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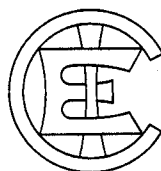
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Appareillage de commande à basse tension
Deuxième partie: Contacteurs à semi-conducteurs (contacteurs statiques)

Low-voltage controlgear
Part 2: Semiconductor contactors (solid state contactors)



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE CONTROLGEAR

Part 2: Semiconductor contactors (solid state contactors)

FOREWORD

- 1) The formal decisions or agreements of the IEC 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 international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 17B: Low-voltage Switchgear and Controlgear, of IEC Technical Committee No. 17: Switchgear and Controlgear.

A first draft was discussed at the meeting held in Moscow in 1977. A second draft was circulated to the National Committees, and replaced later on by a third draft circulated under the Accelerated Procedure in June 1978; as a result of which a fourth draft, Document 17B(Central Office)106, was submitted to the National Committees for approval under the Six Months' Rule in May 1979.

Amendments, Document 17B(Central Office)115, were submitted to the National Committees for approval under the Two Months' Procedure in March 1981.

The National Committees of the following countries voted explicitly in favour of publication:

Argentina	France	South Africa (Republic of)
Australia	German Democratic Republic	Spain
Austria	Germany	Sweden
Belgium	Hungary	Switzerland
Bulgaria	Israel	Turkey
China	Italy	Union of Soviet Socialist Republics
Denmark	Japan	United Kingdom
Egypt	Netherlands	United States of America
Finland	Romania	Yugoslavia

Other IEC publications quoted in this standard:

- Publications Nos. 60-2: High-voltage Test Techniques, Part 2: Test Procedures.
- 65: Safety Requirements for Mains Operated Electronic and Related Apparatus for Household and Similar General Use.
- 144: Degrees of Protection of Enclosures for Low-voltage Switchgear and Controlgear.
- 147-0: Essential Ratings and Characteristics of Semiconductor Devices and General Principles of Measuring Methods, Part 0: General and Terminology.
- 158-1: Low-voltage Controlgear, Part 1: Contactors. Including Supplements A and B.
- 664: Insulation Co-ordination within Low-voltage Systems including Clearances and Creepage Distances for Equipment.
- 664A: First Supplement.

LOW-VOLTAGE CONTROLGEAR

Part 2: Semiconductor contactors (solid state contactors)

1. General

1.1 Scope

This standard applies to semiconductor contactors intended for performing electrical operations by changing the state of electric circuits between on state and off state.

This standard is additional to IEC Publication 158-1: Low-voltage Controlgear, Part 1: Contactors (including Supplements A and B) which is applicable, provided it is not amended by this standard.

It applies only to semiconductor contactors, the main circuit of which is intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.

Notes 1. — Semiconductor contactors dealt with in this standard are not intended to provide short-circuit protection of the main circuit, but may contain short-circuit protective devices for semiconductor parts.

2. — Semiconductor motor-starters will be dealt with in a later publication.

This standard applies also to hybrid semiconductor contactors, which are also covered by the scope of IEC Publication 158-1 as concerns their electromagnetic part.

1.2 Object

See IEC Publication 158-1*.

2. Definitions

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

2.1 Definitions concerning contactors and semiconductor contactors

2.1.1 Semiconductor switching device

A switching device designed to make the current in an electric circuit by means of the controlled conductivity of a semiconductor.

Note. — In a circuit where the current passes through zero (alternately or otherwise), the effect of "not making" the current following such a zero value is equivalent to breaking the current.

2.1.2 Mechanical switching device

See IEC Publication 158-1.

* Whenever reference is made to IEC Publication 158-1, the clause with the same clause number applies, in some instances modified by the text which follows, it being understood that the word "contactor" shall be replaced by "semiconductor contactor".

2.1.3 *Controlgear*

See IEC Publication 158-1.

2.1.4 *Contactor (mechanical)*

See IEC Publication 158-1.

2.1.5 *Semiconductor* (Sub-clause 0-1.1 of IEC Publication 147-0*)

A material with resistivity usually in the range between metals and insulators, in which the electrical charge carrier concentration increases with increasing temperature over a certain temperature range.

2.1.6 *Semiconductor contactor*

A device which performs the function of a contactor by utilizing a semiconductor switching device.

Note. — A semiconductor contactor may also contain mechanical switching devices.

2.1.7 *Hybrid semiconductor contactor*

A device which performs the function of a contactor by utilizing a combination of semiconductor and mechanical devices with the switching duty performed by a semiconductor device while the current-carrying duty is taken care of by a mechanical device.

2.1.8 (Vacant)

2.1.9 (Vacant)

2.1.10 *Main circuit (of a semiconductor contactor)*

All the conductive parts of a semiconductor contactor included in the circuit it is designed to control.

2.1.11 *Pole of a contactor*

See IEC Publication 158-1.

2.1.12 (Vacant)

2.1.13 *Breaking current (of a semiconductor contactor)*

A general term used to designate the value of current in a pole of a semiconductor contactor:

- a) for a.c., the r.m.s. value of the current immediately before the change from the "on-state" to the "off-state";
- b) for d.c., the value of the current just before the turn-off is initiated.

* Essential Ratings and Characteristics of Semiconductor Devices and General Principles of Measuring Methods, Part 0: General and Terminology.

2.1.14 *Breaking capacity (of a semiconductor contactor)*

For a.c., the r.m.s. value of the maximum breaking current of a semiconductor contactor which will cease to flow when the control initiating the "on-state" is removed and for d.c., the maximum current that can be turned off when the "turn off" signal is applied and the "turn on" signal is removed, at a stated value of voltage under prescribed conditions of use and behaviour.

2.1.15 *Making capacity*

See IEC Publication 158-1.

2.1.16 *Recovery voltage*

See IEC Publication 158-1.

2.1.16.1 *Transient recovery voltage*

See IEC Publication 158-1.

2.1.16.2 *Power-frequency recovery voltage*

See IEC Publication 158-1.

2.1.17 *Short-time withstand current*

The current that a semiconductor contactor can carry in the on-state during a specified short-time under prescribed conditions of use and behaviour.

2.1.18 *Over-current*

See IEC Publication 158-1.

2.1.19 *Overload*

See IEC Publication 158-1.

2.1.20 *Conductive part*

See IEC Publication 158-1.

2.1.21 *Clearance*

See IEC Publication 158-1.

2.1.21.1 *Clearance between poles*

See IEC Publication 158-1.

2.1.21.2 *Clearance to earth*

See IEC Publication 158-1.

2.1.21.3 (Vacant)

2.1.22 *Creepage distance*

See IEC Publication 158-1.

2.1.23 *Exposed conductive part*

A conductive part which can be touched readily and which normally is not live, but which may become live under fault conditions.

Note. — Typical exposed conductive parts are walls of enclosures, operating handles, etc.

2.1.24 *Ambient air temperature*

See IEC Publication 158-1.

2.1.25 *Maximum on-state current for one-half a cycle*

The peak value of the current which a semiconductor contactor can carry in the on-state for half a cycle of the supply voltage without losing its ability to perform as intended.

2.1.26 *Off-state leakage current I_L*

The maximum current which flows through the main circuit of a semiconductor contactor in the off-state.

2.1.27 *Minimum load current*

The minimum operational current in the main circuit which is necessary for correct action of a semiconductor contactor in the on-state.

Note. — The minimum load current should be given as r.m.s. value.

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

2.2.1 *Inactive state*

The condition of a semiconductor contactor without any control signal.

2.2.2 *Control circuit (of a semiconductor contactor)*

All the conductive parts (conductors, resistors, capacitors, coils, diodes, etc.) of a semiconductor contactor intended to be included in a circuit (other than the main circuit) used to initiate the making and breaking operation of the semiconductor contactor.

2.2.3 (Vacant)

2.2.4 *Auxiliary circuit*

All the conductive parts (conductors, resistors, capacitors, contacts, diodes, etc.) of a semiconductor contactor intended to be included in a circuit other than the main circuit and the control circuits of the semiconductor contactor.

Note. — Some auxiliary circuits serve supplementary requirements such as signalling, interlocking, cooling, 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 semiconductor contactor and operated by the contactor.

2.2.6 (Vacant)

2.2.7 (Vacant)

2.2.8 *ON-state*

The condition of a semiconductor contactor when the conduction current can flow through its main circuit.

2.2.9 *OFF-state*

The condition of a semiconductor contactor when no control signal is applied and no current exceeding the OFF-state leakage current I_L flows through the main circuit.

Note. — Semiconductor contactors may not provide in the OFF-state a contact gap in the main circuit. Therefore, the main circuit on the load side shall be considered to be live.

2.2.10 *Operation (of a semiconductor contactor)*

The transition from the ON-state to the OFF-state or the reverse.

2.2.11 *Operating cycle (of a semiconductor contactor)*

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

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

2.2.12 *Making operation*

An operation by which the semiconductor contactor is brought from the OFF-state to the ON-state.

