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BSI Standards Publication

# High-voltage switchgear and controlgear — Gas-filled cast aluminium alloy enclosures

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**National foreword**

This British Standard is the UK implementation of EN 50052:2016. It supersedes BS 6878:1988+A2:1993 which is withdrawn.

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**EN 50052**

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English Version

# High-voltage switchgear and controlgear - Gas-filled cast aluminium alloy enclosures

Enveloppes moulées en alliage d'aluminium pour les appareillages à haute tension sous pression de gaz

Hochspannungs-Schaltgeräte und -Schaltanlagen - Gasgefüllte Kapselungen aus Leichtmetallguss

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European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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# Contents

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# European foreword

This document (EN 50052:2016) has been prepared by CLC/TC 17AC "High-voltage switchgear and controlgear".

The following dates are fixed:

| | | |
|---|---|---|
| • latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2017-09-12 |
| • latest date by which the national standards conflicting with this document have to be withdrawn | (dow) | 2019-09-12 |

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 50052:1986.

This European Standard supplements the relevant product standards on gas-insulated switchgear and controlgear in that it provides specific requirements for pressurized high-voltage switchgear and controlgear.

This European Standard has been written to get a European specification for the design, construction, testing, inspection and certification of pressurized enclosures used in high-voltage switchgear and controlgear.

In this respect, this European Standard constitutes the exclusion of HV switchgear from the scope of the Directive 2014/68/EU (superseding 97/23/EC) concerning pressure equipment. Article 1, 2. (l) excludes "enclosures for high-voltage electrical equipment such as switchgear, controlgear, transformers, and rotating machines" from the scope of the Directive.

This European Standard deals with gas-insulated switchgear enclosures of cast aluminium alloy. For different enclosure materials other European Standards are available.

# 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 requirements.

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

(c) As the thorough drying of the inert, non-corrosive gas medium is fundamental to the satisfactory operation of the electrical equipment, the gas 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.

Due to the foregoing reasons and to ensure maximum service continuity as well as to reduce the risk of moisture and dust entering the enclosures which may endanger safe electrical operation of the switchgear, no pressure tests should be carried out after installation and before placing in service and no periodic inspection of the enclosure interiors or pressure tests should be carried out after the equipment is placed in service.

# 1 General

## 1.1 Scope

This European 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 above 1 kV, where the gas is used principally for its dielectric and/or arc-quenching properties with rated voltages

- above 1 kV and up to and including 52 kV and with gas-filled enclosures with design pressure higher than 300 kPa relative pressure (gauge);
- and with rated voltage above 52 kV.

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
- etc.

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

## 1.2 Normative references

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

EN 10204, *Metallic products — Types of inspection documents*

EN 12258-1:2012, *Aluminium and aluminium alloys — Terms and definitions — Part 1: General terms*

EN 50064, *Wrought aluminium and aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear*

EN 62271-1:2008, *High-voltage switchgear and controlgear — Part 1 Common specifications (IEC 62271-1:2007)*

EN 62271-203:2012, *High-voltage switchgear and controlgear — Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV (IEC 62271-203:2011)*

EN ISO 898 (series), *Mechanical properties of fasteners made of carbon steel and alloy steel*

EN ISO 6520-1:2007, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding (ISO 6520-1:2007)*

EN ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel (ISO 9712)*

EN ISO 15614-4, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 4: Finishing welding of aluminium castings (ISO 15614-4)*

### 1.3 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 the 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 the 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 of this standard are satisfied.

## 2 Normal and special service conditions

Clause 2 of EN 62271-1:2008 is applicable.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**3.1**
**enclosure**
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

**3.2**
**manufacturer**
organisation that is responsible for the design of the enclosure and the production of the gas-insulated switchgear. In this standard this is the switchgear manufacturer

**3.3**
**founder**
organisation that produces the raw casting of the enclosure

**3.4**
**design pressure**
pressure, expressed in relative terms (gauge), used to determine the thickness of the enclosure

Note 1 to entry: It is at least equal to the maximum pressure in the enclosure at the highest temperature that the gas used for insulation can reach under specified maximum service conditions.

