BRITISH STANDARD

BS 5424-2: 1987

Incorporating Amendment No. 1

Low-voltage controlgear —

Part 2: Specification for semiconductor contactors (solid state contactors) —

(Implementation of CENELEC HD 419.2 S1)

UDC [621.316.3/.5].027.2:621.382.316.53

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Power Electrical Engineering Standards Committee (PEL/-) to Technical Committee PEL/10, upon which the following bodies were represented:

ASTA Certification Services
Association of Manufacturers Allied to the Electrical and Electronic Industry (BEAMA Ltd)
British Gas plc
ERA Technology Ltd
Electrical Contractors Association
Electrical Installation Equipment Manufacturers Association (BEAMA Ltd)
Electricity Supply Industry in England and Wales
Electronic Components Industry Federation
GAMBICA (BEAMA Ltd)
Health and Safety Executive
Institution of Electrical Engineers

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Contents

Foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Committee and is related to IEC 158-2:1982 published by the International Electrotechnical Commission (IEC). This standard is in agreement with Harmonization Document HD 419.2 S1 published by the European Committee for Electrotechnical Standardization (CENELEC), which has introduced modifications to **8.2.3.3**, **8.2.9.2**b) and **8.2.9.3**b).

BS 5424 consists of the following Parts:

— *Part 1:1977: Contactors;*

— *Part 2:1987: Specification for semiconductor contactors (solid state contactors);*

— *Part 3:1987: Additional requirements for contactors subject to certification.*

Terminology and conventions. For ease of reproduction, most of the text and format of IEC 158-2 has been used as the basis of this British Standard. Some terminology and conventions are not identical with those in British Standards.

Cross-references

International Standard	Corresponding British Standard
IEC 60-2:1973	BS 923 *Guide on high-voltage testing techniques* Part 2:1980 *Test procedures* (Identical)
IEC 144:1963	BS 5420:1977 *Specification for degrees of protection of enclosures of switchgear and controlgear for voltages up to and including 1 000 V a.c. and 1 200 V d.c.* (Identical)
IEC 158-1:1970	BS 5424 *Specification for controlgear for voltages up to and including 1 000 V a.c. and 1 200 V d.c.* Part 1:1977 *Contactors* (Identical)
IEC 664:1980	PD 6499:1981 *Guide to insulation co-ordination within low-voltage systems including clearances and creepage distances for equipment* (Identical)

The Technical Committee has reviewed the provisions of IEC 65 and IEC 147-0, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard. A related British Standard to IEC 65:1987 is BS 415:1979.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 26, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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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.

NOTE 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.

NOTE 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[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

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[2)])

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.

[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)] 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 inservice 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.

NOTE 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.

NOTE 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.

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 I — Utilization category

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

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.

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

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

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[a]

	Category	Value of the rated operational current	Test conditions		
			I/I_e	U/U_e	cos φ[b]
	AC-1	(All values)	1.5	1.1	0.95
	AC-2	(All values)	4	1.1	0.65
	AC-3	$I_e \leqslant$ 17 A	10	1.1	0.65
	AC-3	17 A < $I_e \leqslant$ 100 A	10	1.1	0.35
	AC-3	$I_e >$ 100 A	8[c]	1.1	0.35
	AC-4	$I_e \leqslant$ 17 A	12	1.1	0.65
	AC-4	17 A < $I_e \leqslant$ 100 A	12	1.1	0.35
	AC-4	$I_e >$ 100 A	10[e]	1.1	0.35
			I/I_e	U/U_e	L/R[f] (ms)
D.C.	DC-1		—	—	—
	DC-2 (shunt-motors)	(All values)	4	1.1	2.5
	DC-3 (shunt-motors)	(All values)	4	1.1	2.5
	DC-4 (series motors)	(All values)	4	1.1	15
	DC-5 (series 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
[a] 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).
[b] Tolerance for cos φ: ± 0.05.
[c] With a minimum of 1 000 A for I or I_e.
[d] (Vacant).
[e] With a minimum of 1 200 A for I.
[f] Tolerance for L/R: ± 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 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.

Table III — Verification of the number of on-load operating cycles Conditions for making and breaking corresponding to the several utilization categories[a]

	Category	Value of the rated operational current	Test conditions		
			I/I_e	U/U_e	cos φ[b]
A.C.	AC-1	(All values)	1	1	0.95
	AC-2	(All values)	2.5	1	0.65
	AC-3	$I_e \leqslant 17$ A	6	1	0.65
		$I_e > 17$ A	6	1	0.35
	AC-4	$I_e \leqslant 17$ A	6	1	0.65
		$I_e > 17$ A	6	1	0.35
			I/I_e	U/U_e	L/R[c] (ms)
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
[a] 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).
[b] Tolerance for cos φ: ± 0.05.
[c] Tolerance for L/R: ± 15 %.

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.).

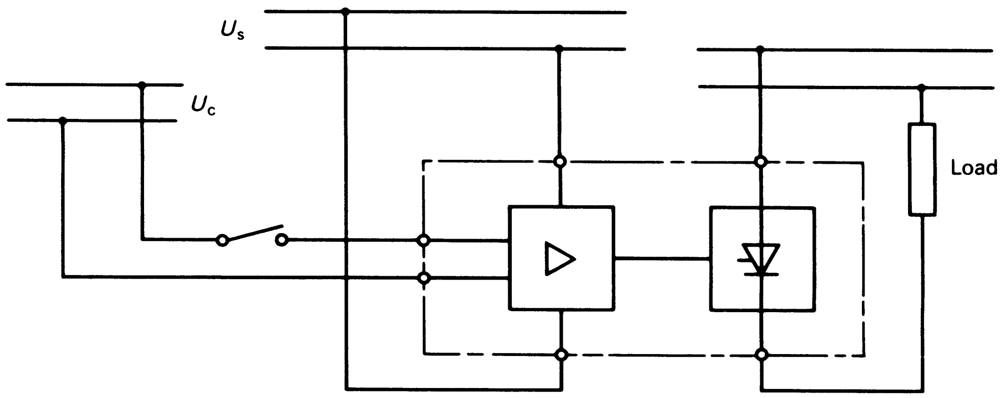
NOTE 1 A distinction has been made above between the control circuit voltage, which is the voltage which would appear across the open control input terminals or which should be applied to the control input terminals for carrying out the control function, and the control supply voltage, which is the voltage 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.