2.2.13 *Breaking operation*

An operation by which the semiconductor contactor is brought from the ON-state to the OFF-state.

3. **Classification**

3.1 (Vacant)

3.2 According to the cooling system, semiconductor contactors can be divided into different groups, for example natural cooling, forced air cooling, liquid cooling. The cooling system is considered as a part of the device.

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 Controlgear.

4. **Characteristics of semiconductor contactors**4.1 *Summary of characteristics*

See IEC Publication 158-1.

4.2 *Type of semiconductor contactor*

The following shall be stated:

4.2.1 *Number of poles*

4.2.2 *Kind of current*

See IEC Publication 158-1.

4.2.3 (Vacant)

4.2.4 (Vacant)

4.3 *Rated values*

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

4.3.1 *Rated voltages*

A semiconductor contactor is defined by the following rated voltages:

4.3.1.1 *Rated operational voltages*

See IEC Publication 158-1.

4.3.1.2 *Rated insulation voltage*

See IEC Publication 158-1.

4.3.2 *Rated currents*

A semiconductor contactor is defined by the following rated currents:

4.3.2.1 *Rated conventional thermal current*

See IEC Publication 158-1B.

4.3.2.2 *Rated enclosed thermal current*

See IEC Publication 158-1B.

4.3.2.3 *Rated operational currents or rated operational powers*

See IEC Publication 158-1B.

4.3.3 *Rated frequency*

See IEC Publication 158-1.

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 semiconductor contactor remains in the on-state while carrying a steady current long enough to reach thermal equilibrium but for not more than 8 h without interruption.

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

4.3.4.2 *Uninterrupted duty*

Duty in which the semiconductor contactor remains in the on-state while carrying a steady current without interruption for periods of more than 8 h (weeks, months or even years).

Note. — For semiconductor contactors, the difference between uninterrupted duty and 8 h duty may be negligible. Uninterrupted duty can be taken account of either by a derating factor, or by special design considerations.

4.3.4.3 *Intermittent periodic duty or intermittent duty*

Duty in which the semiconductor contactor remains in the on-state for periods bearing a definite relation to the no-load periods, both periods being too short to allow the semiconductor contactor to reach a thermal equilibrium.

Intermittent duty is characterized by the actual values of current during the on-load time period, the duration of the current flow and 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 every 10 min may be stated as: "intermittent duty 100 A, 4 min/10 min" or "intermittent duty 100 A, six operating cycles per hour, 40%".

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

Note. — If this duty is applied with a variable on-load factor in order to vary the effective value of a quantity controlled by the semiconductor contactor (e.g. the temperature of an oven), it is also called "multicycle control" (see IEC standards for thyristor a.c. power controllers) (under consideration), and is not covered by this standard.

Classes of intermittent duty

According to the number of operating cycles (see Sub-clause 2.2.11) which they shall be capable of carrying out per hour, semiconductor 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;
- Class 30: up to 3 000 operating cycles per hour;
- Class 100: up to 12 000 operating cycles per hour;
- Class 300: up to 30 000 operating cycles per hour;
- Class 1 000: up to 120 000 operating cycles per hour;
- Class 3 000: up to 300 000 operating cycles per hour.

For intermittent duty with a large number of operating cycles per hour, the manufacturer shall indicate the values of the rated operational currents, either in terms of the true cycle if this

is known, or in terms of conventional cycles designated by him, or in the form of a load diagram.

Note. — Appendix E shows the preferred method of presenting a load diagram.

4.3.4.4 *Temporary duty*

Duty in which the semiconductor contactor remains in the on-state for periods of time insufficient to allow the semiconductor 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.

4.3.5 *Making and breaking capacities*

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

4.3.5.1 *Rated making capacity*

The rated making capacity of a semiconductor contactor is a value of current determined under steady-state conditions which the semiconductor contactor can make without undue change of its relevant characteristics, under specified making conditions.

The making conditions which shall be specified are:

- the voltage between poles before the making operation;
- 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.

Notes 1. — For a.c., the peak value of the current during the first half-cycles following closing of the semiconductor 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 semiconductor contactor shall be capable of making 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.

2. — In performing the test, the value of di/dt specified by the manufacturer should not be exceeded.

The rated making capacity is only valid when the semiconductor contactor is operated in accordance with the requirements of Sub-clause 7.5.

4.3.5.2 *Rated breaking capacity*

The rated breaking capacity of a semiconductor contactor is a value of current which the semiconductor contactor can break without undue change of its characteristics, 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 semiconductor contactor shall be capable of breaking any value of the load current up to its highest rated breaking capacity according to Sub-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.

This rating applies when the starting temperature of the semiconductor contactor is at the thermal equilibrium temperature corresponding to the rated operational current, at the maximum ambient temperature specified in Sub-clause 6.1.1.

4.3.5.3 Ability to withstand overload currents

See IEC Publication 158-1B.

4.3.6 Utilization category

See IEC Publication 158-1.

TABLE I
Utilization category

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

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 semiconductor contactors to the switching of capacitors, tungsten filament lamps, or d.c. circuits, with very low inductance should be subject to special agreement between manufacturer and user.

4.3.7 (Vacant)

4.3.8 Endurance

A semiconductor contactor is characterized by the number of on-load operating cycles, corresponding to the service conditions given in Table III, at a stated frequency of operation and on-load factor, which can be made without repair or replacement and also without failure or change in its relevant operating characteristics.

TABLE II

*Verification of rated making and breaking capacities (see Sub-clause 8.2.4)
Conditions for making and breaking corresponding to the several utilization categories ¹⁾*

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

I_e = rated operational current (see Sub-clause 4.3.2.3)
 U_e = rated operational voltage (see Sub-clause 4.3.1.1)
 I = test current
 U = voltage before make (approximately equal to recovery voltage U_r)
 U_r = recovery voltage

¹⁾ For 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 Sub-clause 4.3.5.1, Note 1).
²⁾ Tolerance for $\cos \varphi$: ± 0.05 .
³⁾ With a minimum of 1 000 A for I or I_e .
⁴⁾ (Vacant).
⁵⁾ With a minimum of 1 200 A for I .
⁶⁾ Tolerance for L/R : $\pm 15\%$.

The manufacturer shall state the number of on-load operating cycles; however, due to the physical properties of semiconductor contactors and of their control circuits, this value may be given as a guide instead of a single figure, for example "Endurance in excess of 20 million operating cycles".

4.3.9 Ability to withstand external electrical influences

The operation and endurance of semiconductor contactors can be influenced by electrical transients in both the control and main circuits.

The influencing factors may be classified as either destructive or non-destructive. The destructive transient (voltage or current) causes irreversible damage to the semiconductor

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	Test conditions		
			I/I_e	U/U_e	$\cos \varphi$ ²⁾
A.C.	AC-1	(All values)	1	1	0.95
	AC-2	(All values)	2.5	1	0.65
	AC-3	$I_e \leq 17 \text{ A}$	6	1	0.65
	{	$I_e > 17 \text{ A}$	6	1	0.35
		$I_e \leq 17 \text{ A}$	6	1	0.65
		$I_e > 17 \text{ A}$	6	1	0.35
D.C.	DC-1	(All values)	1	1	1
	DC-2	(All values)	2.5	1	2
	DC-3	(All values)	2.5	1	2
	DC-4	(All values)	2.5	1	7.5
	DC-5	(All values)	2.5	1	7.5
	I_e = rated operational current (see Sub-clause 4.3.2.3) U_e = rated operational voltage (see Sub-clause 4.3.1.1) I = test current U = voltage before make U_r = recovery voltage ¹⁾ For 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 Sub-clause 4.3.5.1, Note 1). ²⁾ Tolerance for $\cos \varphi$: ± 0.05 . ³⁾ Tolerance for L/R : $\pm 15\%$.				

contactor. The non-destructive transient voltage may cause a malfunction with the contactor returning to normal operation after the transient has occurred.

Susceptibility of the contactor to transient voltages depends upon the peak value of the transient, the wave-shape front time and duration, its energy content and the mode of coupling.

Since the semiconductor contactor contains both active and passive elements, it has complex susceptibility to transient influences. It has been found practicable therefore to determine the withstandability of semiconductor contactors to electrical transients found in industrial control environments by subjecting the contactors to type tests according to Sub-clause 8.2.9.

In locations where transient overvoltages of greater magnitude or duration than those foreseen in the tests of Sub-clause 8.2.9 may occur, it is the responsibility of the user to provide additional surge protection.

Note. — The type tests, according to Sub-clause 8.2.9, are intended to determine the ability of the semiconductor contactor to withstand external electrical influences. However, when installing the semiconductor contactor, precautions should be taken to minimize transient external influences in the external control circuits. For example, control circuits should be kept separated from main circuits. Where close coupling with other control circuits is anticipated, twisted pairs or shielded control circuit conductors should be used.

4.4 Control circuits

The characteristics of control circuits are:

- 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.).

