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Specification for

Motor starters for voltages up to and including 1000 V a.c. and 1200 V d.c.

Part 4. Reduced voltage a.c. starters, two-step auto-transformer starters

Spécification des démarreurs de moteur pour les tensions inférieures et égales à 1000 V en courant alternatif et 1200 V en courant continu
Partie 4. Démarreurs sous tension réduite en courant alternatif, démarreurs par autotransformateurs à deux étapes

Spezifikation für Motorstarter für Spannungen bis und einschließlich 1000 V Wechselstrom und 1200 V Gleichstrom
Teil 4. Motorstarter zum Einschalten unter verminderter Spannung, zweistufige Anlasstransformatoren

British Standards Institution

Foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Committee. It is identical with Publication 292 'Low-voltage motor starters', Part 4 'Reduced voltage a.c. starters : Two-step auto-transformer starters' published by the International Electrotechnical Commission (IEC). It supersedes those requirements of BS 587 : 1957 'Motor starters and controllers' that relate to reduced voltage a.c. starters, two-step auto-transformer starters for voltages up to and including 1000 V a.c.

Cross references. For each of the following references to other IEC Publications that are given in the text, there is an equivalent British Standard; these are as listed below:

Reference to IEC Publication	Equivalent British Standard
IEC Publication 76 : 1967 Power transformers	BS 171 : 1970 Power transformers
IEC Publication 144 : 1963 Degrees of protection of enclosures for low-voltage switchgear and controlgear	BS 5420 : 1977 Degrees of protection of enclosures of switchgear and controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c.
IEC Publication 158 Low-voltage controlgear Part 1 : 1970 Contactors	BS 5424 Controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c. Part 1 : 1977 Contactors
IEC Publication 292 Low-voltage motor starters Part 1 : 1969 Direct-on-line (full voltage) a.c. starters	BS 4941 Motor starters for voltages up to and including 1000 V a.c. and 1200 V d.c. Part 1 : 1973 Direct-on-line (full voltage) a.c. starters
IEC Publication 292-1A : 1971 First supplement to Publication 292-1	Appendix C to BS 4941 : Part 1 Co-ordination with short-circuit protective devices
IEC Publication 337 Control switches (low-voltage switching devices for control and auxiliary circuits, including contactor relays) Part 1 : 1970 General requirements	BS 4794 Control switches (switching devices, including contactor relays, for control and auxiliary circuits up to and including 1000 V a.c. and 1200 V d.c.) Part 1 : 1973 General requirements

Additional information. In 4.8.1 reference is made to a specified-time all-or-nothing relay as a type of automatic change-over device.

The term 'all-or-nothing relay' is defined (number 103 2103) in Group 03, Relay terminology, of Part 1 'Terms common to power, telecommunications and electronics' of BS 4727 'Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms' as:

> 'A relay having no specified accuracy and intended to be energized by a quantity having a value either higher than that at which it picks up or lower than that at which it drops out.'

Furthermore, a specified-time all-or-nothing relay is an all-or-nothing relay of which one or more of the times that characterize it, e.g. the operating time, are subject to specification.

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LOW-VOLTAGE MOTOR STARTERS

Part 4: Reduced voltage a.c. starters: Two-step auto-transformer starters

1. General

1.1 *Scope*

This standard applies to two-step auto-transformer starters for industrial use, intended to start, in the starting position, and accelerate an a.c. induction motor to normal speed and to provide means for the protection of the motor and its associated circuits against operating overloads, and to cause the motor to stop intentionally.

Note. — Auto-transformer starters with more than two steps are considered as special cases subject to agreement between manufacturer and user.

This standard is additional to IEC Publication 292-1, Low-voltage Motor Starters, Part 1: Direct-on-line (Full Voltage) A.C. Starters, which also applies provided it is not amended by the present standard.

The auto-transformer starters dealt with in this standard are not intended for inching duty or reversing motors rapidly and, therefore, utilization category AC-4 does not appear. Moreover, they are not designed to interrupt short-circuit currents; therefore, suitable short-circuit protection should form part of the installation but not necessarily in the starter (see Appendix C of IEC Publication 292-1).

This standard applies only to starters the main contacts of which are intended to be connected to circuits the rated voltage of which does not exceed 1 000 V a.c.

The clauses of this standard relating to overload protection are not applicable to starters operating in conjunction with over-temperature protective devices built into the motors.

Note. — In the starting position, the current in the line and the torque of the motor related to the motor starting with rated voltage are reduced approximately as the square of the ratio (starting voltage)/(rated voltage). Therefore, auto-transformer starters are used when the inrush current due to the starting is to be limited, or when the driven machine requires a limited torque for starting. The figure on page 43 indicates typical curves of starting current, of starting torque of the motor, and of torque of the driven machine.

1.2 *Object*

The object of this standard is to state:

1. the characteristics of auto-transformer starters;
2. the conditions with which starters shall comply with reference to:
   a) their operation and behaviour;
   b) their dielectric properties;
   c) the degrees of protection provided by their enclosures;
3. the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
4. the data to be marked on the apparatus.

2. Definitions

For the purpose of this standard, the following definitions shall apply.

2.1 *Starter*

See IEC Publication 292-1*.

* Whenever reference is made to IEC Publication 292-1, the clause with the same clause number in the first edition (1969) applies, in some instances modified by the text which follows.

2.1.1 *Auto-transformer starter*

A starter for an induction motor which uses for starting one or several reduced voltages derived from an auto-transformer.

2.2 *Direct-on-line starter*

See IEC Publication 292-1.

2.3 *Reversing starter*

See IEC Publication 292-1.

2.4 *Manual starter*

See IEC Publication 292-1.

2.5 *Electromagnetic starter*

See IEC Publication 292-1.

2.6 *Motor operated starter*

See IEC Publication 292-1.

2.7 *Pneumatic starter*

See IEC Publication 292-1.

2.8 *Electro-pneumatic starter*

See IEC Publication 292-1.

2.9 *Over-current*

See IEC Publication 292-1.

2.10 *Overload*

See IEC Publication 292-1.

2.11 *Short-circuit current*

See IEC Publication 292-1.