NOTE 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.

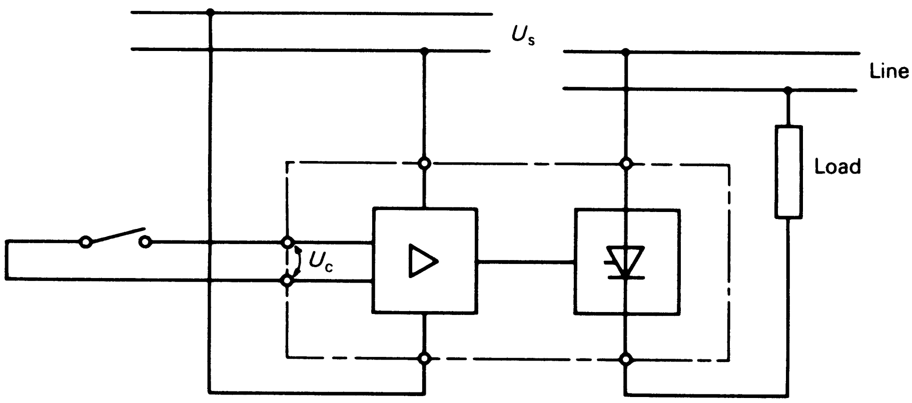
The rated control supply voltage and rated frequency, if any, are the values on which the operating and temperature-rise characteristics of the control circuits are based. The correct operating conditions are based upon a value of the control supply voltage not less than 85 % of its rated value with 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.

Figure 1 and Figure 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



U_s = control supply voltage
U_c = internal control circuit voltage

NOTE Control supply voltage U_s may be taken from either an external or internal source.

Figure 2

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 — 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

NOTE The manufacturer should be prepared to state the value or values of the input impedances presented to the external control signal source or sources.

4.4.1 (Vacant)

4.4.2 (Vacant)

4.5 Auxiliary circuits

The characteristics of auxiliary circuits are:

a) the number of those circuits;

b) the kind of switching elements (a-contact, b-contact, transistor, etc.);

c) for each of these circuits:

— rated voltage;

— rated frequency, if any;

— rated current;

— rated breaking capacity of the contacts, if any.

4.6 Co-ordination with short-circuit protective devices

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 Table I and Table 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[3)] and 664A[4)].

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.

[3)] Insulation co-ordination within low-voltage systems including clearances and creepage distances for equipment.
[4)] First supplement.

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.

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.

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
— copper { eight-hour, intermittent, or temporary duty	65
— silver or silver-faced	[a]
— all other metals or sintered metals	[b]
Contact parts in oil	65
Bare conductors including non-insulated coils	[a]
Metallic parts acting as springs	[c]
Metallic parts in contact with insulating materials	[d]
Parts of metal or of insulating material in contact with oil	65
Terminals for external insulated connections	70[e]
Manual operating means:	
— parts of metal	15
— parts of insulating material	25
Electronic components	[g]

[a] Limited solely by the necessity of not causing any damage to adjacent parts.
[b] To be specified according to the properties of the metals used and limited by the necessity of not causing any damage to adjacent parts.
[c] 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.
[d] Limited solely by the necessity of not causing any damage to insulating materials.
[e] 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.
[f] (Vacant).
[g] See IEC Publication 65: Safety Requirements for Mains Operated Electronic and Related Apparatus for Household and Similar General Use.

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 °C and + 40 °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.

NOTE For the time being, the values of Table VIII of IEC Publication 158-1 should be used.

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 ± 2 °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 *l*)].

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 °C and at the rated values 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.

A transient surge voltage generator shall set transients across the semiconductor contactor. The amplitude of the transients shall be equal to 2.3 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 turn "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, the control input circuit shown in Figure 4, and, where a separate control voltage is used, in the circuit shown in Figure 5.

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, Figure F.1 and Figure F.4).

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, and detailed as shown in Figure 7. 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 2.3 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 **8.2.3.2**b).

