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(Reprinted, incorporating Amendment No. 1)

Specification for

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

Part 1. Direct-on-line (full voltage) a.c. starters

(Implementation of CENELEC HD 421)

Spécification des démarreurs de moteur pour les tensions inférieures et égales à 1000 V en courant alternatif et 1200 V en courant continu
Partie 1. Démarreurs directs (sous pleine tension) en courant alternatif

Spezifikation für Motorstarter für Spannungen bis und einschließlich 1000 V Wechselstrom und 1200 V Gleichstrom
Teil 1. Wechselstrom- Motorstarter zum direkten einschalten

British Standards Institution

Foreword

This revision of BS 4941 : Part 1 has been prepared under the direction of the Power Electrical Engineering Standards Committee. It specifies direct-on-line (full voltage) a.c. motor starters. BS 4941 : Part 1 : 1973 was harmonized technically with IEC 292-1 : 1969, published by the International Electrotechnical Commission (IEC), but was not published as a dual-numbered standard. Since its publication Parts 2, 3 and 4 of BS 4941 were published as dual-numbered standards. BS 4941 : Part 1 incorporated IEC 292-1A : 1971 but subsequently substantial amendments to the IEC Publication have been published by way of IEC 292-1B : 1973 and IEC 292-1C : 1975 and since these affected certification it was decided to issue a revision of BS 4941 : Part 1 as a dual-numbered standard incorporating these amendments. Amendment No. 1 to the 1979 revision of BS 4941 : Part 1 brings the British Standard into alignment with the harmonized standard document HD 421 published by the European Committee for Electrotechnical Standardization (CENELEC) and removes the dual-numbering. HD 421 consists of IEC Publication 292-1 : 1969 and its Amendment No. 1 : 1979 and supplements 292-1A : 1971, 292-1B : 1973 and 292-1C : 1975, but has introduced modifications to clauses **4.4.4.3.1**, **7.1.3.2** and **7.2.2**. HD 421 also incorporates IEC Publication 292-2 : 1970 and IEC Publication 292-3 : 1973.

For ease of reproduction most of the text and format of the referenced IEC Publications have been used as the basis of this British Standard. Some terminology and conventions are not identical with those in British Standards; attention is drawn especially to the following.

Wherever the word 'Recommendation' appears referring to this standard, it should be read as 'Part of BS 4941'.

Cross-references

International standards	Corresponding British Standards
IEC 85 : 1984	BS 2757 : 1986 Method for determining the thermal classification of electrical insulation (Identical)
IEC 144 : 1963	BS 5420 : 1977 Specification for degrees of protection of enclosures of switchgear and controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c. (Identical)
IEC 292	BS 4941 Specification for motor starters for voltages up to and including 1000 V a.c. and 1200 V d.c.
IEC 292-2 : 1970	Part 2 : 1977 Reduced voltage a.c. starters, star delta starters (Identical)
IEC 292-3 : 1973	Part 3 : 1977 Rheostatic rotor starters (Identical)
IEC 439 (now reissued as IEC 439-1 : 1985)	BS 5486 Low voltage switchgear and controlgear assemblies Part 1 : 1986 Specification for type-tested and partially type-tested assemblies (Identical)

The Technical Committee has reviewed the provisions of the following international standards to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

International standards	Related British Standards
IEC 157-1 : 1973	BS 4752 Specification for switchgear and controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c. Part 1 : 1977 Circuit-breakers
IEC 158-1 : 1970	BS 5424 Specification for controlgear for voltages up to and including 1000 V a.c. and 1200 V d.c. Part 1 : 1977 Contactors
IEC 269-1 : 1968	BS 88 Cartridge fuses for voltages up to and including 1000 V d.c. and 1500 V d.c. Part 1 : 1977 General requirements BS 1361 : 1971 Cartridge fuses for a.c. circuits in domestic and similar premises BS 1362 : 1973 General purpose fuse links for domestic and similar purposes (primarily for use in plugs)
IEC 282 : 1974	BS 2692 Fuses for voltages exceeding 1000 V a.c. Part 1 : 1975 Current limiting fuses

NOTE. In table V, note 2 to table V, table VI, note 5 to table VI and in paragraphs 3 and 5 of **8.2.2.5**, the unit symbol 'deg C' should be read as '°C'. In paragraph 6, of **8.2.2.2** and paragraph 5 of **8.2.2.3** '1 deg C per hour' should be read as '1 °C/h'.

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British Standard Specification for

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

Part 1. Direct-on-line (full voltage) a.c. starters

1. General

1.1 *Scope*

This Recommendation applies to direct-on-line starters for industrial use, intended to start and accelerate a motor to normal speed and to provide means for the protection of the motor and its associated circuits against operating overloads, and to cause intentionally the motor to stop. It applies only for a.c.

This Recommendation applies also to reversing starters.

The direct-on-line starters dealt with in this Recommendation are not designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see Appendix C) should form part of the installation, but not necessarily in the starter.

It 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. Starters for d.c. motors and static starters are not dealt with.

The clauses of this Recommendation relating to overload protection are not applicable in the case of controlgear relying for its operation on built-in over-temperature protective devices.

Note. — The expression "built-in" means built into the motor.

1.2 *Object*

The object of this Recommendation is to state:

1. the characteristics of direct-on-line starters;
2. the conditions with which starters must 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

2.1 *Starter*

The combination of all the switching means necessary to start and stop the motor, in combination with suitable overload protection.

2.2 *Direct-on-line starter*

A starter which connects the line voltage across the motor terminals in one step.

2.3 *Reversing starter*

A starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections while it is running.

2.4 *Manual starter*

A starter in which the force for closing the main contacts is provided exclusively by manual energy.

2.5 *Electromagnetic starter*

A starter in which the force for closing the main contacts is provided by an electro-magnet (e.g.: contactor starter).

2.6 *Motor operated starter*

A starter in which the force for closing the main contacts is provided by an electric motor.

2.7 *Pneumatic starter*

A starter in which the force for closing the main contacts is provided by a device using compressed air, without the use of electrical means.

2.8 *Electro-pneumatic starter*

A starter in which the force for closing the main contacts is provided by a device using compressed air under the control of electrically operated valves.

2.9 *Over-current*

Any current exceeding the rated current.

2.10 *Overload*

Operating conditions in an electrically undamaged circuit, which cause an over-current.

Note. — An overload may cause damage if sustained for a sufficient time.

2.11 *Short-circuit current*

An over-current resulting from a fault in an electrical circuit.

2.12 *Overload relay or release*

An over-current relay or release intended for protection against overloads.

2.13 *Thermal overload relay or release*

An inverse time-delay overload relay or release depending for its operation (including its time-delay) on the thermal action of the current flowing in the relay or release.

Magnetic overload relay or release

An overload relay or release depending for its operation on the force exerted by a current flowing in the coil of an electromagnet.

Note. — Such a relay or release usually has an inverse time-delay/current characteristic.

2.14 *Current setting of an overload relay or release*

The value of current for which the relay or release is adjusted and in accordance with which its operating conditions are defined.

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

The range between the minimum and maximum values over which the current setting of the relay or release can be adjusted.

2.17 *Phase failure sensitive thermal overload relay or release*

A multiple thermal overload relay or release which, in accordance with specified requirements, operates at a current value lower than its current setting in the case of current unbalance.

3. Classification

3.1 According to the method of control, starters are designated as:

— automatic (by pilot switch or sequence control);
— non-automatic (such as by hand operation or by push-buttons).

3.2 According to the method of operation, starters are designated as:

— manual;
— electromagnetic;
— motor operated;
— pneumatic;
— electro-pneumatic.

3.3 According to the interrupting medium, starters are divided into different groups, e.g.:

— air break;
— oil-immersed break.

3.4 According to the degree of protection provided by the enclosure. Full details are given in IEC Publication 144, Degrees of Protection of Enclosures for Low-voltage Switchgear and Controlgear.

4. Characteristics of starters

4.1 *Summary of characteristics*

The characteristics of a 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 relays and releases (see Clause 4.3) and number of these devices.
— Degrees of protection of enclosures (see Clause 3.4).
— Rated values (see Clause 4.4).
— Control circuits and air supply systems (see Clause 4.5).
— Auxiliary circuits (see Clause 4.6).
— Co-ordination with short-circuit protective devices (see Appendix C).

[IEC 292-1 page 11
IEC 292-1B page 5
and IEC 292-1C page 5]

4.2 *Types of switching devices*

The following shall be stated:

4.2.1 *Number of poles*

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

4.2.3 *Method of operation*, for example: dependent manual operation, dependent power operation (e. g.: contactor), stored energy operation, etc.

In the case of manual starters, the type of operating device shall be stated: handle, lever, push-buttons, etc.

4.3 *Types and characteristics of relays and releases*

Note. — In the remainder of the Recommendation, the words "overload relay" shall be taken to apply equally to an overload relay or an overload release as appropriate.

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).
   c) dependent on previous load (e.g. thermal overload relay) and also sensitive to phase failure (see Clause 2.17).
4. Instantaneous over-current relay or release (when applicable).
5. Other relays or releases (e. g.: phase unbalance relay).

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);
   — time-current characteristics (or range of characteristics), when necessary;
   — number of poles;
   — nature of the relay: thermal or magnetic.

Note. — 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.

4.3.3 *Designation and current settings of overload relays*

Overload relays are designated by their type and their current setting.

An overload relay is said to be:

— of Type 1 if the current setting refers to the associated motor full-load current (see Clause 7.5.3.2.1 1);
— of Type 2 if the current setting is the ultimate trip current (see Clause 7.5.3.2.1 2).

[IEC 292-1 page 13
as modified by IEC 292-1C page 5,
and IEC 292-1B page 51

Both types are designated by the current setting (or the upper and lower limits of the current setting range, if adjustable).

The current setting (or current setting range) shall be marked on the overload relay or its scale. The marking may be either directly in amperes, or as a function of the current value marked on the relay or, *in the case of a thermal overload relay*, on the heaters if these are replaceable.

However, if the current setting is influenced by the conditions of use or other factors which cannot readily be marked on the relay, then the relay or any interchangeable parts thereof (e. g.: operating coils, heaters or current transformers) shall carry a number or an identifying mark which makes it possible to obtain the relevant information from the manufacturer or his catalogue, or preferably, from data furnished with the starter.

In the case of indirect (current transformer operated) overload relays, the marking may refer either to the primary current of the current transformer through which they are supplied, or to the current setting of the overload relays. In either case, the ratio of the current transformer shall be stated.

4.3.4 *Time-current characteristics of overload relays*

The time-current characteristics shall be given in the form of curves supplied by the manufacturer. These shall indicate how the tripping time, starting from the cold state (see Clause 4.3.5), varies with the current up to a value of at least eight times the full-load current of the motor with which it is intended that the relay be used. The manufacturer shall indicate, by suitable means, the tolerances applicable to these curves.

These curves must be given for each extreme value of the current setting and, if the time-current characteristics are adjustable, it is recommended that they be given in addition for each extreme value of the time setting.

Note. — It is recommended that the current be plotted as abscissae and the time as ordinates, using logarithmic scales. Further, in order to facilitate the study of co-ordination of different types of protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheet detailed in IEC Publication 282-1, High-voltage Fuses, Part 1: Current-limiting Fuses (First edition, Clause 17.9).

4.3.5 *Influence of ambient air temperature*

The time-current characteristics (see Clause 4.3.4) refer to a stated value of ambient air temperature, and are based on no previous loading of the overload relay (viz. from an initial cold state). This value of the ambient air temperature shall be clearly given on the time curves; the preferred values are + 20 °C or + 40 °C.

