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enclosures and degrees of protection

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Since 1983 he has been Technical Delegate for Merlin Gerin in standardization bodies (IEC, UTE, CENELEC,...)
That led to him becoming in particular:
- **chairman of the French Committee 70 in charge of the preparation of standards for «Degrees of protection provided by enclosures» in 1987,**
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enclosures and degrees of protection

The protection of persons against direct contacts is required by certain regulations (in France the Decret of the 14th of November 1988), and specified by electrical installation standards, such as IEC 364. On the other hand, types of external stresses likely to influence the behaviour of equipment are described in IEC 721-2. The protection against some of these influences is often specified in product standards. Therefore, to explain the degrees of protection that enclosures can provide, and how standards codify them, constitutes an essential information for all, prescribers, installers, operators and inspecting organizations, the purpose of this «Cahier Technique». It replaces «Cahier Technique» No 6 written in 1982, made obsolete by the revision of IEC 529.

summary

1. introduction

It is not sufficient that a piece of equipment fulfils the functional requirements assigned to it. It also has to be protected against possible adverse external influences, and likewise to ensure that it is not harmful to the user or to the environment.

Different means can be used alone or combined to comply with this last requirement. All of them derive from one of the following methods:
- placing out of reach vertically or horizontally, for instance by means of an obstacle,
- total solid insulation as used particularly for cables, but which is not easily applicable when moving parts are involved,
- putting into an enclosure, which is the object of this «Cahier Technique».

This last method has the advantage of providing an easy solution to the other requirement, i.e. the protection of equipment against certain influences such as:
- the ingress of foreign bodies which could disturb the mechanical or electrical operation. They comprise not only sand and dust but also small animals and flying or creeping insects,
- water and other liquids which could alter the insulation and generate degradation,
- mechanical impacts which might deform or break brittle parts,
- corrosive gas from the environment,
- radiated electromagnetic fields,
- various radiations including light.

Constituting a supporting structure, the enclosure also allows for the building of assemblies of complementary and coordinated apparatus. Therefore it is the most common method of protection. It is used for electronic or information technology equipment as well as for domestic appliances or for high or low voltage equipment, or for rotating machines. The enclosure may be built into the equipment or manufactured separately and sold empty to an assembly-maker. It can be made of various materials: metal or synthetic, insulating or conductive.

In order to facilitate the relationships between manufacturers, users and legislators, standards define terminology, characteristics and means of checking a product, a service or an installation. As far as protection provided by enclosures is concerned, it is the aim of Publication 529 of the IEC and of prEN 50102 of CENELEC (see corresponding French standards in appendix 3). It must be noted at this point that standards define the protections that enclosures can provide, but not the characteristics of the enclosures themselves.
These so-called «horizontal» standards apply only when referred to by the relevant product standard. By extension, degrees of protection by enclosures are also used to characterize protection provided by barriers.

2. general

definitions

To understand the actual importance of standards, it is absolutely necessary to refer to the definitions of the vocabulary used, definitions which are themselves standardized for a given field. Some terms which are used when protection of electrical equipment by enclosure is referred to are therefore given hereafter. Given the extent of international trading connections, the corresponding French terms are also provided. The reference which is sometimes stated just after, is the index of the term in the International Electrotechnical Vocabulary (IEV).

■ enclosure (enveloppe) IEV 826-03-12
«A part providing protection of equipment against certain external influences and, in any direction, protection against direct contact».

IEC 529 adds the following note:
This definition taken from the existing IEV needs the following explanations under the scope of this standard:
«1) enclosures provide protection of persons or livestock against access to hazardous parts,
2) barriers, shapes of openings or any other means - whether attached to the enclosure or formed by the enclosed equipment - suitable to prevent or limit the penetration of the specified test probes are considered as a part of the enclosure, except when they can be removed without the use of a key or tool».
Figures 1 and 2 display this definition.

So enclosures provide protection against direct contacts. The way they are made can also participate into the protection against indirect contacts when the continuity of conducting parts is secured.

