

The capacitors shall conform to the requirements prescribed in the relevant standard specification when tested as in 7.9.

#### 5.1.10 Ability to withstand electrical surges

The capacitors shall conform to the requirements prescribed in the relevant standard specification when tested as in 7.10.

#### 5.1.11 Charge and discharge

The capacitors shall conform to the requirements prescribed in the relevant standard specification when tested as in 7.11.

#### 5.1.12 Characteristics at high and low temperatures

The capacitors shall conform to the requirements prescribed in the relevant standard specification when tested as in 7.12.

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## 5.2 Mechanical and physical

### 5.2.1 Robustness of terminations

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to the capacitors when tested as in 7.13.

### 5.2.2 Resistance to soldering heat

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to the capacitors when tested as in 7.14.

### 5.2.3 Solderability

The terminations of the capacitor shall have signs of good tinning as evidenced by free flowing of the solder with wetting of the termination when tested as in 7.15.

### 5.2.4 Ability to withstand rapid change of temperature

The capacitors shall conform to the requirements prescribed in the relevant standard specification. and there shall be no visible damage to the capacitors when tested as in 7.16.

### 5.2.5 Ability to withstand vibrations

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to the capacitors when tested as in 7.17.

### 5.2.6 Ability to withstand bumps

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to the capacitors when tested as in 7.18.

### 5.2.7 Ability to withstand shocks

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to the capacitors when tested as in 7.19.

### 5.2.8 Effectiveness of seals

The capacitors shall conform to the requirements prescribed in the relevant standard specification when tested as in 7.20.

### 5.2.9 Climatic sequence requirements

The capacitors shall conform to the requirements prescribed in the relevant standard specification when tested as in 7.21.

### 5.2.10 Damp heat, steady state

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to capacitors when tested as in 7.22.

### 5.2.11 Suitability of capacitors for use and storage at low & high temperature

The capacitors shall conform to the requirements prescribed in the relevant standard specification and there shall be no visible damage to the capacitors when tested as in 7.23.

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## 6. MARKING

6.1 The relevant standard specification shall indicate the identification criteria and other information to be shown on the capacitor and/or packing.

The order of priority for marking small capacitors shall be according to the relevant standard specification.

6.2 When coding is used for capacitance value, tolerance or date of manufacture, the method shall be selected from those given in SLS 520.

## 7. METHOD OF TESTS

### 7.1 Capacitance

7.1.1 The capacitance shall be measured at one of the following frequencies unless otherwise prescribed by the relevant standard specification.

Electrolytic Capacitance: 100 Hz to 120 Hz

other capacitors : $C_R \leq 1nF$ : 100 kHz or 1 MHz (1 MHz shall be reference).

: $1\ nF < C_R \leq 10\ \mu F$ : 1 kHz or 10 kHz (1 kHz shall be reference)

: $C_R > 10\ \mu F$ : 50 Hz or 100 Hz

The tolerance on all frequencies shall not exceed ± 20 per cent.

The measuring voltage shall not exceed 3 per cent of $V_R$ or 5V, whichever is the smaller, unless otherwise prescribed in the relevant standard specification.

7.1.2 The accuracy of the measuring equipment shall be such that the error does not exceed:

a) for absolute capacitance measurements : 10 per cent of the rated capacitance tolerance or 2 per cent absolute, whichever is the smaller ;

b) for measurement of variation of capacitance : 10 per cent of the specified maximum change of capacitance.

In neither of cases a) and b) should the accuracy be better than the minimum absolute measurement error prescribed in the relevant standard specification.

7.1.3 The relevant standard specification shall prescribe :

a) the temperature for measurement if different from the standard atmospheric conditions for testing ;

b) the frequencies for measurement and the capacitance range over which they apply, if different from those specified in 7.1.1

c) the absolute measurement error, when applicable.

d) measuring voltage if different from those specified in 7.1.1.

e) the applied polarizing voltage, when applicable.

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## 7.2 Tangent of loss angle

7.2.1 The tangent of loss angle shall be measured under the same conditions as those given for the measurement of capacitance at once or more frequencies taken from the list of 7.1.1 or as prescribed in the relevant standard specification.

7.2.2 The measuring method shall be such that the error does not exceed 10 per cent of the specified value or 0.0001, whichever is the greater.

## 7.3 Leakage current

7.3.1 Before this measurement is made, the capacitors shall be fully discharged.

7.3.2 The leakage current shall be measured, unless otherwise prescribed in the relevant standard specification, using the direct voltage ($V_R$ or $V_C$) appropriate to the test temperature, after a maximum electrification period of five minutes. The full five minute electrification need not be applied if the specified leakage current limit is reached in a shorter time.

7.3.3 A steady source of power such as a regulated power supply shall be used.

7.3.4 The measurement error shall not exceed + 5 per cent or 0.1 µA, whichever is the greater.

7.3.5 When prescribed in the relevant standard specification, a 1000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current.

7.3.6 The relevant standard specification shall prescribe:

a) the leakage current limit at a reference temperature of 27°C, and at other specified temperatures ;

b) when necessary, the correction factor, if the measurements are made at a temperature other than 27°C, but within the range of temperature covered by the standard atmospheric conditions for testing ;

c) electrification time if different from 5 min ;

d) whether or not a 1000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current as defined in 7.3.5.

