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IS 8623-1 (1993): Low-Voltage Switchgear and Control gear Assemblies, Part 1: Requirements for Type-Tested and Partially Type-Tested Assemblies [ETD 7: Low Voltage Switchgear and Controlgear]



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“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक

अल्प-वोल्टता स्विच गियर और नियंत्रण गियर समुच्चयों
की विशिष्टि

भाग 1 टाइप-परीक्षित और आंशिक टाइप परीक्षित समुच्चयों की अपेक्षाएं
(पहला पुनरीक्षण)

Indian Standard

**SPECIFICATION FOR LOW-VOLTAGE
SWITCHGEAR AND CONTROLGEAR
ASSEMBLIES**

**PART 1 REQUIREMENTS FOR TYPE-TESTED AND PARTIALLY
TYPE-TESTED ASSEMBLIES**

(*First Revision*)

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Indian Standard

SPECIFICATION FOR LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES

PART 1 REQUIREMENTS FOR TYPE-TESTED AND PARTIALLY TYPE-TESTED ASSEMBLIES

(*First Revision*)

NATIONAL FOREWORD

This Indian Standard (Part 1) is identical to IEC Pub 439-1 (1985) covering requirements for assemblies of low-voltage switchgear and controlgear equipment. The term factory built assemblies has been now abandoned internationally taking into account the installation engineering practice of using non-factory built assemblies (such as site built). As such the terms (fully) type-tested assemblies (TTA) and partially type tested assemblies (PTTA) are introduced. The bulk of the requirements for these two types being the same, these are covered in the same standard.

The text of the IEC standard has been examined and approved by ET 07, Low Voltage Switchgear and Controlgear Sectional Committee of BIS, as suitable for publication as Indian Standard, as the first revision of IS 8623 (Part 1).

CROSS REFERENCES

In this Indian Standard the following International Standards are referred to. Read in their respective place the following:

<i>International Standard (IEC)</i>	<i>Indian Standard</i>
73	Nil
146-2	Nil
158-2	IS 12974
292-1	IS 8544 (Part 1)
364-3	SP 30
364-4-41	
364-5-53	
364-5-54	
408	IS 4064 (Part 1)
417	IS 11353
445	
446	IS 7118
447	
529	
536	
664	IS 12083
	IS 9409
	SP 39

All these Indian Standards are technically equivalent to the International Standards. As regards IEC Pub 408, and IEC Pub 292-1 it may be noted that this has been replaced by IEC Pub 947-3 for which identical Indian Standards IS 13947 (Part 3) and IS 13947 (Part 4/Sec 1) are under print.

In the case of IEC Pub 73 and 146-2, the Technical Committee responsible for the preparation of this standard has decided that they are acceptable for use in conjunction with this standard.

NATIONAL ANNEX

Keeping in view the application of this standard in Indian conditions, the Technical Committee responsible for this standard has felt the need to select from out of the ratings/ranges those best suited for Indian conditions and provide elaboration/interpretations where felt necessary. For convenience of the users and facilitate comparison, these aspects to be taken note of for claiming conformity to this standard under Indian conditions are summarized in the form of a National Annex. The text of this standard shall be read in conjunction with this annex which is an integral part of it.

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1. General

1.1 Scope

This standard applies to low-voltage switchgear and controlgear assemblies (Type-tested Assemblies (TTA) and Partially Type-tested Assemblies (PTTA)), the rated voltage of which does not exceed 1 000 V a.c. at frequencies not exceeding 1 000 Hz, or 1 500 V d.c.

Note. — For higher frequencies, special considerations may be necessary.

This standard also applies to assemblies incorporating control and/or power equipment, the frequencies of which are higher. In this case, appropriate additional requirements shall apply.

This standard applies to stationary or movable assemblies with or without enclosures.

Note. — Additional requirements for certain specific types of assemblies are given in supplementary standards.

This standard applies to assemblies intended for use in connection with generation, transmission, distribution and conversion of electric energy and for the control of electric energy consuming equipment.

It also applies to such assemblies designed for use under special service conditions, for example in ships, in rail vehicles, for machine tools, for hoisting equipment, or in explosive atmospheres, and for domestic (operated by unskilled persons) applications, provided that the relevant specific requirements are complied with.

This standard does not apply to individual devices and self-contained components, such as motor starters, fuse switches, electronic equipment, etc., complying with their relevant standards.

1.2 Object

The object of this standard is to lay down the definitions and to state the service conditions, construction requirements, technical characteristics and tests for low-voltage switchgear and controlgear assemblies.

2. Definitions

For the purpose of this standard, the following definitions apply.

2.1 General definitions

2.1.1 LV switchgear and controlgear assembly (hereinafter called "ASSEMBLY")

A combination of one or more low-voltage switching devices together with associated control, measuring, signalling, protective, regulating equipment, etc., completely assembled under the responsibility of the manufacturer with all the internal electrical and mechanical interconnections and structural parts (see Sub-clause 2.4).

Notes 1. — The components of the ASSEMBLY may be electromechanical or electronic.

2. — For various reasons, for example transport or production, certain steps of assembly may be made in a place outside the factory of the manufacturer.

2.1.1.1 *Type-tested low-voltage switchgear and controlgear assembly (TTA)*

A low-voltage switchgear and controlgear assembly conforming to an established type or system without deviations likely to significantly influence the performance, from the typical ASSEMBLY verified to be in accordance with this standard.

Notes 1. — Throughout this standard, the abbreviation TTA is used for type-tested low-voltage switchgear and controlgear assembly.

2. — For various reasons, for example transport or production, certain steps of assembly may be made in a place outside the factory of the manufacturer of the type-tested ASSEMBLY. Such an ASSEMBLY is considered as a type-tested ASSEMBLY provided the assembly is performed in accordance with the manufacturer's instructions in such a manner that compliance of the established type or system with this standard is assured, including submission to applicable routine test.

2.1.1.2 *Partially type-tested low-voltage switchgear and controlgear assembly (PTTA)*

A low-voltage switchgear and controlgear assembly, containing both type-tested and non-type-tested arrangements provided that the latter are derived (e.g. by calculation) from type-tested arrangements which have complied with the relevant tests (see Table VII).

Note. — Throughout this standard, the abbreviation PTTA is used for a partially type-tested switchgear and controlgear assembly.

2.1.2 *Main circuit (of an ASSEMBLY)*

All the conductive parts of an ASSEMBLY included in a circuit which is intended to transmit electrical energy.

2.1.3 *Auxiliary circuit (of an ASSEMBLY)*

All the conductive parts of an ASSEMBLY included in a circuit (other than the main circuit) intended to control, measure, signal, regulate, process data, etc.

Note. — The auxiliary circuits of an ASSEMBLY include the control and the auxiliary circuits of the switching devices.

2.1.4 *Busbar*

A low-impedance conductor to which several electric circuits can be separately connected.

2.1.5 *Functional unit*

A part of an ASSEMBLY comprising all the electrical and mechanical elements that contribute to the fulfilment of the same function.

2.1.6 *Incoming unit*

A functional unit through which electrical energy is normally fed into the ASSEMBLY.

2.1.7 *Outgoing unit*

A functional unit through which electrical energy is normally supplied to one or more outgoing circuits.

2.1.8 *Functional group*

A group of several functional units which are electrically interconnected for the fulfilment of their operational functions.

2.1.9 *Test situation*

A condition of an ASSEMBLY or part of it in which the relevant main circuits are open but not necessarily disconnected (isolated) whilst the associated auxiliary circuits are connected, allowing tests of the operation of incorporated devices.

2.2 *Definitions concerning constructional units of ASSEMBLIES*

2.2.1 *Section (see Figure C4, page 109)*

A constructional unit of an ASSEMBLY between two successive vertical delineations.

2.2.2 *Sub-section*

A constructional unit of an ASSEMBLY between two successive horizontal delineations within a section.

2.2.3 *Compartment*

A section or sub-section enclosed except for openings necessary for interconnection, control or ventilation.

2.2.4 *Barriered section or sub-section*

A section or sub-section fitted with barriers designed and arranged to protect against accidental contact with adjacent equipment when handling the elements in the section or sub-section.

2.2.5 *Transport unit*

A part of an ASSEMBLY or a complete ASSEMBLY suitable for shipping without being dismantled.

2.2.6 *Fixed part (see Figure C9, page 114)*

A part consisting of components assembled and wired on a common support and which is designed for fixed installation (see Sub-clause 7.6.3).

2.2.7 *Removable part*

A part which may be removed entirely from the ASSEMBLY and replaced even though the circuit to which it is connected may be live.

2.2.8 *Withdrawable part (see Figure C10, page 115)*

A removable part which can be moved to a position where an isolating distance (see Sub-clause 7.1.2.2) is established, whilst remaining mechanically attached to the ASSEMBLY.

Note. — This isolating distance may relate either to the main circuits only or to the main circuits and the auxiliary circuits (see Sub-clause 2.2.11), see also Table VI.

2.2.9 *Connected position*

The position of a removable or withdrawable part when it is fully connected for its normally intended function.

2.2.10 *Test position*

A position of a withdrawable part in which the relevant main circuits are open but not necessarily disconnected (isolated) and in which the auxiliary circuits are connected, allowing tests of the operation of the withdrawable part, that part remaining mechanically attached to the ASSEMBLY.

Note. — The opening may also be achieved without any mechanical movement of the withdrawable part by operation of a suitable device.

2.2.11 *Disconnected position (isolated position)*

A position of a withdrawable part in which an isolating distance (see Sub-clause 7.1.2.2) is established in main and auxiliary circuits, the withdrawable part remaining mechanically attached to the ASSEMBLY.

Note. — The isolating distance may also be established without any mechanical movement of the withdrawable part by operation of a suitable device.

2.2.12 *Removed position*

The position of a removable or withdrawable part when it is outside the ASSEMBLY and mechanically and electrically separated from it.

2.3 *Definitions concerning the external design of ASSEMBLIES*

2.3.1 *Open-type ASSEMBLY (see Figure C1, page 106)*

An ASSEMBLY consisting of a supporting structure which supports the electrical equipment, the live parts of the electrical equipment being accessible.

2.3.2 *Dead-front ASSEMBLY (see Figure C2, page 107)*

An open-type ASSEMBLY with a front covering which provides a degree of protection of at least IP2X from the front. Live parts may be accessible from the other directions.

2.3.3 *Enclosed ASSEMBLY*

An ASSEMBLY which is enclosed on all sides—with the possible exception of its mounting surface—in such a manner as to provide a degree of protection of at least IP2X.

2.3.3.1 *Cubicle-type ASSEMBLY (see Figure C3, page 108)*

An enclosed ASSEMBLY in principle of the floor-standing type which may comprise several sections, sub-sections or compartments.

2.3.3.2 *Multi-cubicle-type ASSEMBLY (see Figure C4, page 109)*

A combination of a number of mechanically joined cubicles.

2.3.3.3 *Desk-type ASSEMBLY (see Figure C5, page 110)*

An enclosed ASSEMBLY with a horizontal or inclined control panel or a combination of both, which incorporates control, measuring, signalling, etc., apparatus.

2.3.3.4 *Box-type ASSEMBLY (see Figure C6, page 111)*

An enclosed ASSEMBLY, in principle intended to be mounted on a vertical plane.

2.3.3.5 *Multi-box-type ASSEMBLY (see Figure C6, page 111)*

A combination of boxes mechanically joined together, with or without a common supporting frame, the electrical connections passing between two adjacent boxes through openings in the adjoining faces.

2.3.4 *Busbar trunking system (busway) (see Figure C7, page 112)*

A type-tested assembly in the form of a conductor system comprising busbars which are spaced and supported by insulating material in a duct, trough or similar enclosure.

The ASSEMBLY may consist of units such as:

- busbar trunking units with or without tap-off facilities;
- phase transposition, expansion, flexible, feeder and adapter units;
- tap-off units.

Note. — The term “busbar” does not presuppose the geometrical shape, size and dimensions of the conductor.

2.4 *Definitions concerning the structural parts of ASSEMBLIES*

2.4.1 *Supporting structure (see Figure C1, page 106)*

A structure forming part of an ASSEMBLY designed to support various components of an ASSEMBLY and an enclosure, if any.

2.4.2 *Mounting structure (see Figure C8, page 113)*

A structure not forming part of an ASSEMBLY designed to support an enclosed ASSEMBLY.

2.4.3 *Mounting panel* (see Figure C9, page 114)*

A panel designed to support various components and suitable for installation in an ASSEMBLY.

2.4.4 *Mounting frame* (see Figure C9)*

A framework designed to support various components and suitable for installation in an ASSEMBLY.

2.4.5 *Enclosure*

A part providing protection of equipment against certain external influences and, in any direction, protection against direct contact to a degree of protection of at least IP2X.

2.4.6 *Cover*

A part of the external enclosure of an ASSEMBLY.

2.4.7 *Door*

A hinged or sliding cover.

* If these structural parts incorporate apparatus, they may constitute self-contained ASSEMBLIES.

2.4.8 Removable cover

A cover which is designed for closing an opening in the external enclosure and which can be removed for carrying out certain operations and maintenance work.

2.4.9 Cover plate

A part of an ASSEMBLY—in general of a box (see Sub-clause 2.3.3.4)—which is used for closing an opening in the external enclosure and designed to be held in place by screws or similar means. It is not normally removed after the equipment is put into service.

Note. — The cover plate can be provided with cable entries.

2.4.10 Partition

A part of the enclosure of a compartment separating it from other compartments.

2.4.11 Barrier

A part providing protection against direct contact from any usual direction of access (minimum IP2X) and against arcs from switching devices and the like, if any.

2.4.12 Obstacle

A part preventing unintentional direct contact, but not preventing deliberate action.

2.4.13 Shutter

A part which can be moved:

- between a position in which it permits engagement of the contacts of removable or withdrawable parts with fixed contacts, and
- a position in which it becomes a part of a cover or a partition shielding the fixed contacts.

2.4.14 Cable entry

A part with openings which permit the passage of cables into the ASSEMBLY.

Note. — A cable entry can at the same time be designed as a cable sealing end.

2.5 Definitions concerning the conditions of installation of ASSEMBLIES

2.5.1 ASSEMBLY for indoor installation

An ASSEMBLY which is designed for use in locations where the usual service conditions for indoor use as specified in Sub-clause 6.1 of this standard are fulfilled.

2.5.2 ASSEMBLY for outdoor installation

An ASSEMBLY which is designed for use under the usual service conditions for outdoor use as specified in Sub-clause 6.1 of this standard.

2.5.3 Stationary ASSEMBLY

An ASSEMBLY which is designed to be fixed at its place of installation, for instance to the floor or to a wall, and to be used at this place.

2.5.4 Movable ASSEMBLY

An ASSEMBLY which is designed so that it can readily be moved from one place of use to another.

2.6 Definitions concerning protective measures with regard to electric shock

2.6.1 Live part

A conductor or conductive part intended to be energized in normal use, including a neutral conductor but, by convention, not a PEN conductor.

Note. — This term does not necessarily imply a risk of electric shock.

2.6.2 Exposed conductive part

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

2.6.3 Protective conductor (PE)

A conductor required by some measures for protection against electric shock for electrically connecting any of the following parts:

- exposed conductive parts;
- extraneous conductive parts;
- main earthing terminal;
- earth electrode;
- earthed point of the source or artificial neutral.

2.6.4 Neutral conductor (N)

A conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy.

2.6.5 PEN conductor

An earthed conductor combining the functions of both protective conductor and neutral conductor.

2.6.6 Fault current

A current resulting from an insulation failure or the bridging of insulation.

2.6.7 Earth fault current

A fault current which flows to earth.

2.6.8 Protection against direct contact

Prevention of dangerous contact of persons with live parts.

2.6.9 Protection against indirect contact

Prevention of dangerous contact of persons with exposed conductive parts.

2.7 Gangways within ASSEMBLIES

2.7.1 Operating gangway within an ASSEMBLY

A space which must be used by the operator for the proper operation and supervision of the ASSEMBLY.

2.7.2 Maintenance gangway within an ASSEMBLY

A space which is accessible to authorized personnel only and primarily intended for use when servicing the installed equipment.

2.8 Definitions relating to electronic functions

2.8.1 Screening

Enclosures used to protect conductors or equipment against interference caused in particular by electromagnetic radiation from other conductors or equipment.

3. Classification of ASSEMBLIES

ASSEMBLIES are classified according to:

- the external design (see Sub-clause 2.3);
- the place of installation (see Sub-clauses 2.5.1 and 2.5.2);
- the conditions of installation with respect to mobility (see Sub-clauses 2.5.3 and 2.5.4);
- the degree of protection (see Sub-clause 7.2.1);
- the type of enclosure;
- the method of mounting, for example fixed or removable parts (see Sub-clauses 7.6.3 and 7.6.4);
- the measures for the protection of persons (see Sub-clause 7.4).

4. Electrical characteristics of ASSEMBLIES

4.1 Rated voltages

An ASSEMBLY is defined by the following rated voltages of its various circuits:

4.1.1 Rated operational voltage (of a circuit of an ASSEMBLY)

A rated operational voltage (U_o) of a circuit of an ASSEMBLY is the value of voltage which, combined with the rated current of this circuit, determines its application.

For polyphase circuits, it is stated as the voltage between phases.

Note. — Standard values of rated control circuit voltages are found in the relevant standards for the incorporated devices.

The manufacturer of the ASSEMBLY shall state the limits of voltage necessary for correct functioning of the main and auxiliary circuits. In any case, these limits must be such that the voltage at the control circuit terminals of incorporated components is maintained under normal load conditions, within the limits specified in the relevant IEC standards.

4.1.2 Rated insulation voltage (of a circuit of an ASSEMBLY)

The rated insulation voltage (U_i) of a circuit of an ASSEMBLY is the value of voltage which designates it and to which dielectric tests, clearances and creepage distances are referred.

The maximum rated operational voltage of any circuit of the ASSEMBLY shall not exceed its rated insulation voltage. It is assumed that the operational voltage of any circuit of an ASSEMBLY will not, even temporarily, exceed 110% of its rated insulation voltage.

Notes 1. — Standard values for rated insulation voltages for main circuits are under consideration.

2. — For single-phase circuits derived from IT systems (see IEC Publication 364-3: Electrical Installations of Buildings, Part 3: Assessment of General Characteristics), the insulation voltage should be at least equal to the voltage between phases of the supply.

4.2 Rated current (of a circuit of an ASSEMBLY)

The rated current of a circuit of an ASSEMBLY is stated by the manufacturer, taking into consideration the ratings of the components of the electrical equipment within the assembly, their disposition and application. This current must be carried without the temperature-rise of its several parts exceeding the limits specified in Sub-clause 7.3 (Table III) when verified according to Sub-clause 8.2.1.

Note. — Due to the complex factors determining the rated currents, no standard values can be given.

4.3 Rated short-time withstand current (of a circuit of an ASSEMBLY)

The rated short-time withstand current of a circuit of an ASSEMBLY is the r.m.s. value of current that this circuit can carry during a specified short time under the test conditions specified in Sub-clause 8.2.3. Unless otherwise specified, the time is 1 s.

Note. — If the time is shorter than 1 s, both the rated short-time withstand current and the time should be stated, for example 20 kA, 0.2 s.

4.4 Rated peak withstand current (of a circuit of an ASSEMBLY)

The rated peak withstand current of a circuit of an ASSEMBLY is the value of peak current that this circuit can withstand under the test conditions specified in Sub-clause 8.2.3 (see also Sub-clause 7.5.3).

4.5 Rated prospective short-circuit withstand current (of a circuit of an ASSEMBLY)

The rated prospective short-circuit withstand current of a circuit of an ASSEMBLY is the r.m.s. value of prospective short-circuit current that this circuit can withstand during a specified time under the test conditions specified in Sub-clause 8.2.3; unless otherwise specified, this time is 1 s.

4.6 Rated conditional short-circuit current (of a circuit of an ASSEMBLY)

The rated conditional short-circuit current of a circuit of an ASSEMBLY is the value of the prospective current that this circuit, protected by a current limiting switching device, can withstand for the operating time of this device under the test conditions specified in Sub-clause 8.2.3 (see also Sub-clause 7.5.2).

Note. — For a.c., the value of current is the r.m.s. value of the a.c. component of the current.

4.7 Rated fused short-circuit current (of a circuit of an ASSEMBLY)

The rated fused short-circuit current of a circuit of an ASSEMBLY is the rated conditional short-circuit current when the current-limiting switching device is a fuse.

4.8 Rated diversity factor

The rated diversity factor of an ASSEMBLY or a part of an ASSEMBLY having several main circuits (e.g. a section or sub-section) is the ratio of the maximum sum, at any one time, of the assumed currents of all the main circuits involved, to the sum of the rated currents of all the main circuits of the ASSEMBLY or the selected part of the ASSEMBLY.