■ degree of protection (degré de protection)
«The extent of protection provided by an enclosure against access to hazardous parts, against ingress of foreign objects and/or against ingress of water and to give additional information in connection with such protection».

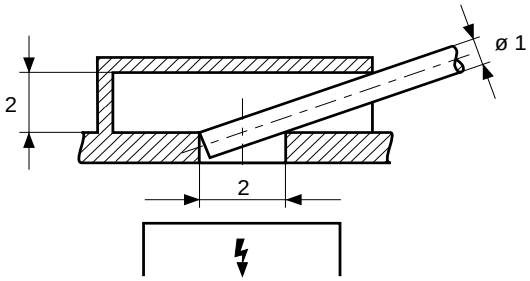


fig. 1: a mask in front of an opening prevents the «test probe» of 1 mm diameter (ø) from penetrating and allows a degree of protection of IP3 XD (according to IEC 529).

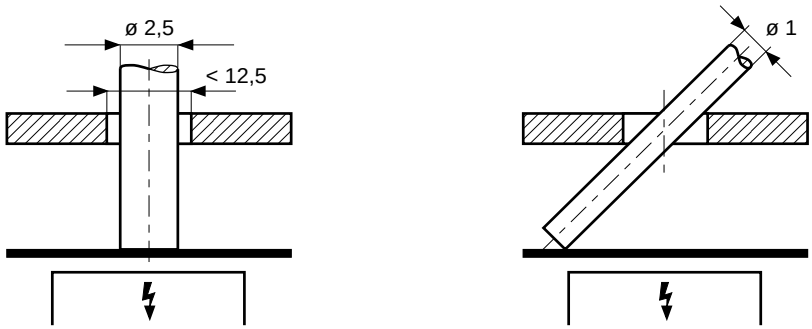


fig. 2: a fixed panel inside the enclosure prevents the «test probe» of 2.5 mm and of 1 mm diameter (ø) from penetrating; therefore it is an IP2 XD (according to IEC 529).

■ hazardous part (partie dangereuse)
«A part that is hazardous to approach or touch».
It may refer to any kind of hazard: electrical (high or low voltage), mechanical, thermal or other.

■ adequate clearance for protection against access to hazardous part (distance suffisante pour la protection contre l'accès aux parties dangereuses)
«A distance to prevent contact or approach of an access probe to a hazardous part».
Distance is related to the internal voltage of the equipment.

■ access probe (calibre d'accessibilité)
«A test probe simulating in **a conventional manner** a part of a person or a tool, or the like, held by a person to verify adequate clearance from hazardous parts».

The conventional approach of the representation of a part of the human body is to be noted here. The «jointed-test finger» does not pretend to represent the longest nor the thinnest phalanges; it is only the name of a test probe showing, typically, a finger. When a more selective protection is looked for, a higher degree should be used.

This type of probe is used to check protection of persons. The criterion to pass a test with such a probe is that, if it penetrates partially, the «adequate distance» is kept.

■ object-probe (calibre-objet)
«A test probe simulating a solid foreign object to verify the possibility of ingress into an enclosure».

The test is satisfactory if the full diameter of the probe does not pass through any opening, as the bore probe.

■ swichgear and controlgear (appareillage) IEV 441-11-01
«A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures».

■ enclosed assembly (ensemble sous enveloppe) IEV 441-12-02
«An assembly enclosed on all sides, top and bottom in such a manner as to provide a specified degree of protection».

uses of a code system

According to the dictionary, a code is «A set of rules on any subject, or a set of letters or figures or word groups with arbitrary meanings for brevity or secrecy». Apart from the purpose of secrecy, both meanings apply to code systems dealt with in this «Cahier Technique».
A code system allows the representation by means of an alphanumerical symbol, of properties according to their definitions and to the way they are tested.

It can be used in different directions:
■ to specify required levels.
It is the case of regulations relevant to the protection of the public or of workers.
It is also the case of some installation standards for a particular environment; it can also be the case of a particular user's specification.
■ for a manufacturer, to describe the properties of his equipment.