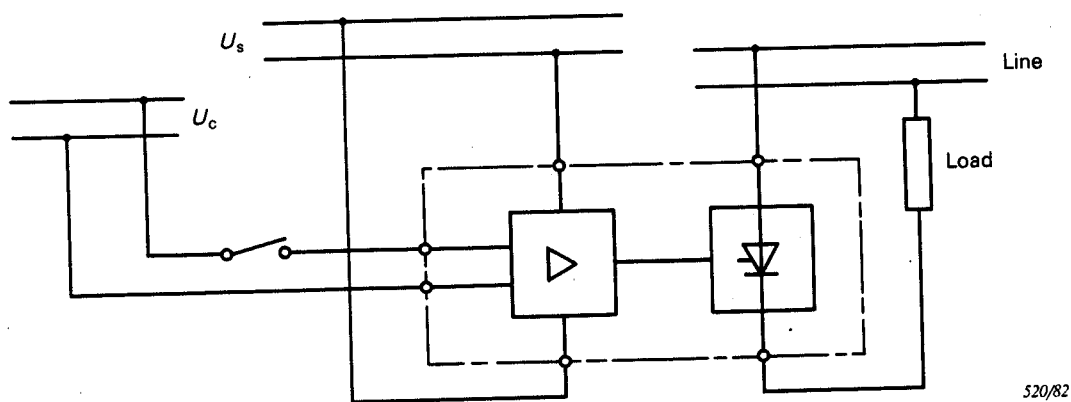
Notes 1. — A distinction has been made above between the control circuit voltage, which is the voltage which would appear across the open control input terminals or which should be applied to the control input terminals for carrying out the control function, and the control supply voltage, which is the voltage applied to the supply terminals of the control circuits of the semiconductor contactor and may be different from the control circuit voltage, due to the presence of built-in transformers, rectifiers, resistors, etc.

2. — The source of control voltage may be internal or external.

The rated control circuit voltage and rated frequency, if any, are the values on which the insulation characteristics of the control circuits 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 supply 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 .

Figures 1 and 2 show the meaning of U_c and U_s .



U_s = external control supply voltage (if any)
 U_c = external control circuit voltage

FIGURE 1



FIGURE 2

TABLE IV

Preferred values of the rated control circuit voltage (U_c) and of the rated control supply voltage (U_s) 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

Under consideration.

Note. — Co-ordination of semiconductor contactors with short-circuit protective devices requires special consideration. Such consideration should include the protection required to limit the short-circuit current to not more than the non-recurring half-cycle surge current rating of the semiconductor contactor or the minimum rupture (case damage) rating of the semiconductor contactor.

5. Nameplates

Each semiconductor 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 semiconductor contactor is installed:

- a) the manufacturer's name or trade mark;
- b) type designation or serial number;
- c) rated operational voltages (see Sub-clause 4.3.1.1);
- d) utilization category and rated operational currents (or rated powers), at the rated operational voltages of the semiconductor contactor (see Sub-clause 4.3.2.3);
- e) either value of the rated frequency, e.g. ~50 Hz or the indication "d.c." (or the symbol ---);
- f) if different from U_c , 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 semiconductor contactor nameplate:

- g) rated insulation voltage (see Sub-clause 4.3.1.2);
- h) rated conventional thermal current (see Sub-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 Sub-clause 4.3.4);
- k) rated control circuit voltage (U_c) (nature and frequency if a.c.);
- l) maximum off-state leakage current in the main circuit at rated voltage and rated frequency;
- m) recommended short-circuit protective device (SCPD);
- n) information concerning power losses and cooling system;
- o) minimum load current (see Sub-clause 2.1.27).

Note. — If the available space on the nameplate is insufficient to carry all the above data, the semiconductor contactor should carry at least the information under Items 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

Semiconductor contactors complying with this standard 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

See IEC Publication 158-1.

6.1.2 Altitude

See IEC Publication 158-1.

6.1.3 *Atmospheric conditions*

See IEC Publication 158-1.

6.1.4 *Conditions of installation*

The semiconductor contactor is installed in accordance with the manufacturer's instructions.

Where an isolating distance is required in the main circuit, this shall be provided by a separate switching device (see Sub-clause 2.2.9).

7. **Standard conditions for construction**

7.1 *Mechanical design*

7.1.1 *General*

See IEC Publication 158-1.

7.1.2 *Clearances and creepage distances*

Under consideration. See also IEC Publications 664* and 664A**.

7.1.3 *Terminals*

See IEC Publication 158-1.

7.1.3.1 *Arrangement of terminals*

See IEC Publication 158-1.

7.1.3.2 *Earth terminal*

See IEC Publication 158-1.

7.2 *Enclosures*

7.2.1 *Degrees of protection of enclosures*

See IEC Publication 158-1.

7.2.2 *Mechanical details*

See IEC Publication 158-1.

7.2.3 *Insulation*

See IEC Publication 158-1.

7.3 *Temperature rise*

7.3.1 *Results to be obtained*

See IEC Publication 158-1.

7.3.2 *Ambient air temperature*

See IEC Publication 158-1.

* Insulation co-ordination within low-voltage systems including clearances and creepage distances for equipment.

** First supplement.

TABLE IV

Temperature-rise limits for the various materials and parts

Type of material Description of part	Temperature- rise limit (measured by thermocouple) (K)
Contact parts in air (main, control and auxiliary contacts):	
— copper { uninterrupted duty	45
{ eight-hour, intermittent, or temporary duty	65
— silver or silver-faced	1)
— all other metals or sintered metals	2)
Contact parts in oil	65
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
Terminals for external insulated connections	70 ⁵⁾
Manual operating means:	
— parts of metal	15
— parts of insulating material	25
Electronic components	7)
<p>1) Limited solely by the necessity of not causing any damage to adjacent parts.</p> <p>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.</p> <p>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.</p> <p>4) Limited solely by the necessity of not causing any damage to insulating materials.</p> <p>5) The temperature-rise limit of 70 K is a value based on the conventional test of Sub-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.</p> <p>6) (Vacant).</p> <p>7) See IEC Publication 65: Safety Requirements for Mains Operated Electronic and Related Apparatus for Household and Similar General Use.</p>	

7.3.3 Main circuit

See IEC Publication 158-1.

7.3.4 Electronic components in main and control circuits

With current flowing through the main circuit according to the 8 h duty as well as in the off-state, the surface temperatures of electronic components shall not exceed under continuous load and at rated frequency, if applicable, the limiting values referred to in Table IV.

Note. — Sub-clause 7.3.4 of IEC Publication 158-1 applies to the electromagnetic device of hybrid contactors.

7.3.5 *Auxiliary circuits*

See IEC Publication 158-1.

7.4 *Dielectric properties*

See IEC Publication 158-1.

Note. — The semiconductors should be short-circuited during the test to prevent damage.
Line-to-load voltages are limited to the ratings specified for the semiconductors.

7.5 *Limiting values of operation*

Unless otherwise stated, semiconductor contactors shall operate with any control supply voltage between 85% and 110% of its rated value U_s at an ambient air temperature between $-5\text{ }^{\circ}\text{C}$ and $+40\text{ }^{\circ}\text{C}$. These limits apply to d.c. or a.c. as the case may be.

The semiconductor contactor shall not operate at control supply voltages lower than 30% of the rated control supply voltage U_s .

These values specified above are applicable when the control circuit of the contactor is cold or at any temperature up to the maximum attained under the rated duties, at maximum rated main and control circuit voltages.

The limiting values of operation of the mechanical parts of a hybrid semiconductor contactor (see note of Sub-clause 2.1.6) are given in IEC Publication 158-1.

8. *Tests*

See IEC Publication 158-1.

8.1 *Verification of the characteristics of semiconductor contactors*

See IEC Publication 158-1.

8.1.1 *Type tests*

They comprise:

- a) verification of temperature-rise limits (see Sub-clause 8.2.2);
- b) verification of dielectric properties (see Sub-clause 8.2.3);
- c) verification of rated making and breaking capacities (see Sub-clause 8.2.4);
- d) (vacant);
- e) verification of operating limits (see Sub-clause 8.2.6);
- f) (vacant);
- g) verification of ability to withstand overload currents (see Sub-clause 8.2.8);
- h) verification of ability to withstand external electrical influences (see Sub-clause 8.2.9).

8.1.2 *Routine tests*

See IEC Publication 158-1.

8.1.3 *Special tests*

These are tests subjected to agreement between manufacturer and user.

They may include the verification of endurance (see Sub-clause 8.4.1).

8.2 *Type tests*

8.2.1 *General*

See IEC Publication 158-1.

8.2.2 *Verification of temperature-rise limits*

8.2.2.1 *Ambient air temperature*

See IEC Publication 158-1B.

8.2.2.2 *Temperature-rise tests of the main circuit*

See IEC Publication 158-1B, except Item *b*) (for all values of test current), which is to be amended as follows:

“In the case of a multipole semiconductor contactor, the test is carried out with a current having the same number of phases as the contactor, all poles being connected as in normal service conditions.”

