

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Railway applications – Fixed installations – Particular requirements for a.c. switchgear –

Part 1: Single-phase circuit-breakers with U_n above 1 kV

Applications ferroviaires – Installations fixes – Exigences particulières pour appareillage à courant alternatif –

Partie 1: Disjoncteurs monophasés avec U_n supérieur à 1 kV



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RAILWAY APPLICATIONS – FIXED INSTALLATIONS – PARTICULAR REQUIREMENTS FOR AC SWITCHGEAR –

Part 1: Single-phase circuit-breakers with U_n above 1 kV

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International Standard IEC 62505-1 has been prepared IEC technical committee 9: Electrical equipment and systems for railways. This standard is based on EN 50152-1.

The text of this standard is based on the following documents:

FDIS	Report on voting
9/1219/FDIS	9/1232/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 62505 series, under the general title *Railway applications – Fixed installations – Particular requirements for a.c. switchgear*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

Withdrawn

INTRODUCTION

The IEC Standard series 62505 is divided as follows.

- Part 1: Single-phase circuit-breakers with U_n above 1 kV.
- Part 2: Single-phase disconnectors, earthing switches and switches with U_n above 1 kV.
- Part 3-1: Measurement, control and protection devices for specific use in a.c. traction systems – Application guide
- Part 3-2: Measurement, control and protection devices for specific use in a.c. traction systems – Single-phase current transformers
- Part 3-3: Measurement, control and protection devices for specific use in a.c. traction systems – Single-phase inductive voltage transformers

IEC 62505-1 is to be used in conjunction with IEC 62271-100 (2008).

The essential requirements of IEC 62271-100 have been transcribed in this International Standard. Other complementary clauses of IEC 62271-100 are mentioned in this Standard. Where a particular clause of IEC 62271-100 is not mentioned, but is not referred as "not applicable" in this Standard, that clause applies as far as reasonable. Where this Standard states "addition" or "replacement", the relevant text of IEC 62271-100 is to be adapted accordingly.

The numbering of clauses in the IEC 62271 series is not used in this Standard. The numbering in square brackets refers to the numbering of clauses in IEC 62271.

NOTE 1 Where terms defined in IEC 62271-100 conflict with definitions of the same terms as given in IEC 60050-811:1991 or of the other railway applications documents listed in the normative references, the definitions used in IEC 62271-100 are to be used.

NOTE 2 The suffix N which appears in this Standard for rated values is not present in IEC 62271-100.

RAILWAY APPLICATIONS – FIXED INSTALLATIONS – PARTICULAR REQUIREMENTS FOR AC SWITCHGEAR –

Part 1: Single-phase circuit-breakers with U_n above 1 kV

1 Scope

This part of IEC 62505 is applicable to single-phase a.c. one-pole circuit-breakers designed for indoor or outdoor fixed installations for operation at frequencies of 16,7 Hz, 50 Hz and 60 Hz on traction systems having an U_{Nm} above 1 kV up to 52 kV.

This International Standard is also applicable to two-pole circuit-breakers when connected in the following manner: one pole supplying the connection to the contact line of the track, the second pole supplying the connection to the feeder cable which runs alongside the same track and which is used to boost the track voltage at regular intervals in combination with autotransformers. The centre of this circuit is connected to earth.

This Standard is also applicable to the operating devices of circuit-breakers and to their auxiliary equipment.

This Standard does not address circuit-breakers with dependent manual operating mechanism.

NOTE A rated short-circuit making current cannot be specified for these circuit-breakers and the use of these mechanisms may give reasons for the objection based on their safety in operation.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60044-1:1999, *Instrument transformers – Part 1: Current transformers*

IEC 60850:2007, *Railway applications – Supply voltages of traction systems*

IEC 62271-1:2007, *High-voltage switchgear and controlgear – Part 1: Common specifications*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*

IEC 62271-102:2003, *High-voltage switchgear and controlgear – Part 102: Alternating-current disconnectors and earthing switches*

IEC 62497-1, *Railway applications – Insulation co-ordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62271-1 and IEC 62271-100, and the following apply:

3.1

single-pole circuit-breaker

circuit-breaker with one electrically separated conducting path for the main circuit suitable for use in a single phase circuit

NOTE The construction arrangement of this device is in principle identical to one phase of a three-phase circuit-breaker.

3.2

two-pole circuit-breaker

circuit-breaker with two independent electrically separated conducting paths for the main circuit

NOTE 1 The two paths may be connected in series for use in a single phase circuit where the establishment and the separation of the two paths are simultaneous.

NOTE 2 The construction arrangement of this device is in principle identical to two phases of a three phase circuit-breaker.

3.3

index of definitions

same as in 3.8 of IEC 62271-100, but amended according to the definitions above

4 Service conditions

Clause 2 of IEC 62271-1:2007 is applicable with the following addition:

The equipment covered by this Standard shall be suitable for installation in trackside locations subject to vibrations from passing trains, airborne iron dust contamination from train brakes and shall meet the electromagnetic compatibility (EMC) requirements.

For special service conditions, agreement shall be made between purchaser and supplier.

5 Rating

5.1 General

A circuit-breaker in correct condition of maintenance and adjustment shall be able to withstand all stresses that occur in service provided that these do not exceed its rated characteristics.

The characteristics of a circuit-breaker, including its operating devices and auxiliary equipment, that shall be used to determine the rating are the following:

Rated characteristics to be given for all circuit-breakers:

- a) rated voltage;
- b) rated insulation level;
- c) rated frequency;
- d) rated normal current;
- e) rated short-time withstand current;
- f) rated peak withstand current;
- g) rated duration of short circuit, for circuit-breakers not fitted with direct over-current release;
- h) rated supply voltage of closing and opening devices and of auxiliary circuits;
- i) rated supply frequency of closing and opening devices and of auxiliary circuits;

- j) rated pressures of compressed gas supply for operation and for interruption, if applicable;
- k) rated gas pressure for sealed gas pressure devices;
- l) rated short-circuit breaking current;
- m) rated transient recovery voltage for terminal faults;
- n) rated short-circuit making current;
- o) rated operating sequence.

5.2 Rated voltage (U_{Ne})

The rated voltage U_{Ne} shall be chosen taking into consideration the maximum voltage level suitable to be permanently applied to the circuit-breaker (i.e. highest permanent voltage U_{max1} as defined in IEC 60850).

NOTE This standard makes reference to the values U_{max1} and U_{max2} , taken from IEC 60850. These values are used to express the values of U_{Ne} , which are expected to be equal or higher than U_{max1} . The insulation characteristics are also expected to be suitable to allow, when required in Clause 5 and Clause 7, the highest non-permanent voltage U_{max2} .

5.3 Nominal voltage (U_n)

The nominal voltage U_n shall be one of the voltages listed in Table 1 of IEC 60850.

5.4 Rated insulation voltage (U_{Nm}) [4.2]

The value of the rated insulation voltage U_{Nm} , of the rated impulse withstand voltage U_{Ni} and of the power-frequency withstand voltage U_a shall be as given in Table 1, taken from the values listed in IEC 62497-1.

Withholding

Table 1 – Nominal voltages (U_n), rated impulse voltages (U_{Ni}) and short-duration power-frequency (AC) test levels U_a for circuits connected to the contact line

U_n	U_{Nm}	U^a	OV	U_{Ni} (1,2/50 μ s)	U_a
kV	kV	kV		kV	kV
IEC 60850	IEC 62497-1	(IEC 62271-1)	IEC 62497-1		
15	17,25	(24,0)	3	95	38 or 50 ^b
			4	125	50
		(36,0)	3	145	70
			4	170	70 or 95 ^b
20	24	N/A	3		
			4	150	50
25	27,5 ^c	N/A	3	170	70 or 95 ^b
			4	200 ^c	95
		(52,0)	3	200 ^c	95
			4	250	95
	30	N/A	3		
			4	200	70
See Note 3	52,0	(72,5)	3	250	95
			4	300	140
NOTE 1 The choice of the different values of U_{Ni} given for the same U_n, depends upon the highest non-permanent voltages (such as U_{max2} of IEC 60850) actually appearing in the system. NOTE 2 OV3 and OV4 are overvoltage categories depending on the system configuration and degree of overvoltage control (inherent control or protective control) as given in IEC 62497-1. NOTE 3 Take care that in those cases in which for circuit reasons it may happen that a higher voltage is applied to the device terminals in transient conditions, a higher rated insulation voltage between contacts might be necessary (e. g. $U_{Nm} = 52$ kV for $U_n = 25$ kV).					
^a The values in brackets give the rated voltages according to Table 1a of IEC 62271-1 having the nearest equivalence in test withstand voltages with the test values for single-phase voltages given in this Table. ^b At purchaser's choice or by agreement ^c These values are used in railway application only and are not of wide industrial use.					