Thus some product standards give a set of degrees of protection to choose in one direction or in an other.

As far as the protection provided by enclosures of electrical switchgear is concerned, nowadays the international standardization defines two codes: the IP code and the IK code.

3. the IP code

general

The IP code is described in Publication 529 of the International Electrotechnical Commission.
IP means «International Protection».
This code allows for the description of the degrees of protection provided by enclosures against access to hazardous parts, ingress of solid foreign bodies and against harmful effects of water, by means of the numerals and letters described hereunder.

This standardized code is intended to be used in product standards. It can also be used to describe an empty enclosure, but then some difficulties can appear as to the application:
■ where to locate harmful parts to keep them at «adequate distance»?
■ where may water or dust deposit without disturbing the correct operation of the equipment?

In fact, degrees of protection will only be required when the enclosure is in service with equipment inside.
The assembler is therefore responsible for the final product complying to its standard. But the manufacturer of the enclosure must state in the documents where equipment has to be installed inside the enclosure to maintain the degrees of protection he has assessed.
Eventually, people in charge of the installation who will connect the equipment (cable pass), fix it and in some cases adapt auxiliaries (push-buttons, meters,...) must ensure that the specified degree of protection is maintained.

Letters IP of the code are followed by two independent numerals and sometimes by letters. When the degree of protection corresponding to one of the numerals is not stated (be it unnecessary or unknown) it is replaced by an X.

first numeral

As a result of decisions made for previous editions of the standard, decisions which cannot to be reconsidered, the first numeral indicates **simultaneously**:
■ protection of persons against access to harmful parts and
■ protection of equipment against ingress of foreign bodies.
To check compliance with the first numeral, two probes must therefore be used (an access-probe and an object-probe) with the application forces specified in the standard, or the same probe is used with two acceptance criteria.

The various degrees correspond to the following meanings:
IP 1X: it can be a wire-mesh or an enclosure, the largest opening of which does not allows a ball of 50 mm diameter to ingress. This corresponds approximately to the ingress of a hand (see fig. 3).

IP 2X: the protective wire-mesh has smaller holes and the diameter of the objet-probe is 12.5 mm. In addition, the «jointed test-finger» must stay at adequate distance from harmful parts.

IP 3X: the enclosure must not allow ingress of foreign bodies 2.5 mm of diameter. The test is performed with a steel wire with edges free from burrs, because the use of a 2.5 mm diameter ball would not be convenient.

IP 4X: as for the previous degree but with 1 mm instead of 2.5.

IP 5X and **IP 6X**: these two degrees correspond to protection against ingress of dust. IP 5X allows penetration of some dust in places where it is not harmful. IP 6X accepts no ingress of dust at all.
The test is performed in a test room where talcum powder is sustained floating by means of an air flow.
In addition, the enclosure is depressurised internally except if the relevant equipment standard specifies that it be of category 2: that is, the normal operation of the enclosed assembly cannot generate significant internal pressure reduction. Although the test is performed with talcum powder, the effects that might give any other type of dust must be taken into account here.

Dust-test of the IP code is currently to be incorporated into IEC 68-2 as test La2.

The indication provided by the first numeral implies that the equipment complies with all lower degrees.

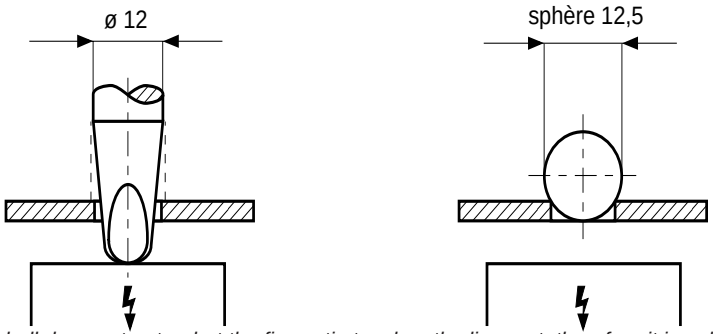


fig. 3: the ball does not enter, but the finger-tip touches the live part; therefore it is only IP 1X (according to IEC 529).

second numeral

The second characteristic numeral of the IP code indicates the degree of protection against harmful effects of water penetration. It is specified that the tests be performed with fresh water (see fig. 4) with no wetting agents.