8.2.2.3 *Temperature-rise tests of control circuits*

The control circuits shall be tested according to the conditions given in Sub-clause 7.3.4, with the specified kind of supply current and at their rated voltage in the on-state as well as in the off-state.

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

Control circuits 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 K per hour.

At the end of these tests, the temperature rise of the different parts of the control circuits shall not exceed the values specified in Tables V and VI of IEC Publication 158-1.

8.2.2.4 *Temperature-rise tests of auxiliary circuits*

See IEC Publication 158-1.

8.2.2.5 *Measurement of the temperature of parts*

See IEC Publication 158-1.

8.2.2.6 *Temperature rise of a part*

See IEC Publication 158-1.

8.2.2.7 *Corrections*

See IEC Publication 158-1.

8.2.3 *Verification of dielectric properties*

8.2.3.1 *Condition of the contactor for tests*

See IEC Publication 158-1.

8.2.3.2 *Application of the test voltage*

Note. — Concerning the procedure to be followed, guidance will be found in IEC Publication 60-2: High-voltage Test Techniques, Part 2: Test Procedures and, in particular, in Sub-clause 5.1: Rated withstand voltage tests, the first paragraph of which reads as follows:

"The voltage should be applied to the test object starting at a value sufficiently low to prevent any effect of overvoltage due to switching transients. It should be raised sufficiently slowly to permit accurate reading of the instruments, but not so slowly as to cause unnecessary prolongation of stressing of the test object near to the test voltage. These requirements are in general met if the rate of rise above 75% of the estimated final voltage is about 2% per second of this voltage. It should be maintained for the specified time and then reduced. The requirements of the test are generally satisfied if no disruptive discharge occurs on the test object."

8.2.3.2a) *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:

- 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.

8.2.3.2b) *Control and auxiliary circuits*

See IEC Publication 158-1.

Note. — A connection of control and auxiliary circuits to earth may be removed for the test.

8.2.3.3 *Value of the test voltage*

Under consideration.

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.

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 standard 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 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 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.

Immediately prior to the test, the contactor shall be conditioned by passing through it the rated operational current until thermal equilibrium is reached, at the maximum ambient temperature.

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

See IEC Publication 158-1.

8.2.4.4 *Test procedure*

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

The test shall be made with the initial temperature of the semiconductor contactor within $\pm 2^\circ\text{C}$ of the maximum ambient air temperature (see Sub-clause 7.5) and at 110% of the rated control supply voltage.

The number of operating cycles to be performed is 50.

The time interval between a breaking operation and the making operation immediately following it shall be 10 ± 1 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 50% of the time of the cycle corresponding to the class of intermittent duty with a maximum of 0.5 s.

8.2.4.5 (Vacant)

8.2.4.6 *Condition of the contactor after making and breaking tests*

After tests within the limits of specified making and breaking capacities and with the specified number of operating cycles, the contactor shall be capable of operating within the limits specified in Sub-clause 7.5.

Furthermore, the off-state leakage current shall not exceed the maximum stated value (see Clause 5, Item 1).

8.2.5 (Vacant)

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 operates satisfactorily within the voltage and temperature limits specified in Sub-clause 7.5.

8.2.7 (Vacant)

8.2.8 *Verification of ability to withstand overload currents*

Under consideration.

8.2.9 *Verification of ability to withstand external electrical influences*

Note. — All tests defined in this sub-clause have been experienced for several years; they have shown that they are adequate for ensuring appropriate operation of semiconductor devices.

Further development is dealt with in different technical bodies of the IEC; the result of such work will be taken into account at a later stage.

8.2.9.1 *General*

The tests shall be performed at an ambient air temperature of $+40^{\circ}\text{C}$ and at the rated value of control supply voltage and main circuit operational voltage. Two types of simulated external electrical influences shall be coupled into the circuit of the semiconductor contactor in accordance with test circuits described in Sub-clause 8.2.9.3.

Test 1 simulates external influences due to showering arcs. This is a disturbance which is caused by interruption of inductive circuits by electrical contacts.

Test 2 simulates external influences due to surge voltage and is applied to the main circuit only. This is a power line disturbance which might result from switching or lightning surges.

8.2.9.2 *Test apparatus and circuits*

8.2.9.2a) *Test 1: Showering arc test*

For test apparatus and circuits, see Appendix F.

8.2.9.2b) *Test 2: Surge voltage test*

The test may be conducted, for example, with the test apparatus shown in Figure 6, page 61.

A transient surge voltage generator shall set transients across the semiconductor contactor. The amplitude of the transients shall be equal to 1.4 times the peak line voltage and the frequency of the transients shall be about 5 kHz.

The transients should be applied in a random manner as regards power frequency, with the following operating times of the contactor:

- a) open: six cycles minimum;
- b) closed: 0.25 cycle minimum.

The interval between two transients shall not be synchronized with the frequency of the line voltage, in order that, during the test duration of 1 min, transients be set at about each point of the whole period (see Figure 6). There shall be no malfunction either to turn "ON" or "OFF" when subjected to the test.

8.2.9.3 *Test procedures*

8.2.9.3a) *Test 1: Showering arc test*

The test is to be conducted with the test apparatus described in Appendix F. The wires in the cable assembly which are used to couple the electrical noise into the semiconductor contactor are determined by the calibration test described in Appendix F.

The coupling into the circuit of the semiconductor contactor is made in three separate tests, the power circuit shown in Figure 3, page 55, the control input circuit shown in Figure 4, page 57, and, where a separate control voltage is used, in the circuit shown in Figure 5, page 59.

The semiconductor contactor shall be connected to its rated voltage source through a load resistor of a value to provide 1 A load current when the contactor is in the on-state. Indicating means shall be connected across the load resistor.

For the above test, the noise generator shall be set by means of the spark gap to provide a test generator output transient voltage of 2 000 V (Appendix F, Figures F1 and F4, pages 75 and 79).

During the test, the semiconductor contactor shall be operated successively in the on-state and off-state at regular intervals, at least ten times.

There shall be no malfunction either to turn "ON" or to turn "OFF" as indicated by the indicator. The minimum duration of the test shall be 10 s.

8.2.9.3b) *Test 2: Surge voltage test*

The test may be conducted with the test apparatus connected as in Figure 6, page 61, and detailed as shown in Figure 7, page 63. A transient surge voltage generator is connected to the main lines at terminals LINE 1 and LINE 2 to the semiconductor contactor test circuit at terminals LOAD 1 and LOAD 2, and to a variable transformer at terminals VAR 1 and VAR 2.

The direct output of the transient generator is monitored by oscilloscope V through probe P as shown in Figure 6.

The coupling into the circuit of the semiconductor contactor is made in the power circuit only, e.g. as shown in Figure 6.

The semiconductor contactor shall be connected to its rated voltage source through a load resistor of a value to provide 1 A load current when the contactor is in the on-state. Indicating means shall be connected across this load resistor.

For the above tests, the transient generator shall be set by means of the variable transformer to produce transients the amplitude of which is 1.4 times the peak line voltage.

The above tests shall be made with the contactor successively in the on-state and the off-state and at both positions of the polarity switch. There shall be no malfunction either to turn "ON" or turn "OFF" when subject to transients of either polarity as indicated by the indicator. Duration of each test shall be 1 min minimum.

8.3 *Routine tests*

8.3.1 *General*

See IEC Publication 158-1.

8.3.2 *Operating tests*

For semiconductor contactors, tests are carried out to verify operation within the limits specified in Sub-clause 7.5, with a load current equal to its minimum value (see Sub-clause 2.1.27).

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 Sub-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 terminals of each pole connected together;
- b) between poles and the frame of the contactor with the terminals of each pole connected together;
- c) to the control and auxiliary circuits, as mentioned in Sub-clause 8.2.3.2b).