When the manufacturer states a rated diversity factor, this factor shall be used for the temperature-rise test in accordance with Sub-clause 8.2.1.

Note. — In the absence of information concerning the actual currents, the following conventional values may be used:

TABLE I

Number of main circuits	Diversity factor
2 and 3	0.9
4 and 5	0.8
6 to 9 inclusive	0.7
10 (and above)	0.6

Unless otherwise specified, for PTTA the diversity factor is 1.0.

4.9 Rated frequency

The rated frequency of an ASSEMBLY is the value of frequency which designates it and to which the operating conditions are referred.

If the circuits of an ASSEMBLY are designed for different values of frequency, the rated frequency of each circuit shall be given.

Note. — The frequency should be within the limits specified in the relevant IEC standards for the incorporated components. Unless otherwise stated by the manufacturer of the ASSEMBLY, the limits are assumed to be 98% and 102% of the rated frequency.

5. Information to be given regarding the ASSEMBLY

The following information shall be given by the manufacturer; such information which is not given on the nameplates shall be provided in some other appropriate way.

5.1 Nameplates

Each ASSEMBLY shall be provided with one or more plates, marked in a durable manner and located in a place such that they are visible and legible when the ASSEMBLY is installed.

Information specified under Items *a)* and *b)* shall be given on the nameplate.

Information from Items *c)* to *q)* may, where applicable, be given on the nameplates, in the relevant documents, the circuit diagrams or in the manufacturer's list or catalogues.

a) The manufacturer's name or trade mark;

Note. — The final assembler of the ASSEMBLY is deemed to be its manufacturer (see Note 2 of Sub-clause 2.1.1).

b) type designation or identification number or other means of identification making it possible to obtain relevant information from the manufacturer;

c) IEC Publication 439-1;

d) type of current (and frequency in the case of a.c.);

e) rated operational voltages (see Sub-clause 4.1.1);

f) rated insulation voltages (see Sub-clause 4.1.2);

- g) rated voltages of auxiliary circuits (if applicable);
- h) limits of operation (see Clause 4);
- i) rated current of each circuit (if applicable; see Sub-clause 4.2);
- k) short-circuit strength (see Sub-clause 7.5.2);
- l) degree of protection (see Sub-clause 7.2.1);
- m) measures for protection of persons (see Sub-clause 7.4);
- n) service conditions for indoor use, outdoor use or special use, if different from the usual service conditions as given in Sub-clause 6.1;
- o) types of system earthing for which the ASSEMBLY is designed;
- p) dimensions (see Figures C3 and C4, pages 108 and 109) given preferably in the order of height, width (or length), depth (not applicable for PTTA);
- q) weight (not applicable for PTTA).

5.2 Markings

Inside the ASSEMBLY, it shall be possible to identify individual circuits and their protective devices.

Where items of equipment of the ASSEMBLY are designated, the designations used shall be identical with those in the wiring diagrams which may be supplied together with the ASSEMBLY.

5.3 Instructions for installation, operation and maintenance

The manufacturer shall specify in his documents or catalogues the conditions, if any, for the installation, operation and maintenance of the ASSEMBLY and the equipment contained therein.

If necessary, the instructions for the transport, installation and operation of the ASSEMBLY shall indicate the measures that are of particular importance for the proper and correct installation, commissioning and operation of the ASSEMBLY.

Where necessary, the above-mentioned documents shall indicate the recommended extent and frequency of maintenance.

If the circuitry is not obvious from the physical arrangement of the apparatus installed, suitable information shall be supplied, for example wiring diagrams or tables.

6. Service conditions

6.1 Normal service conditions

ASSEMBLIES conforming to this standard are intended for use under the following service conditions.

Note. — If components, for example relays, electronic equipment, are used which are not designed for these conditions, appropriate steps should be taken to ensure proper operation (see Sub-clause 7.6.2.4, second paragraph).

6.1.1 Ambient air temperature

6.1.1.1 Ambient air temperature for indoor installations

The ambient air temperature does not exceed $+40^{\circ}\text{C}$ and its average over a period of 24 h does not exceed $+35^{\circ}\text{C}$.

The lower limit of the ambient air temperature is -5°C .

6.1.1.2 *Ambient air temperature for outdoor installations*

The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.

The lower limit of the ambient air temperature is:

- 25 °C in a temperate climate, and
- 50 °C in an arctic climate.

Note. — The use of ASSEMBLIES in an arctic climate may require a special agreement between manufacturer and user.

6.1.2 *Atmospheric conditions*

6.1.2.1 *Atmospheric conditions for indoor installations*

The air is clean and its relative humidity does not exceed 50% at a maximum temperature of +40 °C. Higher relative humidities may be permitted at lower temperatures, for example 90% at +20 °C. Care should be taken of moderate condensation which may occasionally occur due to variations in temperature.

6.1.2.2 *Atmospheric conditions for outdoor installations*

The relative humidity may temporarily be as high as 100% at a maximum temperature of +25 °C.

6.1.3 *Altitude*

The altitude of the site of installation does not exceed 2 000 m (6 600 ft).

Note. — For electronic equipment to be used at altitudes above 1 000 m (3 300 ft) it may be necessary to take into account the reduction of the dielectric strength and of the cooling effect of the air. Electronic equipment intended to operate in these conditions should be designed or used in accordance with an agreement between manufacturer and user.

6.2 *Special service conditions*

Where any of the following special service conditions exist, the applicable particular requirements shall be complied with or special agreements shall be made between user and manufacturer. The user shall inform the manufacturer if such exceptional service conditions exist.

Special service conditions are for example:

- 6.2.1 Values of temperature, relative humidity and/or altitude differing from those specified in Sub-clause 6.1.
- 6.2.2 Applications where variations in temperature and/or air pressure take place at such a speed that exceptional condensation is liable to occur inside the ASSEMBLY.
- 6.2.3 Heavy pollution of the air by dust, smoke, corrosive or radioactive particles, vapours or salt.
- 6.2.4 Exposure to strong electric or magnetic fields.
- 6.2.5 Exposure to extreme temperatures, for example radiation from sun or furnaces.
- 6.2.6 Attack by fungus or small creatures.
- 6.2.7 Installation in locations where fire or explosion hazards exist.
- 6.2.8 Exposure to heavy vibration and shocks.

6.2.9 Installation in such a manner that the current-carrying capacity or breaking capacity is affected, for example equipment built into machines or recessed into walls.

6.2.10 Consideration of appropriate remedies against electrical and radiated interferences, shall be the subject of agreement between manufacturer and user.

6.3 *Conditions during transport, storage and erection*

6.3.1 A special agreement shall be made between user and manufacturer if the conditions during transport, storage and erection, for example temperature and humidity conditions, differ from those defined in Sub-clause 6.1.

Unless otherwise specified, the following temperature range applies during transport and storage: between -25°C and $+55^{\circ}\text{C}$ and, for short periods not exceeding 24 h, up to $+70^{\circ}\text{C}$.

Equipment subjected to these extreme temperatures without being operated, shall not undergo any irreversible damage and shall then operate normally in the specified conditions.

7. Design and construction

7.1 *Mechanical design*

7.1.1 *General*

The ASSEMBLIES shall be constructed only of materials capable of withstanding the mechanical, electrical and thermal stresses as well as the effects of humidity which are likely to be encountered in normal service.

Protection against corrosion shall be ensured by the use of suitable materials or by the application of equivalent protective coatings to the exposed surface, taking account of the intended conditions of use and maintenance.

All enclosures or partitions shall be of a mechanical strength sufficient to withstand the stresses to which they may be subjected in normal service.

The apparatus and circuits in the ASSEMBLY shall be so arranged as to facilitate their operation and maintenance and at the same time to ensure the necessary degree of safety.

7.1.2 *Clearances, creepage distances and isolating distances**

7.1.2.1 *Clearances and creepage distances*

The apparatus forming part of the ASSEMBLY shall have distances complying with those specified in their relevant specifications, and these shall be maintained during normal service conditions.

When arranging the apparatus within the ASSEMBLY, the clearances and creepage distances specified for them shall be complied with, taking into account the relevant service conditions.

For bare live conductors and terminations (e.g. busbars, connections between apparatus, cable lugs), the clearances and creepage distances shall at least comply with those specified for the apparatus with which they are immediately associated.

In addition, abnormal conditions such as short-circuit shall not permanently reduce the distances between busbars and/or connections other than cables below the values specified for the apparatus with which they are immediately associated. See also Sub-clause 8.2.2.2.

* Application of the data given in IEC Publication 664: Insulation Co-ordination within Low-voltage Systems Including Clearances and Creepage Distances for Equipment, to switchgear and controlgear assemblies is under consideration. This may also affect Clauses 4, 5 and 8.

7.1.2.2 Isolating distances

In the case of functional units being mounted on withdrawable parts, the isolating distances provided shall at least comply with minimum requirements in the relevant specification for disconnectors*, taking account of the manufacturing tolerances and changes in dimensions due to wear.

7.1.3 Terminals for external conductors

7.1.3.1 The manufacturer shall indicate if the terminals are suitable for connection of copper or aluminium conductors or both. The terminals shall be such that the external conductors may be connected by a means (screws, connectors, etc.) which ensures that the necessary contact pressure corresponding to the current rating and the short-circuit strength of the apparatus and the circuit is maintained.

7.1.3.2 In the absence of a special agreement between manufacturer and user, terminals shall be capable of accommodating conductors and cables of copper from the smallest to the largest cross-sectional areas corresponding to the appropriate rated current (see Appendix A).

Where aluminium conductors are used, terminals which cater for the maximum sizes of conductors given in column c of Table AI of Appendix A are usually dimensionally adequate. In those instances where the use of this maximum size of aluminium conductor prevents the full utilization of the rated current of the circuit, it will be necessary, subject to agreement between manufacturer and user, to provide means of connection for an aluminium conductor of the next larger size.

In the case where external conductors for electronic circuits with low level currents (less than 1 A and less than 50 V a.c. or d.c.) have to be connected to an ASSEMBLY, the Table AI of Appendix A does not apply (see Note 2 of Appendix A).

7.1.3.3 The available wiring space shall permit proper connection of the external conductors of the indicated material and, in the case of multicore cables, spreading of the cores.

The conductors must not be subjected to stresses which reduce their normal life.

7.1.3.4 Unless otherwise agreed between manufacturer and user, on three-phase and neutral circuits, terminals for the neutral conductor shall allow the connection of copper conductors having a current-carrying capacity:

- equal to half the current-carrying capacity of the phase conductor, with a minimum of 16 mm², if the size of the phase conductor exceeds 16 mm².
- equal to the full current-carrying capacity of the phase conductor if the size of the latter is less than or equal to 16 mm².

Notes 1. — For conductors other than copper conductors, the above cross-sections should be replaced by cross-sections of equivalent conductivity, which may require larger terminals.

2. — For certain applications in which the current in the neutral conductor may reach high values, for example large fluorescent lighting installations, a neutral conductor having the same current-carrying capacity as the phase conductors may be necessary, subject to special agreement between manufacturer and user.

7.1.3.5 If connecting facilities for incoming and outgoing neutral, protective and PEN conductors are provided, they shall be arranged in the vicinity of the associated phase conductor terminals.

* IEC Publication 408: Low-voltage Air-break Disconnectors, Air-break Switch-disconnectors and Fuse-combination Units.

7.1.3.6 Openings in cable entries, cover plates, etc., shall be so designed that when the cables are properly installed, the stated protective measures against contact and degree of protection shall be obtained. This implies the selection of means of entry suitable for the application as stated by the manufacturer.

7.1.3.7 Identification of terminals

Identification of terminals shall comply with IEC Publication 445: Identification of Apparatus Terminals and General Rules for a Uniform System of Terminal Marking, Using an Alphanumeric Notation.

7.2 Enclosure and degree of protection

7.2.1 Degree of protection

7.2.1.1 The degree of protection provided by any ASSEMBLY against contact with live parts, ingress of solid foreign bodies and liquid is indicated by the designation IP... according to IEC Publication 529: Classification of Degrees of Protection Provided by Enclosures.

For ASSEMBLIES for indoor use where there is no requirement for protection against ingress of water, the following IP references are preferred:

IP00, IP2X, IP3X, IP4X, IP5X.

Where some degree of protection against ingress of water is required, the following table gives the preferred IP numbers.

TABLE II
List of preferred IP numbers

First characteristic numeral Protection against contact and protection against ingress of solid foreign bodies	Second characteristic numeral Protection against harmful ingress of water				
	1	2	3	4	5
2	IP21				
3	IP31	IP32			
4		IP42	IP43		
5			IP53	IP54	IP55
6				IP64	IP65

7.2.1.2 For ASSEMBLIES for outdoor use having no supplementary protection, the second characteristic numeral shall be at least 3.

Note. — For outdoor installation, supplementary protection may be protective roofing or the like.

7.2.1.3 Unless otherwise specified, the degree of protection indicated by the manufacturer applies to the complete ASSEMBLY when installed in accordance with the manufacturer's instructions (see also Sub-clause 7.1.3.6), for example sealing of the open mounting surface of an ASSEMBLY, if necessary.

7.2.1.4 If the degree of protection of part of the ASSEMBLY—for example on the operating face—differs from that of the main portion, the manufacturer shall indicate the degree of protection of that part separately. Example: IP00 — operating face IP20.

7.2.1.5 For PTTA, no IP number(s) can be given unless the appropriate tests can be made, or the degree(s) of protection can be checked by inspection according to IEC Publication 529, or tested prefabricated enclosures are used.

7.2.2 Measures to take account of atmospheric humidity

In the case of an ASSEMBLY for outdoor installation and in the case of an enclosed ASSEMBLY for indoor installation intended for use in locations with high humidity and temperatures varying within wide limits, suitable arrangements (ventilation and/or internal heating, etc.) shall be made to prevent harmful condensation within the ASSEMBLY. However, the specified degree of protection shall at the same time be maintained (for built-in apparatus, see Sub-clause 7.6.2.4).

7.3 Temperature-rise

The temperature rise limits given in Table III shall not be exceeded for ASSEMBLIES when verified in accordance with Sub-clause 8.2.1.

Note. — The temperature rise of an element or part is the difference between the temperature of this element or part measured in accordance with Sub-clause 8.2.1.5 and the ambient air temperature outside the ASSEMBLY.

TABLE III
Temperature rise limits

Parts of ASSEMBLIES	Temperature rise (K)
Built-in components ¹⁾	In accordance with the relevant requirements for the individual components, if any, or, in accordance with the manufacturer's instructions, taking into consideration the temperature in the ASSEMBLY
Terminals for external insulated conductors	70 ²⁾
Busbars and conductors, plug-in contacts of removable or withdrawable parts which connect to busbars	Limited by: <ul style="list-style-type: none"> — mechanical strength of conducting material; — possible effect on adjacent equipment; — permissible temperature limit of the insulating materials in contact with the conductor; — the effect of the temperature of the conductor on the apparatus connected to it; — for plug-in contacts, nature and surface treatment of the contact material
Manual operating means: <ul style="list-style-type: none"> — of metal — of insulating material 	15 ³⁾ 25 ³⁾
Accessible external enclosures and covers: <ul style="list-style-type: none"> — metal surfaces — insulating surfaces 	30 ⁴⁾ 40 ⁴⁾
Discrete arrangements of plug and socket-type connection	Determined by the limit for those components of the related equipment of which they form part ⁵⁾

¹⁾ The term "built-in components" means:

- conventional switchgear and controlgear;
- electronic sub-assemblies (e.g. rectifier bridge, printed circuit);
- parts of the equipment (e.g. regulator, stabilized power supply unit, operational amplifier).

²⁾ The temperature-rise limit of 70 K is a value based on the conventional test of Sub-clause 8.2.1. An ASSEMBLY used or tested under installation conditions may have connections, the type, nature and disposition of which will not be the same as those adopted for the test, and a different temperature rise of terminals may result and may be required or accepted.

³⁾ Manual operating means within ASSEMBLIES which are only accessible after the ASSEMBLY has been opened, for example emergency handles, draw-out handles, which are operated infrequently, are allowed to assume higher temperature rises.

⁴⁾ Unless otherwise specified in the case of covers and enclosures which are accessible but need not be touched during normal operation, an increase in the temperature-rise limits by 10 K is permissible.

⁵⁾ This allows a degree of flexibility in respect of equipment (e.g. electronic devices) which is subject to temperature-rise limits different from those normally associated with switchgear and controlgear.

7.4 Protection against electric shock

The following requirements are intended to ensure that the required protective measures are obtained when an ASSEMBLY is installed in a system conforming to the relevant specification.

For generally accepted protective measures refer to IEC Publication 364-4-41: Electrical Installations of Buildings, Part 4: Protection for Safety, Chapter 41: Protection against Electric Shock.

Those protective measures which are of particular importance for an ASSEMBLY are reproduced in detail below, taking into account the specific needs of ASSEMBLIES.

7.4.1 Protection against both direct and indirect contact

7.4.1.1 Protection by safety extra-low voltage

See IEC Publication 364-4-41, Clause 411.1.

7.4.2 Protection against direct contact (see Sub-clause 2.6.7)

Protection against direct contact can be obtained either by appropriate constructional measures on the ASSEMBLY itself or by additional measures to be taken during installation; this may require information given by the manufacturer.

An example of additional measures to be taken is the installation of an open-type ASSEMBLY without further provisions in a location where access is only permitted for authorized personnel.

One or more of the protective measures defined below may be selected, taking into account the requirements laid down in the following sub-clauses. The choice of the protective measure shall be subject to an agreement between manufacturer and user.

Note. — Information given in the manufacturer's catalogues may take the place of such an agreement.

7.4.2.1 Protection by insulation of live parts

Live parts shall be completely covered with insulation which can only be removed by destruction.

This insulation shall be made of suitable materials capable of durably withstanding the mechanical, electrical and thermal stresses to which it may be subjected in service.

Note. — Examples are electrical components embedded in insulation, cables.

Paints, varnishes, lacquers and similar products alone are generally not considered to provide an adequate insulation for protection against electric shock in normal service.

7.4.2.2 Protection by barriers or enclosures

The following requirements shall be complied with:

7.4.2.2.1 All external surfaces shall conform to a degree of protection of at least IP2X. The distance between the mechanical means provided for protection and the live parts they protect shall be not less than the values specified for the clearances and creepage distances in Sub-clause 7.1.2, unless the mechanical means are of insulating material.

7.4.2.2.2 All barriers and enclosures shall be firmly secured in place. Taking into account their nature, size and arrangement, they shall have sufficient stability and durability to resist the strains and stresses likely to occur in normal service without reducing the clearances according to Sub-clause 7.4.2.2.1.

7.4.2.2.3 Where it is necessary to make provision for the removal of barriers, opening of enclosures, or withdrawal of parts of enclosures (doors, casings, lids, covers, and the like), this shall be in accordance with one of the following requirements:

- a) Removal, opening or withdrawal shall necessitate the use of a key or tool.
- b) All live parts which can unintentionally be touched after the door has been opened shall be disconnected before the door can be opened.

Example: By interlocking the door or doors with a disconnecter so that they can only be opened when the disconnecter is open and it shall not be possible to close the disconnecter while the door is open, except by overriding the interlock or using a tool.

If, for reasons of operation, the ASSEMBLY is fitted with a device permitting authorized persons to obtain access to live parts while the equipment is live, the interlock shall automatically be restored on reclosing the door or doors.

- c) The ASSEMBLY shall include an internal obstacle or shutter shielding all live parts in such a manner that they cannot unintentionally be touched when the door is open. This obstacle or shutter shall meet the requirements of Sub-clauses 7.4.2.2.1 (for exceptions, see Item d)) and 7.4.2.2.2. It shall either be fixed in place or shall slide into place the moment the door is opened. It shall not be possible to remove this obstacle or shutter except by the use of a key or tool.

It may be necessary to provide warning labels.

- d) Where any parts behind a barrier or enclosure need occasional handling (such as replacement of a lamp or of a fuse-link), the removal, opening or withdrawal without the use of a key or tool and without switching off shall be possible only if the following conditions are fulfilled:

- An obstacle shall be provided inside the barrier or enclosure so as to prevent persons from coming unintentionally into contact with live parts not protected by another protective measure. However, this obstacle need not prevent persons from coming intentionally into contact by by-passing this obstacle with the hand. It shall not be possible to remove the obstacle except through the use of a key or tool.
- Live parts, the voltage of which fulfils the conditions for the safety extra-low voltage, need not be covered.

7.4.2.3 Protection by obstacles

This measure applies to open-type ASSEMBLIES, see IEC Publication 364-4-41, Clause 412.3.