5.5 Rated frequency [4.3]

Subclause 4.3 of IEC 62271-1 is applicable.

5.6 Rated normal current and temperature rise [4.4]

Subclauses 4.4.1 and 4.4.2 of IEC 62271-1 are applicable with the following additions:

The values of rated currents shall be selected from the following standard values:

400 A; 630 A; 800 A; 1 250 A; 1 600 A; 2 000 A; 2 500 A; 4 000 A.

NOTE The above values are selected from the R 10 series, and, if required, higher values than those shown should also be selected from this series.

If the circuit-breaker is fitted with a series connected accessory, such as a direct over-current release, the rated normal current of the accessory is the r.m.s. value of the current which the

accessory shall be able to carry continuously without deterioration at its rated frequency, with a temperature rise not exceeding the values specified in Table 3 of IEC 62271-1.

Current transformers shall comply with IEC 60044-1.

5.7 Rated short-time withstand current [4.5]

Subclause 4.5 of IEC 62271-1 is applicable with the following addition:

The rated short-time withstand current is equal to the rated short-circuit breaking current (see 5.13).

5.8 Rated peak withstand current [4.6]

Subclause 4.6 of IEC 62271-1 is applicable with the following addition:

The rated peak withstand current is equal to the rated short-circuit making current (see 5.16).

5.9 Rated duration of short-circuit [4.7]

Subclause 4.7 of IEC 62271-1 is applicable with the following addition:

A rated duration of a short-circuit need not be assigned to a circuit-breaker fitted with a direct over-current release provided that, when connected in a circuit the prospective breaking current of which is equal to its rated short-circuit breaking current, the circuit-breaker shall be capable of carrying the resulting current for the break-time required by the circuit-breaker with the over-current release set for the maximum setting and maximum time delay if adjustable, when operating in accordance with its rated operating sequence (see 7.6.1).

5.10 Rated supply voltage of closing and opening devices and auxiliary circuit [4.8]

Subclause 4.8 of IEC 62271-1 is applicable.

5.11 Rated supply frequency of closing and opening devices and auxiliary circuits [4.9]

Subclause 4.9 of IEC 62271-1 is applicable.

5.12 Rated pressures of compressed gas supply for operation and for interruption [4.10]

The value of the pressures to which the circuit-breaker is filled.

Subclause 4.10 of IEC 62271-1 is applicable to the pressure of the compressed gas supply for operation.

No standard values are given for rated pressure of compressed gas supply for interruption.

The rated pressures of compressed gas shall be given by the manufacturer of the circuit-breaker.

5.13 Rated short-circuit breaking current (I_{Nss}) [4.101]

5.13.1 General [4.101]

The rated short-circuit breaking current (I_{Nss}) is the highest short-circuit current which the circuit-breaker shall be capable of breaking under the conditions of use and behaviour prescribed in this standard in a circuit having a power-frequency recovery voltage

corresponding to the rated voltage of the circuit-breaker and having a transient recovery voltage equal to the rated value specified in 5.14.1.

Short-line fault interruption is not a requirement for circuit-breakers to this standard. Such a requirement shall be deemed to be special and subject to agreement between purchaser and supplier.

The rated short-circuit breaking current is characterized by two values:

- the r.m.s. value of its a.c. component, termed "rated short-circuit current" for shortness, and
- the percentage d.c. component.

NOTE 1 If the d.c. component does not exceed 20 %, the rated short-circuit breaking current is characterized only by the r.m.s. value of its a.c. component.

For determination of the a.c. and d.c. components, see Figure 8 of IEC 62271-100.

The circuit-breaker shall be capable of breaking any short-circuit current up to its rated short-circuit breaking current containing any a.c. component up to the rated value and associated with it any percentage d.c. component up to that specified, under the conditions mentioned above.

The following applies to a standard circuit-breaker:

- a) At voltages below the rated voltage, it will be capable of breaking its rated short-circuit breaking current.

NOTE 2 For circuit-breakers having proved rated short-circuit breaking currents I_{Nss} at two different rated voltages U_{Ne} , intermediate characteristics may be assigned from the straight line drawn between the two proved rating points on a plot of $\log U$ versus $\log I$. In case of doubt, tests should be carried out to check the validity of the interpolation.

- b) At voltages above the rated voltage, no short-circuit breaking current is guaranteed except to the extent provided for in 5.18.

5.13.2 AC component of the rated short-circuit breaking current [4.101.1]

The r.m.s. value of the a.c. component of the rated short-circuit breaking current shall be selected from the values shown in Table 6.

NOTE The values in Table 6 are selected from the R 10 series, and, if required, higher values than those shown should also be selected from this series.

5.13.3 DC component of the rated short-circuit breaking current [4.101.2]

The value of the percentage d.c. component shall be determined as follows:

- a) For a circuit-breaker which can be tripped by a short-circuit current without the aid of any form of auxiliary power, the percentage d.c. component shall correspond to a time interval τ equal to the minimum opening time of the circuit-breaker.
- b) For a circuit-breaker which can be tripped solely by a form of auxiliary power, the percentage d.c. component shall correspond to a time interval τ equal to the minimum opening time of the circuit-breaker plus one-half cycle of rated frequency.

The minimum opening time mentioned above is the shortest opening time of the circuit-breaker obtainable under any service conditions whether in a breaking operation or a make-break operating cycle.

The percentage value of the d.c. component is dependent on the time interval τ . Standard values and special case values are given in Figure 9 of IEC 62271-100.

5.14 Rated transient recovery voltage for terminal faults [4.102]

5.14.1 General

The rated transient recovery voltage (TRV) for terminal faults, relating to the rated short-circuit breaking current in accordance with 5.13.1, is the reference voltage which constitutes the limit of the prospective transient recovery voltage of circuits which the circuit-breaker shall be capable of breaking in the event of a short-circuit at its terminals.

5.14.2 Representation of transient recovery voltage waves [4.102.1]

The wave form of transient recovery voltages varies according to the arrangement of actual circuits.

NOTE 1 The transient recovery voltage approximates to a damped single frequency oscillation. This wave form is adequately represented by an envelope consisting of two line segments defined by means of two parameters. Methods of drawing TRV envelopes are given in IEC 62271-100, Annex F.

The influence of local capacitance on the source side of the circuit-breaker produces a slower rate of rise of the voltage during the first few microseconds of the TRV. This is taken into account by introducing a time delay.

It appears that every part of the TRV wave may influence the interrupting capability of a circuit-breaker. The very beginning of the TRV may be of importance for some types of circuit-breakers.

NOTE 2 This part of TRV, called initial TRV (ITRV), is caused by the initial oscillations of small amplitude due to reflections from the first major discontinuity along the busbar. The ITRV is a physical phenomenon which is very similar to the short-line fault. Compared with the short-line fault, the first voltage peak is rather low, but the time to the first peak is extremely short, that is within the first microseconds after current zero. Therefore the thermal mode of interruption may be influenced.

NOTE 3 Since the ITRV is proportional to the busbar surge impedance and to current, the ITRV requirement can be neglected for metal-enclosed switchgear and in most railway applications, because of the low surge impedance and for all switchgear with a rated short-circuit breaking current of less than 50 kA.

NOTE 4 If the circuit-breaker has a short-line fault rating the ITRV requirements are considered to be covered if the short-line fault tests are carried out using a line without time delay (see 7.10.5.2).

5.14.3 Representation of rated TRV [4.102.2]

The following parameters are used for the representation of rated TRV:

- a) four-parameter reference line not applicable;
- b) two-parameter reference line (see Figure 11 of IEC 62271-100):
 - u_c = reference voltage (TRV peak value), in kV,
 - t_3 = time to reach u_c , in ms;
- c) delay line of TRV (see Figure 11 of IEC 62271-100):
 - t_d = time delay, in ms,
 - u' = reference voltage, in kV,
 - t' = time to reach u' , in ms.

