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(affiliée à l'Organisation Internationale de Normalisation — ISO)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

(affiliated to the International Organization for Standardization — ISO)

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Low-voltage controlgear

Part 1: Contactors

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE CONTROLGEAR

Part 1: Contactors

FOREWORD

1) The formal decisions or agreements of the I E C on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote this international unification, the I E C expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the I E C recommendations as the fundamental basis for these rules in so far as national conditions will permit.

4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.

PREFACE

This Recommendation has been prepared by Sub-Committee 17B, Low-Voltage Switchgear and Controlgear, of Technical Committee No. 17, Switchgear and Controlgear.

It forms the second edition of Publication 158-1 and supersedes the first edition issued in 1964.

Work was commenced in January 1968 and the draft of revision was examined during the meeting held in Brussels in October 1968. The final draft was submitted to the National Committees for approval under the Six Months' Rule in March 1969, a corrigendum being circulated in July 1969.

The following countries voted explicitly in favour of publication:

Australia
Austria
Belgium
Denmark
Finland
France
Germany*
Iran
Israel
Italy
Norway
Poland
South Africa
Sweden
Switzerland
Turkey
Union of Soviet Socialist Republics
United Kingdom
United States of America**
Yugoslavia

The Netherlands National Committee has cast a negative vote since it considers too high the values of the temperature-rise limits for insulated coils in air as stated in Clause 7.3.1.

* Except for the temperature-rise limits for insulated coils in air (Clause 7.3.1), deemed to be too high.
** With the exception of Appendix B.

LOW-VOLTAGE CONTROLGEAR

Part 1: Contactors

1. General

1.1 *Scope*

This Recommendation applies to contactors intended for closing and opening electric circuits and, if combined with suitable relays, for protecting these circuits against operating overloads which may occur therein.

It applies only to contactors, 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. or 1 200 V d.c.

Notes 1. — In the present absence of international specifications, an agreement shall take place between manufacturer and user in the case of a voltage exceeding 1 000 V a.c. or 1 200 V d.c., the present Publication being considered as a basis wherever applicable.

2. — Contactors which are intended to provide short-circuit protection shall additionally satisfy the relevant conditions specified for circuit-breakers (IEC Publication 157-1).

1.2 *Object*

The object of this Recommendation is to state:

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

2. Definitions

For the purpose of this Recommendation, the following definitions shall apply:

2.1 *Definitions concerning contactors*

2.1.1 *Switching device*

A device designed to make or break the current in one or more electric circuits.

2.1.2 *Mechanical switching device*

A switching device designed to close and open one or more electric circuits by means of separable contacts.

2.1.3 *Controlgear*

A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for the control of power consuming equipment.

2.1.4 *Contactor (mechanical)*

A mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions.

Notes 1. — A contactor is usually intended to operate frequently.

2. — A contactor may also be capable of making and breaking short-circuit currents.

3. — In French, a contactor the main contacts of which are closed in the position of rest is usually called "rupteur". The word "rupteur" has no equivalent in the English language.

2.1.5 (Vacant.)

2.1.6 *Electromagnetic contactor*

A contactor in which the force for closing or opening the main contacts is provided by an electro-magnet.

2.1.7 *Pneumatic contactor*

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

2.1.8 *Electro-pneumatic contactor*

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

2.1.9 *Latched contactor*

A contactor, the moving elements of which leave the position of rest when the operating means are energized, but which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized. The latching and the release of the latching may be mechanical, magnetic, electrical, pneumatic, etc.

Note. — Because of the latching, the latched contactor actually acquires a second position of rest and, according to the definition 2.1.4, it is not a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are applicable.

2.1.10 *Main circuit*

All the conducting parts of a contactor included in the circuit which it is designed to close or open.

2.1.11 *Pole of a contactor*

The portion of a contactor associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together.

Note. — A contactor is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

2.1.12 *Main contact*

A contact included in the main circuit of a contactor, intended to carry, in the closed position, the current of the main circuit.

2.1.13 *Breaking current*

The current in a pole of a contactor at the instant of initiation of the arc during a breaking operation.

For a.c., it is the r.m.s. value of the a.c. component.

2.1.14 *Breaking capacity*

A value of breaking current that the contactor is capable of breaking at a stated voltage and under prescribed conditions of use and behaviour.

2.1.15 *Making capacity*

A value of current that the contactor is capable of making at a stated voltage and under prescribed conditions of use and behaviour.

For a.c., it is the r.m.s. value of the a.c. component.

2.1.16 *Recovery voltage*

The voltage which appears across the terminals of a pole of a contactor after the breaking of the current.

Note. — This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which power-frequency voltage (Clause 2.1.16.2) alone exists.

2.1.16.1 *Transient recovery voltage (restriking voltage)*

The recovery voltage during the time in which it has a significant transient character.

Notes 1. — The transient voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit and the contactor. It includes the voltage shift of the neutral of a polyphase circuit.

2. — The transient recovery voltage in three-phase circuits is, unless otherwise stated, that across the first pole to clear because this voltage is generally higher than that which appears across each of the other two poles.

2.1.16.2 *Power-frequency recovery voltage*

The recovery voltage after the transient voltage phenomena have subsided.

Notes 1. — The power-frequency recovery voltage may be referred to as a percentage of the rated voltage.

2. — This definition applies also to the case of d.c., the frequency then being considered as zero.

2.1.17 *Short-time withstand current*

The current that a contactor can carry in the closed position during a specified short time under prescribed conditions of use and behaviour.

2.1.18 *Over-current*

Any current exceeding the rated current.

2.1.19 *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.

2.1.20 *Conducting part*

A part which is capable of conducting current although it may not necessarily be used for carrying service current.

2.1.21 *Clearance*

The distance between two conducting parts along a string stretched the shortest way between these conducting parts.

2.1.21.1 *Clearance between poles*

The clearance between any conducting parts of adjacent poles.

2.1.21.2 *Clearance to earth*

The clearance between any conducting parts and any parts which are earthed or intended to be earthed.

2.1.21.3 *Clearance beween open contacts (gap)*

The total clearance between the contacts, or any conducting parts connected thereto, of a pole of a contactor in the open position.

2.1.22 *Creepage distance*

The shortest distance along the surface of an insulating material between two conducting parts.