**3.5**
**design temperature (of an enclosure)**
maximum temperature that the enclosures can reach under specified maximum service conditions

[SOURCE: 3.112, EN 62271-203:2012]

Note 1 to entry: This is generally the upper limit of ambient air temperature increased by the temperature rise due to the flow of rated normal current.

Note 2 to entry: 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 materials. Similarly, the effects of low temperatures on the properties of materials should be considered.

**3.6**
**design stress**
maximum permissible stress on the enclosure imposed by conditions of operation, environment or test that determine the (material) characteristics of an enclosure

**3.7**
**normal load**
load whose occurrence and level can be planned or predicted

**3.8**
**exceptional load**
load whose probability of occurrence during the lifetime of product is very small or accidental

**3.9**
**casting**
product at or near finished shape, formed by solidification of the metal in a mould or a die

[SOURCE: EN 12258-1:2012, 2.5.1]

**3.10**
**melt**
quantity of molten metal that has simultaneously undergone the same preparatory treatment in the furnace before the casting operation

[SOURCE: EN 12258-1:2012, 4.1.3]

**3.11**
**alloy**
substance having metallic properties and composed of two or more elements so combined that they cannot readily be separated by physical means

[SOURCE: EN 12258-1:2012, 2.2.1]

**3.12**
**casting defect**
imperfections in castings after solidification

**3.12.1**
**cold shut**
linear discontinuity in a cast surface caused by freezing of the melt meniscus in contact with the mould and the liquid metal flowing over the solidified metal

[SOURCE: EN 12258-1:2012, 5.2.1]

**3.12.2**
**cold crack**
crack in cast metal initiated by mechanical stresses at temperatures significantly below the solidus temperature

[SOURCE: EN 12258-1:2012, 5.2.9]

**3.12.3**
**hot crack (hot tear)**
crack formed in a cast metal or in a welding because of internal stress developed upon cooling at the solidus temperature or slightly above

[SOURCE: EN 12258-1:2012, 5.2.8]

**3.12.4**
**inclusion**
extraneous material accidentally entrapped into the liquid metal during melting or melt treatment or entrapped into the metal surface during hot or cold working

[SOURCE: EN 12258-1:2012, 5.5.7]

**3.12.5**
**blister**
raised spot whose inside is hollow, that forms on the surface of products and is caused by the penetration of a gas into a subsurface zone typically during thermal treatment

[SOURCE: EN 12258-1:2012, 5.5.10]

Note 1 to entry: A void resulting from blister that has ruptured is often termed “blow hole”.

**3.13**
**weld defect**
imperfections in metallic fusion welds

**3.13.1**
**lack of fusion**
lack of union between the weld metal and the parent material or between the successive layers of weld metal

[SOURCE: EN ISO 6520-1:2007, Reference No. 401]

**3.13.2**
**overlap**
excessive weld metal covering the parent material surface but not fused to it

[SOURCE: EN ISO 6520-1:2007, Reference No. 506]

**3.13.3**
**undercut**
irregular groove at a toe of a run in the parent material or in previously deposited weld metal

[SOURCE: EN ISO 6520-1:2007, Reference No. 501]

**3.14**
**thermal treatment**
heating, holding at elevated temperature and cooling of the solid metal in such a way as to obtain desired metallurgical structure or properties

[SOURCE: EN 12258-1:2012, 3.6.1]

Note 1 to entry: The term “heat treatment” is used for the same concept as a synonym.

**3.15**
**ductility**
ability of a material to deform plastically before fracturing

[SOURCE: EN 12258-1:2012, 4.3.15]

**3.16**
**fatigue**
tendency for a metal to break under conditions of repeated cyclic stressing considerably below the tensile strength

[SOURCE: EN 12258-1:2012, 4.3.23]

**3.17**
**tensile strength**
ratio of maximum load before rupture in a tensile test to original cross-sectional area

[SOURCE: EN 12258-1:2012, 4.3.3]

**3.18**
**yield stress**
stress necessary to produce a defined small plastic deformation in a material under uniaxial tensile or compressive load

[SOURCE: EN 12258-1:2012, 4.3.4, modified]