## 7.4 Impedance

The basic method of measurement of impedance of a capacitor is to pass a known current through it and to measure the voltage across it. At frequencies of 100 kHz or less, this is relatively simple, but at higher frequencies, care is necessary by the use of coaxial cables and screening to avoid spurious coupling.

The basic circuit diagram is shown in Fig. 1 where the impedance of the capacitor be given by ;

$$Z_c = R_c + j\left(wL_c - \frac{1}{wC}\right)$$
$$= R_c + jX_c$$

where,

$Z_c$ = impedance of the capacitor at the frequency of measurement;

$R_c$ = effective series resistance of the capacitor;

$w$ = $2\pi f$, f being the frequency of measurement ;

$L$ = inductance of the capacitor ; and

$C$ = capacitance of the capacitor at the frequency of measurement.

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Using the notation of Fig. 2

$$I_{in} = \frac{V_{R_s}}{R_s}$$

$$V_{out} = I_{in} Z_c = \frac{V_{R_s}}{R_s} \times Z_c$$

Therefore

$$|Z_c| = \frac{V_{out}}{V_{R_s}} \times R_s$$

This equation can be used to determine the impedance at any frequency.

NOTE - The loss angle ($\delta$) can be computed using the vector diagram in Fig.1.

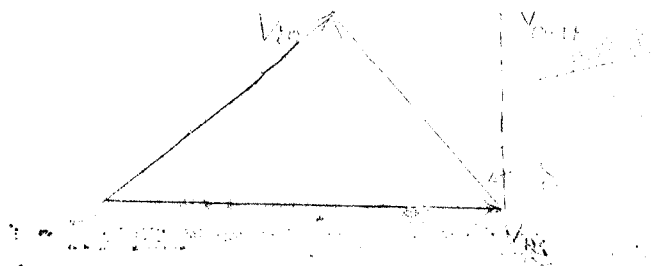

FIGURE 1 - Veeter diagram indicating loss angle

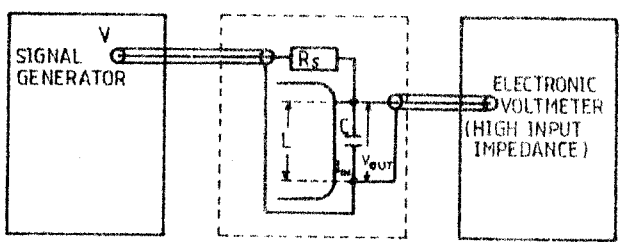


FIGURE 2 - Method of determination of impedance, resonant frequency or inductance of capacitors

C = capacitor under test

$R_s$ = non-inductive resistor approximately equal to the output impedance of the signal generator (normally 50 Ω or 75 Ω)

L = specified length (terminal wire and body) at which measurement is made

$V_{in}$ = voltage output of the signal generator with the measuring circuit connected

$I_{in}$ = current in the measuring circuit

$V_{out}$ = voltage measured across the capacitor as indicated by the electronic voltmeter

$V_{R_s}$ = voltage measured across $R_s$

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## 7.5 Inductance

The inductance shall be measured using resonance frequency method.

at resonance,

$$wL_c = \frac{1}{wC} \text{ and}$$

$$Z_c = R_c$$

Thus Z passes through a minimum at the resonant frequency ($w_o = 2\pi f_o$)
This is a convenient way of determining the inductance which is given by:

$$L = \frac{1}{w_o^2 C}$$

## 7.6 Insulation resistance

7.6.1 Before this measurement is made, the capacitors shall be fully discharged.

7.6.2 Unless otherwise specified in the relevant standard specification, the insulation resistance shall be measured, with the voltage specified in Table 1 between the points specified in Table 2.

Table 4 - Measuring voltages for capacitors of different voltage ratings

| Voltage rating of capacitor | Measuring voltage |
|---|---|
| $V_R$ or $V_C$ < 10V | $V_R$ ± 10 per cent |
| 10V ≤ $V_R$ or $V_C$ < 100V | 10 ± 1V* |
| 100V ≤ $V_R$ or $V_C$ < 500V | 100 ± 15V |
| 500V ≤ $V_R$ or $V_C$ | 500 ± 50V |

* When it can be demonstrated that the voltage has no influence on the measuring result, that a known relationship exists, measurement can be performed at voltages up to the rated voltage (10V shall be used in case of dispute).

$V_R$ is the rated voltage for use in defining the measuring voltage to be used under standard atmospheric conditions for testing.

$V_C$ is the category voltage for use in defining the measuring voltage to be used at the upper category temperature.