The overload relays shall be able to operate within the ambient air temperature range of − 5 °C to + 40 °C, and the manufacturer shall be prepared to state the effect of variations in ambient air temperature on the characteristics of overload relays.

4.4 *Rated values*

The rated values established for a starter shall be stated in accordance with Clauses 4.4.1 to 4.4.8, but it is not necessary to establish all the rated values listed.

4.4.1 *Rated voltages*

A starter is defined by the following rated voltages:

4.4.1.1 *Rated operational voltages*

A rated operational voltage (U_e) of a starter is a value of voltage which, combined with a rated operational current, determines the application of the starter and to which are referred the making and breaking capacities, the type of duty and the utilization category.

For polyphase circuits, it is stated as the voltage between phases.

Note. — For rated voltages of control circuits, see Clause 4.5.1.

4.4.1.2 *Rated insulation voltage*

The rated insulation voltage (U_i) of a starter is the value of voltage which designates it, and to which dielectric tests, clearances and creepage distances are referred.

Unless otherwise stated, the rated insulation voltage is the value of the maximum rated operational voltage of the starter. In any case, the maximum rated operational voltage shall not exceed the rated insulation voltage.

4.4.2 *Rated currents*

A starter is defined by the following rated currents:

4.4.2.1 *Rated conventional thermal current*

The rated conventional thermal current (I_{th}) of a starter is the maximum current stated by the manufacturer that the unenclosed starter can carry in 8 h duty (see Sub-clause 4.4.4.1) when tested in free air, without the temperature-rise of its several parts exceeding the limits specified in Sub-clause 7.3 (Tables V and VI) when tested according to Sub-clause 8.2.2.

Notes 1.– Free air is understood to be that obtained under normal indoor conditions reasonably free from dust and external radiation.

2.– An unenclosed starter is a starter supplied by the manufacturer without an enclosure or a starter supplied by the manufacturer with an enclosure forming an integral part of the starter.

4.4.2.2 *Rated enclosed thermal current*

The rated enclosed thermal current (I_{the}) of a starter is the maximum current stated by the manufacturer that the starter can carry in the stated duty (see Sub-clause 4.4.4) when mounted in a specified enclosure. Tests for this rating shall be in accordance with Sub-clause 8.2.2, but are not mandatory if the test for "rated conventional thermal current" has been made, and the manufacturer is prepared to state an enclosed thermal current rating.

The rating may be an unventilated rating, in which case the enclosure shall be of the size stated by the manufacturer to be the smallest that is applicable in service. Alternatively, the rating may be a ventilated rating with the ventilation in accordance with the manufacturer's data.

Note. – It is not possible to usefully define a "rated service thermal current" as the installation and service conditions can vary greatly. (The "rated current" in Sub-clause 4.2 of IEC Publication 439 is in effect the "rated service thermal current".)

4.4.2.3 *Rated operational currents or rated operational powers*

A rated operational current (I_e) of a starter is stated by the manufacturer and takes into account the rated operational voltage (see Sub-clause 4.4.1.1), the rated frequency (see Sub-clause 4.4.3), the rated duty (see Sub-clause 4.4.4), the utilization category (see Sub-clause 4.4.6) and the type of protective enclosure.

In the case of a starter for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the starter is intended. The manufacturer shall be prepared to state the relationship assumed between the current and the power.

4.4.3 *Rated frequency*

The supply frequency for which a starter is designed and to which the other characteristic values correspond.

4.4.4 *Rated duty*

The rated duties considered as normal are as follows:

4.4.4.1 *Eight-hour duty*

Duty in which the main contacts of a starter remain closed, whilst carrying 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 current of the apparatus is determined.
2.— Interruption means breaking of the current by operation of the starter.

4.4.4.2 *Uninterrupted duty*

Duty in which the main contacts of a starter remain closed, whilst carrying 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 contacts) (see Table VI).

4.4.4.3 *Intermittent periodic duty or intermittent duty*

Duty in which the main contacts of a starter 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 the current, the duration of current flow and by the on-load factor which is the ratio of the in-service period to the entire period, often expressed as a percentage.

Example : An intermittent duty comprising a current flow of 100 A for 4 min in every 10 min may be stated as: "Intermittent duty 100 A, 4 min/10 min" or "Intermittent duty 100 A, 6 operating cycles per hour, 40 %".

Standard values of 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, starters are divided into the following classes:

- Class 0.03: up to 1 operating cycle per hour;
- Class 0.1 : up to 12 operating cycles per hour;
- Class 0.03: up to 3 operating cycles per hour;
- Class 1 : up to 120 operating cycles per hour;
- Class 3 : up to 300 operating cycles per hour;
- Class 10 : up to 1 200 operating cycles per hour.

It is recalled that an operating cycle is a complete working cycle comprising one make and one break.

For intermittent duty with a large number of operating cycles per hour, the manufacturer shall indicate, either in terms of the true cycle if this is known, or in terms of conventional cycles designated by him, the values of the rated operational currents which shall be such that:

$$\int_0^T i^2\,dt \leq I_{th}^2 \times T$$

where T is the total operating cycle time.

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*

Duty in which the main contacts of a starter remain closed for periods of time insufficient to allow the starter to reach thermal equilibrium, the current-carrying periods being separated by no-load periods of sufficient duration to restore equality of temperature with the cooling medium.

Standard values of temporary duty are 10 min, 30 min, 60 min and 90 min with contacts closed.

4.4.5 *Making and breaking capacities*

The making and breaking capacities of a starter are defined in accordance with utilization categories as specified in Clause 4.4.6.

Note. — Certain starters may also be subjected to requirements as to their making and breaking capacities in the case of a short-circuit occurring where they are installed. They must then comply with the requirements of this Recommendation, and with the requirements of IEC Publication 157-1, Low-voltage Distribution Switchgear, Part 1: Circuit-breakers (First edition, Clauses 8.2.4 and 8.2.5), for the rated short-circuit making and breaking capacities and for the rated short-time current.

4.4.5.1 *Rated making capacity*

The rated making capacity of a starter is a value of current which the starter can make without welding or undue erosion of the contacts or excessive display of flame, under specified making conditions.

The making conditions which must be specified are:

— the voltage between poles before contact making;
— the characteristics of the test circuit.

The rated making capacity is stated by reference to the rated operational voltage and rated current and to the utilization category, according to Table II.

The rated making capacity is expressed by the r.m.s. value of the symmetrical component of the current.

Note. — The peak value of the current during the first half-cycles following closing of the starter may be appreciably greater than the peak value of the current under steady conditions used in the definition of making capacity, depending on the characteristics of the circuit, and the instant on the voltage wave when closing occurs.
A starter must be capable of closing on a current corresponding to the symmetrical value of the current which defines its making capacity, whatever the value cf the d.c. component may be, within the limits which result from power-factors indicated in Table II.

The rated making capacity is only valid when the starter is operated in accordance with the requirements of Clause 7.5.

4.4.5.2 *Rated breaking capacity*

The rated breaking capacity of a starter is a value of current which the starter can break without undue erosion of the contacts or excessive display of flame, under specified breaking conditions at the rated operational voltage.

The breaking conditions which must be specified are:

— the characteristics of the test circuit;
— the recovery voltage.

The rated breaking capacity is stated by reference to the rated operational voltage and rated current and to the utilization category, according to Table II.

A starter shall be capable of breaking any value of the load current up to its highest rated breaking capacity according to Clause 4.4.6.

The rated breaking capacity is expressed by the r.m.s. value of the symmetrical component of the current.

4.4.6 *Utilization category*

The two utilization categories as given in Table I are considered standard in this Recommendation. Any other type of utilization category shall be based on agreement between manufacturer and user, but information given in the manufacturer's catalogue or tender may constitute such an agreement.

Each 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 definition of the rated making and breaking capacities.

For starters defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities as those values depend directly on the utilization category as shown in Table II.

The utilization categories of Table II correspond in principle to the applications listed in Table I.

TABLE I

Utilization categories

Category	Typical application
AC-3	Starting of squirrel-cage motors, switching-off motors during running
AC-4	Starting of squirrel-cage motors including inching [1]) and, for reversing starters only, plugging [2])

[1]) By inching (jogging) is understood energizing a motor once or repeatedly for short periods to obtain small movements of the driven mechanism.

[2]) By plugging is understood stopping or reversing the motor rapidly by reversing the motor primary connections while it is running (see Clause 8.2.4.6).

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 categories [1])

Category		Make			Break		
		I	U	$\cos\varphi$ [2])	I	U_r	$\cos\varphi$ [2])
AC-3	$I_e \leqq 100$ A	$10\ I_e$	$1.1\ U_e$	0.35 [6])	$8\ I_e$	$1.1\ U_e$	0.35 [6])
	$I_e > 100$ A	$8\ I_e$ [3])		0.35 [6])	$6\ I_e$ [4])		0.35 [6])
AC-4	$I_e \leqq 100$ A	$12\ I_e$	$1.1\ U_e$	0.35 [6])	$10\ I_e$	$1.1\ U_e$	0.35 [6])
	$I_e > 100$ A	$10\ I_e$ [5])		0.35 [6])	$8\ I_e$ [3])		0.35 [6])

I_e = rated operational current (see Clause 4.4.2.3)
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 $\cos\varphi$: $\pm$ 0.05.
[3]) With a minimum of 1 000 A.
[4]) With a minimum of 800 A.
[5]) With a minimum of 1 200 A.
[6]) However, for values of I_e not exceeding 17 A, the value of $\cos\varphi$ is given in Appendix D.

4.4.7 *Mechanical endurance*

With respect to its resistance to mechanical wear, a starter is characterized by the number of no-load operating cycles (i.e. without current on the main contacts) which can be made before it becomes necessary to service or replace any mechanical parts; however, normal maintenance including replacement of contacts as specified in Clause 8.2.7.3 is permitted.

The preferred numbers of no-load operating cycles, expressed in millions, are:

0.001 — 0.003 — 0.01 — 0.03 — 0.1 — 0.3 — 1 — 3 and 10.

If no mechanical endurance is stated by the manufacturer, a class of intermittent duty implies a minimum mechanical endurance corresponding to 8 000 h of operation at the highest corresponding frequency of operating cycles.

4.4.8 *Electrical endurance*

With respect to its resistance to electrical wear, a starter is characterized by the number of on-load operating cycles, corresponding to the service conditions given in Table III, which can be made without repair or replacement.

Unless otherwise stated, the number of on-load operating cycles for Category AC-3 shall be not less than 1/20 of the number of no-load operating cycles corresponding to the mechanical endurance of the starter.

It is recommended that the manufacturer state the above mentioned number of on-load operating cycles.

TABLE III

Verification of the number of on-load operating cycles

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

Category	Make			Break		
	I	U	$\cos \varphi$ [2]	I	U_r	$\cos \varphi$ [2]
AC-3	$6\ I_e$	U_e	0.35	I_e	$0.17\ U_e$	0.35
AC-4	$6\ I_e$	U_e	0.35	$6\ I_e$	U_e	0.35

I_e = rated operational current (see Clause 4.4.2.3)

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 $\cos \varphi$: $\pm$ 0.05.

4.5 *Control circuits and air-supply systems*

The characteristics of control circuits and air-supply systems are:

4.5.1 *For control circuits*

— the rated control circuit voltage (U_c) (nature and frequency if a.c.);

— the rated control supply voltage (U_s) (nature and frequency if a.c.).