**3.19**
**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

**3.20**
**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.

**Table 1 — List of recommended cast aluminium alloys [1]**

| | | | | | | |
|---|---|---|---|---|---|---|
| Europe | EN 1706 | Alloy | EN AC-AlSi7Mg0.3 | EN AC-AlSi9Mg | EN AC-AlSi10Mg(a) | EN AC-AlSi12(a) |
| | | Coding | EN AC - 42100 | EN AC - 43300 | EN AC - 43000 | EN AC - 44200 |
| International | ISO 3522 | Alloy | AlSi7Mg0.3 | AlSi9Mg | AlSi10Mg | AlSi12(a) |
| USA | Register Record | Coding | A356.0 | | | B413.0 |
| China | GB/T 1173 | Alloy | ZAlSi7MgA | | ZALSi9Mg | |
| | | Coding | ZL 101A | | ZL 104 | |
| India | IS 202, IS 617 | Coding | 4458 | | 4535 | 4700 |
| Japan | JIS H5202 | Alloy | AC4CH | | Al-Si10Mg | Al-Si12 |
| Canada | CSA.HA.3 | Alloy | SG70N (old) | | SC84 (old) | Sn12 (old) |
| Australia | AS 1874 | Coding | AA601 | | | CA401 |
| Russia | GOST 1583 (old : GOST 2685) | Coding | AL9–1 (old) | AL4–1 (old) | AL4 (old) | AL2 (old) |

These alloys are recommended because of their low content of copper and zinc (lower than 0,5 % each) as well as their low content of magnesium (lower than 0,7 %).

Alloys listed in this table are similar but not identical regarding chemical composition and mechanical properties. They are not interchangeable without a re-qualification of the enclosure; i.e. re-calculation or re-testing.

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

For applications where specified temperatures exceed 100 °C heat treated materials are not permitted due to the loss of material properties, i.e. the thermal treatment will be nullified.

## 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 may 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 of the range of aluminium-magnesium alloys. Alloys with magnesium content above 0,7 % 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. If necessary, aluminium enclosures should be protected 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.

It should be noted that contact with certain gasket materials 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 (refer to Introduction) which distinguish them from compressed air receivers and similar storage vessels. Examples of such enclosures are listed in Clause 1.

As part of the validation process of the enclosure the mechanical strength of an enclosure shall be proven by a type test according to 9.1.

An enclosure can be designed by two alternative methods:

- Design by Formulae (DbF)
- Design by Analysis (DbA)

The geometry of an enclosure is determined by electrical rather than mechanical considerations. Moreover, constraints in shape can be enforced by the casting process used. These constraints can result in an enclosure geometry which cannot be calculated by DbF. In such cases DbA shall be applied.

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

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

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

c) superimposed loads and vibrations by external effects e.g. as they are caused by thermal or seismic effects.

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

## 5.2 Calculation Methods

### 5.2.1 General

This part provides calculation rules, design stresses and boundary conditions for the design of enclosures. In 5.2.4 and 5.2.5 boundary conditions for the design of flanges and bolts are given. For the design of the casted enclosure itself two methods may be used to proof appropriate design stress: the Design by Formula given in 5.2.2 and the Design by Analysis given in 5.2.3.

### 5.2.2 Evaluation of mechanical strength using "Design by Formula"

When the wall and flange thicknesses of the enclosure are calculated, the formulas from established specifications such as the following codes shall be taken, using the design pressure and the design temperature as defined in 3.4 and 3.5:

| | |
|---|---|
| AD 2000 Regelwerk | [2] |
| ASME Code | [3] |
| CODAP | [4] |
| Raccolta VSR | [5] |
| SVTI | [6] |
| EN 13445 | |

The formulas in the specifications are equivalent to each other; the choice is left to the manufacturer.

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

$$f_d = \frac{R_m}{3{,}5} \cdot CF$$

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 covers deviations of the material properties caused by the casting process; 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 (refer to 6.5).

### 5.2.3 Evaluation of mechanical strength using "Design by Analysis"

#### 5.2.3.1 Normal loads

The design stress ($f_{d\_n}$) for normal loads is given by:

$$f_{d\_n} = \frac{R_m}{S_n} \cdot CF$$

where

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

$S_n$: safety factor for normal loads $S_n = 2{,}0$

CF: casting factor covers deviations of the material properties caused by the casting process; 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 (refer to 6.5).