The delay line starts on the time axis at the rated time delay and runs parallel to the first section of the reference line of rated TRV and terminates at the voltage u' (time-coordinate t');

- d) not applicable.

5.14.4 Standard values of rated TRV [4.102.3]

Standard values of rated TRV for single-phase circuit-breakers are given in Table 2.

Where the purchaser has requirements for higher severities of TRV than those in Table 2, these shall be identified in purchaser's specification.

**Table 2 – Standard values of rated transient recovery voltage –
Representation by two parameters – Single pole circuit-breaker**

U_n kV	U_{max1}^a kV	U_{max2}^a kV	TRV peak value U_c kV	t_3 μs	t_d μs	u' kV	t' μs	Rate of rise U_c/t_3 kV/μs
15	17,25	18	36	108	16,0	12	52	0,33
20	24,0	N/A	41	82	12,3	14	40	0,50
25	27,5	29	57	132	20,0	19	64	0,43
25	30,0	N/A	62	103	15,5	21	50	0,60
^a See IEC 60850. N/A not applicable.								

with:

$$U_c = 1,4 \times \sqrt{2} \times U_{max2};$$

1,4 = amplitude factor (see IEC 62271-100);

$$u' \approx \frac{U_c}{3};$$

$$t' = \frac{t_3}{3} + t_d;$$

$$t_d = 0,15 \times t_3.$$

NOTE 1 The values in Table 2 are minimum values. The values of Table 1 of IEC 62271-100 may be adopted with $U(\text{IEC 62271-100}) = \sqrt{3} \times U_{max2}$ and t_3 unchanged.

NOTE 2 The TRV figures are for a single-pole circuit-breaker. The equivalent three-phase circuit-breaker is tested with u_c and U_c/t_3 values equal to 1,5 times those shown in Table 2. Values for the time delay t_d are to be in accordance with Table 1a of IEC 62271-100.

5.15 Standard values of initial transient recovery voltage [4.102.4]

Subclause 4.102.4 of IEC 62271-100 is not applicable to single-phase circuit-breakers for railway applications.

5.16 Rated short-circuit making current [4.103]

The rated short-circuit making current (see Figure 8 of IEC 62271-100) of a circuit-breaker is that which corresponds to the rated voltage, and shall be 2,5 times the r.m.s. value of the a.c. component of its rated short-circuit breaking current (see 5.13).

5.17 Rated operating sequence [4.104]

There are two alternative rated operating sequences as follows:

O - t - CO - t' - CO

Unless otherwise specified:

$t = 180$ s for circuit-breakers not intended for rapid auto-reclosing;

NOTE 1 Instead of $t' = 180$ s, $t' = 60$ s is also used for circuit-breakers not intended for rapid auto-reclosing.

$t = 0,3$ s for circuit-breakers intended for rapid auto-reclosing (dead time);

$t' = 180$ s.

NOTE 2 Instead of $t' = 180$ s, other values: $t' = 15$ s (for rated voltages less than or equal to 52 kV) and $t' = 60$ s are also used for circuit-breakers intended for rapid auto-reclosing.

CO - t'' - CO

with:

$t'' = 15$ s, for circuit-breakers non intended for rapid auto-reclosing;

where:

O represents an opening operation;

CO represents a closing operation followed immediately (that is, without any intentional time-delay) by an opening operation;

t , t' and t'' are time-intervals between successive operations.

NOTE 3 t , t' and t'' should always be expressed in s.

If the dead time is adjustable, the limits of adjustment shall be specified.

5.18 Rated out-of-phase breaking current [4.106]

If required by the purchaser, a single-pole circuit-breaker may be used in service in the open position with two different phases across its open terminals, such as a circuit-breaker used for supplying an alternative feed in emergency conditions. This test shall be performed at a rating specified by the purchaser based on the maximum fault current which can exist for this condition. This out-of-phase breaking current cannot exceed 50 % of the rated short-circuit current with two phases displaced by a maximum of 120° or 180°. The purchaser shall identify if out-of-phase breaking current is applicable and which condition applies.

NOTE The 120° case occurs when voltage is derived from two different phases of a three-phase system. The 180° case typically occurs when the neutral is the central point of a single-phase system (currently indicated as $\pm U_n$ system).

The transient recovery voltage shall be as given in Tables 3 and 4.

Table 3 – Standard values of prospective transient recovery voltage for 120° out-of-phase breaking–Representation by two parameters – Single pole circuit-breaker

Nominal voltage U_n kV	$U_{\max 1}^a$ kV	$U_{\max 2}^a$ kV	TRV peak value U_c kV	Time t_3 μs	Rate of rise U_c/t_3 kV/μs
15	17,25	18	55	216	0,25
20	24,0	N/A	61	164	0,37
25	27,5	29	88	264	0,33
25	30,0	N/A	92	206	0,45
^a See IEC 60850. N/A not applicable.					

with:

$$U_c = 1,25 \times \sqrt{2} \times \sqrt{3} \times U_{\max 2} ;$$

1,25 = corrected amplitude factor (see IEC 62271-100);

$\sqrt{3}$ = factor of maximum phase-displacement;

$t_3 = 2 \times t_3$ (of Table 2).

Table 4 – Standard values of prospective transient recovery voltage for 180° out-of-phase breaking – Representation by two parameters – Single pole circuit-breaker

Nominal voltage U_n kV	$U_{\max 1}^a$ kV	$U_{\max 2}$ kV	TRV peak value U_c kV	Time t_3 μs	Rate of rise U_c/t_3 kV/μs
15	17,25	18	64	216	0,30
20	24,0	N/A	70	164	0,43
25	27,5	29	102	264	0,39
25	30,0	N/A	106	206	0,51
^a See IEC 60850. N/A not applicable.					

with:

$$U_c = 1,25 \times \sqrt{2} \times 2 \times U_{\max 2} ;$$

1,25 = corrected amplitude factor (see IEC 62271-100);

2 = factor of phase opposition;

$$t_3 = 2 \times t_2 \text{ (of Table 2).}$$

Where the purchaser has requirements for higher severities of TRV than those given in Tables 3 and 4, these shall be identified in the purchaser's specification.

5.19 Rated line-charging breaking current [4.107.1]

When specified by the purchaser the circuit-breaker shall be capable of breaking the capacitive current of the feeder cable or the catenary at a voltage value of not less than $U_{\max 1}$ (see IEC 60850), and with a current not exceeding 10 A.

5.20 Rated cable-charging breaking current [4.107.2]

The rated cable-charging breaking current is the maximum cable-charging current that the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this Standard and without exceeding the appropriate maximum permissible switching overvoltages specified by the manufacturer. Suggested values are given in Table 5.

The specification of rated cable-charging breaking current to a circuit-breaker is not mandatory but is made on request, and is considered unnecessary for circuit-breakers of rated voltages equal to or less than 24 kV. If assigned, it is recommended that the rated cable-charging breaking current be 50 A for 15 kV systems and 80 A for 25 kV systems.

5.21 Rated single capacitor bank breaking current [4.107.3]

The rated single capacitor bank breaking current is the maximum capacitor current that the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard and without exceeding the maximum permissible switching overvoltages specified by the manufacturer. Suggested values are given in Table 5, columns B.

NOTE 1 This breaking current refers to the switching of a shunt capacitor bank where no shunt capacitors are connected to the source side of the circuit-breaker.

The specification of a rated single capacitor bank breaking current is not mandatory.

NOTE 2 Values of rated single capacitor bank breaking current should be selected from the R 10 series and with a current not exceeding 200 A unless otherwise agreed between purchaser and supplier.

5.22 Rated back-to-back capacitor bank breaking current [4.107.4]

The rated back-to-back capacitor bank breaking current is the maximum capacitor current that the circuit-breaker shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard and without exceeding the maximum permissible switching overvoltages specified by the manufacturer. Suggested values are given in Table 5, columns B.

The specification of a rated back-to-back capacitor bank breaking current is not mandatory.

NOTE 1 This breaking current refers to the switching of a shunt capacitor bank where one or several shunt capacitor banks are connected to the source side of the circuit-breaker giving an inrush making current equal to the rated capacitor bank inrush making current.