Table 2 - Measuring points

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| Test | 1) Single section capacitors | 2) Multiple section capacitors having a common termination for all sections | 3) Multiple section capacitors having no common termination |
| A. Between terminations | 1a) Between terminations | 2a) Between each of the terminations and the common termination | 3a) Between terminations of each section |
| B. Internal insulation | 1b) Between terminations connected together and the case (except where the case is one termination) (metal cased types only) | 2b) Between all terminations connected together and the case (except where the case is one of the terminations) (metal cased types only) | 3b) Between all terminations connected together and the case (metal cased types only) |
| | | 2c) Between the non-common termination of each section and all the other terminations connected together | 3c) Between the terminations of separate sections, the two terminations of each section being connected together |
| C. External insulation | 1c) Between terminations connected together and the metal plate or foil (insulated types not employing metal cases)<br>1d) Between case and the metal plate or foil (insulated metal cased types only) | 2d) Between all terminations connected together and the metal plate or foil (insulated types not employing metal cases)<br>2e) Between case and the metal plate or foil (insulated metal cased types only) | 3d) Between all terminations connected together and the metal plate or foil (insulated types not employing metal cases)<br>3e) Between case and the metal plate or foil (insulated metal cased types only) |

7.6.3 For test ii and iii (see Table 2) when the case of the capacitor is non-metallic, or when the capacitor has a metallic case with an insulating sleeve, the test voltage shall be applied in one of the following ways:

7.6.3.1 Foildmethod

A metal foil shall be closely wrapped around the body of the capacitor to a distance of not less than 0.5 mm from the terminations.

7.6.3.2 Method for capacitors with mounting devices

The capacitor shall be mounted in its normal manner on a metal plate which extends at least 13 mm in all directions beyond the mounting face of the capacitor.

7.6.3.3 V-block method

The capacitor shall be clamped in the trough of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block. The clamping force shall be such as to guarantee adequate contact between the capacitor and the block. The clamping force is to be chosen in such a way that no destruction or damage to the capacitor occurs. The capacitor shall be positioned in accordance with the following :

a) For cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block.

b) For rectangular capacitors: the capacitor shall be positioned in the block so that the termination nearest to the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors with axial leads, any out-of-centre positioning of the point of emergence of the terminations from the capacitor body shall be ignored.

7.6.4 The insulation resistance shall be measured after the voltage has been applied for 1 min ± 5s unless otherwise prescribed in the relevant standard specification.

7.6.5 When prescribed in the relevant standard specification, the temperature at which the measurement is made shall be noted. If this temperature differs from 27°C, a correction shall be made to the measured value by multiplying the value by the appropriate correction factor prescribed in the relevant specification.

7.6.6 The relevant standard specification shall prescribe:

a) the measuring voltage and measuring points;

b) the method of applying the test voltage (either 7.6.3.1, 7.6.3.2. or 7.6.3.3);

c) time of electrification if other than 1 min ;

d) any special precautions to be taken during measurement;

e) any correction factor required for measurement over the range of temperature covered by the standard testing conditions ;

f) the temperature of measurement if other than the standard atmospheric conditions for testing ;

g) the minimum value of insulation resistance for the various measuring points (see Table 2).

7.7 Voltage proof

The test prescribed below is a d.c. voltage proof test. When the relevant standard specification prescribes an a.c. voltage proof test, the same test procedure shall be used, except that an alternating voltage shall be applied in place of a direct voltage.

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7.7.1 An example of a suitable test circuit is shown in Fig.2 below:

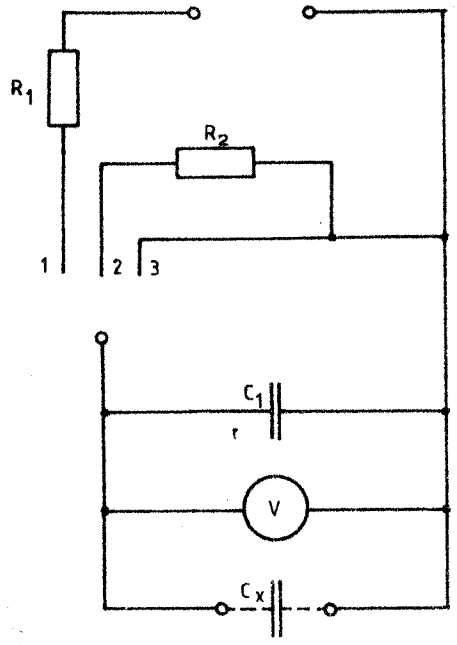


FIGURE 3 - Voltage proof test circuit

NOTE- The capacitor $C_1$ may be omitted for the testing of certain types of capacitors. This should be stated in the relevant standard specification.

7.7.2 The sensitivity of the voltmeter shall be not less than 10000 Ω/V.

7.7.3 The resistance $R_1$ and $R_2$ shall be chosen so that, in conjuction with the capacitance $C_1$ and the capacitance of the part under test, the charging and discharging currents do not exceed the specified value at the highest test voltage. The capacitance of $C_1$ shall be at least ten times the capacitance of the part under test.

7.7.4 The switch shall be connected to $R_2$. The two terminals at the top of the diagram shall be connected to a variable d.c. supply of sufficient power which shall be adjusted to the required test voltage. The capacitor to be tested ($C_x$) shall be connected as indicated in the Fig. 3.

The switch shall then be connected to $R_1$ so that the capacitors $C_1$ and $C_x$ are charged.

The switch shall remain in this position for the time specified after the test voltage has been reached. The capacitor shall be discharged by connecting the switch to $R_2$. As soon as the voltmeter reading has fallen to zero, the capacitors shall be short-circuited and $C_x$ shall be disconnected.