Examples for normal loads:

- gas pressure
- temperature (ambient, current)
- dead load
- erection load
- ice and/or wind
- tension loads (cable, overhead lines)

Combinations of different loads shall reflect the operating conditions on site. Load combinations do not change the overall safety factor.

#### 5.2.3.2 Exceptional loads

The design stress ($f_{d\_e}$) for exceptional loads is given by:

$$f_{d\_e} = \frac{R_m}{S_e} \cdot CF$$

where

| | |
|---|---|
| $R_m$: | minimum tensile strength of the material at the design temperature taken from the material standard for the chosen alloy |
| $S_e$: | safety factor for exceptional loads $S_e$ = 1,05 |
| CF: | casting factor covers deviations of the material properties caused by the casting process; the casting factor has a value of 0,8 |

Examples for exceptional loads:

- earthquakes
- extreme wind and/or extreme ice
- short-circuit tensile loads (overhead lines, cable)

Combinations of different loads shall reflect the operating conditions on site. Load combinations do not change the overall safety factor.

Exceptional loads can be combined with normal loads depending on the operating conditions on site, but they should not be combined.

### 5.2.4 Flanges

The design of flange connections (refer to 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 shall be as small as technically feasible.
- the radius *R* between the flange and the cylindrical neck shall be as large as technically feasible.

If flange connections successfully passed the bursting test of the enclosure, no calculation of the permissible design stresses for the flanges is necessary.

#### 5.2.5 Bolted connections

Bolted connections shall be designed in accordance with EN 50064 or established specifications (refer to 5.2.2) taking into consideration the design pressure and the sealing forces of gaskets, if necessary.

NOTE O-ring sealing forces may be neglected in relation to the flange forces.

The mechanical properties of the nuts and bolts are in accordance with EN ISO 898- series. The material strength of bolts should not exceed a ratio of

$R_e / R_m = 0,8$

where

$R_m$: minimum tensile strength

$R_e$: minimum yield stress

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

If bolted connections successfully passed the bursting test of the enclosure, no calculation of the strength of bolts is necessary.

### 5.3 Inspection and access openings

No access 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 may be thermally treated and afterwards machined, if required. If thermal treatment is applied it shall be ensured that operating temperatures are below 100 °C; otherwise the improvement of mechanical properties will be lost.

The castings may 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 thermal treatment process.

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

If the foundry technique needs to be altered, the manufacturer shall be informed and if the change is accepted by the manufacturer, the bursting test shall be repeated.

NOTE If the manufacturer changes the founder, it is considered to be a change of the foundry technique. If there are several founders, each has to be qualified by a bursting test of a casting.

## 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.

On machined surfaces residues of raw casting surface are not permitted. 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 production, samples shall be taken from each melt and production batch of castings. For continuous melting process a maximum of 2 t is considered as a melt and production batch.

### 6.5.2 Chemical composition

To permit determination of the chemical composition of each casting, one or more 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 thermal 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 thermal treatment, test bars shall be made for each thermal 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 thermally 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 between manufacturer and founder on the sample casting.

### 6.6.2 Soundness

The castings shall be uniform in composition and shall be free from defects which have a negative impact on its mechanical properties.

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 involved in the repair of cast enclosures in accordance with this standard shall pass welder performance tests according to EN ISO 15614-4 which are intended to demonstrate their competence to make sound welds on the same material composition as the casting to be repaired.

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 repeat 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; however, the 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 thermal treatment

### 7.2.3 Weld procedure test

The test piece representing the weld procedure to be approved shall satisfy the assessment requirements in EN ISO 15614-4.

### 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 Reference Standard ASTM E 155–10 [7] 'Standard reference radiographs for inspection of aluminium and magnesium castings' is used to grade defects.

a) Blisters
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
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 and not deeper than 3 mm.

