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**Railway applications—Fixed
installations—DC switchgear—
Part 2: DC circuit-breakers**

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Land, Infrastructure, Transport and Tourism through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard submitted by Railway Electrical Engineering Association of Japan (REEAJ)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 clause 1 of the Industrial Standardization Law.

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JIS E 2501 series consists of the following two parts under the general title “*Railway applications—Fixed installations—DC switchgear*”:

Part 1: General

Part 2: DC circuit-breakers

Railway applications— Fixed installations—DC switchgear— Part 2: DC circuit-breakers

Introduction

This Japanese Industrial Standard has been prepared based on the second edition of **IEC 61992-1** published in 2006 with some modifications of the technical contents so as to include provisions in domestic standards.

The portions given sidelines or dotted underlines in this Standard are the matters in which the contents of the original international standard have been modified. A list of modifications with the explanations is given in Annex JF.

1 Scope

This Standard specifies requirements for d.c. circuit-breakers which are intended to be used in fixed electrical installations with nominal voltage not exceeding 3 000 V d.c., which supply electrical power to railway vehicles.

NOTE 1 Switchgear assemblies, electromagnetic compatibility (EMC) and dependability are not covered in this Standard, but by other parts of **IEC 61992** series or by other standards.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows:

IEC 61992-2:2006 *Railway applications—Fixed installations—DC switchgear—Part 2: DC circuit-breakers* (MOD)

The symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are **IDT** (identical), **MOD** (modified, and **NEQ** (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. For standards with the year indication, only the editions of the indicated year shall be applied and the revisions (including amendments) made thereafter shall not be applied. For those without the indication of the year, the most recent edition (including amendments) shall be applied.

JIS C 0617-2 *Graphical symbols for diagrams—Part 2: Symbol elements, qualifying symbols and other symbols having general application*

JIS E 2501-1:2000 *Railway applications—Fixed installations—DC switchgear—Part 1: General*

NOTE : The corresponding International Standard: IEC 61992-1:2006 *Railway applications—Fixed installations—DC switchgear—Part 1: General* (MOD)

IEC 61992-6 *Railway applications—Fixed installations—DC switchgear—Part 6: DC switchgear assemblies*

EN 50124-1 *Railway applications—Insulation coordination—Part 1: Basic requirements—Clearances and creepage distances for electrical and electronic equipment*

3 Terms and definitions

For the purposes of this Standard, the terms and definitions given in **JIS E 2501-1** and the following apply.

3.1 valve device (of a switching device)

one of the smallest device units constituting a switching device, which makes and/or breaks by utilizing the movement of carriers in semiconductor, vacuum or ionized gas

3.2 arc control device

device which has a function to protect a valve device from overvoltage and to consume electrical energy supplied from the outside in the transient and arc period immediately after opening a valve device, and to restore the insulation of the main terminals after the main current is attenuated and extinct

NOTE : As circuit-breaker with arc control device, semiconductor circuit-breaker (see 3.4.2 of **JIS E 2501-1**) and d.c. vacuum circuit-breaker (see 3.4.3 of **JIS E 2501-1** and Annex JE of this Standard) are appropriate.

3.3 non-linear resistor (of an arc control device)

resistor which is a main component of an arc control device utilizing the constant-voltage characteristic of zinc oxide varistor and the like

3.4 commutation device

device for supplying commutation impulse current to the terminals of a vacuum valve in a state of opening, which consists of capacitor, reactor and trigger switch

3.5 tripping current

current value which starts tripping operation for circuit-breaker

3.6 clamping voltage, U_c

peak value of transient voltage (arc voltage) that appears between the main terminals of a valve device due to a breaking operation

NOTE : An example of the clamping voltage in a vacuum circuit-breaker is shown in figure JE.2.

3.7 rated clamping voltage, U_{Nc}

upper limit of transient voltage (arc voltage) that appears between the main terminals of a valve device due to a breaking operation

NOTE : The voltage between the main terminals of a valve device should not exceed the rated clamping voltage when an instantaneous value of a fault current is equal to or less than the rated cut-off current.

3.8 arc energy

total electric energy supplied to an arc control device from outside during the arcing time

3.9 rated arc energy

upper limit of the energy which the arc control device can discharge in a series of breaking operations when the breaking operations are carried out according to the prescribed making and breaking conditions

3.10 varistor voltage (of arc control device)

voltage of a zinc oxide varistor when very small current is provided to it (see **JA.2.12**)

3.11 di/dt factor

rate of the increase of rush current per unit time in the initial rush of current

3.12 circuit R/L factor

ratio of the circuit resistance R to the circuit inductance L (R/L)

NOTE : Circuit R/L factor is an inverse of circuit time constant (see **3.2.20** of **JIS E 2501-1**).

3.13 current detector

electrical element that sends a signal to a control circuit by detecting the main current

3.14 voltage detector

electrical element that sends a signal to a control circuit by detecting the voltage between main terminals of a valve device or the circuit voltage

4 Service requirements

Environmental conditions applicable to the equipment discussed in this Standard are covered in **4.1** of **JIS E 2501-1**.