7.4.3 Protection against indirect contact (see Sub-clause 2.6.8)

The user shall indicate the protective measure which is applied to the installation for which the ASSEMBLY is intended. In particular, attention is drawn to IEC Publication 364-4-41, where requirements for protection against indirect contact are specified for the complete installation, for example the use of protective conductors.

7.4.3.1 Protection by using protective circuits

A protective circuit in an ASSEMBLY consists of either a separate protective conductor or the conductive structural parts or both. It provides the following:

- protection against the consequences of faults within the ASSEMBLY;
- protection against the consequences of faults in external circuits supplied through the ASSEMBLY

The requirements to be complied with are given in the following sub-clauses:

7.4.3.1.1 Constructional precautions shall be taken to ensure electrical continuity between the exposed conductive parts of the ASSEMBLY (see Sub-clause 7.4.3.1.5) and between these parts and the protective circuits of the installation (see Sub-clause 7.4.3.1.6).

For PTTA, unless a type-tested arrangement is used, or verification of the short-circuit strength is not necessary in accordance with Sub-clauses 8.2.3.1.1 to 8.2.3.1.3, a separate protective conductor shall be used for the protective circuit and it shall be so disposed with respect to the busbars that the effects of electro-magnetic forces are negligible.

7.4.3.1.2 Certain exposed conductive parts of an ASSEMBLY which do not constitute a danger:

- either because they cannot be touched on large surfaces or grasped with the hand,
- or because they are of small size (approx. 50 mm by 50 mm) or so located as to exclude any contact with live parts,

need not be connected to the protective circuits. This applies to screws, rivets and nameplates. It also applies to electromagnets of contactors or relays, magnetic cores of transformers (unless they are provided with a terminal for connection to the protective conductor), certain parts of releases, etc., irrespective of their size.

7.4.3.1.3 Manual operating means (handles, wheels, etc.) shall be:

- either electrically connected, in a secure and permanent manner, with the parts connected to the protective circuits,
- or provided with additional insulation which insulates them from other conductive parts of the ASSEMBLY. This insulation shall be rated for at least the maximum insulation voltage of the associated device.

It is preferable that parts of manual operating means that are normally grasped by the hand during operation are made of or covered by insulating material rated for the maximum insulation voltage of the equipment.

7.4.3.1.4 Metal parts covered with a layer of varnish or enamel cannot generally be considered to be adequately insulated to comply with these requirements.

7.4.3.1.5 Continuity of protective circuits shall be ensured by effective interconnections either directly or by means of protective conductors.

- a) When a part of the ASSEMBLY is removed from the enclosure, for example for routine maintenance, the protective circuits for the remainder of the ASSEMBLY shall not be interrupted.

Means used for assembling the various metal parts of an ASSEMBLY are considered sufficient for ensuring continuity of the protective circuits if the precautions taken guarantee permanent good conductivity and a current-carrying capacity sufficient to withstand the earth fault current that may flow in the ASSEMBLY.

Note. — Flexible metal conduits should not be used as protective conductors.

- b) When removable or withdrawable parts are equipped with metal supporting surfaces, these surfaces are considered sufficient for ensuring continuity of protective circuits provided that the pressure exerted on them is sufficiently high. Precautions may have to be taken to guarantee permanent good conductivity. The protective circuit of a withdrawable part shall remain effective from the connected position to the test position inclusively.

- c) For lids, doors, cover plates and the like, the usual metal screwed connections and metal hinges are considered sufficient to ensure continuity provided that no electrical equipment is attached to them.

If apparatus with a voltage exceeding the limits of extra-low voltage are attached to lids, doors, cover plates, etc., steps shall be taken to ensure continuity of the protective circuits. It is recommended that these parts be fitted with a carefully attached protective conductor whose cross-sectional area depends on the maximum cross-section of the supply lead to the equipment attached. An equivalent electrical connection especially designed for this purpose (sliding contact, hinges protected against corrosion) shall also be considered satisfactory.

- d) All parts of the protective circuit within the ASSEMBLY shall be so designed that they are capable of withstanding the highest thermal and dynamic stresses that may occur at the place of installation of the ASSEMBLY.
- e) When the enclosure of an ASSEMBLY is used as part of a protective circuit, the cross-sectional area of this enclosure shall be at least electrically equivalent to the minimum cross-sectional area specified in Sub-clause 7.4.3.1.7.
- f) Where continuity can be interrupted by means of connectors or plug-and-socket devices, the protective circuit shall be interrupted only after the live conductors have been interrupted and continuity shall be established before the live conductors are reconnected.
- g) In principle, with the exception of the cases mentioned under Item f), protective circuits within an ASSEMBLY shall not include a disconnecting device (switch, disconnector, etc.). The only means permitted in the run of protective conductors shall be links which are removable by means of a tool and accessible only to authorized personnel (these links may be required for certain tests).

7.4.3.1.6 The terminals for external protective conductors and sheathing shall, where required, be bare and, unless otherwise specified, suitable for the connection of copper conductors. A separate terminal of adequate size shall be provided for the outgoing protective conductor(s) of each circuit. In the case of enclosures and conductors of aluminium or aluminium alloys, particular consideration shall be given to the danger of electrolytic corrosion. In the case of ASSEMBLIES with conductive structures, enclosures, etc., means shall be provided to ensure electrical continuity between the exposed conductive parts (the protective circuit) of the ASSEMBLY and the metal sheathing of connecting cables (steel conduit, lead sheath, etc.). The connecting means to ensure the continuity of the exposed conductive parts with external protective conductors shall have no other function.

Note. — Special precautions may be necessary with metal parts of the ASSEMBLY, particularly gland plates, where abrasion resistant finishes, for example powder coatings, are used.

7.4.3.1.7 The cross-section of protective conductors (PE) in an ASSEMBLY shall be determined in one of the following ways:

- a) The cross-sectional area of the protective conductor shall be not less than the appropriate value shown in Table IV.

If the application of this table produces non-standard sizes, conductors having the nearest standard cross-sectional area are to be used.

TABLE IV

Cross-sectional area of phase conductors S (mm ²)	Minimum cross-sectional area of the corresponding protective conductor S_p (mm ²)
$S \leq 16$	S
$16 < S \leq 35$	16
$S > 35$	$\frac{S}{2}$

The values in Table IV are valid only if the protective conductor is made of the same metal as the phase conductors. If this is not so, the cross-sectional area of the protective conductor is to be determined in a manner which produces a conductance equivalent to that which results from the application of Table IV.

- b) The cross-sectional area of the protective conductor shall be calculated with the aid of the formula indicated in Appendix B or obtained by some other method, for example by testing.

For determining the cross-section of protective conductors, the following conditions have to be satisfied simultaneously:

- 1) when the test according to Sub-clause 8.2.4.2 is carried out, the value of the fault-loop impedance shall fulfil the conditions required for the operation of the protective device;
- 2) the conditions of operation of the electrical protective device shall be so chosen as to eliminate the possibility of the fault current in the protective conductor causing a temperature rise that tends to impair this conductor or its electrical continuity.

7.4.3.1.8 In the case of an ASSEMBLY containing structural parts, frameworks, enclosures, etc., made of conducting material, a protective conductor, if provided, need not be insulated from these parts (for exceptions, see Sub-clause 7.4.3.1.9).

7.4.3.1.9 Conductors to certain protective devices—including the conductors connecting them to a separate earth electrode—shall be carefully insulated. This applies, for instance, to voltage-operated fault detection devices, and can also apply to the earth-connection of the transformer neutral.

Note. — Attention is drawn to the special precautions to be taken in applying the requirements relating to such devices.

7.4.3.2 *Protection by measures other than using protective circuits*

ASSEMBLIES can provide protection against indirect contact by means of the following measures which do not require a protective circuit:


- separation of circuits;
- total insulation.

7.4.3.2.1 *Separation of circuits*

See IEC Publication 364-4-41, Clause 413.5.

7.4.3.2.2 *Protection by total insulation**

For protection, by total insulation, against indirect contact, the following requirements shall be met:

- a) The apparatus shall be completely enclosed in insulating material. The enclosure shall carry the symbol  which shall be visible from the outside.
- b) The enclosure shall be made of an insulating material which is capable of withstanding the mechanical, electrical and thermal stresses to which it is liable to be subjected under normal or special service conditions (see Sub-clauses 6.1 and 6.2) and it shall be resistant to ageing and flame-resistant**.

* According to IEC Publication 364-4-41, Sub-clause 413.2.1.1, this is equivalent to Class II equipment, see IEC Publication 536: Classification of Electrical and Electronic Equipment with Regard to Protection against Electric Shock (under revision).

** Under consideration by ISO/TC 61.

- c) The enclosure shall at no point be pierced by conducting parts in such a manner that there is the possibility of a fault voltage being brought out of the enclosure.

This means that for example metal parts, such as handles, which for constructional reasons have to be brought through the enclosure shall be sufficiently insulated either on the inside or the outside.

- d) The enclosure, when the ASSEMBLY is ready for operation and connected to the supply, shall enclose all live parts, exposed conductive parts and parts belonging to a protective circuit in such a manner that they cannot be touched. The enclosure shall give at least the degree of protection IP4X*

If a protective conductor, which is extended to electrical equipment connected to the load side of the ASSEMBLY, is to be passed through an ASSEMBLY whose exposed conductive parts are insulated, the necessary terminals for connecting the external protective conductors shall be provided and identified by suitable marking.

Inside the enclosure, the protective conductor and its terminal shall be insulated from the live parts and the exposed conductive parts in the same way as the live parts are insulated.

- e) Exposed conductive parts within the ASSEMBLY shall not be connected to the protective circuit, i.e. they shall not be included in a protective measure involving the use of a protective circuit. this applies also to built-in apparatus even if they have a connecting terminal for a protective conductor.
- f) If doors or covers of the enclosure can be opened without the use of a key or tool, an obstacle or insulating material shall be provided which will afford protection against unintentional contact not only with the accessible live parts, but also with the exposed conductive parts which are only accessible after the cover has been opened; this obstacle, however, shall not be removable except with the use of a tool.

7.4.4 *Discharging of electrical charges*

If the ASSEMBLY contains items of equipment which may retain dangerous electrical charges after they have been switched off (capacitors, etc.), a warning plate is required.

Small capacitors such as those used for arc extinction, for delaying the response of relays, etc., shall not be considered dangerous.

Note. — Unintentional contact is not considered dangerous if the voltages resulting from static charges fall below 120 V d.c. in less than 5 s after disconnection from the power supply.

7.4.5 *Operating and maintenance gangways within ASSEMBLIES (see Sub-clauses 2.7.1 and 2.7.2)*

Note. — Recesses within ASSEMBLIES of limited depth of the order of 1 m are not considered to be gangways.

7.4.5.1 *Gangways separated from the live parts by obstacles which provide at least the degree of protection IP2X.*

The operating and maintenance gangways shall have the following minimum dimensions:
(Under consideration.)

7.4.5.2 *Gangways which are not separated from unprotected live parts or which are separated by obstacles having a degree of protection of less than IP2X.*

* See IEC Publication 529.

These gangways shall be so designed that they can be considered to be locations reserved for authorized persons.

This presupposes that

- they are kept locked;
- they must not be unlocked except by properly authorized persons;
- they are only accessible to qualified persons;
- they are clearly marked with warning notices.

These gangways shall have the following minimum dimensions:

(Under consideration.)

7.4.6 *Requirements related to accessibility in service by authorized personnel*

For accessibility in service by authorized personnel, as agreed between manufacturer and user, one or more of the following requirements shall be fulfilled subject to agreement between manufacturer and user. These requirements shall be complementary to the protective measures specified in Sub-clause 7.4.

Note. — This implies that the agreed requirements shall be valid when an authorized person can obtain access to the assembly, for example by the use of tools or by overriding an interlock (see Sub-clause 7.4.2.2.3) when the ASSEMBLY or part of it is under voltage.

7.4.6.1 *Requirements related to accessibility for inspection and similar operations*

The ASSEMBLY shall be designed and arranged in such a way that certain operations, according to agreement between manufacturer and user, can be performed when the ASSEMBLY is in service and under voltage.

Such operations may be:

- visual inspection of:
 - switching devices and other apparatus,
 - settings and indicators of relays and releases,
 - conductor connections and markings;
- adjusting and resetting of relays, releases and electronic devices;
- replacement of fuse-links;
- replacement of indicating lamps;
- certain fault location operations, for example voltage and current measuring with suitably designed and insulated devices.

7.4.6.2 *Requirements related to accessibility for maintenance*

To enable maintenance agreed upon between manufacturer and user on a disconnected functional unit or group of the ASSEMBLY, with adjacent functional units or groups still under voltage, necessary measures shall be taken. The choice, which is subject to agreement between manufacturer and user, depends on such factors as service conditions, frequency of maintenance, competence of the authorized personnel, local installation rules, etc. Such measures may be:

- sufficient space between the actual functional unit or group and adjacent functional units or groups. It is recommended that parts likely to be removed for maintenance have as far as possible retainable fastening means;
- use of barrier-protected sub-sections for each functional unit or group;
- use of compartments for each functional unit or group;
- insertion of additional protective means provided or specified by the manufacturer.

7.4.6.3 *Requirements related to accessibility for extension under voltage*

When it is required to enable future extension of the ASSEMBLY with additional functional units or groups, with the rest of the assembly still under voltage, the requirements specified in Sub-clause 7.4.6.2 apply, subject to agreement between manufacturer and user. These requirements also apply for the insertion and connection of additional outgoing cables when the existing cables are under voltage.

The connection of additional units to their incoming supply shall not be made under voltage, unless the design of the ASSEMBLY permits such connections.

7.5 *Short-circuit protection and short-circuit withstand strength*

Note. — For the time being, this sub-clause applies primarily to a.c. equipment. Requirements concerning d.c. equipment are under consideration.

7.5.1 *General*

ASSEMBLIES shall be so constructed as to be capable of withstanding the thermal and dynamic stresses resulting from short-circuit currents up to the rated values.

Note. — The short-circuit stresses may be reduced by the use of current-limiting devices (inductances, current-limiting fuses or other current-limiting switching devices).

ASSEMBLIES shall be protected against short-circuit currents by means of for example circuit-breakers, fuses or combinations of both, which may either be incorporated in the ASSEMBLY or arranged outside it.

Note. — For ASSEMBLIES intended for use in IT systems*, the short-circuit protective device should have a sufficient breaking capacity on each single pole at line-to-line voltage to clear a double earth fault.

The user, when ordering an ASSEMBLY, shall specify the short-circuit conditions at the point of installation.

Note. — It is desirable that the highest possible degree of protection to personnel should be provided in case of a fault leading to arcing inside an ASSEMBLY, although the prime object should be to avoid such arcs by suitable design or to limit their duration.

For PTTA, it is recommended to use type-tested arrangements, for example busbars, unless the exemptions given in Sub-clauses 8.2.3.1.1 to 8.2.3.1.3 apply. In exceptional cases, where the use of type-tested arrangements is not possible, the short-circuit withstand strength of such parts shall be verified by extrapolation from type-tested arrangements.

7.5.2 *Information concerning the short-circuit withstand strength*

7.5.2.1 For an ASSEMBLY having only one incoming unit, the manufacturer shall state the short-circuit withstand strength as follows:

7.5.2.1.1 For ASSEMBLIES with a short-circuit protective device incorporated in the incoming unit, by indicating the maximum allowable value of prospective short-circuit current at the terminals of the incoming unit. This value shall not exceed the appropriate rating(s) (see Sub-clauses 4.3, 4.4, 4.5, 4.6 and 4.7). The corresponding power factor and peak values shall be those shown in Sub-clause 7.5.3.

If the short-circuit protective device is a fuse, the manufacturer shall state the characteristics of the fuse-link (current rating, breaking capacity, cut-off current, Pt , etc.).

* For explanation, see IEC Publication 364-3.

If a circuit breaker with time-delay release is used, it may be necessary to indicate the maximum time delay and current setting corresponding to the indicated prospective short-circuit current.

7.5.2.1.2 For ASSEMBLIES where the short-circuit protective device is not incorporated in the incoming unit, by indicating the short-circuit withstand strength in one or more of the following ways:

- a) The rated short-time withstand current (see Sub-clause 4.3) and the rated peak withstand current (see Sub-clause 4.4) together with the associated time if different from 1 s. The relationship between peak and r.m.s. value shall be as in Table V.

Note. — For times up to a maximum of 3 s, the relationship between the short-time withstand current and the associated time is given by the formula:

$$I^2t = \text{constant}$$

provided that the peak value does not exceed the rated peak withstand current.

- b) The rated prospective short-circuit current at the incoming terminals of the ASSEMBLY together with the associated time if different from 1 s. The relationship between peak and r.m.s. values shall be as in Table V.
- c) The rated conditional short-circuit current (see Sub-clause 4.6).
- d) The rated fused short-circuit current (see Sub-clause 4.7).

For Items c) and d), the manufacturer shall indicate the characteristics (current rating, breaking capacity, cut-off current, I^2t , etc.) of the current limiting switching devices (e.g. current limiting circuit-breakers or fuses) necessary for the protection of the ASSEMBLY.

Note. — When replacement of fuse-links is necessary, it is assumed that fuse-links with the same characteristics are used.

7.5.2.2 For an ASSEMBLY having several incoming units which are unlikely to be in operation simultaneously, the short-circuit withstand strength can be indicated for each of the incoming units in accordance with Sub-clause 7.5.2.1.

7.5.2.3 For an ASSEMBLY having several incoming units which are likely to be in operation simultaneously, and for an ASSEMBLY having one incoming unit and one or more outgoing units for high-power rotating machines likely to contribute to the short-circuit current, a special agreement shall be made to determine the values of prospective short-circuit current in each incoming unit, in each outgoing unit and in the busbars.

7.5.3 Relationship between peak and r.m.s. values of short-circuit current

The value of peak short-circuit current (peak value of the first loop of the short-circuit current including d.c. component) for determining the electrodynamic stresses shall be obtained by multiplying the r.m.s. value of the short-circuit current by the factor n . Standard values for the factor n and the corresponding power factor are given in Table V.

TABLE V

R.M.S. value of short-circuit current	$\cos \phi$	n
$I \leq 5 \text{ kA}$	0.7	1.5
$5 \text{ kA} < I \leq 10 \text{ kA}$	0.5	1.7
$10 \text{ kA} < I \leq 20 \text{ kA}$	0.3	2
$20 \text{ kA} < I \leq 50 \text{ kA}$	0.25	2.1
$50 \text{ kA} < I$	0.2	2.2

Note. — Values of Table V represent the majority of applications. In special locations, for example in the vicinity of transformers or generators, lower values of power factor may be found, whereby the maximum prospective peak current may become the limiting value instead of the r.m.s. value of the short-circuit current.

7.5.4 *Co-ordination of short-circuit protective devices*

7.5.4.1 The co-ordination of protective devices shall be the subject of an agreement between manufacturer and user. Information given in the manufacturer's catalogue may take the place of such an agreement.

7.5.4.2 If the operating conditions require maximum continuity of supply, the settings or selection of the short-circuit protective devices within the ASSEMBLY should, where possible, be so graded that a short-circuit occurring in any outgoing branch circuit is cleared by the switching device installed in the faulted branch circuit without affecting the other outgoing branch circuits, thus ensuring selectivity of the protective system.

7.5.5 *Circuits within an ASSEMBLY*

7.5.5.1 *Main circuits*

7.5.5.1.1 The busbars (bare or insulated) shall be arranged in such a manner that an internal short-circuit is not to be expected under normal operating conditions. Unless otherwise specified, they shall be rated in accordance with the information concerning the short-circuit withstand strength (see Sub-clause 7.5.2) and designed to withstand at least the short-circuit stresses limited by the protective device(s) on the supply side of the busbars.

7.5.5.1.2 The conductors between the main busbars and the supply side of a single functional unit as well as the components included in this unit may be rated on the basis of the reduced short-circuit stresses occurring, on the load side of the short-circuit protective device in this unit provided that these conductors are arranged such that under normal operating conditions an internal short-circuit between phases and/or between phases and earth is only a remote possibility, for example by being provided with adequate insulation or shrouding. This also applies to the conductors on the supply side of single functional units within ASSEMBLIES not containing busbars.

7.5.5.2 *Auxiliary circuits*

In general, auxiliary circuits shall be protected against the effects of short circuits. However, a short-circuit protective device shall not be provided if its operation is liable to cause a danger. In such a case, the conductors of auxiliary circuits shall be arranged in such a manner that short circuits would not be expected under normal operating conditions.

7.6 *Components installed in ASSEMBLIES*

7.6.1 *Selection of components*

Components incorporated in the ASSEMBLIES shall comply with the relevant IEC standards.

