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Cast aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear

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Kapselungen aus Leichtmetallguss fur gasgefüllte Hochspannungs-Schaltgeräte und -Schaltanlagen

Enveloppes en alliage d'aluminium coulé pour l'appareillage à haute tension sous pression de gaz

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English version

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

This European Standard has been prepared by CENELEC Technical Committee 17C: High voltage enclosed switchgear and controlgear. It is based on Amendment No. 2 to IEC Publication 517 (1975) which gives, however, only general guidance not sufficient for the service allowance of pressurized high-voltage switchgear and controlgear.

The present EN has been written to get an international specification for the design, construction, testing, inspection and certification of pressurized enclosures used in high-voltage switchgear and controlgear.

This standard follows to that extent also, Article 2 of the Directive 76/767/EEC.

This standard deals only with cast aluminium alloy enclosures. Other standards for metallic enclosures are under consideration and will be issued progressively.

Reference is made to IEC Publication 517 (1975):

High-voltage metal-enclosed switchgear for rated voltages of 72,5 kV and above (HD 358)

with its Amendments No. 1 (1977), No. 2 (1982) and No. 3 (1983).

This European Standard contains a normative technical Annex A: Welder performance test.

Contents

Cast aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear

0 Introduction

This standard covers the requirements for the design, construction, testing, inspection and certification of gas-filled enclosures for use specifically in high-voltage switchgear and controlgear, or for associated gas-filled equipment. Special consideration is given to these enclosures for the following reasons.

(a) The enclosures usually form the containment of electrical equipment, thus their shape is determined by electrical rather than mechanical considerations.

(b) The enclosures are installed in restricted access areas and the equipment is operated by experts and instructed persons only.

(c) As the thorough drying of the inert, non-corrosive gas-filling medium is fundamental to the satisfactory operation of the electrical equipment, it is periodically checked. For this reason, no internal corrosion allowance is required on the wall thickness of these enclosures.

(d) The enclosures are subjected to only small fluctuations of pressure as the gas-filling density shall be maintained within close limits to ensure satisfactory insulating and arc-quenching properties. Therefore the enclosures are not liable to fatigue due to pressure cycling.

(e) The operating pressure is relatively low.

For the foregoing reasons and to ensure the minimum disturbance, hence reducing the risk of moisture and dust entering the enclosures which would prevent correct electrical operation of the switchgear, no pressure tests shall be carried out after installation and before placing in service and no periodic inspection of the enclosure interiors or pressure tests shall be carried out after the equipment is placed in service.

1 Scope

This standard applies to cast aluminium alloy enclosures pressurized with dry air, inert gases, for example sulphur hexafluoride or nitrogen or a mixture of such gases, used in indoor or outdoor installations of high-voltage switchgear and controlgear with rated voltages above 1 kV, where the gas is used principally for its dielectric and/or arc-quenching properties.

The enclosures comprise parts of electrical equipment not necessarily limited to the following examples:

Circuit-breakers
Switch-disconnectors
Disconnectors
Earthing switches
Current transformers
Voltage transformers
Surge arrestors
Busbars and connections

The scope also covers pressurized components such as the centre chamber of live tank switchgear, gas-insulated current transformers, etc. .

2 Quality assurance

It is the intention of this standard that the switchgear manufacturer shall be responsible for achieving and maintaining a consistent and adequate quality of product.

Sufficient examinations shall be made by the founder to ensure that the materials, production and testing comply in all respects with the requirements of this standard. Inspection by user inspectors shall not absolve the manufacturer or the founder from their responsibility to exercise such quality assurance procedures as to ensure that the requirements and intent of this standard are satisfied.

3 Definitions

For the purposes of this standard the following definitions apply.

3.1 national standard. A technical specification available to the public drawn up with the cooperation and in general agreement with all interests affected by it, and approved by a standards organization recognized on the national level. (CLC-Memorandum No. 1 (1974), ISO Guide 2-1976)

3.2 enclosure. A part of gas-insulated metal-enclosed switchgear retaining the insulating gas under the prescribed conditions necessary to maintain safely the rated insulation level, protecting the equipment against external influences and providing a high degree of protection to personnel. (IEC Publication 517)

3.3 manufacturer. Individual or body responsible for designing and producing the enclosure. In this standard this is the switchgear manufacturer.

3.4 designer. Individual or body who determines the shape, dimensions and thickness of the enclosure and selects the materials and method of construction and testing.

3.5 founder. Individual or body who produces the raw casting.