Note. — A distinction has been made above between the *control circuit voltage*, which is the voltage which would appear across the normally open contacts of a control device in the coil circuit, and the *control supply voltage*, which is the voltage applied to the input terminals of the control circuit in the starter and may be different from the control circuit voltage, due to the presence of built-in transformers, rectifiers, resistors, etc.

The rated control circuit voltage and rated frequency, if any, are the values on which the insulation characteristics of the operating coil circuit are based.

The rated control supply voltage and rated frequency, if any, are the values on which the operating and temperature-rise characteristics of the control circuit are based. The correct operating conditions are based upon a value of the control supply voltage not less than 85% of its rated value with the highest value of control circuit current flowing, nor more than 110% of its rated value. The control supply voltage for the open circuit shall not exceed 120% of the rated control supply voltage U_s.

If the rated control circuit voltage is different from that of the main circuit, its value should preferably be chosen from Table IV.

TABLE IV

Standard values of rated control circuit voltages, if different from that of the main circuit

D.C. V	Single-phase a.c. V
24, 48, 110, 125, 220, 250	24, 48, 110, 127, 220

Note. — The manufacturer shall be prepared to state the value or values of the current taken by the control circuits at the rated supply voltage.

4.5.2 *For air-supply systems*

— rated pressure and its limits;

— volumes of air, at atmospheric pressure, required for each closing and each opening operation.

The rated supply pressure of a pneumatic or electro-pneumatic starter is the air pressure upon which the operating characteristics of the pneumatic control system are based.

4.6 *Auxiliary circuits*

The characteristics of auxiliary circuits are:

a) the number of those circuits;

b) the number and kind of contacts (make contact, break contact, etc.);

c) for each of these circuits:
- — rated voltage;
- — rated frequency, if any;
- — rated current;
- — rated breaking capacity of the contacts.

Unless otherwise stated, the rated current of the auxiliary circuits is 6 A and the rated voltage and frequency (if any) of the auxiliary circuits shall be the rated voltage and frequency of the main circuit.

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

The following information shall be given by the manufacturer:

— types and characteristics of short-circuit protective devices (see Appendix C);

— type of co-ordination (see Appendix C).

5. Nameplates

Each starter shall be provided with a nameplate carrying the following data, marked in a durable manner, and located in a place such that they are visible and legible when the starter is installed:

a) the manufacturer's name or trademark;

b) type designation or serial number;

c) rated operational voltages (see Clause 4.4.1.1);

d) utilization category and rated operational currents (or rated powers), at the rated operational voltages of the starter (see Sub-clause 4.4.2.3);

e) rated frequency, e.g.: ~ 50 Hz;

f) if different from those of the coil: nature of current, rated frequency and rated control supply voltage (U_s).

If not evident from information stated elsewhere by the manufacturer, the following should also be stated on the starter nameplate:

g) rated insulation voltage (see Clause 4.4.1.2);

h) rated thermal current (see Sub-clause 4.4.2.1 and 4.4.2.2);

Note. – If the overload relay is Type 2, its rating shall be given on the nameplate of the starter.

i) rated making and breaking capacities. These indications may be replaced, if applicable, by the indication of the utilization category (see Tables I, II and III);

j) rated duty with the indication of the class of intermittent duty, if any (see Clause 4.4.4).

The following information concerning the operating coils of the starter shall be placed either on the coil or on the starter:

k) either the indication "d.c." (or the symbol ⎓) or value of the rated frequency, e.g.: ~ 50 Hz;

l) rated coil voltage.

For starters operated by compressed air:

m) rated supply pressure of the compressed air and the limits of variation of this pressure, if they are different from those specified in Clause 7.5.2.

The following information shall be placed on the overload relay:

n) type number: 1 or 2 (see Clauses 4.3.3 and 7.5.3.2.1);

o) current setting or setting range or an identifying mark, according to Clause 4.3.3. The information given shall make it possible for a user to obtain the time-current characteristics from the manufacturer, or from his catalogue, or from data supplied with the starter.

Note. — If the available space on the nameplate is insufficient to carry all the above data, the starter shall carry at least the information under *a)* and *b)* permitting the complete data to be obtained from the manufacturer.

6. Standard conditions for operation in service

6.1 *Normal service conditions*

Starters complying with this Recommendation shall be capable of operating under the following standard conditions.

For non-standard conditions in service, see Appendix A.

6.1.1 *Ambient air temperature*

The ambient air temperature does not exceed + 40 °C and its average over a period of 24 hours does not exceed + 35 °C.

The lower limit of the ambient air temperature is — 5 °C.

Note. — Starters intended to be used in ambient air temperatures above + 40 °C (e. g.: in forges, boiler rooms, tropical countries) or below — 5 °C shall be designed or used according to an agreement between manufacturer and user. Information given in the manufacturer's catalogue may constitute such an agreement.

6.1.2 *Altitude*

The altitude of the site of installation does not exceed 2 000 m (6 600 ft).

Note. — For installations at higher altitudes, it is necessary to take into account the reduction of the dielectric strength and of the cooling effect of the air. Starters so used shall be designed or used according to an agreement between manufacturer and user. Information given in the manufacturer's catalogue may constitute such an agreement.

6.1.3 *Atmospheric conditions*

The air is clean and its relative humidity does not exceed 50% at a maximum temperature of + 40 °C. Higher relative humidities may be permitted at lower temperatures, e.g.: 90% at + 20 °C. Care should be taken of moderate condensation which may occasionally occur due to variations in temperature.

6.1.4 *Conditions of installation*

The starter shall be installed in accordance with the manufacturer's instructions.

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.

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.

In the case of oil-immersed starters, the tank shall be provided with means for indicating the correct oil level.

7.1.2 *Clearances and creepage distances*

The clearances and creepage distances shall be as large as practicable and creepage distances shall, wherever practicable, incorporate ridges, in order to break the continuity of conducting deposits which may form.

Note. — Recommendations are given in Appendix B.

7.1.3 *Terminals*

Terminal connections shall be such that the conductors may be connected by means of screws or other equivalent means so as to ensure that the necessary contact pressure is maintained permanently.

Terminals shall be so designed that they clamp the conductor between metal surfaces with sufficient contact pressure and without significant damage to the conductor.

Terminals shall not allow the conductors to be displaced, or be displaced themselves in a manner detrimental to the operation or the insulation (minimum prescribed values to be maintained for clearances and creepage distances).

7.1.3.1 *Arrangement of terminals*

The terminals intended for the connection of external conductors shall be so arranged that they are readily accessible under the intended conditions of use.

7.1.3.2 *Earth terminal*

The chassis, frameworks and the fixed parts of the metal enclosures of equipment shall be interconnected electrically and connected to a terminal which enables them to be earthed. This requirement can be met by the normal structural parts providing adequate electrical continuity.

When an earth terminal is provided, it shall be readily accessible, and so placed that the earth connection of the equipment is maintained when the cover or other removable parts are removed.

Under no circumstances shall a removable metal part of the enclosure be insulated from that part carrying the earth terminal when the removable part is in place.

The earth terminal shall be suitably protected against corrosion.

The earth terminal shall be permanently and indelibly marked with either the sign ⏚ (IEC 417-5017a) or the sign ⏚ (IEC 417-5019a).

7.2 *Enclosures*

7.2.1 *Degrees of protection of enclosures*

Recommendations concerning degrees of protection provided by enclosures are given in IEC Publication 144.

7.2.2 *Mechanical details*

The enclosure shall be so arranged that when it is opened, the terminals as well as all parts requiring maintenance, as prescribed by the manufacturer, are readily accessible.

Sufficient space shall be left in the interior of the enclosure for the accommodation of external conductors from their point of entry into the enclosure as far as the terminals.

The movable parts of the protective enclosure shall be firmly secured to the fixed parts by a device such that they cannot be accidentally loosened or detached owing to the effects of the operation of the apparatus or of its vibrations.

Metal handles shall be reliably connected to the earthed parts.

When an enclosure is so designed as to allow the cover to be opened without the use of a tool, means shall be provided to prevent loss of the fastening devices.

7.2.3 *Insulation*

Metallic enclosures shall be so arranged as to prevent any contact between the enclosure and live parts when the enclosure is in place and during opening and closing of the enclosure, when these operations are correctly performed. If, for this purpose, the enclosure is partly or completely lined with insulating material, this lining shall be securely fixed to the enclosure.

7.3 *Temperature rise*

7.3.1 *Results to be obtained*

The temperature rises of the several parts of a starter, measured during a test carried out under the conditions specified in Clause 8.2.2, shall not exceed the limiting values stated in Tables V and VI.

TABLE V

Temperature-rise limits for insulated coils in air and in oil

Class of insulating material	Temperature-rise limit (measured by resistance variation)	
	Coils in air	Coils in oil
A	85 deg C	60 deg C
E	100 deg C	60 deg C
B	110 deg C	60 deg C
F	135 deg C	—
H	160 deg C	—

Notes 1.— The classification of insulation is that given in Section II of IEC Publication 85, Recommendations for the Classification of Materials for the Insulation of Electrical Machinery and Apparatus in Relation to their Thermal Stability in Service.

2.— For coils in air, the above temperature-rise limits are 10 deg C higher than those in Table IV of IEC Publication 158-1 (first edition), Low-voltage Controlgear for Industrial Use, Part 1: Contactors. The latter will be amended accordingly in due course.

7.3.2 *Ambient air temperature*

The temperature-rise limits given in Tables V and VI are applicable only if the ambient air temperature remains within the limits given in Clause 6.1.1.

7.3.3 *Main circuit*

The main circuit of a starter shall be capable of carrying its rated thermal current (see Clauses 4.4.2.1 and 4.4.2.2) without the temperature rises exceeding the limits specified in Table VI.

Note. — Only the terminals intended for external connections are considered, in this Recommendation, 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, must 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 to 10 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	180
0.3	120	72
1	30	18
3	12	4.8
10	3	1.2

TABLE VI

Temperature-rise limits for the various materials and parts

Type of material Description of part	Temperature-rise limit (measured by thermocouple)
Contact parts in air (main, control and auxiliary contacts):	
– copper { uninterrupted duty	45 deg C
– copper { eight-hour, intermittent, or temporary duty	65 deg C
– silver or silver-faced	1)
– all other metals or sintered metals	2)
Contact parts in oil	65 deg C
Bare conductors including non-insulated coils	1)
Metallic parts acting as springs	3)
Metallic parts in contact with insulating materials	4)
Parts of metal or of insulating material in contact with oil	65 deg C
Terminals for external insulated connections	70 deg C 5)
Manual operating means:	
– parts of metal	15 deg C
– parts of insulating material	25 deg C
Oil in oil-immersed apparatus (measured at the upper part of the oil)	60 deg C 6)

1) Limited solely by the necessity of not causing any damage to adjacent parts.
2) To be specified according to the properties of the metals used and limited by the necessity of not causing any damage to adjacent parts.
3) The resulting temperature should not reach a value such that the elasticity of the material is impaired. For pure copper, this implies a total temperature not exceeding + 75 °C.
4) Limited solely by the necessity of not causing any damage to insulating materials.
5) The temperature-rise limit of 70 deg C is a value based on the conventional test of Clause 8.2.2.2. A starter used or tested under installation conditions may have connections the type, nature and disposition of which will not be the same as those adopted for the test; a different temperature rise of terminals may result and it may be required or accepted.
6) May be measured by thermometer.

7.3.5 *Auxiliary circuits*

Auxiliary circuits shall be capable of carrying their rated current without the temperature rises exceeding the limits specified in Table VI.

7.4 *Dielectric properties*

The starter shall be capable of withstanding the dielectric tests specified in Clause 8.2.3.