2.12 *Overload relay or release*

See IEC Publication 292-1.

2.13 *Thermal overload relay or release*

See IEC Publication 292-1.

2.14 *Current setting of an overload relay or release*

See IEC Publication 292-1.

2.15 *Current setting range of an overload relay or release*

See IEC Publication 292-1.

2.16 *Undercurrent relay*

A measuring relay which operates when the current through it is reduced below the operating value.

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2.17 *Auto-transformer* (Clause 4.1.2 of IEC Publication 76 (1967), Power Transformers).

A transformer in which at least two windings have a common part.

2.18 *Two-step starter*

A starter in which there is only one intermediate accelerating position between the OFF and FULL ON positions.

2.19 *Starting time* t_s (of an auto-transformer starter)

The length of time while the auto-transformer carries current.

2.20 *Open transition*

A circuit arrangement such that the current to the motor is interrupted when changing over from one step to another.

2.21 *Closed transition*

A circuit arrangement such that the current to the motor is not interrupted (even momentarily) when changing over from one step to another.

Note. — The transition stage is not considered an additional step.

3. Classification

3.1 (See IEC Publication 292-1.)

3.2 (See IEC Publication 292-1.)

3.3 (See IEC Publication 292-1.)

3.4 According to the degree of protection provided by the enclosure, distinction is made in accordance with IEC Publication 144, Degrees of Protection of Enclosures for Low-voltage Switchgear and Controlgear.

3.5 According to the method of changing from the starting position to the FULL ON position, auto-transformer starters are designated as:

— automatic change-over (i.e. independent of the operator), e.g. controlled by a timer or an undercurrent relay;

— non-automatic change-over (i.e. dependent on the operator), e.g. controlled by hand or by push-buttons.

3.6 According to the method of connecting the auto-transformer, auto-transformer starters are classified as open transition starters or closed transition starters (see diagrams on page

3.7 According to the method of cooling the auto-transformer, auto-transformer starters are designated as:

— having the auto-transformer air cooled by convection;

— having the auto-transformer cooled by immersion in oil.

4. Characteristics of auto-transformer starters

In an auto-transformer starter, the starting position is transitional only. If, for special applications, the starting position is not transitional but on the contrary is a normal operating position, an agreement concerning these special characteristics shall be reached between manufacturer and user.

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4.1 *Summary of characteristics*

The characteristics of an auto-transformer starter shall be stated in the following terms, where such terms are applicable:

— Type of switching devices (see Clause 4.2).
— Type and characteristics of automatic change-over devices (see Clause 4.8).
— Type and characteristics of relays and releases (see Clause 4.3) and number of these devices.
— Degrees of protection provided by enclosures (see IEC Publication 144).
— Rated values (see Clause 4.4).
— Control circuits and air-supply systems (see Clause 4.5).
— Auxiliary circuits (see Clause 4.6).
— Type and characteristics of the auto-transformer (see Clause 4.9).
— Co-ordination with short-circuit protective devices (see IEC Publication 292-1A (1971): First supplement to Publication 292-1).

4.2 *Types of switching devices*

See IEC Publication 292-1.

4.2.1 *Number of poles*

4.2.2 *Interrupting medium (air, oil, etc.)*

4.2.3 *Method of operation*

See IEC Publication 292-1.

4.3 *Types and characteristics of relays and releases*

See IEC Publication 292-1.

4.3.1 *Types*

1. Release with shunt coil (shunt trip).
2. Under-voltage opening relay or release.
3. Overload time-delay relay, the time lag of which is:
   a) substantially independent of previous load (e.g. time-delay magnetic overload relay);
   b) dependent on previous load (e.g. thermal overload relay).
4. Instantaneous over-current relay or release (when applicable).
5. Other relays or releases (e.g. phase unbalance relay, control switch associated with devices for the thermal protection of the starter).

Note. — Types referred to in Items 4 and 5 require consultation between manufacturer and user according to the particular application.

4.3.2 *Characteristics*

1. Release with shunt coil and under-voltage opening relay or release:
   — rated voltage;
   — rated frequency.
2. Overload relay:
   — either the associated motor full-load current or the ultimate trip current (see Clause 7.5.3.2);
   — rated frequency (when necessary);
   — current setting (or range of settings);

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— time-current characteristics (or range of characteristics), when necessary;

— number of poles;

— nature of the relay: thermal or magnetic.

Notes 1. — Depending on the nature of the relay, the opening conditions are given in Clause 7.5.3.2 or in Clause 7.5.3.3.

2. — The starting auto-transformer is normally designed for use during the starting period only; as a result, it cannot be efficiently protected by the overload relay in the event of faulty starting. Protection of the auto-transformer shall be the subject of specific agreement between manufacturer and user (see Clause 7.1.1).

4.3.3 *Designation and current settings of overload relays*

See IEC Publication 292-1.

4.3.4 *Time-current characteristics of overload relays*

See IEC Publication 292-1.

4.3.5 *Influence of ambient air temperature*

See IEC Publication 292-1.

4.4 *Rated values*

See IEC Publication 292-1.

4.4.1 *Rated voltages*

See IEC Publication 292-1.

4.4.1.1 *Rated operational voltages*

See IEC Publication 292-1.

4.4.1.2 *Rated insulation voltage*

See IEC Publication 292-1.

4.4.1.3 *Rated starting voltage*

The rated starting voltage of an auto-transformer starter is the reduced voltage derived from the transformer.

Preferred values of rated starting voltage are 50%, 65% or 80% of the rated operational voltage.

4.4.2 *Rated currents*

An auto-transformer starter is defined by the following rated currents; except in the case of the special applications quoted in Clause 4, all these rated currents relate to the FULL ON position (since the starting position is a transitional one).

4.4.2.1 *Rated thermal current*

See IEC Publication 292-1.

4.4.2.2 *Rated operational currents or rated operational powers*

See IEC Publication 292-1.

4.4.3 *Rated frequency*

See IEC Publication 292-1.

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4.4.4 *Rated duty*

Whatever the duty envisaged, the starter shall be capable of permitting two successive operating cycles, starting from the cold state, the time interval between two starts being equal to twice the starting time t_s.