3.6 design pressure (of an enclosure). Pressure used to determine the thickness of the enclosure. It is at least the upper limit of pressure reached within the enclosure at the design temperature. (IEC Publication 517)

3.7 design temperature (of an enclosure). Highest temperature reached by the enclosure which can occur under service conditions. This is generally the upper limit of ambient air temperature increased by the temperature rise due to the flow of rated normal current. (IEC Publication 517)

NOTE. Solar radiation should be taken into account when it has a significant effect on the temperature of the gas and on the mechanical properties of some materials. Similarly, the effects of low temperatures on the properties of some materials should be considered.

3.8 casting. A general term for products at or near finished shape, formed by solidification of a molten metal or alloy in a mould. (ISO/DIS 3134)

3.9 melt. A furnace load of homogeneous molten metal resulting from a single melting operation. (Ideological foundry dictionary (1979), CTIAF*).

*CTIAF = Comité International des Associations Techniques de Fonderie (International Committee of Foundry Technique Associations).

3.10 alloy. A metallic substance consisting of a mixture of the basic metallic element (the element predominating by mass) and other elements such as alloying elements and impurities.
(ISO/DIS 3134).

3.11 casting defect. Imperfections in castings after solidification.

3.11.1 cold shut. A discontinuity with rounded edges extending either partially or entirely through the section of the casting.
(Ideological foundry dictionary (1979), CTIAF*).

3.11.2 cold crack. A crack often scarcely visible due to carelessness or excessive stresses during shake out, cleaning, machining or handling.
(Ideological foundry dictionary (1979), CTIAF*)

3.11.3 hot crack (hot tear). A more or less deep inter-crystalline fissure of irregular outline appearing mostly in the last sections of the casting to solidify in which constraints are present.
(Ideological foundry dictionary (1979), CTIAF*)

3.11.4 inclusion. Particle of a chemical composition, different from that of the casting, embedded in the casting or at its surface which may be formed of slag, sand, blacking, oxides, silicates or sulphides.
(Ideological foundry dictionary (1979), CTIAF*)

3.11.5 blowholes (pinholes). Smooth-walled cavities, essentially spherical, often not contacting the casting surface, the largest (blowholes) are mostly isolated, the smallest (pinholes) generally appear in groups.
(Ideological foundry dictionary (1979), CTIAF*)

3.12 weld defect. Imperfections in metallic fusion welds.

3.12.1 lack of fusion. Lack of union between weld metal and parent metal or weld metal and weld metal.
(ISO 6520-1982 : 401)

3.12.2 overlap. Excess of weld metal at the toe of a weld covering the parent metal surface but not fused to it.
(ISO 6520-1982: 506)

3.12.3 undercut. A groove at the toe(s) (or at the root) of a weld run due to welding.
(ISO 6520-1982 : 5011)

3.13 heat treatment. Process in which the metal in the solid state is subjected to one or more temperature cycles, to confer certain desired properties.

3.14 ductility. The property of a material to undergo permanent deformation without rupture under tensile stresses.
(Ideological foundry dictionary (1979), CTIAF*)

3.15 fatigue. Change of the properties of a material due to repeated application of stresses or strains which leads, in particular, to cracks or rupture.
(ISO R 373)

3.16 tensile strength. The maximum unit stress related to the initial cross-section of the test specimen at which the material ruptures.

3.17 test piece. Two or more parts of material welded together in accordance with a specified weld procedure, or a portion of a casting taken in order to make one or more test specimens.

3.18 test specimen. Portion detached from a test piece, in specified dimensions, finally prepared as required for testing.

4 Materials

4.1 Selection of material

Any suitable cast aluminium alloy is permissible; a list of recommended materials is given in table 1.

The properties of the materials should be taken from the applicable standards.

4.2 Chemical analysis

Ingots used shall comply with the requirements of the appropriate material specification and any special requirement called for on the order; they shall be clean and free from harmful defects.

Providing the chemical analysis of the melt meets the requirements of the appropriate specification, the founder may use scrap which arises from his own production from approved ingots, which is segregated and identifiable. It can include heavy fettling scrap, but shall exclude all drosses and small particles such as sawings and chippings.

NOTE 1. Attention is drawn to a limitation in the otherwise very useful range of aluminium-magnesium alloys. The high strength, relatively high magnesium content alloys can become susceptible to stress-corrosion cracking after use for long periods at temperatures above 66 °C.