7.5 *Operating conditions*

7.5.1 *General*

Starters shall be trip-free.

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

7.5.2 *Limits of operation*

Unless otherwise stated, electromagnetic and electro-pneumatic starters shall close with any control supply voltage between 85% and 110% of its rated value U_s and an ambient air temperature between − 5 °C and + 40 °C. These limits apply to d.c. or a.c. as appropriate.

Note. — For starters with latched contactors, operating limits should be agreed between manufacturer and user.

For electromagnetic and electro-pneumatic starters, the drop-out voltage shall be not higher than 75%, nor (with worn contacts) lower than 10% of the rated control supply voltage U_s.

The close and drop-out values specified above are applicable after the coils have reached a stable temperature corresponding to indefinite application of 100% U_s. In the case of a.c. coils, the voltage limits apply at rated frequency.

For pneumatic and electro-pneumatic starters, unless otherwise stated, the limits of variation of the air supply pressure are 85% and 110% of the rated pressure.

7.5.3 *Opening by relays or releases*

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

An opening release with shunt coil shall operate correctly at all values of supply voltage between 70% and 120% of its rated voltage, under all operating conditions of a starter.

7.5.3.2 Opening by thermal and time-delay magnetic overload relays

A distinction is made according to whether an overload relay is energized on all its poles or not.

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

1. *Type 1 overload relay* (designated by the associated motor full-load current).

   At *A* times the current setting, tripping shall not occur in less than 2 h, starting from the cold state, i.e. with the starter in its enclosure, if any, at the value of ambient air temperature stated in Table VII. Moreover, when the value of current is subsequently raised to *B* times the current setting, tripping shall occur less than 2 h later.

2. *Type 2 overload relay* (designated by the ultimate trip current).

   At *C* times the current setting, tripping shall not occur in less than 2 h, starting from the cold state, i.e. with the starter in its enclosure, if any, at the value of ambient air temperature stated in Table VII. Moreover, when the value of current is subsequently raised to *D* times the current setting, tripping shall occur less than 2 h later.

The values of factors *A*, *B*, *C* and *D* are given in Table VII below both for type 1 and type 2 of overload relays, either compensated or not compensated for ambient air temperature.

Note. — For the purpose of this Recommendation, an overload relay is considered to be compensated for ambient air temperature if it complies with the relevant figures of Table VII, by whatever means this is achieved.

TABLE VII

Characteristics of the opening operation of thermal and time-delay magnetic overload relays when energized on all poles

Overload relay	Type 1		Type 2		Reference ambient air temperature
	A	*B*	*C*	*D*	
Thermal type not compensated for ambient air temperature, *and magnetic type*	1.05	1.20	0.87	1.00	1)
Thermal type compensated for ambient air temperature	1.05 1.05 1.00	1.20 1.30 1.20	0.87 0.87 0.87	1.05 1.11 1.00	+ 20 °C − 5 °C + 40 °C

1) See Clause 4.3.5. The ambient air temperature can be any stated value between − 5 °C and + 40 °C (see Clause 6.1.1); the preferred values are + 20 °C and + 40 °C.

7.5.3.2.2 *Opening by multipole thermal overload relays* of type 3 b) of Clause 4.3.1 *when only some of their poles are energized*

When all the poles of a multipole thermal relay are not energized, the requirements of Clause 7.5.3.2.1 do not apply.

In the special case of a three-pole overload relay operating on two poles only, the values of factors *A*, *B*, *C* and *D* are given in Table VIII below.

TABLE VIII A

Characteristics of the opening operation of three-pole thermal overload relays when energized on two poles only

Overload relay	Type 1		Type 2		Reference ambient air temperature
	A	*B*	*C*	*D*	
Not compensated for ambient air temperature	1.05	1.32	0.87	1.10	+ 20 °C or + 40 °C
Compensated for ambient air temperature	1.05	1.32	0.87	1.16	+ 20 °C only

The figures in this table apply only to type tests. The overload relay is heated on three poles for 2 h with a current equal to *A* or *C* times the current setting; one heater is then disconnected and the current in the two remaining is increased to *B* or *D* times the current setting; then, tripping shall occur less than 2 h later.

For simplicity, the above tests may be made at one ambient air temperature only.

[IEC 292-1 page 41
as modified by IEC 292-1B page 5
and by IEC 292-1C page 5]

7.5.3.2.3 *Opening by three-pole phase failure sensitive thermal overload relays of type 3 c) of Clause 4.3.1 when their poles are not equally energized*

Depending on whether the overload relay is type 1 or type 2 (see Clause 7.5.3.2.1), at *A* or *C* times the current setting, tripping shall not occur in less than 2 h starting from the cold state, i.e. with the starter in its enclosure, if any, at the value of ambient air temperature stated in Table VIII B. Moreover when the value of the current in the two poles which carried the higher current is respectively increased to *B* or *D* times the current setting and the pole which carried the lower current is disconnected, tripping shall occur less than 2 h later.

TABLE VIII B

Characteristics of the opening operation of three-pole phase failure sensitive thermal overload relays when their poles are not equally energized

Overload relay	Type 1		Type 2		Reference ambient air temperature
	A	*B*	*C*	*D*	
Compensated for ambient air temperature	2 poles: 1.0 1 pole: 0.9	2 poles: 1.15 1 pole: 0	2 poles: 0.83 1 pole: 0.75	2 poles: 0.95 1 pole: 0	+20 °C

Note. — Relays not compensated for ambient air temperature are considered as special cases, subject to agreement between manufacturer and user.

The above values shall apply to all combinations of poles: for example, for columns *B* and *D*: poles I and III energized and pole II disconnected, poles I and II energized and pole III disconnected, poles II and III energized and pole I disconnected.

In the case of thermal overload relays having an adjustable current setting, the characteristics shall apply both when the relay is carrying the current associated with the maximum setting and also when the relay is carrying the current associated with the minimum setting.

Opening by magnetic instantaneous overload relays

7.5.3.3 For all values of the current setting, magnetic instantaneous overload relays shall trip with an accuracy of $\pm 10\%$ of the value of the current setting.

Note. — Magnetic instantaneous overload relays covered by this Recommendation are not intended for short-circuit protection.

7.5.3.4 *Opening by undervoltage relays or releases*

An undervoltage relay or release, when associated with a switching device, shall operate to open the starter even on a slowly falling voltage within the range between 75% and 10% of its rated voltage. An undervoltage relay or release shall prevent the starter being closed (or remaining closed in the case of certain types of starters) when the supply voltage is below 35% of the rated voltage of the relay or release; it shall not prevent closing when the supply voltage is 85% or more of the rated voltage.

The figures given above apply equally to d.c. coils and to a.c. coils when at rated frequency.

8. Tests

8.1 *Verification of the characteristics of a starter*

The tests to verify the characteristics of starters comprise:

— Type tests (see Clauses 8.1.1 and 8.2).
— Routine tests (see Clauses 8.1.2 and 8.3).
— Special tests (see Clauses 8.1.3 and 8.4).

When a starter embodies a mechanical switching device complying with IEC Publication 157-1 or 158-1, tests carried out to prove compliance with the quoted publication need not be repeated on the mechanical switching device, where they are identical to or more severe than the tests detailed in the present publication.

The tests shall be carried out by the manufacturer at his works, or at any suitable laboratory of his choice.

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 (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).

8.1.3 *Special tests*

These are tests subjected to agreement between manufacturer and user.

They may include the verification of electrical endurance (see Clause 8.4.1).

8.2 *Type tests*

8.2.1 *General*

Unless otherwise specified or stated by the manufacturer, each type test shall be carried out on a device in a clean and new condition.

All tests shall be made at the rated frequency.

For tests, the starter shall be mounted and installed as indicated by the manufacturer. The details of installation (type and size of enclosure, if any, size of conductors, etc.) shall be part of the test report.

8.2.2 *Verification of temperature-rise limits*

8.2.2.1 *Ambient air temperature*

The ambient air temperature shall be measured during the last quarter of the test period by means of at least two thermometers or thermocouples equally distributed around the starter at about half its height and at a distance of about 1 m from the starter. The thermometers or thermocouples shall be protected against air currents and heat radiations and indicating errors due to rapid temperature changes.

8.2.2.2 *Temperature-rise tests of the main circuit*

The starter shall be fitted with the overload relay complying with Sub-clause 4.3.3, and stated by the manufacturer to be suitable for the motor full-load current corresponding to the rated conventional thermal current of the starter. If the starter is fitted with an adjustable relay, then that overload relay which is adjusted nearest to the maximum of its scale shall be used.

The starter and its auxiliary devices shall be mounted approximately as under usual service conditions and shall be protected against undue external heating or cooling.

Starter having an integral enclosure and starter only intended for use with a special type of enclosure shall be tested in its enclosure for the rated conventional thermal current test. No openings giving false ventilation shall be allowed.

Details of any enclosure, ventilation arrangements, and sizes of test conductors shall be stated in the test report.

For tests with a.c. single-phase or d.c. currents, the test current shall be not less than the rated conventional thermal current. For tests with multi-phase currents, the current shall be balanced in each phase within ±5%, and the average of these currents shall be not less than the rated conventional thermal current.

It is permissible, before beginning the tests, to operate the starter a few times with or without load.

For a starter with contactor, the contacts shall, where practicable, be closed by energizing the contactor-operating coil at its rated voltage and, if electro-pneumatic, at the rated pressure.

The temperature-rise test of the main circuit is made at the rated conventional thermal current (see Sub-clause 7.3.3).

Tests on d.c. rated starter may be made with a.c. supply for convenience of testing, but only with the consent of the manufacturer. Tests on a.c. rated starter shall be made at a frequency of between 45 Hz and 62 Hz where the rated frequency of the equipment is 50 Hz or 60 Hz; for lower or higher rated frequencies, a tolerance of ±20% shall apply.

The test shall be made over a period of time sufficient for the temperature-rise to reach a constant value, but not exceeding 8 h. In practice, this condition is reached when the variation does not exceed 1 °C per hour.

Notes 1. – In practice, to shorten the test, the current may be increased during the first part of the test, it being reduced to the specified test current afterwards.

2. – When a control electromagnet is energized during the test, the temperature shall be measured when thermal equilibrium is reached in both the main circuit and the control electromagnet.

At the end of the test, the temperature-rise of the different parts of the main circuit shall not exceed the values specified in Table VI.

Depending on the value of the rated conventional current, the test procedures shall be:

For values of test current up to and including 400 A:

a) The connections shall be single-core, PVC insulated, copper cables or wires with cross-section areas as given in Table IX.

b) In the case of multi-pole starter, tested with a.c., the test may be carried out with single-phase current with all poles connected in series provided magnetic effects can be neglected.

c) The connections shall be in free air, and spaced at approximately the distance existing between the terminals.

d) For single-phase or multi-phase tests the minimum length of any temporary connection from starter terminal to another terminal or to the test supply or to a star point shall be:

— 1 m for cross-sections up to and including 35 mm^2 (or AWG 2);
— 2 m for cross-sections larger than 35 mm^2 (or AWG 2).

For values of test current higher than 400 A but not exceeding 800 A:

a) The connections shall be single core, PVC insulated, copper cables with cross-section areas as given in Table X, or the equivalent copper bars given in Table X as recommended by the manufacturer.

b) In the case of multi-pole starter, tested with a.c., the test may be carried out with single-phase current, with all poles connected in series provided magnetic effects can be neglected.

c) Cables or copper bars shall be spaced at approximately the distance between terminals. Copper bars shall be finished matt black. Multiple parallel cables per terminal shall be bunched together and arranged with approximately 10 mm air space between each other. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals, or are not available, other bars having approximately the same cross-section and approximately the same or smaller cooling surface may be used. Cables or copper bars shall not be interleaved.

d) For single-phase or multi-phase tests the minimum length of any temporary connection from equipment terminal to another terminal or to the test supply shall be 2 m. The minimum length to a star point may be reduced to 1.2 m.