5 Characteristics of the circuit-breaker

5.1 Enumeration of the characteristics

The characteristics of a circuit-breaker and its assigned designations and values (where applicable) are covered below as follows:

- type of circuit-breaker (see **5.2**);
- rated values and limit values of the main circuit and short-circuit characteristics (see **5.3**);
- control circuits (see **5.4**);
- auxiliary circuits (see **5.5**);
- releases (see **5.6**);
- arc voltages (see **5.7**).

5.2 Type of circuit-breaker

A circuit-breaker is defined by the following details, as applicable.

NOTE 1 As far as applicable, the following requirements also apply to single-pole circuit-breakers electrically or mechanically interlocked in multiple systems.

a) **Interruption media** Interruption media shall be as follows:

- in air;
- via a semiconductor;
- in vacuum bulb.

NOTE 2 In this Standard, only interruption in air, via a semiconductor or in vacuum bulb are addressed. This Standard may be used for other specified interrupting media, as far as applicable, where clearly specified by mutual agreement between purchaser and supplier.

b) **Breaking characteristics (class designation)** Types of breaking characteristics shall be as follows:

1) **High speed current limiting circuit-breaker: type H;**

— Limits of opening time and total break time are specified (**type H₁**);

The H₁ circuit-breaker has an opening time not greater than 5 ms and a total break time not greater than 20 ms, when the current to be interrupted has a prospective sustained value of at least 7 times the circuit-breaker setting current (see 3.4.19 of JIS E 2501-1) and the di/dt factor satisfies the following condition:

$$\left[\frac{di}{dt} \right]_{t=0} \geq 5 \text{ kA/ms}$$

— Limits of cut-off current are specified (**type H₂**);

The H₂ circuit-breaker has a cut-off current which does not exceed the rated values specified in table 0A, when the short-circuit load at rated voltage corresponds to table 2A of JIS E 2501-1.

Table 0A Limits of cut-off current

Short-circuit load (According to table 2A of JIS E 2501-1)			Rated cut-off current
Rated short-circuit current I_{Nss} kA	Rated track time constant T_{Nc} ms	di/dt factor (informative) kA/ms	
20	13.3	1.5	15
50	16.7	3	25
75	7.5	10	50
100	10	10	55

- 2) **Very-high speed current limiting circuit-breaker: type V;** Circuit-breaker in which the opening time is not greater than 2 ms, irrespective of the other parameters of the circuit;
- 3) **Semi-high speed circuit-breaker: type S;** The S circuit-breaker has an opening time not greater than 15 ms and a total break time not greater than 30 ms, when the current to be interrupted has a prospective sustained value of at least 3.5 times the circuit-breaker setting current and the di/dt factor satisfies the following condition:

$$\left[\frac{di}{dt} \right]_{t=0} \geq 1.7 \text{ kA/ms}$$

- c) **Use (installation point) in the system** Types of use are as follows:
 - interconnector circuit-breaker (**type I**) (also called bus-section or section circuit-breaker);
 - line circuit-breaker (**type L**);
 - rectifier circuit-breaker (**type R**).
- d) **Current interruption direction** Types of current interruption direction are as follows:
 - 1) **unidirectional: type U;**
 - fitted with a series unidirectional release (**type U₁**);
 - fitted with a series bidirectional release (**type U₂**);

NOTE 3 Type U₂ circuit-breakers are used for application where the reverse fault current is low (distant fault current) and cannot operate the overload protection for normal discrimination purposes (i.e. substations where adjacent substations are a far distance away);
 - 2) **Bidirectional: type B.**
- e) **Duty of the main circuit** Duty of the main circuit shall be according to 5.3.4.2 and table 2 or table 2A.

NOTE 4 To be specified when different from 5.3.4.2 and table 2 or table 2A.
- f) **Actuating of the closing and opening operations** For actuating of the closing and opening operations, the following items shall be specified:
 - stored energy operation (including pneumatic operation type);
 - independent manual operation;
 - independent power operation;
 - use of magnet;
 - type of automatic tripping due to a release or relay;
 - interlocks for opening and/or closing operations;
 - trip-free provision;
 - anti-pumping device.

g) **Relay or release type** Types of involved relays or releases shall be specified.

h) **Provision of an enclosure** Types of enclosure shall be as follows:

- without provision of an enclosure (see 3.3.13 of JIS E 2501-1) (**type O**);
- with provision of an integral enclosure (see 3.3.14 of JIS E 2501-1) (**type E**);
- with provision of a separate protection enclosure (**type P**).

The purchaser shall indicate which characteristics are to be present in the required circuit-breaker(s) and only those tests which relate to the chosen type are applicable to the selected type of circuit-breaker.

The above designations are used in this Standard and may be used elsewhere adopting the conventional grouping as given in table 1.

Where semiconductor circuit-breakers are only designed for use in rectifier equipped substations, they shall be clearly so marked. If they may also be used as track paralleling circuit-breakers, when the substation rectifier circuit-breakers are out of service, they shall also be clearly so marked.

NOTE 5 For use as track paralleling circuit-breakers, one example case is a substation which serves as a sectioning post.