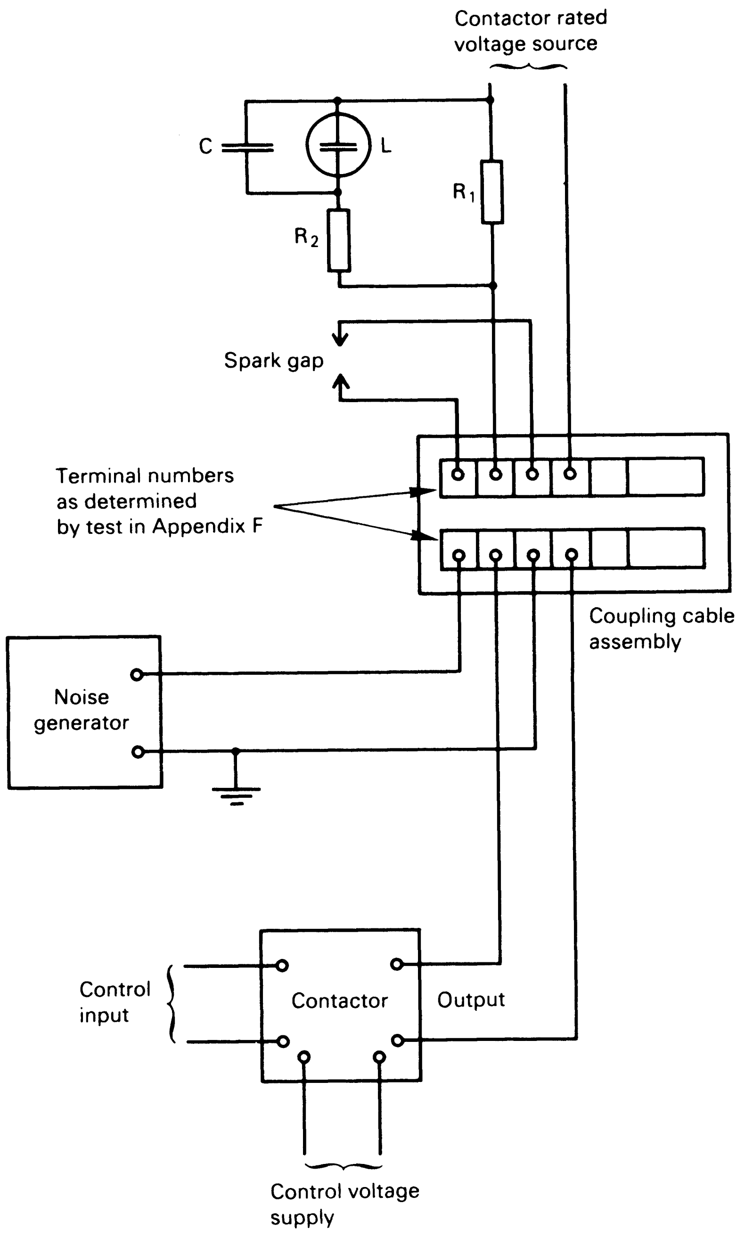
8.4 Special tests

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.

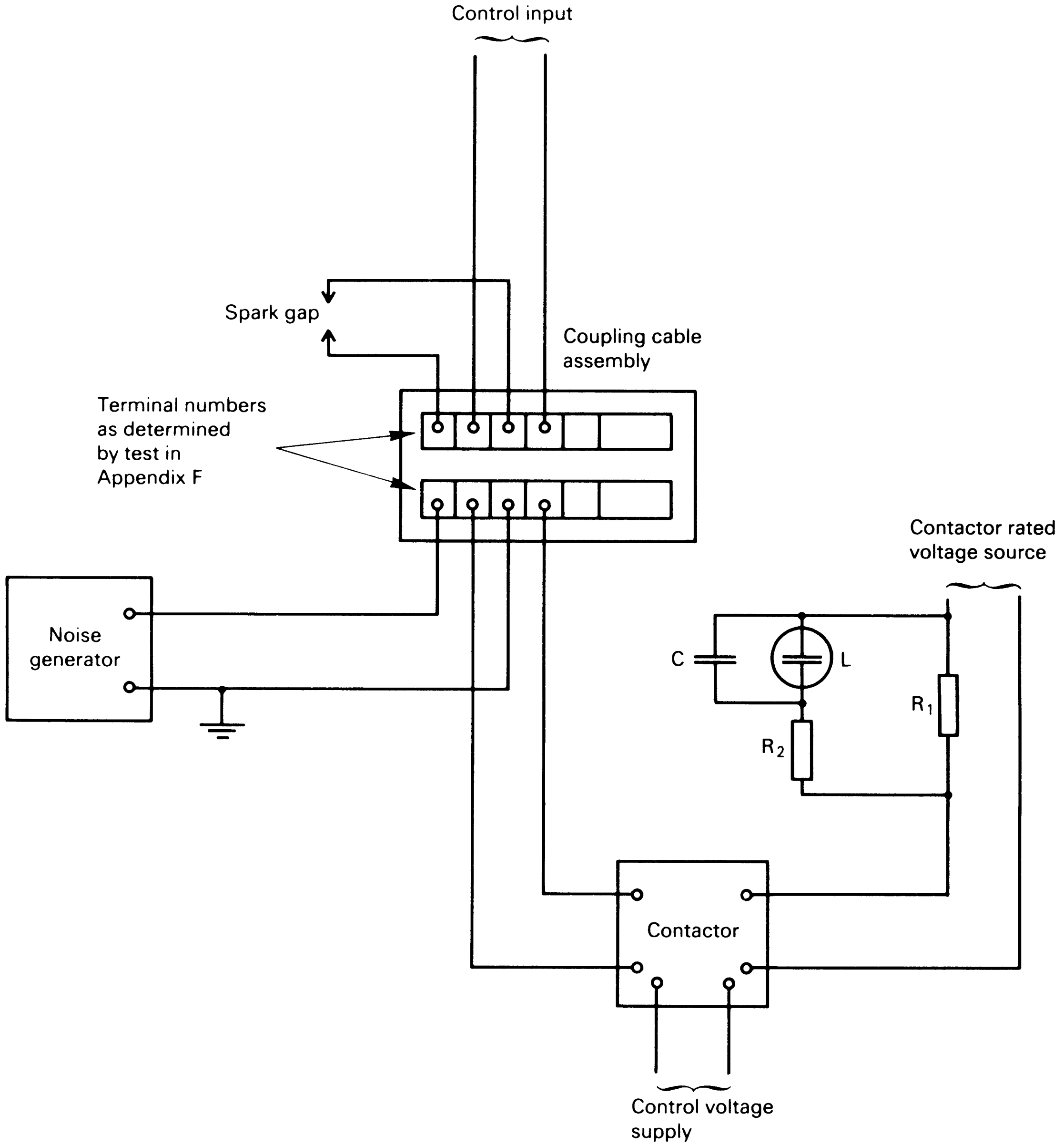
After the test, the contactor shall fulfil the operating conditions specified in Sub-clause **8.2.6**, and withstand the dielectric test voltages of Sub-clause **8.2.3.3**.