The interpretation of tests for this numeral may be difficult since water penetration into the enclosure is permitted, provided it does not generate harmful effects.

The various degrees of the second numeral correspond to the following situations:

IP X1: this first degree correspond to the protection against vertical water drops to which indoor equipment can be exposed due to leaks or condensation-drops from the ceiling of the room or on tubes passing above the enclosure.

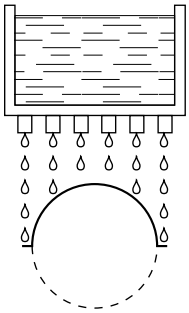
IP X2: this degree corresponds also to water drops, but with a larger flow and with an angle up to 15°. It is for instance the case of equipment on ships.

IP X3: this degree corresponds to the protection against rain. The maximum spray angle is 60° from vertical. The base of the enclosure may be open. The test may be performed by means of a oscillating arc-tube equipped with nozzles (over 60° from each side of vertical) or of a mobile spray with a mask limiting the incidence of the jets. In both cases, the water flow is specified.

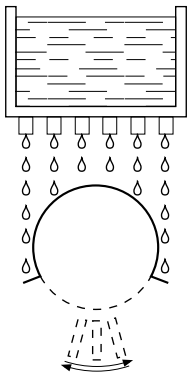
IP X4: the water flow of each nozzle is the same for this degree as for the previous one but there are nozzles over 180°; in addition, the tube oscillates over ± 180° so that water is sprayed in every direction.This test simulates heavy rain and splashes.

IP X5 and **IP X6**: these degrees are tested by water jet hose simulating water-jets, heavy sea, etc. Test conditions are more severe for degree 6 than for degree 5: a larger diameter of the nozzle and water flow.

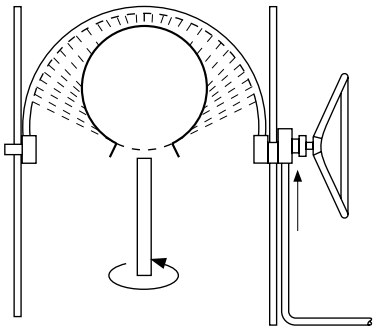
IP X7 and **IP X8**: no longer correspond to water projections but to transient or permanent immersions.



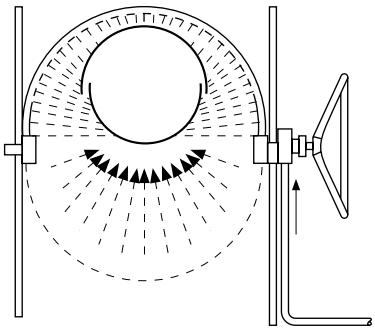
IP X1 : protégé contre les chutes verticales de gouttes d'eau.



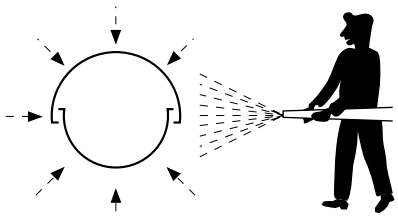
IP X2 : protégé contre les chutes de gouttes d'eau jusqu'à 15° de la verticale.



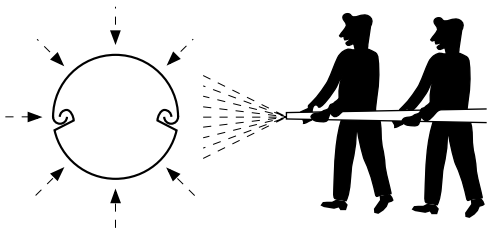
IP X3 : protégé contre l'eau en pluie.