Table 1 Shortened type-designation

Items in 5.2	b)	c)	d) ^{a)}	h) ^{a)}
Options	H ₁ H ₂ V S	I L R	U ₁ U ₂ B	O E P
Examples	H ₁ /L/B/E			
	V/I/P, S/R/O			
	H ₁ /R & L/U ₂ ^{b)}			
NOTE : When a circuit-breaker is not suitable to perform all duties as given in 5.3.4.2, this fact will be indicated by means of the lower case letter(s) designating actual capability according to table 2, first column (for example: H₁/I ff, fr/P). Notes ^{a)} Optional designations (not mandatory). ^{b)} When a circuit-breaker is or shall be suitable for multiple alternate functions, the indication of these functions shall be preceded by an “&”.				

5.3 Rated values and limit values for the main circuit

5.3.1 General

The rated characteristic values shall be specified by the purchaser. Nominal voltage values shall be selected from the values specified of Type 1 or Type 2 in 4.2.1 of JIS E 2501-1. Current values and the rated track time constant (based on the track configuration which gives the largest track time constant) should have one of the preferred values listed in 5.1.2 of JIS E 2501-1.

These values should be confirmed by the supplier, who should indicate the rated values for the type of circuit-breaker proposed and supply any other relevant data.

All these values shall be stipulated in accordance with 5.3.2 to 5.3.4. Definitions are given in JIS E 2501-1. Some data may be omitted by agreement.

5.3.2 Voltages

A circuit-breaker is identified by the following voltages:

- maximum system voltage (see 3.2.2 of JIS E 2501-1);
- nominal voltage U_n (see 3.2.1 and table 1 or table 1A of JIS E 2501-1);
- rated voltage U_{Ne} (see 3.2.4 of JIS E 2501-1);
- rated insulation voltage U_{Nm} (see 3.2.3 of JIS E 2501-1). It shall be equal to or higher than U_{max} ;
- rated impulse withstand voltage U_{Ni} (see 3.2.6 of JIS E 2501-1);
- power-frequency voltage withstand level U_a (see 3.2.7 and table 1 or table 1A of JIS E 2501-1);
- maximum arc voltage $\hat{U}_{arc}$ (see 3.2.9 of JIS E 2501-1) or rated clamping voltage U_{Nc} (see 3.7, if applicable);
- rated control supply voltage (see 3.2.5 of JIS E 2501-1);
- rated closing operation voltage [see 5.4A a), if applicable];
- rated holding voltage [see 5.4A c), if applicable];
- rated voltage [see 5.6.2 b) NOTE, if applicable].

5.3.3 Currents

A circuit-breaker is defined by the following currents:

- conventional thermal current I_{th} , I_{the} (see 3.2.11 and 3.2.12 of JIS E 2501-1);
- rated service current I_{Ne} (see 3.2.13 of JIS E 2501-1);
- rated short-circuit current I_{Nss} (see 3.2.17 of JIS E 2501-1);
- rated short-time withstand current I_{Ncw} (see 3.2.14 of JIS E 2501-1);
- rated holding current [see 5.4A c), if applicable];
- overload capability

Rated short-time withstand current applies only to circuit-breakers not fitted with series current release, or in a unidirectional device where a series release is inoperative. In practice, this would apply to a rectifier circuit-breaker in the forward direction where a series release only acts in the reverse direction. In addition, rated short-time withstand current does not need to have the same value as the rated short-circuit current I_{Nss} .

If overload capability is necessary, the purchaser shall inform the supplier of the load cycle requirements (see 3.2.13, NOTE 2 of JIS E 2501-1).

5.3.3A Energy

A circuit-breaker fitted with an arc control device is defined by the rated arc energy (see 3.9).

5.3.3B Pressure

A circuit-breaker of air operation system is defined by the rated closing operation pressure [see 5.4A b)].

5.3.4 Short-circuit characteristics

5.3.4.1 Rated short-circuit breaking and making capacities

Rated short-circuit breaking and making capacities are defined in 3.2.26 and 3.2.30 of JIS E 2501-1 and are identified by the following characteristics. And those values are associated with the rated voltage U_{Nc} , the rated service current I_{Nc} , the rated short-circuit current I_{Nss} , the rated track time constant T_{Nc} and the class designation H_1 , H_2 , V or S.

- The rated short-circuit making capacity is the prospective peak value of the rated short-circuit current I_{Nss} (see 3.2.17 of JIS E 2501-1).
- A rated short-circuit breaking capacity requires the circuit-breaker to be capable of interrupting any short-circuit current of a value lower than or equal to this rated breaking capacity at the circuit time constant stipulated.
- A circuit-breaker having a breaking capacity at a rated track time constant T_{Nc} is capable of having the same breaking capacity at a lower track time constant T_c .
- The prospective maximum short-circuit current is the sum of the prospective short-circuit currents from all sources connected to the system, including rectifier converters and regenerative trains.
- When fixing the maximum short-circuit current and the above track time constant, clause 5 of JIS E 2501-1 shall be considered.

5.3.4.2 Duties and test duty cycles

The duties required of the circuit-breaker for each of the uses, type H_1 , H_2 , V and S are listed in table 2 and table 2A. The test duty cycles applying to the duties are shown in table 3 and table 3A. Unless otherwise specified, table 2 and table 3 shall be applied to all the circuit-breakers except type H_2 , and table 2A and table 3A shall be applied to the type H_2 circuit-breaker.