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

NOTE Provide grounding in accordance with manufacturer's specifications.

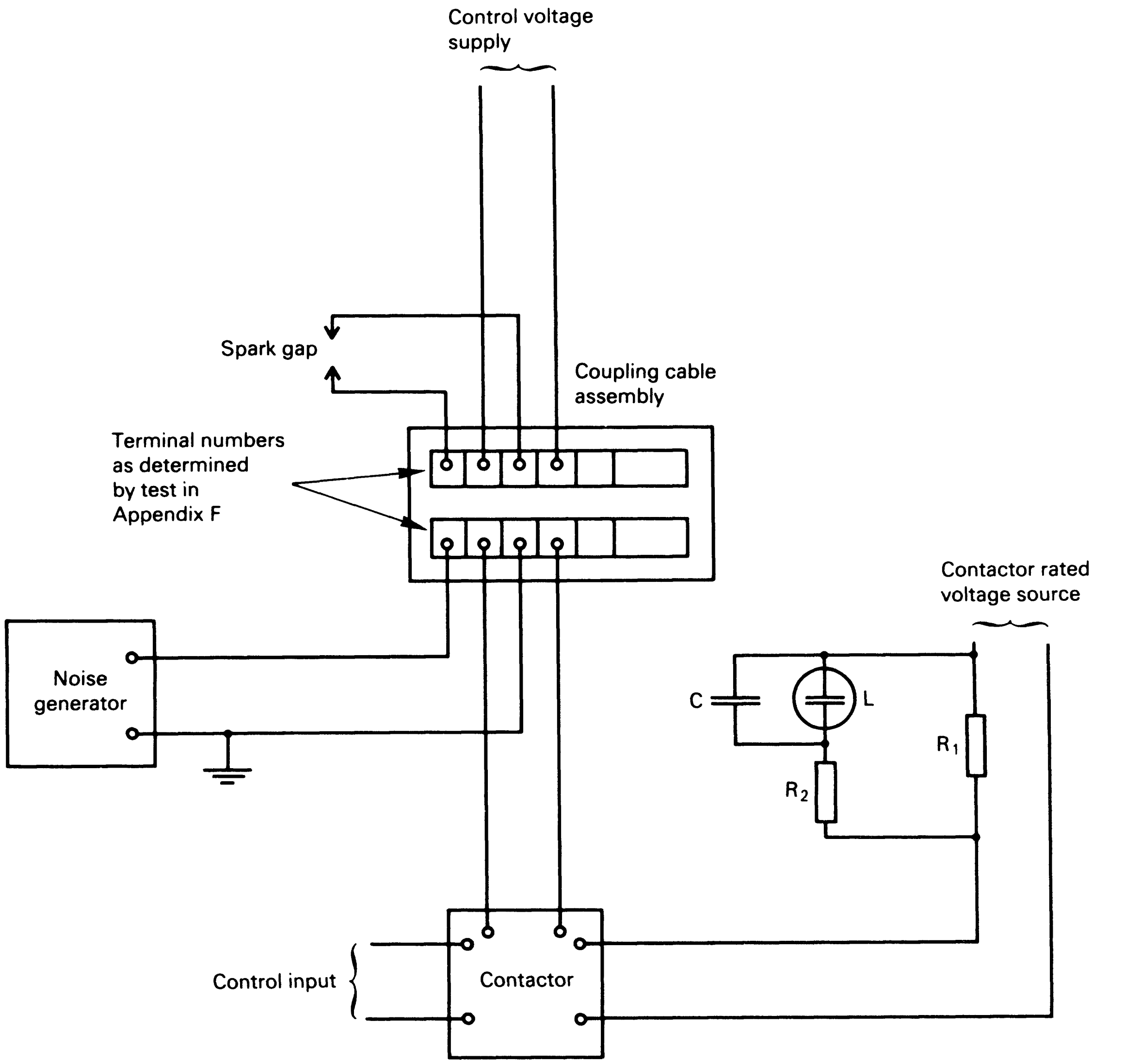
Figure 3 — Showering arc test on output circuit



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

NOTE Provide grounding in accordance with manufacturer's specifications.

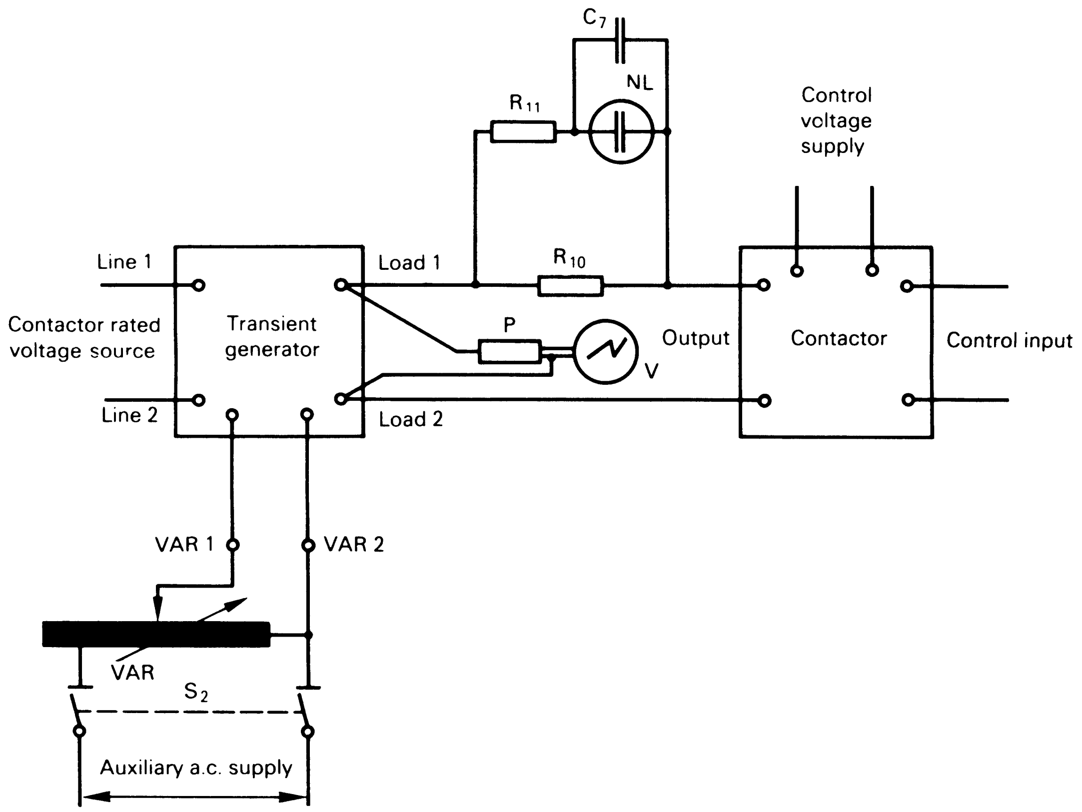
Figure 4 — Showering arc test on control input circuit