For values of test current higher than 800 A but not exceeding 3 150 A:

a) The connections shall be copper bars of the sizes stated in Table X unless the starter is designed only for cable connection. In this case, the size and arrangement of the cables to be as specified by the manufacturer.

TABLE IX

Standard cross-sections of copper conductors corresponding to the rated conventional thermal current

Cross-sections expressed in square millimetres

Range of the rated thermal current A 1)	0 7.9	7.9 15.9	15.9 22	22 30	30 39	39 54	54 72	72 93	93 117	117 147	147 180	180 216	216 250	250 287	287 334	334 400
S (mm²)	1	1.5	2.5	4	6	10	16	25	35	50	70	95	120	150	185	240
Values of the rated thermal current A 2)	≦6	8 10 12	16 20	25	32	40 50	63	80	100	125	160	200	250	—	315	400

Cross-sections expressed in AWG (table given as a guide)

Range of the rated thermal current A 1)	0 11	11 18	18 25	25 34	34 45	45 61	61 78	78 91	91 106	106 123	123 143	143 166	166 193	193 220	220 247	247 276	276 302	302 328	328 353	353 390
AWG	16	14	12	10	8	6	4	3	2	1	0	00	000	0000	250 MCM	300 MCM	350 MCM	400 MCM	450 MCM	500 MCM
Values of the rated thermal current A 2)	≦8	12 16	20 25	32	40	50	63	80	100	—	125	160	—	200	—	250	—	315	—	—

1) The value of current shall be greater than the value in the first line and less than or equal to the value in the second line.
2) These are standard recommended currents and are given for reference purposes only.

b) In the case of multi-pole starter, tested with a.c., the test may be carried out with single-phase current with all poles connected in series provided magnetic effects can be neglected.

c) Copper bars shall be spaced at approximately the distance between terminals. Copper bars shall be finished matt black. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals, or are not available, other bars having approximately the same cross-section and approximately the same or smaller cooling surfaces may be used. Copper bars shall not be interleaved.

d) For single-phase or multi-phase tests, the minimum length of any temporary connection from starter terminal to another terminal or to the test supply shall be 3 m but this can be reduced to 2 m provided that the temperature-rise at the supply end of the connection is not more than 5 °C below the temperature-rise in the middle of the connection length. The minimum length to a star point shall be 2 m.

For values of test current higher than 3 150 A:

Agreement shall be reached between manufacturer and user on all relevant items of the test, such as: type of supply, number of phases and frequency (where applicable), cross-sections of test connections, etc. This information shall form part of the test report.

Note. – In all cases, the use of single-phase a.c. current for testing multi-pole starters is only permissible if magnetic effects are small enough to be neglected. This requires careful consideration especially for currents above 400 A.

TABLE X

Standard test conductors for rated conventional thermal currents higher than 400 A

Value of rated thermal current (A)	Range of rated thermal current (A)	Test connection			
		Cables		Copper bars	
		Quantity	Cross-sections (mm^2)	Quantity	Dimensions (mm)
500	400- 500	2	150 (16)	2	30 × 5 (15)
630	500- 630	2	185 (18)	2	40 × 5 (15)
800	630- 800	2	240 (21)	2	50 × 5 (17)
1 000	800-1 000	–	–	2	60 × 5 (19)
1 250	1 000-1 250	–	–	2	80 × 5 (20)
1 600	1 250-1 600	–	–	2	100 × 5 (23)
2 000	1 600-2 000	–	–	3	100 × 5 (20)
2 500	2 000-2 500	–	–	4	100 × 5 (21)
3 150	2 500-3 150	–	–	3	100 × 10 (23)

Notes 1. – Value of current shall be greater than the first value and less than or equal to the second value.

2. – Bars are assumed to be arranged with their long faces vertical. Arrangements with long faces horizontal may be used if specified by the manufacturer.

3. – Values in brackets are estimated temperature rises of the test conductors given for reference.

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

The control electro-magnets shall be tested according to the conditions given in Clause 7.3.4, with the specified kind of supply current and at their rated voltage.

Electro-magnets of starters intended for uninterrupted, eight-hour or temporary duty are subjected only to the conditions prescribed in the first paragraph of Clause 7.3.4, with the corresponding rated current flowing through the main circuit for the duration of the test.

The temperature shall be measured when thermal equilibrium is reached in both the main circuit and the control electro-magnet.

Electro-magnets of starters intended for intermittent duty shall be subjected to the test as stated above, and also to the test prescribed in the paragraph of Clause 7.3.4 dealing with their class, with no current flowing through the main circuit.

Electro-magnets shall be tested for a sufficient time for the temperature rise to reach a steady-state value. In practice, this condition is reached when the variation does not exceed 1 deg C per hour.

At the end of these tests, the temperature rise of the different parts of the control electro-magnets shall not exceed the values specified in Tables V and VI.

8.2.2.4 *Temperature-rise tests of auxiliary circuits*

The temperature-rise tests of auxiliary circuits are made under the same conditions as those provided in Clause 8.2.2.3.

At the end of these tests, the temperature rise of auxiliary circuits shall not exceed the values specified in Tables V and VI.

Note. — When the mutual heating effect between main circuit, control circuits and auxiliary circuits may be of significance, the temperature-rise tests stated in Clauses 8.2.2.2, 8.2.2.3 and 8.2.2.4 shall be made simultaneously.

8.2.2.5 *Measurement of the temperature of parts*

For conductors other than coils, the temperature of the different parts shall be measured by means of thermocouples, at the nearest accessible position to the hottest spot. The temperature of oil in oil-immersed starters shall be measured at the upper part of the oil. Thermocouples shall be protected against cooling from outside. The protected area shall, however, be a negligible part of the cooling area of the part under test. Good heat conductivity between the thermocouple and the surface of the part under test shall be ensured.

For coils of electro-magnets, the method of measuring the temperature by variation of resistance shall generally be used. Other methods are permitted only if it is impracticable to use the resistance method.

The temperature of the coil as measured by a thermocouple before beginning the test shall not differ from that of the surrounding medium (air, oil, etc.) by more than 3 deg C.

For copper conductors, the value of the hot temperature T_2 may be obtained from the value of the cold temperature T_1 as a function of the ratio of the hot resistance R_2 to the cold resistance R_1 by the following formula:

$$T_2 = \frac{R_2}{R_1}(T_1 + 234.5) - 234.5$$

where T_1 and T_2 are expressed in Celsius degrees.

A simpler method, applying also to copper conductors, giving results only slightly less accurate, may be used for most tests by calculating the temperature rise on the assumption that 0.4% increase in resistance represents a 1 deg C increase in temperature.

Note. — Strictly speaking, such an assumption is correct only if the cold resistance R_1 is measured at approximately + 16 °C.

8.2.2.6 *Temperature rise of a part*

The temperature rise of a part is the difference between the temperature of this part measured in accordance with Clause 8.2.2.5, and the ambient air temperature measured in accordance with Clause 8.2.2.1.

8.2.2.7 *Corrections*

If the ambient air temperature during the test is between + 10 °C and + 40 °C, no corrections are necessary to take account of the ambient air temperature during the test and the values of Tables V and VI are the limiting values of temperature rise. If the ambient temperature exceeds + 40 °C or is lower than + 10 °C, this Recommendation does not apply and the manufacturer and the user shall make a special agreement.

8.2.3 *Verification of dielectric properties*

8.2.3.1 *Condition of the starter for tests*

Dielectric tests shall be made on new starters mounted as for service, including internal wiring, and in a clean and dry condition.

When the base of the starter is of insulating material, metallic parts shall be placed at all the fixing points in accordance with the conditions of normal installation of the starter and these parts shall be considered as part of the frame of the starter. When the starter is in an insulating enclosure, the latter shall be covered externally by a metal foil connected to the frame.

When the dielectric strength of the starter is dependent upon the taping of leads or the use of special insulation, such taping or special insulation shall also be used during the tests.

8.2.3.2 *Application of the test voltage*

When the circuits of a starter include devices such as motors, instruments, snap switches and solid state devices which, according to their relevant specifications, have been subjected to dielectric test voltages lower than those specified in Clause 8.2.3.3, such devices may, at the discretion of the manufacturer, be disconnected before subjecting the starter to the required test.

8.2.3.2.1 *Main circuit*

For these tests, any control and auxiliary circuits, which are not normally connected to the main circuit, shall be connected to the frame. The test voltage shall be applied for 1 min as follows:

a) with the main contacts closed:

1. between all live parts of all poles connected together and the frame of the starter;
2. between each pole and all the other poles connected to the frame of the starter:

b) with the main contacts open:

1. between all live parts of all poles connected together and the frame of the starter:
2. between the terminals of one side connected together, and the terminals of the other side connected together.

8.2.3.2.2 *Control and auxiliary circuits*

For these tests, the main circuit shall be connected to the frame. The test voltage shall be applied for 1 min as follows:

1. between all the control and auxiliary circuits which are not normally connected to the main circuit, connected together, and the frame of the starter;
2. where appropriate, between each part of the control and auxiliary circuits which may be isolated from the other parts during normal operation and all the other parts connected together.

8.2.3.3 *Value of the test voltage*

The test voltage shall have a practically sinusoidal waveform, and a frequency between 45 Hz and 65 Hz.

The value of the dry one-minute test voltage shall be as follows:

a) For the main circuit and for the control and auxiliary circuits which are not covered by paragraph *b)* below: in accordance with Table XI.

TABLE XI

Rated insulation voltages V	Dielectric test voltage (a.c.) (r.m.s.) V
Up to and including 60	1 000
61 - 300	2 000
301 - 660	2 500
661 - 800	3 000
801 - 1 000	3 500

b) For control circuits and auxiliary circuits which are indicated by the manufacturer as unsuitable for connection to the main circuit:

— Where the rated insulation voltage U_i does not exceed 60 V: 1 000 V.

— Where the rated insulation voltage U_i exceeds 60 V: $2\ U_i + 1\,000$ V, with a minimum of 1 500 V.

8.2.4 *Verification of rated making and breaking capacities*

8.2.4.1 *General*

The tests concerning the verification of the making and breaking capacities of a starter are intended to verify that the starter is capable of making and breaking the currents stated in Table II, 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.

The tests are made solely with the current of the same kind as the service current specified. In particular, starters intended for use on three-phase loads shall be tested with three-phase current; single-phase tests of such starters are not covered by this Recommendation and shall be the subject of special agreement.

8.2.4.2 *Condition of the starter for tests*

The starter under test shall be mounted complete on its own support or on an equivalent support. A starter intended to be enclosed shall be tested in the same type of enclosure as that in which it will be installed.

The starter shall be fitted with an overload relay having a current setting corresponding to the maximum operational current of the starter for the intended utilization category.

For the making test, the main circuit of the overload relay may be short-circuited.

The connections to the main circuit shall be similar to those intended to be used when the starter is in service. If necessary, or for convenience, the control and auxiliary circuits, and in particular the magnet coil of a contactor, may be supplied by an independent source. Such a source must deliver the same kind of current at the same voltage as those specified for service conditions.