NOTE 2. Contact with more noble metals, particularly copper and its alloys, can lead to heavy galvanic corrosion. Austenitic stainless steel is an exception to this rule because of its protective oxide film, and can often be used in contact with aluminium.

Aluminium enclosures should be protected externally where, for example, they come into contact with mild steel supports. Zinc chromate paint, bitumen, thin zinc sheet (which gives sacrificial protection) or a combination of these are useful in this respect. Alternatively, the mild steel supports can be galvanized or zinc or aluminium sprayed.

NOTE 3. It should be noted that contact with certain gasket materials such as compressed asbestos fibre can cause corrosion of aluminium; the gasket manufacturer should be consulted.

5 Design

5.1 General

The rules for the design of enclosures of gas-insulated switchgear and controlgear prescribed in this clause take into account that these enclosures are subjected to particular operating conditions (see Introduction) which distinguish them from compressed air receivers and similar storage vessels. Examples of such enclosures are listed in clause 1.

The geometry of an enclosure can be determined by electrical rather than mechanical considerations; moreover, further constraints in shape can be enforced by the casting process used. These constraints can result in an enclosure

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geometry which requires an unacceptable degree of calculation or which cannot be calculated at all. In the case of such an enclosure or an enclosure for which calculations are not made a proof test is necessary.

When designing an enclosure, account shall be taken of the following, if applicable:

(a) the possible evacuation of the enclosure as part of the filling process;

(b) the full differential pressure possible across the enclosure wall or partition;

(c) superimposed loads and vibrations by external effects.

5.2 Corrosion allowance

The enclosures are filled in service with a non-corrosive thoroughly dried gas, therefore no internal corrosion allowance is necessary.

5.3 Design stresses

Design stresses can be established either by calculation or proof tests, see **9.1**.

The permissible design stress (f_a) at the design pressure including the safety factor of the appropriate equations is given by:

$$f_a = \frac{R_m}{3{,}5} \times CF$$

where

R_m : minimum tensile strength of the material at the design temperature taken from the material standard for the chosen alloy.

3,5 : safety factor.

CF : casting factor which makes allowance for the reduction in properties achieved in the casting. The casting factor has a value of 0,8.

The calculation may be based on higher values of tensile strength and casting factor, if the values are guaranteed by a material certification (see **6.5**).

When the strength of the enclosure or part thereof has not been determined by calculation, proof tests shall be made in order to demonstrate that the permissible design stress is not exceeded at the design pressure (see **9.1**).

5.4 Calculation methods

5.4.1 *General.* When the wall and flange thicknesses of the enclosure are calculated the permissible design stress shall be taken from **5.3** and the equations from established specifications such as:

AD – Merkblätter
ANCC VSR
ASME Section VIII
BS
CODAP
ISO
Netherlands Rules for P.V.
SVDB
Swedish P.V. Code

using the design pressure and the design temperature as defined in **3.6** and **3.7**.

The equations in the specifications are equivalent to each other, the choice is left to the manufacturer.

NOTE. Pressure stresses due to an internal electrical fault are not considered in the design of an enclosure since after such an occurrence, the enclosure would be carefully checked and, if necessary, replaced.

For the case of arcing due to an internal fault, reference is made to IEC Publication 517.

5.4.2 *Flanges.* The design of flange connections (see figure 1, flange A or B) shall be based on the following:

the number of bolts shall be chosen to ensure a plane support surface,

the distance *a* between bolt and gasket should be as small as possible.

the radius *R* between the flange and the cylindrical neck shall be as large as possible.

If flange connections have been proven sound in the bursting test of the enclosure no calculation of the flanges is necessary.

5.4.3 *Bolts.* Bolted connections can be designed in accordance with ISO 898 or established specifications (see **5.4.1**) taking into consideration the design pressure and the sealing forces of gaskets, if necessary. O-ring sealing forces may be neglected in relation to the flange forces.

The mechanical properties of the bolted connections are in accordance with ISO 898. The material of bolts should not exceed a ratio of

$$R_e/R_m = 0{,}8$$

where

R_m : minimum tensile strength

R_e : minimum yield strength

Where the design requires the use of high strength bolts, they shall be appropriately marked.

If bolted connections have been proven sound in the bursting test of the enclosure no calculation of the bolts is necessary.

5.5 Manholes and inspection openings

No manholes or inspection openings are necessary for inspection of the enclosure.