Where the circuit-breaker chosen by the manufacturer or offered by the supplier has been designed with short-circuit breaking characteristics in excess of those actually required in the installation, it may be agreed between purchaser and supplier to perform additional tests in accordance with 8.3.8 for duties f and/or e and/or d using the test current actually required. These tests may be performed either at a standard test duty cycle (duty 1 or duty 2) or at an agreed duty cycle. And those tests may be repeated a number of times upon agreement between purchaser and supplier.

Table 2 Circuit-breaker duties (except type H₂ circuit-breaker)

Duty	Use	Conditions	Test current	Prospective peak	Time constant
f	L	Maximum fault	I_{Nss}	$\geq 1.42 I_{Nss}$	By consequence of other circuit parameters
e	L ^{a)}	Maximum energy	$0.5 I_{Nss}$	By consequence of other circuit parameters	$0.5 T_{Nc}$
d	L	Distant fault	$2 I_{Nc}$	By consequence of other circuit parameters	T_{Nc}
l	L	Low current	I_c	Not applicable	≈ 0.01 s
ff	I	Maximum fault forward	I_{Nss}	$\geq 1.42 I_{Nss}$	By consequence of other circuit parameters
fr	I	Maximum fault reverse	I_{Nss}	$\geq 1.42 I_{Nss}$	By consequence of other circuit parameters
lr	I R ^{b)}	Forward low current after reverse short circuit	I_c	Not applicable	≈ 0.01 s
r	R	Maximum fault reverse (with paralleled converters)	I_{Nss}	$\geq 1.42 I_{Nss}$	—
s	R	Short-time current forward	I_{Ncw}	$\geq 1.42 I_{Ncw}$	—

NOTE 1 For substations equipped with smoothing reactors of high value, the maximum energy condition may correspond to the maximum fault condition.

NOTE 2 I_{Nss} may be different for Line (L), Interconnector (I) and Rectifier (R) circuit-breakers.

Notes ^{a)} The factor affecting both I_{Nss} and T_{Nc} for maximum energy fault position is taken for practical reasons as 0.5. For low values of T_{Nc} , see table 2 of JIS E 2501-1.

^{b)} R only when explicitly required by the purchaser.

Table 2A Circuit-breaker duties (only apply to type H₂ circuit-breaker)

Duty	Use	Conditions	Test current	Circuit conditions (Time constant, etc.)
jf	L, I, R	Short-circuit fault	I_{Nss}	The test current corresponds to the rated short-circuit current in table 0A. For the time constant of test circuit, the rated track time constant corresponding to I_{Nss} in table 0A is applied.
m	L, I, R	Manual break	^{a)}	According to JA.2.10.3.
jl	L, I, R	Low current break	I_c	According to JA.4.4.1.

Note ^{a)} Test current depends on the direction of current breaking. See JA.2.10.2.

Table 3 Test duty cycles (except type H₂ circuit-breaker)

Duties	Test cycles
f, e, d ^{a)}	
Duty 1	O-15 s-CO-15 s-CO-60 s-CO
Duty 2	O-7 s-CO-10 s-CO-60 s-CO
ff, fr, r	O-15 s-CO
l, lr	10 times (O-120 s-CO)
s	Carrying for 0.25 s
NOTE 1 O: opening operation, CO: opening operation immediately after closing operation.	
NOTE 2 First opening is made on a short circuit being established.	
Note ^{a)} The choice of duty 1 or 2 is left to the purchaser. If no choice is made, then the duty cycle required is duty 1.	

Table 3A Test duty cycles (only apply to type H₂ circuit-breaker)

Duties	Test cycles
jf	O-10 s or less ^{a)} -CO
m	If applicable, do manually each one time in forward and reverse directions. (O)
jl	^{b)}
NOTE 1 O: opening operation, CO: opening operation immediately after closing operation.	
NOTE 2 First opening is made on a short circuit being established.	
Notes ^{a)} The standard duty is O-10 s-CO. However, taking an a.c. equivalent short-circuit test into consideration, the duration between O and CO may be reduced to 10 s or less. See JA.2.9.2.	
^{b)} The small current break test is performed as an investigation into critical current I_c . See JA.4.4.	

Tests shall be done as follows for each duty according to corresponding test duty cycles:

- Circuit-breakers designed to comply with more than one duty shall be fully tested for each duty;
- Unless otherwise agreed between purchaser and supplier, these tests shall be carried out on a single circuit-breaker which may be maintained between duty cycles. Occasionally maintenance work may be done between tests for each duty;
- Any further duty cycles on the same circuit-breaker shall not be performed unless a sufficient time to cool down the circuit-breaker components is allowed;
- For circuit-breakers except type H₂, the tests shall be performed with the series overcurrent release set at the maximum setting. For example, four times I_{Ne} , I_{th} or I_{thc} for test duties f, e, ff, fr, and 0.5 times for test duties r and s;

- e) For test duties d and l, the circuit-breaker shall be set to trip when the sustained value is reached. For test duty d, when the track time constants are long, the trip shall be initiated at 0.15 s.

5.4 Control circuits

The control circuits are identified by the following characteristics as a minimum:

- the voltage of the control circuits;
- the kind of current (d.c. or a.c.);
- the current frequency (in the case of an a.c. current).

The voltage of the supply source and its frequency are the values on which the performances, the thermal behaviour and the insulation characteristics are based.

Unless otherwise required, the voltage shall be in accordance with 5.2 of **JIS E 2501-1** and the rated insulation voltage shall be in accordance with **EN 50124-1**.