The rated duties considered as normal are as follows:

4.4.4.1 *Eight-hour duty*

Duty in which the starter is in the FULL ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed whilst each of them carries a steady current long enough for the starter to reach thermal equilibrium but not for more than eight hours without interruption.

Notes 1. — This is the basic duty on which the rated thermal currents of the starter are determined.

2. — Interruption means breaking of the current by operation of the starter to the OFF position.

4.4.4.2 *Uninterrupted duty*

Duty in which the starter is in the FULL ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed whilst each of them carries a steady current without interruption for periods of more than 8 hours (weeks, months, or even years).

Note. — This kind of service is set apart from the eight-hour duty because oxides and dirt can accumulate on the contacts and lead to progressive heating. Uninterrupted duty can be taken account of either by a derating factor, or by special design consideration (e.g. silver or silver-faced contacts) (see Table VI of IEC Publication 292-1 (1969)).

4.4.4.3 *Intermittent periodic duty or intermittent duty*

Duty in which the starter is in the FULL ON position and the main contacts of the switching devices which constitute it remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the starter to reach thermal equilibrium.

Intermittent duty is characterized by the value of current, the duration of current flow and by the on-load factor which is the ratio of the in-service period of the switching device which is closed the longest to the entire period, often expressed as a percentage.

Standard values of the on-load factor are 15%, 25%, 40% and 60%.

4.4.4.3.1 *Classes of intermittent duty*

According to the number of operating cycles which they shall be capable of carrying out per hour, auto-transformer starters are divided into the following classes:

— Class 0.03: up to 3 operating cycles per hour;
— Class 0.1 : up to 12 operating cycles per hour;
— Class 0.3 : up to 30 operating cycles per hour.

For an auto-transformer starter, an operating cycle comprises the starting operation from the starting position up to and including the attainment of full speed in the FULL ON position, followed by the stopping of the motor.

Note. — For intermittent duty, the difference between the thermal time-constant of the overload relay and that of the motor may render a thermal relay unsuited for overload protection. It is recommended that, for installations intended for intermittent duty, the question of overload protection be covered by special agreement between manufacturer and user.

4.4.4.4 *Temporary duty*

See IEC Publication 292-1.

4.4.5 *Making and breaking capacities*

See IEC Publication 292-1.

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4.4.5.1 *Rated making capacity*

See IEC Publication 292-1.

4.4.5.2 *Rated breaking capacity*

See IEC Publication 292-1.

4.4.6 *Utilization category*

All auto-transformer starters belong to utilization category AC-3.

This utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and of the rated operational voltage, and by the power-factors as shown in Table II and other test conditions used in the definitions of the rated making and breaking capacities; the values given in Table II correspond to direct starting conditions in the FULL ON position.

TABLE I

Utilization categories

Category	Typical application
AC-3	Starting of squirrel-cage motors, switching-off motors during running

Note. — The application of starters to the switching of induction motors with individual power-factor correction by capacitors shall be subject to special agreement between manufacturer and user.

TABLE II

Verification of the rated making and breaking capacities (see Clause 8.2.4)

Conditions for making and breaking corresponding to the utilization category [1]

Category	Value of the rated operational current	Make			Break		
		I	U	cos φ [2]	I	U_r	cos φ [2]
AC-3	$I_e \leq 17$ A	$10\ I_e$	$1.1\ U_e$	0.65	$8\ I_e$	$1.1\ U_e$	0.65
	17 A $< I_e \leq 100$ A	$10\ I_e$	$1.1\ U_e$	0.35	$8\ I_e$	$1.1\ U_e$	0.35
	$I_e > 100$ A	$8\ I_e$ [3]	$1.1\ U_e$	0.35	$6\ I_e$ [4]	$1.1\ U_e$	0.35

I_e = rated operational current (see Clause 4.4.2.2)
U_e = rated operational voltage

I = current made or broken
U = voltage before make
U_r = recovery voltage

[1] The conditions for making are expressed in r.m.s. values, but it is understood that the peak value of asymmetrical current corresponding to the power-factor of the circuit may assume a higher value (see Clause 4.4.5.1, Note).
[2] Tolerance for cos φ: ± 0.05.
[3] With a minimum of 1 000 A.
[4] With a minimum of 800 A.

Since auto-transformer starters are defined by their utilization category AC-3, it is unnecessary to specify separately the rated making and breaking capacities, as those values depend directly on this utilization category as shown in Table II.

The utilization category of Table II corresponds in principle to the applications listed in Table I.

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4.4.6.1 *Starting characteristics*

Unless otherwise stated, the auto-transformer starters and specifically the auto-transformers are designed on the basis of the following starting characteristics:

4.4.6.1.1 *Starting current*

The starting current with stalled rotor, when the motor is energized at its rated voltage, does not exceed 8 I_e for values of $I_e \leqslant 100$ A and 6 I_e for values of $I_e > 100$ A.

4.4.6.1.2 *Starting time*

The starting time t_s (see Clause 2.19) for all classes of duty (see Clause 4.4.4.3.1) shall not exceed 15 s. The number of starting cycles per hour assumes equal periods between starts except that, in the event of two operating cycles being made in rapid succession (see Clause 4.4.4), the starter and the auto-transformer shall be allowed to cool to ambient air temperature before a further start is made.

Note. — When a starting time in excess of 15 s is required, this shall be the subject of agreement between manufacturer and user.

4.4.7 *Mechanical endurance*

See IEC Publication 292-1.

4.4.8 *Electrical endurance*

With respect to its resistance to electrical wear, an auto-transformer starter is characterized by the number of on-load operating cycles which can be made without repair or replacement.

Since the operation of an auto-transformer starter is subjected to large variations in the service conditions, it is deemed convenient not to give standard values. However, it is recommended that the manufacturer indicate the electrical endurance of the starter for stated service conditions; this electrical endurance may be estimated from the results of tests on the component parts of the starter.

4.5 *Control circuits and air-supply systems*

See IEC Publication 292-1.

4.5.1 *For control circuits*

See IEC Publication 292-1.

4.5.2 *For air-supply systems*

See IEC Publication 292-1.