NOTE 2 Values of rated back-to-back capacitor bank breaking currents should be selected from the R 10 series and with a current not exceeding 200 A unless otherwise agreed between purchaser and supplier.

NOTE 3 Similar conditions could apply for the switching of cables.

5.23 Rated capacitor bank inrush making current [4.107.5]

The rated capacitor bank inrush making current is the peak value of the current that the circuit-breaker shall be capable of making at its rated voltage and with a frequency of the inrush current appropriate to the service conditions.

The specification of a rated capacitor bank inrush making current is mandatory for circuit-breakers that have a rated back-to-back capacitor bank breaking current.

Table 5 – Suggested values of maximum permissible switching overvoltage to earth

U_n	U_{Nm}	U_{max2}	U_{Ni}	$U_{max.earth}$			
				A		B	
kV	kV	kV	kV	kV ^a	p.u. ^b	kV ^a	p.u. ^b
15	24	18	170	97	3,8	64	2,5
25	36	29	250	144	3,5	103	2,5
^a Peak value.							
^b $U_{max2} \times \sqrt{2}$.							

NOTE 1 Values of rated capacitor bank inrush making currents should be selected from the R 10 series and with a rated current not exceeding 200 A unless otherwise agreed between purchaser and supplier.

NOTE 2 In service, the frequency of the inrush current is normally in the range 2 kHz - 5 kHz.

NOTE 3 The circuit-breaker is considered to be suitable for any frequency of the inrush current lower than that for which it has been tested.

NOTE 4 The values shown in Table 5 apply only to the test conditions of 7.15. Other overvoltages such as, for instance, those appearing when reclosing a line with trapped charges and when breaking a small inductive current as well as phase-to-phase overvoltages, are not covered by this Table.

NOTE 5 The values shown in Table 5 cannot always guarantee that phase-to-phase flashovers will not occur.

NOTE 6 The values of columns A of Table 5 apply to circuit-breakers for general use intended for switching unloaded lines and cables of the types most generally used in power systems.

The values of columns B of Table 5 apply to circuit-breakers for special use intended for switching capacitor banks or no-load lines and cables in supply systems where there are special insulation co-ordination problems such as, for instance, limitation of energy absorption by surge diverters, spark-over of spark-gaps, etc.

5.24 Rated time quantities [4.109]

5.24.1 General

Rated values may be assigned to the following time quantities:

- opening time;
- break time;
- closing time;
- open-close time;
- reclosing time;
- close-open time.

Rated time quantities are based on:

- rated values for supply voltages of closing and opening devices and auxiliary circuits (see 5.10);
- rated value for supply frequency of closing and opening devices and auxiliary circuits (see 5.11);
- rated values for pressures of compressed gas supply for operation and for interruption (see 5.12);
- rated value for pressure of hydraulic supply for operation;
- an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$. If tests are carried out at other ambient temperatures, agreement between manufacturer and user may be necessary for the interpretation of the results.

NOTE Usually it is not practical to assign a rated value of make time or of make-break time due to the variation of the pre-arcing time.

5.24.2 Rated break time [4.109.1]

The maximum break time determined during test-duties T30, T60 and T100s of 7.12.2, 7.12.3 and 7.12.4 with the circuit-breaker operated at auxiliary supply voltage and frequency and pressures of pneumatic or hydraulic supply at their rated values at an ambient air temperature of $20\text{ °C} \pm 5\text{ °C}$ (see 5.24.1) shall not exceed the rated break time.

NOTE 1 According to 7.8.3 the basic short-circuit test-duties should be carried out at minimum voltage or pressure of the operating devices. In order to verify the rated break time during these test-duties the recorded maximum break time should be amended to take account of the lower auxiliary supply voltage and pressure as follows:

$$t_b \geq t_1 - (t_2 - t_3);$$

where:

- t_b is the rated break time;
- t_1 is the maximum recorded break time during test-duties T30, T60 and T100s;
- t_2 is the opening time recorded on no-load with auxiliary supply voltage and pressures of compressed gas supply as used during test-duties T30, T60 and T100s;
- t_3 is the rated opening time.

If the break time determined according to this procedure exceeds the rated break time, the test-duty which has given the longest break time may be repeated with auxiliary supply voltage and frequency and pressure of pneumatic or hydraulic supply at their rated values and if applicable, at rated pressure of the interrupting medium.

NOTE 2 The break time during a make-break operation of test-duty T100s should not exceed the rated break time by more than 0,5 cycle.

5.25 Co-ordination of rated values

Co-ordinated values of rated voltages (5.2), short-circuit breaking currents (5.13) and rated normal currents (5.6) are given in Table 6, which is to be used as a guide for preferred values.

Table 6 – Co-ordination table of rated values for circuit-breakers

Basic voltages			Rated short circuit breaking current I_{sc} kA	Rated normal current I_n A							
U_n kV	U_{Nm} kV	U^a kV									
15 ^b	17,5 ^b	(24)	8 12,5 16 20 25 31,5 40 50	400	630 630 630		1 250 1 250 1 250 1 250 1 250 1 250 1 250	1 600 1 600 1 600 1 600 1 600 1 600 1 600	2 000 2 000 2 000 2 000 2 000 2 000 2 000	2 500 2 500 2 500 2 500 2 500 2 500 2 500	4 000 4 000 4 000 4 000 4 000 4 000 4 000
15 or 25 ^{b)}	24,0 27,5 ^{b)}	(36) N/A	8 12,5 16 20 25 31,5 40 50		630 630 630		1 250 1 250 1 250 1 250 1 250 1 250 1 250	1 600 1 600 1 600 1 600 1 600 1 600 1 600	2 000 2 000 2 000 2 000 2 000 2 000 2 000	2 500 2 500 2 500 2 500 2 500 2 500 2 500	4 000 4 000 4 000 4 000 4 000 4 000 4 000
20	24	N/A	12,5 20 25 40 50 63		600 600 600		1 200 1 200 1 200 1 200 1 200		2 000 2 000 2 000 2 000 2 000	3 000 3 000 3 000 3 000 3 000	4 000 4 000 4 000 4 000 4 000
25	30	N/A	12,5 16 25 31,5 40		600 600 600		1 200 1 200 1 200 1 200 1 200		2 000 2 000 2 000 2 000 2 000	3 000 3 000 3 000 3 000 3 000	
25	36,0	(52)	8 12,5 20			800	1 250 1 250 1 250	1 600	2 000	2 500	
	52,0	(72,5)	12,5 16 20 31,5 50			800 800	1 250 1 250 1 250 1 250 1 250	1 600 1 600 1 600 1 600 1 600	2 000 2 000 2 000 2 000 2 000	2 500 2 500 2 500 2 500 2 500	4 000
^a The values in brackets give the rated voltages according to Table 1a of IEC 62271-1 having the nearest equivalence in test withstand voltages with the test values for single-phase equipment given in this Table. ^b These values are used in railway applications only and are not of wide industrial use. N/A not applicable.											

6 Design and construction [5]

6.1 Requirements for liquids in circuit-breakers [5.1]

Subclause 5.1 of IEC 62271-1 is applicable.

6.2 Requirements for gases in circuit-breakers [5.2]

Subclause 5.2 of IEC 62271-1 is applicable.

6.3 Earthing of circuit-breakers [5.3]

Subclause 5.3 of IEC 62271-1 is applicable.

6.4 Auxiliary equipment [5.4]

Auxiliary equipment is used in the control and auxiliary circuits of circuit-breakers.

Subclause 5.4 of IEC 62271-1 is applicable with the following additions:

- Connections shall withstand the stresses imposed by the circuit-breaker, especially those due to mechanical forces during operations.
- In the case of outdoor circuit-breakers all auxiliary equipment including the wiring shall be adequately protected against dust, rain and humidity.
- Where auxiliary switches are used as position indicators, they shall indicate the end position of the circuit-breaker at rest, open or closed.
- Where special items of control equipment are used, they shall operate within the limits specified for supply voltages of auxiliary and control circuits, quenching and operating media, and be able to switch the loads which are stated by the circuit-breaker manufacturer.
- Special items of auxiliary equipment such as liquid-indicators, pressure indicators, relief valves, filling and draining equipment, heating and interlock contacts shall operate within the limits specified for supply voltages of auxiliary and control circuits and/or within the limits of use of quenching and operating media.
- The power consumption of heaters at rated voltage shall be within the tolerance of $\pm 10\%$ of the values stated by the manufacturer.

