SLOVENSKI STANDARD
SIST EN 50068:1995

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Wrought steel enclosures for gas-filled high-voltage switchgear and controlgear

Wrought steel enclosures for gas-filled high-voltage switchgear and controlgear

Kapselungen aus Schmiedestahl für Gasgefüllte Hochspannungs-Schaltgeräte und -Schaltanlagen

Enveloppes en acier soudé pour l'appareillage à haute tension sous pression de gaz

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ENGLISH VERSION

WROUGHT STEEL ENCLOSURES FOR GAS-FILLED HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

Enveloppes en acier soudé pour l'appareillage à haute tension sous pression de gaz

Kapselungen aus Schmiedestahl für gasgefüllte Hochspannungs-Schaltgeräte und -Schaltanlagen

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Up-to-date list and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

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

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FOREWORD

At the request of CENELEC technical committee TC 17C, the text of the draft EN 50068 prepared by TC 17C, was submitted to the Unique Acceptance Procedure (UAP).

The text of the draft was approved by CENELEC as EN 50068 on 5 March 1990.

The following dates were fixed:

- latest date of publication of an identical national standard	(dop)	1991-06-01
- latest date of withdrawal of conflicting national standards	(dow)	1991-06-01

For products which have complied with the relevant national standard before 1991-06-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 1996-06-01.

This document forms a supplement to EN 50 052 (1986): "Cast aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear" and EN 50 064 (1989): "Wrought aluminium and aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear", concerning welded enclosures for the same type of switchgear and controlgear but composed of parts made of wrought steel. It is based on the general specifications given in HD 358 S2 (IEC 517 (1986) ed 2)) which are however not sufficient to satisfy the conditions for the service allowance of pressurized high-voltage switchgear and controlgear.

These specifications are appropriate for pressurized switchgear enclosures allowing an economic production without sacrificing aspects of safety. For unusual shapes dictated by electrical conditions they permit the verification of sound design by proof tests instead of calculations. Nevertheless this European Standard makes use of many internationally well acknowledged calculation rules and the Technical Committee will in addition pursue the progress in standardization in CEN/TC 121 and ISO/TC 44 on welding and allied processes.

For the time being reference can only be made to published international standards as far as they are appropriate for the purpose of production of enclosures to be used in gas-filled switchgear and controlgear.

The present EN has been established as 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.

The European Standard contains two normative and one informativ technical annexes:

- Annex A: Welding procedure and welder performance tests.
- Annex B: Sample of record form.
- Annex C: National deviations.

List of standards referred to in this standard:

HD 358 S2 (IEC 517 (1986) ed 2)	Gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above.
ISO 6213:1983	Welding: Items to be considered to ensure quality in welding structures.
ISO 9000:1987	Guidelines for selection and use of the standards on quality management, quality system elements and quality assurance.
ISO/IEC Guide 2:1986	General terms and their defintions concerning standardization and related activities.
ISO 6520:1982	Classification of imperfections in metallic fusion welds, with explanations.
ISO/R 373:1964	General principles for fatigue testing of metals.

C O N T E N T S

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1. 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 arcquenching 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.

2. Scope and field of application

2.1 Type of Equipment

This standard applies to fusion welded wrought steel enclosures pressurised 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 72,5 kV and above, 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 pressurised components such as the centre chamber of live tank switchgear, gas-insulated current transformers, etc.

2.2 Production

The production of the enclosures shall be in accordance with documented welding procedures which shall be carried out by well trained and supervised welding personnel. Where International

Standards (ISO or CEN) are not available National Standards may be used.

NOTE
The Standard will be revised as soon as possible when ISO or CEN standards covering the various aspects are available.

2.3 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 product.

Sufficient examinations shall be made by the enclosure manufacturer to ensure that the materials, production and testing comply in all respects with the requirements of this standard and ISO 6213/1983. Inspection by user's inspectors shall not absolve the switchgear manufacturer from this responsibility to exercise such quality assurance procedures as to ensure that the requirements and intent of this standard are statisfied.

NOTE
Reference should be made to the ISO 9000 series of standards for quality systems.

3. Definitions

3.1 National standard

A technical specification established by general agreement with the important part of the concerned interests, approved by a recognized national standards organization and made available to the public (ISO/IEC Guide 2:1986).

3.2 Enclosure

A part of gas-insulated metal-enclosed switchgear retaining the insulated 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. HD 358 S2 = IEC 517 (1986) ed 2.

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 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. HD 358 S2 = IEC 517 (1986) ed 2.

3.6 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. HD 358 S2 = IEC 517 (1986) ed 2.