6 Manufacture and workmanship

6.1 Manufacture

Castings can be made by introducing molten metal by gravity or low pressure into:

sand moulds,

semi-permanent metallic moulds with sand cores,

permanent metallic moulds

and allowing it to solidify.

In order to obtain specific mechanical properties, the castings can then be heat treated following which they can be machined, if required.

The castings can receive, in part or in their entirety, special surface treatments such as anodizing, chemical oxidization, electroplating or hot blast metal plating.

6.2 Consultation between manufacturer and founder

It is strongly advised that the manufacturer, having defined the necessary geometry and thickness of the casting, shall obtain the founder's and pattern maker's agreement to the design prior to casting to enable sound castings to be produced consistently, having the required mechanical properties.

6.3 Foundry technique

For each enclosure design the founder shall record the essential particularities of the foundry technique such as the position of runners, risers, dead heads, chills, mould lines, the mould material and mould temperature, and the attitude of the mould when pouring the metal. This record shall also include the metal pouring temperature and subsequent heat treatment process.

All subsequent production castings shall be made by the same foundry technique and under the same conditions, without significant deviation.

If, for any reason, the foundry technique needs to be altered, production shall not proceed without the permission of the manufacturer.

6.4 Geometry and dimensions

The geometry and dimensions of the casting shall be defined by:

- the manufacturer's drawings, when the founder is required to make the pattern or permanent mould, or
- the pattern or the permanent mould when these are provided by the manufacturer, or
- the accepted sample casting when mass production methods are employed.

Tolerances on dimensions shall be agreed between manufacturer and founder and recorded on the approved drawings.

The castings shall be capable of being machined, when provided in the drawing, to the finished dimensions without leaving evidence of the cast surface. Drawings shall indicate the datum points to be used for machining or jigging.

6.5 Chemical composition and mechanical properties

6.5.1 *Sampling.* In order to provide a control on the quality of normal production, samples shall be taken from each melt and production batch of castings.

6.5.2 *Chemical composition.* To permit determination of the chemical composition of each casting, a sample or samples shall be taken from each melt which, without any further additions, is used to make castings. The sample shall be suitably marked to ensure identification with the castings it represents.

The chemical composition of the sample or samples shall meet the material specification.

6.5.3 *Mechanical properties.* As a control check on the mechanical properties and heat treatment operations, separately cast test bars in accordance with the dimensions given in the material specification shall be made for each melt. Where a number of castings are made from one melt and undergo separate heat treatment, test bars shall be made for each heat treatment batch. The test bars shall be suitably marked to ensure identification with the batch of castings they represent.

The separately cast test bars shall be heat treated with the casting or batch of castings they represent.

The mechanical properties of the test bars representing each casting or batch of castings shall meet the requirements of the material specification.

6.6 Workmanship

6.6.1 *Surface finish.* The castings shall be suitably cleaned. Runners, risers, dead heads and chills shall be removed without reducing the strength of the casting.

The surfaces of the castings which are not to be machined shall be equal to a surface finish which is agreed on the sample casting.

6.6.2 *Soundness.* The castings shall be uniform in composition and shall be free from injurious defects.

The acceptable limits for the extent and frequency of defects shall be as defined in clause **7**.

Defects may be repaired only by processes in accordance with clause **7**, which have been agreed between manufacturer and founder.

7 Repair of casting defects

7.1 General

Castings may be repaired only by processes approved and agreed upon by founder and manufacturer.

Limitations on the location, extent and frequency of such repairs and methods of inspection of repaired areas shall also be agreed upon.

Surface irregularities caused by locally broken down moulding sand or fettling damage which does not affect the strength of the casting may be repaired after agreement has been obtained between the manufacturer and the founder. After such repairs, visual examination is sufficient and the requirements of **7.2.6** can be disregarded.

This clause shall also apply to the filling of core support apertures.

7.2 Repair by welding

7.2.1 *Welding performance test.* All welders engaged in the repair of cast enclosures in accordance with this standard shall pass welder performance tests which are designed to demonstrate their competence to make sound welds on the same material composition as the casting to be repaired (see annex A).

If there is any reason to doubt the welder's ability to make satisfactory weld repairs, the manufacturer can, at his discretion, require the welder to retake the whole or part of the approval test.

7.2.2 *Weld procedure.* A written weld instruction shall be produced for each specified method of weld repair which shall state:

(a) parent metal specification

(b) welding process

(c) method of excavation of defective material

NOTE. Excavation by the use of flame is not permitted.