The components shall be suitable for the particular application with respect to the external design of the ASSEMBLY (e.g. open type or enclosed), their rated voltages, rated currents, service life, making and breaking capacities, short-circuit withstand strength, etc.

Components having a short-circuit withstand strength and/or a breaking capacity which is insufficient to withstand the stresses likely to occur at the place of installation, shall be protected by means of current-limiting protective devices, for example fuses or circuit-breakers. When selecting current limiting protective devices for built-in switching devices, account shall be taken of the

maximum permissible values specified by the manufacturer of the device, having due regard to co-ordination (see Sub-clause 7.5.4).

Co-ordination of components, for example co-ordination of motor starters with short-circuit protective devices, shall comply with the relevant IEC standards.

7.6.2 *Installation of components*

Components shall be installed in accordance with the instructions of their manufacturer (position of use, clearances to be observed for electric arcs or for the removal of the arc chute, etc.).

7.6.2.1 *Accessibility*

The apparatus, functional units mounted on the same support (mounting plate, mounting frame) and the terminals for external conductors shall be so arranged as to be accessible for mounting, wiring, maintenance and replacement. In particular, it is recommended that the terminals are situated at least 0.2 m above the base of floor-mounted ASSEMBLIES and, moreover, are so placed that the cables can be easily connected to them.

Adjusting and resetting devices which have to be operated inside the ASSEMBLY shall be easily accessible.

In general, for floor-mounted ASSEMBLIES, indicating instruments which need to be read by the operator should not be located higher than 2 m above the base of the ASSEMBLY. Operating devices, such as handles, push buttons, etc., should be located at such a height that they can easily be operated; this means that in general their centreline should not be higher than 2 m above the base of the ASSEMBLY.

Notes 1. — Actuators for emergency switching devices (see IEC Publication 364-5-537: Electrical Installations of Buildings, Part 5: Selection and Erection of Electrical Equipment, Chapter 53: Switchgear and Controlgear, Section 537: Devices for Isolation and Switching — Clause 537.4) should be accessible within a zone between 0.8 m and 1.6 m above servicing level.

2. — It is recommended that wall-mounted and floor-mounted ASSEMBLIES should be installed at such a height with respect to the operating level that the above requirements for accessibility and operating heights are met.

7.6.2.2 *Interaction*

The equipment shall be installed and wired in the ASSEMBLY in such a manner that its proper functioning is not impaired by interaction, such as heat, arcs, vibration, fields of energy, which are present in normal operation. In the case of electronic ASSEMBLIES, this may necessitate the separation or screening of monitoring circuits from power circuits.

In the case of enclosures designed to accommodate fuses, special consideration shall be given to thermal effects (see Sub-clause 7.3). The manufacturer shall state the type and rating of the fuse-links to be used.

7.6.2.3 *Barriers*

Barriers for manual switching devices shall be so designed that the switching arcs do not present a danger to the operator.

To minimize danger when replacing fuse-links, interphase barriers shall be applied unless the design and location of the fuses makes this unnecessary.

7.6.2.4 *Conditions existing at site of installation*

The components for ASSEMBLIES are selected on the basis of the normal service conditions of the ASSEMBLY specified in Sub-clause 6.1 (see also Sub-clause 7.6.2.2).

Where necessary, suitable precautions (heating, ventilation) shall be taken to ensure that the service conditions essential for proper functioning are maintained, for example the minimum temperature for correct operation of relays, meters, electronic components, etc., according to the relevant specifications.

7.6.2.5 *Cooling*

For ASSEMBLIES both natural and forced cooling may be provided. If special precautions are required at the place of installation to ensure proper cooling, the manufacturer shall furnish the necessary information (for instance, indication of the need for clearances with respect to parts that are liable to impede the dissipation of heat or produce heat themselves).

7.6.3 *Fixed parts*

In the case of fixed parts (see Sub-clause 2.2.6), the connections of main circuits (see Sub-clause 2.1.4) can only be established or broken when the ASSEMBLY is dead. In general, removal and installation of fixed parts requires the use of a tool.

The disconnection of a fixed part may require the disconnection of the complete ASSEMBLY or part of it.

Note. — If under certain conditions working on the live circuits is allowed, the relevant safety precautions must be respected.

7.6.4 *Removable parts and withdrawable parts*

7.6.4.1 *Design*

The removable parts and withdrawable parts shall be so designed that their electrical equipment can be safely disconnected from or connected to the main circuit whilst this circuit is live. Minimum clearances and creepage distances (see Sub-clauses 7.1.2.1) shall be complied with in the different positions as well as during transfer from one position to another.

Notes 1. — This may require the use of proper tools.

2. — It may be necessary to ensure that these operations are not performed under load.

Removable parts shall have a connected position (see Sub-clause 2.2.9) and a removed position (see Sub-clause 2.2.12).

Withdrawable parts shall have in addition a disconnected position (see Sub-clause 2.2.11) and may have a test position (see Sub-clause 2.2.10), or a test situation (see Sub-clause 2.1.9). They shall be distinctly located in these positions.

For the electrical conditions for the different positions of withdrawable parts, see Table VI.

7.6.4.2 *Interlocking and padlocking of withdrawable parts*

Unless otherwise specified, withdrawable parts shall be fitted with a device which ensures that the apparatus can only be withdrawn and/or re-inserted after its main circuit has been interrupted.

In order to prevent unauthorized operation, withdrawable parts may be provided with means for a padlock or lock to secure them in one or more of their positions.

7.6.4.3 *Degree of protection*

The degree of protection (see Sub-clause 7.2.1) indicated for ASSEMBLIES normally applies to the connected position (see Sub-clause 2.2.9) of the removable and/or withdrawable parts. If required, the manufacturer shall indicate the degree of protection obtained in the other positions and during the transfer between positions.

ASSEMBLIES with withdrawable parts may be so designed that the degree of protection applying to the connected position is also maintained in the test and disconnected positions and during transfer from one position to another.

If, after the removal of a removable and/or withdrawable part, the original degree of protection is not maintained, an agreement shall be reached as to what measures shall be taken to ensure adequate protection. Information given in the manufacturer's catalogue may take the place of such an agreement.

7.6.4.4 *Mode of connection of auxiliary circuits*

Auxiliary circuits may be so designed that they can be opened with or without the use of a tool.

In the case of withdrawable parts, the connection of the auxiliary circuits shall preferably be possible without the use of tools.

7.6.5 *Identification*

7.6.5.1 *Identification of the conductors of main and auxiliary circuits*


With the exception of the cases mentioned in Sub-clause 7.6.5.2, the method and extent of identification of conductors, for example by numbers, colours or symbols, is the responsibility of the manufacturer and it shall be in agreement with the indications on the wiring diagrams and drawings. This identification may be limited to the end of the conductors. Where appropriate the identification according to IEC Publication 445, Sub-clause 5.4, and IEC Publication 446: Identification of Insulated and Bare Conductors by Colours, may be applied.

7.6.5.2 *Identification of the protective conductor (PE)* and of the neutral conductor (N)* of the main circuits*

The protective conductor shall be readily distinguishable by shape, location, marking or colour. If identification by colour is used, it must be green and yellow (twin-coloured). When the protective conductor is an insulated single-core cable, this colour identification shall be used, preferably throughout the whole length.

Note. — The colour identification green/yellow is strictly reserved for the protective conductor.

Any neutral conductor of the main circuit should be readily distinguishable by shape, location, marking or colour. If identification by colour is used, it is recommended to select a light blue colour.

The terminals for external protective conductors shall be marked with the symbol  (No. 5019) of IEC Publication 417: Graphical Symbols for Use on Equipment. Index, Survey and Compilation of the Single Sheets. This symbol is not required where the external protective conductor is intended to be connected to an internal protective conductor which is clearly identified with the colours green-yellow.

* The identification of the PEN conductor is under consideration.

TABLE VI

Electrical conditions for the different positions of withdrawable parts

Circuits	Method of connection	Position			
		Connected position (see Sub-clause 2.2.9)	Test situation/position (see Sub-clauses 2.1.9/2.2.10)	Disconnected position (see Sub-clause 2.2.11)	Removed position (see Sub-clause 2.2.12)
Incoming main circuit	Incoming line plug and socket or other connection facilities			○	○
Outgoing main circuit	Outgoing side plug and socket or other connection facilities		or ¹⁾	or ○ ¹⁾	○
Auxiliary circuit	Plug and socket or similar connection facilities			○	○
Condition of circuits within withdrawable parts		Live	Live Auxiliary circuits ready for operational testing	Dead if no backfeed is present	○
Condition of outgoing ASSEMBLY terminals of main circuits		Live	Live or not disconnected ²⁾	Dead if no backfeed is present	Dead if no backfeed is present
			Sub-clause 7.4.4 shall be complied with		

Earth continuity shall be in accordance with Item *b)* of Sub-clause 7.4.3.1.5 and maintained until the isolating distance is established.

¹⁾ Depending on design.

²⁾ Depending on the terminals being fed from alternative sources of supply such as a standby supply.

| = connected
○ = disconnected (isolated)
| = open, but not necessarily disconnected (isolated)

7.6.5.3 *Direction of operation and indication of switching positions*

These must be in agreement with the specifications applicable to the apparatus concerned, if such specifications exist.

For all other cases, IEC Publication 447: Standard Direction of Movement for Actuators which Control the Operation of Electrical Apparatus, applies.

7.6.5.4 *Indicator lights and push-buttons*

Colours of indicator lights and push-buttons are given in IEC Publication 73: Colours of Indicator Lights and Push-buttons.

7.7 *Internal separation of ASSEMBLIES by barriers or partitions*

One or more of the following conditions can be attained by dividing ASSEMBLIES by means of partitions or barriers (metallic or non-metallic) into separate compartments or barriered sub-sections:

- protection against contact with live parts belonging to the adjacent functional units;
- limitation of the probability of initiating arc faults;

Notes 1. — Openings between compartments should be such that the gases produced by short-circuit protective devices do not impair the operation of functional units in adjacent compartments.

2. — The effects of an arc can be reduced by the use of means limiting the magnitude and duration of the short-circuit current.

- protection against the passage of solid foreign bodies from one unit of an ASSEMBLY to an adjacent unit.

The following are typical forms of separation by barriers or partitions (for examples, see Appendix D).

Form 1 — No separation.

Form 2 — Separation of busbars from the functional units.

Form 3 — Separation of busbars from the functional units and separation of all functional units but not of their outgoing terminals, from one another. The outgoing terminals need not be separated from the busbars.

Form 4 — Separation of busbars from the functional units and separation of all functional units, including their outgoing terminals, from one another.

The form of separation shall be the subject of an agreement between manufacturer and user.

7.8 *Electrical connections inside an ASSEMBLY: Bars and insulated conductors*

7.8.1 *General*

The connections of current-carrying parts shall not suffer undue alteration as a result of normal temperature rise, ageing of the insulating materials and vibrations occurring in normal operation. In particular, the effects of thermal expansion and of the electrolytic action in the case of dissimilar metals, and the effects of the endurance of the materials to the temperatures attained, shall be taken into consideration.

Connections between current-carrying parts shall be established by means which ensure a sufficient and durable contact pressure.

7.8.2 *Dimensions and rating of busbars and insulated conductors*

The choice of cross-sections of conductors inside the ASSEMBLY is the responsibility of the manufacturer. In addition to the current which must be carried, the choice is governed by the mechanical stresses to which the ASSEMBLY is subjected, by the way these conductors are laid, by the type of insulation and, if applicable, by the kind of elements connected (e.g. electronics).

7.8.3 *Wiring (see also Sub-clause 7.8.2)*

7.8.3.1 The insulated conductors shall be rated for at least the rated insulation voltage (see Sub-clause 4.1.2) of the circuit concerned. (Minimum values of rated insulation voltage for the conductors used: under consideration.)

7.8.3.2 Cables between two connecting devices shall have no intermediate splices or soldered joints. Connections shall, as far as possible, be made at fixed terminals.

7.8.3.3 Insulated conductors shall not rest against bare live parts at different potentials or sharp edges and shall be adequately supported.

7.8.3.4 Supply leads to apparatus and measuring instruments in covers or doors shall be so installed that no mechanical damage can occur to the conductors as a result of movement of these covers or doors.

7.8.3.5 Soldered connections to apparatus shall be permitted in ASSEMBLIES only in cases where provision is made for this type of connection on the apparatus.

Where this equipment is subject to heavy vibration during normal operation, soldered cables or wire connections shall be mechanically secured by supplementary means at a short distance from the soldered joint.

7.8.3.6 In locations where heavy vibrations exist during normal operation, for example in the case of dredger and crane operation, operation on board ships, lifting equipment and locomotives, attention should be given to the support of the conductors. For apparatus other than those mentioned in Sub-clause 7.8.3.5, soldering cable lugs or soldered ends of stranded conductors are not acceptable under conditions of heavy vibration.

7.8.3.7 Generally only one conductor should be connected to a terminal: the connection of two or more conductors to one terminal is permissible only in those cases where the terminals are designed for this purpose.

7.9 *Requirements for electronic equipment supply circuits*

Unless otherwise specified in the relevant IEC specifications for electronic equipment, the following requirements apply:

7.9.1 *Input voltage variations**

1) Supply voltage range for battery sources equal to the rated supply voltage $\pm 15\%$.

Note. — This range does not include the additional voltage range required for charging batteries.

2) Range of the input direct voltage which is obtained by rectification of the alternating supply voltage (see Item 3).

* In compliance with IEC Publication 146-2: Semiconductor Convertors, Part 2: Semiconductor Self-commutated Convertors.

- 3) Supply voltage range for a.c. sources equal to the rated input voltage $\pm 10\%$.
- 4) If a wider tolerance is necessary this is subject to agreement between manufacturer and user.

7.9.2 Overvoltages*

Supply overvoltages are specified in Figure 1. This figure applies to the non-periodic overvoltages as a deviation from the rated peak value within the short-time range. The ASSEMBLIES shall be so designed that their service ability in the case of overvoltages below the values represented by curve 1 is ensured.

If overvoltages occur within the range between curves 1 and 2, the operation may be interrupted by the response of protective devices safeguarding the ASSEMBLY, no damage to the ASSEMBLY being allowed to occur up to peak value of a voltage $2U + 1\,000\text{ V}$.

Notes 1. — Transient durations less than 1 ms are under consideration.

2. — Higher overvoltages than those given above are assumed to be limited by appropriate measures.

3. — See also IEC Publication 158-2: Low-voltage Controlgear, Part 2: Semiconductor Contactors (Solid State Contactors).

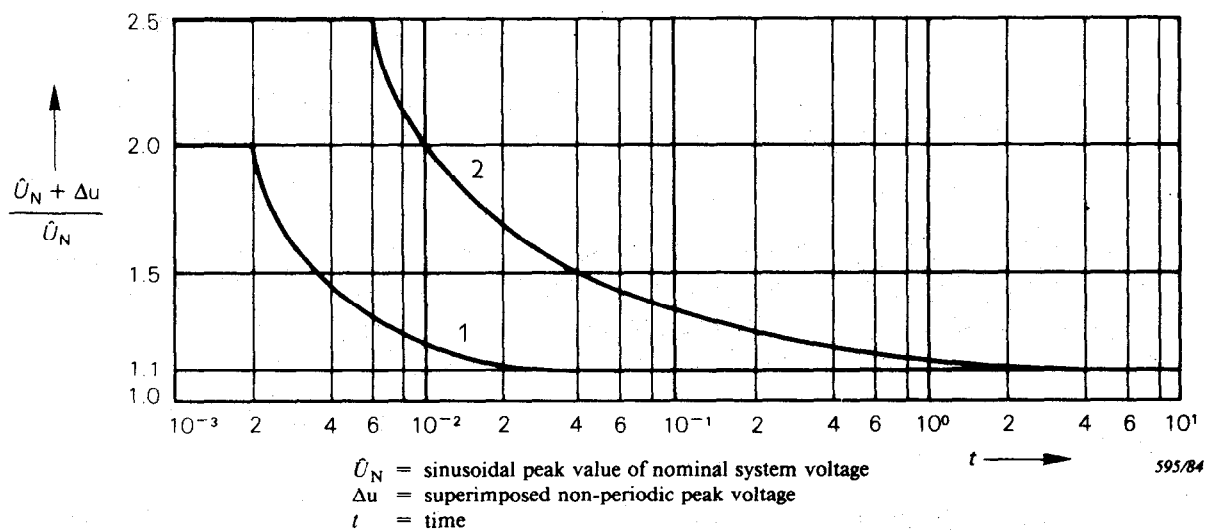


FIG. 1. — The ratio $\frac{\hat{U}_N + \Delta u}{\hat{U}_N}$ as a function of time.

7.9.3 Waveform*

Harmonics of the input alternating voltage supplying ASSEMBLIES incorporating electronic equipment are restricted in the following limits:

- 1) relative harmonic content shall not exceed 10%, i.e. a relative fundamental content $\geq 99.5\%$;
- 2) harmonic components shall not exceed the values given in Figure 2, page 75;

Notes 1. — The sub-assembly is assumed to be disconnected and the internal impedance of the supply source should be specified in agreement between manufacturer and user, if this impedance is of significant value.

2. — The same values are indicated for electronic control and monitoring.

* In compliance with IEC Publication 146-2.

- 3) the highest periodic momentary value of the a.c. supply voltage is not more than 20% above the peak value of the fundamental.

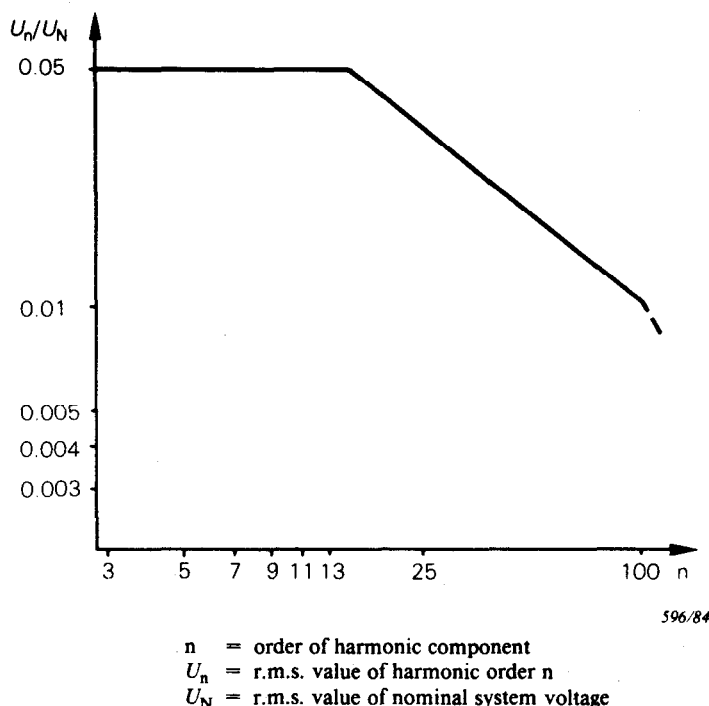


FIG. 2. — Maximum permitted harmonic component of the nominal system voltage.

7.9.4 Temporary variations in voltage and frequency

The equipment shall operate without damage when there are temporary variations in the following conditions:

- a) Voltage drops not exceeding 15% of rated voltage for periods not longer than 0.5 s.
- b) Supply frequency deviation of up to $\pm 1\%$ of rated frequency. If a wider tolerance is necessary, this is subject to agreement between manufacturer and user.
- c) The maximum admissible duration of an interruption of the supply voltage for equipment shall be indicated by the manufacturer.

3. Test specifications

3.1 Classification of tests

The tests to verify the characteristics of an ASSEMBLY include:

- type tests (see Sub-clauses 8.1.1 and 8.2);
- routine tests (see Sub-clauses 8.1.2 and 8.3).

The manufacturer shall, on request, specify the basis for the verifications.

Note. — Verifications and tests to be performed on TTA and PTTA are listed in Table VII.

8.1.1 Type tests (see Sub-clause 8.2)

Type tests are intended to verify compliance with the requirements laid down in this standard for a given type of ASSEMBLY.

Type tests will be carried out on a sample of such an ASSEMBLY or on such parts of ASSEMBLIES manufactured to the same or a similar design.

They shall be carried out on the initiative of the manufacturer.

Type tests include:

- a) verification of temperature-rise limits (Sub-clause 8.2.1);
- b) verification of the dielectric properties (Sub-clause 8.2.2);
- c) verification of the short-circuit strength (Sub-clause 8.2.3);
- d) verification of the continuity of the protective circuit (Sub-clause 8.2.4);
- e) verification of clearances and creepage distances (Sub-clause 8.2.5);
- f) verification of mechanical operation (Sub-clause 8.2.6);
- g) verification of the degree of protection (Sub-clause 8.2.7).