The supply voltage shall be within a range between 85 % and 110 % of the voltage in accordance with 5.2 of **JIS E 2501-1**. Where the control voltage is the same as in the main circuit, the same variations as in the main circuit apply.

The manufacturer shall indicate the values of the current drawn by the control circuits at the rated voltage. In the case of control circuits which draw current intermittently, the duration of the current flow shall be given.

5.4A Closing device and holding device (only for the air circuit-breaker of type H₂)

For air circuit-breakers of type H₂, closing device and holding device characteristics shall be provided as follows, regardless of the provision of 5.4:

- a) **Closing operation device (electric operation system)** For a circuit-breaker of electric operation system, rated closing operation voltage of the circuit-breaker is the voltage which the closing operation device is designed for, and indicated by the terminal voltage.

The rated closing operation voltage shall be 100 V or 200 V which is specified in table 3 of **JIS E 2501-1**.

The circuit-breakers shall be capable of making without any trouble, and closing in the unloaded condition, at all voltages in the range listed in table 3B.

NOTE : The rated closing operation voltage is represented by the terminal voltage of the making coil (including attached resistance, if any). This terminal voltage may drop significantly due to the closing operation current. The rated closing operation voltage shows the terminal voltage when the closing operation current is flowing, so particular attention is required for the measurement.

- b) **Closing operation device (pneumatic operation system)** For a circuit-breaker with pneumatic operation system, rated closing operation pressure of the circuit-breaker is the pressure which the closing operation device is designed for, and indicated by the air pressure (gauge pressure) of the breaking air tank immediately before the operation.

The rated closing operation pressure shall be 0.49 MPa (gauge pressure).

The circuit-breaker shall be capable of making without any trouble, and closing in the unloaded condition, at all pressures in the range from 85 % to 110 % of the rated value.

- c) **Holding device** The rated holding voltage of a circuit-breaker is the voltage which the holding device is designed for, and indicated by the terminal voltage of the holding coil (including attached resistance).

The rated holding voltage shall be 100 V d.c.

The rated holding current of a circuit-breaker is represented by a current flowing in a holding coil which gives an operation of an accuracy within the specified range for any setting current (current scale) of relays or releases (see 6.13.2.2). Unidirectional circuit-breaker fitted with a series release in the forward direction [see 5.2 d)] shall not make self-holding by the reverse current of 1.1 times or less than the maximum current scale.

Table 3B Variation range of closing operation voltage

Unit: %

Operation	Kind of voltage	
	d.c.	a.c.
Loaded	85 to 110	85 to 110
Unloaded	75 to 110	85 to 110

5.5 Auxiliary contacts and circuits

Auxiliary circuits are mainly defined by the number of contacts provided, by their rating (thermal current and voltage) and by their characteristics (for example, normal open contact, normal close contact, etc.). Unless otherwise required, the rated voltage shall be in accordance with 5.2 of JIS E 2501-1, and the rated insulation voltage shall be in accordance with EN 50124-1.

The purchaser shall specify the minimum number of auxiliary contacts required.

The auxiliary wiring connected to a circuit at 1 000 V a.c. or above or at 1 500 V d.c. or above shall be physically separated from those connected to a circuit at a voltage below these limits.

For other characteristics of the auxiliary circuits, the requirements of 5.4 shall apply.

5.6 Releases

5.6.1 Type

Classification of the releases comprises

- series overcurrent releases (direct or indirect),
- shunt releases,
- under-voltage releases,
- other releases.

5.6.2 Characteristics

A release may be instantaneous, time-lagged or time-dependant, or a combination of all three. Other characteristics are as follows:

a) **for series overcurrent (d.c.) releases:**

- type (direct or indirect);
- rated current;
- the setting current (or setting current range);
- the direction of the main carrying current in the case of a unidirectional circuit-breaker;
- characteristics of the operating time which the release gives the circuit-breaker as a function of the rate of rise of the current (selectivity).

The following requirements apply to direct or indirect releases which are part of the circuit-breaker:

- 1) The release shall be capable of withstanding the test current under the test conditions specified in clause 8 or Annex JA, without the temperature-rise exceeding the values specified in clause 6 of JIS E 2501-1;
- 2) The indication of rated current may be either in amperes or in multiples of the current indicated on the release. The purchaser shall specify the required setting range. The ratio of the minimum and maximum values shall not exceed 1:2 in normal conditions;
- 3) For circuit-breakers provided with interchangeable or adjustable releases, the current setting (or the setting range, if applicable) shall be indicated on the release or on its setting scale.

b) **for the shunt release:**

- the rated voltage;

NOTE : For a circuit breaker of the shunt release system, the rated tripping voltage of the circuit-breaker is the voltage which the release is designed for, and indicated by the terminal voltage.

- the power taken at the rated voltage for a specified time.

5.7 Arc voltage and clamping voltage

The manufacturer shall specify the maximum value of the arc voltage $\hat{U}_{arc}$ or the rated clamping voltage U_{Nc} caused by the operation of the circuit-breaker when it is tested in accordance with clause 8 or Annex JA.

NOTE : This maximum voltage is the peak voltage measured during any test duty and is not necessarily seen with maximum current.