4.6 *Auxiliary circuits*

See IEC Publication 292-1.

4.7 *Co-ordination with short-circuit protective devices*

See IEC Publication 292-1A (1971).

4.8 *Types and characteristics of automatic change-over devices*

4.8.1 *Types*

a) Timers, e.g.: time-delay contactor relays (see IEC Publication 337-1, Control Switches (Low-voltage Switching Devices for Control and Auxiliary Circuits, including Contactors Relays), Part 1: General Require-

ments) or specified-time all-or-nothing relays (see IEC Publication 255-2, Electrical Relays, Part 2: Specified-time All-or-Nothing Relays).

b) Undercurrent devices (undercurrent relays).

4.8.2 *Characteristics*

a) The characteristics of timers are:
- — the rated time delay, or range of time delay if adjustable;
- — for timers fitted with a coil, the rated voltage when it differs from the starter line voltage.

b) The characteristics of the undercurrent devices are:
- — the rated current (thermal and/or temporary duty current, as stated by the manufacturer);
- — the current setting, or its range if adjustable.

4.9 *Types and characteristics of auto-transformers*

Account being taken of the starting characteristics (see Clause 4.4.6.1) and of Clause 4.4.4 dealing with successive starts, the starting auto-transformers shall be characterized by:
- — the number of taps available for adjusting the starting torque and current;
- — the rated starting voltage, i.e. the voltage at the tapping terminals;
- — the current they can carry for a specified duration;
- — the rated duty (see Clause 4.4.4);
- — the method of cooling: air-cooled;
  oil-cooled.

Auto-transformers can be:
- — either built-in into the starter, in which case the resulting temperature rise has to be taken into account in determining the ratings of the starter;
- — or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between manufacturer of the transformer and manufacturer of the starter.

5. Nameplates

See IEC Publication 292-1, but:
- — in Item *d),* the words "utilization category and" are to be deleted;
- — Item *i)* is to be deleted;
- — the following additional requirement is to be added:

"The following data shall be given on the transformer:

"*p)* rated starting voltage(s), i.e. voltage(s) at the tapping terminals.

"*Note.* — This may be expressed as a percentage of the rated operational voltage of the starter."

6. Standard conditions for operation in service

6.1 *Normal service conditions*

See IEC Publication 292-1.

6.1.1 *Ambient air temperature*

See IEC Publication 292-1.

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6.1.2 *Altitude*

See IEC Publication 292-1.

6.1.3 *Atmospheric conditions*

See IEC Publication 292-1.

6.1.4 *Conditions of installation*

See IEC Publication 292-1.

7. Standard conditions for construction

7.1 *Mechanical design*

7.1.1 *General*

Materials shall be suitable for the particular application and capable of passing the appropriate tests. If any part of the starter is oil-immersed, the construction shall be such that ignitable gases do not accumulate, and arcing parts and fuses shall be so located that there is no risk of gas ignition.

Special attention shall be called to flame and humidity resisting qualities, and to the necessity to protect certain insulating materials against humidity.

No contact pressure shall be transmitted through insulating material other than ceramic, pure mica or other material with characteristics not less suitable, unless there is sufficient resiliency in the metallic parts to compensate for any possible shrinkage of the insulating material.

If any part of the starter is oil-immersed, the tank shall be provided with means for indicating the correct oil level.

When starters are used in conditions in which overheating of the starting transformer would represent an exceptional hazard, it is recommended that a suitable device be fitted to switch off the starter in the event of overheating. In particular, in the case of an oil-immersed transformer, the starter shall be equipped with a suitable device to switch off the starter in the event of overheating of the oil.

7.1.2 *Clearances and creepage distances*

See IEC Publication 292-1.

7.1.3 *Terminals*

See IEC Publication 292-1.

7.1.3.1 *Arrangement of terminals*

See IEC Publication 292-1.

7.1.3.2 *Earth terminal*

See IEC Publication 292-1.

7.2 *Enclosures*

7.2.1 (Vacant)

7.2.2 *Mechanical details*

See IEC Publication 292-1.

7.2.3 *Insulation*

See IEC Publication 292-1.

7.3 *Temperature rise*

7.3.1 *Results to be obtained*

See IEC Publication 292-1, but add after Table V:

For the reason that (in an auto-transformer starter) the auto-transformer is energized only intermittently, a maximum temperature rise of 15°C greater than the figures in the above table is permissible for the windings of the transformer when the starter is operated according to the requirements of Clauses 4.4.4 and 4.4.6.1.

7.3.2 *Ambient air temperature*

See IEC Publication 292-1.

7.3.3 *Main circuit*

The main circuit of an auto-transformer starter shall be capable of carrying, in the FULL ON position, its rated thermal current (see Clause 4.4.2.1) without the temperature rises exceeding the limits specified in Table VI of IEC Publication 292-1.

Note. — Only the terminals intended for external connections are considered, in this standard, as terminals of the starter. When the terminals are intended for the connection of insulated conductors, they have to meet the temperature-rise conditions specified in Table VI.

7.3.4 *Windings of control electro-magnets*

With current flowing through the main circuit, the windings of coils, including those of the electrically operated valves of electro-pneumatic starters, shall withstand under continuous load and at the rated frequency, if applicable, their rated voltage without the temperature rises exceeding the limits specified in Tables V and VI. Specially rated coils, e.g.: trip coils of latched contactors and certain magnetic valve coils for interlocked pneumatic starters, shall withstand without damage the most severe operating cycle for which they are intended.

With no current flowing through the main circuit, under the same conditions of supply and without the temperature-rise limits being exceeded, the coil windings of starters for intermittent duty Classes 0.1 and 0.3 shall also withstand the following frequencies of operation:

Intermittent duty class of the starter	One close-open operating cycle every	Interval of time during which the supply of the control coil is maintained
0.1	300 s	180 s
0.3	120 s	72 s

Note. — Operating coils of auto-transformer starters which are energized during the starting period only may be considered as specially rated coils, mentioned in the first paragraph of the present clause.

7.3.5 *Auxiliary circuits*

See IEC Publication 292-1.

7.4 *Dielectric properties*

See IEC Publication 292-1.