These tests may be carried out in any order and/or on different samples of the same type.

If modifications are made to the components of the ASSEMBLY, new type tests have to be carried out only in so far as such modifications are likely to adversely affect the results of these tests.

8.1.2 Routine tests (see Sub-clause 8.3)

Routine tests are intended to detect faults in materials and workmanship. They are carried out on every new ASSEMBLY after its assembly or on each transport unit. Another routine test at the place of installation is not required.

ASSEMBLIES which are assembled from standardized components outside the works of the manufacturer of these components, by the exclusive use of parts and accessories specified or supplied by the manufacturer for this purpose, shall be routine-tested by the firm which has assembled the ASSEMBLY.

Routine tests include:

- a) inspection of the ASSEMBLY including inspection of wiring and, if necessary, electrical operation test (Sub-clause 8.3.1);
- b) dielectric test (Sub-clause 8.3.2);
- c) checking of protective measures and of the electrical continuity of the protective circuit (Sub-clause 8.3.3).

These tests may be carried out in any order.

Note. — The performance of the routine tests at the manufacturer's works does not relieve the firm installing the ASSEMBLY of the duty of checking it after transport and installation.

8.1.3 Testing of devices and self-contained components incorporated in the ASSEMBLY

Type tests or routine tests are not required to be carried out on devices and self-contained components incorporated in the ASSEMBLY when they have been selected in accordance with Sub-clause 7.6.1 and installed in accordance with the instructions of the manufacturer.

8.2 Type tests

8.2.1 Verification of temperature-rise limits

8.2.1.1 General

The temperature-rise test is designed to verify that the temperature-rise limits specified in Sub-clause 7.3 for the different parts of the ASSEMBLY are not exceeded.

TABLE VII
List of verifications and tests to be performed on TTA and PT TA

No.	Characteristics to be checked	Clause number	TTA	PTTA
1	Temperature-rise limits	8.2.1	Verification of temperature-rise limits by test (type test)	Verification of temperature-rise limits by test or extrapolation from type-tested ASSEMBLIES
2	Dielectric properties	8.2.2	Verification of dielectric properties by test (type test)	Verification of dielectric properties by test according to Sub-clause 8.2.2 or Sub-clause 8.3.2, or verification of insulation resistance according to Sub-clause 8.3.4 (see No. 11)
3	Short-circuit withstand strength	8.2.3	Verification of the short-circuit withstand strength by test (type test)	Verification of the short-circuit withstand strength by test or by extrapolation from similar type-tested arrangements
4	Effectiveness of the protective circuit	8.2.4		
	Effective connection between the exposed conductive parts of the ASSEMBLY and the protective circuit	8.2.4.1	Verification of the effective connection between the exposed conductive parts of the ASSEMBLY and the protective circuit by inspection or by resistance measurement (type test)	Verification of the effective connection between the exposed conductive parts of the ASSEMBLY and the protective circuit by inspection or by resistance measurement
	Short-circuit withstand strength of the protective circuit	8.2.4.2	Verification of the short-circuit withstand strength of the protective circuit by test (type test)	Verification of the short-circuit withstand strength of the protective circuit by test or appropriate design and arrangement of the protective conductor (see Sub-clause 7.4.3.1.1, last paragraph)
5	Clearances and creepage distances	8.2.5	Verification of clearances and creepage distances (type test)	Verification of clearances and creepage distances
6	Mechanical operation	8.2.6	Verification of mechanical operation (type test)	Verification of mechanical operation
7	Degree of protection	8.2.7	Verification of degree of protection (type test)	Verification of degree of protection
8	Wiring, electrical operation	8.3.1	Inspection of the ASSEMBLY including inspection of wiring and, if necessary, electrical operation test (routine test)	Inspection of the ASSEMBLY including inspection of wiring and, if necessary, electrical operation test
9	Insulation	8.3.2	Dielectric test (routine test)	Dielectric test or verification of insulation resistance according to Sub-clause 8.3.4 (see No. 11)
10	Protective measures	8.3.3	Checking of protective measures and of the electrical continuity of the protective circuits (routine test)	Checking of protective measures
11	Insulation resistance	8.3.4	—	Verification of insulation resistance unless test according to Sub-clause 8.2.2 or Sub-clause 8.3.2 has been made (see Nos. 2 and 9)

The test shall normally be carried out at the values of rated current in accordance with Sub-clause 8.2.1.3, with the apparatus of the ASSEMBLY installed.

The test may be carried out with the aid of heating resistors of an equivalent power loss in accordance with Sub-clause 8.2.1.4.

It is permissible to test individual parts (panels, boxes, enclosures, etc.) of the ASSEMBLY (see Sub-clause 8.2.1.2), provided proper precautions are taken to make the test representative.

The temperature-rise test on the individual circuits shall be made with the type of current for which they are intended, and at the design frequency. The test voltages used shall be such that a current equal to the current determined according to Sub-clause 8.2.1.3 flows through the circuits. Coils of relays, contactors, releases, etc., shall be supplied with rated voltage.

Open-type ASSEMBLIES need not be subjected to the temperature-rise test if it is obvious from type tests on the individual parts or from the size of the conductors and from the arrangement of the apparatus that there will be no excessive temperature rise and that no damage will be caused to the equipment connected to the ASSEMBLY, and to adjacent parts of insulating material.

The verification of temperature-rise limits for PTTA shall either be made:

- by test in accordance with Sub-clause 8.2.1, or
- by extrapolation.

Note. — An example of a method of extrapolation is given in IEC Report XXX (under consideration).

8.2.1.2 *Arrangement of the ASSEMBLY*

The ASSEMBLY shall be arranged as in normal use, with all covers, etc., in place.

When testing individual parts or constructional units, the adjoining parts or constructional units shall produce the same temperature conditions as in normal use. Heating resistors may be used.

8.2.1.3 *Temperature-rise test using current on all apparatus*

The test shall be made on one or more representative combinations of circuits for which the ASSEMBLY is designed so chosen as to obtain with reasonable accuracy the highest possible temperature rise.

For this test, each circuit is loaded with its rated current (see Sub-clause 4.2) multiplied by the diversity factor (see Sub-clause 4.8). If the ASSEMBLY includes fuses, these shall be fitted for the test with fuse-links as specified by the manufacturer. The power losses of the fuse-links used for the test shall be stated in the test report.

The size and the disposition of external conductors used for the test shall be stated in the test report.

The test shall be made for a time sufficient for the temperature rise to reach a constant value (normally not exceeding 8 h). In practice, this condition is reached when the variation does not exceed 1 K/h.

Notes 1. — To shorten the test, if the devices allow it, the current may be increased during the first part of the test, it being reduced to the specified test current afterwards.

2. — When a control electro-magnet is energized during the test, the temperature shall be measured when thermal equilibrium is reached in both the main circuit and the control electro-magnet.

In the absence of detailed information concerning the external conductors and the service conditions, the cross-section of the external test conductors shall be as follows:

8.2.1.3.1 For values of test current up to and including 400 A:

- a) the conductors shall be single-core, copper cables or insulated wires with cross-sectional areas as given in Table VIII;
- b) as far as practicable the conductors shall be in free air;
- c) the minimum length of each temporary connection from terminal to terminal shall be:
 - 1 m for cross-sections up to and including 35 mm²,
 - 2 m for cross-sections larger than 35 mm².

TABLE VIII

Standard cross-sections of copper conductors corresponding to the test current

Range of test current ¹⁾ (A)	0 7.9	7.9 15.9	15.9 22	22 30	30 39	39 54	54 72	72 93	93 117	117 147	147 180	180 216	216 250	250 287	287 334	334 400
S (mm ²)	1	1.5	2.5	4	6	10	16	25	35	50	70	95	120	150	185	240
Values of the rated current ²⁾ (A)	6	8 10 12	16 20	25	32	40 50	63	80	100	125	160	200	250	—	315	400

¹⁾ The value of current shall be greater than the value in the first line and less than or equal to the value in the second line.

²⁾ These are standard recommended currents and are given for reference purposes only.

8.2.1.3.2 For values of test current higher than 400 A but not exceeding 800 A:

- a) The conductors shall be single-core, p.v.c. insulated, copper cables with cross-sectional areas as given in Table IX, or the equivalent copper bars given in Table IX as recommended by the manufacturer.
- b) Cables or copper bars shall be spaced at approximately the distance between terminals. Copper bars shall be finished matt black. Multiple parallel cables per terminal shall be bunched together and arranged with approximately 10 mm air space between each other. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals, or are not available, it is allowed to use other bars having approximately the same cross-section and approximately the same or smaller cooling surfaces. Cables or copper bars shall not be interleaved.
- c) For single-phase or multi-phase tests, the minimum length of any temporary connection to the test supply shall be 2 m. The minimum length to a star point may be reduced to 1.2 m.

8.2.1.3.3 For values of test current higher than 800 A but not exceeding 3 150 A:

- a) The conductors shall be copper bars of the sizes stated in Table IX unless the ASSEMBLY is designed only for cable connection. In this case, the size and arrangement of the cables shall be as specified by the manufacturer.
- b) Copper bars shall be spaced at approximately the distance between terminals. Copper bars shall be finished matt black. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals, or are not available, it is allowed to use other bars having approximately the same cross-section and approximately the same or smaller cooling surfaces. Copper bars shall not be interleaved.

- c) For single-phase or multi-phase tests, the minimum length of any temporary connection to the test supply shall be 3 m, but this can be reduced to 2 m provided that the temperature rise at the supply end of the connection is not more than 5 K below the temperature rise in the middle of the connection length. The minimum length to a star point shall be 2 m.

TABLE IX
Standard cross-sections of copper conductors corresponding to the test current

Values of the rated current (A)	Range of test current (A)	Test conductor			
		Cables		Copper bars	
		Quantity	Cross-sections (mm ²)	Quantity	Dimensions (mm)
500	400 to 500	2	150 (16)	2	30 × 5 (15)
630	500 to 630	2	185 (18)	2	40 × 5 (15)
800	630 to 800	2	240 (21)	2	50 × 5 (17)
1 000	800 to 1 000			2	60 × 5 (19)
1 250	1 000 to 1 250			2	80 × 5 (20)
1 600	1 250 to 1 600			2	100 × 5 (23)
2 000	1 600 to 2 000			3	100 × 5 (20)
2 500	2 000 to 2 500			4	100 × 5 (21)
3 150	2 500 to 3 150			3	100 × 10 (23)

- Notes 1. — Value of current shall be greater than the first value and less than or equal to the second value.
2. — Bars are assumed to be arranged with their long faces vertical. Arrangements with long faces horizontal may be used if specified by the manufacturer.
3. — Values in brackets are estimated temperature rises (in kelvins) of the test conductors given for reference.

8.2.1.3.4 For values of test current higher than 3 150 A:

Agreement shall be reached between manufacturer and user on all relevant items of the test, such as: type of supply, number of phases and frequency (where applicable), cross-sections of test conductors, etc. This information shall form part of the test report.

Note. — In all cases, the use of single-phase a.c. current for testing multi-phase ASSEMBLIES is only permissible if magnetic effects are small enough to be neglected. This requires careful consideration especially for currents above 400 A.

8.2.1.4 Temperature-rise test using heating resistors with an equivalent power loss

For certain types of enclosed ASSEMBLIES with main and auxiliary circuits having comparatively low-rated currents, the power loss may be simulated by means of heating resistors which produce the same amount of heat and are installed in suitable places inside the enclosure.

The cross-section of the leads to these resistors shall be such that no appreciable amount of heat is conducted away from the enclosure.

This test with heating resistors is considered to be reasonably representative of all ASSEMBLIES using the same enclosure, even if they are equipped with different apparatus, provided that the sum of the power losses of the built-in apparatus, taking into account the diversity factor, does not exceed the value applied in the test.

The temperature rise of the built-in apparatus shall not exceed the values given in Table III (see Sub-clause 7.3). This temperature rise can be approximately calculated by taking the temperature rise of this apparatus, measured in the open air, increased by the difference between the temperature inside the enclosure and the temperature of the air surrounding the enclosure.

8.2.1.5 *Measurement of temperatures*

Thermocouples or thermometers shall be used for temperature measurements. For windings, the method of measuring the temperature by resistance variation shall generally be used. For measuring the temperature of the air inside an ASSEMBLY, several measuring devices shall be arranged in convenient places.

The thermometers or thermocouples shall be protected against air currents and heat radiation.

8.2.1.6 *Ambient air temperature*

The ambient air temperature shall be measured during the last quarter of the test period by means of at least two thermometers or thermocouples equally distributed around the ASSEMBLY at about half its height and at a distance of about 1 m from the ASSEMBLY. The thermometers or thermocouples shall be protected against air currents and heat radiations.

If the ambient temperature during the test is between +10 °C and +40 °C, the values of Table III, Sub-clause 7.3, are the limiting values of temperature rise.

If the ambient air temperature during the test exceeds +40 °C or is lower than +10 °C, this standard does not apply and the manufacturer and the user shall make a special agreement.

8.2.1.7 *Results to be obtained*

At the end of the test, the temperature rise shall not exceed the values specified in Table III, Sub-clause 7.3. The apparatus shall operate satisfactorily within the voltage limits specified for them at the temperature inside the ASSEMBLY.

8.2.2 *Verification of dielectric properties*

8.2.2.1 *General*

This type test need not be made on such parts of the ASSEMBLY which have already been type-tested according to their relevant specifications provided their dielectric strength is not impaired by their mounting.

Furthermore, this test need not be made on PTTAs whose insulation resistance has been verified in accordance with Sub-clause 8.3.4.

The test voltage shall be applied:

- 1) between all live parts and the interconnected exposed conductive parts of the ASSEMBLY;
- 2) between each pole and all the other poles connected for this test to the interconnected exposed conductive parts of the ASSEMBLY.

When the ASSEMBLY includes a protective conductor insulated from the exposed conductive parts according to Item *d*) of Sub-clause 7.4.3.2.2, this conductor shall be regarded as a separate circuit, i.e. it shall be tested with the same voltage as the main circuit to which it belongs.

The test voltage at the moment of application shall not exceed 50% of the values given in Sub-clause 8.2.2.4. It shall then be increased steadily within a few seconds to this full value specified in Sub-clause 8.2.2.4 and maintained for 1 min. The a.c. power sources shall have sufficient power to maintain the test voltage irrespective of any leakage currents. The test voltage shall have a practically sinusoidal waveform and a frequency between 45 Hz and 62 Hz.

8.2.2.2 Testing of enclosures made of insulating material

For enclosures made of insulating material, an additional dielectric test shall be carried out by applying a test voltage between a metal foil laid on the outside of the enclosure over openings and joints, and the interconnected live and exposed conductive parts within the enclosure located next to the openings and joints. For this additional test, the test voltage shall be equal to 1.5 times the values indicated in Table X.

Note. — Test voltages for enclosures for ASSEMBLIES protected by total insulation are under consideration.

8.2.2.3 External operating handles of insulating material

In the case of handles made of or covered by insulating material for the purpose of complying with Sub-clause 7.4.3.1.3, a dielectric test shall be carried out by applying a test voltage equal to 1.5 times the test voltage indicated in Table X between the live parts and a metal foil wrapped round the whole surface of the handle. During this test, the frame must not be earthed or connected to any other circuit.

8.2.2.4 Value of the test voltage

The value of the test voltage shall be as follows:

8.2.2.4.1 For the main circuit and for the auxiliary circuits which are not covered by Sub-clause 8.2.2.4.2 below, in accordance with Table X:

TABLE X

Rated insulation voltage U_i (V)	Dielectric test voltage (a.c.) (r.m.s.) (V)
$U_i \leq 60$	1 000
$60 < U_i \leq 300$	2 000
$300 < U_i \leq 660$	2 500
$660 < U_i \leq 800$	3 000
$800 < U_i \leq 1 000$	3 500
$1 000 < U_i \leq 1 500^*$	3 500

* For d.c. only.

8.2.2.4.2 For auxiliary circuits which are indicated by the manufacturer as unsuitable for being directly supplied from the main circuit, in accordance with Table XI:

TABLE XI

Rated insulation voltage U_i (V)	Dielectric test voltage (a.c.) (r.m.s.) (V)
$U_i \leq 12$	250
$12 < U_i \leq 60$	500
$U_i > 60$	$2 U_i + 1 000$ with a minimum of 1 500

8.2.2.5 *Results to be obtained*

The test is considered to have been passed if there is no puncture or flash-over.

8.2.3 *Verification of the short-circuit withstand strength*

8.2.3.1 Circuits of ASSEMBLIES which are exempted from the verification of the short-circuit withstand strength.

A verification of the short-circuit withstand strength is not required:

8.2.3.1.1 For ASSEMBLIES having a rated prospective short-circuit current not exceeding 10 kA.

8.2.3.1.2 For ASSEMBLIES protected by current limiting devices having a cut-off current not exceeding 15 kA at their rated breaking capacity.

8.2.3.1.3 For auxiliary circuits of ASSEMBLIES intended to be connected to transformers whose rated power does not exceed 10 kVA for a rated secondary voltage of not less than 110 V or 1.6 kVA for a rated secondary voltage less than 110 V, and whose relative short-circuit voltage is not less than 4%.

8.2.3.1.4 For all parts of ASSEMBLIES (busbars, busbar supports, connections to busbars, incoming and outgoing units, switching devices, etc.) which have already been subjected to type tests valid for conditions in the ASSEMBLY.

Note. — Examples of switching devices are those with a rated conditional short-circuit current according to IEC Publication 408 or motor starters coordinated with short-circuit protective devices according to IEC Publication 292-1A: First Supplement to Publication 292-1: Low-voltage Motor Starters, Part 1: Direct-on-line (Full Voltage) A.C. Starters.

8.2.3.2 *Circuits of ASSEMBLIES the short-circuit withstand strength of which shall be verified by tests*

This sub-clause applies to all circuits not mentioned in the preceding Sub-clause 8.2.3.1.

8.2.3.2.1 *Test arrangements*

The ASSEMBLY or its parts shall be set up as in normal use. Except for tests on the busbars and depending on the type of construction of the ASSEMBLY, it will be sufficient to test a single functional unit if the remaining functional units are constructed in the same way and cannot affect the test result.

8.2.3.2.2 *Performance of the test: General*

If the test circuit incorporates fuses, fuse-links of the maximum current rating (corresponding to the rated current), and if required, of the type indicated by the manufacturer to be acceptable, shall be used.

The supply conductors and the short-circuit connections required for testing the ASSEMBLY shall have sufficient strength to withstand short circuits and be so arranged that they do not introduce any additional stresses.

Unless otherwise agreed, the test circuit shall be connected to the input terminals of the ASSEMBLY. Three-phase ASSEMBLIES shall be connected on a three-phase basis.

Except for the verification of the rated short-time withstand current and the rated peak withstand current (see Item a) of Sub-clause 7.5.2.1.2), the value of the prospective short-circuit current at a supply voltage equal to 1.1 times the rated operational voltage shall be determined from a calibration oscillogram which is taken with the supply conductors to the ASSEMBLY short-circuited by a connection of negligible impedance placed as near as possible to the input supply of the ASSEMBLY. The oscillogram shall show that there is a constant flow of current such that it is

measurable at a time equivalent to the operation of the protective device incorporated in the ASSEMBLY or for a specified period of time, this current approximating the value specified in Sub-clause 8.2.3.2.4.

For a.c. tests, the frequency of the test circuit during the short-circuit tests shall be that of the rated frequency subject to a tolerance of 25%.

All parts of the equipment intended to be connected to the protective conductor in service, including the enclosure, shall be connected as follows:

- 1) for equipment suitable for use on TN and TT systems* with an earthed star point and marked accordingly, to the neutral point of the supply or to a substantially inductive artificial neutral permitting a prospective fault current of at least 100 A;
- 2) for equipment suitable also for use on IT systems* and marked accordingly, to the phase conductor least likely to arc to earth.

The test circuit shall include a reliable device (e.g. a fuse of copper wire of 0.1 mm diameter and not less than 50 mm in length) for the detection of the fault current and, if necessary, a resistor to limit the value of the prospective fault current to about 100 A.

8.2.3.2.3 *Testing of the main circuits*

For ASSEMBLIES with busbars, the tests according to Items *a)*, *b)* and *d)* below apply.

For ASSEMBLIES without busbars, the test according to Item *a)* applies.

For ASSEMBLIES where the requirements of Sub-clause 7.5.5.1.2 are not fulfilled, in addition the test according to Item *c)* applies.