The Arc voltage of the circuit-breakers except type H₂ shall not exceed both that of the rated impulse withstand voltage of the equipment and four times the nominal voltage.

For the type H₂ circuit-breaker, unless otherwise specified, the maximum arc voltage or rated clamping voltage shall be in accordance with table 3C.

The maximum arc voltage shall be applied to air circuit-breakers, and the rated clamping voltage shall be applied to semiconductor circuit-breakers and vacuum circuit-breakers.

If lower arc voltage and clamping voltage are required, their limit values shall be specified by the purchaser.

**Table 3C Maximum arc voltage and rated clamping voltage
(only for type H₂ circuit-breaker)**

Unit: V

Rated voltage	Maximum arc voltage	Rated clamping voltage
750	4 000	2 500
1 500		4 000
NOTE 1	For a circuit-breaker whose rated voltage is 3 000 V, the values shall be agreed between purchaser and supplier.	
NOTE 2	When a circuit-breaker of 1 500 V rated voltage is applied to a circuit of 750 V rated voltage, the rated clamping voltage may be set at 4 000 V based on the agreement between purchaser and supplier.	

5.8 Arc energy

For a type H₂ circuit-breaker fitted with an arc control device, rated arc energy value for the arc control device shall be specified. The values are listed in table 3D. Values different from table 3D may be determined by agreement between purchaser and supplier.

Table 3D Rated arc energy

Maximum current scale A	Rated arc energy kJ	
	Rated voltage 750 V	Rated voltage 1 500 V
3 000	110	220
4 000	150	300
4 500	165	330
6 000	220	440
7 500	280	560
8 000	295	590
9 000	335	670
10 000	370	740
12 000	445	890

6 Construction

6.1 General

All apparatus and connections required for the safe and satisfactory operation, control and protection of the equipment concerned shall be provided, whether or not specifically mentioned, unless otherwise agreed between the circuit-breaker manufacturer

and the switchgear assembly manufacturer. Unless otherwise specified, the equipment shall be earthed, insulated, screened or enclosed as may be appropriate to ensure the protection of the equipment and safety of those concerned in its operation and maintenance.

Control and auxiliary circuits and contacts shall comply with the requirements of 5.2 of JIS E 2501-1.

6.2 Materials

No materials containing asbestos shall be used in the construction of the circuit-breaker.

NOTE : Special attention should be paid to the capability of the material used to resist moisture and fire. Materials used should be of the self-extinguishing type, such that the risk of propagation of fire from one cubicle to another is minimised (see Annex B of JIS E 2501-1).

6.3 Arcing contacts

Arcing contacts, if any, which are liable to be consumed during arc interruption shall be easy to replace.

6.4 Clearances and creepage distances

When 4.2.1 type 1 of JIS E 2501-1 is applied, clearances shall not be lower than those indicated in table 1 in JIS E 2501-1.

NOTE : Clearances may be increased to take into account the presence of foreign substances after the number of operations, in normal and short-circuit conditions, that occur during the normal lifespan between cleaning procedures.

The manufacturer of switchgears shall prescribe a minimum clearance between the arc chute and the surroundings in consideration of influences of ionization by arc.

Where applicable, ribs shall be provided in order to break the continuity of conducting deposit which occurs during operation.

6.5 Primary connections

The circuit-breakers shall be equipped with fixed, removable (bolted or clamped) or plug-in coupling connections.

6.6 Location of the primary connections

For non-withdrawable circuit-breakers, the terminals for the primary connections shall be accessible with the circuit-breaker in its normal operating position. The position of the terminals shall be agreed between purchaser and supplier, unless covered by other provision.

For withdrawable circuit-breakers, the terminals for the primary connections shall be accessible in the conditions detailed in IEC 61992-6.

6.7 Earthing terminal

The frames, the structure and the fixed parts of the metallic enclosures shall be connected to each other and to a suitable earthing terminal, placed in a position accessible

to the metallic enclosures, in order to allow earthing. The purchaser shall indicate the earthing method for the metallic enclosures.

NOTE 1 According to the requirements for d.c. systems, "earthing" means connection to either the ground or a return circuit.

NOTE 2 This condition may be fulfilled by normal construction elements, ensuring an adequate electric continuity.

For withdrawable circuit-breakers, the earth connection shall be made before the shutters are opened, and the shutters shall be closed before the earth connection is disconnected. When there are condensers inside, they shall not be taken out of enclosure unless they are discharged to a safe value.

The purchaser may require a dedicated earth connection for this purpose. For a non-dedicated earth connection, where bolts or similar fixings are used for earth continuity, the maintenance instructions should state the requirements for cleaning the surfaces and ensuring tightness.

The earthing terminal shall be protected against corrosion. The standard earth symbol according to JIS C 0617-2 shall be permanently marked.

The purchaser shall specify either the rated ground fault current I_{Ncwe} or the thickness of the ground wire to be connected to an earthing terminal. From the typical breaking time of a.c. circuit-breaker, ground fault duration time shall be set to 0.25 s. When the time is different, the purchaser shall specify it.

The earth terminal should be capable of carrying the rated earth fault current for a specified period of time.

NOTE 3 For the value of the rated ground fault current, the short circuit between the positive electrode and the negative electrode should be assumed.

NOTE 4 The earthing terminal is assumed to be a fixed earthing terminal.