For verification of the making and breaking capacities, all parts of the starter normally earthed in service, including its enclosure, shall be connected to the neutral point of the supply or to a substantially inductive artificial neutral permitting a prospective fault current of at least 100 A. This connection shall include a reliable device (such as a fuse consisting of a copper wire 0.1 mm diameter and not less than 50 mm in length) for the detection of the fault current and, if necessary, a resistor limiting the value of the prospective fault current to about 100 A.

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

The making and breaking capacity tests shall be carried out with the conventional test circuit as specified in Appendix D.

8.2.4.4 *Verification of making capacity*

The making current to be obtained during the test shall be as given in Table II for Category AC-3 or AC-4, as appropriate.

The number of closing operations to be made is the following:

— For starters with contactors, the number is 100: 50 operations of which are made at 85% and 50 operations at 110% of the rated contactor coil voltage.

— For manual starters, the number is 20.

The time interval between an opening operation and the closing operation immediately following it 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.

The duration of the test current shall be not less than 50 ms (thereby exceeding the total bounce time, if any, of the contacts). However, if the mechanical switching device has satisfied the tests of IEC Publication 158-1 (Clause 8.2.4.4 of the first edition), this test need not be repeated.

8.2.4.5 *Verification of breaking capacity*

The breaking current to be obtained during the test shall be as given in Table II for Category AC-3 or AC-4, as appropriate. The total number of opening operations to be made is 25.

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

The remaining operations 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 operation, and the time interval between two successive opening operations 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.

The overload relay shall be reset, if necessary, after each operation.

However, if the mechanical switching device has satisfied the tests of IEC Publication 158-1 (Clause 8.2.4.4 of the first edition), these operations (tripped by the operator) need not be repeated.

8.2.4.6 *Verification of reversibility*

In the case of a reversing starter, the following test shall be carried out in addition to the making and breaking capacity tests of Clauses 8.2.4.4 and 8.2.4.5. A new starter may be used for the verification of reversibility.

The test circuit shall be in accordance with Clause 8.2.4.3, and the current to be obtained shall be as given in Table III for Category AC-4.

The test comprises ten operating sequences, each sequence comprising the two operating cycles described below:

— 1st cycle: Close A — open A/close B — open B — 10 s to 30 s rest;

— 2nd cycle: Close B — open B/close A — open A — 10 s to 30 s rest

(where A and B are either the two mechanical switching devices of the starter or the two circuits of a single switching device).

These cycles are repeated alternately.

The use of a symbolic form such as "open A/close B" implies that the change-over operation concerned shall be made as fast as the normal control system will allow.

During the test, the starter shall be operated in the manner in which it is intended to be used in service, and any mechanical or electrical interlocking devices which are normally provided shall be in use.

[IEC 292-1 page 59
as modified by IEC 292-1B page 7
and by IEC 292-1C page 7]

8.2.4.7 *Behaviour of the starter during making and breaking tests and during reversing tests*

During tests within the limits of specified making and breaking capacities and with the specified number of operations, there shall be no permanent arcing, no flash-over between poles, no blowing of the fuse in the earth circuit (see Clause 8.2.4.2) and no welding of the contacts.

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 must not extend beyond the safety area stated by the manufacturer.

8.2.5 *Verification of operating limits*

When a starter can be supplied in several forms, according to the conditions of use (open type, various types of enclosure, etc.), the tests need only be carried out on one form stated by the manufacturer. The details of type and installation must form part of the test report.

It shall be verified that the starter opens and closes cleanly within the voltage and temperature limits specified in Clause 7.5.2 when the coil circuits are rapidly opened or closed. Tests shall be performed with no current flowing through the main circuit.

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

When a starter can be supplied in several forms, according to the conditions of use (open type, various types of enclosure, etc.), the tests need only be carried out on one form stated by the manufacturer, taking into account the last paragraph of Clause 4.3.3. However, in the case of tests at − 5°C on thermal overload relays compensated for ambient air temperature, the tests may be carried out on a starter without enclosure. The details of type and installation must form part of the test report.

The starter shall be connected as in service, using cables the cross-sections of which shall be chosen, depending on the current setting of the overload relay, in accordance with the relation given in Table IX between cross-sections and the value of the rated thermal current.

Operating characteristics shall be verified in accordance with the performance requirements of Clause 7.5.3.2 or Clause 7.5.3.3 as appropriate: however, in order to simplify testing, the test corresponding to Clause 7.5.3.2.2 need only be carried out at one specified value of ambient air temperature.

Tests shall also be made to verify that the time-current characteristics of the overload relay conform (within stated tolerances) to the curves provided by the manufacturer up to a current at least eight times the full-load current of the largest motor with which the starter is intended to be used (see Clause 4.3.4). If a test is carried out at an ambient air temperature different from the one stated (see Clause 4.3.5), a correction shall be made.

The influence of ambient air temperature on the operating and time-current characteristics shall also be verified for relays which are not compensated for ambient air temperature (see Clauses 7.5.3.2 (or 7.5.3.3) and 4.3.5).

8.2.7 *Verification of mechanical endurance*

8.2.7.1 *Condition of the starter for tests*

The starter shall be installed as for normal service; in particular, the conductors shall be connected in the same manner as for normal use.

During the test, there shall be no voltage or current in the main circuit. The starter may be lubricated before the test if lubrication is prescribed in normal service.

[IEC 292-1 page 61
as modified by IEC 292-1C page 7]

8.2.7.2 *Operating conditions*

The coils of the control electro-magnets shall be supplied at their rated voltage and, if applicable, at their rated frequency.

If a resistance or an impedance is provided in series with the coils, whether short-circuited or not during the operation, the tests shall be carried out with these elements connected as in normal operation.

Pneumatic and electro-pneumatic starters shall be supplied with compressed air at the rated pressure.

Manual starters shall be operated as in normal service.

8.2.7.3 *Test procedure*

The tests are carried out at the frequency of operations 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 operations, he may do so in order to reduce the duration of the tests.

In the case of electromagnetic and electro-pneumatic starters, the duration of energization of the control coil shall be greater than the time of operation of the starter, and the time during which the coil is not energized shall be of such a duration that the starter can come to rest at both extreme positions.

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

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

After each tenth of the total number of operations 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.

8.3 *Routine tests*

8.3.1 *General*

Routine tests shall be carried out under the same, or equivalent, conditions to those specified for type tests in the above clauses. However, for overload relays, the operation tests may be carried out on the relay alone and at the prevailing ambient air temperature; hence, a correction may be necessary to take care of these conditions.

8.3.2 *Operation tests*

For electromagnetic, pneumatic and electro-pneumatic starters, tests are carried out to verify operation within the limits specified in Clauses 7.5.1 and 7.5.2. Main contacts shall be in a new condition, and hence, an adjustment may be necessary to the figure for minimum drop-out voltage which is specified in Clause 7.5.2 for worn contacts.

For manual starters, tests are carried out to verify the proper operation of the starter (see Clauses 7.5.1, 7.5.3.1 and 7.5.3.4).

Tests shall be made to verify the calibration of overload relays. In the case of thermal overload relays, this may be a single test at a multiple of the current setting to check that the tripping time conforms (within tolerances) to the curves held by the manufacturer.

Tests shall be made to verify the calibration of overload relays. In the case of a thermal or a time-delay magnetic overload relay, this may be a single test with all poles equally energized at a multiple of the current setting to check that the tripping time conforms (within tolerances) to the curves supplied by the manufacturer; in the case of an instantaneous magnetic overload relay, the test shall be carried out at 1.1 times the current setting.

Note.– In the case of a time-delay magnetic overload relay comprising a time-delay device working with a fluid dashpot, calibration may be carried out with the dashpot empty at a percentage of the current setting indicated by the manufacturer and capable of being justified by a special test.

8.3.3 *Dielectric tests*

The tests shall be carried out on dry and clean starters.

The value of the test voltage shall be in accordance with Clause 8.2.3.3.

The duration of each test may be reduced to 1 s.

The test voltage shall be applied as follows:

a) between poles with the main contacts closed (with the main contacts open if there is a shunt circuit between poles);

b) between poles and the frame of the starter with the main contacts closed;

c) across the terminals of each pole with the main contacts open;

d) to the control and auxiliary circuits, as mentioned in Clause 8.2.3.2.2.

The use of a metal foil, as specified in Clause 8.2.3.1, is unnecessary.

8.4 *Special tests*

8.4.1 *Verification of electrical endurance*

Note. — Although strictly a type test, because of the difficulty and cost of carrying out electrical endurance tests on all types of starters, this is included under special tests (i.e. subject to agreement between manufacturer and user). However, it is recommended that, for apparatus manufactured in large quantities, the manufacturer shall be prepared to give values for electrical endurance when tested as below.

The currents to be made and broken shall be as given in Table III. For Category AC-3, the test circuit shall comprise inductors and resistors so arranged as to give the appropriate values of current, voltage and power-factor; for Category AC-4, the test circuit shall be arranged in accordance with Appendix D. In both cases, the speed of operation shall be chosen by the manufacturer.

In the case of starters with a contactor, if the contactor has already satisfied an equivalent test, the test need not be repeated on the starter.

Tests shall be carried out with the starter under the appropriate conditions of Clauses 8.2.7.1 and 8.2.7.2 using the test procedure where applicable of Clause 8.2.7.3, except that replacement of contacts is not permitted.

After the test, the starter shall fulfil the operating conditions specified in Clause 8.2.5, and withstand the dielectric test voltages of Clause 8.2.3.3 applied only as in Clause 8.2.3.2.1 *a)* 1 and 2.

APPENDIX A

INFORMATION TO BE GIVEN BY THE USER WHEN CONDITIONS FOR OPERATION IN SERVICE DIFFER FROM THE STANDARD

1. **Ambient air temperature**

The user shall state to the manufacturer the expected range of ambient air temperature if this temperature can be lower than − 5 °C or higher than + 40 °C.

2. **Altitude**

The user shall state to the manufacturer the altitude of the place of installation if it is more than 2 000 m (6 600 ft).

3. **Atmospheric conditions**

The user shall call the manufacturer's attention if the atmosphere in which the starter is to be installed may have a relative humidity greater than the values specified in Clause 6.1.3 or contain an abnormal amount of dust, acids, corrosive gases, etc. The same applies if the starter is to be installed near the sea.

4. **Conditions of installation**

The user shall call the manufacturer's attention if the starter may be fitted to a moving device, if its support may be capable of assuming a sloping position either permanently or temporarily (starters fitted aboard ships), or if it may be exposed in service to abnormal shocks or vibrations.

The user shall also call the manufacturer's attention to any special need for silent operation of the starter.

5. **Connections with other apparatus**

The user shall inform the manufacturer of the type and dimensions of any special electrical connections with other apparatus, in order to enable him to provide enclosures and terminals meeting the conditions of installation and temperature rise prescribed by this Recommendation, and also to enable him to provide space where necessary to spread out conductors within the enclosure.

6. **Special applications**

The user shall call the manufacturer's attention if the starter may be used for types of use not covered by Table I.

APPENDIX B

CLEARANCES AND CREEPAGE DISTANCES FOR LOW-VOLTAGE A.C. MOTOR STARTERS

See Appendix C of IEC Publication 158-1
(First edition).

FIRST SUPPLEMENT TO PUBLICATION 292-1 (1969)

LOW-VOLTAGE MOTOR STARTERS

Part 1: Direct-on-line (full voltage) a.c. starters

APPENDIX C

CO-ORDINATION WITH SHORT-CIRCUIT PROTECTIVE DEVICES

1. Scope

This Appendix deals with the co-ordination to be achieved between a starter and the short-circuit protective device mentioned in Clause 1.1 of Publication 292-1. Examples of protective devices are fuses (see IEC Publication 269-1, Low-voltage Fuses with High Breaking Capacity for Industrial and Similar Purposes, Part 1: General Requirements) and circuit-breakers (see IEC Publication 157-1, (1st edition) Low-voltage Distribution Switchgear, Part 1: Circuit-breakers).

