B.6 Constructional and performance requirements

B.6.1 Constructional requirements

B.6.1.1 General

Contactors shall be designed and manufactured to withstand the stresses occurring during installation and normal use.

B.6.1.2 Current-carrying parts and their connections

Current-carrying parts shall have the necessary mechanical strength and current-carrying capacity for their intended use.

For electrical connections, no contact pressure shall be transmitted through insulating material other than ceramic or other material with characteristic not less suitable, unless there is sufficient resiliency in the metallic parts to compensate for any possible shrinkage or yielding of the insulation material.

Compliance shall be verified by inspection and by conducting test following test sequences of the type test (see B.8).

B.6.1.3 Clearance and creepage

The minimum values shall be in accordance with EN 60664-1 with the following parameters:

— $U_i = 1{,}25 \times U_{e,max}$;

— pollution degree 3;

— comparative tracking index (CTI) of used materials.

B.6.2 Performance requirements

B.6.2.1 Limits of operation

All values shall be based on the operating coils being at the temperature which they would attain in operation with rated control circuit voltage U_c in an ambient temperature of 40 °C.

Contactors shall close with any control supply voltage of the coil between 70 % and 115 % of rated U_c.

Where a range of operation is given, the value of 70 % shall apply to the lower limit of the range, and the value of 115 % to the upper limit of the range.

The drop-out voltage shall not be more than 40 % and not less than 5 (with worn contacts) % of the rated control supply voltage.

Where a range of operation is given, the value of 5 % shall apply to the upper limit of the range, and the value of 40 % to the lower limit of the range.

The contactor shall close fully and drop out fully in one continuous motion.

B.6.2.2 Temperature

B.6.2.2.1 General

The temperature rise of the parts of contactors, measured during the following type test carried out under the conditions specified in B.7.1, shall not exceed the values stated in this annex.

B.6.2.2.2 Terminals

The temperature rise of the terminals shall not exceed the values stated in Table B.3.

B.6.2.2.3 Control circuit

The control circuit of a contactor to be used for closing and opening operations shall permit the rated duty according to B.2.5 and pass the temperature rise test specified in B.7.2.3, not exceeding the limits specified in Table B.4.

B.6.2.3 Dielectric properties

The dielectric properties shall be in accordance with EN 60664-1.

B.6.2.4 Mechanical durability

Contactors of Class 1 shall be capable of performing 300 000 closing and opening operations without load. Contactors of Class 2, 3 and 4 shall be capable of performing 3 000 000 closing and opening operations without load.

B.7 Tests

B.7.1 Kind of tests

B.7.1.1 General

Tests shall be done to prove compliance with the requirements laid down in this document. The tests are:

— type tests which shall be made on representative samples of contactors;

— routine tests which shall be made on each individual piece of contactor manufactured.

These tests may consist of test sequences, in accordance with the requirements.

B.7.1.2 Type tests

Type tests are intended to verify compliance of the design of a given contactor with this document.

They may comprise, as appropriate, the verification of:

— constructional requirements;

— temperature-rise;

— dielectric properties;

— making and breaking capacities;

— short-circuit making capacities;

— operating limits;

— conventional operational performance.

NOTE This list is not exhaustive.

The type tests results shall be documented, and if relevant, the test sequences and the number of samples.

B.7.1.3 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain proper functioning of the equipment. They shall be made on each individual piece of equipment.

Routine tests shall at least comprise:

— functional test (operating limit);

— dielectric test or insulation resistance test.

B.7.2 Tabulation of tests

B.7.2.1 General

If not mentioned the ambient temperature during the tests shall be within the range 20 °C to 40 °C.

B.7.2.2 Operating limits

See B.6.2.1.

B.7.2.3 Temperature rise

B.7.2.3.1 Main circuit

The test shall be carried out with DC current and may be made at any convenient voltage. With the consent of the manufacturer, testing with an AC supply is allowed. The cross-sectional areas of the connecting wires or cables shall be in accordance with Table B.2 and each shall be 2 m in length. For multipole contactors all poles shall be connected in series.