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.

3.7 Weld imperfections

3.7.1 Lack of fusion

Lack of union between weld metal and parent metal or weld metal and weld metal. ISO 6520:1982, No. 400.

3.7.2 Overlap

Excess of weld metal at the toe of a weld covering the parent metal surface but not fused to it. ISO 6520:1982, No. 506.

3.7.3 Undercut

A groove at the toe(s) (or at the root) of a weld run due to welding. ISO 6520:1982, No. 5012.

3.8 Heat treatment

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

3.9 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 373:1964.

3.10 Tensile strength

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

3.11 Test piece

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

3.12 Test specimen

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

4. Materials

Any suitable steel is permissible; a list of examples is given in table 1. The properties of the materials should be taken from the applicable standards.

5. Design

5.1 General

The rules for the design of enclosures of gas-insulated switchgear and controlgear prescribed in this clause are solely for the purpose of determining the dimensions and the minimum thickness to ensure safety of the enclosures against gross plastic deformation, incremental collapse and collapse through buckling with the materials given in clause 4.

The rules take into account that these enclosures are subjected to particular operating conditions (clause 1) which distinguish them from compressed air receivers and similar storage vessels.

The thicknesses determined by the various equations are minima and therefore, the specific nominal thickness shall be increased by the amount of any negative tolerance permitted by the material specification.

NOTE
There are designs of enclosures which differ in geometry from those for which equations are given in sub-clauses 5.7 and 5.8. These are permitted provided the calculations are justified or proof tests are carried out as prescribed in 7.5.3.

TABLE 1

EXAMPLES OF MATERIALS [NOT EXHAUSTIVE OTHER STEELS MAY BE USED FROM NATIONAL STANDARDS]

EURO	STANDARD	GERMANY	AUSTRIA	SWITZERLAND	FRANCE	SWEDEN	ITALY	U.K.
				DIN 17440	NFA 36 - 205	SS14 13 30-01	UNI 5869-75	BS 1501
				x 6 Cr Ni 1810				
25	Fe360B	DIN 17100			A37 - CP			
				x 2 Cr Ni 1911				
	Fe360C	ST 52-3	AS		A37 - AP	SS14 14 30-01	UNI 7382-75	151 400
	Fe360D	UST 37-2	GERMANY	x 6 Cr Ni Ti 1810	A37 - FP			
	Fe510D	RST 37-2		DIN 17155	A42 - CP	SS14 14 32-01	UNI 7070-82	151 430A
		ST 37-3			A42 - AP			
28	Fe42-1KP			KBL HII	A42 - FP	SS14 21 06-01	UNI 8317-81	321 S12
	Fe42-1KW				A48 - CP			
	Fe42-2KW				A48 - AP	SS14 21 17-01	UNI 7660-77	BS 1449
		DIN 17440			A48 - FP		[FORGINGS]	
11	Ti-3	x 6 Cr Ni Ti 1810			A52 - CP	SS 142333	UNI 7660-77	321 S12
	FeE355KG	x 6 Cr Ni Nb 1810			A52 - AP			
	F3E355KT				A52 - FP	SS 142343		BS 970
30	Fe42B1				NFA 36 - 601			316 S16
	Fe42B3				[FORGINGS]			
	Fe42-3				A37 - CP			
					A37 - AP			BS 4360
					A37 - FP			
					A42 - CP			GRADE 43A
					A42 - AP			
					A42 - FP			
					A48 - CP			
					A48 - AP			
					A48 - FP			

NOTE: ALIGNMENT OF MATERIALS HORIZONTALLY DOES NOT IMPLY EQUIVALENCE

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 Considerations

The geometry of an enclosure may be determined by electrical rather than mechanical considerations. This constraint can result in an enclosure 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 of the individual housing is necessary before the internal parts are added.

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

(a) The possible evacuation of the enclosures as part of the filling process.

For enclosures of this type it is usually necessary to evacuate the air before introducing gas pressure, this ensures purity of the gas. The evacuated condition is therefore not an operational condition and in most cases enclosures designed for internal pressure will be suitable for the evacuated condition without buckling.

For certain long lengths and large diameters of busbar sections, however, it is possible that the enclosure will buckle due to external pressure. In such cases the design should be checked for external pressure and the enclosure strengthened if necessary. Since this is not an operational condition it is not a matter of safety.

(b) The full differential pressure possible across the enclosure wall.

(c) Superimposed loads and vibrations by external effects.

(d) Stresses caused by temperature differences including transient conditions and by differences in coefficients of thermal expansion.

(e) Effects of solar radiation.