6.8 Manual operation for maintenance

Where a fixed handle is provided, it shall not be accessible to the operator until the circuit-breaker is fully withdrawn from its enclosure, if any, or until all primary connections are opened.

NOTE : A handle may be required by the purchaser or provided by the supplier for closing during maintenance. The handle may be fixed or removable.

6.9 Circuit-breaker enclosures

Circuit-breaker enclosures should conform to IEC 61992-6. When a withstand voltage test is necessary for the component of the enclosure, the test value shall be according to 4.2.1, type 1 or type 2 of JIS E 2501-1.

6.10 Temperature-rises

6.10.1 Limits

The temperature shall not rise by more than the values given in clause 6 of JIS E 2501-1.

6.10.2 Main circuit

The main circuit of a circuit-breaker, including the series releases and the associated relays, shall withstand its rated currents I_{Ne} or temperature-rise test current (open) I_{th} or the test current (close) I_{thc} . It shall also comply with the load cycle which may be specified by the purchaser. See NOTE 2 in 3.2.13 of JIS E 2501-1.

6.10.3 Control circuits and control devices

The control circuits, as well as the control devices, used for the opening and closing operations of a circuit-breaker shall not exceed the rated temperature-rise limits, during their operation.

6.10.4 Auxiliary circuits and auxiliary devices

The auxiliary circuits, as well as the auxiliary devices, shall withstand their temperature-rise test current (for switching devices) or their rated service current (for other equipment), without exceeding the rated temperature-rise limits.

6.11 Dielectric strength

Dielectric strength shall conform to the values stipulated for type 1 or type 2 in 4.2.1 of JIS E 2501-1.

6.12 Electrical and mechanical endurance

The circuit-breaker shall be capable of carrying out the following number of operations when tested in accordance with 7.3.2 and 7.3.3 of JIS E 2501-1:

a) To check mechanical endurance, without current in the main circuit, the following operating cycles shall be performed:

- 1) feeding circuit-breaker (L): 20 000 or 10 000;
- 2) sectioning (I) and rectifier (R) circuit-breakers: 4 000;

NOTE : The value of 20 000 cycles for L circuit-breakers is recommended when two or more operations per day are expected.

b) To check electrical endurance, with the rated service current I_{Ne} in the main circuit, the following operating cycles shall be performed:

- 1) feeding circuit-breaker (L): 200;
- 2) sectioning (I) and rectifier (R) circuit-breakers: 100.

The test shall consist of carrying out the above number of operating cycles in groups of no less than 20 CO operations at no greater than 180 s intervals. When the rated current is higher than 4 000 A, the group number may be reduced subject to agreement between purchaser and supplier.

When a circuit-breaker of type H₂ is tested according to Annex JA, for the mechanical endurance, the test of 2 000 cycles shall be performed without depending on the use of the breaker (see JA.2.2.3). The number may be changed to 10 000 cycles by agreement between purchaser and supplier (see JA.4.3). Electrical endurance is not specified, but 6.12 b) may be applied by agreement between purchaser and supplier.

6.13 Operation

6.13.1 Closing operation

The closing device, including the auxiliary control relays, if any, shall operate correctly for any voltage value of the supply source as given in 5.4 and in any operating condition of the circuit-breaker.

6.13.2 Opening operation

6.13.2.1 General

The circuit-breakers shall be, unless otherwise specified, trip-free.

Relays shall be according to 6.13.2 only if fitted to the circuit-breaker.

6.13.2.2 Opening operation due to overcurrent relay or release

For a new circuit-breaker except type H₂, the release or relay shall operate with an accuracy of $\pm 5\%$ of the set operating point, if electronic, and of $\pm 10\%$ of the set operating point, if electromagnetic, for any value of its current range.

For a type H₂ circuit-breaker, the operation shall be performed with an accuracy of the allowance shown in table 3E without depending on the kind of release or relay.

A current scale may be set exceeding the maximum current scale in table 3E by agreement between purchaser and supplier. However when the higher scale is used, the rated cut-off current specified in table 0A shall not apply.

When the current rises above the current scale (A) in table 3E, standard values of an allowance for the current scale (A), rated cut-off current and rated arc energy shall be agreed between purchaser and supplier.

Table 3E Current scale and its allowance (only for type H₂ circuit-breaker)

Unit: A

Rated current	Current scale	Allowance for current scale
1 000	1 000, 1 500, 2 000	± 200
2 000	2 000, 3 000, 4 000	± 250
	3 000, 4 000, 5 000, 6 000	± 300
3 000	3 000, 4 000, 5 000, 6 000	± 300
	5 000, 6 000, 7 000, 8 000	± 400
	6 000, 7 000, 8 000, 9 000, 10 000	± 500
4 000	5 000, 6 000, 7 000, 8 000	± 400
	6 000, 8 000, 10 000, 12 000	± 500
5 000	5 000, 6 000, 7 000, 8 000	± 400
	8 000, 10 000, 12 000	± 600
6 000	8 000, 10 000, 12 000	± 600

6.13.2.3 Opening operation due to shunt release

For circuit-breakers except type H₂, a shunt release shall correctly operate for any supply voltage value of the supply source as given in 5.4, and with a further decrease of the minimum voltage by 15 % of the rated operating voltage, and for any operating condition of the circuit-breaker up to the breaking capacity of the circuit-breaker itself.