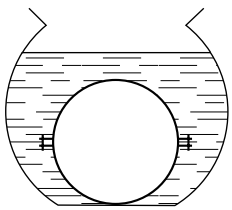
IP X4 : protégé contre les projections d'eau.



IP X5 : protégé contre les jets d'eau.



IP X6 : protégé contre les paquets de mer et projections assimilable.



IP X7 : protégé contre les effets d'une immersion temporaire.

IP X8 : matériel submersible (essais sur accord particulier).

fig. 4: test means provided by the standard to assess the second numeral of the IP code.

Therefore enclosures complying with these degrees must have double marking if they also comply with a lower degree, for instance IP X5/X7 (a bucket immersed upside down is IP X8, but not IP X4).

Water-tests of the IP code have been recently incorporated into IEC 68-2-18 with the following correspondence (see appendix 1).

additional letter

In some cases, the protection provided by an enclosure against access to harmful parts is better than indicated by the first numeral (which also indicates the protection against ingress of foreign bodies). For instance it is frequently the case of an opening of the enclosure blinded by a staggered joint or a sheet-bent. This protection can be characterized by an additional letter added after the two numerals. It allows openings useful for thermal dissipation when keeping the degree of protection required for the protection of persons.

It has one of the following meanings:

IP XXA has no practical application since the test for the letter A is the same as for the first numeral 1 (see fig. 3).

IP XXB means that foreign bodies of diameter larger than 12.5 mm can ingress into the enclosure, but that the test-finger does not penetrate more than 80 mm, i.e. not beyond its 50 x 20 mm guard and stays at an adequate distance from harmful parts (see fig. 5).

IP XXC allows penetration of foreign bodies of diameter larger than 2.5 mm, but a straight steel wire of this diameter and 100 mm long stays at an adequate distance from harmful parts.

IP XXD the situation is similar to the previous degree, but for a diameter of 1 mm.

The additional letter is also used when only the protection of persons is aimed at.

supplementary letter

The IP code also comprises some supplementary letters following the other characters in order to add particular information.

For electrical switchgear, only supplementary letter W is used.

It indicates a protection against bad weather checked by other means than those specified for the second characteristic numeral, which are difficult to apply to large equipment.

For instance, the spraying equipment designed for dielectric wet tests is used to check the weather proofing of enclosed high voltage switchgear.

Letters M and S are used for rotating machines to indicate that they have been tested with the rotor in Movement or Stationary.

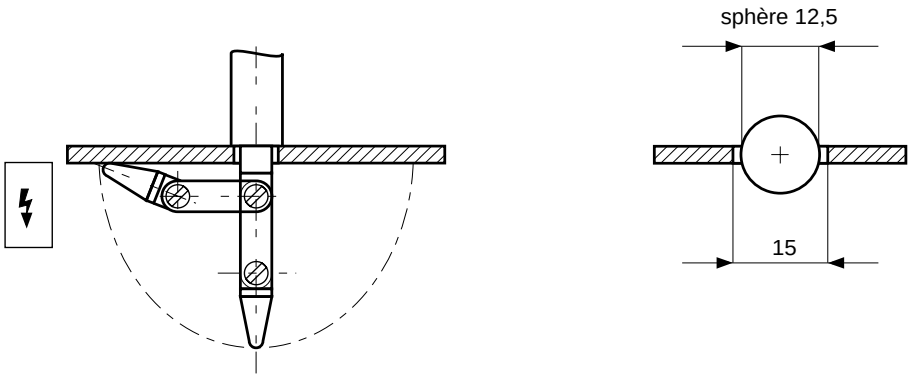


fig. 5: the ball penetrates but the test finger stays away from the live-part; it is therefore IP 1XB (according to IEC 529).

4. the IK code

introduction

Some countries had felt the need also to codify the protection provided by enclosures against mechanical impacts.

To do that, they added a third characteristic numeral to the IP code (the case of Belgium, Spain, France and Portugal). But now that IEC 529 has been adopted as a European standard, no countries may have a different IP code.