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7.5 *Operating conditions*

7.5.1 *General*

Auto-transformer starters shall be trip-free in both starting and FULL ON positions.

In order to avoid too large a peak of current or torque when changing from the starting to the FULL ON position, it is recommended that this change-over occurs only when the motor has reached a speed higher than 80% of its rated speed.

If the starter can be left in the starting position, the overload relay or release shall protect the motor in this position as well as in the FULL ON position; furthermore, an appropriate protection of the transformer when the starter is in the starting position shall be provided.

The starter shall be designed to permit stopping the motor from the starting position as well as from the FULL ON position.

For a starter employing contactors, it is also necessary to ensure that, when the starter has been carrying the full-load motor current continuously, at the ambient air temperature corresponding to the rated characteristics, the overload relay does not trip and open the coil circuit of the starter, as a result of mechanical shocks of operating the contactors.

7.5.2 *Limits of operation*

See IEC Publication 292-1.

7.5.3 *Opening by relays or releases*

7.5.3.1 *Opening by releases with shunt coil (shunt-trips)*

See IEC Publication 292-1.

7.5.3.2 *Opening by thermal and magnetic time-delay overload relays*

See IEC Publication 292-1.

7.5.3.2.1 *Opening by thermal and magnetic time-delay overload relays when all their poles are energized*

See IEC Publication 292-1.

7.5.3.2.2 *Opening by multipole thermal overload relays when only some of their poles are energized*

See IEC Publication 292-1.

7.5.3.3 *Opening by magnetic instantaneous overload relays*

See IEC Publication 292-1.

7.5.3.4 *Opening by undervoltage relays or releases*

See IEC Publication 292-1.

7.5.4 *Automatic change-over from the starting position to the FULL ON position by undercurrent relays*

The lowest drop-out current of an undercurrent relay shall be not less than 1.5 times the highest current setting of the overload relay of Type 1 (see Clause 4.3.3) and not less than 1.3 times the highest current setting of the overload relay of Type 2 which is active in the starting position. The undercurrent relay shall be able to carry any value of current from its lowest current setting to the stalled current in the starting position for the tripping time determined by the overload relay at its highest current setting.

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8. Tests

8.1 *Verification of the characteristics of a starter*

See IEC Publication 292-1.

8.1.1 *Type tests*

They comprise:

a) verification of temperature-rise limits (see Clause 8.2.2);
b) verification of dielectric properties (see Clause 8.2.3);
c) verification of rated making and breaking capacities and of change-over ability (see Clause 8.2.4);

d) verification of operating limits (see Clause 8.2.5);
e) verification of operating limits and characteristics of overload relays (see Clause 8.2.6);

f) verification of mechanical endurance (see Clause 8.2.7).

8.1.2 *Routine tests*

They comprise:

a) operation tests (see Clause 8.3.2);
b) dielectric tests (see Clause 8.3.3);
c) verification of the voltage at the auto-transformer taps;
d) verification, at the motor terminals of the starter, that the phase sequence is the same in both the starting and the FULL ON positions of the starter.

8.1.3 *Special tests*

These are tests subjected to agreement between manufacturer and user.

8.2 *Type tests*

8.2.1 *General*

See IEC Publication 292-1.

8.2.2 *Verification of temperature-rise limits*

When the starting auto-transformer is mounted within the starter enclosure or in such a way that it can significantly affect the temperature within the enclosure, it shall be separately energized during the temperature-rise tests of Clauses 8.2.2.2, 8.2.2.3 and 8.2.2.4. The power dissipated in the auto-transformer shall be calculated taking into account the rated duty (see Clause 4.4.4) and the starting characteristics (see Clause 4.4.6.1); it shall correspond to the average power dissipated in the starting auto-transformer.

When the auto-transformer is mounted apart from the starter or does not significantly affect the temperature within the starter enclosure, it may be disconnected during the tests.

8.2.2.1 *Ambient air temperature*

See IEC Publication 292-1.

8.2.2.2 *Temperature-rise tests of the main circuit*

See IEC Publication 292-1 with the following exceptions:

— 4th paragraph shall read:
"For a starter with contactors, the contacts shall, where practicable, be closed by energizing the contactor-operating coils at their rated voltage and, if electro-pneumatic, at the rated pressure."

[IEC page 31]

— 5th paragraph shall read:
"The temperature-rise test of the main circuit is made at the rated thermal current (see Clause 7.3.3) and the starter shall be in the FULL ON position."

8.2.2.3 *Temperature-rise tests on control electro-magnets*

See IEC Publication 292-1.

Note. — These tests do not apply to the coils mentioned in the Note to Clause 7.3.4.

8.2.2.4 *Temperature-rise tests of auxiliary circuits*

See IEC Publication 292-1.

8.2.2.4a *Temperature-rise tests of the auto-transformer*

The temperature rise of the auto-transformer (and of the oil in the case of an oil-cooled transformer) shall not exceed the limits specified in Table V of IEC Publication 292-1 increased by 15 °C (see Clause 7.3.1), and those specified in Table VI of IEC Publication 292-1 when the starter is operated at its rated duty (see Clause 4.4.4) and according to its starting characteristics (see Clause 4.4.6.1).

The current through each winding of the auto-transformer shall be thermally equivalent to the current carried when the controlled motor is operating with the maximum starting current and starting time for which the starter is rated (see Clause 4.4.6.1); this condition is assumed to be reached when the current drawn from the auto-transformer during the starting time is equal to the maximum starting current, specified in Clause 4.4.6.1.1, multiplied by:

$$0.8 \times \frac{\text{starting voltage}}{U_e} \qquad \text{(see Clause 4.4.1.3)}$$

The operating cycles shall be evenly spaced in time according to the number of starts per hour (see Clause 4.4.3.1).

In the event of two successive operating cycles (see Clause 4.4.4), the temperature rise of the auto-transformer may exceed the maximum value given in Clause 7.3.1 but no damage shall result to the auto-transformer.

In the case of an auto-transformer with several sets of taps, the test shall be made with the taps giving the highest power loss in the transformer; it shall be made over a period of time sufficient for the temperature rise to reach a constant value, but not exceeding eight hours.