Internal cold shut is not acceptable. In this case weld repairs are not permitted.

c) Oxide inclusions
If oxide inclusions are observed, radiographs shall be taken. These defects may be repaired according to the following criteria[1]:

**Table 2 — Permissible oxide inclusions**

| Wall thickness<br>mm | Defect area size<br>mm | Type of inclusions ASTM standard [7] | Maximum number of inclusions per defect area | Maximum number of defect areas |
|---|---|---|---|---|
| ≤ 12 | 100 × 100 | Less dense | 6 | 4 |
| > 12 | 150 × 150 | Less dense | 8 | 2 |

d) Cracks
Cracks are not acceptable. Weld repairs are not permitted.

e) Tungsten Inclusions after Welding - When tungsten inclusions are observed on radiographs of welded areas, these may be repaired according to the following criteria:

**Table 3 — Permissible tungsten inclusions**

| Wall thickness<br>mm | Type of inclusions ASTM standard [7] | Maximum number of inclusions |
|---|---|---|
| ≤ 12 | More dense | 4 |
| > 12 | More dense | 4 |

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.

[1] 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.

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 that 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 test 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 thermal 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

Impregnation of castings is not permitted.

NOTE: Service experience revealed that impregnation is not long term gas-tight.

## 8 Thermal treatment

### 8.1 Thermal treatment procedure

The thermal treatment shall be carried out in accordance with a documented procedure.

### 8.2 Methods of heating

Cast aluminium alloys are usually heated in air chamber furnaces. Other methods can be used, however, in specific applications.

Whichever heating means are employed, careful evaluation is required to ensure that the alloy responds properly to the thermal treatment and is not damaged by overheating or contamination from the environment.

Thermal treatment furnaces can be oil or gas-fired or electrically heated. The temperature of the air enclosed in the furnace shall be controlled to prevent high temperature oxidization during thermal treatment.

The furnaces shall be fitted with automatic temperature recording and control equipment capable of maintaining the specified temperature in the working zone within a tolerance of ± 5 °C.

### 8.3 Quenching

Quenching of cast aluminium alloys is normally performed by immersion in water. The baths shall be located close enough to the thermal treatment furnace to minimize the delay in quenching. The quench delay time shall not exceed 40 s.

### 8.4 Calibration of furnace temperature

A temperature survey to ensure compliance with the requirements of this standard shall be performed for each furnace.

A new temperature survey shall be carried out after any change in the furnace which can affect the operational characteristics.

### 8.5 Thermal treatment charts

For castings to be subjected to thermal treatment, charts shall be provided to record the temperature for the full duration of the thermal treatment cycle. The serial numbers of the enclosures treated shall be included on the charts.

# 9 Inspection, testing and certification

## 9.1 Type tests

### 9.1.1 General

For all designs of castings which are not calculated, or where doubt exists regarding the accuracy of the calculations and where having been calculated the predicted stress at the routine pressure test will exceed 90 % of the 0,2 % proof stress of the material in the enclosure, a type test shall be carried out on one casting.

One of the following type tests is applicable:

a) Burst test

b) Strain measurement test

The type test may be used for the purpose of establishing the design pressure of enclosures or enclosure parts provided that only the design rules given in this standard. The design pressure of all other parts shall be determined by means of the applicable design rules.

### 9.1.2 Burst test procedure

Enclosures shall be type tested by a bursting test. Any casting surviving this test shall be scrapped.

The minimum burst pressure calculates as follows:

$$B = \frac{p}{CF \cdot TF} \cdot 3{,}5$$

where

| | |
|---|---|
| *B* | minimum burst pressure |
| *p* | design pressure |
| 3,5 | safety factor |
| CF | casting factor, CF = 0,8 |
| TF | test factor, TF = 0,875 |

NOTE The casting factor (CF) covers the possible variability in the production of castings, the test factor covers potential tolerances in the pressure test.

The design pressure (*p*) for which an enclosure meets the requirements of this standard can be calculated by this formula.

### 9.1.3 Strain measurement test

In the case of a non-destructive pressure test using a strain indication technique, the following procedure shall be applied:

Before the test, strain gauges capable of indicating strains to 5 × 10–5 mm/mm shall be affixed to the surface of the enclosure. The number of gauges, their position and their direction shall be chosen so that principal strains and stresses can be determined at all points of importance for the integrity of the enclosure.

Hydrostatic pressure shall be applied gradually in steps of approximately 10 % until the routine test pressure for the expected design pressure is reached or significant yielding of any part of the enclosure occurs.