Since IEC has so far refused to add this third numeral to the IP code, the only possibility keeping a code system in this area has been to create a different code. This is the object of the European draft standard prEN 50102: IK code.

Since the third numeral of the different countries might have different meanings, and to introduce supplementary severity levels in order to cover the main needs of Product Committees, the degrees of the IK code have meanings different from the old third numerals (see appendix 2).

In order to limit confusion, each new degree is indicated by a number of two numerals.

degrees of protection

The degrees of protection correspond to impact energy levels, given in Joules. An «impact», action of a hammer directly applied to the equipment must be distinguished from a «shock» transmitted by the support and expressed in vibration terms i.e. in frequency and acceleration.

Figure 6 shows table 1 of the standard completed with information relevant to test means. In fact, the degrees of protection against mechanical impacts can be checked with different types of hammers: a pendulum hammer, a spring hammer or a free fall hammer (see fig. 7). Each has a particular scope in energy and in direction of application. In order to get similar severity with impacts of the same energy, certain characteristics of the test means have to be complied with: the radius and the hardness of the striking element.

The product standard must specify on which parts the blows are to be applied and what the acceptance criteria are.

IK code	IK 01	IK 02	IK 03	IK 04	IK 05	IK 06	IK 07	IK 08	IK 09	IK 10
energy Joules	0.15	0.2	0.35	0.5	0.7	1	2	5	10	20
radius mm (1)	10	10	10	10	10	10	25	25	50	50
material (1) steel = S (2) polyamide = P (3)	P	P	P	P	P	P	S	S	S	S
pendulum hammer	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
spring hammer	yes	yes	yes	yes	yes	yes	yes	no	no	no
vertical hammer	no	no	no	no	no	no	yes	yes	yes	yes

(1) of the striking element
(2) Fe 490-2 according to ISO 1052, of hardness 50 HR to 58 HR to ISO 6508
(3) of hardness HR 100 according to ISO 2039/2

fig. 6: test requirements for the various IK degrees.