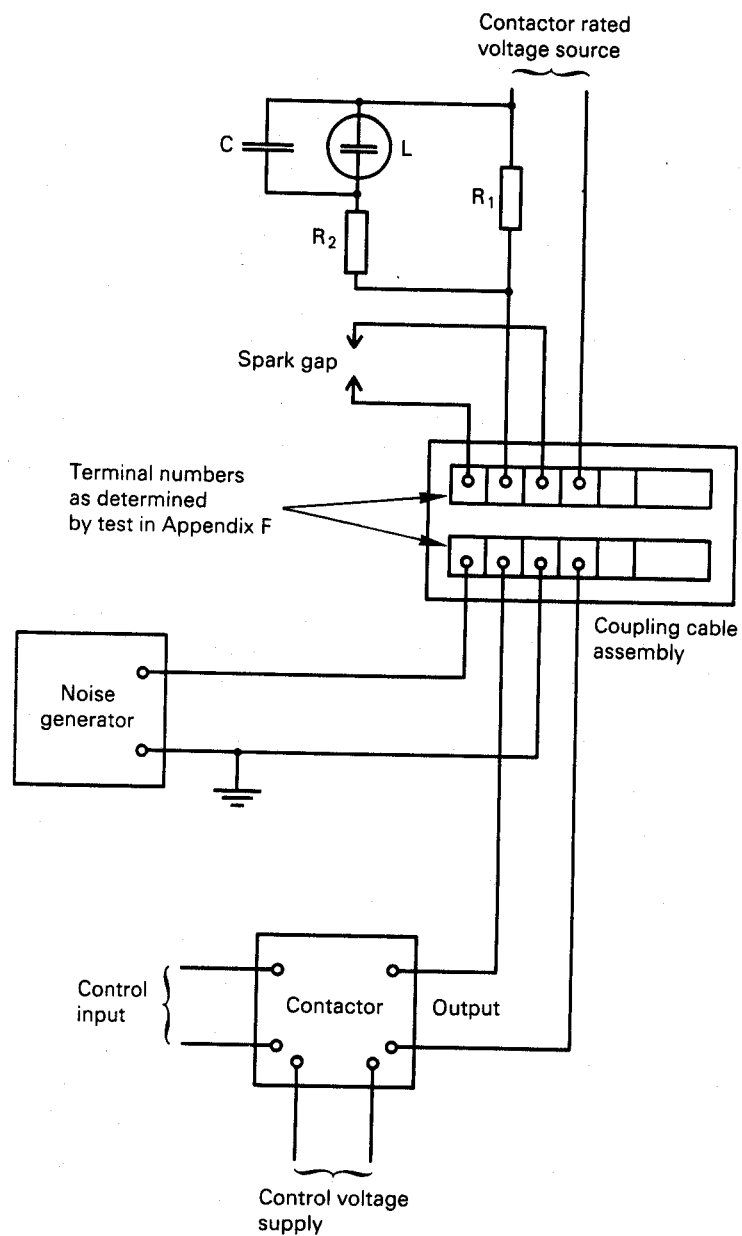
8.4 *Special tests*

8.4.1 *Verification of 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 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 endurance when tested as below.

The currents to be obtained shall be as given in Table III (see Sub-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. The test circuit shall be arranged in accordance with Appendix D. The speed of operation shall be chosen by the manufacturer.

After the test, the contactor shall fulfil the operating conditions specified in Sub-clause 8.2.6, and withstand the dielectric test voltages of Sub-clause 8.2.3.3.

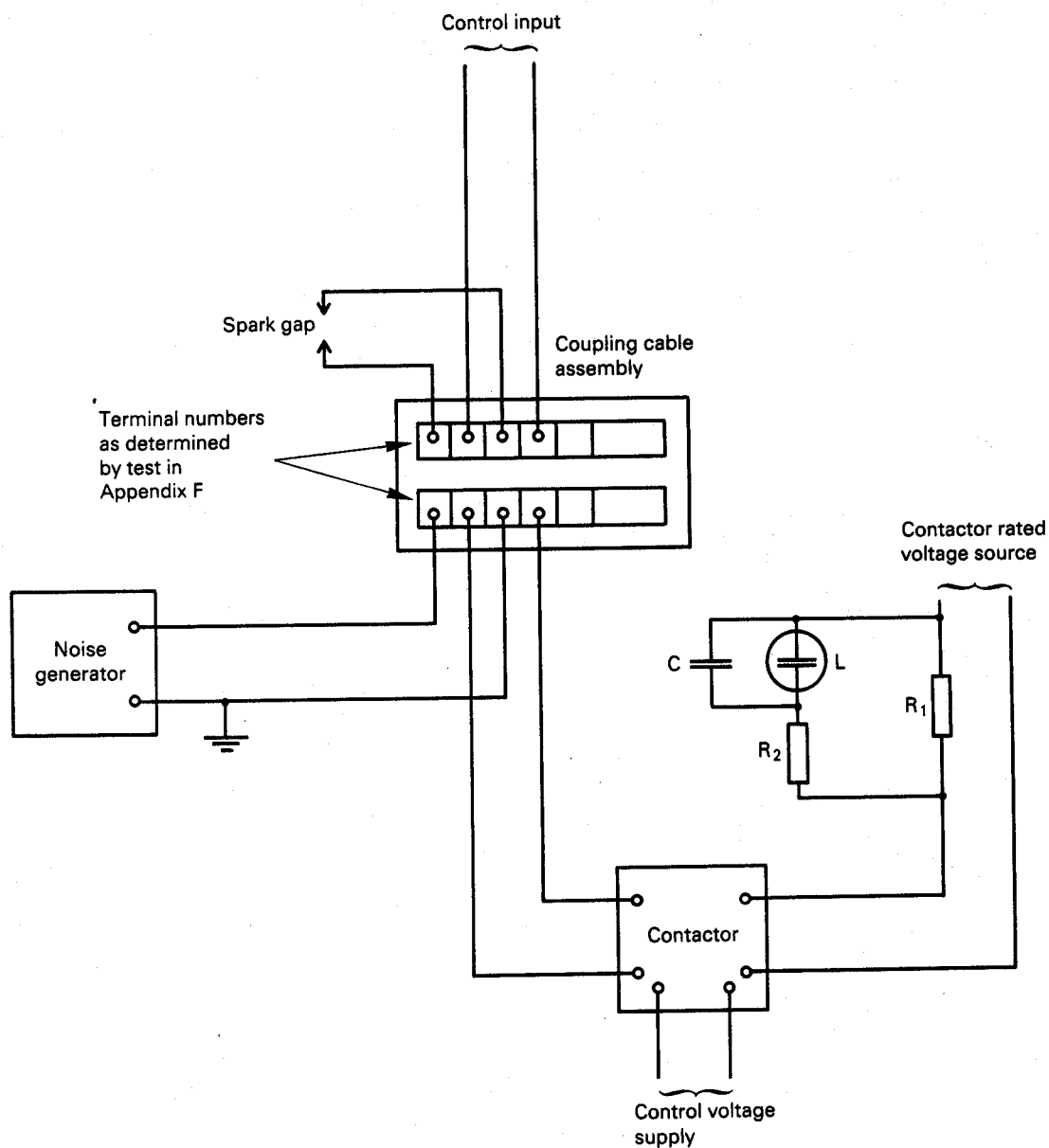


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R_1 = resistance and power rating to allow 1 A load current
 R_2 = neon lamp protecting resistor
 L = indicator
 C = $68 \pm 20\%$ pF 1 kV ceramic capacitor

Note. — Provide grounding in accordance with manufacturer's specifications.

FIG. 3. — Showering arc test on output circuit.