Note. — A joint between two pieces of insulating material is considered part of the surface.

2.1.23 *Accidentally dangerous part*

A conducting part which can be touched readily by an operator and which is normally not alive, but which may become alive, for instance as a result of an insulation failure.

Note. — Typical accidentally dangerous parts are walls of enclosures, operating handles, etc.

2.1.24 *Ambient air temperature*

The temperature, determined under prescribed conditions, of the air surrounding the complete contactor (e.g., for enclosed contactors, it is the air outside the enclosure).

2.2 *Definitions concerning positions, control and auxiliary circuits of a contactor*

2.2.1 *Position of rest*

The position which the moving elements of the contactor take up when its electro-magnet or its compressed-air device is not energized.

2.2.2 *Control circuit*

All the conducting parts of a contactor (other than the main circuit) used for the closing operation or opening operation, or both, of the contactor.

Note. — Pneumatic contactors do not include control circuits.

2.2.3 *Control contact*

A contact included in a control circuit of a contactor and mechanically operated by the contactor.

Note. — A control contact is part of the design of a contactor.

2.2.4 *Auxiliary circuit*

All the conducting parts of a contactor intended to be included in a circuit other than the main circuit and the control circuits of the contactor.

Note. — Some auxiliary circuits serve supplementary requirements such as signalling, interlocking, etc., and as such they may be part of the control circuit of another switching device.

2.2.5 *Auxiliary contact*

A contact included in an auxiliary circuit of a contactor and mechanically operated by the contactor.

Note. — An auxiliary contact is intended to satisfy supplementary requirements such as signalling, interlocking, etc., and as such it may be part of a control circuit of another switching device.

2.2.6 *a-contact (make contact)*

A control or auxiliary contact which is closed when the main contacts of the contactor are closed and open when they are open.

2.2.7 *b-contact (break contact)*

A control or auxiliary contact which is open when the main contacts of the contactor are closed and closed when they are open.

2.2.8 *Closed position*

The position in which the pre-determined continuity of the main circuit of the contactor is secured.

2.2.9 *Open position*

The position in which the pre-determined clearance between open contacts in the main circuit of the contactor is secured.

2.2.10 *Operation (of a contactor)*

The transfer of the moving contact(s) from one position to the other.

Notes 1. — This may be a closing operation or an opening operation.

2. — If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

2.2.11 *Operating cycle (of a contactor)*

A succession of operations from one position to the other and back to the first position.

Notes 1. — This may be a closing operation followed by an opening operation.

2. — A succession of operations not forming an operating cycle is referred to as an *operating series.*

2.2.12 *Closing operation*

An operation by which the contactor is brought from the open position to the closed position.

2.2.13 *Opening operation*

An operation by which the contactor is brought from the closed position to the open position.

3. Classification

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

- electromagnetic,
- pneumatic,
- electro-pneumatic.

Note. — This Recommendation may also concern contactors fitted with other types of control as far as it is practically applicable.

3.2 According to the interrupting medium, contactors are divided into different groups, e.g.:

- air break,
- oil-immersed break.

3.3 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 Control-gear.

4. Characteristics of contactors

4.1 *Summary of characteristics*

The characteristics of a contactor shall be stated in the following terms, where such terms are applicable:

Type of contactor (see Clause 4.2);

Rated values (see Clause 4.3);

Control circuits and air-supply systems (see Clause 4.4);

Auxiliary circuits (see Clause 4.5);

Degrees of protection of enclosures (see Clause 3.3).

4.2 *Type of contactor*

The following shall be stated:

4.2.1 *Number of poles*

4.2.2 *Kind of current*

Kind of current, and in the case of a.c., number of phases and rated frequency.

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

4.2.4 *Method of control* (see Clause 3.1)

4.3 *Rated values*

The rated values established for a contactor shall be stated in accordance with Clauses 4.3.1 to 4.3.8, but it is not necessary to establish all the rated values listed.

4.3.1 *Rated voltages*

A contactor is defined by the following rated voltages:

4.3.1.1 *Rated operational voltages*

A rated operational voltage (U_e) of a contactor is a value of voltage which, combined with a rated operational current, determines the application of the contactor 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.

Notes 1. — A contactor may be assigned a number of combinations of rated operational voltages and rated operational currents for different duties and utilization categories.

2. — For rated voltages of control circuits, see Clause 4.4.1.

4.3.1.2 *Rated insulation voltage*

The rated insulation voltage (U_i) of a contactor 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 contactor. In no case shall the maximum rated operational voltage exceed the rated insulation voltage.

4.3.2 *Rated currents*

A contactor is defined by the following rated currents:

4.3.2.1 *Rated thermal current*

The rated thermal current (I_{th}) of a contactor is the maximum current it can carry on eight-hour duty (see Clause 4.3.4.1) without the temperature rise of its several parts exceeding the limits specified in Clause 7.3 (Tables V and VI) when tested according to Clause 8.2.2.

Note. — The rated thermal current can differ according to the type of enclosure.

4.3.2.2 *Rated operational currents or rated operational powers*

A rated operational current (I_e) of a contactor is stated by the manufacturer and takes into account the rated operational voltage (see Clause 4.3.1.1), the rated frequency (see Clause 4.3.3), the rated duty (see Clause 4.3.4), the utilization category (see Clause 4.3.6) and the type of protective enclosure.

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

4.3.3 *Rated frequency*

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

4.3.4 *Rated duty*

The rated duties considered as normal are as follows:

4.3.4.1 *Eight-hour duty*

Duty in which the main contacts of a contactor remain closed whilst carrying a steady current long enough to reach thermal equilibrium but not for more than eight hours without interruption.

Notes 1. — This is the basic duty on which the rated thermal current of the apparatus is determined.

2. — Interruption means breaking of the current by operation of the contactor.

4.3.4.2 *Uninterrupted duty*

Duty in which the main contacts of a contactor remain closed whilst carrying a steady current without interruption for periods of more than eight 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 considerations (e.g. silver contacts) (see Table VI).

4.3.4.3 *Intermittent periodic duty or intermittent duty*

Duty in which the main contacts of a contactor remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the contactor 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%.