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

NOTE Provide grounding in accordance with manufacturer's specifications.

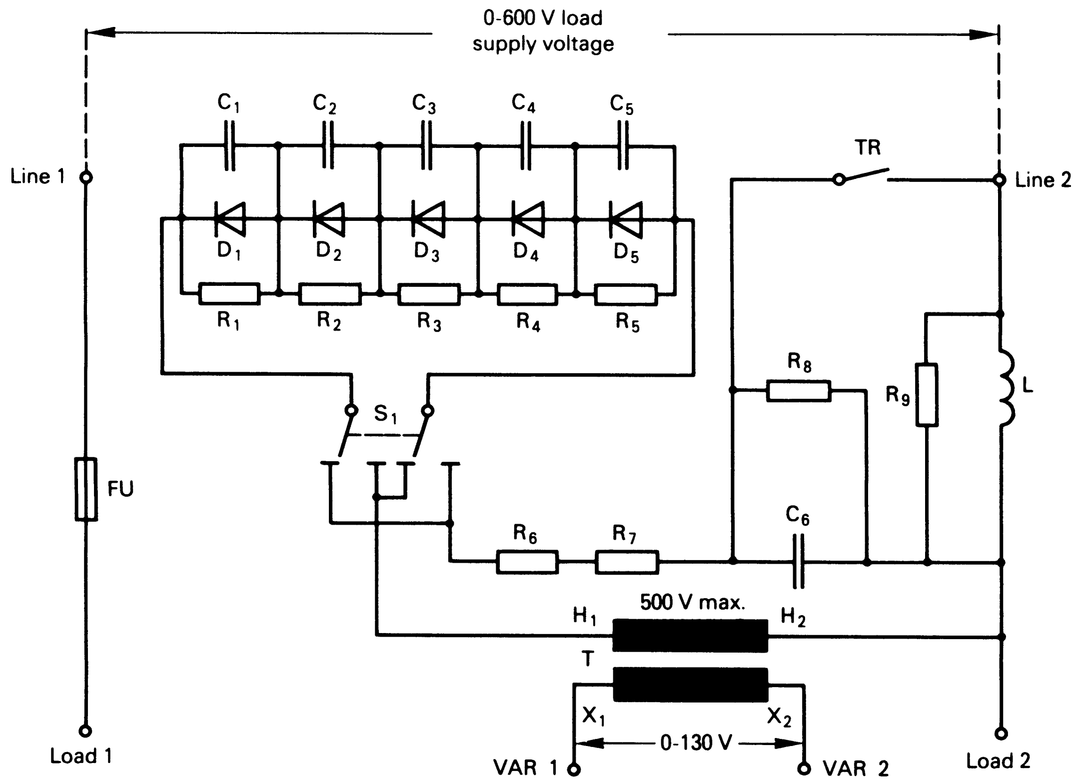
Figure 5 — Showering arc test on control voltage supply



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

VAR = VARIAC

Figure 6 — Surge voltage test on output circuit



T	= transformer 300 VA to 500 V primary, 110 V secondary
C_1 to C_5	= ceramic capacitor 0.0047 μF, 500 V d.c.
C_6	= oil-filled capacitor 8.0 μF, 440 V a.c.
D_1 to D_5	= silicon rectifier 0.5 A, 400 V
R_1 to R_5	= 330 kΩ, 1 W resistor
R_6, R_7	= 500 Ω, 135 W wirewound resistor
R_8	= 100 kΩ, 1 W resistor
R_9	= 35 Ω, 10 W wirewound resistor
L	= air core inductor, 54 turns, 6 mm^2 copper wire, 125 μH, approximately 0.03 Ω
S_1	= 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

Figure 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 E.1 shows a method of presenting such a load diagram. The straight lines are based on simplifying approximations, particularly in short time ratings.

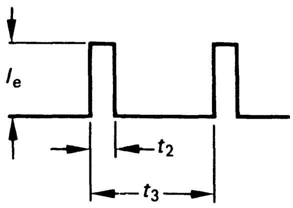
Load ratings may also be expressed in tables that specify the influencing parameters.

Assuming that the values of Figure E.1 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?