7.7.5 For tests ii and iii (see Table 2) when the case of the capacitor is non-metallic or when the capacitor has a metallic case with an insulating sleeve, the test voltage shall be applied in one of the three following ways:

7.7.5.1 A metal foil shall be closely wrapped around the body of the capacitor to a distance from the terminations equal to approximately 1 mm/kV test voltage with a minimum of 0.5 mm. The test voltage shall be applied between the terminations connected together and this foil.

7.7.5.2 The capacitor shall be mounted in its normal manner on a metal plate, which extends at least 13 mm beyond the mounting face of the capacitor in all directions ; the test voltage shall be applied between the terminations connected together and the metal plate.

7.7.5.3 The capacitor shall be clamped in the trough of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block. The clamping force shall be such as to guarantee adequate contact between the capacitor and the block.

The capacitor shall be positioned in accordance with the following:

a) For cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block.

b) For rectangular capacitors: the capacitor shall be positioned in the block so that the termination nearest to the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors with exial leads, any out-of-centre positioning of the point of emergence of the terminations from the capacitor body shall be ignored.

7.7.6 Repeated application of the voltage proof test may cause permanent damage to the capacitor and should be avoided as far as possible.

7.7.7 The relevant standard specification shall prescribe:

a) the test voltage and test points (see Table 2) ;

b) the method of applying the test voltage (either 7.7.5.1, 7.7.5.2 or 7.7.5.3);

c) the duration of the test ;

d) the maximum charging and discharging currents;

e) when applicable, the maximum value of time constant $R_1(C_1 + C_x)$.

## 7.8 Endurance

7.8.1 The measurements prescribed in the relevant standard specification shall be made.

7.8.2 The capacitors shall be submitted to an endurance test. The duration of this test, value(s) of the applied voltage and the chamber temperature(s) at which it should be conducted, shall be prescribed in the relevant standard specification.

The capacitors shall be placed in the test chamber in such a manner that:

a) for heat dissipating capacitors no capacitor is within 25 mm of any other capacitor;

b) for non-heat dissipating capacitors no capacitor is within 5 mm of any other capacitor.

The capacitors shall not be heated by direct radiation and the circulation of the air in the chamber shall be adequate to prevent the temperature from departing by more than 3°C from the specified temperature of the chamber at any point where the capacitors may be placed.

After the specified period, the capacitors shall be allowed to recover under standard atmospheric conditions for testing.

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7.8.3 The measurements prescribed in the relevant standard specification shall then be made.

## 7.9 Variation of capacitance with temperature

### 7.9.1 Static method

7.9.1.1 Measurements of capacitance shall be made under the conditions prescribed in the relevant standard specification.

7.9.1.2 The capacitor shall be maintained at each of the following temperatures in turn:

a) 27 ± 2°C ;

b) lower category temperature ± 3°C;

c) intermadiate temperatures, (below 27° C) if required by the relevant standard specification ;

d) 27 + 2° C;

e) intermediate temperatures(above 27° C) if required by the relevant standard specification ;

f) upper category temperature ± 2° C;

g) 27 ± 2° C.

If required for a particular type of capacitor, the relevant standard specification shall prescribe whether thermal shock is to be avoided or whether a maximum rate of change of temperature shall be observed.

7.9.1.3 Capacitance measurements shall be made at each of the temperature specified above after the capacitor has reached thermal stability.

The condition of thermal stability is considered to be reached when two readings of capacitance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

The measurement of the actual temperature must be made with a precision compatible with the requirements of the relevant standard specification.

Care must be taken during measurements to avoid condensation or frost on the surface of the capacitors.

7.9.1.4 For the lot-by-lot quality conformance testing, the relevant standard specification may prescribe a shortened procedure.

### 7.9.2 Dynamic method

As an alternative to the static method of 7.9.1 a dynamic plotting method may be employed. The capacitors shall be subjected to a slowly varying temperature.

A temperature-sensitive device shall be embedded in a dummy capacitor to be included with the capacitor under test in a manner that will ensure that the measured temperature is the same as that occurring in the capacitor under test. The capacitance shall be measured using a self-balancing bridge or comparator.

The output of the bridge or comparator shall be coupled to the "Y" axis of a plotting table.

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The output of the temperature sensing device shall be coupled to the "X" axis of a plotting table.

The temperature shall be varied slowly enough to produce a uniform curve with no loop at the lower or upper category temperature. The temperature shall be varied subsequently from 27° C to the lower category temperature, to the upper category temperature and to 27° C. Two cycles shall be carried out.

This method may be employed only when it can be demonstrated that the results are the same as for the static method.

In case of dispute, the static method shall be used.

7.9.3 Method of calculation

$C_o$ = capacitance measured at step d) of 7.9.1.2

$\theta_o$ = temperature measured at step d) of 7.9.1.2

$C_i$ = capacitance measured at the test temperature, other than at step a), d) and g).

$\theta_o$ = test temperature

7.9.3.1 Temperature characteristic of capacitance

The variation of capacitance as a function of temperature shall be calculated for all the values of $C_i$ as follows:

$$\frac{\Delta C}{C_o} = \frac{C_i - C_o}{C_o}$$

The variation of capacitance is normally expressed in per cent.