When either of these points is reached, the pressure shall not be increased further.

Strain readings shall be taken during the increase of pressure and repeated during pressure decrease.

Indication of localized permanent set may be disregarded provided there is no evidence of general distortion of the enclosure.

If the curve of the strain/pressure relationship show a nonlinearity, the pressure may be reapplied not more than five times until the loading and unloading curves corresponding to two successive cycles substantially coincide. If coincidence is not attained, the design pressure and the test pressure shall be taken from the pressure range corresponding to the linear portion of the curve obtained during the final unloading.

If the routine test pressure is reached within the linear portion of the strain/pressure relationship, the expected design pressure shall be considered to be confirmed.

If the final test pressure or the pressure range corresponding to the linear portion of the strain/pressure relationship (see above) is less than the routine test pressure, the design pressure shall be calculated from the following equation:

$$p = \frac{1}{1{,}1k} \cdot \left( p_y \cdot \frac{\sigma_a}{\sigma_t} \right)$$

where

$p$ is the design pressure;

$p_y$ is the pressure at which significant yielding occurs or the pressure range corresponding to the linear portion of the strain/pressure relationship of the most highly strained part of the enclosure during final unloading (see above);

$k$ is the routine test pressure factor, for cast aluminium enclosures k = 2;

$\sigma_t$ is the permissible design stress at test temperature;

$\sigma_a$ is the permissible design stress at design temperature.

## 9.2 Inspection and routine tests

### 9.2.1 General

Any casting can be rejected for defects, whether discovered during inspection or subsequently during machining, notwithstanding that the casting has been passed previously as conforming to the chemical composition and mechanical test requirements of the material specification.

Qualification of NDT personnel shall be in accordance with Level 2 of EN ISO 9712.

### 9.2.2 Visual inspection

A visual inspection shall be made of all internal and external surfaces. Where any doubt exists, dye penetrant or radiographic examination of the suspect area shall be made.

Reports of visual inspection shall be provided.

### 9.2.3 Dye penetrant examination

Dye penetrant examination is required in cases of doubt arising from visual inspection.

### 9.2.4 Radiographic examination

Radiographic examination is required:

a) in case of doubt arising from visual inspection of production castings,

b) to establish the type and extent of defects as to the possibility of a weld repair,

c) to determine the quality of weld repairs.

### 9.2.5 Ultrasonic examination

Ultrasonic examination can be used as an alternative to radiography.

#### 9.2.6 Reporting of non-destructive test examinations

The following information shall be given on reports:

a) the dates of the examination and the issue of the report,

b) identification of the enclosure,

c) description and location of all defects, together with records,

d) test method applied.

#### 9.2.7 Routine pressure test

Pressure tests shall be made on enclosures after complete machining.

The routine test pressure shall be *k* times the design pressure, where the factor $k = 2$ for cast aluminium enclosures.

The test pressure shall be maintained for at least 1 min.

No rupture or permanent deformation shall occur during this test.

#### 9.2.8 Tightness test

If the enclosure is intended to be filled with an insulating gas that has environmental impact, the enclosure shall be subject to a tightness test. For $SF_6$-insulated switchgear reference is made to EN 62271-203.

### 9.3 Certification

#### 9.3.1 Design specification, drawings and data sheets

The founder or manufacturer shall maintain a technical file of all data and foundry techniques supporting the type test (refer to 9.1). This file shall be kept available for a period of not less than 10 years from the date of completion of the enclosure.

#### 9.3.2 Certificate

The manufacturer shall issue a certificate stating that all castings have been designed, cast and tested in accordance with this standard.

The founder shall issue at least a 3.1 inspection certificate according to EN 10204.

#### 9.3.3 Stamping

Each enclosure shall be stamped by visible marking in an area where operating stresses are low, e.g. on the outside edge of a flange, or on a permanently attached nameplate to indicate that it has passed the routine pressure test.

#### 9.3.4 Final inspection of castings

An internal and external inspection of the completed enclosures shall be carried out prior to despatch, and the certificates and stamping on the, enclosure shall be checked.