4.3.4.3.1 *Classes of intermittent duty*

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

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

Note. — On the occasion of a future revision, Class 30 will be considered.

It is recalled that an operating cycle is a complete working cycle comprising one closing operation and one opening operation.

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.

4.3.4.4 *Temporary duty*

Duty in which the main contacts of a contactor remain closed for periods of time insufficient to allow the contactor 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.

4.3.5 *Making and breaking capacities*

A contactor is defined by its making capacities and breaking capacities, in accordance with utilization categories as specified in Table II (see Clause 4.3.6).

Note. — Certain contactors associated with over-current devices may also be subject to requirements as to their making and breaking capacities in the case of a short-circuit occurring where they are installed. They shall then comply with the requirements of this Recommendation including Appendix C or alternatively with the requirements of IEC Publication 157-1, Low-voltage Distribution Switchgear, Part 1: Circuit-breakers, for the rated short-circuit making and breaking capacities and the rated short-time withstand current.

4.3.5.1 *Rated making capacity*

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

The making conditions which shall 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 operational current and to the utilization category, according to Table II.

For a.c., the rated making capacity is expressed by the r.m.s. value of the symmetrical component of the current.

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

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

4.3.5.2 *Rated breaking capacity*

The rated breaking capacity of a contactor is a value of current which the contactor 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 shall 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 operational current and to the utilization category, according to Table II.

A contactor shall be capable of breaking any value of the load current up to its highest rated breaking capacity according to Clause 4.3.6.

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

4.3.5.3 *Ability to withstand overload currents*

Under consideration.

4.3.6 *Utilization category*

The 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 or time-constants as shown in Table II and other test conditions used in the definitions of the rated making and breaking capacities.

For contactors 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 applications
A.C.	AC-1	Non-inductive or slightly inductive loads, resistance furnaces.
	AC-2	Slip-ring motors : Starting, plugging [1].
	AC-3	Squirrel-cage motors : Starting, switching off motors during running.
	AC-4	Squirrel-cage motors : Starting, plugging [1]), inching [2]).
D.C.	DC-1	Non-inductive or slightly inductive loads, resistance furnaces.
	DC-2	Shunt-motors : Starting, switching off motors during running.
	DC-3	Shunt-motors : Starting, plugging [1]), inching [2]).
	DC-4	Series-motors : Starting, switching off motors during running.
	DC-5	Series-motors : Starting, plugging [1]), inching [2]).

[1]) By plugging, is understood stopping or reversing the motor rapidly by reversing motor primary connections while the motor is running.

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

Note. — The application of contactors to the switching of rotor circuits, capacitors or tungsten filament lamps shall be subject to special agreement between manufacturer and user.

TABLE II

Verification of rated making and breaking capacities (See Clause 8.2.4)

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

	Category	Value of the rated operational current	Make			Break		
			I/I_e	U/U_e	cos φ [2]	I_c/I_e	U_r/U_e	cos φ [2]
A.C.	AC-1	(All values)	1.5	1.1	0.95	1.5	1.1	0.95
	AC-2	(All values)	4	1.1	0.65	4	1.1	0.65
	AC-3	$I_e \leq$ 17 A	10	1.1	0.65	8	1.1	0.65
		17 A < $I_e \leq$ 100 A	10	1.1	0.35	8	1.1	0.35
		$I_e >$ 100 A	8 [3]	1.1	0.35	6 [4]	1.1	0.35
	AC-4	$I_e \leq$ 17 A	12	1.1	0.65	10	1.1	0.65
		17 A < $I_e \leq$ 100 A	12	1.1	0.35	10	1.1	0.35
		$I_e >$ 100 A	10 [5]	1.1	0.35	8 [3]	1.1	0.35
			I/I_e	U/U_e	L/R [6] (ms)	I_c/I_e	U_r/U_e	L/R [6] (ms)
D.C.	DC-1		—	—	—	—	—	—
	DC-2 (shunt-motors)	(All values)	4	1.1	2.5	4	1.1	2.5
	DC-3 (shunt-motors)	(All values)	4	1.1	2.5	4	1.1	2.5
	DC-4 (series-motors)	(All values)	4	1.1	15	4	1.1	15
	DC-5 (series-motors)	(All values)	4	1.1	15	4	1.1	15

I_e Rated operational current (see Clause 4.3.2.2); U Voltage before make;
U_e Rated operational voltage (see Clause 4.3.1.1); U_r Recovery voltage;
I Current made; I_c Current broken.

1) In a.c. 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 4.3.5.1, Note).

2) Tolerance for cos φ : ± 0.05.
3) With a minimum of 1 000 A for I or I_c.
4) With a minimum of 800 A for I_c.
5) With a minimum of 1 200 A for I.
6) Tolerance for L/R: ± 15%.

4.3.7 *Mechanical endurance*

With respect to its resistance to mechanical wear, a contactor 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.

4.3.8 *Electrical endurance*

With respect to its resistance to electrical wear, a contactor 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 categories AC-3, DC-2 and DC-4 shall be not less than 1/20 of the number of no-load operating cycles corresponding to the mechanical endurance of the contactor.

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 several utilization categories(1)

	Category	Value of the rated operational current	Make			Break		
			I/I_e	U/U_e	cos φ (2)	I_c/I_e	U_r/U_e	cos φ (2)
A.C.	AC-1	(All values)	1	1	0.95	1	1	0.95
	AC-2	(All values)	2.5	1	0.65	2.5	1	0.65
	AC-3	$I_e \leq 17$ A	6	1	0.65	1	0.17	0.65
		$I_e > 17$ A	6	1	0.35	1	0.17	0.35
	AC-4	$I_e \leq 17$ A	6	1	0.65	6	1	0.65
		$I_e > 17$ A	6	1	0.35	6	1	0.35
			I/I_e	U/U_e	L/R (3) (ms)	I_c/I_e	U_r/U_e	L/R (3) (ms)
D.C.	DC-1	(All values)	1	1	1	1	1	1
	DC-2	(All values)	2.5	1	2	1	0.10	7.5
	DC-3	(All values)	2.5	1	2	2.5	1	2
	DC-4	(All values)	2.5	1	7.5	1	0.30	10
	DC-5	(All values)	2.5	1	7.5	2.5	1	7.5

I_e Rated operational current (see Clause 4.3.2.2); U Voltage before make;
U_e Rated operational voltage (see Clause 4.3.1.1); U_r Recovery voltage;
I Current made; I_c Current broken.