Table B.2 — Test copper conductors for test currents up to 640 A, inclusive

Range of test current [a] A		Conductor size [b] mm²
0	20	1,5
20	30	2,5
30	39	4
39	54	6
54	72	10
72	93	16
93	117	25
117	147	35
147	180	50
180	216	70
216	250	95
250	287	120
287	334	150
334	400	185

Range of test current [a] **A**		**Conductor size** [b] **mm²**
400	500	2 × 120
500	575	2 × 150
575	640	2 × 185

[a] The value of test current shall be greater than the first value in the first column and less than or equal to the second value in that column.

[b] For convenience of testing and with the manufacturer consent, smaller conductors than those given for a stated test current may be used.

The temperature rise test shall be carried out using new contactors. The test shall be made at rated thermal current for enough time for the main circuit components to reach a stable temperature, but not more than 8 h.

At the end of the test the temperature rise of the components shall not exceed the values specified in Table B.3.

Table B.3 — Temperature rise limits for the various materials and parts

Description of parts / Type of material		**Temperature rise limit**
Contact tips in air (main, control and auxiliary)	copper	70 K
	silver or silver-faced	A
	other metals or sintered metals	B
Bare conductors including non-insulated coils		A
Metallic parts acting as springs		C
Metallic parts in contact with insulating materials		D
Terminals for external insulated connections		70 K

Key

A Limited solely by the necessity of not causing any damage to adjacent parts.

B To be specified in accordance with the properties of the metals used and limited by the necessity of not causing any damage to adjacent parts.

C The 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.

After performing the test sequences described in B.8, the temperature rise values shall not exceed those recorded during the test of new contacts by more than 20 K.

B.7.2.3.2 Operating coils

With conventional free air thermal current I_{th} applied to the main circuit, the coils shall withstand the application of their nominal control circuit voltage without exceeding the appropriate temperature rise limits of Table B.4 when thermal equilibrium has been reached. In accordance with the assigned class of duty, the coil voltage shall be either continuously or intermittently applied in accordance with the appropriate duty cycle of B.2.5.

Table B.4 — Temperature rise limits for insulated coils in air

Class of insulating material	Temperature rise limit
E	100 K
B	110 K
F	135 K
H	160 K

NOTE With reference to an ambient temperature of 40 °C the temperature rise limits assigned above exceed those indicated by the class letter by 20 K. The classification of insulating material is given in EN 60085. Experience has shown however that contactors designed to this specification have an adequate insulation life at temperature greater than those associated with the temperature classes.

Results shall be calculated by the resistance method. In this method the temperature rise of the windings is determined by their increase in resistance.

The temperature rise of windings at the end of the test is determined by the following formula:

$$T_2 - T_a = \frac{R_2}{R_1}\left(k + T_1\right) - \left(k + T_a\right)$$

where

T_a is the ambient temperature at the end of test, in degrees Celsius;

T_1 is the temperature of the cold winding when the initial resistance measurement is taken, in degrees Celsius;

T_2 is the temperature of the winding at the end of the test, in degrees Celsius;

R_1 is the initial resistance of the cold winding, in Ω;

R_2 is the resistance of the winding at the end of the test, in Ω;

k is 235 for copper. For materials other than copper is the reciprocal of the temperature coefficient of resistance at 0 °C.

B.7.2.4 Dielectric test

For new contacts the test shall be carried out with AC or DC test voltage and with a magnitude in accordance with Table B.5. The AC test voltage shall have an approximately sinusoidal waveform and a frequency between 25 Hz and 100 Hz. The voltage shall be applied for 1 min:

— between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the enclosure or mounting plate, with the contacts in all normal positions of operation;

— between each pole of the main circuit and the other poles connected together and to the enclosure or mounting plate, with the contacts in all normal positions of operation;

— between each control and auxiliary circuit not normally connected to the main circuit and:

  — the main circuit;

  — the other circuits;

— the exposed conductive parts;

— the enclosure or mounting plate, which may be connected together wherever appropriate;

— for equipment suitable for isolation, across the poles of the main circuit, the line terminals being connected together, and the load terminals connected together.