For type H₂ air circuit-breakers, the rated tripping voltage shall be 100 V or 200 V specified in table 3 of JIS E 2501-1, and its permissible allowance shall be between 60 % to 125 %. At all voltages within this range, tripping shall be done without any trouble.

6.13.2.4 Opening due to undervoltage relay or release

An undervoltage relay or release, if provided, shall cause the opening of a circuit-breaker, when the voltage is decreasing slowly, when the voltage is between 70 % and 35 % of its rated value.

An undervoltage relay or release shall not allow the circuit-breaker to close when the supply voltage is lower than 35 % of its rated voltage; it shall not prevent the circuit-breaker from closing for a supply voltage equal to or higher than 85 %.

NOTE : A relay or release for loss of voltage is a particular type of undervoltage relay or release for which the operating voltage is between 35 % and 10 % of the rated supply voltage.

6.14 Corrosion protection

Steelwork and other materials of the equipment shall be treated in accordance with an approved type of corrosion protection except for arc-extinguishing sheets in the arc chute.

Purchasers may have their own specification, in which case the supplier shall either comply or offer an equivalent specification.

6.15 Noise emission

Noise emission from all equipment shall be minimised. The level of the noise emission during the breaking of its rated service current I_{Nc} shall be given by the supplier, if required by the purchaser.

6.16 Cooling

Unless otherwise agreed between purchaser and supplier, all equipment is expected to be naturally cooled.

6.17 Servo-control

Where applicable, the servo-control shall be mounted either on the circuit-breaker or on a structure on which the circuit-breaker is also mounted. In that case, the structure shall be earthed.

It shall not be possible for a fault in the servo-control to prevent the opening of the circuit-breaker by a manual, electric or automatic control.

6.18 Other facilities

Circuit-breakers shall have the following facilities:

- a) A latching device, either electrical, magnetic or mechanical;
- b) A mechanical indicator coupled to the moving contact, or an equivalent means to indicate the “closed” and the “open” conditions of the circuit-breaker. Symbols “入” and “切”, “I” and “O” or “ON” and “OFF” shall be used to indicate the closed and open positions respectively;
- c) Means for earthing the circuit-breaker structure either through a moving contact or a terminal.

Circuit-breakers shall have the following facilities, when specified by the purchaser:

- means of closing manually for maintenance;
- operation counter.

These facilities may be supplied as standard by the manufacturer.

In addition to the number of auxiliary switch contacts required for normal operating circuits of the circuit-breaker, the manufacturer shall provide an additional two for remote control and monitoring circuits. The number and type of contacts in addition to these shall be subject to agreement between purchaser and supplier.

7 Information and marking

7.1 Information

Purchaser and supplier shall exchange any necessary information in order to ensure that the circuit-breaker is suitable for the intended duty. This information is given in general in clause 5, and with regard to particular features or alternative choices for the contents, in clause 6. A summary of this information is provided in Annex A.

7.2 Marking

Each circuit-breaker shall be indelibly marked.

The following indications shall be placed on the circuit-breaker itself or on one or more rating plates attached to the circuit-breaker:

- a) name of the manufacturer or trade mark;
- b) number of the corresponding standard;
- c) type designation (examples are given in table 1);
- d) serial number designation;
- e) year of manufacture;
- f) rated voltage(s) U_{Ne} ;
- g) rated auxiliary and control supply voltages;
- h) rated service current I_{Ne} , and temperature-rise test current I_{th} or I_{thc} (if applicable);
- i) rated short-circuit breaking capacity (if applicable);

- j) rated track time constant T_{Nc} (if applicable);
- k) rated short-time withstand current I_{Ncw} (if applicable);
- l) input and output terminals, (unless they can be connected either way);
- m) earth terminal, (if applicable, by the symbol);
- n) range of setting for releases (current or voltage);
- o) Compliance to service requirements differing from the environmental conditions indicated as normal (see Annex B of JIS E 2501-1) (on a separate label if convenient);
- p) type of circuit-breaker;
- q) rated closing operation voltage (if applicable);
- r) rated closing operation pressure (if applicable);
- s) rated holding voltage (if applicable);
- t) rated holding current (if applicable);
- u) rated tripping voltage (if applicable);
- v) closing operation current (if applicable);
- w) normal duty cycles;
- x) mass.

All necessary labelling shall be provided for the purposes of safety, identification, instruction and information. Lifting attachments shall be marked.

The serial number and type designation shall be visible after installation of the circuit-breaker when in the test position. The other markings shall be visible at least before installation. The manufacturer may fit an additional rating plate containing the prominent data for the circuit-breaker on the corresponding circuit-breaker enclosure.

8 Tests

8.1 General

General requirements concerning tests for circuit-breakers except type H₂ are shown in clause 7 of JIS E 2501-1.

NOTE : For procedural matters not covered either in this Standard or in JIS E 2501-1, reference may be made to other IEC publications or other standards covering similar equipment.

Unless otherwise indicated, the tests shall be performed at the rated service values of current, voltage, frequency (if applicable) and air pressure (if applicable). This applies to the complete circuit-breaker (main, control and auxiliary) and in accordance with the values indicated in clause 5.

The test variables shall be within the tolerances indicated in table 6 of JIS E 2501-1.