7.9.3.2 Temperature coefficient of capacitance and temperature cyclic drift of capacitance

a) Temperature coefficient of capacitance ($\alpha_i$)

Temperature coefficient of capacitance ($\alpha_i$) shall be calculated for all the values of C as follows:

$$\alpha_i = \frac{C_i - C_o}{C_o(\theta_i - \theta_o)}$$

The temperature coefficient is normally expressed in parts per million per degree Celsius ($10^{-6}/C$).

b) Temperature cyclic drift of capacitance

The temperature cyclic drift of capacitance shall be calculated at the steps given in 7.9.1.2 a, d and g. in the following manner:

$$\delta_1 = \frac{C_o - C_a}{C_o}$$

$$\delta_2 = \frac{C_g - C_o}{C_o}$$

$$\delta_3 = \frac{C_g - C_a}{C_o}$$

as required by the relevant standard specification. The largest of these values is the temperature cyclic drift of capacitance.

The capacitance drift is normally expressed in per cent.

7.10 Surge

7.10.1 The measurements specified in the relevant standard specification shall be made.
Suitable test circuits are shown in Fig. 4a and 4 b.

NOTE- The thyristor circuit has the advantage of high repetition rates and is free from troubles associated with dirty contacts and contact bounce.

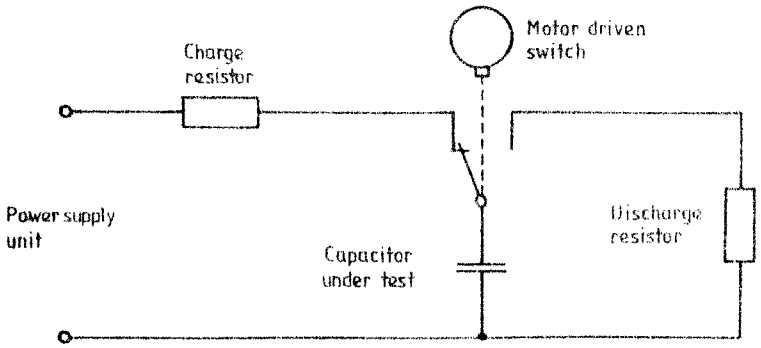



FIGURE 4a - Relay circuit

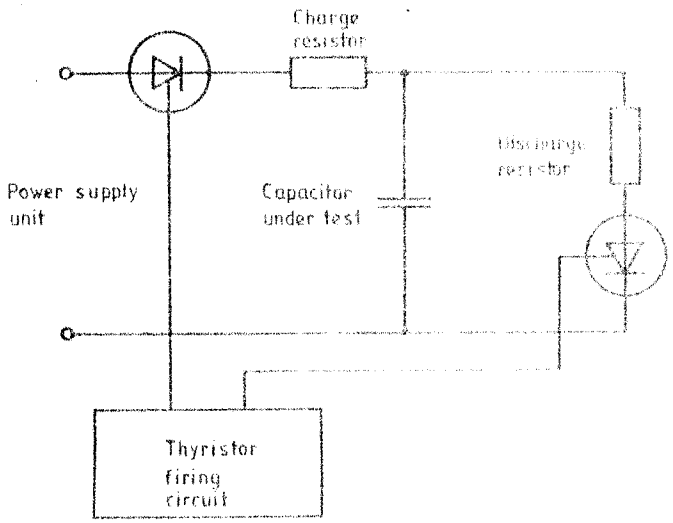
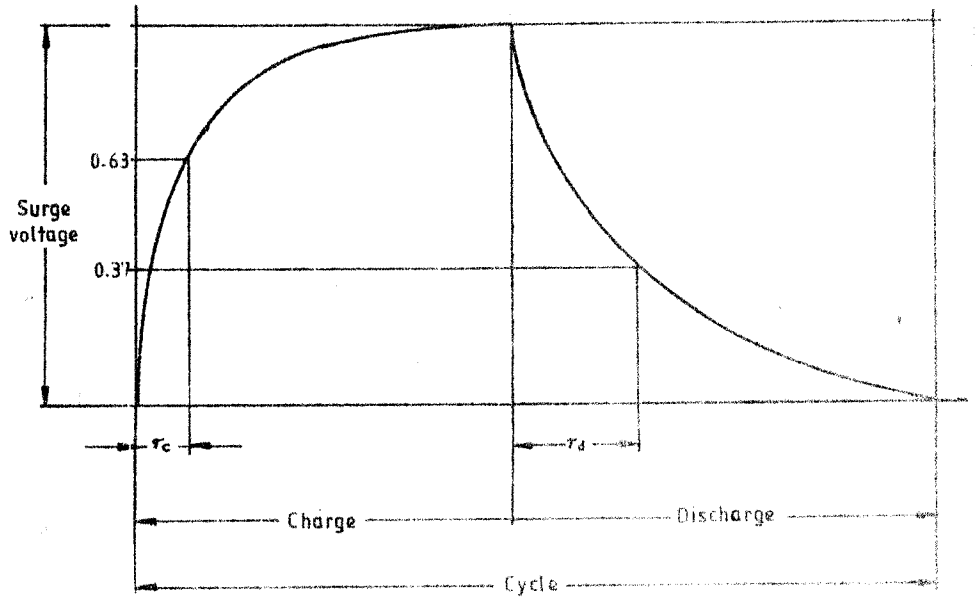



FIGURE 4b - Thyristor circuit

The voltage waveform across the capacitor under test shall be approximately as shown in Figure 5.