## 10 Pressure relief devices

### 10.1 General

If necessary, enclosures within the scope of this standard shall be provided with protective devices which can be one of the following:

a) bursting discs

b) self-closing valves

c) non-self-closing devices

The protective devices should be constructed, located and installed so that they are accessible for inspection and repair. They should be protected against accidental damage.

The devices need not be installed directly on the enclosure, but the discharge areas and any connecting ports to or within the enclosure shall be of adequate size to permit effective relief in the event of overpressure.

Pressure relief devices shall be arranged so as to minimize the danger to an operator during the time he is performing his normal operating duties, if gases or vapours are escaping under pressure.

Pressure relief devices may be connected to the enclosure or in the gas supply lines of gas-filling plant.

In the case of devices fitted to enclosures connected to an external source of pressure and devices fitted in gas supply lines of gas-filling plant, they shall be designed to limit overpressure to 1,1 times the design pressure.

Each device shall be marked with its nominal opening pressure.

It might be considered necessary to design the pressure relief device in order to limit the pressure rise in the event of an internal fault.

NOTE : For internal arc faults reference is made to EN 62271–203.

## 10.2 Bursting discs

Bursting discs can be manufactured from brittle or ductile materials.

The rupture pressure of the bursting disc should be chosen to ensure long service without premature bursting.

## 10.3 Self-closing pressure relief valves

Self-closing pressure relief valves shall be of the direct spring loaded type.

## 10.4 Non-self-closing pressure relief devices

Non-self-closing pressure relief devices which operate by the 'breaking bolt' system may be used.

NOTE The breaking bolt system pressure relief device is one whereby a diaphragm being secured by a bolt or bolts relieves pressure by fracture or bending of the bolt or bolts, the diaphragm being restrained after venting by other bolts or a cover.