Table B.5 — Power frequency withstand test voltage

Rated insulation voltage U_i V	**AC test voltage V RMS**	**DC test voltage [b] [c] V**
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 690$	1 890	2 670
$690 < U_i \leq 800$	2 000	2 830
$800 < U_i \leq 1\,000$	2 200	3 110
$1\,000 < U_i \leq 1\,500$ [a]	-	3 820

[a] DC only.

[b] Test voltages based on EN 60664-1:2007, 4.1.2.3.1.

[c] A direct current test voltage may be used only if an alternating test voltage cannot be applied.

For power frequency withstand verification after switching and short circuit tests the value of test voltage shall be $2 \times U_e$ with a minimum of 1 000 V RMS or 1 415 V DC. The value of U_e referred to conforms to the voltage used for switching and/or short circuit tests. The voltage shall be applied for 1 min between the upper mentioned points.

During the test, no flashover, breakdown of insulation either internally (puncture) or externally (tracking) or any other manifestation of disruptive discharge shall occur.

B.7.2.5 Verification of making and breaking test

The power supply shall have enough power to permit the verification of the characteristics given in Table B.6. It shall consist of a battery source or an equivalent voltage source having capacity sufficient to maintain the test current with a voltage not less than 85 % of the rated operating voltage.

The making and breaking capacities to be obtained during the test are specified in Table B.6. The operating coil shall be energised with its nominal supply voltage. Contactors shall be capable of making and breaking currents without failures.

Table B.6 — Making and breaking capacities – making and breaking conditions according to category

	Conditions for making and breaking								
	Making			Breaking					
	I_c (A)	U (V)	L/R (ms)	I_c (A)	U (V)	L/R (ms)	on-time (s)	off-time (s)	Number of operating cycles
Category 1 [a]	4 I_{th}	U_e	1	I_{th}	U_e	1	> 0,3	[c]	50 [d]
Category 2 [b]	See EN 60947-4–1								

[a] Contactor normally used as main contactor with mainly capacitive load, low switch-off current.
[b] Contactor controlling resistive loads or auxiliary circuits shall comply with EN 60947-4–1.
[c] See Table B.8.
[d] For bidirectional contactors: 25 operation cycles with one polarity and 25 operation cycles with opposite polarity.
I_c Making and breaking current.

B.7.2.6 Verification of conventional operational performance

The power supply shall have enough power to permit the verification of the characteristics given in Table B.7. It shall consist of a battery source or an equivalent source having the capacity to maintain the test current with a voltage not less than 85 % of the rated operating voltage.

The making and breaking capacities to be obtained during the test are specified in Table B.7. The operating coil shall be energised with its nominal supply voltage.

Contactors shall be capable of making and breaking currents without failures.

Table B.7 — Conventional operational performance – making and breaking conditions according to category

	Conditions for making and breaking								
	Making			Breaking					
	I_c (A)	U (V)	L/R (ms)	I_c (A)	U (V)	L/R (ms)	on-time (s)	Off-time (s)	Number of operating cycles
Category 1 [a]	$2 \times I_{th}$	U_e	1	$0{,}5 \times I_{th}$	U_e	1	> 0,3	[c]	100 000 [d]
Category 2 [b]	See EN 60947-4–1								

[a] Contactor normally used as main contactor with mainly capacitive load, low switch-off current.

[b] Contactor controlling resistive loads or auxiliary circuits shall comply with EN 60947-4–1.

[c] See Table B.8.