$\tau_c$ = Charge time constant
$\tau_d$ = Discharge time constant

~~= charge time constant~~
~~/ discharge time constant~~

FIGURE 5 - Charge and discharge waveform

7.10.2 The following information shall be given in the relevant standard specification:

a) the charge time constant arising from the internal resistance of the power supply and the resistance of the charge circuit and the capacitor under test;

b) the discharge time constant arising from the resistance of the discharge circuit and the capacitor under test;

c) the ratio of the surge voltage to rated or category voltage (as appropriate);

d) the number of cycles of test ;

e) the duration of the surge period ;

f) the duration of the discharge perid ;

g) the repetition rate (cycles per second) ;

h) temperature, if different from standard atmospheric conditions for testing.

7.10.3 The measurement specified in the relevant standard specification shall be made.

## 7.11 Charge and discharge test

7.11.1 The measurements specified in the relevant standard specification shall be made.

Suitable test circuits are given in 7.10.2, Figures 4a and 4b.

The voltage and current waveforms across and through the capacitor under test are approximately given in Fig. 6.

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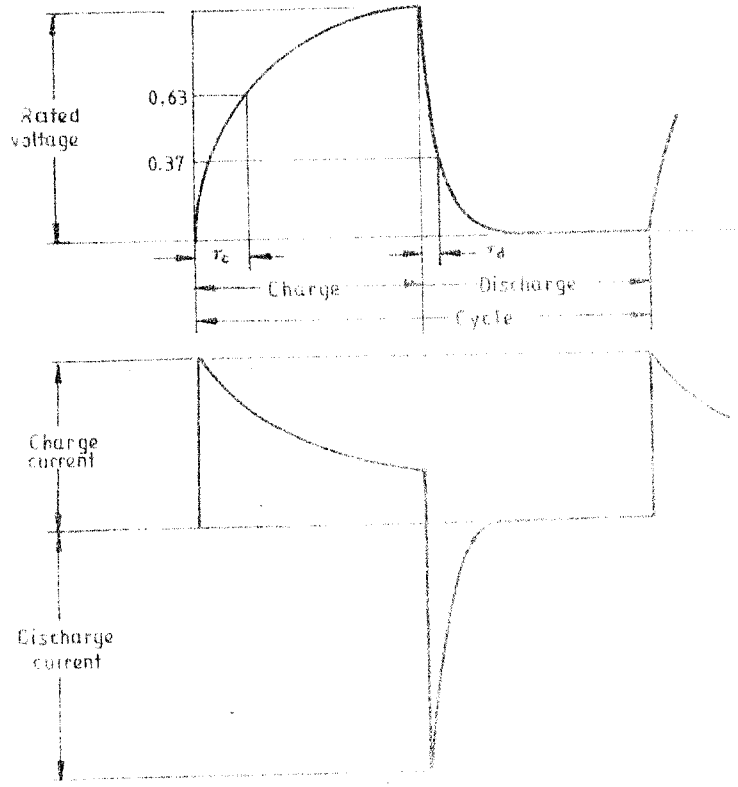


Tc = charge time constant

Td = discharge time constant

FIGURE 6 - Voltage and current waveforms across the capacitors under test

7.11.2 The following information shall be given in the relevant standard specification :

a) the charge time constant arising from the internal resistance of power supply and the resistance of the charge circuit and the capacitance of the capacitor under test ;

b) the discharge time constant arising from the resistance of the discharge circuit and the capacitance of the capacitor under test;

c) the voltage to be applied during the charge period, if different from the rated voltage ;

d) the number of cycles of test ;

e) the duration of the charge period ;

f) the duration of the discharge period ;

g) the repetition rate (cycles per second) ;

h) temperature, if different from standard atmospheric conditions for testing.

7.11.3 The measurements specified in the relevant standard specification shall be made again.

7.12 Characteristics at high and low temperatures

The capacitors shall be subjected to the procedures of the dry heat and cold test (7.21.2 and 7.21.4 respectively) with the following details :

a) The temperatures for these tests shall be the same as for the dry heat and cold tests. Tests at intermediate temperatures may be prescribed by the relevant standard specification.

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b) Measurements shall be made at each of the specified temperatures after the capacitor has reached thermal stability. The condition of thermal stability is considered to be reached when two readings of a characteristc, taken in an interval of not less than 5 min, do not differ by an amount greater than that which can be attributed to the measuring appratus.

7.13 Robustness of terminations

The capacitors shall be subjected to Tests $U_{a_1}$, $U_b$, $U_c$ and $U_d$ of IEC Publication 68-2-21 (1975), as applicable.

7.13.1 Tensile - Test $U_{a_1}$

For the purpose of carrying out of this test the force applied shall be :

a) for terminations other than wire terminations: 20N

b) for wire terminations see Table 3.