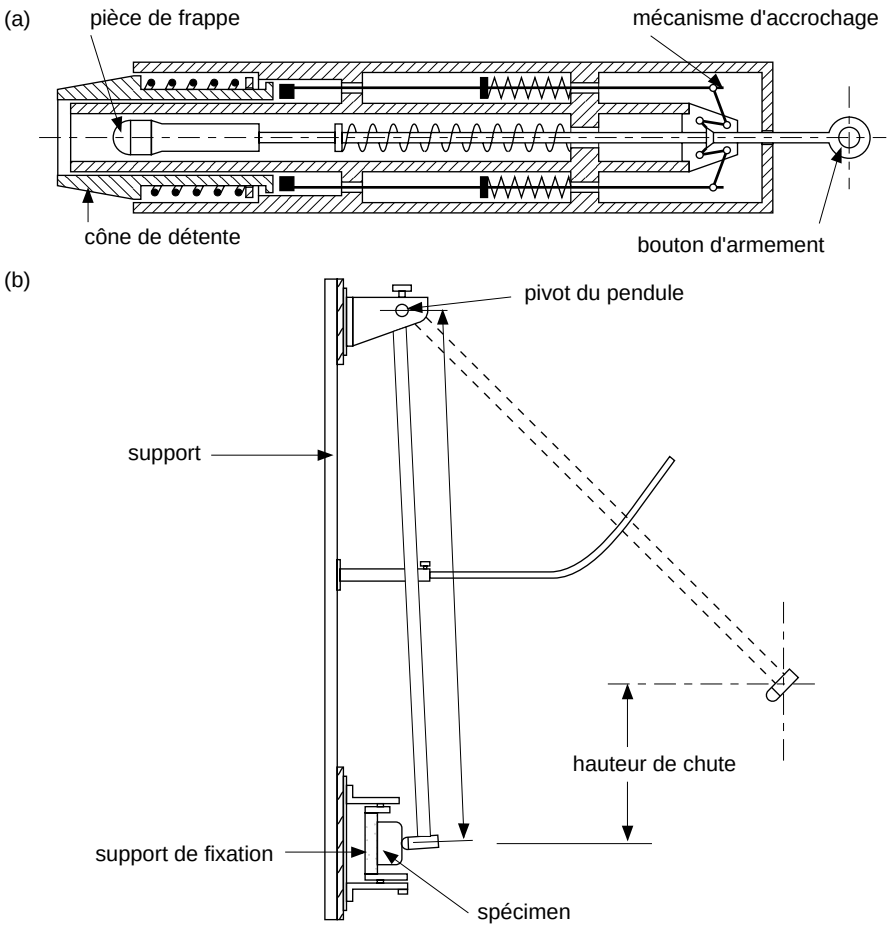


fig. 7: spring-hammer (a) (according to IEC 68-2-63 and pendulum hammer (b) (according to IEC 68-2-62). Note that a calibration device not represented here is required.

5. application to the design of electrical equipment

These notions of protection have a large influence on the design of equipment because protection has to be assessed not only by the external enclosure, but also by internal enclosures or parts of internal enclosures (partitions, shutters, etc). Therefore the degree of protection of persons has to be defined also for internal parts which can initiate a direct contact during an operation, for instance when withdrawing a circuit-breaker. In addition, even if an enclosure provides the required degree of protection, it is also necessary that it cannot be removed partially or totally. The point does not concern pieces of equipment such as motors, transformers, etc, but it is of primary importance for some compartments of assemblies which have to be accessible during servicing of the equipment.

Two kinds of compartments are considered in this case:

■ those which are opened only rarely (bus bars) and for which bolted covers can be considered as satisfactory. Opening them being not a simple operation, it is supposed that adequate precautions dictated by safety requirements will be taken.

■ those which may have to be opened during normal operation of the equipment. They are generally closed by doors which can be locked or blocked by an additional control system which completes the protection provided by the enclosure.

During all these service and maintenance operations the electrical continuity of the enclosure must not be interrupted whatever the position of the equipment is.

6 . conclusion

To be satisfactory, any piece of equipment has to comply with its relevent product standard. But this standard uses «horizontal» ones, particularly those relevant to the degree of protection.

The manufacturer as well as the user should therefore refer to the corresponding standards after reading this «Cahier Technique» (see bibliography).

appendix 1: correspondence between water-tests of the IP code and water-tests of IEC 68-2-18

IP code	IP X1 & 2	IP X3 & 4	IP X5 & 6	IP X7
water-tests of IEC 68-2-18	**test Ra2**	**test Rb2**	**test Rb3**	**test Rc1**

appendix 2: equivalence between the old third numerals of the french IP code and IK code

old 3d numerals of the IP code of NF C 20-010 (1986)	IP XX1	IP XX3	IP XX5	IP XX7	IP XX9
IK code	**IK 02**	**IK 04**	**IK 07**	**IK 08**	**IK 10**

appendix 3: bibliography

Documents describing degrees of protection

■ IEC 529 (1989-11): Degrees of protection provided by enclosures (IP code)
□ European application: EN 60529,
□ French application: NF C 20-010 (1992).

■ prEN 50102 (1993): Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code). Draft.

■ French application: prNF C 20-015 (1993). Draft.

Documents specifying degrees of protection for switchgear

■ Decret of the 14th of November 1988 from the French government: Protection of workers against electrical currents.

■ HN 60-E-01 (1974) EDF: Specification for general rules relevant to plastic materials used in electrical equipment for low-voltage networks and connecting points.

■ IEC 298 (1990): A.C.metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV.
□ European application: HD 187,
□ French application: NF C 64-200.

■ IEC 439-1 (1985): Requirements for type-tested and partially type-tested (low-voltage) assemblies.
□ European application: EN 60439,
□ French application: NF C 63-421.

■ IEC 947-1 (1988): Low-voltage switchgear and controlgear.
□ European application: EN 60947,
□ French application: NF C 63-001.

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