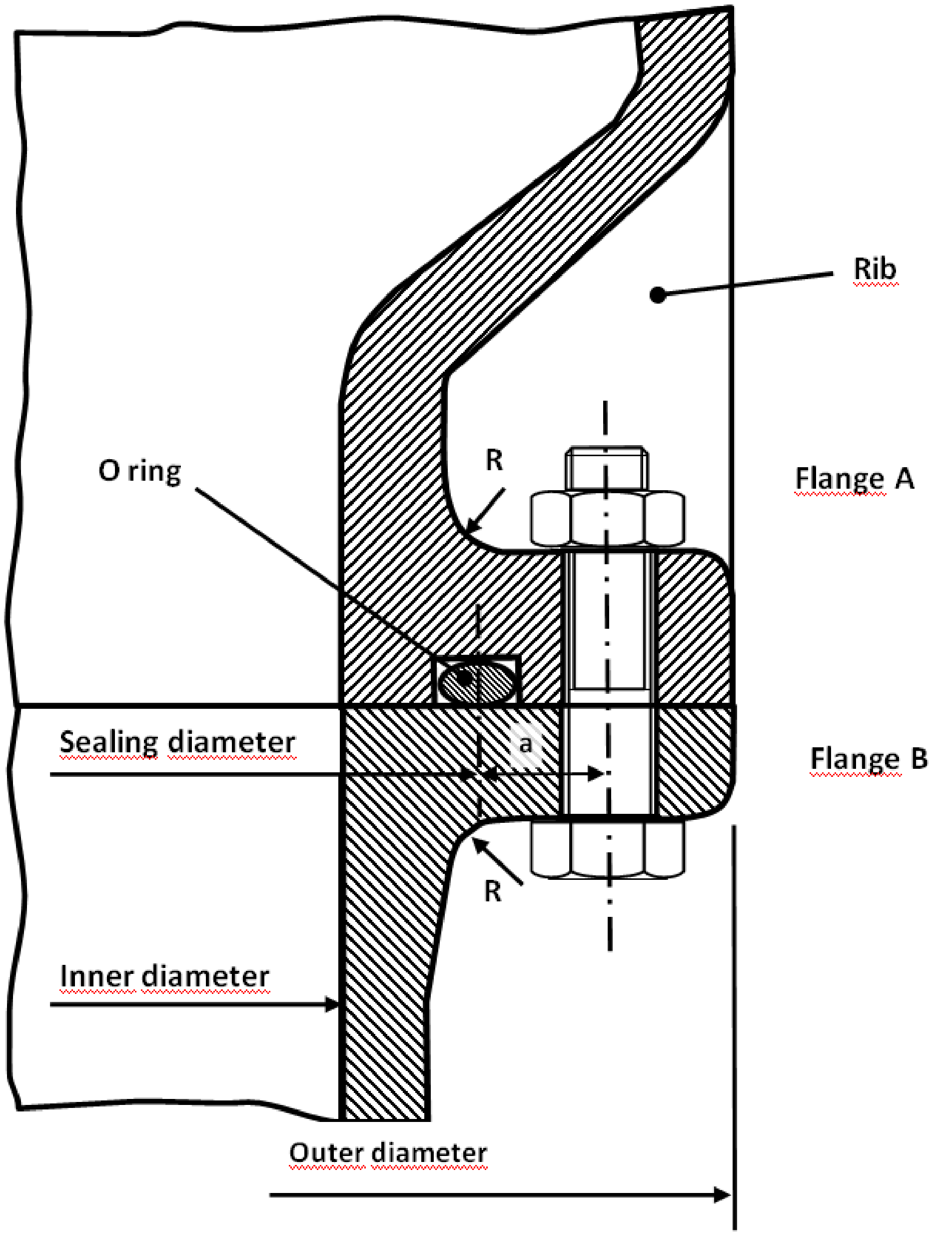


**Figure 1 — Flange connections**

# Annex A
(informative)

# A-deviations

A-deviations: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN-CENELEC national member.

This European Standard does not fall under any Directive of the EU.

In the relevant CEN-CENELEC countries these A-deviations are valid instead of the provisions of the European Standard until they have been removed.

| Clause | Deviation |
|---|---|
| **Italy** | |
| Introduction (last paragraph) | (CAPITOLO VSR 8.B D.M. 1 DICEMBRE 1980 e succ. modifiche)<br>Disciplina dei contenitori a pressione di gas con membrature miste di materiale isolante e di materiale metallico, contenenti parti attive di apparecchiature elettriche.<br>A routine test at 1,1 the design pressure is required on the complete assembly. The test can be performed in the factory or at site. |
| Clause 4 | (ISPESL/INAIL RACCOLTA M)<br>Only cast aluminium alloys which are listed in the Raccolta M of ISPESL/INAIL are permitted. |
| Clause 5.2 | (ISPESL/INAIL RACCOLTA VSR)<br>The rules of the design are listed in the Raccolta VSR. The design shall be approved by the Authority. |
| Clause 5.2.2 | (ISPESL/INAIL RACCOLTA VSR).<br>Design stress established by calculation (Clauses VSR5 of the Raccolta VSR).<br>The permissible design stress ($f_a$) at the design pressure and for a temperature up to 50 °C is:<br>$f_a = Rm / (4 \times 1{,}2) = R_m / 4{,}8$ |
| Clause 7.2 | (ISPESL/INAIL RACCOLTA S)<br>Welding procedure and welders shall be approved by the Authority according to ISPESL/INAIL Raccolta S. |
| Clause 8 | (ANCC RACCOLTA M)<br>Heat treatment shall be carried out according to ISPESL/INAIL Raccolta M. |
| Clause 9.1.2 | (ISPESL/INAIL CAPITOLO VSR 6.B)<br>The bursting pressure shall be higher or equal than the value given in the following formula:<br>$B = 4{,}25 \times k / R_m \times 1 / s_{min} \times p$<br>where:<br>k = actual tensile strength of the sample under test<br>s = actual thickness of the sample under test<br>$s_{min}$ = minimum design thickness permitted |
| Clause 9.1.3 | (ISPESL/INAIL CAPITOLO VSR 6.B AND VSR7.A)<br>The permissible design stress ($f_a$) computed according VSR 6.B and VSR 7.A shall be equal or less than:<br>$f_a \leq R_m / 4{,}8$ |

| | |
|---|---|
| Clause 9.2 | (ISPESL/INAIL CAPITOLO VSR 8.B)<br>Inspection and certification shall be carried out according to ISPESL/INAIL Capitolo VSR 8.B |

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