- a)* Where an outgoing circuit includes a component which has not previously been subjected to the appropriate test, the following test shall apply:

For testing an outgoing circuit, the associated outgoing terminals shall be provided with a bolted short-circuit connection. The switching device shall be closed and held closed in the manner normally used in service. The test voltage shall then be applied once and for a time sufficiently long to enable the short-circuit protective device in the outgoing unit to operate to clear the fault, and, in any case, for not less than 10 cycles (test voltage duration).

- b)* ASSEMBLIES containing main busbars shall be subjected to one additional test to prove the short-circuit withstand strength of the main busbars and the incoming circuit including any joints. The point where the short-circuit is produced shall be (2 ± 0.40) m distant from the nearest point of supply. For the verification of rated short time withstand current (see Sub-clause 4.3) and rated peak withstand current (see Sub-clause 4.4), this distance may be increased. If the length of the busbars of the ASSEMBLY is less than 1.6 m, the short-circuit shall be established at the end of these busbars. If a set of busbars consists of different sections (as regards cross-sections, distance between adjacent busbars, type and number of supports per metre), each section shall be tested separately or concurrently, provided that the above conditions are met.

- c)* A short circuit is obtained by bolted connections on the conductors connecting the busbars to a single outgoing unit, as near as practicable to the terminals on the busbar side of the outgoing unit. The value of the short-circuit current shall be the same as that for the main bars.

* For explanation, see IEC Publication 364-3.

- d) If a neutral bar exists, it shall be subjected to one test to prove its short-circuit withstand strength in relation to the nearest phase busbar including at least one joint. For the connection of the neutral bar to this phase busbar, the requirements of Item b) of Sub-clause 8.2.3.2.3 apply. Unless otherwise agreed between manufacturer and user, the value of the test current in the neutral bar shall be 60% of the phase-to-phase current.

8.2.3.2.4 Value and duration of the short-circuit current

- a) ASSEMBLIES with a short-circuit protective device incorporated in the incoming unit (see Sub-clause 7.5.2.1.1).

The current corresponding to the stated prospective short-circuit current shall flow until it is broken by the protective device.

- b) ASSEMBLIES which do not incorporate a short-circuit protective device in the incoming unit (see Sub-clause 7.5.2.1.2).

For ASSEMBLIES with rated short-time withstand current and rated peak withstand current, the dynamic and thermal strength shall be verified with these rated currents.

The rated short-time withstand current test (see Sub-clause 4.3) may be made at any suitable voltage and its r.m.s. value shall be determined from the oscillogram.

Notes 1. — However, if necessary, due to test limitations, a different test period is permissible; in such a case, the test current should be modified in accordance with the formula $I^2t = \text{constant}$, provided that the peak value does not exceed the rated peak withstand current without the manufacturer's consent and that the r.m.s. value of the short-time withstand current is not less than the rated value in at least one phase for at least 0.1 s after current initiation.

2. — The peak withstand current test and the short-time withstand current test may be separated. In this case, the time during which the short-circuit is applied for the peak withstand current test should be such that the value I^2t is not larger than the equivalent value for the short-time withstand current test, but it should be not less than three cycles.

The test may be made at any suitable voltage and with the busbars at any convenient temperature. The highest peak value of the major loop during the first cycle of the test shall be not less than the rated peak withstand current (see Sub-clause 7.5.3).

For ASSEMBLIES having rated prospective short-circuit withstand currents, rated conditional short-circuit currents or rated fused short-circuit currents (see Sub-clauses 4.5, 4.6 and 4.7), the dynamic and thermal stresses shall be verified with a prospective current, at the supply side of the specified protective device, if any, equal to the value of the prospective short-circuit withstand current or conditional or fused short-circuit current.

8.2.3.2.5 Results to be obtained

After the test, the conductors shall not show any undue deformation. Slight deformation of busbars is acceptable provided that the clearances and creepage distances specified in Sub-clause 7.1.2 are still complied with. Also, the insulation of the conductors and the supporting insulating parts shall not show any significant signs of deterioration, that is, the essential characteristics of the insulation remain such that the mechanical and dielectric properties of the equipment satisfy the requirements of this standard.

The detection device shall not indicate a fault current.

There shall be no loosening of parts used for the connection of conductors and conductors shall not separate from the outgoing terminals.

Deformation of the enclosure is permissible to the extent to which the degree of protection is not impaired and the clearances are not reduced to values which are less than those specified.

Any distortion of the busbar circuit or the frame of the ASSEMBLY which impairs normal insertion of withdrawable or removable units shall be deemed a failure.

In case of doubt, it shall be checked that the apparatus incorporated in the ASSEMBLY are in condition as prescribed in the relevant specifications.

8.2.3.2.6 For PTTA, the verification of short-circuit withstand strength shall be made either:

- by test in accordance with Sub-clauses 8.2.3.2.1 to 8.2.3.2.5, or
- by extrapolation from similar type-tested arrangements.

Notes 1. — An example of a method of extrapolation from type-tested arrangements is under consideration.

- 2. — Care should be taken to compare the conductor strength, distance between live parts and exposed conductive parts, distance between supports, height and strength of supports and strength and type of support locating structure.

8.2.4 *Verification of the effectiveness of the protective circuit*

8.2.4.1 *Verification of the effective connection between the exposed conductive parts of the ASSEMBLY and the protective circuit*

It shall be verified that the different exposed conductive parts of the ASSEMBLY are effectively connected to the protective circuit in accordance with the requirements of Sub-clause 7.4.3.1.

In case of doubt, where constructional methods other than those quoted in Sub-clause 7.4.3.1.1 are used to ensure continuity, a measurement may be carried out to verify that the resistance between the terminal for the incoming protective conductor and the relevant exposed conductive part of the ASSEMBLY is sufficiently low.

8.2.4.2 *Verification of the short-circuit strength of the protective circuit by test*

A single-phase test supply shall be connected to the incoming terminal of one phase and to the terminal for the incoming protective conductor. When the ASSEMBLY is provided with a separate protective conductor, the nearest phase conductor shall be used. For each representative outgoing unit, a separate test shall be made with a bolted short-circuit connection between the corresponding outgoing phase terminal of the unit and the terminal for the relevant outgoing protective conductor.

Each outgoing unit on test shall be provided with that protective device of those intended for the unit which lets through the maximum values of peak current and I^2t . The test may be made with the protective device located outside the ASSEMBLY.

For this test, the frame of the ASSEMBLY shall be insulated from earth. The values of prospective current and voltage used shall be the single-phase values derived from the three-phase short-circuit withstand strength of the ASSEMBLY.

All other conditions of this test shall be analogous to Sub-clause 8.2.3.2.

8.2.4.3 *Results to be obtained*

The continuity and the short-circuit withstand strength of the protective circuit, whether it consists of a separate conductor or the frame, shall not be significantly impaired.

Besides visual inspection, this may be verified by measurements with a current in the order of the rated current of the relevant outgoing unit.

Notes 1. — Where the frame is used as a protective conductor, sparks and localized heating at joints are permitted, provided they do not impair the electrical continuity, and provided that adjacent flammable parts are not ignited.

- 2. — A comparison of the resistances, measured before and after the test, between the terminal for the incoming protective conductor and the terminal for the relevant outgoing protective conductor gives an indication of conformity with this condition.

3.2.5 *Verification of clearances and creepage distances*

It shall be verified that the clearances and creepage distances comply with the values specified in Sub-clause 7.1.2.

If necessary, these clearances and creepage distances shall be verified by measurement, taking account of possible deformation of parts of the enclosure or of the internal screens, including any possible changes in the event of a short circuit.

If the ASSEMBLY contains withdrawable parts, it is necessary to verify that both in the test position (see Sub-clause 2.2.10), if any, and in the disconnected position (see Sub-clause 2.2.11), the clearances and creepage distances are complied with.

8.2.6 *Verification of mechanical operation*

This type test shall not be made on such devices of the ASSEMBLY which have already been type-tested according to their relevant specifications provided their mechanical operation is not impaired by their mounting.

For those parts which need a type test, satisfactory mechanical operation shall be verified after installation in the ASSEMBLY. The number of operating cycles shall be 50.

Note. — In the case of withdrawable functional units, the cycle shall be from the connected to the disconnected position and back to the connected position.

At the same time, the operation of the mechanical interlocks associated with these movements shall be checked. The test is considered to have been passed if the operating conditions of the apparatus, interlocks, etc., have not been impaired and if the effort required for operation is practically the same as before the test.

8.2.7 *Verification of degree of protection*

The degree of protection provided in accordance with Sub-clause 7.2.1 shall be verified in accordance with IEC Publication 529, making, where necessary, adaptations to suit the particular type of the ASSEMBLY.

8.3 *Routine tests*

8.3.1 *Inspection of the ASSEMBLY including inspection of wiring and, if necessary, electrical operation test*

The effectiveness of mechanical actuating elements, interlocks, locks, etc., shall be checked. The conductors and cables shall be checked for proper laying and the devices for proper mounting. A visual inspection is also necessary to ensure that the prescribed degree of protection, creepage and clearance distances are maintained.

The connections, especially the screwed connections, shall be checked for adequate contact, possibly by random tests.

Further it shall be verified that the information and markings specified in Sub-clauses 5.1 and 5.2 are complete, and that the ASSEMBLY corresponds to these. In addition, the conformity of the ASSEMBLY to the circuit and wiring diagrams, technical data, etc., provided by the manufacturer shall be checked.

Depending on the complexity of the ASSEMBLY, it may be necessary to inspect the wiring and to carry out an electrical functioning test. The test procedure and the number of tests depend on whether or not the ASSEMBLY includes complicated interlocks, sequence control facilities, etc.

In some cases, it may be necessary to make or repeat this test on site when putting the installation for which the ASSEMBLY is intended into operation. In this case, a special agreement shall be made between manufacturer and user.

8.3.2 *Dielectric test*

This test need not be made on PTTA whose insulation resistance has been verified in accordance with Sub-clause 8.3.4.

8.3.2.1 *General*

The test voltage according to Sub-clause 8.2.2.4 shall be applied for 1 s. The a.c. source shall have sufficient power so as to maintain the test voltage irrespective of all leakage currents. The test voltage shall have a practically sinusoidal waveform and a frequency between 45 Hz and 62 Hz.

All electrical equipment of the ASSEMBLY shall be connected for the test, except those apparatus which, according to the relevant specifications, are designed for a lower test voltage, and current-consuming apparatus (e.g. windings, measuring instruments) in which the application of the test voltage would cause the flow of a current, shall be disconnected. These apparatus shall be disconnected at one of their terminals unless they are not designed to withstand the full test voltage, in which case all terminals may be disconnected.

Anti-interference capacitors installed between live and exposed conductive parts shall not be disconnected and shall be capable of withstanding the test voltage.

For the test:

- either all switching devices shall be closed, or
- the test voltage shall be applied successively to all parts of the circuit.

The test voltage shall be applied between the live parts and the frame of the ASSEMBLY.

8.3.2.2 *Value of test voltage (see Sub-clause 8.2.2.4)*

If the equipment included in the main or auxiliary circuits to be tested has previously been subjected to a dielectric test, the test voltage shall be reduced to 85% of the value indicated in Sub-clause 8.2.2.4.

8.3.2.3 *Results to be obtained*

The test is considered to have been passed if there is no puncture or flash-over.

8.3.3 *Checking of protective measures and of the electrical continuity of the protective circuits*

The protective measures with regard to protection against direct and indirect contact shall be checked.

The protective circuits shall be checked by inspection to ascertain that the measures prescribed in Sub-clause 7.4.3.1.5 are complied with. In particular, screwed connections shall be checked for adequate contact, possibly by random tests.

8.3.4 *Verification of insulation resistance*

For PTTA which have not been subjected to a dielectric test according to Sub-clauses 8.2.2 or 8.3.2, an insulation measurement using an insulation measuring device at a voltage of at least 500 V shall be carried out.

In this case, the test is deemed satisfactory if the insulation resistance between circuits and exposed conductive parts is at least 1 000 Ω/V per circuit referred to nominal voltage to earth of these circuits.

APPENDIX A

MINIMUM AND MAXIMUM CROSS-SECTIONS OF COPPER CONDUCTORS SUITABLE FOR CONNECTION (See Sub-clause 7.1.3.2)

The following table applies for the connection of one copper cable per terminal.

TABLE AI

Rated current	Solid or stranded conductors		Flexible conductors	
	Cross-sections		Cross-sections	
	min.	max.	min.	max.
a	b	c	d	e
(A)	(mm ²)		(mm ²)	
6	0.75	1.5	0.5	1.5
8	1	2.5	0.75	2.5
10	1	2.5	0.75	2.5
12	1	2.5	0.75	2.5
16	1.5	4	1	4
20	1.5	6	1	4
25	2.5	6	1.5	4
32	2.5	10	1.5	6
40	4	16	2.5	10
63	6	25	6	16
80	10	35	10	25
100	16	50	16	35
125	25	70	25	50
160	35	95	35	70
200	50	120	50	95
250	70	150	70	120
315	95	240	95	185

Notes 1. — If the external conductors are connected directly to built-in apparatus, the cross-sections indicated in the relevant specifications are valid.

2. — In cases where it is necessary to provide for conductors other than those specified in the table, special agreement shall be reached between manufacturer and user.

APPENDIX B

METHOD OF CALCULATING THE CROSS-SECTIONAL AREA OF PROTECTIVE CONDUCTORS WITH REGARD TO THERMAL STRESSES DUE TO CURRENTS OF SHORT DURATION

(More detailed information is to be found in IEC Publication 364-5-54.)

The following formula shall be used to calculate the cross-section of the protective conductors necessary to withstand the thermal stresses due to currents with a duration of the order of 0.2 s to 5 s:

$$S_p = \frac{\sqrt{I^2 t}}{k}$$

where:

S_p = cross-sectional area, in square millimetres

I = value (r.m.s.) of a.c. fault current for a fault of negligible impedance which can flow through the protective device, in amperes

t = operating time of the disconnecting device, in seconds

Note. — Account should be taken of the current limiting effect of the circuit impedances and the limiting capability (Joule integral) of the protective device.

k = factor dependent on the material of the protective conductor, the insulation and other parts and the initial and the final temperature

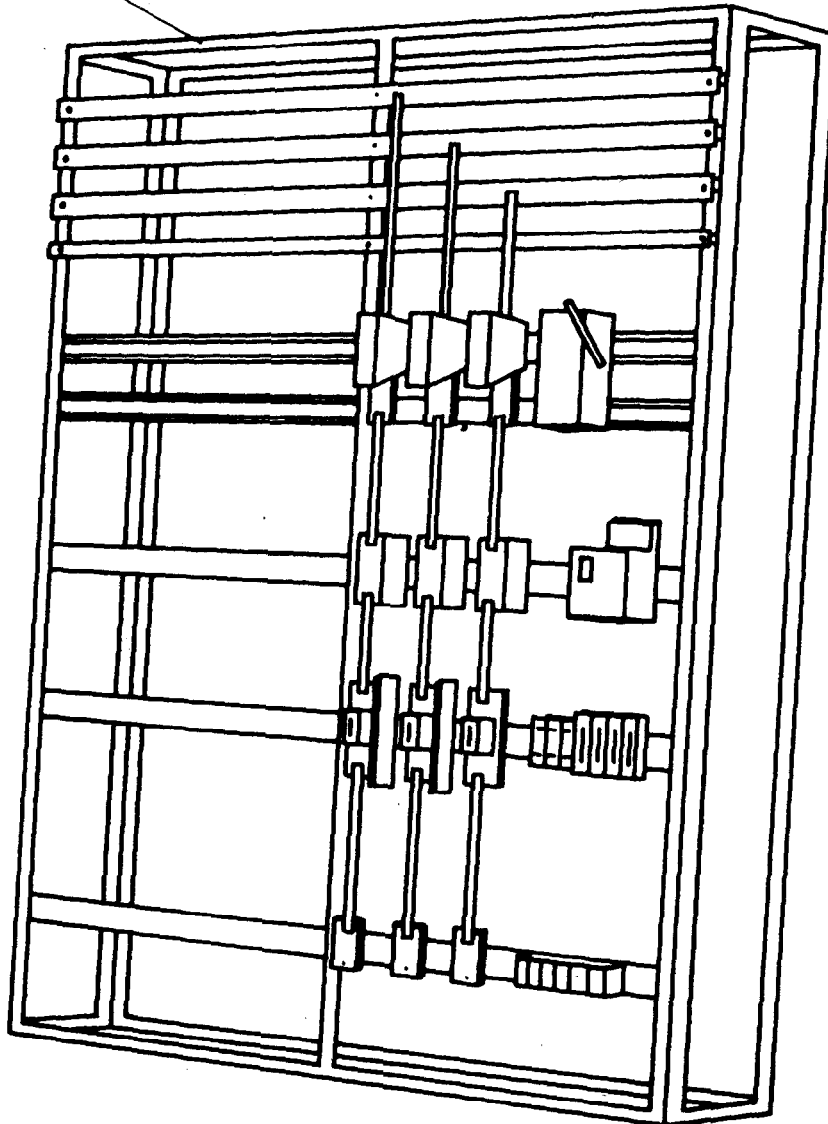
TABLE BI

(This table is based on Table 54B of IEC Publication 364-5-54.)

Values of k for insulated protective conductors not incorporated in cables, or bare protective conductors in contact with cable covering.

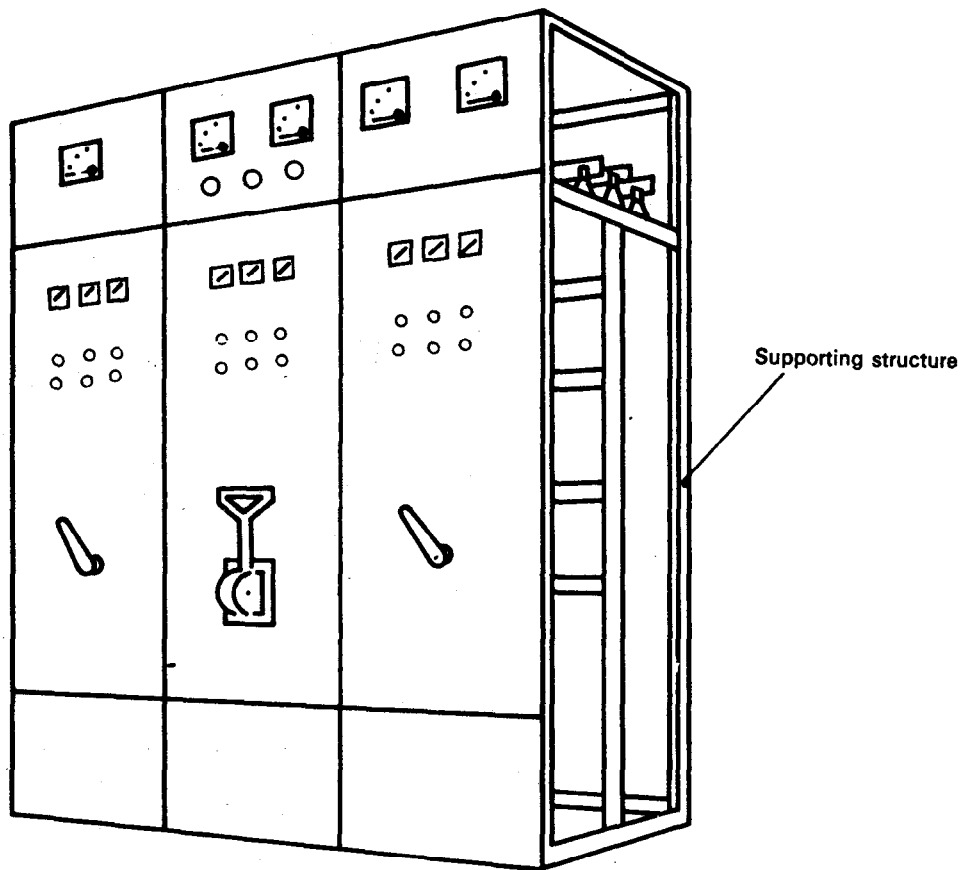
	Insulation of protective conductor or cable covering		
	PVC	XLPE EPR Bare conductors	Butyl rubber
Final temperature	160 °C	250 °C	220 °C
Material of conductor	k		
Copper	143	176	166
Aluminium	95	116	110
Steel	52	64	60
<i>Note.</i> — The initial temperature of the conductor is assumed to be 30 °C.			

Supporting structure



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FIG. C1. — Open-type ASSEMBLY.