Table 3 - Force for wires of different sizes

| Nominal Cross-sectional area (s) in ($mm^2$) | Corresponding diameter for circular-section Wires (d) in (mm) | Force) in (N) |
|---|---|---|
| $S \leq 0.05$ | $d \leq 0.25$ | 1 |
| $0.05 < S \leq 0.07$ | $0.25 < d \leq 0.3$ | 2.5 |
| $0.07 < S \leq 0.2$ | $0.3 < d \leq 0.5$ | 5 |
| $0.2 < S \leq 0.5$ | $0.5 < d \leq 0.8$ | 10 |
| $1.2 < S \leq 1.2$ | $0.8 < d \leq 1.25$ | 20 |
| $1.2 < S$ | $1.25 < d$ | 40 |

7.13.2 Bending Test

Method 1 of test $U_b$ given in IEC 68-2-21 shall be applied unless otherwise specified in the relevant standard specification. This test shall not apply if the terminations are described as rigid. Half of the terminations of the capacitors shall be used for this test and the other half for the Torsion test in 7.15.3.

7.13.3 Torsion test

Method A of test $U_c$ given in IEC-2-21 shall be applied unless otherwise specified in the relevant standard specification.

The test speciman shall be subjected to a severity of two sucessive rotations of 180°. This test shall not apply if in the relevant standard specification the terminations are descrived as rigid and to components with unidirectional terminations designed for printed wiring application.

7.13.4 Test $U_d$ - Torque

This test shall be applied for terminations with threaded studs or screws and for integral mounting devices only. The severity conditions shall be selected from Table 4 according to the relevant stnadard specification.

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Table 4 - Severity of the torque applied for different sizes

| Nominal thread diameter (mm) | | 2.6 | 3 | 3.5 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Torque (N.m) | Severity 1 | 0.4 | 0.5 | 0.8 | 1.2 | 2.0 | 2.5 |
| | Severity 2 | 0.2 | 0.25 | 0.4 | 0.6 | 1.0 | 1.25 |

For diameter greater than 6mm, the torque values shall be prescribed by the relevant standard specification. The nuts or screws shall be capable of being loosened afterwards.

7.14 Resistance to soldering heat

7.14.1 When prescribed by the relevant standard specification, the capacitors shall be dried as given in 7.14.1.1 and 7.14.1.2.

7.14.1.1 Unless otherwise specified in the relevant standard specification, the capacitor shall be conditioned for 96 ± 4 h by heating in a circulating air oven at a temperature of 55 ± 2° C and a relative humidity not exceeding 20 per cent.

7.14.1.2 The capacitor 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 removal from the oven to the begining of the specified tests.

7.14.2. Unless otherwise stated in the relevant standard specification the capacitors shall be tested as follows.

a) all capacitors except those listed in item b below, be tested in accerdance with method 1A of test Tb prescribed in IEC 68-2-20 (1979) with the following conditions

   i) duration of test : 5S or 10S as specified in the relevant standard specification.

   ii) depth of immersion : $2^{+0}_{-0.5}$ mm from the seating plane.

   iii) thermal insulation : using a screen of 1.5 ± 0.5 mm thickness

b) Capacitors not designed for use on printed boards be tested in accordance with method 1A of test Tb of IEC 68-2-20 with the following conditions.

   i) depth of immersion : $3.5^{+0}_{-0.5}$ mm from the component body.

   ii) period of recovery : not less than 1 h nor more than 2h, unless otherwise specified in the relevant stnadard specification.

7.15 Solderability

7.15.1 Capacitors shall be subject to Test Ta of IEC publication 68-2-20 (1979), either using the solder bath method (Method 1) or the soldering iron method (method 2) or the solder globule method (Method 3) as prescribed by the relevant standard specification.

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7.15.2 For the solder bath method (method 1) the following requirements apply:

7.15.2.1 Test conditions

Bath temperature : $235 \pm 5^{\circ}$ C

Immersion time : $2.0 \pm 0.5$ s

Depth of immersion (from the seating plane or component body):

a) all capacitors except those of b) below:
$2.0^{+0}_{-0.5}$ mm, using a thermal insulating screen of $1.5 \pm 0.5$ mm thickness

b) capacitors indicated by the relevant standard specification as being not designed for use on printed boards : $3.5^{+0}_{-0.5}$ mm.

7.15.2.2 The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations.

7.15.3 When the solder bath method is not applicable, the relevant standard specification shall define both the method, test conditions and the requirements.

7.15.3.1 When the solder globule method is used, the requirements shall include the soldering time.

7.16 Rapid change of temperature

7.16.1 The measurements prescribed in the relevant standard specification shall be made.

7.16.2 The capacitors shall then be subjected to test Na of IEC publication 68-2-14 (1974), using the degree of severity as prescribed in the relevant standard specification.

7.17 Vibration

7.17.1 The measurements prescribed in the relevant standard specification shall be made.

7.17.2 The capacitors shall be subjected to test Fc of IEC publication 68-2-6(1970) using the mounting method and the degree of severity prescribed in the relevant standard specification.

7.17.3 When prescribed in the relevant standard specification, during the last 30 minutes of the vibration test in each direction of movement, an electrical measurement shall be made to check intermittent contacts or open or short circuit. There shall be no intermittent contact greater than or equal to 0.5 ms nor open or short circuit.