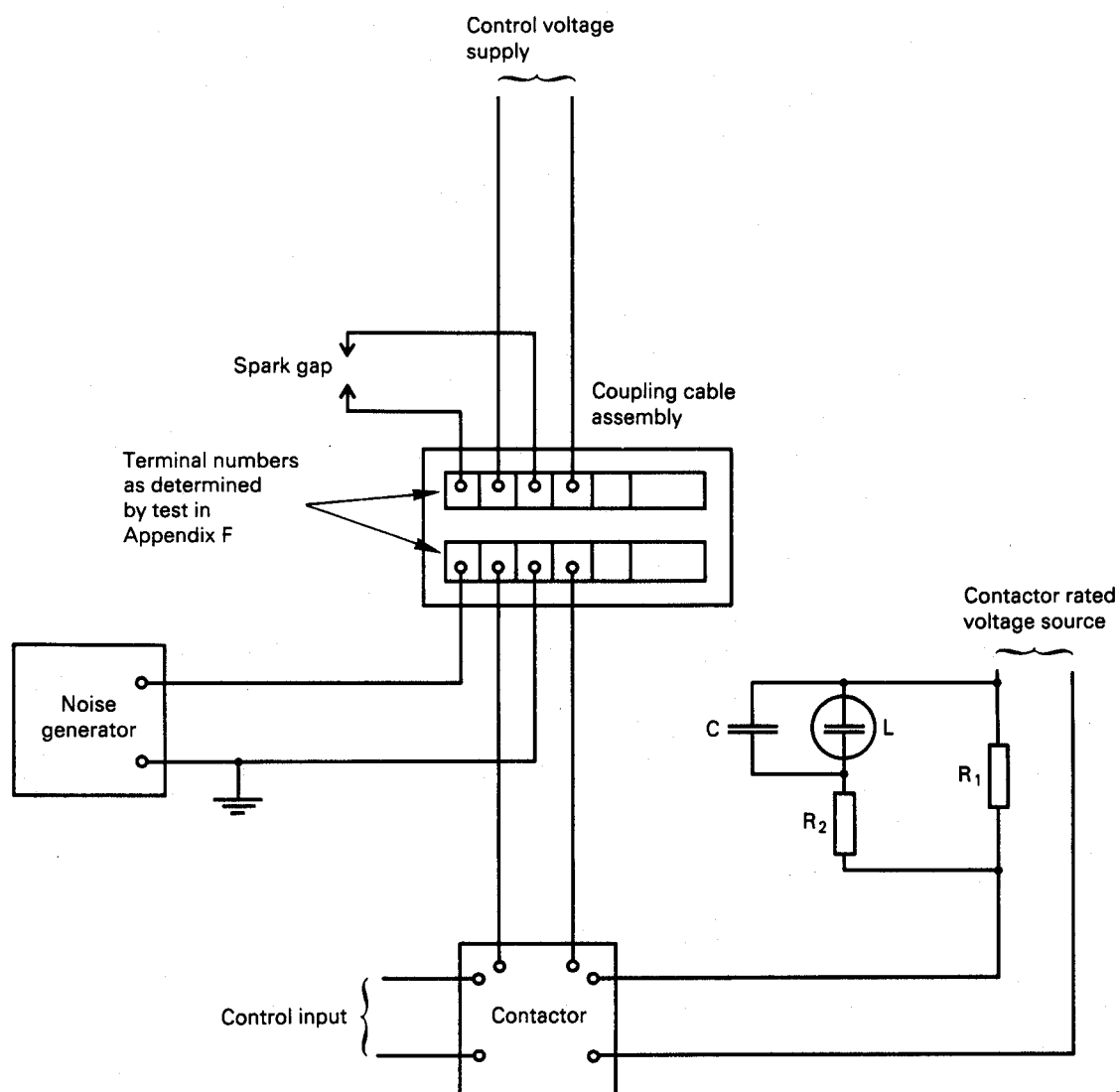


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- R₁ = resistance and power rating to allow 1 A load current
 R₂ = neon lamp protecting resistor
 L = indicator
 C = 68 ± 20% pF 1 kV ceramic capacitor

Note. — Provide grounding in accordance with manufacturer's specifications.

FIG. 4. — Showering arc test on control input circuit.

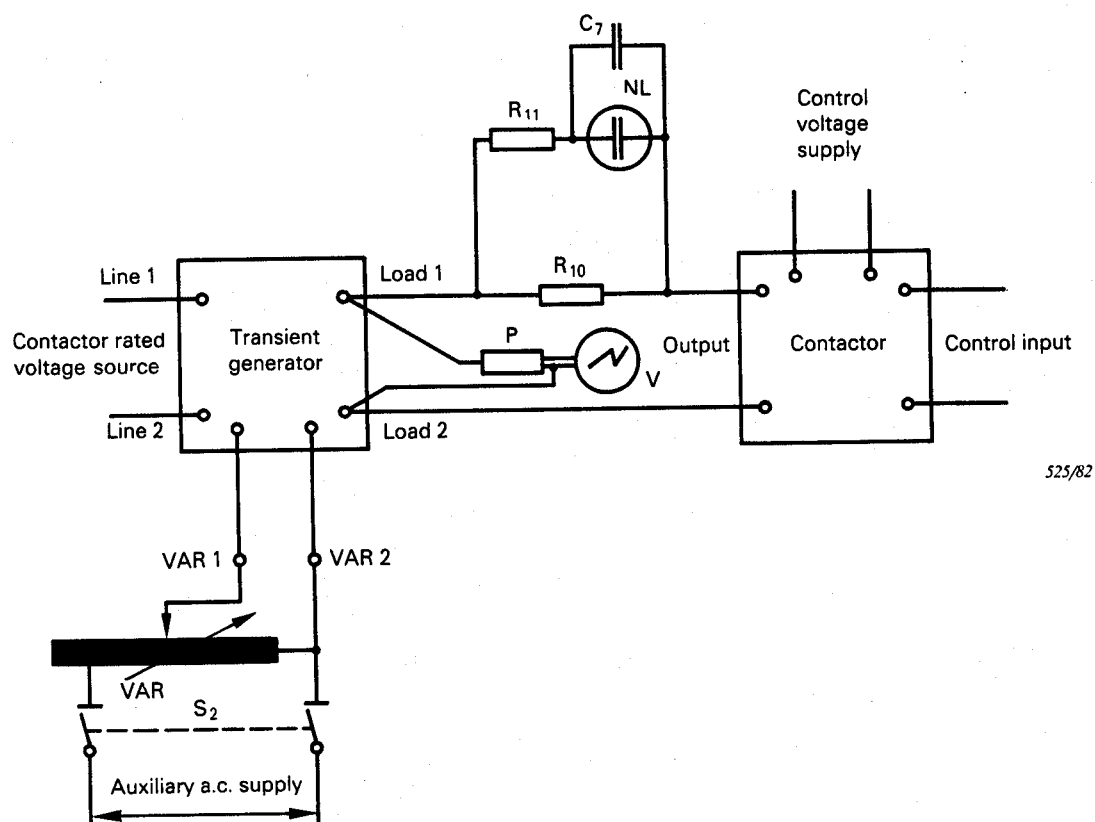


524/82

- R_1 = resistance and power rating to allow 1 A load current
 R_2 = neon lamp protecting resistor
 L = indicator
 C = $68 \pm 20\%$ pF 1 kV ceramic capacitor

Note. — Provide grounding in accordance with manufacturer's specifications.

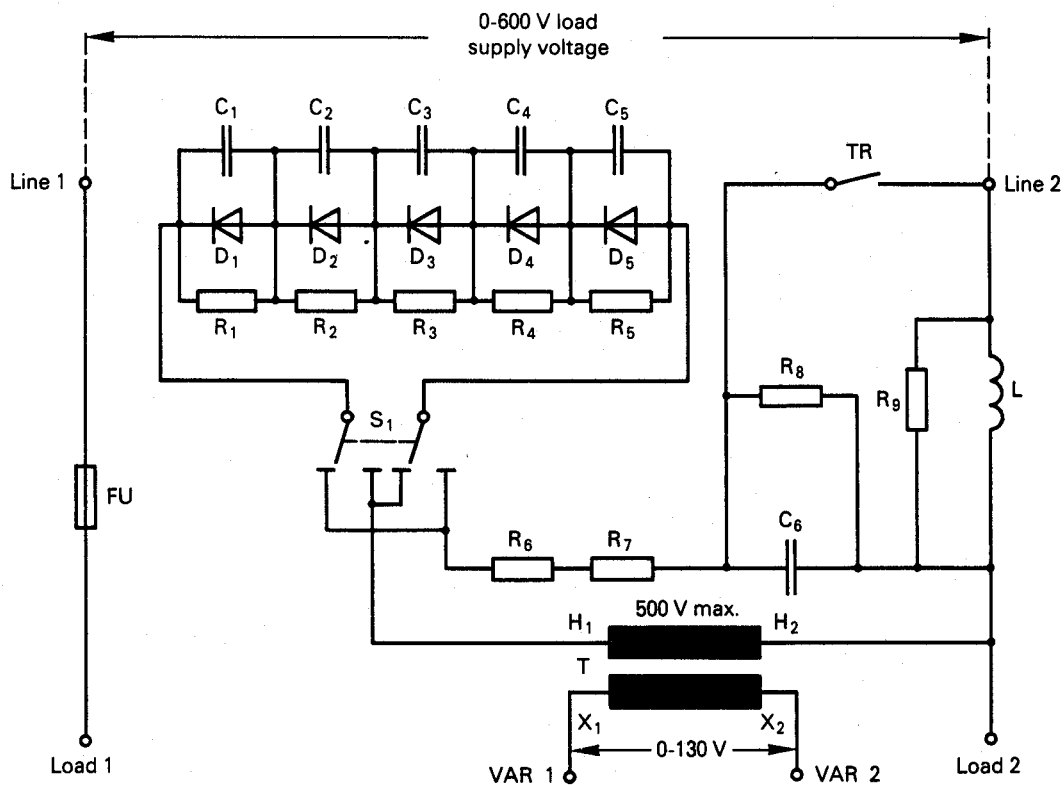
FIG. 5. — Showering arc test on control voltage supply.



- R_{10} = resistance and power rating to allow 1 A load current
 R_{11} = indicator protecting resistor
 NL = indicator
 C_7 = $68 \pm 20\%$ pF 1 kV ceramic capacitor
 P = 2 kV oscilloscope probe
 V = oscilloscope (100 kHz or greater upper bandwidth limit)

VAR = VARIAC

FIG. 6. — Surge voltage test on output circuit.



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- T = transformer 300 VA to 500 V primary, 110 V secondary
 C₁ to C₅ = ceramic capacitor 0.0047 μ F, 500 V d.c.
 C₆ = oil-filled capacitor 8.0 μ F, 440 V a.c.
 D₁ to D₅ = silicon rectifier 0.5 A, 400 V
 R₁ to R₅ = 330 k Ω , 1 W resistor
 R₆, R₇ = 500 Ω , 135 W wirewound resistor
 R₈ = 100 k Ω , 1 W resistor
 R₉ = 35 Ω , 10 W wirewound resistor
 L = air core inductor, 54 turns, 6 mm² copper wire, 125 μ H, approximately 0.03 Ω
 S₁ = DPDT switch
 FU = fuse 20 A, 600 V
 V = oscilloscope (100 kHz or greater upper bandwidth limit)
 P = 2 kV oscilloscope probe
 TR = contact — random operation with respect to line frequency — operating time: open — six cycles minimum, closed — one-quarter cycle minimum

FIG. 7. — Electrical transient generator schematic diagram and parts list.