6.5 Dependent power closing [5.5]

Subclause 5.5 of IEC 62271-1 is applicable with the following addition:

A circuit-breaker arranged for dependent power closing with external energy supply shall also be capable of opening immediately following the closing operation with the rated short-circuit making current.

6.6 Stored energy closing [5.6]

Subclause 5.6 of IEC 62271-1 is applicable with the following addition to the first paragraph:

A circuit-breaker arranged for stored energy closing shall also be capable of opening immediately following the closing operation with the short-circuit making current.

6.7 Operation of releases [5.8]

6.7.1 General

Subclause 5.8 of IEC 62271-1 is applicable with the following additions:

6.7.2 Over-current release [5.8.101]

6.7.2.1 Operating current [5.8.101.1]

An over-current release shall be marked with its rated normal current and its current setting range.

Within the current setting range, the over-current release shall always operate at currents of 110 % and above of the current setting, and shall never operate at currents of 90 % and below of this current setting.

6.7.2.2 Operating time [5.8.101.2]

For an inverse time delay over-current release, the operating time shall be measured from the instant at which the over-current is established until the instant at which the release actuates the tripping mechanism of the circuit-breaker.

The manufacturer shall provide tables or curves, each with the applicable tolerances, showing the operating time as a function of current, between twice and six times the operating current. These tables or curves shall be provided for the extreme current settings together with the extreme settings of time delay.

6.7.2.3 Resetting current [5.8.101.3]

If the current in the main circuit falls below a certain value, before the time delay of the over-current release has expired, the release shall not complete its operation and shall reset to its initial position.

The relevant information shall be given by the manufacturer.

6.7.3 Multiple releases [5.8.102]

If a circuit-breaker is fitted with multiple releases for the same function, a defect in one release shall not disturb the function in the others.

6.8 Low and high pressure interlocking devices [5.9]

All circuit-breakers having an energy storage in gas receivers or hydraulic accumulators (see 5.6.1 of IEC 62271-1) and all circuit-breakers except sealed pressure devices, using compressed gas for interruption (see 6.11) shall be fitted with low pressure interlocking device, and can also be fitted with high pressure interlocking devices, set to operate at, or within, the appropriate limits of pressure stated by the manufacturer.

6.9 Nameplates [5.10]

Subclause 5.10 of IEC 62271-1 is applicable with the following additions:

The nameplates of a circuit-breaker and its operating devices shall be marked in accordance with Table 10 of IEC 62271-100.

Coils of operating devices shall have a reference mark permitting the complete data to be obtained from the manufacturer.

Releases shall bear the appropriate data.

In addition, it is desirable that the year of manufacture of the circuit-breaker is recognizable.

The nameplate shall be visible in the position of normal service and installation.

6.10 Requirements for simultaneity of poles [5.101]

Subclause 5.101 of IEC 62271-100 is not applicable to single-phase circuit-breakers for railway applications.

6.11 General requirement for operation [5.102]

A circuit-breaker including its operating devices shall be capable of completing its rated operating sequence (5.17) in accordance with the relevant provisions of 6.5 to 6.8 and 6.12.

This requirement is not applicable to auxiliary manual operating devices; where provided, these shall be used only for maintenance and for emergency operation on a dead circuit.

6.12 Pressure limits of compressed gas for interruption in gas blast circuit-breakers [5.103]

The manufacturer shall state the maximum and minimum pressures of the compressed gas interruption at which the circuit-breaker is capable of performing according to its ratings and at which the appropriate low and high-pressure interlocking devices shall be set (see 6.8).

For double-pressure gas-blast circuit-breakers, the manufacturer may specify pressure limits at which the circuit-breaker is capable of each of the following performances:

- a) breaking its rated short-circuit breaking current, i.e. an "O" operation;
- b) making its rated short-circuit making current immediately followed by breaking its rated short-circuit breaking current, i.e. a "CO" operating cycle;
- c) for circuit-breakers intended for rapid auto-reclosing; breaking their rated short-circuit breaking current followed after a time interval t of the rated operating sequence (5.17) by making their rated short-circuit making current immediately followed by again breaking their rated short-circuit breaking current, i.e. an "O - t - CO" operating sequence.

The circuit-breakers shall be provided with energy storage of sufficient capacity for satisfactory performance of the appropriate operations at the corresponding minimum pressures stated.

Furthermore, for circuit-breakers having individual pumps or compressors the output of the pump or compressor and the capacity of the receivers shall be sufficient to provide for the performance of the rated operating sequence (5.17) at all currents up to the rated short-circuit making and breaking currents of the circuit-breaker. The pressure at the commencement of the operating sequence shall be equal to the appropriate minimum pressure stated by the manufacturer in accordance with the above requirements, and with the pump or compressor operating normally. When appropriate the manufacturer may specify pressure limits for the operation of the pump or compressor.

6.13 Vent outlet [5.104]

Vent outlets of circuit-breakers shall be so situated that a discharge of oil or gas or both will not cause electrical breakdown and is directed away from any location where persons may be present.

The construction shall be such that gas cannot collect at any point where ignition can be caused, during or after operation, by sparks arising from normal operation of the circuit-breaker or its auxiliary equipment.

6.14 Safety overpressure device

When specified by the purchaser, the circuit-breaker shall be equipped with a device allowing the release of accidental overpressures without breakages in the enclosure.

7 Type tests [6]

7.1 General

Clause 6 of IEC 62271-1 is applicable with the following additions:

The type tests also include:

- mechanical and environmental tests, including mechanical operation test at ambient air temperature, low and high temperature tests, humidity test, test to prove operation under severe ice conditions and static terminal load test (see 7.7);
- short-circuit making and breaking tests and out-of-phase tests, if applicable (see 7.8 to 7.14 as applicable);
- capacitive current switching tests, including line-charging, cable-charging, single capacitor bank and back-to-back capacitor bank tests (see 7.15);
- magnetizing and small inductive current switching tests (see 7.16).

NOTE It is to be noted that the circuit-breakers covered by this document do not exceed an U_{Nm} of 72,5 kV and are mainly single-pole circuit-breakers operating at one of the phase voltages. However some circuit-breakers may have line voltage across the open terminals. Two-pole circuit-breakers are often installed either in series on a single-phase circuit, or in phases displaced by 180° or on two different phases of a three-phase system. In the latter two cases, however, the two poles of the circuit-breaker are seldom required to operate simultaneously in making or breaking the circuit.

In principle, the individual type tests shall be made on a circuit-breaker in a new and clean condition, and the various type tests may be made at different times and at different locations.

Where tests are made on a circuit-breaker whose report of type tests has already been accepted, the responsibility of the manufacturer is limited by the specified values and not by the result obtained during the type tests previously made.

Details relating to records and reports of type tests for making, breaking and short time current performance are given in Annex C of IEC 62271-100.

7.2 Dielectric tests [6.2]

7.2.1 Ambient air conditions during tests [6.2.1]

Subclause 6.2.1 of IEC 62271-1 is applicable.

7.2.2 Wet test procedure [6.2.2]

Subclause 6.2.2 of IEC 62271-1 is applicable with the following addition:

NOTE For dead tank circuit-breakers, see Note of 7.2.7.

7.2.3 Condition of circuit-breaker during dielectric tests [6.2.3]

Subclause 6.2.3 of IEC 62271-1 is applicable.

7.2.4 Application of test voltage and test conditions [6.2.5]

Subclause 6.2.5 of IEC 62271-1 is applicable.

7.2.5 Test voltages [6.2.6]

Subclause 6.2.6 of IEC 62271-1 is applicable.

7.2.6 Lightning and switching impulse voltage tests [6.2.7.2, 6.2.7.3]

Subclauses 6.2.7.2 and 6.2.7.3 of IEC 62271-1 are applicable with the following addition.

Lightning impulse voltage tests

When the rated lightning impulse withstand voltages are chosen according to 5.4, a higher test voltage when testing the insulation across the open breaker may be required.