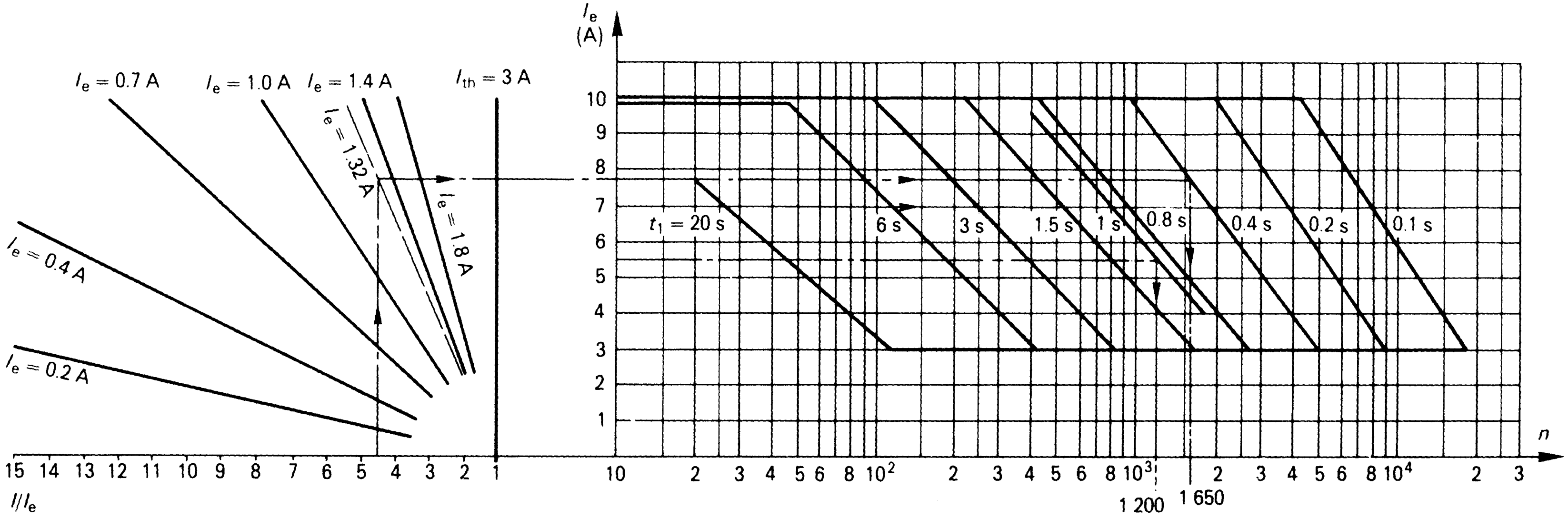


Answer: The part of the diagram to be utilized is the right-hand side, giving the relation between I_e (as ordinates), the duration of the current flow (sloping curves) and n (as abscisses).

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

n = 1 200 operating cycles/hour

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



n = number of operating cycles per hour (see Sub-clause **4.3.4.3**)

I = test current (see Table II and Table III) or making current

I_e = 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**)

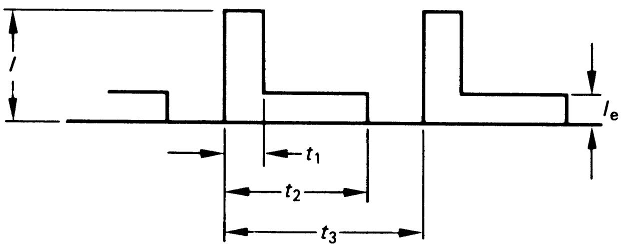
I_{th} = rated thermal current[a] (see Sub-clauses **4.3.2.1** and **6.1.1**)

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

Figure E.1 — 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:

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

Using both left-hand and fight-hand sides of Figure E.1, (line of dots and dashes), the diagram gives a maximum admissible operating frequency of:

n = 1 650 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 **8.2.9.3**a)]

F.1 Test equipment

An electrical noise generator shall be used as shown in Figure F.1. A coupling cable assembly used to couple the generated noise into the device under test is shown in Figure F.2, and the arrangement and connection of the wires within the cable is shown in Figure F.3.

The direct output of the noise generator is monitored by oscilloscope V through probe P (voltage divider) as shown in Figure F.1. A typical display of the oscilloscope is shown in Figure F.4.

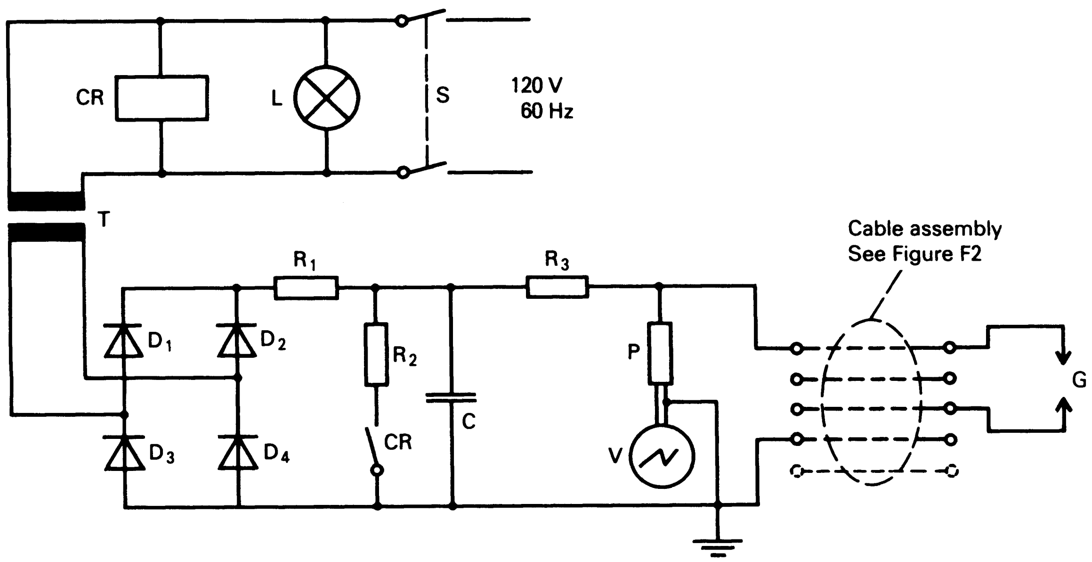
F.2 Calibration of test equipment

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 F.5. Adjust the noise generator by means of the spark gap G to produce 1 000 V transients, similar to the display shown in Figure F.4. After setting the noise generator, make an oscilloscope measurement of the output of the cable assembly as shown in Figure F.5 and Figure F.6. 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 F.6, 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 F.6, the test apparatus is ready for use in the test specified in Sub-clause **8.2.9.3**a).