APPENDIX A

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

See IEC Publication 158-1.

APPENDIX B

CLEARANCES AND CREEPAGE DISTANCES FOR LOW-VOLTAGE CONTACTORS

(Under consideration)

APPENDIX C

PROTECTION OF A CONTACTOR BY A SHORT-CIRCUIT PROTECTIVE DEVICE

(Under consideration)

APPENDIX D

CONVENTIONAL TEST CIRCUIT FOR THE VERIFICATION OF RATED MAKING
AND BREAKING CAPACITIES OF CONTACTORS

See IEC Publication 158-1.

APPENDIX E

METHOD OF PRESENTING A LOAD DIAGRAM

(See Sub-clause 4.3.4.3)

The temperature rise of a semiconductor contactor for intermittent duty depends on the current as well as on the associated time intervals. In order to give to the user an information which is easy to survey, load diagrams are suitable means.

Figure E1, page 69, shows a method of presenting such a load diagram. The straight lines are based on simplifying approximations, particularly in short time ratings.

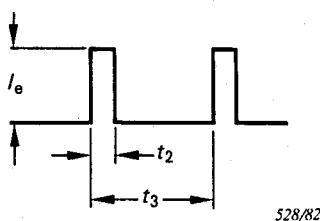
Load ratings may also be expressed in tables that specify the influencing parameters.

Assuming that the values of Figure E1 refer to a contactor the rated thermal current I_{th} of which is 3 A at an ambient air temperature of +35 °C, the utilization of this load diagram may be illustrated by the following two examples:

Note. — The diagram described, like the rated thermal current, applies to a certain value of ambient air temperature (+35 °C in the given example). If the contactor is utilized at another ambient air temperature, the values deduced shall be corrected accordingly.

Example 1: Determination of the maximum admissible operating frequency

A load with a rated operational current $I_e = 5.5$ A is to be switched with a duration of current flow $t_2 = 1$ s. What is the maximum admissible operating frequency n ?

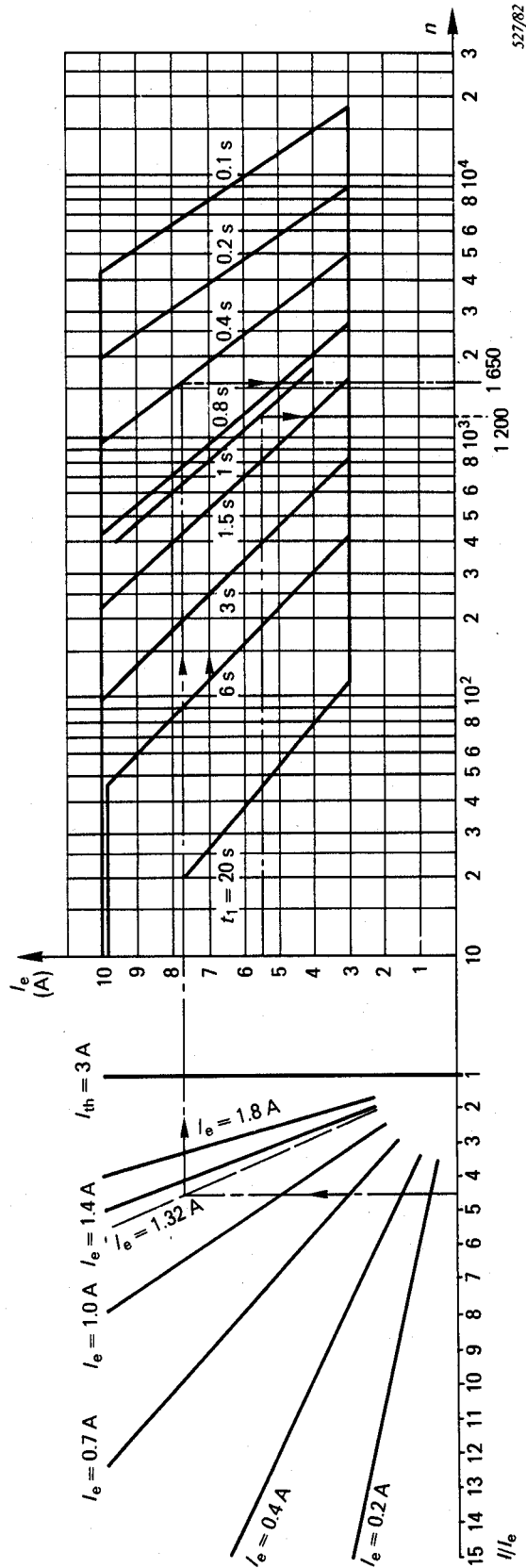


Answer: The part of the diagram to be utilized is the right-hand side, giving the relation between I_e (as ordinates), the duration of the current flow (sloping curves) and n (as abscisses).

For the value $I_e = 5.5$ A, the diagram (broken line) gives:

$$n = 1\,200 \text{ operating cycles/hour}$$

Note. — Any other loading case is admissible if it corresponds to a duration of current flow not exceeding 1 s, $I_e \leq 5.5$ A and/or $n \leq 1\,200$ operating cycles/hour.



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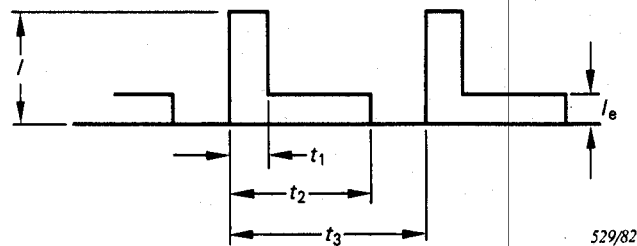
- n = number of operating cycles per hour (see Sub-clause 4.3.4.3)
- I = test current (see Tables II and III) or making current
- I_c = rated operational current
- t_1 = duration of the test current
- t_2 = total duration of current flow
- t_3 = duration of an operating cycle (see Sub-clause 4.3.4.3)
- t_2/t_3 = on-load factor (see Sub-clause 4.3.4.3)
- I_{th} = rated thermal current* (see Sub-clauses 4.3.2.1 and 6.1.1)

* The value given on this diagram corresponds to an ambient air temperature of +35 °C.

FIG. E1. — Load diagram.

Example 2: Suitability of the contactor to a given use

A 0.5 kW squirrel-cage motor with a rated operational current of 1.32 A and a starting current of 5.9 A is to be operated at 1 500 operating cycles per hour; the starting time of the motor is 0.4 s. Can the 3 A contactor be utilized?



Answer: As the duty is intermittent and with inconstant load, additional account shall be taken of the left-hand side of the diagram.

The making current I and the rated operational current I_e correspond to an overload factor of:

$$I/I_e = 5.9/1.32 \approx 4.5$$

Using both left-hand and right-hand sides of Figure E1, page 69 (line of dots and dashes), the diagram gives a maximum admissible operating frequency of:

$$n = 1\,650 \text{ operating cycles/hour}$$

Consequently, the aforesaid 3 A contactor can be utilized for this purpose.

APPENDIX F

TEST EQUIPMENT AND CIRCUITS FOR SHOWERING ARC TEST

(See Sub-clause 8.2.9.3a))

F1. Test equipment

An electrical noise generator shall be used as shown in Figure F1, page 75. A coupling cable assembly used to couple the generated noise into the device under test is shown in Figure F2, page 77, and the arrangement and connection of the wires within the cable is shown in Figure F3, page 77.

The direct output of the noise generator is monitored by oscilloscope V through probe P (voltage divider) as shown in Figure F1. A typical display of the oscilloscope is shown in Figure F4, page 79.