In these cases:

- the test voltage shall be subject to agreement between manufacturer and user. Requirements of IEC 62497-1 in respect to isolating voltages shall be taken into consideration;
- the first test series consists of the application, to each terminal, of 15 consecutive impulses at the peak value of the agreed voltage level, the opposite terminal being earthed. The other terminals (if any), the terminal to which the voltage is applied and the base, may be insulated in such a way as to prevent disruptive discharges to earth;
- the second test series consists of the application, to each terminal in turn, of 15 consecutive impulses at the rated withstand voltage U_{Ni} . The other terminals and the base shall be earthed.

7.2.7 Power-frequency voltage tests [6.2.7.1]

Subclause 6.2.7.1 of IEC 62271-1 is applicable with the following addition:

The test voltage values shall be in accordance with Table 1 and IEC 62497-1.

If during a wet test a disruptive discharge on external self-restoring insulation occurs, this test shall be repeated in the same test condition and the circuit-breaker shall be considered to have passed this test successfully if no further disruptive discharge occurs.

NOTE In the case of dead tank circuit-breakers, when the bushings have been previously tested according to the relevant EN/HD or IEC Standard, tests under wet conditions can be omitted.

7.2.8 Artificial pollution tests [6.2.8]

Subclause 6.2.8 of IEC 62271-1 is applicable with the following addition:

NOTE 1 Appropriate tests for checking the open breaker insulation are under consideration.

NOTE 2 To obviate the necessity of erecting large circuit-breakers for test purposes alone, in the case of circuit-breakers of modular construction one single module may be tested. In this case, however, the test severity is different from that of the test of the complete pole.

7.2.9 Partial discharge tests [6.2.9]

Subclause 6.2.9 of IEC 62271-1 is applicable with the following addition:

No partial discharge tests are required to be performed on the complete circuit-breaker.

However, in the case of circuit-breakers using components for which a relevant IEC or EN Standard exists including partial discharge measurements (e.g. for bushings see IEC 60137), evidence shall be produced by the manufacturer showing that those components have passed the partial discharge tests as laid down in the relevant EN or IEC Standard.

7.2.10 Tests on auxiliary and control circuits [6.2.10]

Subclause 6.2.10 of IEC 62271-1 is applicable.

7.3 Radio interference voltage (r.i.v.) tests [6.3]

Radio interference voltage tests shall be performed by agreement between manufacturer and purchaser.

Subclause 6.3 of IEC 62271-1 is applicable with the following addition:

Tests shall be performed on one pole of the circuit-breaker in both closed and open position.

7.4 Temperature-rise tests [6.5]

7.4.1 Conditions of the circuit-breaker to be tested [6.5.1]

Subclause 6.5.1 of IEC 62271-1 is applicable.

7.4.2 Arrangement of the equipment [6.5.2]

Subclause 6.5.2 of IEC 62271-1 is applicable with the following additions:

For a circuit-breaker not fitted with series connected accessories, the test shall be made with the rated normal current of the circuit-breaker.

For a circuit-breaker fitted with series connected accessories having a range of rated normal currents, the following tests shall be made:

- a) a test of circuit-breaker fitted with the series connected accessory having a rated normal current equal to that of the circuit-breaker, and made at the rated normal current of the circuit-breaker;
- b) a series of tests of the circuit-breaker fitted with the intended accessories, and made with currents equal to the rated normal current of each accessory.

If the accessories can be removed from the circuit-breaker, and if it is evident that the temperature rise of the circuit-breaker and of accessories do not appreciably influence each other, Test b) above may be replaced by a series of tests on the accessories alone.

7.4.3 Measurement of the temperature and the temperature rise [6.5.3]

Subclause 6.5.3 of IEC 62271-1 is applicable.

7.4.4 Ambient air temperature [6.5.4]

Subclause 6.5.4 of IEC 62271-1 is applicable.

7.4.5 Temperature-rise tests of the auxiliary equipment [6.5.5]

Subclause 6.5.5 of IEC 62271-1 is applicable.

7.4.6 Interpretation of the temperature-rise tests [6.5.6]

Subclause 6.5.6 of IEC 62271-1 is applicable.

7.5 Measurement of the resistance of the main circuit [6.4.1]

Subclause 6.4.1 of IEC 62271-1 is applicable.

7.6 Short-time withstand current and peak withstand current tests [6.6]

Subclause 6.6 of IEC 62271-1 is applicable.

7.6.1 Arrangement of the circuit-breaker and of the test circuit [6.6.1]

Subclause 6.6.1 of IEC 62271-1 is applicable with the following addition:

If the circuit-breaker is fitted with direct over-current releases, these shall be arranged for test with the coil of the minimum operating current set to operate at the maximum current and maximum time delay; the coil shall be connected to the source side of the test circuit. If the circuit-breaker can be used without direct over-current releases, it shall also be tested without them.

7.6.2 Test current and duration [6.6.2]

Subclause 6.6.2 of IEC 62271-1 is applicable with the following addition:

For circuit-breakers fitted with direct over-current releases, the rated operating sequence confined to opening operations only shall be performed. Where the test is made at rated voltage, then the prospective current value shall be used.

7.6.3 Behaviour of circuit-breaker during test [6.6.3]

Subclause 6.6.3 of IEC 62271-1 is applicable.

7.6.4 Conditions of circuit-breaker after test [6.6.4]

Subclause 6.6.4 of IEC 62271-1 is applicable with the following addition:

The condition of circuit-breakers fitted with direct over-current releases shall comply with 7.8.9.

7.7 Mechanical and environmental tests [6.101]

7.7.1 Miscellaneous provisions for mechanical and environmental tests [6.101.1]

7.7.1.1 Component tests [6.101.1.2]

When testing a complete circuit-breaker is not practicable, component tests may be accepted as type tests. The manufacturer should determine the components which are suitable for testing.

Components are separate functional sub-assemblies which can be operated independently of the complete circuit-breaker (e.g. breaking unit, operating mechanism).

When component tests are made the manufacturer shall prove that the mechanical stress on the component during the tests is not less than the mechanical stress applied to the same component when the complete circuit-breaker is tested.

Component tests shall cover all different types of components of the complete circuit-breaker, provided that the particular test is applicable to the component. The conditions for the type tests shall be derived from the normal or special service conditions and rated characteristics of the circuit-breaker.

Parts of auxiliary and control equipment which have been manufactured in accordance with relevant standards shall comply with these standards. The proper function of such parts in connection with the function of the other parts of the circuit-breaker shall be verified.

7.7.1.2 Characteristics and settings of the circuit-breaker to be recorded before and after the tests [6.101.1.3]

Before and after the tests the following operating characteristics or setting shall be recorded or evaluated if applicable:

- a) closing time;
- b) opening time;
- c) time spread between units of one pole;
- d) not applicable;
- e) recharging time of the operating device;
- f) consumption of the control circuit;

- g) consumption of the tripping device, possible recording of the current of releases;
- h) duration of opening and closing command impulse;
- i) tightness;
- j) gas densities or pressures;
- k) resistance of the main circuit;
- l) other important characteristics or settings as specified by the manufacturer.

And, if the design of the circuit-breaker permits, such measurements as:

- m) time-travel chart;
- n) closing speed;
- o) opening speed.

The above operating characteristics shall be recorded at:

- rated supply voltage and rated operating pressure;
- maximum supply voltage and maximum operating pressure;
- minimum supply voltage and minimum operating pressure;
- minimum supply voltage and maximum operating pressure.

7.7.1.3 Condition of the circuit-breaker during and after the tests [6.101.1.4]

During and after the tests, the circuit-breaker shall be in such a condition that it is capable of operating normally, carrying its rated normal current, making and breaking its rated short-circuit current and withstanding the voltage values according to its rated insulation level.

In general, these requirements are deemed to be fulfilled if:

- during the tests, the circuit-breaker operates on command and does not operate without command;
- during and after the tests, the characteristics measured according to 7.7.1.2 are within the tolerances given by the manufacturer;
- during and after the tests, all parts, including contacts, do not show undue wear;
- after the test, coated contacts are such that a layer of coating material remains at the contact area. If this is not the case the contacts shall be regarded as bare and the test requirements are fulfilled only if the temperature-rise of the contacts during temperature-rise test (according to 7.4) does not exceed the value permitted for bare contacts;
- during and after the tests, any distortion of mechanical parts is not such that it adversely affects the operation of the circuit-breaker or prevents the proper fitting of any replacement part;
- after the tests the insulating properties of the circuit-breaker in the open position shall be in essentially the same condition as before the tests. Visual inspection of the circuit-breaker after the tests is usually sufficient for verification of the insulating properties. In case of doubt, the conditions checking test according to 6.2.11 of IEC 62271-1 is deemed sufficient to prove the insulating properties. For circuit-breakers with sealed-for-life interrupters the condition check is mandatory.