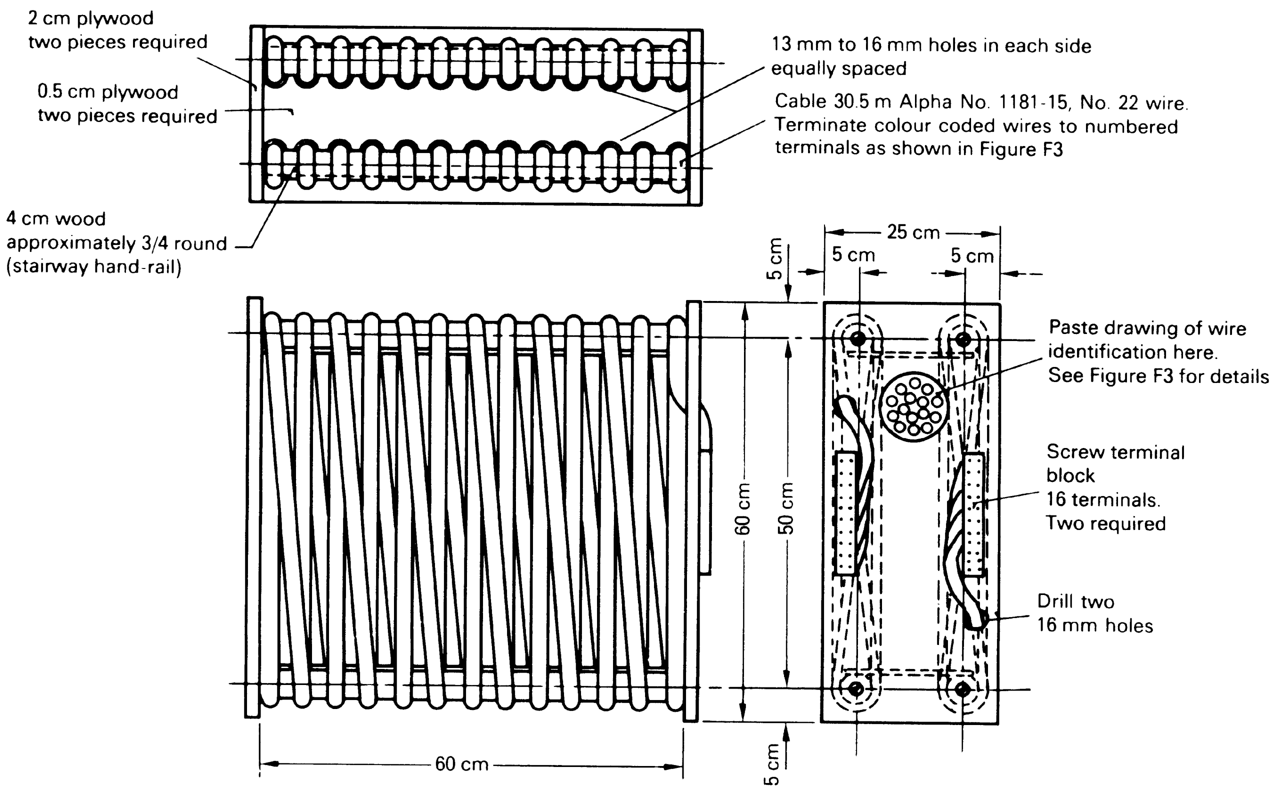


CR = 120 V, 60 Hz relay with N.C. contacts (normally closed)
T = luminous sign transformer 100 VA, 120 V primary, 3 kV secondary
R_1, R_2 = 50 kΩ, 20 W wirewound resistor
R_3 = 300 kΩ, 30 W non-inductive resistor
S = ON – OFF switch
L = red warning lamp
D_1, D_2, D_3, D_4 = 10 kV 25 mA silicon diodes
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 insulted 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.

Figure F.1 — Electrical noise generator schematic diagram and parts list



NOTE Assemble frame with wood screws and glue.
Finish with two coats of shellac and then mount cable.