1) In a.c. 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 4.3.5.1, Note).

2) Tolerance for cos φ: ± 0.05.
3) Tolerance for L/R: ± 15%.

4.4 *Control circuits and air-supply systems*

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

4.4.1 *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 circuits of the contactor 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 circuits 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 the rated control circuit voltage, 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.

4.4.2 *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 contactor is the air pressure upon which the operating characteristics of the pneumatic control system are based.

4.5 *Auxiliary circuits*

The characteristics of auxiliary circuits are:

a) the number of those circuits;

b) the number and kind of contacts (a-contact, b-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 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.

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

Under consideration.

5. Nameplates

Each contactor 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 contactor is installed:

a) the manufacturer's name or trademark;

b) type designation or serial number;

c) rated operational voltages (see Clause 4.3.1.1);

d) utilization category and rated operational currents (or rated powers), at the rated operational voltages of the contactor (see Clause 4.3.2.2);

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

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 shall also be stated on the contactor nameplate:

g) rated insulation voltage (see Clause 4.3.1.2);

h) rated thermal current (see Clause 4.3.2.1);

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

j) rated duty with the indication of the class of intermittent duty, if any (see Clause 4.3.4).

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

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

l) rated coil voltage.

For contactors 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.

Note. — If the available space on the nameplate is insufficient to carry all the above data, the contactor 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*

Contactors 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 h does not exceed + 35 °C.

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

Note. — Contactors 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. Contactors 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 contactor 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, 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 contactors, 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*

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

Under no circumstances shall a removable metal part of the enclosure be insulated from the 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 the sign  .

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 operation of the apparatus or of its vibration.

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 contactor, 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	—

Note. — The classification of insulations is that given in Section Two 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.

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 contactor, including the over-current releases which may be associated with it, shall be capable of carrying, without the temperature rises exceeding the limits specified in Table VI:

- for a contactor intended for eight-hour duty: its rated thermal current;
- for a contactor intended for uninterrupted duty, intermittent duty or temporary duty: its rated operational current.

Note. — Only the terminals intended for external connections are considered, in this Recommendation, as terminals of the contactor. 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 electrically operated valves of electro-pneumatic contactors, shall withstand under continuous load and at the rated frequency, if applicable, their rated voltage without the temperature rises exceeding the limits specified in Tables V and VI. Specially rated coils, e.g. trip coils of latched contactors and certain magnetic valve coils for interlocked pneumatic and electro-pneumatic contactors, 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 contactors for intermittent duty Classes 0.1 to 10 shall also withstand the following frequencies of operation:

Intermittent duty class of the contactor (see Clause 4.3.4.3.1)	One close-open operating cycle every	Interval of time during which the supply of the control coil is maintained
0.1	300 s	180 s
0.3	120 s	72 s
1	30 s	18 s
3	12 s	4.8 s
10	3 s	1.2 s

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

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 shall 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 contactor 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.

7.5 *Limits of operation*

Unless otherwise stated, electromagnetic and electro-pneumatic contactors 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 latched contactors, operating limits shall be agreed upon between manufacturer and user.

For electromagnetic and electro-pneumatic contactors, the drop-out voltage shall not be 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 contactors, unless otherwise stated, the limits of variation of the air supply pressure are 85% and 110% of the rated pressure.

8. Tests

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

8.1 *Verification of the characteristics of contactors*

The tests to verify the characteristics of contactors 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).

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) where appropriate, verification of short-circuit making and breaking capacities and rated short-time withstand current (see Clause 8.2.5);

e) verification of operating limits (see Clause 8.2.6);

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

Note. — In the case of a small quantity production, this test may constitute a special test.

g) verification of ability to withstand overload currents (see Clause 8.2.8).

8.1.2 *Routine tests*

They comprise:

a) operating 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 contactor 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 contactor at about half its height and at a distance of about 1 m from the contactor. The thermometers or thermocouples shall be protected against air currents and heat radiations.

8.2.2.2 *Temperature-rise tests of the main circuit*

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

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

Where practicable, the contacts shall be closed by energizing the contactor operating coil at its rated voltage and, if electro-pneumatic, at the rated supply pressure.

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

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 deg 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 electro-magnet is energized during the test, the temperature shall be measured when thermal equilibrium is reached in both the main circuit and the control electro-magnet.

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 thermal current, one of the following procedures shall be followed:

For values of rated thermal current I_{th} *up to and including 400 A:*

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

b) The test shall be carried out with single-phase current, with all poles connected in series.

c) The connections shall be in free air and spaced not less than the distance existing between the terminals.

d) The minimum length of each temporary connection from terminal to terminal shall be:

- 1 m for cross-sections up to and including 10 mm² (or AWG 8);
- 2 m for cross-sections larger than 10 mm² (or AWG 8).

TABLE VII

Standard cross-sections of copper conductors corresponding to the rated 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	210
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.

For values of rated thermal current higher than 400 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.

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 contactors intended for uninterrupted, eight-hour or temporary duty are subject 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 contactors intended for intermittent duty shall be subject 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 contactors shall be measured at the upper part of the oil; this measurement may be made by means of a thermometer.

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 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 contactor for tests*

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

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

When the dielectric strength of the contactor 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*

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 contactor;

2) between each pole and all the other poles connected to the frame of the contactor;

b) with the main contacts open:

1) between all live parts of all poles connected together and the frame of the contactor;

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 contactor;

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

TABLE VIII

Rated insulation voltage U_i V	Dielectric test voltage (a.c.) (r.m.s.) V
$U_i \leq 60$	1 000
$60 < U_i \leq 300$	2 000
$300 < U_i \leq 660$	2 500
$660 < U_i \leq 800$	3 000
$800 < U_i \leq 1\,000$	3 500
$1\,000 < U_i \leq 1\,200$ *	3 500

* For d.c. only.

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 contactor are intended to verify that the contactor 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, contactors intended for use on three-phase loads shall be tested with three-phase current; single-phase tests of such contactors are not covered by this Recommendation and shall be the subject of a special agreement.