7.7.1.4 Condition of auxiliary and control equipment during and after the tests [6.101.1.5]

During and after the tests, the following conditions for the auxiliary and control equipment shall be fulfilled:

- during the tests, care should be taken to prevent undue heating;
- during the tests, a set of contacts (both make and break auxiliary contacts) shall be arranged to switch the current of the circuits to be controlled (see 6.4);

- during and after the tests, the auxiliary and control equipment shall fulfil its functions;
- during and after the tests, capability of the auxiliary circuits of the auxiliary switches and of the control equipment shall not be impaired. In case of doubt, the tests according to 6.2.10 of IEC 62271-1 shall be performed;
- during and after the tests, the contact resistance of the auxiliary switches shall not be affected adversely. The temperature rise when carrying the rated current shall not exceed the specified values (see Table 3 of IEC 62271-1).

7.7.2 Mechanical operation test at ambient air temperature [6.101.2]

7.7.2.1 General [6.101.2.1]

The mechanical operation test shall be made at the ambient air temperature of the test location. The ambient air temperature should be recorded in the test report. Auxiliary equipment forming part of the operating devices shall be included.

The mechanical operation test consists of 5 000 operating cycles.

Except for circuit-breakers fitted with over-current releases, the test shall be made without voltage on or current in the main circuit.

For circuit-breakers fitted with over-current releases, approximately 10 % of the operating cycles shall be performed with the opening device energized by the current in the main circuit. The current shall be the minimum current necessary to operate the over-current release. For these tests, the current through over-current releases may be supplied by a suitable low-voltage source.

During the test, lubrication is allowed in accordance with the manufacturer's instructions, but no mechanical adjustment or other kind of maintenance is allowed.

The tested circuit-breaker shall be considered successfully tested if it retains its electrical and mechanical characteristics after the test.

7.7.2.2 Condition of the circuit-breaker before the test [6.101.2.2]

The circuit-breaker for the test shall be mounted on its own support and its operating mechanism shall be operated in the specified manner. It shall be tested according to its type as follows:

A two-pole circuit-breaker actuated by a single operating device and/or with all poles mounted on a common frame shall be tested as a complete unit.

A two-pole circuit-breaker in which each pole is actuated by a separate operating device may be tested regarding each pole as a separate circuit-breaker in respect of:

- closing speed;
- opening speed;
- power and strength of closing and opening mechanism;
- rigidity of structure.

7.7.2.3 Description of test [6.101.2.3]

The circuit-breaker shall be tested in accordance with Table 7.

Table 7 – Mechanical operation test at ambient temperature

Operating sequence	Control voltage and operating pressure	Number of operating sequences for circuit-breakers	
		autoreclosing	non-autoreclosing
C - t_a - O - t_a	minimum	1 250	1 250
	rated	1 250	1 250
	maximum	1 250	1 250
O - t - CO - t_a - C - t_a	rated	625	-
CO - t_a	rated	-	1 250

where:

O is the opening;

C is the closing;

CO is a closing operation followed immediately (i.e. without any intentional delay) by an opening operation;

t_a is the time between two operations which is necessary to restore the initial conditions and/or to prevent undue heating of parts of the circuit-breaker (this time can differ according the type of operation);

t = 0,3 s for circuit-breakers intended for rapid auto-reclosing, if not otherwise specified.

7.7.3 Low and high temperature tests [6.101.3]

7.7.3.1 General [6.101.3.1]

The low and high temperature tests shall be made only upon agreement between manufacturer and purchaser. The two tests need not be performed in succession, and the order in which they are made is arbitrary. For class -5 °C indoor circuit-breakers, no low temperature test is required.

For single-pole or two-pole circuit-breakers with independent poles, testing of one complete pole shall be made.

Owing to limitations of the test facilities, multi-enclosure type circuit-breakers may be tested using one or more of the following alternatives provided that the circuit-breaker in its testing arrangement is not in a more favourable condition than normal condition for mechanical operation (see 7.7.2.2):

- a) reduced length of phase-to-earth insulation;
- b) reduced pole spacing;
- c) reduced number of modules.

If heat sources are required they shall be in operation.

Liquid or gas supplies for circuit-breaker operation are to be at the test air temperature unless the circuit-breaker design requires a heat source for these supplies.

No maintenance, replacement of parts, lubrication or readjustment of the circuit-breaker is permissible during the tests.

NOTE In order to determine the material temperature characteristics, ageing, etc., tests of longer duration than those specified in the following clauses may be necessary.

As an alternative approach to the methods in this standard, a manufacturer may establish compliance with performance requirements for an established circuit-breaker family by documenting satisfactory circuit-breaker field experience in at least one location with ambient air temperatures frequently at or above the specified maximum ambient air temperature of 40 °C, and at least one location with satisfactory field experience in specified minimum ambient air temperature of –25 °C or –40 °C depending on the class of the circuit-breaker (see Clause 2 of IEC 62271-1).

7.7.3.2 Measurement of ambient air temperature [6.101.3.2]

The ambient air temperature of the test environment shall be measured at half the height of the circuit-breaker and at a distance of 1 m from the circuit-breaker.

The maximum temperature deviation over the height of the circuit-breaker shall not exceed 5 K.

7.7.3.3 Low temperature test [6.101.3.3]

The diagram of the test sequences and identification of the application points of the tests specified are given in Figure 17a of IEC 62271-100.

If the low temperature test is performed immediately after the high temperature test, the low temperature test can proceed after completion of item j) of the high temperature test. In this case item a) and b) are omitted.

- a) The test circuit-breaker shall be adjusted in accordance with the manufacturer's instruction.
- b) Characteristics and settings of the circuit-breaker shall be recorded in accordance with 7.7.1.2 and at an ambient air temperature of $(20 \pm 5) ^\circ\text{C}$ (T_A). The tightness test (if applicable) shall be performed according to 6.8 of IEC 62271-1.
- c) With the circuit-breaker in the closed position, the air temperature shall be decreased to the appropriate minimum ambient air temperature (T_L), according to the class of the circuit-breaker. Values of T_L may be –25 °C, or –40 °C, as appropriate. The circuit-breaker shall be kept in the closed position for 24 h after the ambient air temperature stabilizes at T_L .
- d) During the 24 h period with the circuit-breaker in the closed position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the circuit-breaker is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed three times the specified permissible value F_p (see 6.8 of IEC 62271-1).
- e) After 24 h at temperature T_L , the circuit-breaker shall be opened and closed at rated values of supply voltage and operating pressure. The opening time and closing time shall be recorded to establish low temperature operating characteristics. Contact velocity should be recorded if feasible.
- f) The low temperature behaviour of the circuit-breaker and its alarms and lock-out systems shall be verified by disconnecting the supply of heating devices for a duration t_X . During this interval, occurrence of the alarm is acceptable but lock-out is not. At the end of the interval t_X , an opening order, at rated values of supply voltage and operating pressure, shall be given. The circuit-breaker shall then open. The opening time shall be recorded (and the contact velocity measured, if feasible) to allow assessment of the interrupting capability. The manufacturer shall state the value of t_X up to which the circuit-breaker is still operable without auxiliary power to the heaters. In the absence of such statement, this value shall be equal to 2 h.
- g) The circuit-breaker shall be left in the open position for 24 h.
- h) During the 24 h period with the circuit-breaker in the open position at temperature T_L , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the circuit-breaker is restored to the

ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed three times the specified permissible value F_p (see 6.8 of IEC 62271-1).