2. Object

The object of this Appendix is to state:

- the general requirements for co-ordination;
- the different types of co-ordination and the corresponding additional conditions;
- the types and characteristics of the apparatus to be co-ordinated;
- the tests intended to verify that the conditions of the co-ordination have been met.

Note. — For simplification purposes, "short-circuit protective devices" are referred to as "SCPD" in the rest of this Appendix.

3. General requirements for co-ordination

It is the responsibility of the manufacturer of the starter to select the proper SCPD according to the following requirements if this SCPD forms an integral part of the starter, or otherwise to recommend a suitable SCPD if this is to be mounted remote from the starter.

3.1 The SCPD shall be located on the supply side of the starter, and have a short-circuit breaking capacity not less than the short-circuit prospective current at its location.

3.2 The SCPD shall not operate in place of the starter for currents up to the maximum overload levels in normal service (including stalled current of the motor). For currents up to and including the breaking currents of the starter indicated in Table II of Clause 4.4.6 of Publication 292-1 for AC-3 utilization category, it shall be verified from information supplied by the manufacturer of the SCPD that the latter is able to withstand those currents for times at least equal to the corresponding tripping time of the overload relays.

3.3 For all values of over-current for which the combination is suitable, the starter, including the SCPD if it forms an integral part of the starter, shall operate in such a manner that the external manifestations (such as emission of flames or hot gases) do not extend beyond a safety perimeter stated by the manufacturer of the starter; if the SCPD is remote from the starter, it shall operate according to its relevant specifications.

4. **Types of co-ordination and corresponding additional conditions**

For currents exceeding the breaking currents of the starter indicated in Table II for the corresponding utilization category, the flow of current in the starter during the breaking time may cause damage to the starter itself. According to the amount of damage acceptable, several types of co-ordination are considered standard:

Type "a" – Any kind of damage to the starter itself (the enclosure, if any, remaining externally undamaged) is allowed and, after inspection, the starter may need replacement of some parts such as contacts, arc-chambers, overload relay, or may need replacement as a whole. Inspection comprises, inter alia, a dielectric test (see Clause 8.2.3 of Publication 292-1).

Type "b" – The characteristics of the overload relay of the starter may be permanently altered. No other damage shall occur, beyond that referred to in the last paragraph of this clause.

Type "c" – No damage (including permanent alteration of the characteristics of its overload relay) shall occur to the starter, beyond that referred to in the last paragraph of this clause.

For all types of co-ordination, light contact burning is allowed and the risk of welding contacts is accepted; depending on the SCPD utilized, this risk may be larger or smaller. Cases where the applications ask for a practically negligible risk of welding contacts are subject to agreement between manufacturer and user and are not covered by this Appendix. It shall be possible to disclose the presence of welded contacts by simple verification, e.g.: an inspection after the removal of the arc-chutes.

5. **Types and characteristics of the apparatus to be co-ordinated**

For a given starter, the starter manufacturer shall state the precise type or types and characteristics of the SCPD to be used in order to achieve a given type of co-ordination, and the maximum prospective short-circuit current, at a stated rated operational voltage, for which the corresponding combination is suitable.

Note. — A given combination of a starter and an SCPD may comply with more than one type of co-ordination for different values of the maximum prospective short-circuit current.

In order to facilitate the estimation of performance of the starter when combined with other SCPD than the ones stated by the manufacturer of the starter, it is advisable that:

- The manufacturer of the starter state:
  - for the mechanical switching device incorporated in the starter, the maximum permissible peak current corresponding to a given type of co-ordination;
  - for the overload relays, the maximum current that the starter alone (without an SCPD) can withstand, and the maximum permissible Joule-integral, starting from the cold state, corresponding to a given type of co-ordination.
- The manufacturer of the SCPD state:
  - the maximum peak current and the maximum Joule-integral let through by the SCPD as a function of the prospective short-circuit current;
  - the time-current characteristics of the SCPD.

Note. — It is recommended that the current be plotted as abscissae and the time as ordinates, using logarithmic scales. Further, in order to facilitate the study of co-ordination of different types of protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheet detailed in IEC Publication 269-1 (First edition, Clause 5.6.4).

6. Verification of the conditions of co-ordination

The verification of the general conditions of co-ordination under Clause 3 shall be as follows:

- For Clause 3.1, the requirement shall be verified by reference to the results of breaking capacity tests carried out on the SCPD according to the relevant specification.
- For Clause 3.2, the requirement shall be verified by reference to the results of overload tests carried out separately on the SCPD according to the relevant specification.
- For Clause 3.3, the type of co-ordination may be verified by the tests specified in Clauses 6.1 to 6.3. Such tests are special tests.

6.1 *Condition of the starter*

The starter and its associated SCPD shall be mounted and connected as in normal use. All the tests shall be performed starting from the cold state.

The safety perimeter referred to in Clause 3.3 is constituted:

- If the starter is in a metal enclosure: by that enclosure.
- If the starter is in an insulating enclosure: by a metal foil covering that enclosure.
- If there is no enclosure: by a wire mesh situated at the safety perimeter stated by the manufacturer of the starter.

In all cases, the safety perimeter defined above shall be connected to the neutral point of the supply source or to a substantially inductive artificial neutral permitting a prospective fault current of at least 100 A; this connection shall include a reliable device (such as a fuse element consisting of a copper wire of 0.1 mm diameter) for the detection of the fault current and, if necessary, a resistor limiting the value of the prospective fault current to about 100 A.

6.2 *Test currents and test circuits*

The following two kinds of test currents and corresponding test circuits shall be considered:

6.2.1 *Test currents "p"*

They are test currents equal to 0.75 $I_c\ {}^{0\%}_{-10\%}$ and 1.25 $I_c\ {}^{+10\%}_{0\%}$ respectively, I_c being the current corresponding to the cross-over point of the mean curves representing the time-current characteristics of the overload relay of the starter on the one hand, and of the SCPD on the other hand.

The test circuit comprises the supply source, the starter under test with its associated SCPD and the load circuit. The prospective short-circuit current at the point of connection of the device to the supply source shall be at least ten times the value of the greater test current "*p*" or at least 50 kA, whichever is the lower.

The load circuit shall consist of resistors in series with reactors in order to obtain a power factor of 0.35±0.05. The recovery voltage shall be 1.1 times the rated operational voltage stated for the combination and for the type of co-ordination referred to. It is not necessary to adjust the transient characteristics of the recovery voltage.

6.2.2 *Test current "q"*

It is a test current not less than the maximum prospective short-circuit current associated with the type of co-ordination referred to.

The test circuit, the supply voltage, the power factor and the recovery voltage shall be in accordance with IEC Publication 157-1 for three-phase tests. The rated voltage to be considered for these tests is the rated operational voltage stated for the combination and for the type of co-ordination referred to.

6.3 *Test procedure and results to be obtained*

6.3.1 *General*

If the switching device is a contactor, its coil shall be connected to a separate source giving the rated control supply voltage of the contactor.

Note. — Although it represents only a small percentage of practical utilizations (control supply voltage not altered by the faults), this requirement is meant to facilitate comparative tests.

6.3.2 *Description of the tests*

For test currents "*p*", one breaking operation (of the starter or of the SCPD, as the cases may be) at each of the two values of current indicated in Clause 6.2.1 shall be performed, the starter being closed prior to the test.

For test current "*q*", one breaking operation of the SCPD shall be performed with the starter closed prior to the test, and two breaking operations of the SCPD shall be performed by closing the mechanical switching device of the starter on the short-circuit.

6.3.3 *Execution of the tests*

The starter with its associated SCPD is successively tested at each current "*p*" and submitted to the three tests at current "*q*". After each of the above tests, the rest time shall be long enough to bring back all the components to nearly the room temperature.

For Type "a" co-ordination, the starter shall be inspected after each test, and the parts replaced as necessary.

For Type "b" co-ordination, the starter shall be inspected after each test, the contacts shall be separated if welded, and the overload relay replaced if necessary after verification of its time-current characteristic.

For Type "c" co-ordination, the only action on the starter after each test shall consist in separating the welded contacts if necessary and resetting the overload relay, if necessary.

In all cases it is necessary to inspect the SCPD, to reset the overload relay if necessary, possibly to reset the release of the circuit-breaker and, in the case of fuses, to replace all fuses if at least one of them has melted.

The test report shall indicate the maximum values of Joule-integral and of peak current experienced during the tests.

6.3.4 *Results to be obtained (see also Clause 4)*

For all types of co-ordination, it shall be verified for the starter alone (or for the combination, if the SCPD forms an integral part of the starter), that during all the tests the apparatus does not endanger the operator or cause fire or any damage to neighbouring equipment not forming part of the starter. Furthermore, there shall be no blowing of the fuse element in the earth circuit (see last paragraph of Clause 6.1).

For Types of co-ordination "b" and "c", there shall be neither prolonged arcing nor flashover between poles or between poles and frame. Furthermore, after the completion of the tests, the starter shall satisfy the dielectric tests according to Paragraphs 8.2.3.2.1*a)* 1 and 2 only of Publication 292-1, and the verification of making capacity and of breaking capacity according to Clauses 8.2.4.4 and 8.2.4.5 of Publication 292-1.

For Type "c" co-ordination, after the completion of the tests, the overload relay shall comply with Clauses 7.5.3.2 and 7.5.3.3 of Publication 292-1. For convenience, the corresponding verification can be performed by tests at currents greater than those indicated in Clause 7.5.3.2 of Publication 292-1. The number and the value of the test currents shall be fixed by agreement between manufacturer and user; the mode of operation shall be according to the procedure of Clause 8.2.6 of Publication 292-1.

APPENDIX D

CONVENTIONAL TEST CIRCUIT FOR VERIFICATION OF MAKING AND BREAKING CAPACITIES AND FOR VERIFICATION OF REVERSIBILITY

Note. — This test circuit shall also be utilized for the verification of electrical endurance in category AC-4 (see Clause 8.4.1 of this Publication).

1. **General**

The test circuit comprises the supply source, the starter under test and the load circuit. The prospective short-circuit current at the point of connection to the supply terminals of the starter shall be at least ten times the value of the test current, or at least 50 kA, whichever is the lower.

To ensure that tests made in different laboratories will be sufficiently comparable, it is necessary to specify in detail a conventional load circuit, composed of passive elements and representing as far as possible the conditions likely to be met by starters when switching actual motors.

The load circuit shall consist of resistors in series with air-cored reactors, in parallel with resistors and capacitors. The values of these components shall be adjusted to obtain, at the specified voltage:

— the values of current and power-factor prescribed in Table II of this Publication (Clause 4.4.6), except that, when $I_e \leqslant 17$ A, the value of the power-factor shall be 0.65;

— the specified oscillatory frequency of the transient recovery voltage and the specified value of factor γ.

Factor γ is the ratio of the value U_1 of the highest peak of the transient recovery voltage to the instantaneous value U_2, at the instant of current zero, of the component of the recovery voltage at the applied frequency (see Figure 1, page 72).

2. **Characteristics of the load circuit**

The oscillatory frequency of the transient recovery voltage of the load circuit shall be adjusted to the value:

$$f = 2\,000 \cdot I_c^{0.2} \cdot U_e^{-0.8} \pm 10\%$$

where: f = oscillatory frequency, in kilohertz

U_e = rated operational voltage of the starter (equal to the rated voltage of the motor), in volts

I_c = breaking (or making) current, in amperes.