Note. — If several utilization categories are specified, the manufacturer and the user may come to an agreement on the most representative utilization category for the intended applications.

8.2.4.2 *Condition of the contactor for tests*

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

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

For verification of the making and breaking capacities, all parts of the contactor 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 of 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 rated 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 rated making capacity*

The making current to be obtained during the test shall be as given in Table II for the appropriate utilization category.

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

- For contactors of utilization category AC-3 or AC-4, the number is 100:50 operations of which are made at 85% and 50 operations at 110% of the rated coil voltage or, for pneumatic and electro-pneumatic contactors, of the rated supply pressure.

- For contactors of any other utilization category than AC-3 or AC-4, the number is 20:10 operations of which are made at 85% and 10 operations at 110% of the rated coil voltage or, for pneumatic and electro-pneumatic contactors, of the rated supply pressure.

The time interval between an opening operation and the closing operation immediately following it shall be 5 s to 10 s.

Note. — For large contactors, 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).

8.2.4.5 *Verification of rated breaking capacity*

The breaking current to be obtained during the test shall be as given in Table II for the appro-

priate utilization category. The total number of opening operations to be made is 25.

The duration of each current flow shall not exceed 0.5 s and the time interval between two successive opening operations shall be 5 s to 10 s.

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

8.2.4.6 *Behaviour of the contactor during making and breaking 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 flashover 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 contactor 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 contactor, arc and flames shall not extend beyond the safety area stated by the manufacturer.

8.2.5 *Verification of short-circuit making and breaking capacities and rated short-time withstand current*

If contactors fitted with relays or over-current releases are required to provide short-circuit protection, this test shall be carried out in accordance with IEC Publication 157-1.

8.2.6 *Verification of operating limits*

When a contactor 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 shall form part of the test report.

It shall be verified that the contactor opens and closes cleanly within the voltage and temperature limits specified in Clause 7.5 when the coil circuits are rapidly opened or closed. Tests shall be performed with no current flowing through the main circuit.

8.2.7 *Verification of mechanical endurance*

8.2.7.1 *Condition of the contactor for tests*

The contactor 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 contactor may be lubricated before the test if lubrication is prescribed in normal service.

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 movement, the tests shall be carried out with these elements connected as in normal operation.

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

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 contactor 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 contactors, the duration of energization of the control coil shall be greater than the time of operation of the contactor, and the time for which the coil is not energized shall be of such a duration that the contactor can come to rest at both extreme positions.

The number of operating cycles to be carried out shall be not less than the number of no-load operating cycles specified in Clause 4.3.7.

After each tenth of the total number of operating cycles given in Clause 4.3.7 has been carried out, it is permissible before carrying on with the test:

- to clean the whole contactor 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 contactor 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 contactor shall still be capable of complying with the operating conditions specified in Clauses 7.5 and 8.2.6. There shall be no loosening of the parts used for connecting the conductors.

8.2.8 *Verification of the ability to withstand overload currents*

Under consideration.

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.

8.3.2 *Operating tests*

For electromagnetic, pneumatic and electro-pneumatic contactors, tests are carried out to verify operation within the limits specified in Clause 7.5. As the main contacts are in a new condition, an adjustment may be necessary to the figure for minimum drop-out voltage which is specified for worn contacts.

8.3.3 *Dielectric tests*

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

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 contactor 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, this is included under special tests (i.e. subject to agreement between manufacturer and user) because of the difficulty and cost of carrying out electrical endurance tests on all types of contactors. 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 (see Clause 4.3.8). The test circuit shall comprise inductors and resistors so arranged as to give the appropriate values of current, voltage, power-factor and time-constant. For Category AC-4, the test circuit shall be arranged in accordance with Appendix D. In all cases, the speed of operation shall be chosen by the manufacturer.

Tests shall be carried out with the contactor 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 contactor shall fulfil the operating conditions specified in Clause 8.2.6, 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 indicate to the manufacturer if the atmosphere in which the contactor 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 contactor is to be installed near the sea.

4. Conditions of installation

The user shall indicate to the manufacturer if the contactor may be fitted to a moving device, if its support may be capable of assuming a sloping position either permanently or temporarily (contactors 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 contactor.

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 indicate to the manufacturer if the contactor may be used for applications not covered by Table I, e.g. the switching of capacitors or tungsten filament lamps.

APPENDIX B

CLEARANCES AND CREEPAGE DISTANCES FOR LOW-VOLTAGE CONTACTORS

Introduction

It is not possible to lay down a simple set of rules relating to clearances and creepage distances which can be applied to contactors, as so much depends on variable factors such as atmospheric conditions, the type of insulation employed, the disposition of the creepage paths and the conditions of the system on which the contactor is to be used.

This Appendix, therefore, is intended to serve as a guide to the values of minimum clearances and creepage distances to be used. The values given are based on those used in various national specifications, and which are known to give satisfactory service under normal industrial conditions and under system conditions generally found in the majority of the countries in which these specifications are in use.

Further investigation is necessary to obtain a better understanding of the effects of the various factors, and thus to determine a more comprehensive set of rules.

1. **Scope**

The recommendations of this Appendix apply to low-voltage contactors specified in this Publication. They apply to equipment in air and to normal atmospheric conditions as defined in Clause 6.1.3 of the same Publication. When the atmospheric conditions differ from the normal, this should be recognized either by the choice of enclosures or by larger creepage distances. Observation of these recommendations does not imply that the contactors will meet the test requirements of this Publication.

2. **Definitions**

(Vacant.)

3. **General**

3.1 It is recommended that the surface of the insulating parts should be designed with ridges so arranged as to break the continuity of conducting deposits which may form.

3.2 The recommended clearances and creepage distances apply to non-arcing parts. In the vicinity of arcs or in areas where ionized gases may be present, the normal atmospheric conditions defined in Clause 6.1.3 of this Publication do not exist and larger values may be necessary.

3.3 The recommended clearances do not apply to the gap between the separable contacts of the same pole when in the open position.

3.4 Conducting parts covered only with varnish or enamel, or protected only by oxidation or a similar process, should not be considered as being insulated.