[d] For bidirectional contactors: 50 000 operation cycles with one polarity and 50 000 operation cycles with opposite polarity.

Table B.8 — Relation between current broken I_c and off-time

Current broken I_C A	**off-time s**
$I_C \leq 100$	10
$100 < I_C \leq 200$	20
$200 < I_C \leq 300$	30
$300 < I_C \leq 400$	40
$400 < I_C \leq 600$	60
$600 < I_C \leq 800$	80
$800 < I_C \leq 1\,000$	100
$1\,000 < I_C \leq 1\,300$	140
$1\,300 < I_C \leq 1\,600$	180
$1\,600 < I_C$	240

B.7.2.7 Verification of impulse withstand current of closed contacts

The requirements of this test shall be in accordance with EN 61643-11 with the following parameters:

— pulse form: 10/350 µs;

— number of repetitions: 3;

— determination of limit (catalogue specification);

— measurement of I^2t.

Contacts shall be capable to withstand each pulse without welding.

B.7.2.8 Verification of short circuit making capacity

The requirements of this test shall be in accordance with EN 60947-4-1:2010, 9.3.4 with the following parameters:

— circuit is closed by the contactor;

— testing time: ≤ 100 ms (external switch off or usage of fuse);

— test voltage: U_e;

— peak current: 8 × I_{th} (minimum);

— time constant L/R: 1 ms;

— measurement of I^2t;

— number of repetitions: 5.

Contacts shall be capable to withstand each making operation without welding.

B.7.2.9 Special tests

B.7.2.9.1 Verification of vibration

The requirements of this test shall be in accordance with EN 60068-2-6 with the following parameters:

— basic motion: sinusoidal;

— amplitude of acceleration: 10 g;

— frequency range: 10 … 500 Hz;

— number of cycles: 20 (test duration: 3,75 h per axis);

— axis: X, Y, Z;

— contact monitoring during vibration: Yes.

The test report shall include the contacts opening characteristics.

B.7.2.9.2 Verification of shock

The requirements of this test shall be in accordance with EN 60068-2-27 with the following parameters:

Continuous shock:

— pulse form: semi-sinusoidal;

— pulse length: 10 ms;

— acceleration: 20 g;

— axis: +X, -X, +Y, -Y, +Z, -Z;

— number of pulses (each axis and direction): 1 000;

— contact monitoring during vibration: Yes.

The test report shall include the contacts opening characteristics.

Transport shock:

— pulse form: semi-sinusoidal;

— pulse length: 10 ms;

— acceleration: 20 g;

— number of cycles: 20 (test duration: 3,75 h per axis);

— axis: +X, -X, +Y, -Y, +Z, -Z;

— number of pulses (each axis and direction): 1 000;

— contact monitoring during vibration: No.

B.7.2.9.3 Verification of mechanical durability

The requirements of this test shall be in accordance with EN 60947-4-1:2010, Annex B.

B.8 Type test sequences

B.8.1 Kind of tests

Type tests are grouped together in sequences as shown in Table B.9.

For all sequences the tests shall be carried out in the order listed.

A new sample may be used for each sequence.

In the test sequence IV (other test) vibration and shock are followed by verification of dielectric withstand and verification of operating limits. Same procedure shall be used for mechanical durability.

A routine test (see B.7.1.3) shall be carried out on every sample before the type test.

Table B.9 — List of test sequences

Test sequences	Tests
I General performance characteristics	Operating limits
	Temperature rise
	Dielectric properties
	Making and breaking capacity
	Verification of dielectric withstand
	Verification of temperature rise
II Operational performance	Conventional operational performance
	Verification of dielectric withstand
	Verification of temperature rise
III Performance under short-circuit conditions	Impulse withstand current
	Short circuit making capacity
	Verification of dielectric withstand
	Verification of temperature rise
IV Other tests	Vibration
	Shock
	Mechanical durability
	Verification of dielectric withstand
	Verification of operating limits