Note. — This formula is based on tests carried out with motors for 50 Hz. The exact influence of frequency is under consideration.

Factor γ shall be adjusted to the value:

$$\gamma = 1.1 \pm 0.05$$

The voltages, the currents and the power factors shall be as mentioned in Table II of this Publication (Clause 4.4.6), except that, when $I_c \leqslant 17$ A, the value of the power-factor shall be 0.65.

The value of reactance necessary for the test may be obtained by coupling several reactors in parallel under the condition that the transient recovery voltage can still be considered as having only one oscillatory frequency. This is generally the case when the reactors have practically the same time-constant.

For the breaking capacity test, the load side terminals of the starter shall be connected as close as possible to the terminals of the adjusted load circuit, in order to make negligible the influence of the connecting leads; otherwise, the adjustment shall be carried out with these leads present.

Note. — It is not necessary to adjust factor γ or the oscillatory frequency for tests concerning only the making capacity.

3. Description of a method for the adjustment of the load circuit

To adjust the load circuit to obtain the characteristics prescribed above, several methods may be applicable in practice. One of them is described below.

The principle is illustrated in Figure 2, page 73.

The oscillatory frequency f of the transient recovery voltage and the value of factor γ are essentially determined by the natural frequency and the damping of the load circuit. Since these values are independent of the voltage and frequency applied to the circuit, the adjustment can be made by energizing the load circuit from an a.c. power supply, the voltage and frequency of which may be different from those of the supply source utilized for the test of the starter. The circuit is interrupted at a current zero by a diode, and the oscillations of the recovery voltage are observed on the screen of a cathode-ray oscilloscope, the sweep of which is synchronized with the frequency of the power supply (see Figure 3, page 72).

To permit reliable measurements to be made, the load circuit is energized by means of a high-frequency generator G giving a voltage suitable for the diode. The frequency of the generator is chosen equal to:

2 kHz for test currents up to and including 1 000 A;
4 kHz for test currents higher than 1 000 A.

Connected in series with the generator are:

— a dropping resistor having a resistance value R_a high with respect to the load circuit impedance ($R_a \geqslant 10\ Z$, where $Z = \sqrt{R^2 + (\omega L)^2}$ and where $\omega = 2\pi \,.\, 2000\ s^{-1}$ or $= 2\ \pi \,.\, 4000\ s^{-1}$ respectively);

— an instantaneously blocking switching diode; switching diodes commonly used in computers such as diffused junction silicon switching diodes of not over 1 A forward rated current are suitable for this application.

Due to the value of frequency of the generator G, the load circuit is practically purely inductive and, at the instant of current zero, the applied voltage across the load circuit will be at its peak value. To ensure that the components of the load circuit are convenient, it must be checked on the screen that the curve of the transient voltage at its initiation (point A in Figure 3) has a practically horizontal tangent.

The actual factor γ is the ratio U_{11}/U_{12}; U_{11} is read on the screen, U_{12} is read between the ordinate of point A and the ordinate of the trace when the load circuit is no longer energized by the generator (see Figure 3).

When observing the transient voltage in the load circuit with no parallel resistor R_p or parallel capacitor C_p, one reads on the screen the natural oscillatory frequency of the load circuit. Care should be taken that the capacitance of the oscilloscope or of its connecting leads does not influence the resonant frequency of the load circuit.

If that natural frequency exceeds the upper limit of the required value f, the suitable values of frequency and factor γ can be obtained by connecting in parallel capacitors C_p and resistors R_p of appropriate values. The resistors R_p shall be practically non inductive.

It is recommended that, as a first step, each of the three phases of the load circuit be adjusted separately. The adjustment is then completed by successively connecting, in each possible combination, the high-frequency generator to one phase in series with the other two in parallel as shown in Figure 2; the adjustment is refined if necessary so that the specified values of f and γ are obtained in each combination.

Notes 1. — A higher value of frequency obtained from the generator G makes easier the observation on the screen and improves the resolution.

2. — Other methods of determining frequency and factor γ (such as the impression of a square-wave current on the load circuit) may also be applicable.

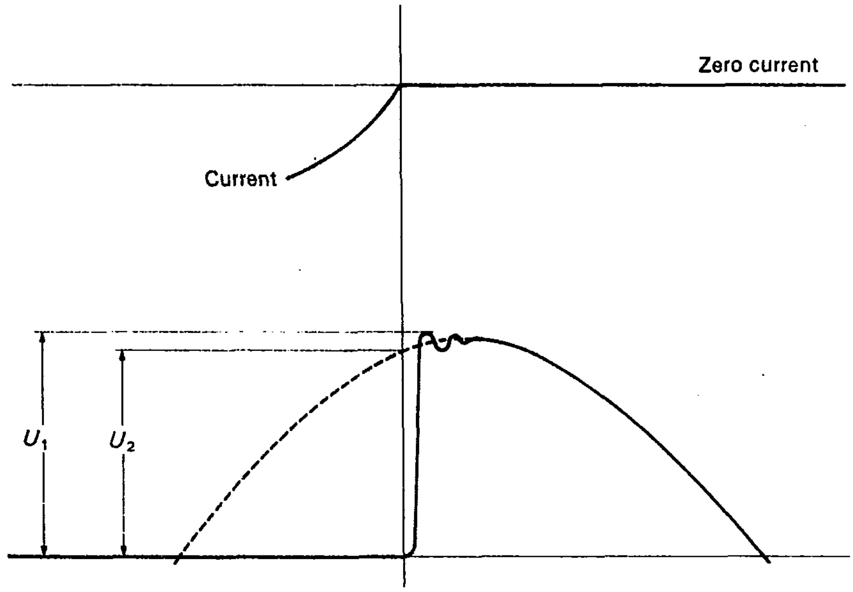


FIG. 1. – Simplified illustration of the recovery voltage across contacts of the first phase to clear.

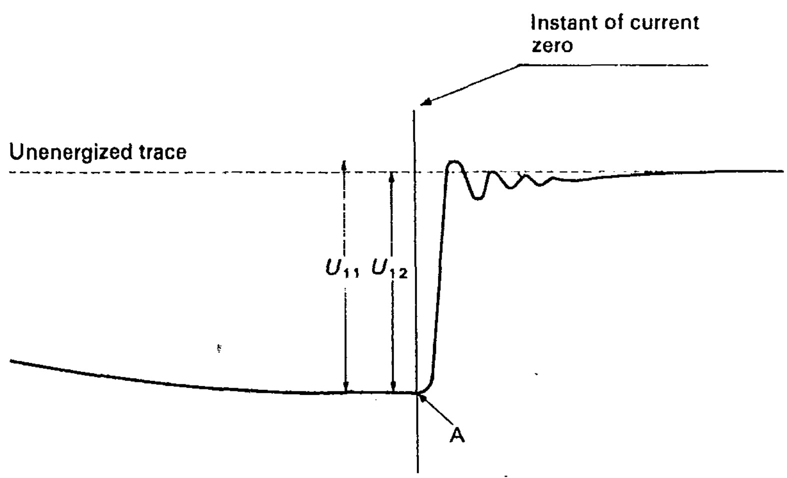
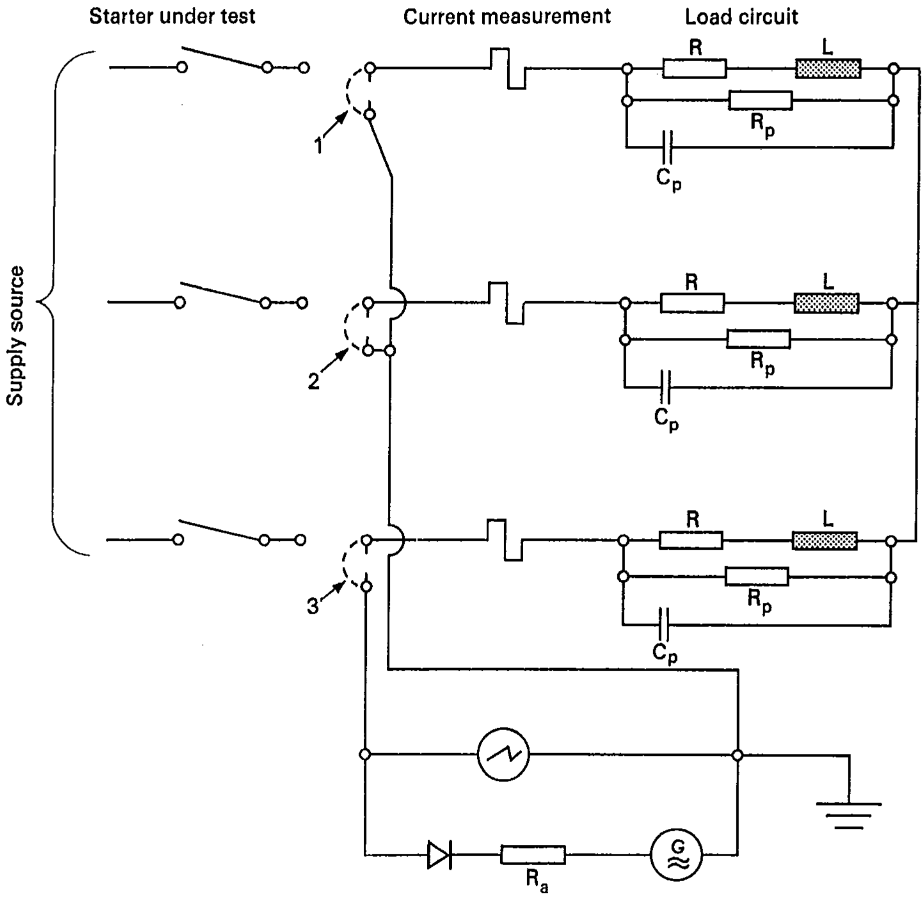


FIGURE 3



R & L	Resistor and reactor of the load circuit	—▷|—	Diode
R_p	Resistor in parallel	(G)	High-frequency generator
C_p	Capacitor in parallel		Cathode-ray oscilloscope
R_a	Resistor		

Notes 1. — The relation of the high-frequency generator G and the diode shall be as shown.

2. — No other point of the circuit that the one indicated on the figure shall be earthed.

3. — In this figure, as an example, dotted leads 1, 2 and 3 are represented in the position corresponding to the adjustment of phase 3 in series with phases 1 and 2 connected in parallel.

FIG. 2. – Scheme of a method of adjustment of the load circuit.

National appendix

Guide to the selection of starters for use with motors having a starting locked rotor current in excess of 6 times full load current

The table gives an approximation of the comparative electrical endurance for starters having a rated operational current (I_e) not exceeding 63 A.

Comparative electrical endurance

Actual starting current (as a multiple of I_e)	Comparative electrical endurance*
6	100 %
7	75 %
8	60 %
9	50 %

* The comparative electrical endurance is the percentage of the number of on-load operating cycles given in **4.4.8** that is appropriate for the starting current indicated.

The actual motor starting current shall not exceed the maximum making and breaking capacities for the starter as given in Table 2.

For starters having a rated operational current (I_e) above 63 A, and in all cases where the electrical endurance is a major consideration, the starter manufacturer should be consulted.

Publications referred to

See foreword.

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Association of Short Circuit Testing Authorities
*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
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Ministry of Defence
National Coal Board
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Association of Control Manufacturers (Tacma) (BEAMA)
British Gas Corporation
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Control and Automation Manufacturers' Association (BEAMA)
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Electronic Components Industry Federation

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