3.5 The recommended clearances and creepage distances must be maintained under the following circumstances:

a) On the one hand, without external electrical connections, on the other hand, when conductors insulated or bare, of the type and of any dimensions specified for the contactor, are installed according to the manufacturer's instructions, if any.

b) After interchangeable parts have been changed, taking into account maximum permissible manufacturing tolerances.

c) Taking into consideration possible deformations due to the effect of temperature, ageing, shocks, vibrations, or due to short-circuit conditions which the contactor is intended to endure.

4. Determination of clearances and creepage distances

In determining clearances and creepage distances, it is recommended that the following points should be considered:

4.1 If a clearance or a creepage distance is influenced by one or more metal parts, either one of the sections between these parts should have at least the prescribed minimum value, or the sum of the two largest sections should have at least 1.25 times the prescribed minimum value. Individual sections less than 2 mm in length should not be taken into consideration in the calculation of the total length of clearances and creepage distances.

4.2 In determining a creepage distance, grooves at least 2 mm wide and 2 mm deep should be measured along their contour. Grooves having any dimension less than these dimensions and any groove liable to be clogged with dirt should be neglected and direct distance only measured.

4.3 In determining a creepage distance, ridges less than 2 mm high should be neglected. Those at least 2 mm high:

- are measured along their contour, if they are an integral part of a component in insulating material (for instance by moulding or welding);
- are measured along the shorter of two paths: length of joint or profile of ridge, if they are not integral part of a component in insulating material.

4.4 The application of the foregoing recommendations is illustrated by the following figures:

Figures 1, 2 and 3 (page 68) indicate the inclusion or exclusion of a groove in a creepage distance.

Figures 4 and 5 (page 68) indicate the inclusion or exclusion of a ridge in a creepage distance.

Figure 6 (page 68) indicates the consideration of the joint when the ridge is formed by an inserted insulating barrier the outside profile of which is longer than the length of the joint.

Figures 7, 8, 9 and 10 (page 69) illustrate how to determine the creepage distance to fixing means situated in recesses in insulating parts.

5. Minimum values of clearances and creepage distances

5.1 The values of clearances and creepage distances are given in Table I (page 67) as a function of the rated insulation voltage and of the rated thermal current of the contactor (I_{th}).

5.2 The values of clearances are given between two live parts (L-L) and between a live part and an accidentally dangerous part (L-A). The distance between a live part and an earthed part (which is not considered accidentally dangerous) may be that specified for L-L for the corresponding voltage.

5.3 The values of creepage distances also depend on the insulating material and the shape of the insulating piece.

Column a: 1. Ceramics (Steatite, Porcelain).

2. Other kinds of insulating materials designed with ridges or with approximately vertical surfaces, for which experience has shown that they are capable of giving satisfactory service with the creepage distances used for ceramics.

Note. — Such materials may be materials having a comparative tracking index of at least 140 V (see IEC Publication 112, Recommended Method for Determining the Comparative Tracking Index of Solid Insulating Materials under Moist Conditions), e.g. phenolic mouldings.

Column b: All other cases.

The values in the table are given only as a guide to what may be regarded as minimum values.

TABLE I

Rated insulation voltage U_i V	Clearances mm				Creepage distances mm			
	$I_{th} \leq 63$ A		$I_{th} > 63$ A		$I_{th} \leq 63$ A		$I_{th} > 63$ A	
	L–L	L–A	L–L	L–A	a	b	a	b
$U_i \leq 60$	2	3	3	5	2	3	3	4
$60 < U_i \leq 250$	3	5	5	6	3	4	5	8
$250 < U_i \leq 380$	4	6	6	8	4	6	6	10
$380 < U_i \leq 500$	6	8	8	10	6	10	8	12
$500 < U_i \leq 660$	6	8	8	10	8	12	10	14
$660 < U_i \leq \begin{cases} 750 \text{ a.c.} \\ 800 \text{ d.c.} \end{cases}$	10	14	10	14	10	14	14	20
$750 < U_i \leq 1\,000$ a.c. $800 < U_i \leq 1\,200$ d.c.	14	20	14	20	14	20	20	28

Notes 1. — The values in Table I apply to the atmospheric conditions as specified in Clause 6.1.3 of this Publication. For more severe conditions, and for marine service, creepage distances should be at least those in Column *b*.

2. — When the clearance L-A is greater than the corresponding creepage distance specified in Column *a* or Column *b*, then the creepage distance from the live part to the accidentally dangerous part shall be not less than the clearance.

3. — The clearances and creepage distances for control and auxiliary circuits should be those given for $I_{th} \leq 63$ A.

Clearances and creepage distances between live parts of the main circuit and live parts of control or auxiliary circuits should be those given in Column L-L corresponding to the rated thermal current I_{th} of the contactor.