(d) electrode size and type

(e) shielding gas and flow rate

(f) filler material and diameter

(g) power source (a.c./d.c.), its frequency/polarity and current

(h) welding position

(i) pre-heating, temperature and method

(j) post-weld heat treatment

7.2.3 *Weld procedure test.* The test piece representing the weld procedure to be approved shall satisfy the assessment requirements in annex A.

If the test piece fails to satisfy the visual inspection and dye penetrant examination requirements given in annex A, one further test piece shall be welded and subjected to the same test.

If any specimen fails to satisfy the macro examination and strength requirements given in annex A, two further test specimens for each one that failed shall be prepared and subjected to the same test. These new test specimens are obtained either from the same test piece, if there is sufficient material available, or from a new test piece.

If either of these additional test specimens or the new test piece do not meet the required quality, the weld procedure shall be regarded as incapable of meeting the requirements of this standard without modification.

7.2.4 *Application to castings.* The decision to repair by welding shall be taken on the basis of visual inspection and/or radiographic examination of the casting.

The limits given below are for guidance only, the ultimate responsibility rests with the manufacturer.

These limits apply to defects in the shell. Repairs should not be permitted in the highly stressed zones in the flange inside the pitch circle of the bolts.

NOTE 1. Definitions of the defects comply with 'Gussfehler Atlas' (Atlas of casting defects) Giesserei-Verlag GmbH, Düsseldorf 1971.

NOTE 2. Reference Standard ASTM E 155 'Standard reference radiographs for inspection of aluminium and magnesium castings' is used to grade defects.

(a) *Blow holes* — Gussfehler Atlas No. B121 and No. B111. Weld repairs are permitted if the extent of the blow holes on the surface is smaller than 20 mm x 10 mm.

(b) *Cold shut* — Gussfehler Atlas No. C311. When cold shut is observed, radiographs shall be taken.

Weld repairs are permitted if the extent of the defect on the surface is not longer than 300 mm or not deeper than 3 mm. Internal cold shut is not acceptable. In this case weld repairs are not permitted.

(c) *Oxide inclusions* — Gussfehler Atlas No. G142. When oxide inclusions are observed, radiographs shall be taken. These defects may be repaired according to the following criteria*:

Wall thickness	Defect area size	Type of inclusions ASTM standard	Maximum number of inclusions per defect area	Maximum number of defect areas
mm	mm			
⩽ 12	100 x 100	Less dense	6	4
> 12	150 x 150	Less dense	8	2

(d) *Cracks* — Gussfehler Atlas No. C221 and No. C222. Cracks are not acceptable. Weld repairs are not permitted.

(e) *Tungsten Inclusions after Welding* — Gussfehler Atlas No. G111. When tungsten inclusions are observed on radiographs of welded areas, these may be repaired according to the following criteria*:

Wall thickness	Type of inclusions ASTM standard	Maximum number of inclusions
mm		
⩽ 12	More dense	4
> 12	More dense	4

(f) *Blackening defects, treatment defects.* These defects are limited in their extent and do not affect the adjacent material. Weld repairs are permitted in all cases.

7.2.5 *Preparation of castings for weld repairs.* Fusion faces prepared for weld repairs are visually examined; if in addition non-destructive testing is specified these faces shall be examined by a dye or fluorescent penetrant check. Particular care shall be taken to ensure that residues from testing materials do not have a deleterious effect on the quality of any subsequent welding.

7.2.6 *Inspection of weld repair areas.* After completion of the weld repair, the repaired areas shall be radiographed to ensure no evidence of the original defect is present and that the weld repair has been executed in such a manner as to give satisfactory bonding and freedom from harmful defects. A dye penetrant check shall be performed on the surface of the repaired areas to ensure freedom from cracks.

All castings subjected to weld repairs shall be heat treated in accordance with the material specification after weld repair.

Enclosures which have been repaired subsequent to the routine pressure test shall be retested after completion of the weld repairs and after any heat treatment.

Relevant certificates for repaired castings shall record the position and extent of the repaired areas and the procedure used.

7.3 Impregnation of castings

Castings which show slight leakage on pressure or gas leakage tests may be rectified by impregnation after agreement has been obtained from the manufacturer.

The process shall only be applied after the casting has been inspected for freedom from other defects, in particular cracks.

The process used shall be agreed between the manufacturer and the founder regarding its suitability for the application.

A gas leakage test shall be carried out after impregnation.

*The tables are for guidance only. The maximum size of the defects which can be repaired is to be determined by the founder and the manufacturer and depends upon the repair technique available.