The duration of the measurement shall be the time needed for one sweep of the frequency range from one frequency extreme to the other.

7.17.4 The measurements prescribed in the relevant standard specification shall then be made again.

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7.18 Bumps

7.18.1 The measurements prescribed in the relevant standard specification shall be made.

7.18.2 The capacitors shall then be subjected to test Eb of IEC publication 68-2-29(1968) using the mounting method and the degree of severity prescribed in the relevant standard specification.

7.18.3 The measurements prescribed in the relevant standard specification shall then be made again.

7.19 Shocks

7.19.1 The measurements prescribed in the relevant standard specification shall be made.

7.19.2 The capacitors shall then be subjected to test Ea of IEC publication 68-2-27 (1972) using the mounting method and the severity prescribed in the relevant standard specification.

7.19.3 The measurements prescribed in the relevant standard specification shall then be made again.

7.20 Container sealing

The capacitors shall be subjected to the procedure of the appropriate method of test Q of IEC 68-2-17 (1978) as prescribed in the relevant standard specification.

7.21 Climatic sequence

In the climatic sequence, an interval of maximum of 3 days is permitted between any of the tests, except that the cold test shall be applied immediately after the recovery period for the first cycle of the damp heat, cyclic, test Db of IEC 68-2-30 (1969).

7.21.1.Initial measurements

The measurements prescribed in the relevant standard specification shall be made.

7.21.2.Dry heat test

The capacitors shall be subjected to test Ba of IEC publication 68-2-2(1974) for 16h, using the degree of severity of the upper category temperature, as prescribed in the relevant standard specification.

While still at the specified high temperature and at the end of the period of high temperature, the measurements prescribed in the relevant standard specification shall be made.

After specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for not less than 4h.

7.21.3 Damp heat, cyclic, test Db, first cycle

The capacitors shall be subjected to test Db of IEC publication 68-2-30 (1969) for one cycle of 24h, using a temperature of 55°C (severity b).

After recovery the capacitors shall be subjected immediately to the cold test.

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7.21.4 Cold test

The capacitors shall be subjected to test Aa of IEC publication 68-2-1 (1974) for 2h, using the degree of severity of the lower category temperature, as prescribed in the relevant standard specification.

While still at specified low temperature and at the end of the period of low temperature, the measurements prescribed in the relevant standard specification shall be made.

After the specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for not less than 4h.

7.21.5 Low air pressure test

The capacitors shall be subjected to test M of IEC publication 68-2-13 (1966) using the appropriate degree of severity prescribed in the relevant standard specification. The duration of the test shall be 10 min, unless otherwise stated in the relevant standard specification.

The relevant standard specification shall prescribe:

a) duration of test, if other than 10 min ;

b) temperature ;

c) degree of severity.

While at the specified low pressure, the rated voltage shall be applied for the last 1 min of the test period, unless otherwise prescribed in the relevant standard specification.

During and after the test there shall be no evidence of permanent breakdown, flashover, harmful deformation of the case or seepage of impregnant.

7.21.6 Damp heat, cyclic, test Db, remaining cycles

The capacitors shall be subjected to test Db of IEC publication 68-2-30(1969) for the following number of cycles of 24h as indicated in the table below, at a temperature of 55°C (severity b).

Table 5 - Number of cycles for different climatic categories of capacitors

| Category climatic | Number of cycles |
|---|---|
| -/-/56 | 5 |
| -/-/21 | 1 |
| -/-/10 | 1 |
| -/-/04 | None |

7.21.7 Final measurements

After the recovery, the measurements prescribed in the relevant standard specification shall be made.

7.22 Damp heat, steady state

7.22.1 The measurements prescribed in the relevant standard specification shall be made.

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7.22.2 The capacitors shall be subjected to test Ca of SLS 580-2-3 using the degree of severity corresponding to the climatic category of the capacitor as indicated in the relevant standard specification.

The relevant standard specification may specifies the application of a polarizing voltage during the whole period of damp heat conditioning. With the exception of electrolytic capacitors, within 15 min after removal from the test chamber, the voltage proof test of sub clause 7.1 shall be carried out at test point A (see table 2) only, using the rated voltage, unless otherwise specified in the relevant standard specification.

7.22.3 The measurements prescribed in the relevant standard specification shall be made again.

7.23 Storage

7.23.1 Storage at high temperature

7.23.1.1 The measurements prescribed in the relevant standard specification shall be made.

7.23.1.2 The capacitors shall then be subjected to test Ba of IEC publication 68-2-2 (1974), using the following severities :

Temperature : upper category temperature

Duration : $96 \pm 4$h.

7.23.1.3 After recovery for at least 16h, the measurements prescribed in the relevant standard specification shall be made.

7.23.2 Storage at low temperature

7.23.2.1 The measurements prescribed in the relevant standard specification shall be made.

7.23.2.2 The capacitors shall then be subjected to test to test Ab of IEC publication 68-2-1 (1974). The capacitors shall be stored at - 40°C for either a period of 4h after thermal stability has been reached, or for 16h, whichever is the shorter period.

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