Dimensions en millimètres

Dimensions in millimetres

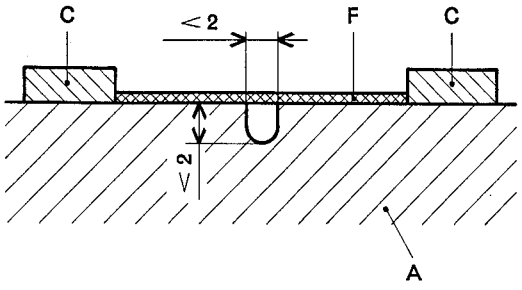


FIGURE 1

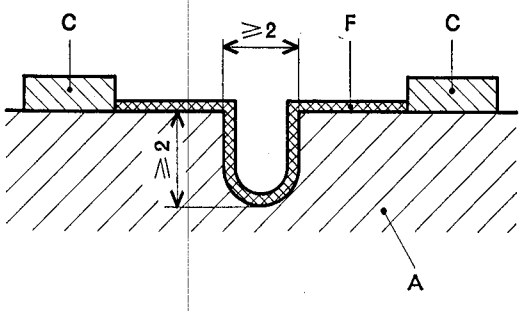


FIGURE 2

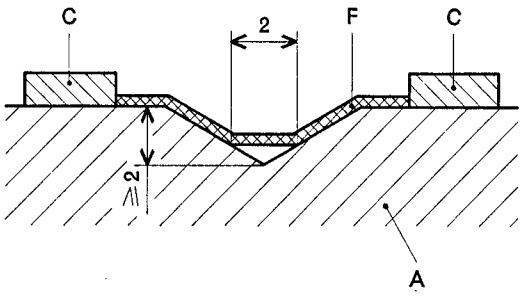


FIGURE 3

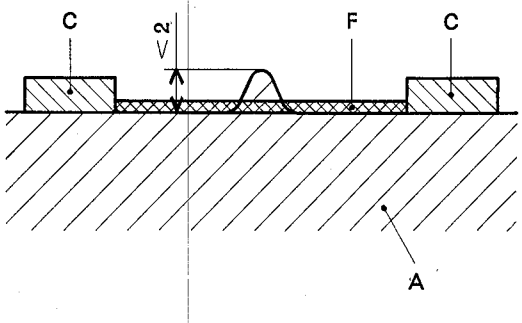


FIGURE 4

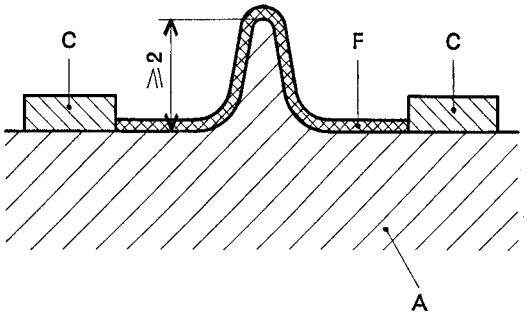


FIGURE 5

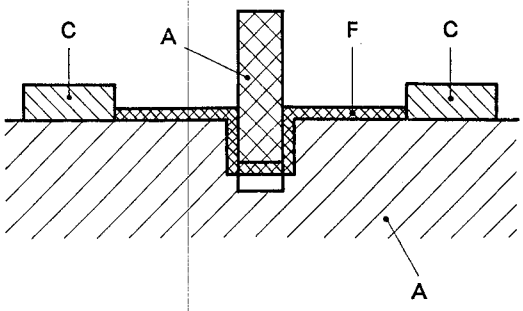


FIGURE 6

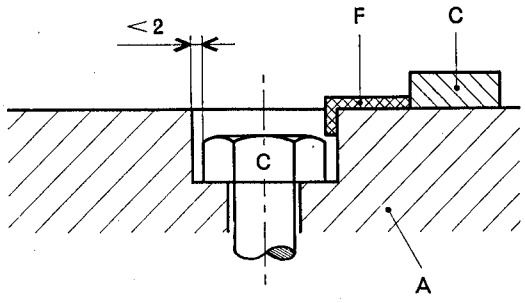


FIGURE 7

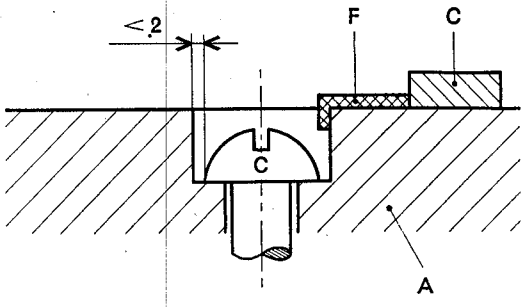


FIGURE 8

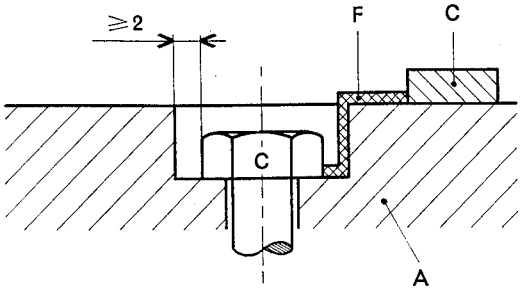


FIGURE 9

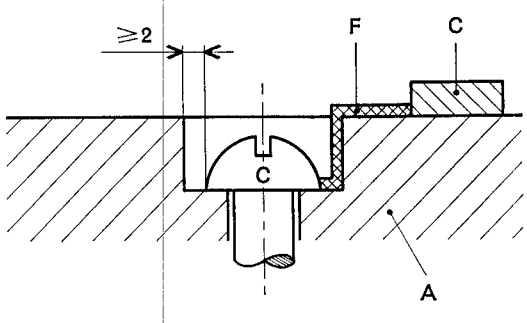


FIGURE 10

A = matière isolante
C = partie conductrice
F = ligne de fuite

A = insulating material
C = conducting part
F = creepage distance

APPENDIX C

CO-ORDINATION WITH SHORT-CIRCUIT PROTECTIVE DEVICES

Under consideration.

APPENDIX D

CONVENTIONAL TEST CIRCUIT FOR VERIFICATION OF MAKING AND BREAKING CAPACITIES FOR CATEGORIES AC-3 AND AC-4*

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 contactor under test and the load circuit. The prospective short-circuit current at the point of connection to the supply terminals of the contactor 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 contactors 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 4.3.6);
- 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 76).

2. Characteristics of the load circuit

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

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

---

* For utilization categories AC-1, AC-2, DC-1, DC-2, DC-3, DC-4 and DC-5, the determination of the test circuit is under consideration.

where: f = oscillatory frequency, in kilohertz;

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

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

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 4.3.6).

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 contactor 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 77.

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 contactor. 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 76).

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 ($R_a \geq 10\ Z$, where $Z = \sqrt{R^2 + (\omega L)^2}$ and where ω is $2\pi \cdot 2\,000\ s^{-1}$ or $2\pi \cdot 4\,000\ s^{-1}$ 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, page 76) 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, page 77: 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 the observation on the screen easier 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.