In order to facilitate this test, star connected impedances may be used in place of a motor.

8.2.2.5 *Measurement of the temperature of parts*

See IEC Publication 292-1.

8.2.2.6 *Temperature rise of a part*

See IEC Publication 292-1.

8.2.2.7 *Corrections*

See IEC Publication 292-1.

8.2.3 *Verification of dielectric properties*

8.2.3.1 *Condition of the starter for tests*

See IEC Publication 292-1.

8.2.3.2 *Application of the test voltage*

See IEC Publication 292-1.

The auto-transformer shall satisfy the dielectric tests specified in IEC Publication 76; consequently, it shall be disconnected during the dielectric tests appearing in the present clause.

8.2.3.2.1 *Main circuit*

See IEC Publication 292-1.

8.2.3.2.2 *Control and auxiliary circuits*

See IEC Publication 292-1.

8.2.3.3 *Value of the test voltage*

See IEC Publication 292-1.

8.2.4 *Verification of rated making and breaking capacities and of change-over ability*

8.2.4.1 *General*

The tests concerning the verification of the making and breaking capacities and of change-over ability of an auto-transformer starter are intended to verify that this starter is capable of making and breaking the currents given in Table II of Clause 4.4.6 and not to verify the contact wear over long periods of operation.

The verifications of making capacity and breaking capacity are made as separate tests.

If the switching devices used in the starter have already been tested for their making and breaking capacities, the purpose of this test is only to verify the ability of the starter to change-over from the starting to the FULL ON position. Moreover, the test will verify the ability of the starter to break the circuit in the starting position under the conditions of Clause 8.2.4.4 and in the FULL ON position under the conditions of Clause 8.2.4.5.

If the switching devices used in the starter have already satisfied the tests of IEC Publication 292-1 concerning the verification of rated breaking and making capacities and of reversibility, the tests called for in present Clause 8.2.4 need not be carried out.

8.2.4.2 *Condition of the starter for tests*

See IEC Publication 292-1.

8.2.4.3 *Test circuit for the verification of making and breaking capacities*

See IEC Publication 292-1.

8.2.4.4 *Verification of making capacity and change-over ability*

I_e being the rated operational current of the auto-transformer starter, the conventional test circuit shall be adjusted so as to obtain, in the FULL ON position, the value of current given for "make" in Table II of Clause 4.4.6.

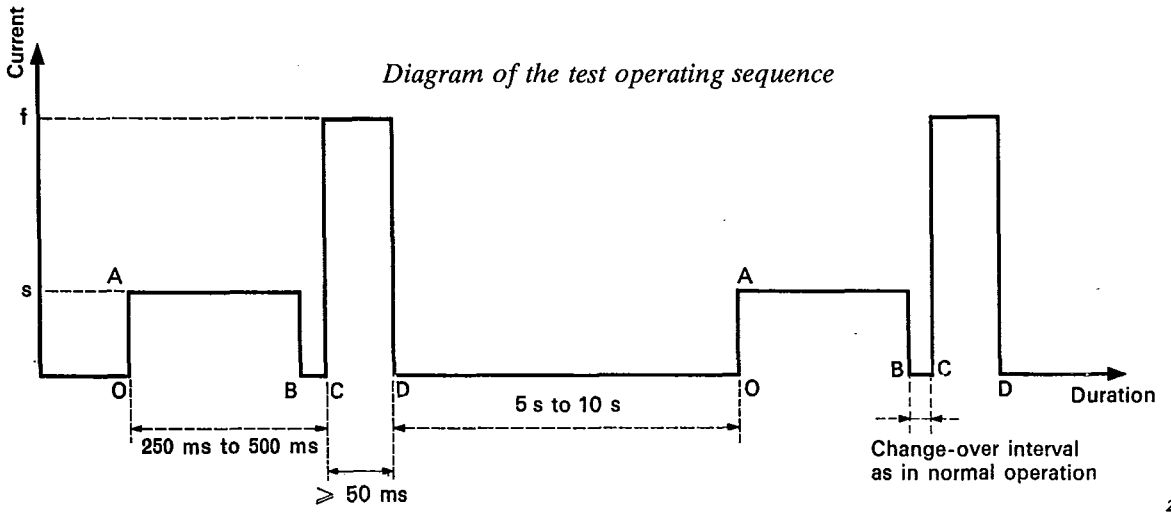
The load circuit shall be connected to the motor terminals of the starter. When a transformer has more than one output voltage, it shall be connected to give the highest starting voltage. Each operating cycle of the verification of making capacity and change-over ability shall be in accordance with the diagram of the test operating sequence and shall consist of:

a) Make current in the starting position by the starter.
b) Break current in the starting position by the starter.
c) Make current in the FULL ON position by the starter.
d) Break current in the FULL ON position by an external device.
e) Return the starter to the OFF position.
f) Close the external device.

Note. — When a starter is provided with an automatic change-over device having a resetting time greater than 10 s, the time interval between successive operations shall be as short as is permitted by this device.

[IEC page 35]

Diagram of the test operating sequence



s = starting position
f = FULL ON position
Note. — With closed transition starters, a current will flow during the transition period BC.

The number of sequences to be made is:
— For starters with contactors: 100 sequences, 50 of which are made at 85% and 50 at 110% of the rated control supply voltage.
— For manual starters: 20 sequences.

8.2.4.5 *Verification of breaking capacity in the FULL ON position*

I_e being the rated operational current of the auto-transformer starter, the conventional test circuit shall be adjusted so as to obtain, in the FULL ON position, the value of current given for "break" in Table II of Clause 4.4.6.

The load circuit shall be connected to the motor terminals of the starter.

The total number of operating sequences to be made is 25. The overload relay shall be reset, if necessary, after each sequence.

Each breaking operating sequence shall consist of:

a) Place the starter in the FULL ON position on no-load.
b) Close the circuit by an external device.
c) Open the circuit by the starter.
d) Open the external device on no-load.

Five of these sequences are carried out with the starter tripped by the overload relay; however, for large starters (of 630 A at least), only three sequences are tripped by the overload. The time interval between two successive opening sequences shall be as short as possible, taking into account the resetting characteristics of the overload relay.