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FIG. C2. — Dead-front ASSEMBLY

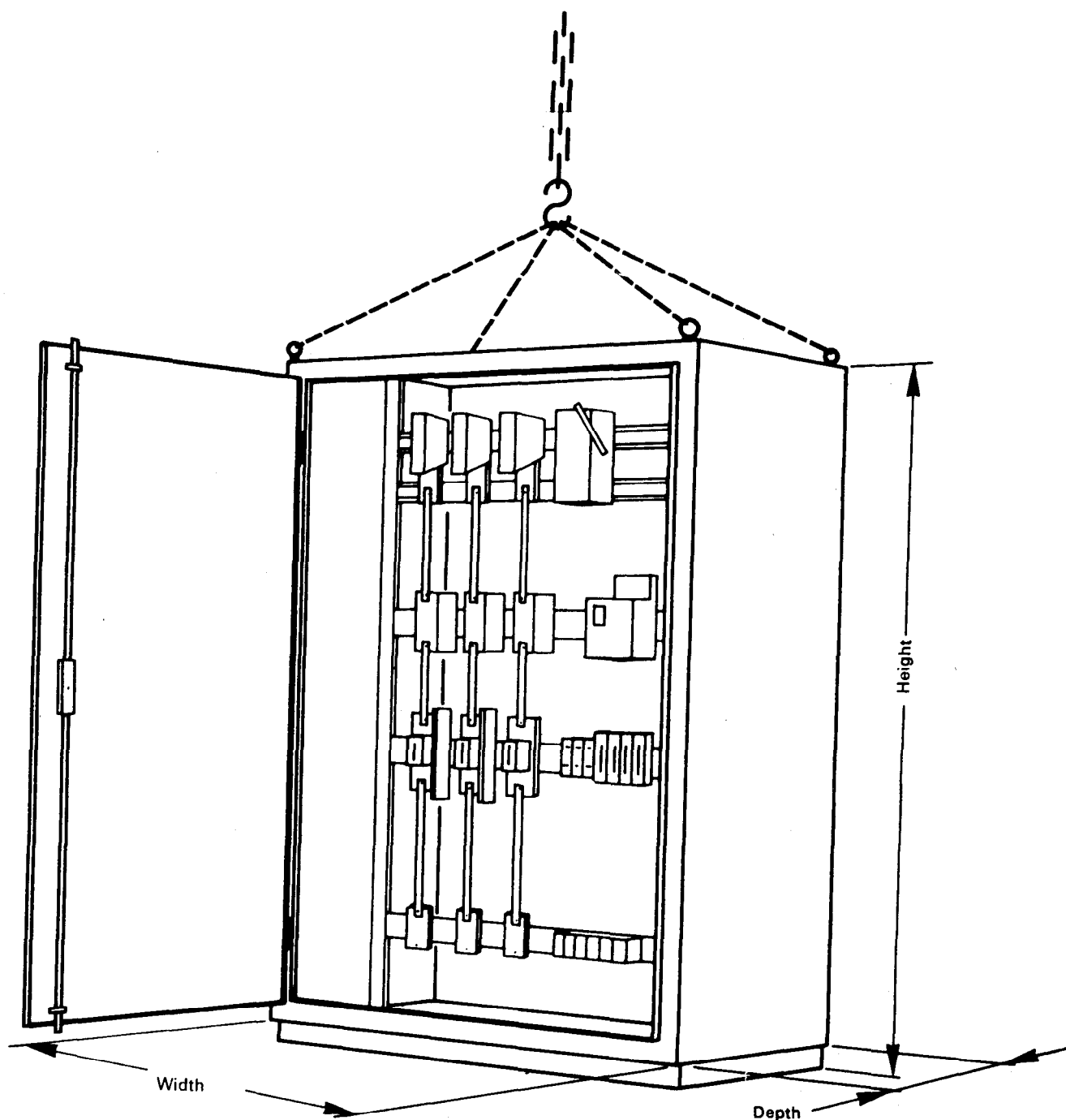


FIG. C3. — Cubicle-type ASSEMBLY.

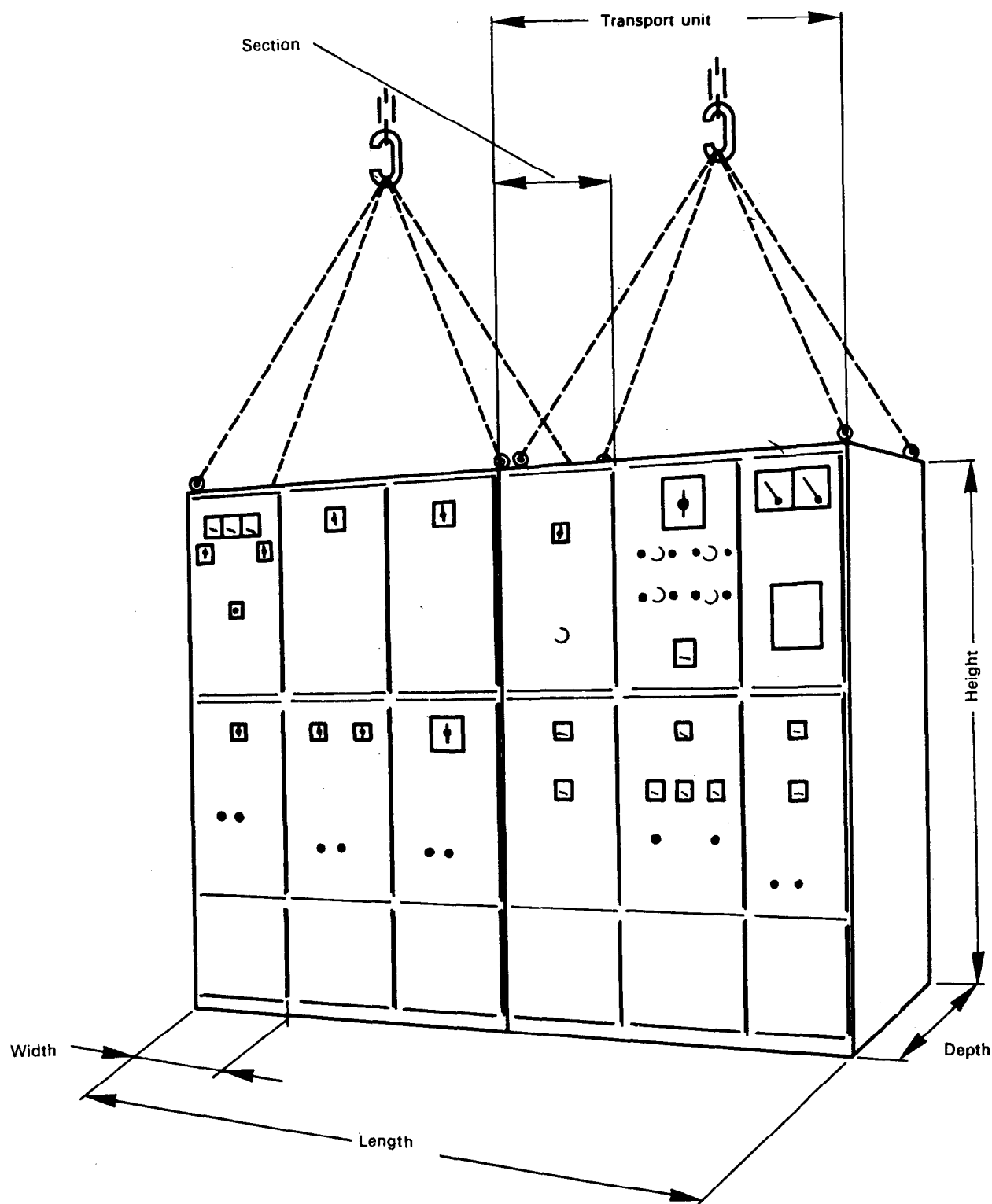
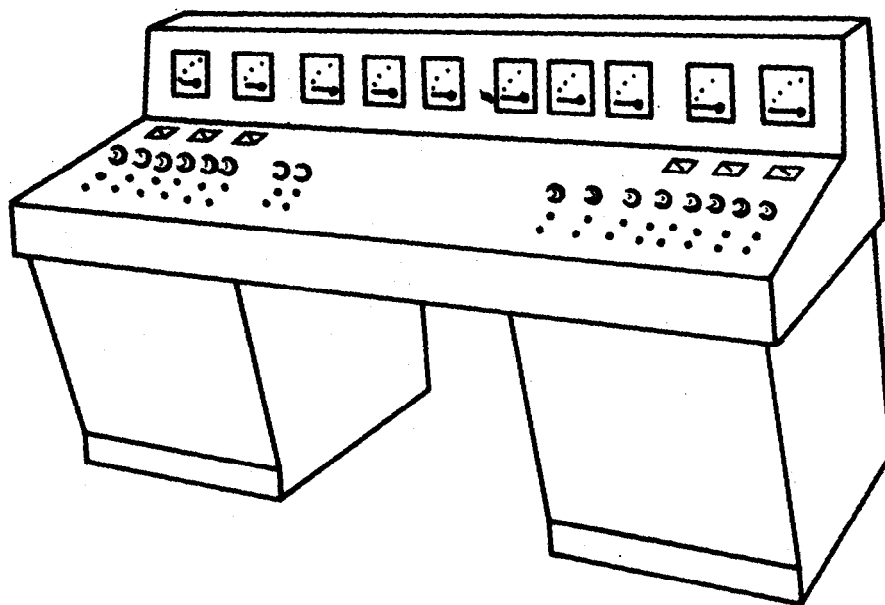
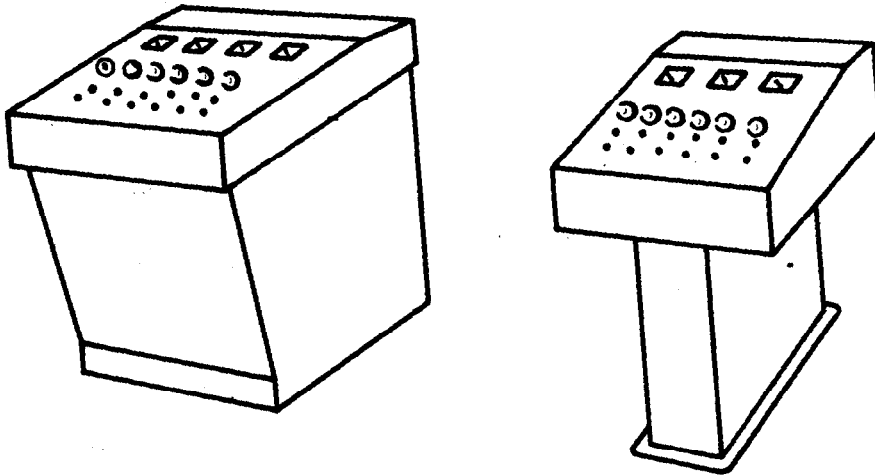
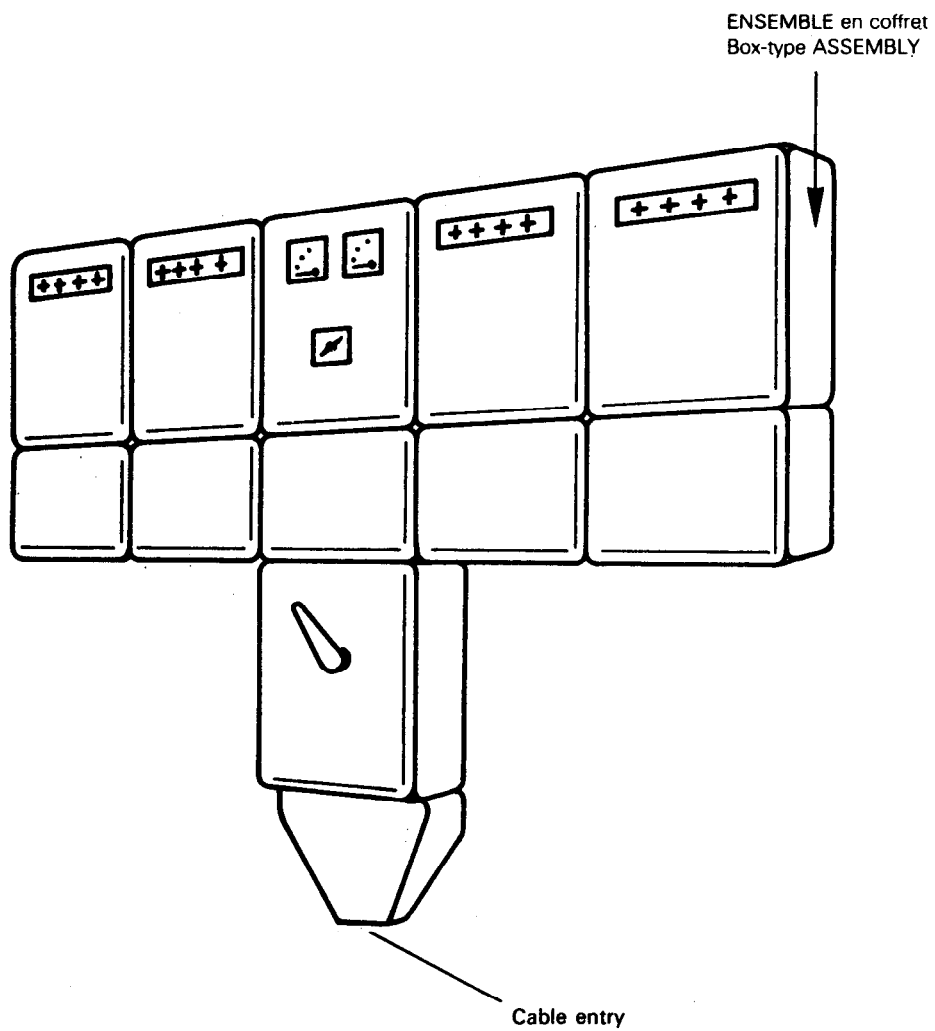


FIG. C4. — Multi-cubicle-type ASSEMBLY.



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FIG. C5. — Desk-type ASSEMBLY.



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FIG. C6. — Multibox-type ASSEMBLY.

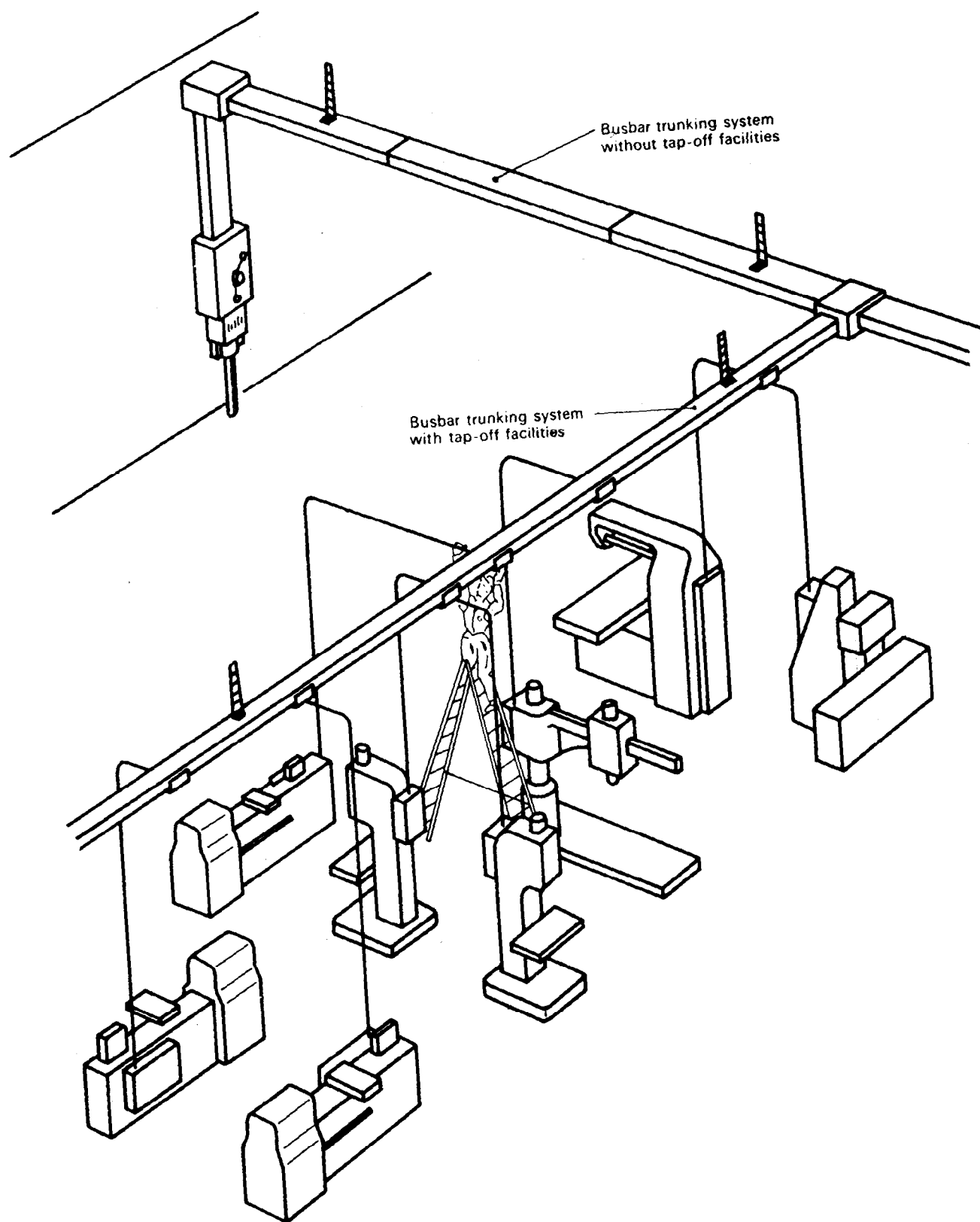
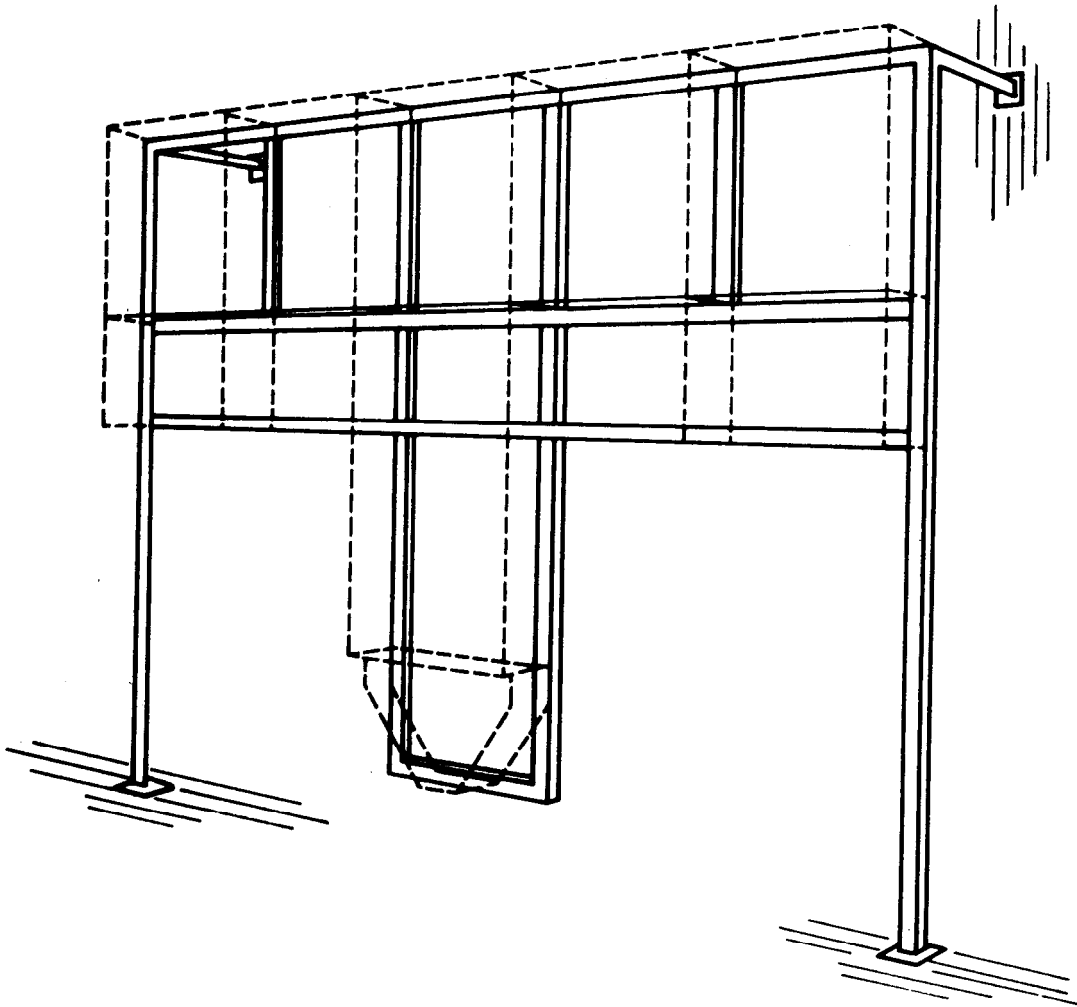
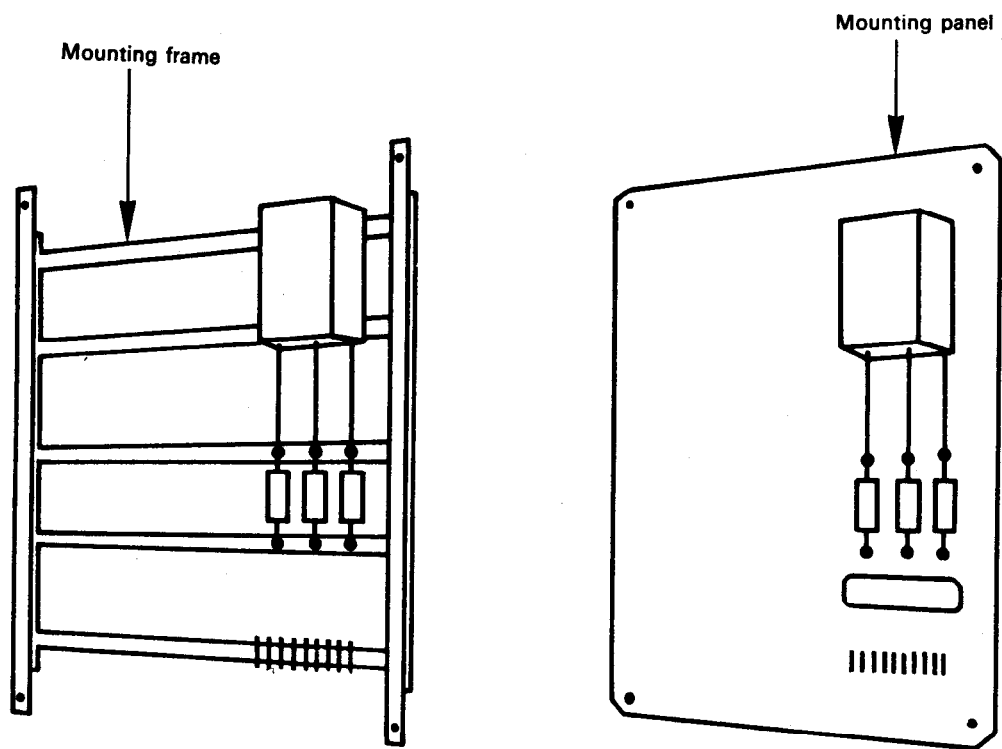


FIG. C7. — Busbar trunking system.