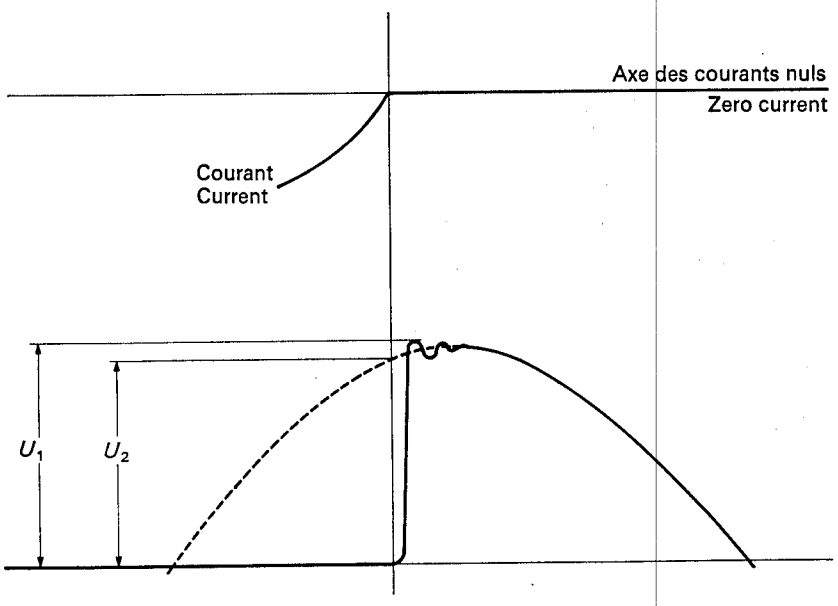


FIG. 1. – Représentation schématique de la tension de rétablissement entre les contacts de la première phase qui coupe.
Simplified illustration of the recovery voltage across contacts of the first phase to clear.

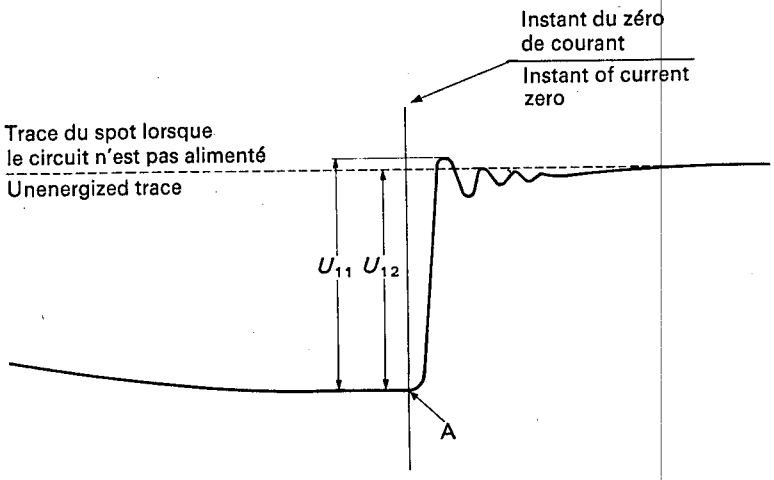
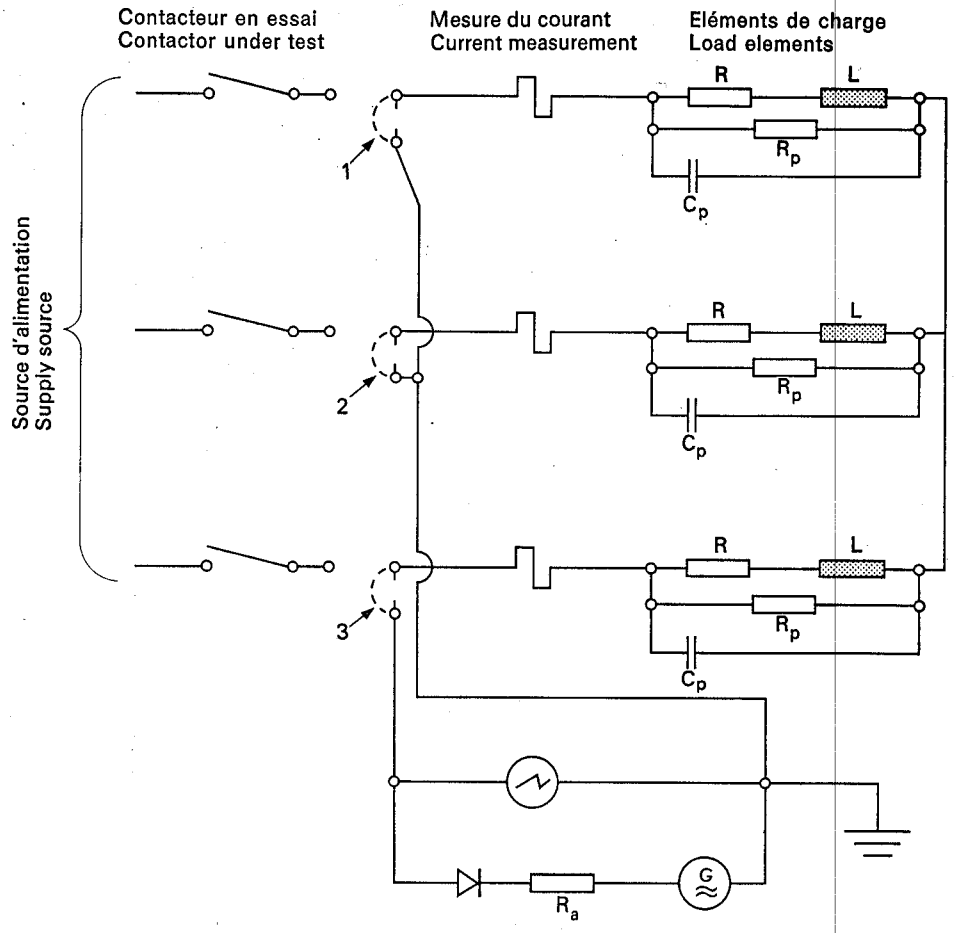


FIGURE 3



R & L = résistance et réactance du circuit de charge
resistor and reactor of the load circuit

R_p = résistance en parallèle
resistor in parallel

C_p = condensateur en parallèle
capacitor in parallel

R_a = résistance
resistor

= diode

= générateur à haute fréquence
high-frequency generator

= oscilloscope cathodique
cathode-ray oscilloscope

Notes 1. — Les positions relatives du générateur à haute fréquence G et de la diode doivent être celles indiquées sur la figure.

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

2. — On ne devra mettre à la terre aucun autre point du circuit que celui indiqué sur la figure.

No other point of the circuit than the one indicated on the figure shall be earthed.

3. — A titre d'exemple, on a représenté sur cette figure des connexions en pointillé 1, 2 et 3 dans la position correspondant au réglage de la phase 3 en série avec les phases 1 et 2 montées en parallèle.

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. – Schéma d'une méthode de réglage du circuit de charge.
Scheme of a method of adjustment of the load circuit.