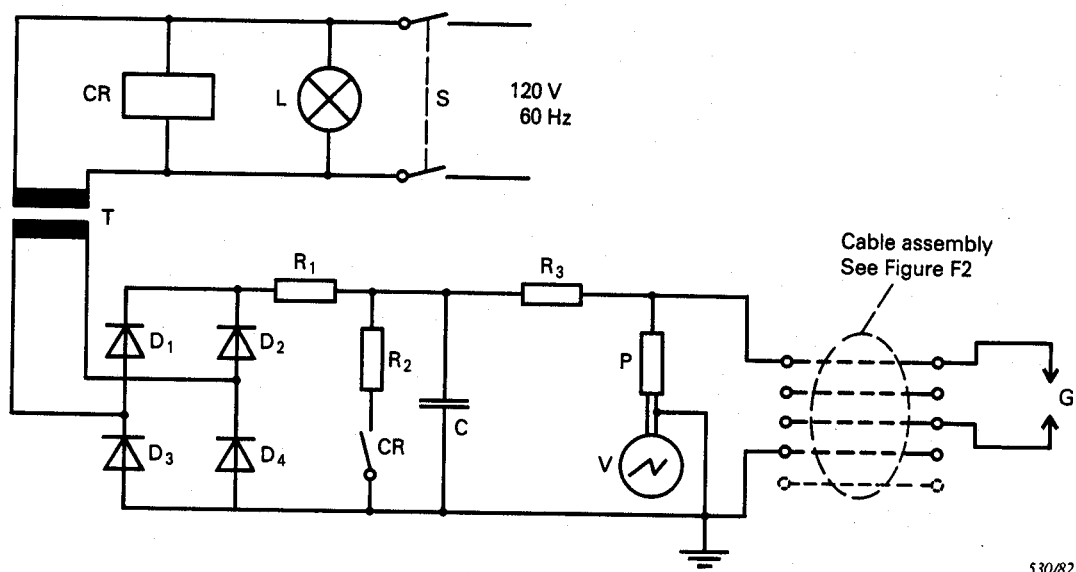
F2. Calibration of test equipment

In order to have a reproducible test, it is necessary to calibrate the output of the coupling cable assembly. This is done by selecting the proper pairs of wires to be used as the input and output of the cable assembly. This should be accomplished as follows:

Connect the test circuit to the terminals as shown in Figure F5, page 79. Adjust the noise generator by means of the spark gap G to produce 1 000 V transients, similar to the display shown in Figure F4. After setting the noise generator, make an oscilloscope measurement of the output of the cable assembly as shown in Figure F5 and Figure F6, page 81. This provides a measure of the peak current and the maximum slope of the current in the leading and trailing edges of the first current pulse of the oscillation caused by each showering arc transient.

If the measurements are not within the tolerances shown in Figure F6, select another adjacent wire pair instead of wires 2-2A and 4-4A, such as 7-7A and 8-8A or 2-2A and 8-8A or 7-7A and 4-4A. If none of these combinations will produce the desired result, it is recommended that another pair of wires be used for the input instead of wires 1-1A and 3-3A and the above test procedure be repeated, with wires adjacent to these wires being used for the output.

Having established the pairs of wires which give an output within the calibration shown in Figure F6, the test apparatus is ready for use in the test specified in Sub-clause 8.2.9.3a).



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- CR = 120 V, 60 Hz relay with N.C. contacts (normally closed)
 T = luminous sign transformer 100 VA, 120 V primary, 3 kV secondary
 R₁, R₂ = 50 kΩ, 20 W wirewound resistor
 R₃ = 300 kΩ, 30 W non-inductive resistor
 S = ON - OFF switch
 L = red warning lamp
 D₁, D₂, D₃, D₄ = 10 kV 25 mA silicon diodes
 C = 1.0 μF, 5 kV capacitor
 V = oscilloscope (100 kHz or greater upper bandwidth limit)
 P = 2 kV oscilloscope probe
 G = tungsten contacts (automobile ignition breaker point set with insulated lever attached. Lever provides 2:1 motion reduction so that 2.5 mm motion provided by micrometer screw results in gap adjustment from 0 to 1.25 mm

Note. — Contacts should be clean (degreased) to prevent glow discharge.

CAUTION: THE VOLTAGES AND POWER AVAILABLE MAY BE DANGEROUS TO HUMAN LIFE. THE EQUIPMENT MUST BE HANDLED WITH CARE. THE RED PILOT LIGHT WARNS OF THE DANGER. THE RELAY CONTACTS PROVIDE A RAPID DISCHARGE PATH FOR CAPACITOR C WHEN S IS OPENED.

FIG. F1. — Electrical noise generator schematic diagram and parts list.



FIG. F2. — Cable assembly for coupling noise into signal and power circuits.



FIG. F3. — Conductor arrangement — Alpha No. 1181-15 Cable (No. 22 wire).

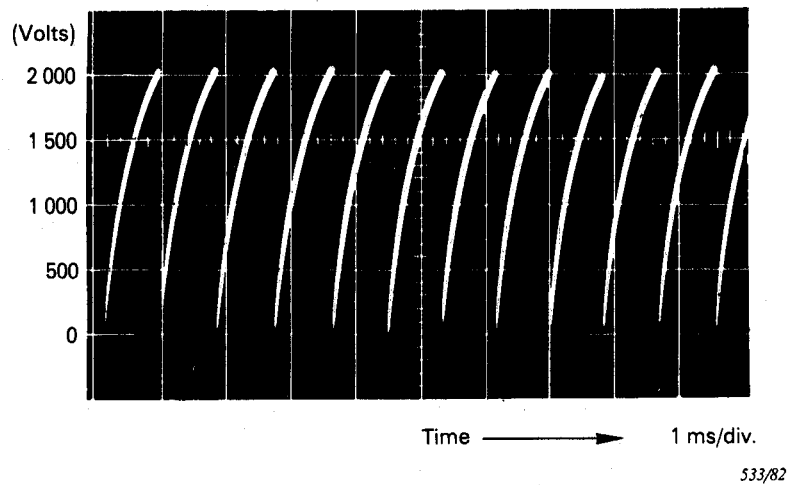
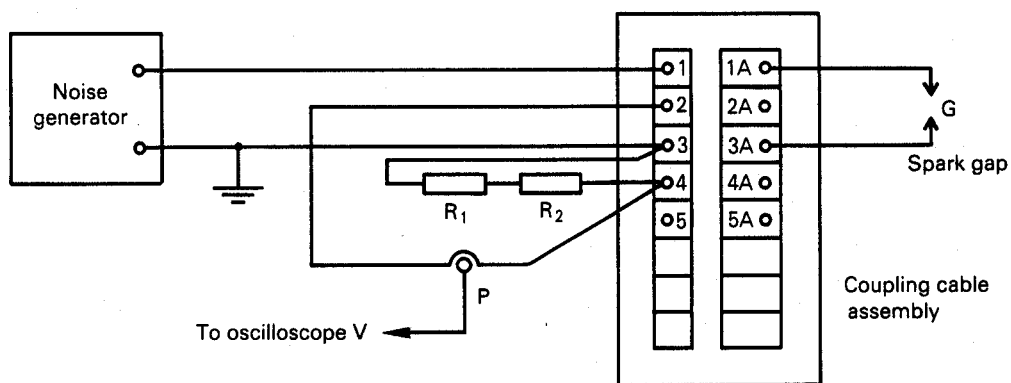


FIG. F4. — Typical oscillogram of continuous transient produced by showering arc electric noise generator.



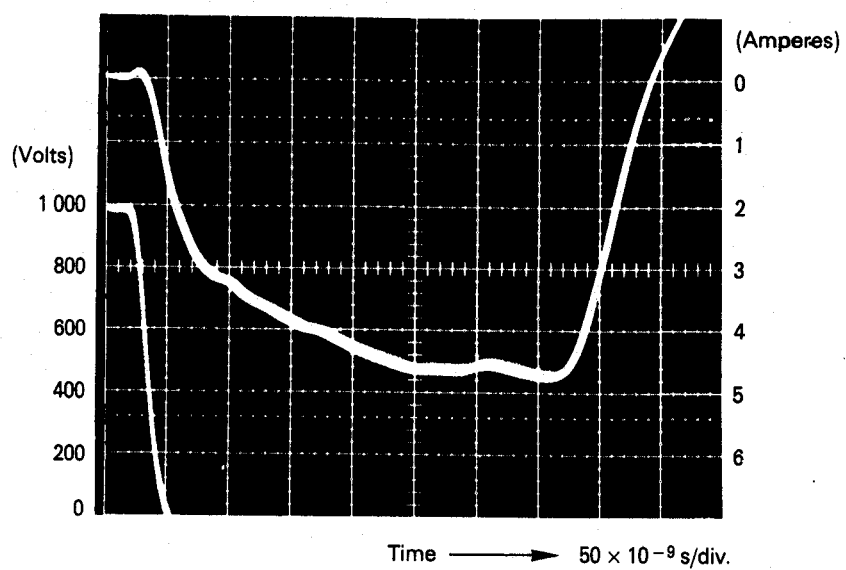
$R_1, R_2 = 270 \pm 10\% \text{ k}\Omega$ carbon resistor

P = current probe for oscilloscope, 50 MHz or greater upper bandwidth limit

V = oscilloscope, 50 MHz or greater upper bandwidth limit.

Second trace of oscilloscope V in Figure F1, page 75, may be used

FIG. F5. — Connection diagram and parts list for coupling cable assembly standardization.



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Peak current = $4.80 \pm 10\%$ A
Leading edge maximum slope = $95.0 \times 10^6 \pm 20\%$ A/s
Trailing edge maximum slope = $80.0 \times 10^6 \pm 20\%$ A/s

FIG. F6. — Current pulse oscillogram for standardizing coupling cable assembly.