- i) At the end of 24 h, 50 closing and 50 opening operations shall be made at rated values of supply voltage and operating pressure with the circuit-breaker at temperature T_L . At least a 3 min interval shall be allowed for each cycle or sequence. The first closing and opening operation shall be recorded to establish low temperature operating characteristics. Contact velocity should be recorded if feasible. Following the first closing operation (C) and the first opening operation (O) three CO operating cycles (no intentional time delay) shall be performed. The additional operations shall be made by performing C - t_a - O - t_a operating sequences (t_a is defined in 7.7.2.3).
- j) After completing the 50 opening and 50 closing operations, the air temperature shall be increased to ambient air temperature T_A at a rate of change of approximately 10 K per hour. During the temperature transition period the circuit-breaker shall be subjected to alternate C - t_a - O - t_a - C and O - t_a - C - t_a - O operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences should be made at 30 min intervals so that the circuit-breaker will be in open and closed positions for 30 min periods between the operating sequences.
- k) After the circuit-breaker has stabilized thermally at ambient air temperature T_A , a recheck shall be made of the circuit-breaker settings, operating characteristics and tightness as in items a) and b) for comparison with the initial characteristics.

The accumulated leakage during the complete low temperature test sequence from item b) to item k) shall not be such that lock-out pressure is reached without gas replacement (whereas reaching alarm pressure is allowed).

7.7.3.4 High temperature test [6.101.3.4]

The diagram of the test sequence and identification of the application points for the tests specified are given in Figure 17b of IEC 62271-100.

If the high temperature test is performed immediately after the low temperature test, the high temperature test can proceed after completion of item k) above of 7.7.3.3. In this case, items a) and b) below are omitted.

- a) The test circuit-breaker shall be adjusted in accordance with the manufacturer's instructions.
- b) Characteristics and settings of the circuit-breaker shall be recorded in accordance with 7.7.1.2 and at an ambient air temperature of $(20 \pm 5)^\circ\text{C}$ (T_A). The tightness test (if applicable) shall be performed according to 6.8 of IEC 62271-1.
- c) With the circuit-breaker closed, the air temperature shall be increased to 40°C , and the circuit-breaker kept in the closed position for 24 h after the ambient air temperature stabilizes at 40°C .

NOTE If the influence of solar radiation is to be considered, it is necessary to simulate the natural conditions of the radiation, e.g. the intensity and direction of the radiation. See IEC 60068-2-5. Attention is drawn to the fact that an increase in ambient temperature of the test room does not simulate this radiation effect.

- d) During the 24 h period with the circuit-breaker in the closed position at the temperature of 40°C , a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the circuit-breaker is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed three times the specified permissible value F_p (see 6.8 of IEC 62271-1).
- e) After 24 h at the temperature of 40°C , the circuit-breaker shall be opened and closed at rated values of supply voltage and operating pressure. The opening time and the closing time shall be recorded to establish high temperature operating characteristics. Contact velocity should be recorded if feasible.
- f) The breaker shall be opened and left open for 24 h at the temperature of 40°C .

g) During the 24 h period with the circuit-breaker in the open position at the temperature of 40 °C, a tightness test shall be performed (if applicable). An increased leakage rate is acceptable, provided that it returns to the original value when the circuit-breaker is restored to the ambient air temperature T_A and is thermally stable. The increased temporary leakage rate shall not exceed three times the specified permissible value F_p (see 6.8 of IEC 62271-1).

h) At the end of 24 h, 50 closing and 50 opening operations shall be made at rated values of supply voltage and operating pressure with the circuit-breaker at the temperature of 40 °C. At least a 3 min interval shall be allowed for each cycle or sequence. The first closing and opening operation shall be recorded to establish high temperature operating characteristics. Contact velocity should be recorded if feasible.

Following the first closing operation (C) and the first opening operation (O) three CO operation cycles (no intentional time delay) shall be performed. The additional operations shall be made by performing C - t_a - O - t_a operating sequences (t_a is defined in 7.7.2.3).

i) After completing the 50 opening and 50 closing operations, the air temperature shall be decreased to ambient air temperature T_A , at the rate of change of approximately 10 K per hour.

During the temperature transition period, the circuit-breaker shall be subjected to alternate C - t_a - O - t_a - C and O - t_a - C - t_a - O operating sequences at rated values of supply voltage and operating pressure. The alternate operating sequences should be made at 30 min intervals so that the circuit-breaker will be in the open and closed positions for 30 min periods between the operating sequences.

j) After the circuit-breaker has stabilized thermally at ambient air temperature T_A , a recheck shall be made of the circuit-breaker settings, operating characteristics and tightness as in items a) and b) for comparison with the initial characteristics.

The accumulated leakage during the complete high temperature test sequence from item b) to item j) shall not be such that lock-out pressure is reached without gas-replenishment (whereas reaching alarm pressure is allowed).

7.7.4 Humidity test [6.101.4]

7.7.4.1 General [6.101.4.1]

The humidity test shall be performed by agreement between manufacturer and purchaser and is limited to circuit-breaker components which may be affected by humidity.

The test procedure described in 7.7.4.2 is applicable to components with a thermal time constant of about 10 min.

NOTE The test for components having higher thermal time constant is under consideration.

7.7.4.2 Test procedure [6.101.4.2]

The circuit-breaker components shall be arranged in a test chamber containing circulating air and in which the temperature and humidity conditions are as follows:

- the temperature of the room undergoes cyclic variations from $(25 \pm 3)^\circ\text{C}$ to $(40 \pm 2)^\circ\text{C}$ according to Figure 18 of IEC 62271-100;
- the relative humidity within the room is constantly above 95 % while the temperature is raised and during the period when the temperature is held at 40 °C.

NOTE 1 In order to obtain these conditions, steam should be injected directly into the room or heated water should be atomized; the rise from 25 °C to 40 °C may be obtained with the provision of heat coming from the steam or atomized water or, if necessary, by additional heaters.

No value of relative humidity is specified during the drop in temperature, however, the humidity shall be above 80 % during the period when the temperature is maintained at 25 °C.

The air shall be circulated in order to obtain uniform distribution of the humidity in the room.

The water used to create the humidity shall be such that the water collected in the room has a resistivity equal to or greater than 100 Ωm and contains neither salt (NaCl) nor corrosive element.

NOTE 2 If the facilities of the test chamber permit, the times t_1 and t_3 may be reduced, but then the times t_2 and t_4 should be increased so that $t_1 + t_2 + t_3 + t_4$ remains constant.

The number of cycles shall be 350.

After the test, the operating characteristics of the circuit-breaker components shall not be affected. The auxiliary and control circuits shall withstand a power frequency voltage of 1,5 kV for 60 s. The degree of corrosion, if any, should be indicated in the test report.

7.7.5 Test to prove the operation under severe ice conditions [6.101.5]

The test under severe ice conditions is applicable only to outdoor circuit-breakers having moving external parts and for which a class of 10 mm or 20 mm of ice thickness is specified. The test shall be performed under the conditions described in IEC 62271-102.

7.7.6 Guide for static terminal load test [6.101.6]

7.7.6.1 General [6.101.6.1]

The static terminal load test is applicable only to outdoor circuit-breakers having rated voltages of 52 kV and above.

If required for circuit-breakers below 52 kV the static terminal load test is made upon agreement between manufacturer and purchaser and is performed to demonstrate that the circuit-breaker operates correctly when loaded by stresses resulting from ice, wind and connected conductors.

Ice coating and wind pressure on the circuit-breaker shall be in accordance with 2.1.2 of IEC 62271-1.

Some examples of forces due to flexible and tubular connected conductors are given as guide in Table 14 of IEC 62271-100.

The tensile force due to the connected conductors is assumed to act at the outermost end of the circuit-breaker terminal.

For simultaneous action of ice, wind and connected conductors, the resultant terminal loads, F_{shA} , F_{shB} and F_{sv} , respectively (see Figure 19 of IEC 62271-100) are defined as rated static terminal loads.

If the manufacturer by calculation can prove that the circuit-breaker can withstand the stresses, tests need not be performed.

7.7.6.2 Tests [6.101.6.2]

The tests shall be made at the ambient air temperature of the test room.

The tests shall be made on the complete pole of the circuit-breaker.

Tests shall be made separately, firstly with a horizontal force, F_{shA} , applied in longitudinal axis of the terminal (direction A in Figure 20 of IEC 62271-100), secondly with a horizontal force, F_{shB} , applied in two directions successively at 90° from the longitudinal axis of the terminals (directions B1 and B2 in Figure 20) and thirdly, with a vertical force, F_{sv} , applied in two directions successively (directions C1 and C2 in Figure 20). To avoid the need to apply a special force representing the force of wind acting at the circuit-breaker's centre of application