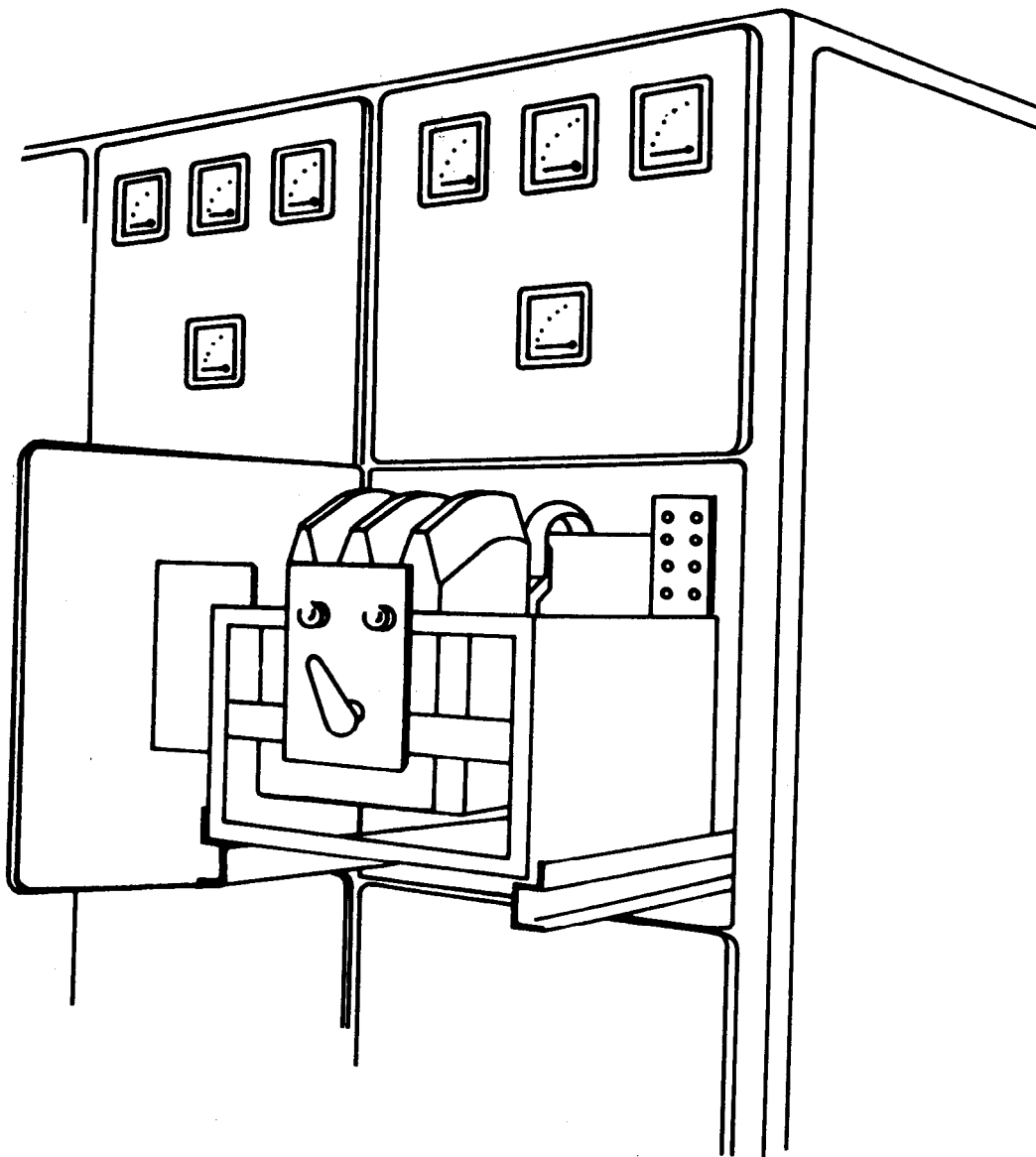
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FIG. C8. — Mounting structure.



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FIG. C9. — Fixed parts.

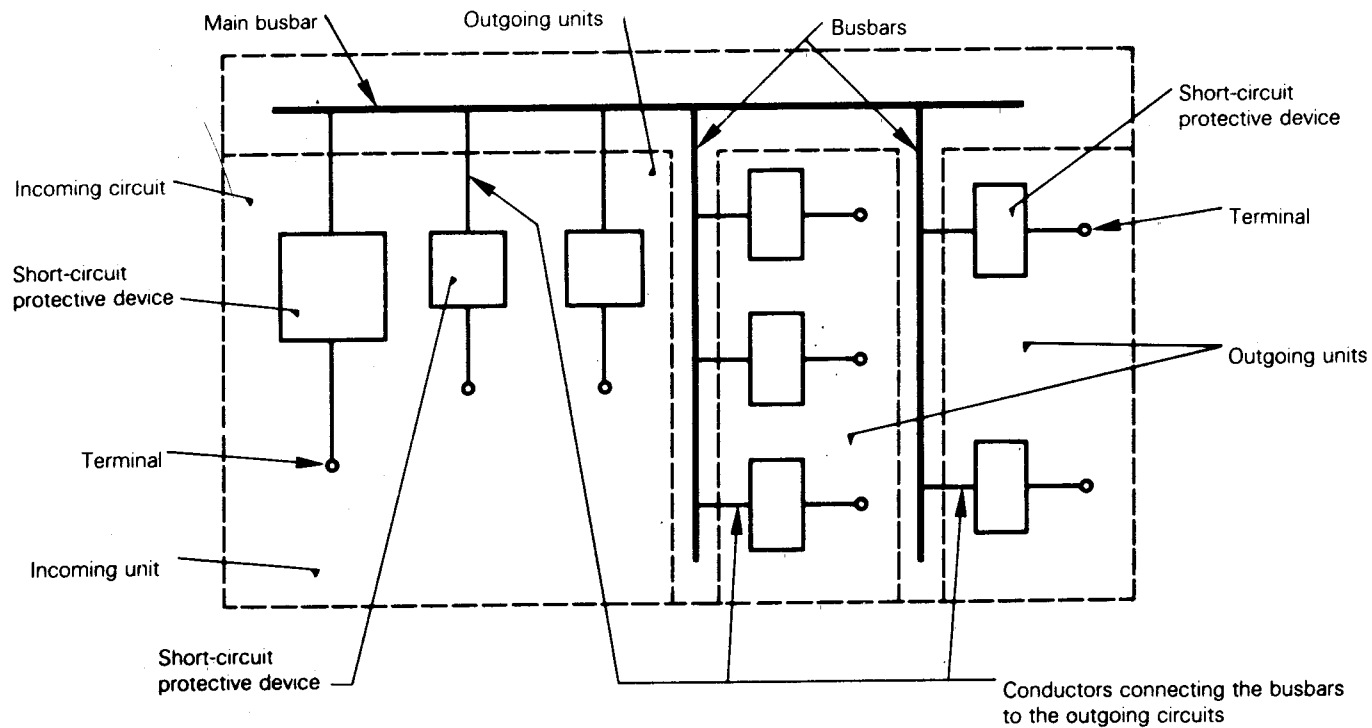


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FIG. C10. — Withdrawable part.

APPENDIX D

TYPICAL ARRANGEMENTS OF FORMS OF SEPARATION BY BARRIERS OR PARTITIONS



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FIG. D1. — Form 2.

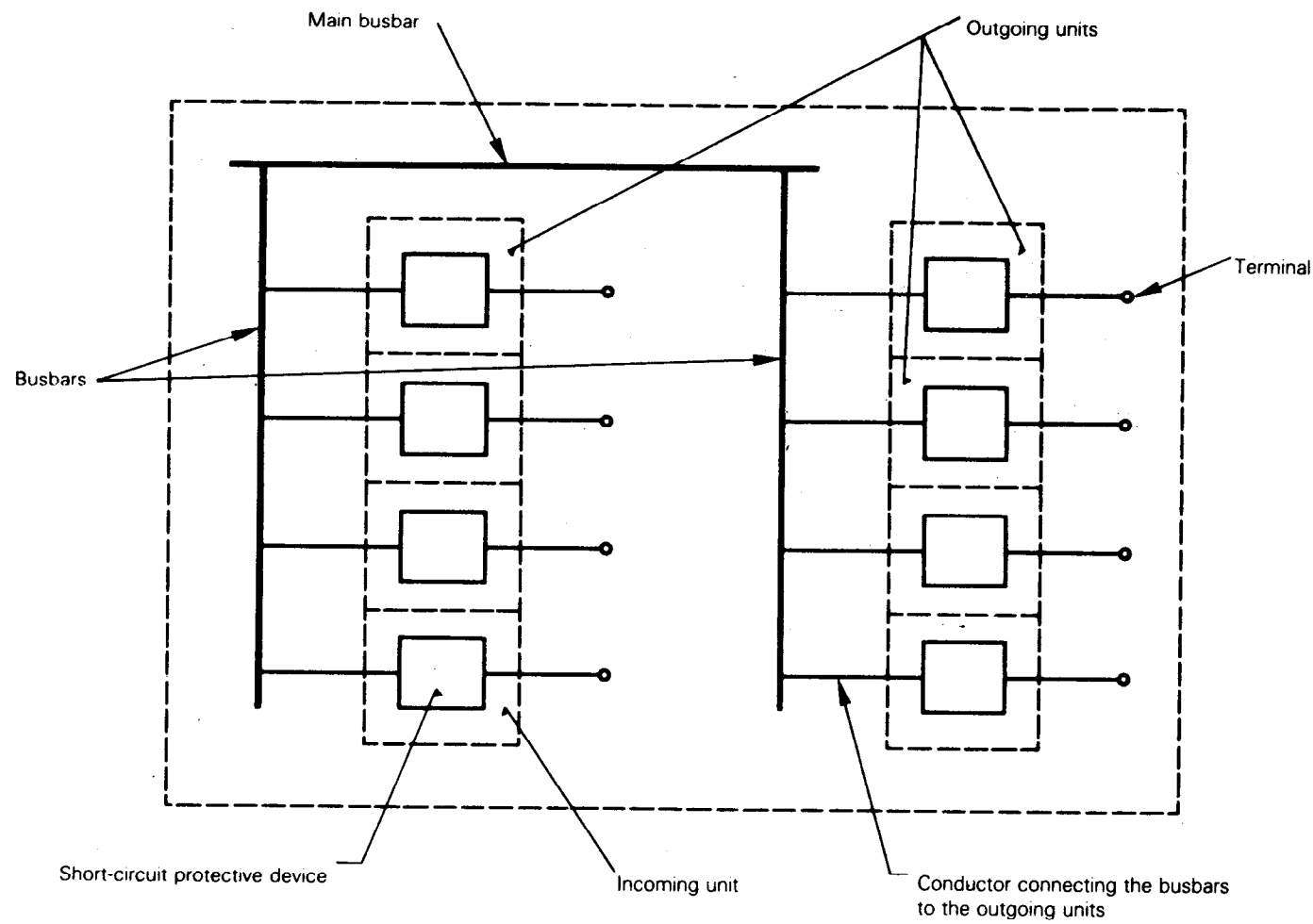
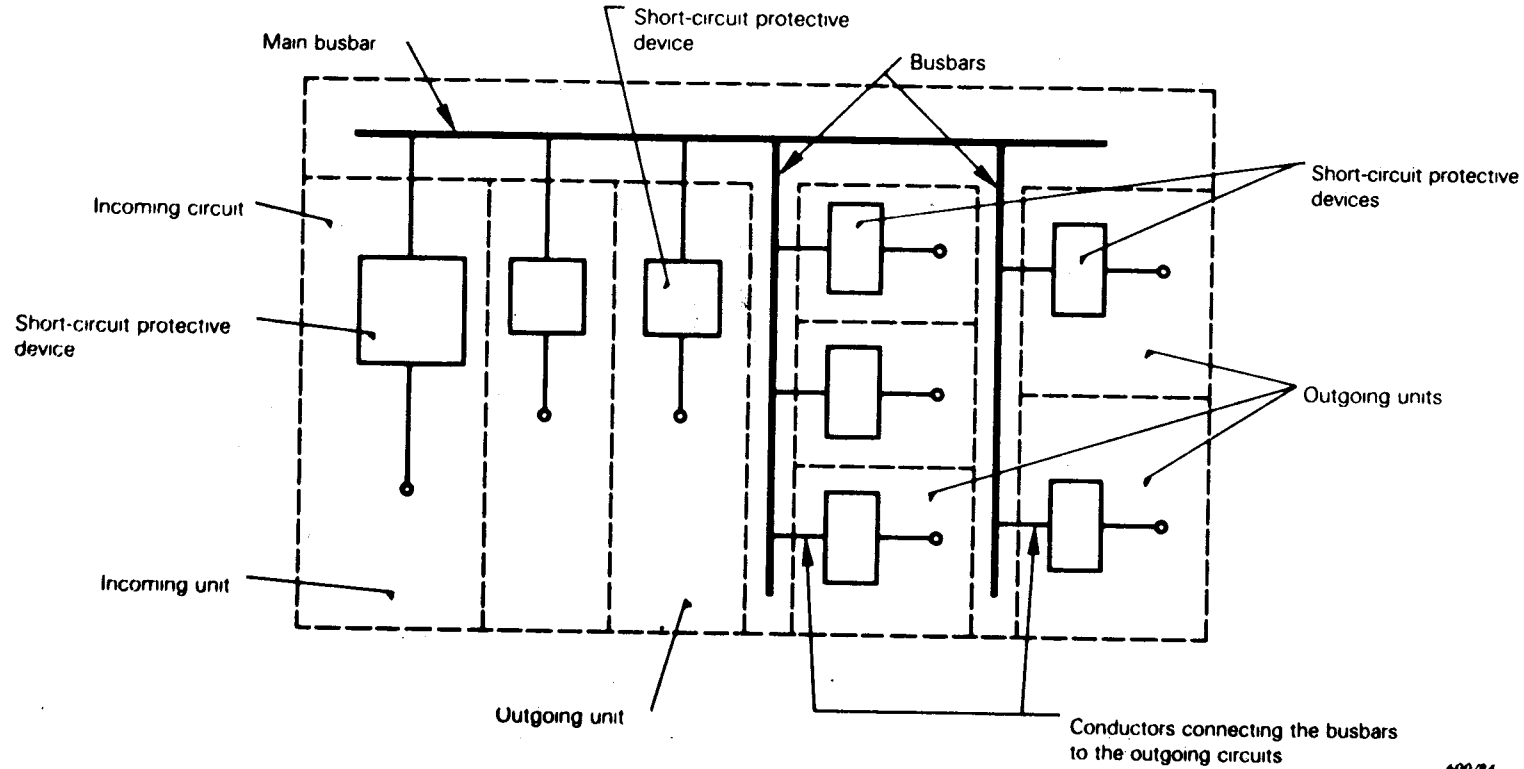


FIG. D2. — Form 3.

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FIG. D3. — Form 4.

APPENDIX E

ITEMS SUBJECT TO AGREEMENT BETWEEN MANUFACTURER AND USER

Sub-clause of this standard

- 6.1.1.2 (Note) Use of ASSEMBLIES in arctic climate.
- 6.1.3 (Note) Use of electronic equipment at altitudes above 1 000 m.
- 6.2 Special service conditions.
- 6.2.10 Electrical and radiated interferences.
- 6.3.1 Conditions during transport, storage and erection.
- 7.1.3.2 Cross-sectional area of cables to be connected.
- 7.1.3.2 Means of connection for aluminium conductors.
- 7.1.3.4 Current-carrying capacities of terminals for neutral conductors.
- 7.2.1.1 Degree of protection required for the intended installation. For floor-mounted ASSEMBLIES also the degree of protection of the bottom to be indicated.
- 7.4.2 Choice of protective measure against direct contact.
- 7.4.3 Choice of protective measure against indirect contact.
- 7.4.6 Accessibility in service by authorized personnel.
- 7.4.6.1 Accessibility for inspection and similar operations.
- 7.4.6.2 Accessibility for maintenance.
- 7.4.6.3 Accessibility for extension under voltage.
- 7.5.2.3 Values of prospective short-circuit current in case of several incoming units or outgoing units for high-power rotating machines.
- 7.5.4 Co-ordination of short-circuit protective devices.
- 7.6.4.3 Degree of protection after removal of a removable or withdrawable part.
- 7.7 Form of separation.
- 7.9.1 Input voltage variations for electronic equipment supply.

- 7.9.4, Item b) Supply frequency deviation.
- 8.2.1.3.4 Temperature-rise test for values of test current higher than 3 150 A.
- 8.2.1.6 Ambient air temperatures for temperature-rise test.
- 8.2.3.2.3, Item d) Value of neutral bar current for short-circuit test.
- 8.3.1 Repetition of electrical operation test on site.

NATIONAL ANNEX

<i>Clause</i>	<i>Remarks</i>
6	Reference is invited to the following Indian Standards: IS 9676 : 1980 Reference ambient temperature for electrical equipment IS 10580 : 1983 Service conditions for electrical equipment
7.1.2.2	It is recommended that reference be made to IS 13947 (Part 3) for isolating distances.
7.1.3	For Indian conditions, use of aluminium conductors shall be taken into account.
7.1.3.4 (Note 1)	For three phase and neutral circuits, terminals of the neutral conductor shall allow the connection of aluminium conductors having current carrying capacity: a) Equal to half the current carrying capacity of the phase conductor, with a minimum of 25 mm ² , if the size of the phase conductor exceeds 25 mm ² , and b) Equal to the full current carrying capacity of the phase conductor if the size of the latter is equivalent to a less than 25 mm ² .
7.4.3.1.7, Table IV	Reference is invited to IS 3043 : 1987 for minimum cross-sectional area of protective conductors of different materials and construction.
8.2.1.3, Tables VIII and IX	<i>Connections for carrying out temperature rise test</i> For the purposes of Indian Standard, unless otherwise specified by the manufacturer, tests for temperature rise shall be made with aluminium conductor with cross-sections given in Tables IXA and XA given in National Annex of IS 13947 (Part 1). The test report shall clearly state the material, type and cross-section of conductors used for connections.

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