Figure F.2 — Cable assembly for coupling noise into signal and power circuits

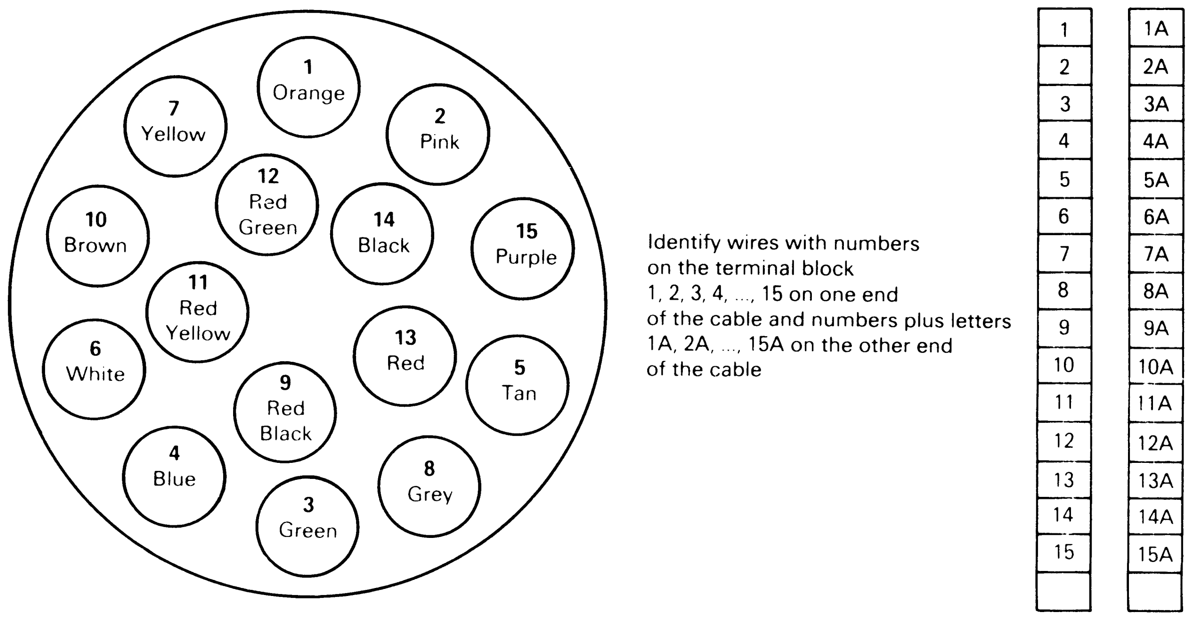


Figure F.3 — Conductor arrangement — Alpha No. 1181-15 Cable (No. 22 wire)

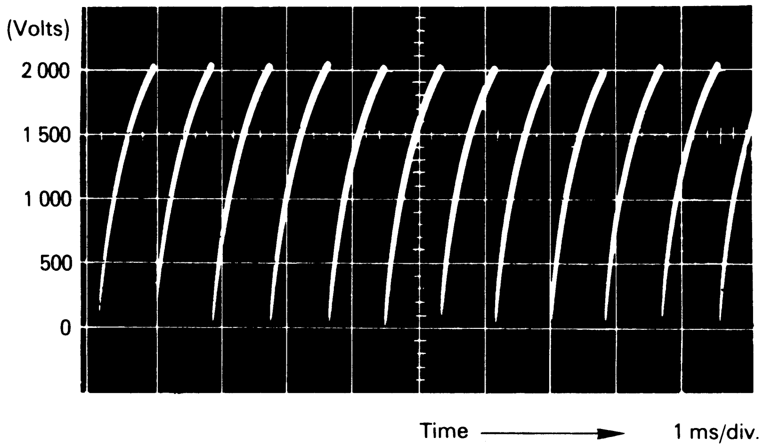
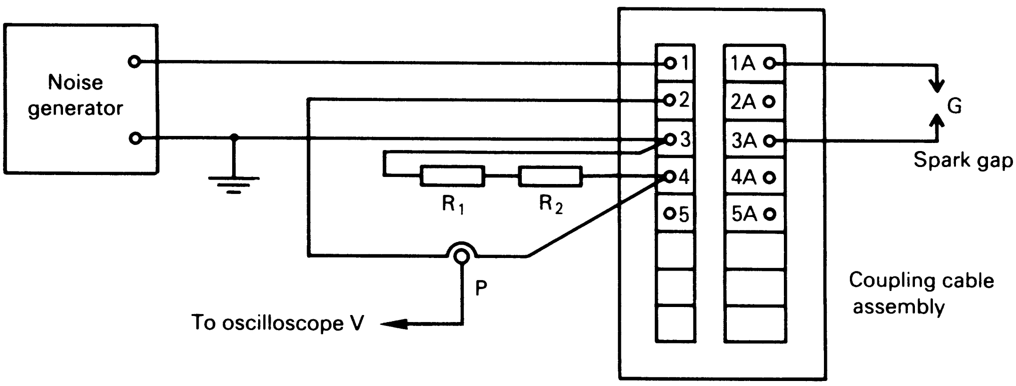


Figure F.4 — Typical oscillogram of continuous transient produced by showering arc electric noise generator

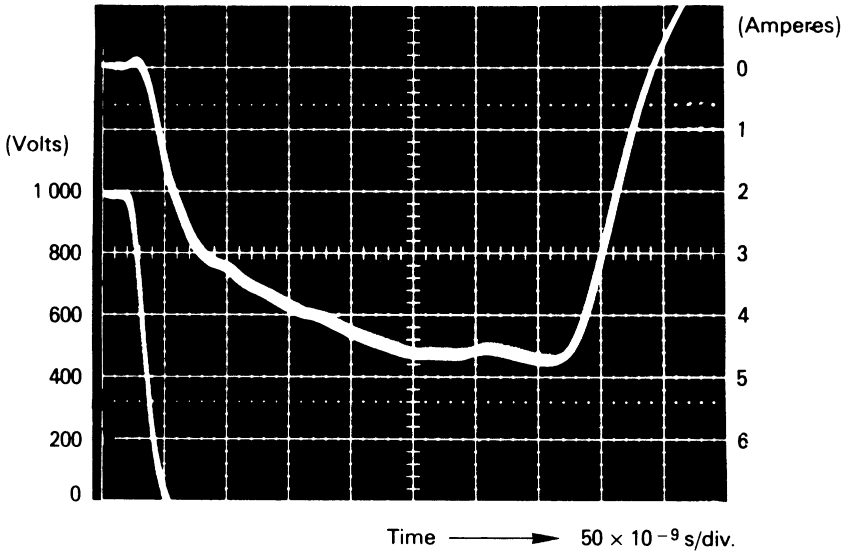


R_1, R_2 = 270 ± 10 % kΩ carbon resistor

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 F.1, page 23, may be used

Figure F.5 — Connection diagram and parts list for coupling cable assembly standardization



Peak current = 4.80 ± 10 % A
Leading edge maximum slope = 95.0 × 10^6 ± 20 % A/s
Trailing edge maximum slope = 80.0 × 10^6 ± 20 % A/s

Figure F.6 — Current pulse oscillogram for standardizing coupling cable assembly

Publications referred to

See national foreword.

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