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 HD 358 S2 (IEC 517 (1986) ed 2).

5.4 Design Pressure

The design is based on the design pressure as defined in clause 3.5.

5.5 Design Temperature

The selection of material and the determination of the design stress depend upon the highest wall temperature which can be expected during service at the design pressure (p).

5.6 Design Stress Basis

The nominal design strength K shall be selected from the material standard, where

K = yield strength or 0.2 % proof stress at the design temperature.
(For austenitic steels the 1 % proof stress may be used)

The safety factor against yield strength, 0.2 % proof stress or 1 % proof stress is S = 1.5. Hence it follows the permissible design stress $\sigma = K/1.5$

5.7 Calculation of Shells, Dished Ends, Openings, Screws and Bolts

For the purpose of calculation of shells, dished ends, bolts, screws and openings the following specific symbols are used:

D_a	external diameter of shells	mm
D_i	internal diameter of shells	mm
D_k	design diameter	mm
D_m	mean diameter of gaskets	mm
d_i	internal diameter of openings and branches	mm
t	required wall thickness	mm
l'_S	protruding length of branches	mm
t_A	required wall thickness at openings	mm
t_S	branch wall thickness	mm
x	distance over which the governing stress is assumed to act	mm
R	crown radius of dished ends	mm
r	knuckle radius	mm
h_1	height of the straight flange of dished ends	mm
h_2	depth of dished ends	mm

v	veld joint factor	---
v_A	weakening factor	---
p	design pressure	bar
p_B	buckling pressure	bar
P_S	total screw clamping force	N
P_i	loading of an area (A) with regard to internal pressure	N
A_b	design area of screw threads	mm²
L	centre distance of branches	mm
β	design factor	
n	number of screws per flange joint $P_s / P_i = P'_s / P'_i$	---
P'_i	loading per screw $= P_i / n$	N
P'_s	clamping force per screw $= P_s / n$	N

5.7.1 Cylindrical shells

The required wall thickness is:

$$t = \frac{D_a \cdot p}{20\ (K/1{,}5) \cdot v + p} \quad \text{(Equation 1)}$$

The minimum permissible wall thickness of cylindrical shells is 3 mm.

5.7.2 Spherical shells

The required wall thickness is:

$$t = \frac{D_a \cdot p}{40\ (K/1{,}5) \cdot v + p} \quad \text{(Equation 2)}$$

The minimum permissible wall thickness of spherical shells is 3 mm.

5.7.3 Conical shells

The determination of the wall thickness of conical shells is based on the stress in the meridional direction (bending stress) in the knuckle or the circumferential joint at the wide end of the cone and the stress in the tangential direction (membrane stress) away from the knuckle (see figures 1 to 4). The greater wall thickness calculated according to 5.7.3.1 or 5.7.3.2 is to be taken into consideration. For the shallow conical shells with an angle of slope to the axis of the cone $\varphi_1 > 70°$ the wall thickness shall be determined according to 5.7.3.3 even if smaller wall thicknesses as according to 5.7.3.1 and 5.7.3.2 are found.

In equations 3 and 7 the weld joint factor (v) refers to the circumferential joint and in equation 6 to the longitudinal joint.

If the distance between the circumferential joint and the knuckle is at least 0,5 x then the equations 3 and 7 is the weld joint factor v = 1,0.

The minimum permissible wall thickness of conical shells is 3 mm.