The remaining sequences of the 25 are carried out with the starter tripped under the control of the operator, with the overload relay short-circuited if necessary. The duration of current flow shall not exceed 0.5 s per sequence, and the time interval between two successive opening sequences shall be 5 s to 10 s.

Note. — For large starters, the maximum time interval of 10 s specified above may be increased by agreement between manufacturer and user.

However, if the mechanical switching device has satisfied the test of IEC Publication 158-1, Low-voltage Controlgear, Part 1: Contactors (Clause 8.2.4.5 of the second edition), these sequences (tripped by the operator) need not be repeated.

8.2.4.6 (Vacant)

8.2.4.7 *Behaviour of the starter during making and breaking tests and during change-over ability tests*

During tests within the limits of specified making and breaking capacities and with the specified number of operating sequences, there shall be no permanent arcing, no flashover between poles, no melting of the fuse in the earth circuit (see Clause 8.2.4.2) and no welding of the contacts.

[IEC page 37]

If a starter is intended for open mounting or to be mounted with other apparatus in an enclosure having large dimensions with respect to the volume of the starter, arc and flames shall not extend beyond the safety area stated by the manufacturer.

8.2.5 *Verification of operating limits*

See IEC Publication 292-1.

8.2.6 *Verification of operating limits and characteristics of overload relays*

See IEC Publication 292-1.

8.2.7 *Verification of mechanical endurance*

8.2.7.1 *Condition of the starter for tests*

See IEC Publication 292-1.

8.2.7.2 *Operating conditions*

See IEC Publication 292-1.

8.2.7.3 *Test procedure*

The tests are carried out at the frequency of operating cycles corresponding to the class of intermittent duty. However, if the manufacturer considers that the starter can satisfy the required conditions when using a higher frequency of operating cycles, he may do so in order to reduce the duration of the test.

In the case of auto-transformer starters comprising electromagnetic and electro-pneumatic contactors, the duration of energization of each of the control coils shall be greater than the time of operation of the contactor and the time during which the coil is not energized shall be of such a duration that the contactor can come to rest. The built-in device causing time delay between closing on the starting position and closing on the FULL ON position, if adjustable, may be set at its lowest value.

The number of operating cycles to be carried out shall be not less than the number of operating cycles specified in Clause 4.4.7.

For starters fitted with shunt releases or undervoltage releases, at least 10% of the total number of opening operating cycles shall be performed by these releases.

The verification of mechanical endurance may be made separately on the various parts of the starter unless a mechanical interlock not previously tested with its contactor is involved.

After each tenth of the total number of operating cycles given in Clause 4.4.7 has been carried out, it is permissible before carrying on with the test:

— to clean the whole starter without dismantling;
— to lubricate parts for which lubrication is prescribed by the manufacturer for normal service;
— to adjust the travel and the pressure of the contacts if the design of the starter enables this to be done, or to replace the contacts if they are worn, the wear of the contacts not being taken into consideration during these tests of mechanical endurance.

This maintenance work shall not include any replacement of parts except for the contacts.

8.2.7.4 *Results to be obtained*

Following the tests of mechanical endurance, the starter shall still be capable of complying with the operating conditions specified in Clauses 7.5 and 8.2.5. There shall be no loosening of the parts used for connecting the conductors, and any timing relays or other devices for the automatic control of acceleration shall still be operating correctly.

[IEC page 39]

8.3 *Routine tests*

8.3.1 *General*

See IEC Publication 292-1.

8.3.2 *Operation tests*

See IEC Publication 292-1.

Tests shall be carried out to verify the stated time delay of the time-delay relays or to verify the operation of the undercurrent relays, according to the requirements of Clause 7.5.4.

It shall also be verified that the starter permits stopping of the motor from the starting position as well as from the FULL ON position (see Clause 7.5.1).

It shall also be verified that the open-circuit voltages on the tapping terminals of the auto-transformer are in accordance with the designed figures and that the phase sequence at the motor terminals of the starter is correct in both the starting and the FULL ON positions of the starter.

8.3.3 *Dielectric tests*

See IEC Publication 292-1.

During these tests, the auto-transformer may be disconnected.

8.4 *Special tests*

No special tests are specified in this standard.

TYPICAL METHODS AND DIAGRAMS OF STARTING ALTERNATING-CURRENT INDUCTION MOTORS BY MEANS OF AUTO-TRANSFORMERS

SERIES CLOSED TRANSITION	PARALLEL OPEN OR CLOSED TRANSITION	PARALLEL OPEN TRANSITION

Three-coil transformer

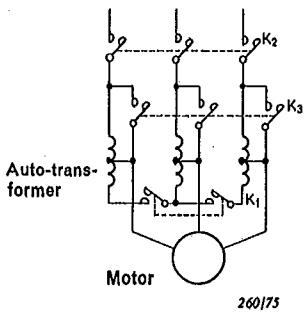


Diagram A_1

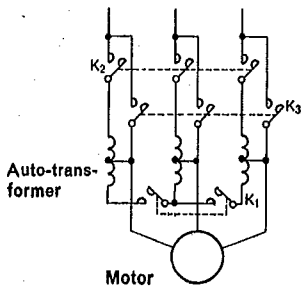


Diagram B_1

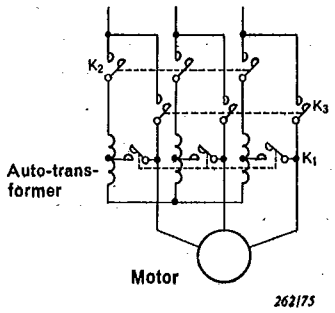


Diagram C_1

Two-coil transformer

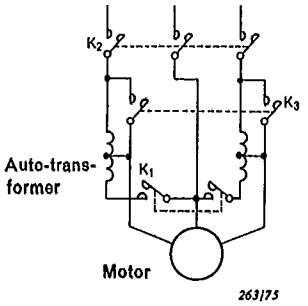


Diagram A_2

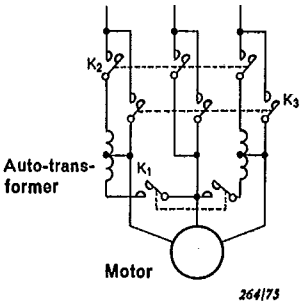


Diagram B_2

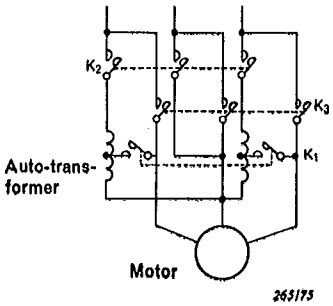


Diagram C_2

Contact sequence			
Contacts	Start	Transi-tion	Full on
K_1	C	O	O
K_2	C	C	C
K_3	O	O	C