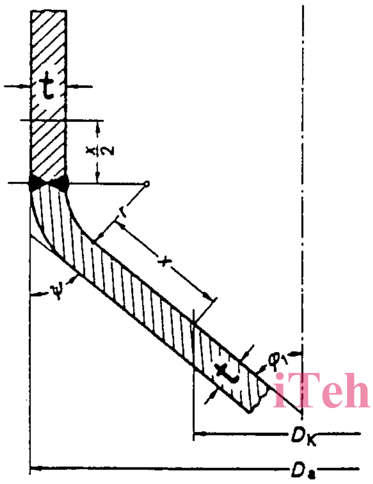

Fig. 1

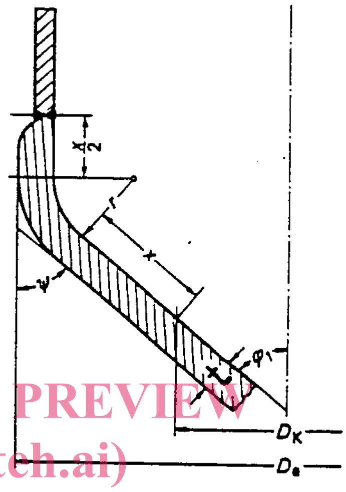

Fig. 2

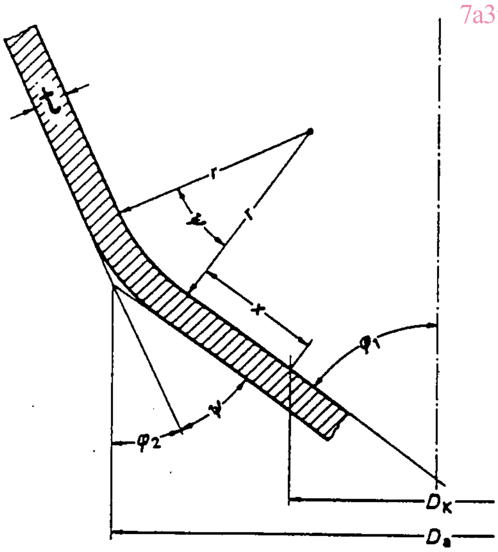

Fig. 3

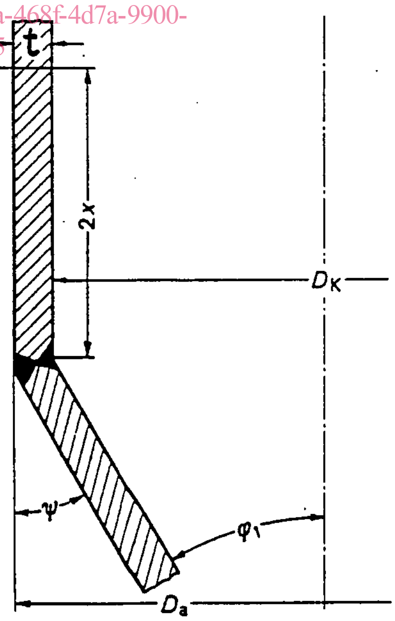

Fig. 4

Fig. 1 to 4
Typical connections between cylindrical and conical shells.

5.7.3.1 Calculation based on the stress in meridional direction

The required wall thickness is:

$$t = \frac{D_a \cdot p \cdot \beta}{40\,(K/1,5)\,\cdot\,v} \qquad \text{(Equation 3)}$$

The design factor β is to be taken from table 2 or figure 5 depending on the difference Ψ between the angles of slope of two adjoining shells

$$\Psi = \varphi_1 - \varphi_2 \qquad \text{(Equiation 4)}$$

and the ratio of the knuckle radius by the external diameter of the shell r/D_a.

A. Shells with knuckle (figures 1 and 2)

If the wide end of a conical shell is flanged to a knuckle then the wall thickness in the knuckle shall be determined according to equation 3 and shall be maintained away from the knuckle in the conical section over a distance of at least

$$x = \sqrt{D_a \cdot t} \qquad \text{(Equation 5)}$$

and along the cylindrical section over a distance of at least 0,5 x.

B. Shells without knuckle (figure 4)

Conical shells may be connected with each other or with cylindrical shells by means of welded butt joints providing the following is met:

a) $\Psi \leq 30°$
b) joints welded from both sides
c) the length of the two shells shall be at least 2 x according to equation 5

If deviating from b) the butt joints are to be welded from one side only, then equivalence with joints welded from both sides shall be demonstrated by a welding procedure test.

The wall thickness for both shells at the butt joint shall be determined under consideration of the bending stress in the circumferential seam according to equation 3.

Table 2 - Design factor β for conical shells and numerical factors cos φ and 1/cos φ

Angle φ resp. Ψ	β for a ratio of r/D_a: 0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,2	0,3	0,4	0,5	cos φ	$\frac{1}{\cos\varphi}$
10	1,4	1,3	1,2	1,2	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	0,985	1,015
20	2,0	1,8	1,7	1,6	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1	0,940	1,064
30	2,7	2,4	2,2	2,0	1,8	1,7	1,6	1,4	1,3	1,1	1,1	1,1	0,866	1,155
45	4,1	3,7	3,3	3,0	2,6	2,4	2,2	1,9	1,8	1,4	1,1	1,1	0,707	1,414
60	6,4	5,7	5,1	4,7	4,0	3,5	3,2	2,8	2,5	2,0	1,4	1,1	0,500	2,000
70	10,0	9,0	8,0	7,2	6,0	5,3	4,9	4,2	3,7	2,7	1,7	1,1	0,342	2,920
75	13,6	11,7	10,7	9,5	7,7	7,0	6,3	5,4	4,8	3,1	2,0	1,1	0,259	3,861