C = contact closed

O = contact open

Contact sequence					
Contacts	Start	Open transi-tion	Closed transition		Full on
			1	2	
K_1	C	O	O	O	O
K_2	C	O	C	C	O
K_3	O	O	O	C	C

For open transition, K_1 and K_2 may be contacts of the same mechanical switching device.

Contact sequence			
Contacts	Start	Transi-tion	Full on
K_1	C	O	O
K_2	C	O	O
K_3	O	O	C

K_1 and K_2 may be contacts of the same mechanical switching device.

Note. — The graphical symbols utilized above correspond to the case where all the mechanical switching devices are contactors.

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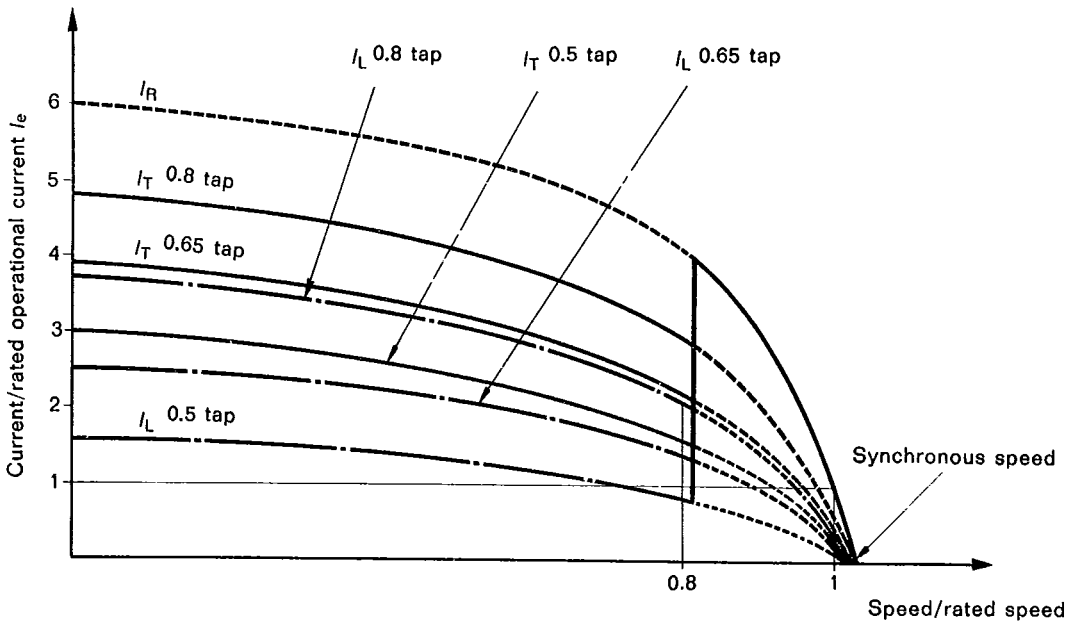

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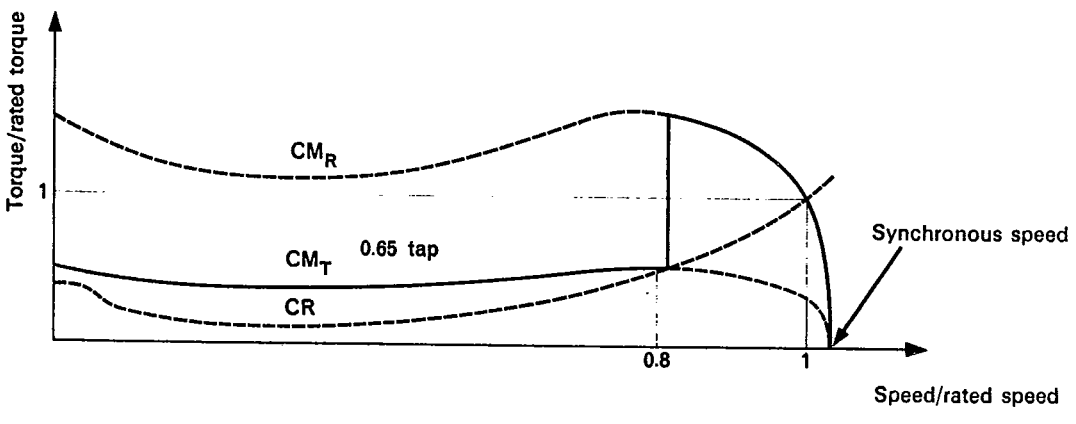
I_R = motor current at rated voltage

I_T = motor current at reduced voltage

I_L = line current at reduced voltage



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CR = load torque

CM = motor torque { CM_R = at rated voltage; CM_T = at reduced voltage

FIGURE. —Typical curves of currents and torques during an auto-transformer start.

[IEC page 43]

Standards publications referred to

See foreword

BS 4941 : Part 4 : 1977
IEC 292-4 : 1975

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Committee reference PEL/92/1 Draft for comment 76/27445 DC

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*British Electrical and Allied Manufacturers' Association (BEAMA)
British Railways Board
British Steel Corporation
Department of Energy (Electricity)
*Electrical Contractors' Association
Electrical Contractors' Association of Scotland
*Electrical Research Association
*Electricity Supply Industry in England and Wales
*Engineering Equipment Users' Association
*Institution of Electrical Engineers
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Copper Development Association
Department of the Environment (PSA)
Electrical Installation Equipment Manufacturers' Association (BEAMA)
Electronic Components Industry Federation
Health and Safety Executive
Transmission and Distribution Association (BEAMA)

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